FLOOR STIFFENER CRACKING IN
LARGE MINING TRUCK DUMP BODIES

CENTRE FOR NEWFOUNDLAND STUDIES

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FLOOR STIFFENER CRACKING IN
LARGE MINING TRUCK DUMP BODIES

by

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in partial fulfillment of the requirements for the
degree of Master of Engineering

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Abstract

Due to the soft nature of the underfoot conditions in an oil sand mine, mobile equipment tends to develop greater amounts of maintenance problems than similar equipment in other types of mines. This is an investigation into cracking of haul truck dump bodies in oil sand mining service using the Finite Element Method (FEM). This work identifies the damage mechanism and source causing this persistent problem, which occurs at the intersection of the widthwise and lengthwise box-style floor stiffeners. In particular, compressive, membrane stresses are setup at these intersections resulting from overall bending of the floor plate from the weight of the ore. Superimposed onto these membrane stresses are localized bending stresses caused by very slight deflections, or twist, within the frame. Depending on the magnitude of twist, these localized bending stresses can overcome the compressive membrane stress producing sufficient tension to propagate a crack in this as-welded, non-heat-treated connection.
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helping me to tell the difference between what was and was not possible in terms of the information we wished to collect. I would like to thank Paul Wohlgemuth, SCL Mine Services for providing insight and direction as to how this work may provide a benefit to Syncrude in the future.

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Syncrude Canada Ltd. (SCL) is the world's largest producer of crude oil from oil sands, and the largest single-source producer in Canada. Its crude oil production facility operates on the immense reserves of the Athabasca oil sand deposit north of Fort McMurray, Alberta, converting bitumen, an asphalt-like oil that is as thick as molasses in its natural state, into a marketable crude oil. Oil sand is mined in open pit using large shovels and heavy hauler trucks. The extraction of bitumen from oil sand involves mixing the ore with hot water and caustic soda, conditioning it for separation as it travels through a hydro-transport pipeline. Once inside the separation vessel, bitumen floats to the surface while the sand settles away. In the upgrading plant, bitumen is converted into a light crude oil by fluid coking, hydrotreating, and blending. The final product (Syncrude Sweet Blend) is transported by pipeline to Edmonton area refineries and to pipeline terminals, which in turn ship it to other refineries in Canada and the United States.

Syncrude uses some of the largest mining trucks available in the world, known as heavy haulers, for its mining operations in both the Mildred Lake and the Aurora mines. These include such trucks as the Komatsu 930E (Figure 1-1) with a payload rating of 320 tons, and the largest truck in the world, the Caterpillar 797 (380 tons). They move overburden material to storage areas, move ore to the crushers where the process starts, move tailings sand, and even move material back into the mine to reclaim depleted areas. To put it into
perspective, it takes two tons of oil sand to produce one barrel of oil. As well, an equal amount of overburden must be removed to expose that ore. At present, Syncrude produces over 250,000 barrels of crude oil daily, which means that over 1 Million tons of material are moved each day.

Figure 1-1: Komatsu 930E Heavy Hauler Mining Truck

To move such vast amounts of material daily, SCL employs a fleet of almost 80 heavy haulers, all of which were acquired through two local dealerships. The business of developing and selling mining trucks, however, is fiercely competitive. Due to this competitiveness, information beyond standard specifications and promotional material is rarely shared by each of the vendors. When specific information is shared, it is usually used to troubleshoot maintenance activities and is safeguarded from being disclosed to other vendors. The result is an environment of limited communication in which
information does not flow freely. Although it hinders research activities, it is an accepted and essential part of the haul truck business; one that researchers and engineers must learn to work with.

SCL is not in the business of designing better haul trucks; however, to improve the reliability, productivity and safety of the haul truck fleet, it is necessary to understand the mine-specific operating conditions. This thesis should help to develop a more detailed understanding of the nature and magnitude of the forces subjected to a typical haul truck body in Syncrude mining operations. This work should provide information useful with respect to maintenance issues with the existing fleet, and help reduce operational costs. The increased understanding may also guide decisions to purchase future equipment, and may generate better designs for oil sand applications.

The equipment modeled in this study is a Syncrude owned Komatsu 930E heavy hauler mining truck. It is currently the second largest type of mining truck used at the site, and has a payload rating of 320 tons (290 metric tonnes). The truck is equipped with what is referred to as a standard dump body. Strictly speaking, however, the body is not a standard 930E body. Significant modifications have been made to adapt the structure for oil sand mining operations, including the addition of abrasion resistant cladding on the floor and sidewalls, and measures for strengthening the floor structure. Considering the fact that this work is an evaluation of a floor-stiffener cracking problem, it should be recognized that the modifications to the floor structure were quite extensive. All of the
stiffening structure from the hinge pivot to the rear was replaced with materials of twice the original thickness, and one-inch thick plates have been added to both sides of the two main rails. Although floor-stiffener cracking is most prevalent in this body, the problem is observed to lesser degrees in all haul truck bodies on the SCL mine sites. In other words, this thesis should not be considered as a design evaluation of standard 930E dump bodies. Rather, it is an investigation into a persistent problem observed in all types of dump bodies in oil sand service.
Chapter: 2 Basic Concepts

Before we get into the details, it would be helpful to introduce some of the basic concepts and techniques of the finite element method. The finite element method, also known as Finite Element Analysis (FEA), is a numerical method for solving problems in engineering and physics. For many real-world problems, it is impossible to obtain an analytical solution. Analytical solutions generally require the solution of differential equations and auxiliary conditions, which can become cumbersome or even impossible depending on the complexity of the geometry, material properties and boundary conditions for the problem at hand. As a result, engineers and scientists often resort to numerical methods such as the finite element method to obtain acceptable solutions. Some of the areas where FEA is frequently applied include structural analysis, heat transfer, mass transfer, and electromagnetism.

Finite element formulations recast the differential equations normally required to solve real world problems with a series of simultaneous algebraic equations. The underlying concept of FEA is to divide the complex geometry into a system of interconnected bodies, such that a solution for each is approximated. This process of dividing a problem into discrete finite elements is called discretization. Rather than attempting to solve the entire problem in one cumbersome operation, algebraic equations for each element are formulated and then combined to obtain the solution of the entire system.
2.1 Finite Element Theory

2.1.1 Basic Principle of Finite Element Analysis (FEA)

To illustrate the basic principle of FEA, we consider the spring displacement system of Figure 2-1. The system consists of three paddles connected together with an arrangement of springs. Each of the three paddles has a single degree of freedom (DOF), which is translation along the horizontal plane, and has an external force applied. The paddles represent nodes in a FEA, while the springs represent the elements interconnecting them. The symbols at the base of the paddles represent the boundary conditions applied to this system. The triangular shaped symbols represent a fixed displacement condition, while the circle shaped symbols represent rollers that imply these paddles are free to move in the horizontal direction only.

![Figure 2-1: Spring Displacement System](image)

The objective is to establish a relationship between displacements and forces.

\[
\begin{align*}
\begin{bmatrix}
  u_1 \\
  u_2 \\
  u_3 
\end{bmatrix}
& \quad & \begin{bmatrix}
  F_1 \\
  F_2 \\
  F_3 
\end{bmatrix}
\end{align*}
\]  

(2-1)
2.1.1.1 Element Stiffness Matrices

The first step in the finite element method is to discretize the problem and to formulate the element stiffness equations. Figure 2-2 represents the behavior of a generic spring element. The governing equation for a spring is $f = kd$. That is, the force in a spring is proportional to the difference in the end displacements, and the constant of proportionality is referred to as the spring stiffness, $k$.

![Figure 2-2: Generic Spring Behavior](image)

For this particular element, the relationship between the nodal displacements ($u_i$) and the nodal forces ($f_i$) can be expressed as:

$$
\begin{bmatrix}
K & -K \\
-K & K
\end{bmatrix}
\begin{bmatrix}
u_A \\
u_B
\end{bmatrix} =
\begin{bmatrix}
f_A \\
f_B
\end{bmatrix}
$$

(2-2)

Similarly, each of the spring elements for the system in Figure 2-1 can be described in terms of the nodal displacements and the element forces, the internal forces within each spring element.

Element #1

$$
K_1\begin{bmatrix}
1 & -1 \\
-1 & 1
\end{bmatrix}\begin{bmatrix}
u_1 \\
u_2
\end{bmatrix} =
\begin{bmatrix}
f_1 \\
f_2
\end{bmatrix}
$$

(2-3)

Element #2

$$
K_2\begin{bmatrix}
1 & -1 \\
-1 & 1
\end{bmatrix}\begin{bmatrix}
u_2 \\
u_3
\end{bmatrix} =
\begin{bmatrix}
f_2 \\
f_3
\end{bmatrix}
$$

(2-4)
2.1.1.2 Assembly of Element Equations into Global Stiffness Matrix

The objective, however, is to represent the relationship between the nodal displacements and the nodal forces, or the forces applied externally to the nodes of the finite element model. To do this, the element stiffness matrices above must be assembled into one global stiffness matrix formulation. By representing the above element stiffness formulations with all the nodal degrees-of-freedom (DOF) present, it is possible to directly superimpose them forming the global stiffness matrix.

\[
K_3 \begin{bmatrix}
1 & -1 & 0 \\
-1 & 1 & 0 \\
0 & 0 & 1 \\
\end{bmatrix}
\begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
\end{bmatrix} = 
\begin{bmatrix}
f_1 \\
f_2 \\
f_3 \\
\end{bmatrix}
\]  \hspace{1cm} (2-5)

\[
\begin{aligned}
K \begin{bmatrix}
1 & -1 & 0 \\
-1 & 1 & 0 \\
0 & 0 & 1 \\
\end{bmatrix}
\begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
\end{bmatrix} + K_2 \begin{bmatrix}
0 & 0 & 1 \\
0 & 1 & -1 \\
-1 & 1 & 0 \\
\end{bmatrix}
\begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
\end{bmatrix} + K_3 \begin{bmatrix}
0 & 0 & 1 \\
0 & 1 & 0 \\
-1 & 1 & 0 \\
\end{bmatrix}
\begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
\end{bmatrix} &= 
\begin{bmatrix}
f_1 \\
f_2 \\
f_3 \\
\end{bmatrix}
\end{aligned}
\]  \hspace{1cm} (2-6)

\[
\begin{bmatrix}
K_1 + K_3 & -K_1 & -K_3 \\
-K_1 & K_1 + K_2 & -K_2 \\
-K_3 & -K_2 & K_2 + K_3 \\
\end{bmatrix}
\begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
\end{bmatrix} = 
\begin{bmatrix}
f_1 \\
f_2 \\
f_3 \\
\end{bmatrix}
\]  \hspace{1cm} (2-7)

2.1.1.3 Boundary Conditions and Solution

The boundary conditions associated with displacement based finite element formulations consist of known displacements and forces (or pressures, etc.) at each node. In order to solve a FEA problem, an externally applied displacement or force must be known for each DOF of each node in the system. Either a displacement or force is specified, or the externally applied force is known to be zero. In the system described in Figure 2-1, the first paddle is fixed. As a result, this nodal displacement is known \((u_1=0)\). Considering
this, it is possible to reduce the system by eliminating the row and column of the stiffness matrix associated with this DOF as follows:

\[
\begin{bmatrix}
K_1 & K_3 & K_1 & K_3 \\
-K_1 & K_1 + K_2 & -K_2 & K_3 \\
-K_3 & -K_2 & K_2 + K_3 &
\end{bmatrix}
\begin{bmatrix}
\mathbf{u}_1 \\
\mathbf{u}_2 \\
\mathbf{u}_3
\end{bmatrix}
= \begin{bmatrix}
\mathbf{F}_1 \\
\mathbf{F}_2 + K_1 \mathbf{u}_1 \\
\mathbf{F}_3 + K_3 \mathbf{u}_1
\end{bmatrix}
\tag{2-8}
\]

\[
\begin{bmatrix}
K_1 + K_2 & -K_2 \\
-K_2 & K_2 + K_3
\end{bmatrix}
\begin{bmatrix}
\mathbf{u}_2 \\
\mathbf{u}_3
\end{bmatrix}
= \begin{bmatrix}
\mathbf{F}_2 + K_1 \mathbf{u}_1 \\
\mathbf{F}_3 + K_3 \mathbf{u}_1
\end{bmatrix}
\tag{2-9}
\]

With the known displacements accounted for, we are left with the global stiffness matrix relating the nodal displacements to the forces applied at the nodes. Therefore, it is possible to determine the unknown displacements by re-arranging and solving the system of equations as follows:

\[
\begin{bmatrix}
\mathbf{u}_2 \\
\mathbf{u}_3
\end{bmatrix}
= \begin{bmatrix}
K_1 + K_2 & -K_2 \\
-K_2 & K_2 + K_3
\end{bmatrix}^{-1}
\begin{bmatrix}
\mathbf{F}_2 + K_1 \mathbf{u}_1 \\
\mathbf{F}_3 + K_3 \mathbf{u}_1
\end{bmatrix}
\tag{2-10}
\]

### 2.1.2 Formulation of a 2D Bar Element Stiffness Matrix

A spring element is perhaps the simplest form of a finite element, which was well suited for describing the overall solution methodology used in FEA. As stated earlier, however FEA is used to solve problems in many different technical disciplines. The first step in any such analysis is to develop the element matrix equations, called stiffness matrices in the structural analysis realm. The following procedure will illustrate the concepts used in structural FEA to develop element stiffness matrices using the case of a one-dimensional bar element, suitable for modeling pin connected truss networks.
2.1.2.1 Definition of the Element Type

Figure 2-3 is a schematic representation of a simple pin connected structural element subjected to the tensile force, $T$. The pin connections are represented in FEA by nodes, labeled 1 and 2. Nodal displacements, $u_1$ and $u_2$, represent positive axial displacements at the pinholes, while $f_1$ and $f_2$ represent positive axial forces acting on the bar element at the pinholes.

The following assumptions have been made in deriving the bar element stiffness matrix$^3$:

1. The bar cannot sustain a shear force.
2. Any effect of transverse displacement is ignored.
3. Hooke’s law applies; that is, axial stress $\sigma_x$ is related to the axial strain $\varepsilon_x$ by $\sigma_x = E\varepsilon_x$.

2.1.2.2 Selection of the Displacement Function

To begin, we must choose a displacement function with the total number of coefficients equal to the number of degrees of freedom associated with the element.
Expressed in matrix form, this equation becomes:

\[ u \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} 1 & \hat{x} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} \]  

(2-12)

To express this function in terms of nodal displacements, \( u_1 \) and \( u_2 \), we evaluate \( u \) at each node solving for \( a_1 \) and \( a_2 \) as follows:

\[ u(0) = u_1 = a_1 \]  

(2-13)

\[ u(L) = u_2 = u_1 + a_2 L \]  

(2-14)

\[ a_2 = \frac{u_2 - u_1}{L} \]  

(2-15)

which gives:

\[ u = u_1 + \left( \frac{u_2 - u_1}{L} \right) \hat{x} \]  

(2-16)

Expressed in matrix form, \( u \) becomes,

\[ u = \begin{bmatrix} 1 - \frac{\hat{x}}{L} & \frac{\hat{x}}{L} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \text{ or } u = \begin{bmatrix} N_1 & N_2 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \]  

(2-17)

where \( N_1 \) and \( N_2 \) are called shape functions:

\[ N_1 = 1 - \frac{\hat{x}}{L} \]  

(2-18a)

\[ N_2 = \frac{\hat{x}}{L} \]  

(2-18b)
2.1.2.3 Strain - Displacement and Stress - Strain Relationships

The strain - displacement relationship for this one-dimensional problem is,

\[ \varepsilon_x = \frac{du}{d\xi} = \frac{u_2 - u_1}{L} \]  

(2-19)

and the stress - strain relationship for this uniaxial state of stress is,

\[ \sigma_x = E \varepsilon_x \]  

(2-20)

where \( E \) is the modulus of elasticity for the bar material, and \( \sigma_x \) is the axial stress.

2.1.2.4 Element Stiffness Matrix

From mechanics, we know that the tension, \( T \), in the bar is,

\[ T = A \sigma_x \]  

(2-21)

where \( A \) is the cross-sectional area of the bar. Using the strain-displacement and stress-strain relationships, the expression becomes

\[ T = AE \left( \frac{u_2 - u_1}{L} \right) \]  

(2-22)

Using the nodal sign convention,

\[ f_1 = -T \quad \text{or} \quad f_1 = \frac{AE}{L} (u_1 - u_2) \]  

(2-23)

Similarly,

\[ f_2 = T \quad \text{or} \quad f_2 = \frac{AE}{L} (u_2 - u_1) \]  

(2-24)

When expressed together, in matrix form, these equations become,
For a one-dimensional bar element, the stiffness matrix is:

\[
\begin{align*}
\begin{bmatrix}
  f_1 \\
  f_2 
\end{bmatrix} &= \frac{AE}{L} \begin{bmatrix}
  1 & -1 \\
  -1 & 1 
\end{bmatrix} \begin{bmatrix}
  u_1 \\
  u_2 
\end{bmatrix} \\
\end{align*}
\]  

(2-25)

\[
\begin{align*}
  k &= \frac{AE}{L} \begin{bmatrix}
  1 & -1 \\
  -1 & 1 
\end{bmatrix} \\
\end{align*}
\]  

(2-26)

2.1.2.5 Transformation into Global Coordinate System

The one-dimensional bar element, as derived above, is not well suited for solving engineering problems in its present form. To solve pin-connected truss networks, it would be helpful to have nodal forces and displacements defined in a bi-axial (planar) coordinate system as opposed to a uniaxial coordinate system (Figure 2-4).

Transforming the nodal displacements, \(u_1\) and \(u_2\), into the global \((x,y)\) coordinate system we get,

\[
\begin{align*}
  \dot{u}_1 &= u_{1x} \cos \theta + u_{1y} \sin \theta \\
  \dot{u}_2 &= u_{2x} \cos \theta + u_{2y} \sin \theta 
\end{align*}
\]  

(2-27) 

(2-28)

which can be written in matrix form as,  

Figure 2-4: Transformation into Global Coordinate System
\[
\begin{bmatrix}
\hat{u}_1 \\
\hat{u}_2
\end{bmatrix} = \begin{bmatrix}
C & S & 0 & 0 \\
0 & 0 & C & S
\end{bmatrix} \begin{bmatrix}
u_{1x} \\
u_{1y} \\
u_{2x} \\
u_{2y}
\end{bmatrix} \quad \text{or} \quad \hat{u} = T^*u
\] (2-29)

where \( C = \cos \theta \) and \( S = \sin \theta \). Similarly, the global force vector can be obtained

\[
\hat{f} = T^*f
\] (2-30)

Substituting the above relations into the equation,

\[
\hat{f} = \hat{k}\hat{u}
\] (2-31)

yields:

\[
T^*f = \hat{k}T^*u
\] (2-32)

In order to determine the expression relating the global forces to global displacements, we must invert \( T^* \) which is not immediately possible because it is not a square matrix. Instead, we must expand the element matrices to be consistent with the global coordinates, recognizing the fact that the nodal forces normal to the bar element axis will always be zero. The relationship between element and global displacements becomes,

\[
\begin{bmatrix}
\hat{u}_{1x} \\
\hat{u}_{1y} \\
\hat{u}_{2x} \\
\hat{u}_{2y}
\end{bmatrix} = \begin{bmatrix}
C & S & 0 & 0 \\
-S & C & 0 & 0 \\
0 & 0 & C & S \\
0 & 0 & -S & C
\end{bmatrix} \begin{bmatrix}
u_{1x} \\
u_{1y} \\
u_{2x} \\
u_{2y}
\end{bmatrix} \quad \text{or} \quad \hat{u} = Tu
\] (2-33)

and similarly,

\[
\hat{f} = Tf
\] (2-34)

The element stiffness matrix must also be expanded to the same order, as follows:
Now as before, substituting the above relations into the equation,

\[
\hat{f} = \hat{k}\hat{u}
\]  

(2-36)

yields:

\[
T\hat{f} = \hat{k}Tu
\]  

(2-37)

By multiplying both sides of this equation by \(T^{-1}\), we obtain the relationship between the global forces and global displacements:

\[
f = T^{-1}\hat{k}Tu
\]  

(2-38)

However, \(T\) is an orthogonal matrix, and as a result, the inverse of \(T\) is equal to its transpose.

\[
T^{-1} = T^T
\]  

(2-39)

Therefore,

\[
f = T^T\hat{k}Tu
\]  

(2-40)

From above, we can see that the stiffness matrix in global coordinates, \(k\), is

\[
k = T^T\hat{k}T
\]  

(2-41)

When expanded, \(k\) becomes
2.2 FEA Techniques

2.2.1 Example of a Bar Element Truss Problem

With the global stiffness matrix for a one-dimensional bar element defined in Cartesian coordinates, it is now possible to use this element to solve a pin-connected truss problem. Figure 2-5 is an example of a pin-connected truss. Each of the truss members has a cross-sectional area, A, and a modulus of elasticity, E; and the truss is subjected to two loads, P and 2P. The purpose of this problem will be to illustrate the process involved in solving for member forces and displacements using the finite element method, and later, to demonstrate several techniques, used throughout the thesis, that could be utilized to reduce the computational effort required in obtaining this solution.

\[
\begin{bmatrix}
C^2 & CS & -C^2 & -CS \\
CS & S^2 & -CS & -S^2 \\
-C^2 & -CS & C^2 & CS \\
CS & -S^2 & CS & S^2
\end{bmatrix}
\]

\(k = \frac{AE}{L}\)  

(2-42)

Figure 2-5: Pin-Connected Truss Problem
2.2.1.1 Discretize Geometry and Formulate Element Equations

The first step in the solution process is to break up the geometry into discrete or finite elements. As shown in Figure 2-6, the truss structure has been broken into nine elements (in red) and the pin connections have been designated as nodes (in blue).

![Figure 2-6: Discretized Truss Structure](#)

The second step is to formulate the stiffness equations for each of the nine elements. Element number 1 has a length of $2L$ and $\theta = 30^\circ$, therefore its stiffness matrix is evaluated as follows:

$$
\begin{bmatrix}
  f_{1x} \\
  f_{1y} \\
  f_{3x} \\
  f_{3y}
\end{bmatrix} =
\begin{pmatrix}
  3 & \sqrt{3} & -3 & -\sqrt{3} \\
  \sqrt{3} & 1 & -\sqrt{3} & -1 \\
  -3 & -\sqrt{3} & 3 & \sqrt{3} \\
  -\sqrt{3} & -1 & \sqrt{3} & 1
\end{pmatrix}
\begin{bmatrix}
  u_{1x} \\
  u_{1y} \\
  u_{3x} \\
  u_{3y}
\end{bmatrix}
$$

Element #1

Element 3 has a length of $\sqrt{2}L$ and $\theta = 45^\circ$, therefore its stiffness matrix is evaluated as follows:
Element 5 has a length of $L$ and $\theta = 270^\circ$, therefore its stiffness matrix is evaluated as follows:

\[
\begin{bmatrix}
  f_{3x} \\
  f_{3y} \\
  f_{5x} \\
  f_{5y}
\end{bmatrix} = \frac{\sqrt{2}AE}{4L}
\begin{bmatrix}
  1 & 1 & -1 & -1 \\
  1 & 1 & -1 & -1 \\
  -1 & -1 & 1 & 1 \\
  -1 & -1 & 1 & 1
\end{bmatrix}
\begin{bmatrix}
  u_{2x} \\
  u_{2y} \\
  u_{3x} \\
  u_{3y}
\end{bmatrix}
\]

(2-44)

Element 7 has a length of $\sqrt{2}L$ and $\theta = 315^\circ$, therefore its stiffness matrix is evaluated as follows:

\[
\begin{bmatrix}
  f_{3x} \\
  f_{3y} \\
  f_{5x} \\
  f_{5y}
\end{bmatrix} = \frac{AE}{L}
\begin{bmatrix}
  0 & 0 & 0 & 0 \\
  0 & 1 & 0 & -1 \\
  0 & 0 & 0 & 0 \\
  0 & -1 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
  u_{3x} \\
  u_{3y} \\
  u_{5x} \\
  u_{5y}
\end{bmatrix}
\]

(2-45)

Element 9 has a length of $2L$ and $\theta = 330^\circ$, therefore its stiffness matrix is evaluated as follows:

\[
\begin{bmatrix}
  f_{3x} \\
  f_{3y} \\
  f_{5x} \\
  f_{5y}
\end{bmatrix} = \frac{\sqrt{2}AE}{4L}
\begin{bmatrix}
  1 & -1 & -1 & 1 \\
  -1 & 1 & 1 & -1 \\
  -1 & 1 & 1 & -1 \\
  1 & -1 & -1 & 1
\end{bmatrix}
\begin{bmatrix}
  u_{3x} \\
  u_{3y} \\
  u_{5x} \\
  u_{5y}
\end{bmatrix}
\]

(2-46)

Elements 4 and 6 have lengths of $L$ and $\theta = 0^\circ$, therefore their stiffness matrices are evaluated as follows:
Elements 2 and 8 have lengths of $(\sqrt{3} - 1)L$ and $\theta = 0^\circ$, therefore their stiffness matrices are evaluated as follows:

\[
\begin{align*}
\begin{bmatrix}
 f_{2x} \\
 f_{2y} \\
 f_{3x} \\
 f_{3y}
\end{bmatrix}
 &= 
\begin{bmatrix}
 1 & 0 & -1 & 0 \\
 0 & 0 & 0 & 0 \\
 -1 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
 u_{2x} \\
 u_{2y} \\
 u_{3x} \\
 u_{3y}
\end{bmatrix}
\end{align*}
\]

Element #4

\[
\begin{align*}
\begin{bmatrix}
 f_{4x} \\
 f_{4y} \\
 f_{5x} \\
 f_{5y}
\end{bmatrix}
 &= 
\begin{bmatrix}
 1 & 0 & -1 & 0 \\
 0 & 0 & 0 & 0 \\
 -1 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
 u_{4x} \\
 u_{4y} \\
 u_{5x} \\
 u_{5y}
\end{bmatrix}
\end{align*}
\]

Element #6

2.2.1.2 Assemble Global Stiffness Matrix

With each of the element equations formulated, it is now possible to assemble the global stiffness matrix. In this particular FEA model, nodal displacements at the two pin supports (nodes 1 and 6) are known to be zero. Since these nodes are inactive, there is no need to include the terms associated with these DOF into the stiffness matrix. For node 2, we wish to assemble the two equations that relate nodal displacement to the global
forces applied to the model at that node. To do this, we must incorporate the stiffness terms related to the global forces, $F_{2x}$ and $F_{2y}$, from each of the three elements connected to this node (elements 2, 3 and 4) as follows:

\[
\frac{AE}{L} \begin{bmatrix}
    1 + \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & 1 & 0 & 0 \\
    \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & -\frac{\sqrt{2}}{4} & 0 & 0 & 0 \\
    \frac{\sqrt{2}}{4} & -\frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & 0 & 0 & 0 \\
\end{bmatrix}
\begin{bmatrix}
    u_{2x} \\
    u_{2y} \\
    u_{3x} \\
    u_{3y} \\
    u_{4x} \\
    u_{4y} \\
    u_{5x} \\
    u_{5y} \\
\end{bmatrix} = \begin{bmatrix}
    F_{2x} \\
    F_{2y} \\
\end{bmatrix}
\]

(2-52)

For node 3, we must incorporate the stiffness terms related to $F_{3x}$ and $F_{3y}$ from each of the five elements connected to this node (elements 1, 3, 5, 7 and 9) as follows:

\[
\frac{AE}{L} \begin{bmatrix}
    \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{3 + 2\sqrt{2}}{8} & \frac{3 + 2\sqrt{2}}{8} & \frac{3 + 2\sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & 0 & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} \\
    \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{3 + 2\sqrt{2}}{8} & \frac{3 + 2\sqrt{2}}{8} & \frac{3 + 2\sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & 0 & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} \\
    \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{3 + 2\sqrt{2}}{8} & \frac{3 + 2\sqrt{2}}{8} & \frac{3 + 2\sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & \frac{\sqrt{3} + \sqrt{2} + \sqrt{2}}{8} & 0 & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} \\
\end{bmatrix}
\begin{bmatrix}
    u_{2x} \\
    u_{2y} \\
    u_{3x} \\
    u_{3y} \\
    u_{4x} \\
    u_{4y} \\
    u_{5x} \\
    u_{5y} \\
\end{bmatrix} = \begin{bmatrix}
    F_{3x} \\
    F_{3y} \\
\end{bmatrix}
\]

(2-53)

which simplifies to,
For node 4, we must incorporate the stiffness terms related to $F_{4x}$ and $F_{4y}$ from each of the three elements connected to this node (elements 4, 5 and 6) as follows:

\[
\frac{AE}{L} \begin{bmatrix}
-1 & 0 & 0 & 2 & 0 & -1 & 0 \\
0 & 0 & 0 & -1 & 0 & 1 & 0 \\
\end{bmatrix}
\begin{bmatrix}
u_{2x} \\
u_{2y} \\
u_{3x} \\
u_{3y} \\
u_{4x} \\
u_{4y} \\
u_{5x} \\
u_{5y}
\end{bmatrix}
= \begin{bmatrix}F_{4x} \\
F_{4y}
\end{bmatrix}
\]

(2.55)

Lastly, for node 5, we must incorporate the stiffness terms related to $F_{5x}$ and $F_{5y}$ from each of the three elements connected to this node (elements 6, 7 and 8) as follows:

\[
\frac{AE}{L} \begin{bmatrix}
0 & 0 & \sqrt{2}/4 & \sqrt{2}/4 & -1 & 0 & 1 + \frac{1}{\sqrt{3} - 1} + \frac{4 + \sqrt{2}}{4} \\
0 & 0 & \frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & 0 & 0 & -\frac{\sqrt{2}}{4} \\
\end{bmatrix}
\begin{bmatrix}
u_{2x} \\
u_{2y} \\
u_{3x} \\
u_{3y} \\
u_{4x} \\
u_{4y} \\
u_{5x} \\
u_{5y}
\end{bmatrix}
= \begin{bmatrix}F_{5x} \\
F_{5y}
\end{bmatrix}
\]

(2.56)

Then, combining these expressions for nodal forces, we obtain the global stiffness matrix:
2.2.1.3 Nodal Displacements

The next portion of the FEA solution process involves applying the specified boundary conditions and solving for nodal displacements. The supporting boundary conditions for this FEA model have already been accounted for. As was mentioned earlier, the DOF associated with nodes 1 and 6 are constrained to be zero by the pin boundary conditions. As a result, these DOF are inactive and have been omitted from the global stiffness matrix formulation. There are, however, two vertical loads applied to nodes on the bottom of the truss frame. Represented in vector form and adhering to the nodal sign convention, the force vector for this FEA problem is:

$$\frac{AE}{L} = \begin{bmatrix}
\frac{1}{(\sqrt{3} - 1)} + \frac{4 + \sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{-\sqrt{2}}{4} & \frac{-\sqrt{2}}{4} & -1 & 0 & 0 & 0 \\
\frac{\sqrt{2}}{4} & \frac{-\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & \frac{-\sqrt{2}}{4} & 0 & 0 & 0 & 0 \\
\frac{4}{4} & \frac{-\sqrt{2}}{4} & \frac{3 + 2\sqrt{2}}{4} & 0 & 0 & -\frac{\sqrt{2}}{4} & \frac{-\sqrt{2}}{4} & 0 \\
\frac{-\sqrt{2}}{4} & \frac{4}{4} & 0 & 5 + 2\sqrt{2} & 0 & -1 & \frac{4}{4} & \frac{4}{4} \\
\frac{-1}{4} & 0 & 0 & \frac{2}{4} & 0 & -1 & 0 & 0 \\
0 & 0 & 0 & -\frac{1}{4} & 0 & 1 & 0 & 0 \\
0 & 0 & -\frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & -1 & 0 & \frac{1}{(\sqrt{3} - 1)} + \frac{4 + \sqrt{2}}{4} & \frac{-\sqrt{2}}{4} \\
0 & 0 & \frac{-\sqrt{2}}{4} & \frac{\sqrt{2}}{4} & 0 & 0 & \frac{-\sqrt{2}}{4} & \frac{4}{4}
\end{bmatrix}
\begin{bmatrix}
u_x \\
u_y \\
u_z \\
u_x \\
u_y \\
u_z \\
u_x \\
u_y
\end{bmatrix} = \begin{bmatrix}
F_x \\
F_y \\
F_z \\
F_x \\
F_y \\
F_z \\
F_x \\
F_y
\end{bmatrix}
$$

or

$$Ku = F$$

(2-57)
To solve for nodal displacements, we must rearrange equation 2-57 by multiplying both sides with the inverse of the stiffness matrix

\[ \mathbf{K}^{-1} \mathbf{K} \mathbf{u} = \mathbf{K}^{-1} \mathbf{F} \]  

which becomes

\[ \mathbf{u} = \mathbf{K}^{-1} \mathbf{F} \]  

(2-60)

To compute the nodal displacement vector, we simply need to carry out the matrix multiplication resulting in

\[
\mathbf{u} = \begin{bmatrix}
\frac{1}{6} \sqrt{3} \left( \sqrt{5} - 1 \right) \left( 5 \sqrt{5} - 3 \right) \\
\frac{1}{9} \sqrt{3} \left( -36 \sqrt{2} - 219 + 44 \sqrt{3} + 6 \sqrt{2} \sqrt{3} \right) \\
\frac{1}{2} \sqrt{3} - 1 \\
\frac{1}{2} \sqrt{3} - 1 \\
\frac{1}{2} \sqrt{3} - 1 \\
\frac{1}{6} \sqrt{3} \left( 7 \sqrt{5} - 3 \right) \\
\frac{1}{9} \sqrt{3} \left( -276 + 55 \sqrt{3} - 72 \sqrt{2} + 12 \sqrt{2} \sqrt{3} \right)
\end{bmatrix} \begin{bmatrix}
\frac{0.485}{AE} \\
-14.0 \\
1.33 \\
-12.0 \\
0.149 \\
-12.0 \\
-0.783 \\
-19.8
\end{bmatrix}
\]

(2-61)

This portion of the results is referred to as the nodal solution.
2.2.1.4 Solve for Element Forces

Having determined the nodal displacements, we may now go back to the element level to determine the forces present within each element. Substituting the now known nodal displacements into the element stiffness equations and solving, we obtain what is referred to as the element solution. For example, the element stiffness equations for element number 1 were:

\[
\begin{align*}
\begin{bmatrix} f_{1x} \\ f_{1y} \\ f_{3x} \\ f_{3y} \end{bmatrix} &= \begin{bmatrix} 3 & \sqrt{3} & -3 & -\sqrt{3} \\ \sqrt{3} & 1 & -\sqrt{3} & -1 \\ -3 & -\sqrt{3} & 3 & \sqrt{3} \\ -\sqrt{3} & -1 & \sqrt{3} & 1 \end{bmatrix} \begin{bmatrix} u_{1x} \\ u_{1y} \\ u_{3x} \\ u_{3y} \end{bmatrix} \\
&= \frac{AE}{8L} \begin{bmatrix} 3 & \sqrt{3} & -3 & -\sqrt{3} \\ \sqrt{3} & 1 & -\sqrt{3} & -1 \\ -3 & -\sqrt{3} & 3 & \sqrt{3} \\ -\sqrt{3} & -1 & \sqrt{3} & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \frac{P L}{AE} \\ \frac{4}{3} \end{bmatrix} \\
&= \begin{bmatrix} f_{1x} \\ f_{1y} \\ f_{3x} \\ f_{3y} \end{bmatrix}
\end{align*}
\] 

(2-62)

Substituting in the nodal displacements,

\[
\begin{align*}
\begin{bmatrix} f_{1x} \\ f_{1y} \\ f_{3x} \\ f_{3y} \end{bmatrix} &= \begin{bmatrix} \frac{1}{2} + \frac{3\sqrt{3}}{2} \\ \frac{3}{6} \sqrt{3} \\ \frac{1}{2} - \frac{3\sqrt{3}}{2} \\ \frac{3}{6} + \frac{\sqrt{3}}{6} \end{bmatrix} \approx \begin{bmatrix} 2.10 \\ 1.21 \\ -2.10 \\ -1.21 \end{bmatrix}
\end{align*}
\] 

(2-63)

and carrying out the multiplication yields:

\[
\begin{align*}
\begin{bmatrix} f_{1x} \\ f_{1y} \\ f_{2x} \\ f_{2y} \end{bmatrix} &= \begin{bmatrix} \frac{1}{2} + \frac{3\sqrt{3}}{2} \\ \frac{3}{6} \sqrt{3} \\ \frac{1}{2} - \frac{3\sqrt{3}}{2} \\ \frac{3}{6} + \frac{\sqrt{3}}{6} \end{bmatrix} \approx \begin{bmatrix} 2.10 \\ 1.21 \\ -2.10 \\ -1.21 \end{bmatrix}
\end{align*}
\] 

(2-64)
Since element 1 is situated on an angle, we must find the resultant of the nodal force components to determine the tensile or compressive inline force within the element. The resultant, R, of the force components \( f_{1x} \) and \( f_{1y} \) is

\[
R = P \sqrt{\left( -2 + \frac{3\sqrt{3}}{2} \right)^2 + \left( \frac{3}{2} - \frac{\sqrt{3}}{6} \right)^2} = P \left( -\frac{1}{2} + \frac{3\sqrt{3}}{2} \right) \left( \frac{3}{2} - \frac{\sqrt{3}}{6} \right) = 2.54P
\]

and from the direction of these force components we can ascertain that element #1 is in compression. This procedure is then repeated to determine the forces in each of the remaining elements, and with these forces it is possible to evaluate the stress and strain within each element.

2.2.2 Symmetry Considerations

The truss problem suggested in Section 2.2.1 was geometrically symmetrical about a line drawn down the center of the structure. If the loading applied to the truss had been symmetrical about this centerline as well (Figure 2-7), then the principle of symmetry could be used to reduce the computational effort required to solve the problem. When subjected to a symmetrical set of loads, the results will be a mirror image on both sides of line of symmetry. To take advantage of this property, the model may be cut along line of symmetry, and only half of the model needs to be processed to obtain a solution. By reducing the number of active DOF required to solve the problem, the size of the stiffness matrix that must be assembled has also been reduced. When used in FEA software to solve large problems, the advantages include faster solution times and a reduction in
storage requirements, or the ability to produce finer mesh densities or larger models within computer hardware and software limitations.

![Symmetrical Truss Problem](image)

Figure 2-7: Symmetrical Truss Problem

In this half model analysis, symmetry boundary conditions are applied to nodes along the cut boundary, and the vertical element is reduced in cross-sectional area by one-half. In general, symmetry boundary conditions consist of constraining nodal displacements normal to the line (or plane) of symmetry, while permitting displacement along this line (or plane). If rotational degrees of freedom were used, then the rotational DOF out of the plane of symmetry would be constrained. For this particular model, the symmetry boundary conditions are simply the condition, $u_x = 0$, applied to the nodes along the line of symmetry (Figure 2-8).
Figure 2-9 shows the discretization used to solve this half model analysis. The element and node numbering has been chosen to be consistent with the full model analysis in Section 2.1.1. As a result, the equations for element numbers 6 thru 9 will be the same.
In this half model analysis, however, element 5 has half the cross-sectional area of the element 5 in the full model problem. Therefore, the equations for this element must be adjusted as follows:

\[
\begin{bmatrix}
    f_{3x} \\
    f_{3y} \\
    f_{4x} \\
    f_{4y}
\end{bmatrix} = \begin{bmatrix}
    0 & 0 & 0 & 0 \\
    0 & 1 & 0 & -1 \\
    0 & 0 & 0 & 0 \\
    0 & -1 & 0 & 1
\end{bmatrix}\begin{bmatrix}
    u_{3x} \\
    u_{3y} \\
    u_{4x} \\
    u_{4y}
\end{bmatrix}
\]

(2-66)

As before, the global stiffness matrix must be assembled, but needs only the terms corresponding to the active DOF included. The global stiffness equations for this half model analysis with symmetry boundary conditions are:

\[
AE \left[ \begin{array}{cccc}
\frac{1}{2} + \frac{\sqrt{2}}{4} + \frac{1}{8} & -\frac{1}{2} & \frac{\sqrt{2}}{4} & -\frac{\sqrt{2}}{4} \\
\frac{1}{2} & 1 & 0 & 0 \\
\frac{\sqrt{2}}{4} & 0 & 1 + \frac{\sqrt{2}}{4} + \frac{1}{\sqrt{3}-1} & -\frac{\sqrt{2}}{4} \\
-\frac{\sqrt{2}}{4} & 0 & -\frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4}
\end{array} \right] \begin{bmatrix}
    u_{3y} \\
    u_{4y} \\
    u_{5x} \\
    u_{5y}
\end{bmatrix} = \begin{bmatrix}
    F_{3y} \\
    F_{4y} \\
    F_{5x} \\
    F_{5y}
\end{bmatrix}
\]

(2-67)

which can be simplified to

\[
AE \left[ \begin{array}{cccc}
\frac{5 + 2\sqrt{2}}{8} & -\frac{1}{2} & \frac{\sqrt{2}}{4} & -\frac{\sqrt{2}}{4} \\
\frac{1}{2} & 1 & 0 & 0 \\
\frac{\sqrt{2}}{4} & 0 & 4 + \frac{\sqrt{2}}{4} + \frac{1}{\sqrt{3}-1} & -\frac{\sqrt{2}}{4} \\
-\frac{\sqrt{2}}{4} & 0 & -\frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4}
\end{array} \right] \begin{bmatrix}
    u_{3y} \\
    u_{4y} \\
    u_{5x} \\
    u_{5y}
\end{bmatrix} = \begin{bmatrix}
    F_{3y} \\
    F_{4y} \\
    F_{5x} \\
    F_{5y}
\end{bmatrix}
\]

(2-68)
The force vector for this half model symmetry analysis is

\[
\mathbf{F} = \begin{bmatrix} F_{3y} \\ F_{4y} \\ F_{5x} \\ F_{5y} \end{bmatrix} = P \begin{bmatrix} 0 \\ 0 \\ 0 \\ -1 \end{bmatrix}
\]

To solve for nodal displacements, we must carry out the matrix multiplication of equation 2-60 resulting in:

\[
\mathbf{u} = \frac{PL}{AE} \begin{bmatrix} -8 \\ -8 \\ -1/3(\sqrt{3} - 1) \\ -1/6(\sqrt{3} - \sqrt{2} + 4\sqrt{3})\sqrt{2}\sqrt{3} \end{bmatrix} \approx \begin{bmatrix} -8.00 \\ -8.00 \\ -0.423 \\ -11.3 \end{bmatrix}
\]

(2-70)

### 2.2.3 Anti-symmetry Considerations

Another useful technique in FEA uses the principle of anti-symmetry. In Section 2.2.2, it was shown that a symmetrical FEA model with a symmetrical load set could be solved by applying appropriate boundary conditions to a reduced FEA model. The same can be done if the loading applied to the symmetrical model was anti-symmetrical about the line of symmetry. An anti-symmetrical load set consists of forces (or pressures, displacements, etc.) applied to mirrored locations on either side of the line of symmetry that are equal and opposite in magnitude and direction. For example, an anti-symmetric load set applied to the same truss arrangement as earlier could look like Figure 2-10. Note that the applied loads are in opposite directions on either side.
Like the symmetrical analysis of Section 2.2.2, the solution for this scenario can be obtained by applying appropriate boundary conditions to a half model analysis. Again, this half model analysis will have a reduced number of active DOF, which reduces the computational effort required in obtaining a solution. In general, anti-symmetry boundary conditions consist of constraining nodal displacements in the line (or plane) of symmetry, while permitting displacement perpendicular to this line (or plane). If rotational degrees of freedom were used, then the rotational DOF within the plane of symmetry would be constrained. For this particular model, the anti-symmetry boundary conditions are simply the condition, $u_y = 0$, applied to the nodes along the line of symmetry (Figure 2-11).
The same discretization used for the symmetry analysis in Section 2.2.2 (Figure 2-9) will be used for this half model analysis. As before, the global stiffness matrix must be assembled, but needs only the terms corresponding to the active DOF included. The global stiffness equations for this half model analysis with anti-symmetry boundary conditions are:

\[
\frac{AE}{L} \begin{bmatrix}
\frac{3+2\sqrt{2}}{8} & 0 & -\frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4} \\
0 & 1 & -1 & 0 \\
-\frac{\sqrt{2}}{4} & -1 & \frac{4+\sqrt{2}}{4} + \frac{1}{\sqrt{3}-1} & -\frac{\sqrt{2}}{4} \\
\frac{\sqrt{2}}{4} & 0 & -\frac{\sqrt{2}}{4} & \frac{\sqrt{2}}{4}
\end{bmatrix}
\begin{bmatrix}
u_{3x} \\
u_{4x} \\
u_{5x} \\
u_{5y}
\end{bmatrix} = \begin{bmatrix}
F_{3x} \\
F_{4x} \\
F_{5x} \\
F_{5y}
\end{bmatrix}
\]

(2-71)
And the force vector for this FEA problem is:

$$\mathbf{F} = \begin{bmatrix} F_{3x} \\ F_{4x} \\ F_{5x} \\ F_{5y} \end{bmatrix} = P \begin{bmatrix} 0 \\ 0 \\ 0 \\ -1 \end{bmatrix}$$

(2-72)

To solve for nodal displacements, we must carry out the matrix multiplication of equation 2-60 resulting in:

$$\begin{bmatrix} u_{3x} \\ u_{4x} \\ u_{5x} \\ u_{5y} \end{bmatrix} = \frac{PL}{AE} \begin{bmatrix} 8 \\ \frac{1}{3} \\ 1 - \sqrt{3} \\ 1 - \sqrt{3} \end{bmatrix} \begin{bmatrix} 2.67 \\ -0.732 \\ -0.732 \\ -6.23 \end{bmatrix}$$

(2-73)

### 2.2.4 Superposition Considerations

The final FEA technique to be described, utilizes the principle of superposition. The properties of superposition are that FEA results are both additive and linear. In other words, the analysis results arising from separate load vectors applied to the same FEA model may be added together, or superimposed, and the combined results would be the same as if both load vectors had been superimposed and solved simultaneously. For instance, the truss frame example in Section 2.2.1 was subjected a load vector \( \mathbf{F} \) that can be expressed as a superposition of two separate load vectors \( \mathbf{F}_3 \) and \( \mathbf{F}_4 \), as follows:
\[
F = \begin{bmatrix}
F_{2x} \\
F_{2y} \\
F_{3x} \\
F_{3y} \\
F_{4x} \\
F_{4y} \\
F_{5x} \\
F_{5y}
\end{bmatrix} = P \begin{bmatrix}
0 \\
-1 \\
0 \\
0 \\
0 \\
0 \\
0 \\
-2
\end{bmatrix} = F_s + F_A = \frac{3P}{2} \begin{bmatrix}
0 \\
-1 \\
0 \\
0 \\
0 \\
0 \\
0 \\
-1
\end{bmatrix}_s + \frac{P}{2} \begin{bmatrix}
0 \\
1 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}_A
\]

(2-74)

where \( F_s \) and \( F_A \) are symmetric and anti-symmetric, respectively, about the centerline of the model. Using the principle of superposition, it is possible to solve these load vectors separately; and considering the fact that FEA results are linear, it is possible to scale the results of results of in Sections 2.2.2 and 2.2.3 to obtain equivalent results, as would be produced from the vectors above. Therefore, it is now possible to obtain the identical results of the full truss problem subjected to the unsymmetrical load vector, \( F \), without assembling the full FEA model, but by superimposing the results of two half model analyses instead.

The results of the symmetry analysis in Section 2.2.2 (\( u_s \)) expanded to the same order of the full truss problem can be expressed as,
taking into consideration the effect of the symmetry conditions on the results of the un-modeled portion of the truss. To obtain the results of the full truss problem subjected to the load vector $\mathbf{F}_s$, we simply need to multiply the results of Section 2.2.2 by the appropriate linearity constant:

\[
\mathbf{U}_s = \frac{3}{2} \mathbf{U}_s = \frac{3}{2} \begin{bmatrix}
    u_{2x} \\
    u_{3x} \\
    u_{4x} \\
    u_{5x} \\
    u_{2y} \\
    u_{3y} \\
    u_{4y} \\
    u_{5y}
\end{bmatrix} = \frac{3}{2} \begin{bmatrix}
    \frac{1}{3} \sqrt{3} (\sqrt{3} - 1) \\
    -\frac{1}{6} (9\sqrt{2} \sqrt{3} - \sqrt{2} + 4\sqrt{3}) \sqrt{2} \sqrt{3} \\
    0 \\
    -8 \\
    0 \\
    -8 \\
    \frac{1}{3} \sqrt{3} (\sqrt{3} - 1) \\
    -\frac{1}{6} (9\sqrt{2} \sqrt{3} - \sqrt{2} + 4\sqrt{3}) \sqrt{2} \sqrt{3}
\end{bmatrix} \frac{PL}{AE} = \begin{bmatrix}
    0.634 \\
    -16.9 \\
    0 \\
    -12.0 \\
    0 \\
    -12.0 \\
    -0.634 \\
    -16.9
\end{bmatrix}
\]

(2-76)
Similarly, the results of the anti-symmetry analysis in Section 2.2.3 (\(u_a\)) expanded to the same order of the full truss problem can be expressed as

\[
\begin{align*}
\begin{bmatrix}
    u_{2x} \\
    u_{2y} \\
    u_{3x} \\
    u_{3y} \\
    u_{4x} \\
    u_{4y} \\
    u_{5x} \\
    u_{5y}
\end{bmatrix} &= \frac{PL}{AE} \begin{bmatrix}
    1 - \sqrt{3} \\
    \frac{1}{6}(3\sqrt{2}\sqrt{3} + 5\sqrt{2} + 12)\sqrt{2} \\
    \frac{8}{3} \\
    0 \\
    1 - \sqrt{3} \\
    0 \\
    1 - \sqrt{3} \\
    -\frac{1}{6}(3\sqrt{2}\sqrt{3} + 5\sqrt{2} + 12)\sqrt{2}
\end{bmatrix} \begin{bmatrix}
    -0.732 \\
    6.23 \\
    2.67 \\
    0 \\
    -0.732 \\
    0 \\
    -0.732 \\
    -6.23
\end{bmatrix}
\end{align*}
\]

(2-77)

taking into consideration the effect of the anti-symmetry conditions on the results of the un-modeled portion of the truss. And, we may obtain the results of the full truss problem subjected to the load vector \(F_A\) by multiplying the results of Section 2.2.3 by the appropriate linearity constant:

\[
\begin{align*}
\begin{bmatrix}
    u_{2x} \\
    u_{2y} \\
    u_{3x} \\
    u_{3y} \\
    u_{4x} \\
    u_{4y} \\
    u_{5x} \\
    u_{5y}
\end{bmatrix} &= \frac{1}{2} \begin{bmatrix}
    \frac{1}{2}PL \\
    \frac{1}{2}PL \\
    \frac{1}{2}PL \\
    \frac{1}{2}PL \\
    \frac{1}{2}PL \\
    \frac{1}{2}PL \\
    \frac{1}{2}PL \\
    \frac{1}{2}PL
\end{bmatrix} \begin{bmatrix}
    1 - \sqrt{3} \\
    \frac{1}{6}(3\sqrt{2}\sqrt{3} + 5\sqrt{2} + 12)\sqrt{2} \\
    \frac{8}{3} \\
    0 \\
    1 - \sqrt{3} \\
    0 \\
    1 - \sqrt{3} \\
    -\frac{1}{6}(3\sqrt{2}\sqrt{3} + 5\sqrt{2} + 12)\sqrt{2}
\end{bmatrix} \begin{bmatrix}
    -0.366 \\
    3.11 \\
    1.34 \\
    0 \\
    -0.366 \\
    0 \\
    -0.366 \\
    -3.11
\end{bmatrix}
\end{align*}
\]

(2-78)
To obtain the same results as the full model analysis in Section 2.2.1, we simply must superimpose the results of the above half model analyses to obtain:

\[
\begin{pmatrix}
\begin{array}{c}
u_{2x} \\
u_{2y} \\
u_{3x} \\
u_{3y} \\
u_{4x} \\
u_{4y} \\
u_{5x} \\
u_{5y}
\end{array}
\end{pmatrix} = \begin{pmatrix}
0.634 & -0.366 \\
-16.9 & 3.11 \\
0 & 1.34 \\
-12.0 & 0 \\
0 & -0.366 \\
-12.0 & 0 \\
-0.634 & -0.366 \\
-16.9 & -3.11
\end{pmatrix} + \begin{pmatrix}
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0
\end{pmatrix} = \begin{pmatrix}
0.268 \\
-13.8 \\
1.34 \\
-12.0 \\
-0.366 \\
-12.0 \\
-1.00 \\
-20.0
\end{pmatrix}
\]

(2.79)

Note that any discrepancy between the results above and those of Section 2.2.1 is due to rounding errors in expressing the exact solution in decimal form using floating-point-arithmetic. This discrepancy was also expected considering the fact that the decimal solution has been presented to only three significant figures. A check of this analysis indicated that there is no discrepancy between the exact solutions.
Chapter: 3 Design and Performance of Heavy Hauler Bodies

3.1 Construction and Fabrication

The standard dump body for most mining trucks is a welded, steel plate structure consisting of flat floor, sidewall and canopy components with an intricate pattern of box-style stiffeners on the outer sides of each. An array of floor stiffeners (called bolsters) run from side to side, while two main rails (called stringers) run lengthwise. Where the two intersect, the main rails are cut to fit over the bolsters and the intersection seam is continuously welded. The floor bolsters are not of a regular, constant cross-section. Instead, they vary in cross-section providing greater stiffness towards the centerline of the structure.

Figure 3-1: Floor Stiffening Arrangement
Size restrictions, imposed by transportation limitations, prevent the entire truck from being assembled at the manufacturing facility. The only way to access or transport goods to the mine sites north of Fort McMurray, Alberta is by a provincial highway. Considering the fact that a fully assembled haul truck is too large to be driven on conventional highways, it is impossible to deliver them in one piece. Instead, large portions are assembled at the factory and transported to the site by tractor-trailer. Final assembly occurs on-site where manufacturing and assembly tools are limited in comparison to the manufacturing facility. In the case of the dump body, the body arrives in several separate pieces and is arranged for welding upside down supported by jacks and blocks, often outdoors on the ground.

Weld repairs, as well, are quite often carried out with the dump body laid upside down outdoors. Cracks and cracked welds are ground away completely with hand-held grinders, and the original volume of material is replaced with multiple weld passes until the original weld fillet is built-up. In some circumstances, SCL replaces the original weld specifications with heavier, more robust weld sizes. Although it is possible to stress relieve such weld repairs with strap-on heat packs, no stress relieving of any sort is carried out on these repairs. The result is that the replacement welds themselves are no better suited to resist cracking, and the cracks quickly return.
3.2 Operational Performance

It is a full time effort for SCL's truck maintenance group to keep these heavy hauler mining trucks running continuously. Haul truck operators work on 12-hour shifts taking only 1-hour worth of breaks daily. At end of each shift, another operator takes over keeping the truck in constant service. These trucks, however, do come out of service on a regular basis for scheduled maintenance. Things like engine oil changes, gearbox oil changes, electrical system inspection and maintenance, and recharging of the suspension strut pressures are necessary to keep the truck operating properly. After a certain number of operating hours, even the engine module gets rebuilt. Because of the lead-time required to rebuild an engine module, a spare engine module is used to keep the fleet operating constantly.

All regularly scheduled maintenance repairs occur at a specified number of operating hours. Quite often, however, repairs are required for incidental occurrences. From time to time, certain items like handrails, stairs and brackets need repair. Other times, trucks are damaged by accidents such as contact with other mining equipment; for example, the shovel operator may contact the haul box while loading. While such repairs are a common part of heavy hauler operation, they are all caused by circumstances outside of what would be referred to as 'regular service'. All heavy haulers at Syncrude mine sites, however, develop some degree of cracking in the dump body during regular service, which requires weld repair on a regular basis. Although these repairs are required regularly, they should not be considered a part of regular truck maintenance. At present,
these non-incidental repairs are a continuous cost of operation, and should be reduced if not eliminated in the future.

This perpetual cracking occurs in the welds forming the intersections between the widthwise and lengthwise floor stiffeners (bolsters and stringers respectively). These regions of interest will hereafter be referred to as bolster-stringer intersections. Cracking seems to develop first on the inside of the stringers, near the hinge pivots, even after very short periods of regular service (Figure 3-2). If left un-repaired, the cracks will propagate until all of the bolster-stringer intersection welds have eventually cracked.

![Region of Interest](image)

**Figure 3-2: Location of Floor Stiffener Cracking**

### 3.3 Weld Repair Costs

Heavy hauler floor stiffener cracking is such a problem in oil sand mining operations that trucks are inspected with Non-Destructive Testing (NDT) to track the extent of crack
growth whenever the truck undergoes routine maintenance such as oil changes. In the case of the Komatsu 930E fleet in operation in the Mildred Lake mines, $248,753 was spent on welding crack repairs alone in these eight trucks over a period of 2 years and 9 months, according to the work orders entered into the Syncrude process information system (Appendix A). In terms of shop time, 3473 man-hours in total were put in to repairing the cracked welds in the Syncrude maintenance shops. Not included in these costs are the charges of getting work done at an outside contractor’s site, where the bulk of large repair overhauls and modification work is done.

To minimize the downtime impact on production required to continually repair floor stiffener cracking, a spare body is used. For a fleet of eight trucks, the ninth (spare) body is continuously out-of-service getting weld repairs. Although fleet downtime is significantly reduced with this spare body, it does represent another $306,000 in a capital expense. In short, floor stiffener cracking is an ongoing and very expensive problem associated with running a fleet of heavy haulers. The company is currently investigating several options to reduce or minimize these costs, including purchasing new body designs. This work is providing insight as to the cause of these problems, which will assist in the decision making process.
4.1 Modeling Methodology

4.1.1 Requirements and Limitations

The primary factors that govern the complexity of a FEA model are the structural geometry, loading conditions, and the information to be extracted from the model. The intricate pattern of reinforcement in this structure need only be included in sufficient detail to model the results of interest. Incorporating a level of detail beyond this would waste both model creation time and valuable computational resources. The information of primary interest from this FEA model is the state of stress at the many bolster-stringer intersections, where cracking is a continual problem. To investigate the stress at these locations, the overall deformation of the haul body floor must be accurately modeled in the analysis. To capture this deformation, the flat plate stiffening arrangement has been modeled in detail.

During regular mining operations, the entire truck structure experiences a combination of static, dynamic and impact loading. While dynamic and impact loading would produce stresses within the structure greater than that of static loading, a static analysis has been used for the purpose of this investigation. The reason for this is that although a dynamic analysis would better reflect the nature of the loading, it would also require an analytical effort well beyond what was achievable in the desired timeline. In addition, a
prerequisite for any dynamic analysis is to understand the static response in detail. This work identifies, for the first time, the damage mechanism and source responsible for floor stiffener cracking.

Since FEA is a numerical analysis technique, the limitations of the computer software and hardware must also be considered. A significant effort has been put into making this FEA model as efficient as possible. This includes efficiency in data storage, computational effort, and overall serviceability and adaptability of the model. Perhaps the most valuable feature of the ANSYS 5.5.3 finite element software package used in this analysis is the ability to use input files. Input files are standard text files containing a sequence of commands to be executed by the software. Instead of saving the FEA model database files directly, a much smaller text file containing the commands used to assemble the model can be stored instead. At present, the ANSYS software does not have a simple 'undo' command for correcting simple mistakes made during model creation. Using input files, small mistakes may be corrected easily by editing the text file. In addition, using the ANSYS parametric design language (APDL) it is possible to include logic statements, program loops, as well as statements calling other input files to be read.

All of the geometry creation, material property selection, mesh sizing, and even analysis commands used in this analysis have been assembled into a hierarchy of thirty-six such text based input files. The first input file (called 1_MAIN_INPUT) is at the top of the
hierarchy, and breaks the work into discrete sections such as geometry creation and meshing. Each section then contains call statements for input files that contain the appropriate commands for that portion. The 2-series of files setup the analysis options and build the model geometry. The 3-series of files assign the appropriate material thickness settings to the geometry areas. The 4-series of files apply the element mesh and boundary conditions for the analysis. While the 5-series of files contain commands for viewing and analyzing the results of the haul body analysis. The 6-series of files contain commands for a shell-to-solid sub-model analysis, which will be discussed later. The 7-series of files were used to model the frame of the haul truck supported on uneven strut forces, and as will be discussed later the 8-series of files combine both the frame and body FEA models. A printed copy of these thirty-six text based files is contained in Appendix B.

As mentioned previously, the software used for this analysis was ANSYS version 5.5.3. This software is licensed for use at SCL's Edmonton Research Center. Unlike university versions that are restricted to 32,000 nodes, this software does not restrict the size of the FEA models that can be analyzed. Instead, computer hardware offers the only modeling limitations. The platform on which the software runs is a DEC Personal Workstation 600au (EV 5/6chip 600 MHz) with a Digital Unix alpha 4.0D operating system. With 1.256Gb of physical memory, 1.270Gb of swap disk space, and 28Gb of storage capacity in a Raid disk, this platform was more than sufficient to solve the largest FEA models used in this analysis.
4.1.2 Element Selection

Two groups of elements are applicable for this type of analysis: shell and solid elements. Shell elements efficiently model the behavior of thin plates provided that the assumptions made in the element formulation are acceptable, and offer a significant reduction in computational effort when compared to a similar analysis using solid elements. The SHELL93 element has a quadratic displacement shape function that produces a linear strain distribution within the element. Bending stresses vary linearly though the thickness, while the transverse shear stresses are assumed constant though the element. This element is well suited to efficiently model the global behavior of the steel plate structure.

Shell elements are limited, however, in that they represent stresses through the material thickness as a linear variation from one surface to another. If greater detail is required, then shell elements will not suffice. In a three-dimensional model, such information can only be obtained through a discretization of volume elements. When compared to an equivalent shell element model, the number of elements and DOF associated with a volume element analysis is enormous. Conducting a volume element analysis of the entire body structure is beyond the solution capabilities of the computer hardware used in this project; hence, it simply was not feasible.

If required later, a Shell-to-Solid sub-model analysis using SOLID95 elements could be used. In a sub-model analysis, results of a larger and coarser global model are used to
form the boundary conditions for a smaller and more refined sub-model. This technique makes it possible to analyze specific regions in detail without having to refine and resolve the entire FEA model. By using solid elements in the sub-model, it is possible to see the results of interest in greater detail than is possible with a shell element analysis alone. The shell element or global model would adequately describe the structural response of the entire body to various loading scenarios, while the solid element sub-model would 'feed' off of these results to reveal the state of stress in localized regions in much greater detail. Presently, however, such detail has not been required and this analysis option has not been used.

### 4.1.3 Meshing

Meshing is the term used to describe the discretization of the model geometry into discrete or 'finite' elements. Two meshing options are available in the ANSYS software package: free and mapped meshing. Mapped meshing allows the user to directly control the element size and pattern during the discretization process. Through such control, clean, uniform and efficient meshes are possible resulting in lower solution times. Free meshing uses computer algorithms to automatically discretize the model geometry. These algorithms respond to the geometry, refining the mesh near regions of detail such as small curves and angles. The primary advantage of free meshing is the speed of mesh generation. By adjusting the algorithm parameters, meshes of varying density can be generated quickly, which is particularly useful in establishing convergence.
The meshing technique used in this model, however, was a combination of both. In the ANSYS software package, it is possible to exercise direct control of the mesh sizing at some locations of the model, while allowing the free meshing routines to generate the mesh and discretize the remaining geometry automatically. In this way, the advantages of both meshing options are exploited.

4.2 Boundary Conditions

The accuracy of FEA results are highly dependant on the accuracy of the boundary conditions (BCs) applied to the model. It is therefore, a major concern of this study to adequately represent the support and load conditions on a working haul truck box. Often, the results of interest are sensitive to some BCs and not sensitive to others. It is important to understand this sensitivity in order to effectively evaluate the effect assumptions have on the results of interest. For BCs that are not sensitive, general engineering judgment may be sufficient, whereas BCs that are sensitive to the results of interest may require a much more judicial effort.

4.2.1 Symmetry

If a model is symmetrical about one or more planes, in terms of both loading and geometry, then symmetry BCs can be used to dramatically reduce the computational effort required in obtaining a solution. A 930E haul body is geometrically symmetrical about a single plane down the middle of the structure. For analyses in which both the applied loading and support conditions are symmetrical about this plane as well, only half of the structure needs to be modeled (see Figure 4-1). Along the plane of symmetry, BCs
are applied to represent the effects of the other half of the model. More specifically, the nodal displacements are not permitted to cross the place of symmetry, and nodal rotations out of the plane of symmetry are held at zero.

Figure 4-1: 930E Body Full Model Geometry and Symmetry Model with BCs

In situations where the applied loading or the support BCs are not symmetrical about this plane, the symmetry condition cannot be used. If the applied load or displacement is equal and opposite on the other symmetrical half of the model, on the other hand, antisymmetry conditions may be used along the cut plane. Symmetrical and antisymmetrical loads may be analyzed separately and superimposed to study the combined effect of each. This technique was used extensively in the trial analyses that identified the need to study support displacement in detail, which will be discussed in Chapter 5.

For asymmetrical loading situations, or verification of superimposed half-model results, a full finite element model has to be assembled. The input routines used for this FEA model have been created in such a way that this poses no significant challenge.
However, solution times of a full model FEA are as much as four times that of a half model analysis. Whenever possible, half model analyses were conducted to save time.

### 4.2.2 Initial Supporting Conditions

In order to obtain a solution, initial supporting conditions were applied to the model geometry. These conditions are meant to simulate the supporting effect the frame has on the haul body when the truck is stationary sitting on level ground, an ideal situation. It later became evident that frame displacement is a source of structural loading, and an entirely different means of supporting the body structure in a FEA will be discussed in detail later. The following initial supporting conditions were used to start the analysis process.

Haul truck dump bodies have three support locations: a hinged pin connection at the rear of the truck frame, a rubber pad distributed support condition along the main beams of the frame, and hinged pivot connections to the hoist cylinders. For this analysis, the lowered box position only will be considered, so the effect of the hoist cylinder supports in this position has been ignored. The distributed support condition of the rubber pads along the front stringers of the frame has been represented by constraining the displacement in the vertical direction $U_y=0$ on the areas representing the stringer bottom plate (see Figure 4-2). Such solid-model BCs are transferred to the nodes of the finite element mesh when a solution is initiated.
Representing hinge pivot conditions effectively is often a considerable challenge. For the present load case, the structure is not expected to rotate significantly about the center axis of the hinge pin. Rather, the bearing forces of the weight resting on the pin were deemed significant. The weight resting on the pin was represented by constraining $U_y=0$ on the lines that make up the top of the hinge pivot holes. To resist any forward motion, due to the $9^\circ$ slope of the floor, the constraint $U_z=0$ was applied to the lines that make up the rear of the same pivot holes (see Figure 4-3).
4.2.3 Ore Load Application

The most significant force that is applied to a truck body is pressure on the inside faces due to the weight of a full load of oil sand. This pressure distribution is a function of the oil sand soil mechanics and the pile shape. The version of FEA software used is limited in that pressure gradients may be specified on only one coordinate direction at a time. To apply the distributed load of a rounded pile of oil sand, some amount of discretization and approximation was necessary. One option was to break the inside face areas into a number of sections, applying appropriate face pressures as required. While this manual discretization would be effective, a more adaptive, adjustable concept proved to be much more useful.

An ANSYS algorithm that applies face pressures to elements based on their location within the structure was developed. The result is a much finer pressure discretization than would be attempted manually, and one that is directly proportional to the mesh density of the inside face areas. With this algorithm, rounded pressure distributions were now possible, circumventing the ANSYS single gradient limitation. Most importantly, the algorithm allows for adjustments in the pressure distribution with minimal effort. In this way, the effect of off-center loads and oversized loads can be investigated for a variety of soil types and conditions.

4.2.3.1 Approximate Profile Shape

The only established standards for haul box design are the Society of Automotive Engineers (SAE) Standard J1363\textsuperscript{5} and the International Standards Organization (ISO)
Standard 6483, which is the same as the SAE standard adopted without modification. The interesting thing about these standards is that both are capacity ratings only. They make no reference to the types of material being hauled, no reference to the forces expected in service, and specify nothing with respect to structural strength. Instead, they specify a detailed way to measure the volumetric rating, or the volume of material that the body can carry, for any given body geometry. While the volumetric rating is useful in comparing the capacity ratings of different bodies, it has little relevant use in haul body design. The ore load shape specified suggests a 2:1 slope above the haul body sidewalls and a 1:1 slope near the rear (Figure 4-4). Such a shape is impossible because no known material would form two separate slopes when poured naturally.

![Figure 4-4: SAE J1363 Capacity Rating](image)

In addition, using this shape as a load profile has been shown to be a poor estimator of the true center-of-gravity location. Philipi-Hagenbuch, a producer of patented lightweight haul body designs, suggests that the center-of-gravity location predicted by the established standards is not accurate when compared to on-site investigations. The result of this is that the true center-of-gravity location is offset from the location for
which the truck has been designed, and the weight distribution onto the frame is affected accordingly. To develop lightweight bodies that also correct the center-of-gravity location onto the truck frame, Philipi-Hagenbuch uses a patented profiled shape that more accurately represents the load shapes seen on individual customer sites.

For similar reasons, it was decided that a more realistic shape than the established standards should be used in this analysis. From a recent payload study, side profile and rear profile pictures were collected for a number of oil sand payloads along with their corresponding weigh scale weights. Some minor editing of the pictures was done to accentuate the features of interest, namely the floor and front wall lines, and the oil sand pile profile lines. The trend line fitting feature of Microsoft Excel was used to determine relative functions describing the geometry (Figures 4-5 and 4-6).

Figure 4-5: Side Profile Shape from Payload Study Picture
Using symbolic math software, the picture rotation effect was subtracted from the shape functions, and known box dimensions were used to return to a true scale. Once scaled, it was then possible to create a three-dimensional function to approximate the payload observed. The average of nine different approximate payload functions was used to develop a simplified shape function (Figure 4-7) shown here along with the floor and front wall planes.
Mathematically, the above function can be described in mm units as follows:

\[
PROFILE = MaxHeight \left[ 1 - \left( \frac{X - XPeak}{4850} \right)^2 \right] \left[ 1 - \left( \frac{Z - ZPeak}{6650} \right)^2 \right]
\]

(4-1)

where \( XPeak \) is the location of the pile peak offset from the centerline of the truck, \( ZPeak \) is the location of the pile peak measured from the floor - front wall edge, and \( MaxHeight \) is the height of the pile peak from that same floor - front wall edge. \( MaxHeight \) in mm can be expressed as a function of oil sand mass and density in the range of interest (250 ~ 400 short tons):

\[
MaxHeight = \left( 22.2 \times \frac{Mass}{Density} \right) + 1020
\]

(4-2)

where \( Mass \) is expressed in metric tonnes (te) and \( Density \) is expressed in metric tonnes per cubic meter (\( \text{te/m}^3 \)).

In a word of caution, it should be noted that this is not meant to be a statistical representation of the ore shapes expected in an oil sand mine. It does not include such factors as seasonal soil properties, large lumps, rocks, etc. This representation is not intended to be used for any other purposes such as the studies used to optimize shovel-loading practices. It does, however, provide an easily adjustable load shape that is more representative of reality than the established SAE standards.
4.2.3.2 Soil Mechanics

The next step in the ore load application scheme was to determine the pressures on the inside faces as a function of this approximate load shape. Using the same soil mechanics principles used in foundation design, the pressures on the walls of this dump box can be broken down into vertical and lateral components. The vertical pressure $\sigma_v$ is simply:

$$\sigma_v = \rho gh \quad \text{or} \quad \sigma_v = \gamma h \quad (4\cdot3)$$

where $\rho$ is the density of oil sand ($\text{kg/m}^3$), $g$ is the acceleration due to gravity (9.81 $\text{m/sec}^2$), and $h$ is the height of the column of soil directly above the area in question (Figure 4-8).

The horizontal or lateral load exerted on a frictionless, vertical wall varies linearly with a maximum pressure at the base (see Figure 4-8). According to Das in *Principles of Foundation Engineering*, the Rankine lateral earth pressure at the base is $\sigma_h = K_a \sigma_v$ where $K_a$ is the Rankine active pressure coefficient:

$$K_a = \tan^2(45 - \phi/2) \quad \text{or} \quad K_a = (1 - \sin \phi)/(1 + \sin \phi) \quad (4\cdot4)$$

and $\sigma_v$ is the vertical pressure evaluated at the base of the wall. The angle $\phi$ refers to the angle of repose, or the soil friction angle. The commonly accepted value for oil sand from the Athabasca oil sand deposit is 33°.
The presence of a sloped pile near the wall has the effect of applying a surcharge to the lateral earth pressure. According to Bowles in *Foundation Analysis and Design*, this effect is incorporated as an increase in the Rankine active pressure coefficient as follows\(^1\):

\[
K_a = \cos \beta \frac{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}
\]  

(4-5)

where \(\beta\) is the average slope angle for the active wedge as defined in Figure 4-8. Theoretically, it is impossible for the angle \(\beta\) to be greater than the angle of friction \(\phi\). Since \(\beta\) is usually a few degrees less than \(\phi\), the value \(\beta \approx 30^\circ\) was chosen as a good estimate resulting in \(K_a \approx 0.5\).
4.2.3.3 Load Application Algorithm

The final step in this load application scheme was to write an algorithm that would autonomously apply an appropriate pressure to the face of each element based on its location within the structure. An overview of the algorithm is as follows.

First, a number of parameters are set to allow for adjustment including total payload, density, $K_a$, as well as the location of the pile peak (for off center loads). The areas that form the inside face of the floor, side and front walls are selected and defined as components for ease of selection later. A specific component (e.g., the front wall) is selected for load application and all the elements making up that component are selected as well. The algorithm then enters a loop indexing through all of the selected elements, executing the commands below.

The algorithm addresses each element by indexing through the elements numbers of the currently selected element set. Entering the loop, the element index is set at the minimum selected element number. After processing that element, ANSYS APDL commands are issued which set the element index to the next selected element number, and the process commands are repeated. Once all the selected elements have been processed, the APDL commands will deliver a value of zero for the next available element number, which causes the loop to be exited.
The first step in processing each element is to determine the appropriate lateral and vertical pressure components for that element. APDL commands are issued which collect the three-dimensional coordinate location of the element centroid. The height of the column of soil directly above the element centroid is determined by evaluating the height of the load shape function by substituting in the element X and Z coordinates into the function stated earlier, and subtracting the Y co-ordinate of the element centroid. The vertical pressure on the element is then calculated by substituting this column height into the equation \( \sigma_v = \rho gh \).

Calculating the lateral pressure on the element is a little more involved. As described earlier, the lateral pressure varies linearly from a maximum pressure at the base. For each element location, this base pressure must first be determined. The base pressure is defined as \( \sigma_h = K_a \rho gh \) where \( H \) is the vertical height up the sloped wall where the oil sand surface and the wall intersect (see Figure 4-8). The appropriate lateral pressure for the element location is then determined using the ratio of element centroid Y co-ordinate to the active height \( H \).

Lastly, the calculated pressures are applied directly to the element face as a constant pressure. This is done by superimposing the normal-to-face components. The normal-to-face component of the vertical pressure is \( \sigma_v \cos \theta \) where \( \theta \) is the angle between the wall and the horizontal plane (see Figure 4-9), and \( \sigma_h \sin \theta \) is the normal-to-face component of the lateral pressure. The pressure components along the element face are
neglected since the wall is assumed frictionless. This assumption is valid in the presence of vibration since any friction effects on the walls will dissipate as the oil sand settles.

![Figure 4-9: Superposition of Normal-To-Face Components](image)

The above process is repeated for all selected elements until appropriate pressures have been applied to all of the elements within the component. Then, the next component is selected (e.g. the floor) and the process is continued with a similar methodology. The result is a well discretized pressure profile on the inside element faces (Figure 4-10).

![Figure 4-10: FEA Model After Pressure Application](image)
4.3 Mesh Convergence

4.3.1 Preliminary Mesh

There is a need to demonstrate convergence of the results from a finite element mesh. The mesh must be such that further refinements are not justified since no significant improvement in the results can be expected. To demonstrate this, a suitable quantifier is needed. The initial concept was to refine the mesh until convergence of the stress pattern in an area of interest was achieved. A coarse mesh of the entire geometry was produced (Figure 4-11) with the applied loading and initial support conditions described above, and a solution was initiated.

![Figure 4-11: Coarse Mesh of 930E Box Structure](image)
Bending stresses are setup in the floor due to the weight resting outside of the central supports resulting in a near uniaxial state of stress in the lower plate of the closed-form bolster stiffeners. Given the simplicity of the stress in this region and its proximity to the troublesome bolster-stinger intersections, this location was isolated as a suitable region to demonstrate convergence of the finite element mesh. The state of stress in one such bolster stiffener may be examined by mapping the mid-plane stress results to a path function or a line drawn down the centerline of the lower bolster plate (see Figure 4-12). Mapping the mid-plane stress results omits the effects of localized bending near the bolster-stringer intersections, which will be discussed in detail later. At this time, the overall bending, or global deformation, of the floor stiffener is the result of interest.

Figure 4-12: Path Function on Bolster, and Plot of Stress Results
Figure 4-13: Bolster Path Mid-Plane Stress Results

Figure 4-13 is a plot of the mid-plane stress results with respect to the path length for the test case examined. As expected, the central portion of the stress pattern resembles that of a bending moment diagram for a beam subjected to a distributed load. Compressive stress in the lower plate increases in magnitude towards the direction of the stringer, or main rail. As the bolster passes through the stringer, some discontinuity is expected. The tension seen in the lower plate near the outside of the bolster path can be explained due to the deformed shape of the stiffener. The outer portion of the floor is attached to the sidewall of the body. As the floor plate deforms downward, one would expect the wall to rotate outward. However, the sidewall resists deflection since it is attached to the front wall, and as a result, there is a change in the curvature of the floor. This effect is less
pronounced in bolster stiffeners further away from the front wall where the sidewall stiffness is considerably less.

With respect to mesh quality, the stress pattern along the span of the bolster is smooth and seems to change little with mesh refinement. Near the stringer intersection, on the other hand, the results are very erratic, discontinuous, and change significantly with mesh refinement. For these reasons, it is obvious that further mesh refinement in this area is required. In addition to this, this location is precisely the location of the persistent floor stiffener cracking problems. Therefore, demonstrating a reliable convergence in the results of this region is of particular importance. Uniformly refining the mesh over the entire structure produced cumbersome models, excessive solution times, and minimal improvements in the results of this region. In order to produce a suitably converged mesh, within the limitations of the computer hardware, an efficient refinement methodology was required.

4.3.2 Estimating Solution Error

The error approximation technique included in the ANSYS software is an elegant means of proving reliable convergence. It estimates the amount of solution error due specifically to mesh discretization. The structural energy error (SERR) is a measure of the discontinuity in the stress field from element to element, while the percentage error (SEPC) indicates the relative amount of error due to a particular discretization.
The continuity assumption used in many displacement-based finite element formulations results in a continuous displacement field from element to element, but a discontinuous stress field. To obtain more acceptable stresses, averaging of the element nodal stresses is done within the ANSYS software. *Element nodal data* consist of the element derived data, such as stresses and strains, calculated at the interior integration points and then extrapolated to the nodes\(^\text{11}\). The POST1 postprocessor averages component tensor or vector data at nodes used by more than one element to arrive at a smoothened *nodal solution*.

The error approximation technique incorporated into the ANSYS software package is similar to that given by Zienkiewicz and Zhu\(^\text{12}\). Using these averaged nodal stresses, the processor returns to the element level and evaluates the discrepancy between the averaged results and the results of each element. The stresses at each node of each element are processed to yield:

\[
\{\Delta \sigma_n^i\} = \{\sigma_n^a\} - \{\sigma_n^i\}
\]

where:

- \(\{\Delta \sigma_n^i\}\) = stress error vector at node \(n\) of element \(i\)
- \(\{\sigma_n^a\}\) = \(\frac{\sum_{i=1}^{N_e^n} \{\sigma_n^i\}}{N_e^n}\) averaged stress vector at node \(n\)
- \(N_e^n\) = number of elements connecting to node \(n\)
- \(\{\sigma_n^i\}\) = stress vector of node \(n\) of element \(i\)
Then for each element, the energy associated with this stress error (structural energy error, or SERR) is evaluated similar to the concept of strain energy:

\[
e_i = \frac{1}{2} \left[ \{\Delta \sigma\}^T [D]^{-1} \{\Delta \sigma\} d(\text{vol}) \right]
\]

(4-7)

where:  
\( e_i \) = energy error for element \( i \)

\( \text{vol} \) = volume of the element

\( [D] \) = constitutive matrix

\( [\Delta \sigma] \) = stress error vector at points as needed (evaluated from all \([\Delta \sigma_a]\) of this element).

The total energy associated with discontinuity in the stress field, or energy error, is:

\[
e = \sum_{i=1}^{N_e} e_i
\]

(4-8)

where:
\( e \) = energy error over the entire (or part of the) model.

\( N_e \) = number of elements in the model or part of model.

Energy error can be normalized against the total strain energy to give some measure of the effect on the results of interest. This can be defined over the entire solution domain, or for element subdomains. When calculated over localized regions, it is more meaningful.

\[
E = 100 \left( \frac{e}{U + e} \right)^2
\]

(4-9)

where:
\( E \) = percentage error in energy norm (or SEPC)

\[
U = \sum_{i=1}^{N_e} E_{ei}^{po}
\]

strain energy over the entire (or part of the) model

\[
E_{ei}^{po}
\]

strain energy of element \( i \)
Although it is a good indicator of mesh quality, the percentage error in energy norm (or SEPC) gives little direct information about the stresses. An estimation of the upper and lower stress bounds considering the effect of discretization error is available. Again, these results are more meaningful when evaluated over a localized element subdomain rather than the entire solution domain.

\[
\sigma_{jn}^{\text{min}} = \min \left( \sigma_{jn}^a - \Delta \sigma_n \right) \tag{4-10}
\]
\[
\sigma_{jn}^{\text{max}} = \max \left( \sigma_{jn}^a + \Delta \sigma_n \right) \tag{4-11}
\]

where min and max are defined over the selected nodes, and:

- \( \sigma_{jn}^{\text{min}} \) = output quantity for nodal minimum of stress (SMNB)
- \( \sigma_{jn}^{\text{max}} \) = output quantity for nodal maximum of stress (SMXB)
- \( j \) = subscript for particular stress component or combined stress component
- \( \sigma_{jn}^a \) = averaged stress quantity \( j \) at node \( n \)
- \( \Delta \sigma_n \) = root mean square of all \( \Delta \sigma_i \) from elements connecting to node \( n \)
- \( \Delta \sigma_i \) = maximum absolute value of any component \( \Delta \sigma_i^j \) for all nodes of the element

### 4.3.3 Adaptive Refinement

The above ANSYS error estimation technique gives the user the tools necessary to evaluate the effectiveness of a FEA discretization, to decide where the mesh should be refined, and the effect discretization error has on the results of interest. When applied to the initial mesh of the 930E body bolster stiffener region, the drastic need for mesh refinement can clearly be seen. A plot of the structural energy error (SERR) reported for
each element clearly shows which regions of the structure are highly stressed and have a large stress discontinuity, and thus require significant mesh refinement (see Figure 4-14).

![Figure 4-14: Coarse Mesh SERR in Bolster Stringer Region](image)

With each refinement iteration, the SERR values reported for each element steered the refinement efforts into the region where the bolster stiffener and the stringer main rail intersect. After considerable refinement in this region, the mesh shown in Figure 4-15 was produced. Note the extensive refinement in the lower edge of the outer bolster-stringer intersection.

![Figure 4-15: Refined Mesh in Bolster Stringer Region](image)
Although mesh refinement reduced the structural energy error in the bolster-stringer region considerably, it was noticed that some error always remained in the sharp corner regardless of the level of refinement (Figure 4-16).

Figure 4-16: SERR in Sharp Corner

The explanation for this has to do with the way that ANSYS estimates solution error. As stated previously, the post-processor averages the element nodal stresses, and the discrepancy between the individual element results and the averaged results is used to evaluate discretization error. In a corner section, shell elements in two or more intersecting planes share common nodes. During the element nodal solution averaging process, component stresses in three separate planes are averaged. The problem arises from relative magnitudes. When subjected to displacements along a particular plane, the elements in that plane will develop large stresses in comparison to the elements experiencing out-of-plane displacement. The result is a discontinuity in the element nodal solution. Since this averaged solution is used to estimate discretization error, some error will always be predicted in shell element corner transitions.
The need to demonstrate a suitable convergence of the results in this region remains. As before, the mid-plane stress results of this refined mesh were mapped to a path function in the location shown in Figure 4-12. By comparing the results alongside those of an unrefined mesh, considerable refinement especially in the region of interest can be clearly seen (Figure 4-17). The two spikes in the solution data correspond to the location of the bolster-stringer intersections.

![Figure 4-17: Bolster Path Mid-plane Stress Results](image)

To understand the structural behavior in this region, in light of this numerical discontinuity, let us zoom in on this region of interest to have a closer look (path length: 625mm–975mm). The *Element Nodal Solution* line represents data mapped from the averaged element nodal results, while the *Element Solution* line represents data mapped from the element solution directly with no averaging of results (Figure 4-18). In order to explain the spike in the element solution results, an explanation of how ANSYS maps
results to path function is necessary. For each path point, elements are searched to find elements containing that geometric location and the results from the first element found are mapped to the path. Therefore, within an element thickness of the intersection, element solution data may be obtained from stinger elements rather than the bolster elements. A sharp transition from a compressed state to a near zero stress state can be seen at both intersection locations, because un-averaged stress results are mapped from the out-of-plane stringer elements instead. The averaged results at these intersections appear as less sharp spikes in the otherwise continuous plot.

![Figure 4-18: Path Mid-plane Stress Results (Bolster - Stringer Intersection)](image)

To confirm this explanation, a similar path results plot was produced with only the bolster stiffener elements selected (Figure 4-19). The result: the intersection effect in the averaging of element nodal data has been eliminated because the out-of-plane stringer elements are no longer selected. Since the structural energy error in this region is less
than other, less important regions and the numerical discontinuity effects have been accounted for, the mesh was considered sufficiently converged.

Figure 4-19: Path Results with Only Bolster Elements Selected
Chapter: 5  Analysis, Results and Implications

5.1 Bolster-Stringer Stress

Away from the bolster-stringer intersection, the compressive stresses in the bolster are relatively uniform across the bolster width. At the bolster-stringer intersection, however, the compressive stresses are greatest in the two corners near the bolster sidewalls (Figure 5-1). In order to interpret useful information from this region, a better understanding of the state of stress needed to be developed. Searching for an explanation of this stress, trials were conducted on a simplified geometry with similar support conditions. This smaller, more efficient model enabled faster manipulation of geometry, boundary conditions, and FEA modeling techniques.

Figure 5-1: Compressive Stresses at a Bolster-Stringer Intersection
5.1.1 Rounded Corner Trial Analysis

The first trial was a shell element representation very similar to the bolster stiffener of the full FEA model. Some subtle differences include the fact that the tapered bolster is replaced with a stiffener of uniform cross section, and the stringer wall is modeled as a single plate in this investigation. When subjected to load conditions similar to the full FEA model, (pressure on the top surface and Uy=0 on the base of the stringer plate) this trial structure develops a similar state of stress at the bolster-stringer intersection (Figure 5-2).

In reality, however, this sharp corner does not exist. On the dump body studied here, bolsters are formed from a single piece of steel with a 38mm rounded corner in this region. The box-like representation above was a geometric modeling simplification. As it will be demonstrated shortly, this representation of the corner does adversely affect the results, and as a result, this oversimplification had to be revisited. The second trial
solution involved a more accurate representation of this rounded corner region (Figure 5-3).

![Figure 5-3: Rounded Corner Section (Bolster-Stringer Stress Trial)](image)

Interestingly, the results of this analysis indicate a significant difference between the in-plane stress results reported from the top and bottom of the shell elements along the rounded corner edge. As stated previously, the formulation of the SHELL93 elements used here includes an assumption that the stress varies linearly through the shell element thickness. This linear variation is reported in the element output as top and bottom results, which correspond here to the inside and outside surfaces of the bolster stiffener respectively. The top solution indicates 4 MPa of tension in the corner (Figure 5-3, Left), while the bottom solution indicates 82 MPa of compression (Figure 5-3, Right). This variation though the thickness implies the presence of localized bending.
5.1.2 Solid Element Trial Analysis

In the analyses thus far, the geometry has been modeled using shell type elements that cannot geometrically represent the fillet weld in this region. To validate whether shell elements effectively model the stress in this region, another trial was conducted using solid-volume brick elements (SOLID95) and the same loading conditions as the two previous trials (Figure 5-4). This time, however, the 12 mm full penetration fillet weld that exists in this region was included.

To explain the stresses near this welded joint, it is helpful to consider the rounded corner section separately. Vertical stresses exist in this region that are set up to equilibrate the vertical load applied to the truck box floor. These vertical forces cause an upward deflection in the plate, which results in a highly localized bending stress (Figure 5-5).
Figure 5-6: Localized Bending (Bolster-Stringer Stress Trial)

Figure 5-6 is a plot of the stress results in the direction of the bolster centerline ($\sigma_x$). Bending stresses appear as a variation of $\sigma_x$ though the thickness of the material. When superimposed over the $\approx 45$MPa of compressive membrane stress set up due to the global bending of the bolster stiffener, this secondary bending stress reduces the magnitude of $\sigma_x$ on the inside surface of the bolster plate to $\approx 7$MPa, and increases the magnitude of $\sigma_x$ on the outside surface to $\approx 87$MPa of compression.
The purpose of these trial analyses was to shed some light on the state of stress in the bolster-stringer intersection region, and to evaluate whether a shell element finite element model is suitable to study the same. The rounded corner trial indicated the need to correct the oversimplification in the bolster-stringer intersection corner in order to obtain meaningful FEA results. The solid element trial solution linked the high stresses in the corner to the presence of localized bending in the region. And, a comparison of the results of the shell element and solid element trial solutions indicate a difference in the outer compression magnitudes of only 5%. With this it was concluded, that the shell element model does reasonably predict the presence and magnitude of both the global and localized stresses in the corner region. By retrofitting the haul body FEA model with proper rounded bolsters, meaningful results at the many troublesome bolster-stringer intersections can be obtained.

5.2 Frame Twist as a Source of Structural Loading

With the shell element model corrected, it was possible to model the stresses present within the structure set up to equilibrate the applied loading and the resulting deformations. Figure 5-7 is a rear-view, schematic diagram of a typical section of a dump body floor. Under the weight of the ore load, the stiffened floor arrangement deflects slightly as illustrated by the exaggerated deformation shown in red. Resulting from this 'global deformation', a slight tensile stress exists in the floor plate, stresses vary linearly down the stiffener sidewalls, and a uniform, compressive membrane stress is setup through the thickness of the stiffener lower plate.
In addition to this, there is some 'local deformation' in the immediate vicinity of the bolster-stringer intersection. The curvature of the plate results in a bending stress component superimposed onto the compressive membrane stress in the area (Figure 5-7). For both the ore load and the self-weight of the structure, the membrane and local bending stresses in this region combine to form compression throughout the plate thickness. Compression, however, does not explain the source of the extensive cracking problems in this area.

Figure 5-7: Localized Bending at Bolster-Stringer Intersection
Crack growth is usually caused by some form of alternating tension. In order to explain the extensive crack growth observed in the floor stiffener intersections, a state of stress producing tension at the outer edge of the material thickness must be demonstrated. At this stage, the hypothesis was that localized bending could be present in the region that is in reverse to the bending demonstrated thus far. If present in sufficient magnitudes, this localized bending could overcome the compressive membrane stress in the area resulting in a variation through the thickness with tension present at the outside edge (Figure 5-8).

5.2.1 Frame Displacement Trial Analyses

The frame or chassis of any heavy hauler mining truck is essentially the backbone of the entire truck structure. When a fully loaded haul truck with a gross vehicle weight of over
one million pounds drives over uneven ground, the frame is subjected to some very intense forces. As the wheels drive over bumps and sink into holes, a certain amount of deflection within the frame can be expected. Deflection within the frame directly translates into displacement of the dump body supports, which is a form of structural loading.

At this stage, the magnitude and mode shape of the frame deflections that could be expected during regular service were not known. Instead, trial mode shapes were applied to see what effect they would have on structural loading. Two modes of frame displacement were investigated using a half model with anti-symmetry conditions along the center plane. With this scenario, any force, pressure or displacement applied to the half model has the effect of being accompanied by an equal and opposite load applied to the other half. In other words, the frame displacements studied are assumed anti-symmetrical about the truck centerline.

Mode #1 (Figure 5-9) is a representation of frame twist, defined as a displacement arrangement in which the vertical deflection varies linearly from a 2mm difference at the stringer nose to an equal and opposite 2mm difference at the hinge pin. Mode #2 (Figure 5-10) is a uniform frame displacement of 2mm from the stringer nose to the hinge pin. These two trial displacement modes may be scaled and or superimposed to represent other feasible displacement patterns, and superimposed with the ore load and self-weight
to investigate the combined effect on the structural deformation. Studying their effects separately, however, offers more insight into the damage mechanisms seen in service.

**Figure 5-9: Trial Frame Displacement Mode - Twist**

**Figure 5-10: Trial Frame Displacement Mode – Uniform**
The uniform displacement mode resulted in negligible stresses. The reason for this is that a shear displacement pattern in the frame will not be transmitted to the body through the rubber support pads. As each side deflects upward or downward, the stringers are free to rotate which causes a slight roll producing no significant stresses within the structure.

Initially, the frame twist results produced a similar state of stress to that of the ore load, but larger in magnitude. That is, global bending of the floor plate resulting in a compressive membrane stress in the lower plate of the bolster, and localized bending at the stringer intersection resulting in a variation of the in-plane stresses through the material thickness. The combined state of stress at the intersection weld is, again, predominately in compression.

According to the anti-symmetry assumption, however, the frame twist applied to the other side is in the opposite direction. To investigate the response of the other side, the frame twist displacement mode can be inverted by multiplication with a scale factor of -1. This inverted frame twist produced equal-and-opposite results, this time, with the state of stress predominately in tension. The implication is that frame twist does produce reversed localized bending in the bolster-stringer intersections that may explain the cracking in this region.

In reality, this frame twist structural loading would coexist with the ore load. When superimposed, this 2mm trial mode of frame displacement was more than sufficient to
overcome the compression results of the ore-load, producing tension at the outside edge of the material thickness at the fillet weld toe (Figure 5-11). It is important to note, however, that these findings were the result of an assumed shape and magnitude of frame displacement. The frame deflections present in reality may produce different results. Nonetheless, this analysis does demonstrate the fact that frame twist can explain the cracking problems present, and a more detailed analysis to determine the true extent of frame deflections was warranted.

Figure 5-11: Superimposed Ore Load and Trial Frame Twist Results
5.2.2 Frame Displacement Verification

Initially, the extent of frame deflection was to be determined through a direct measurement. The data collected would have served as an excellent input, validating the support boundary conditions of the analyses. Although multiple means of measuring frame deflections were proposed, no feasible alternatives were found. The most promising concept involved a beam welded to both sides of the frame main rails and instrumented with strain gauges to monitor deflection within the beam. The concept was ruled out, however, due to the inability to differentiate between relative vertical deflection and rotation of the ends of the beam. The need to gather physical inputs to validate the results remained, despite the fact that there was no feasible means of directly measuring frame deflection. The alternative was to model the frame of the haul truck using FEA and using strut pressure data as the physically collected input.

The frame of a typical haul truck consists of box section main rails, tubular cross members, and castings at critical stress transition zones. Near the front, a rigid horse collar structure accommodates the strut mounts while providing clearance for the engine and associated propulsion equipment. For the purpose of this analysis, frame stresses at critical locations are not of interest; rather, capturing the true deflection shape is the intent. Hence, the model created represents the overall dimensions and metal thickness properly. However, details and features that would have little effect on the overall deformation of the frame have been omitted (see Figure 5-12). The de-featured FEA
model is sufficient to capture the true deflection shape, but frame stresses at transition regions should be ignored.

Figure 5-12: Haul Truck Frame and De-featured FEA Model

5.2.2.1 Strut Force Boundary Conditions

Modern haul trucks are equipped with telemetry capable of monitoring most of the onboard vital systems. The truck investigated here was equipped with pressure transducers in each of the four hydro-pneumatic suspension struts for use in a payload metering system. By attaching a laptop to the onboard payload meter, it was possible to acquire real-time pressure data at a rate of 50 Hz. It was then possible to determine the corresponding forces and moments applied to the frame using the strut active areas collected from the manufacturer, and relevant dimensions (moment arms) that were measured directly.
In the FEA, the four struts are modeled as spring elements. At the rear, the struts are attached to the frame with a clevis pin mounted in a spherical bushing. This ensures a straight line-force with no significant moment applied to the frame. In the FEA, the line-forces from the spring elements are distributed evenly over the nodes representing the clevis pinhole. At the front, the upper strut housing is rigidly bolted to the horse collar at four locations. Here, both a vertical force component and an associated moment are transferred to the frame structure (Figure 5-13). In the FEA, a rigid region is defined between the nodes of the strut mount and a node located the appropriate distance away to capture the moment arm effect. This way, the vertical strut force present in the spring element is transferred to the horse collar as both a vertical force and moment.

![Figure 5-13: Front and Rear Suspension Struts](image)

Much of the strut pressure data collected for this investigation was collected with the truck moving. For the most part, this was done to interfere with normal production as little as possible. By multiplying the force difference between the right and left struts by
the appropriate moment arm, moments about the truck centerline exerted onto the frame by the front and rear strut-pairs can be plotted (Figure 5-14). As can be seen, these forces are dynamic in nature. This analysis, however, is purely static. Each haul run begins with the truck parked next to the shovel getting loaded with ore (see Figure 6-1). The underfoot conditions at this location are characterized by soft uneven ground. The data used for this FEA was the static strut pressures after the last shovel bucket of ore is placed into the dump body, and the truck is stationary momentarily before being cleared to proceed along the haul route (shown in red, Figure 5-14).

![Figure 5-14: Front and Rear Moment Data Calculated from Strut Pressure Data](image)

A large component of the raw strut pressure data, however, is the weight of haul truck including the engine, propulsion systems, etc. To remove this component, averages of
dynamic data were collected with the truck 'running empty' along a relatively smooth portion of the haul road. These running empty average pressures were then subtracted from the raw data leaving only the ore load component of the strut forces. In the FEA, the self-weight of the body and frame were neglected, leaving only the ore load to be in equilibrium with these strut forces. The end result was that the frame twist demonstrated in this analysis is due solely to the way the ore load is distributed onto the four struts while the truck is parked on uneven ground.

5.2.2.2 Haul Body - Frame Interaction

Modeling the interaction between the frame and the haul body using conventional boundary conditions (forces, pressures, displacements, etc.) would have been difficult. The weight of the body and ore load is distributed onto the hinge pins and rubber pads, and this distribution changes significantly as the frame twists. Since a FEA model of the dump body was already in existence, the simplest solution was to import the model combining both body and frame into a single FEA, leaving it to the software to work out the appropriate force transfer between them.

The rubber pad support was modeled by meshing the region between the dump body stringers and the main rails of the frame with solid elements. Modeling the hinge pin connection, however, was a little more difficult. It was necessary to form a connection between the two models that accurately represented the force transfer and allowed free rotation about the pin axis. Defining a rigid region comprised of the nodes representing the pinholes, would accomplish the force transfer. Without allowing the rotation DOF
about the hinge, however, there was a risk of over-constraining the FEA model. Instead, the following hinge-pin representation scheme was devised.

The pinholes for the body and frame are nearly concentric in the FEA model because in the real structure there is a slight clearance to allow for rotation about the hinge. For each hole, a node was placed in the center of the circle and a series of very stiff springs connect this center node to the outer nodes of the circle forming a 'wagon wheel' pattern. For each near pair of holes, all of the center node degrees of freedom were coupled using constraint equations with the exception of rotation about the pin axis. Thus, the nodes in this region are forced to behave much like a real pin connection (Figure 5-15).

![Figure 5-15: 'Wagon Wheel' Representation of Hinge Pin Connections](image)

Ideally, these very stiff springs would have been defined as rigid regions. Problems were encountered, however, in that the master node of a rigid region cannot be used in other constraint equations. The reason for this has to do with how constraint equations are
handled by the solution process. Constraint equations define a relationship between the nodal DOF of a group of nodes called slave nodes and one master node. When processed by the software, the nodal DOF for each of the slave nodes are condensed out of the element stiffness matrix, keeping only those of the master node. If a master node for one constraint equation is used as a slave node in another, errors occur. What happened here was that the constraint equations coupling the DOF at the center would be processed, condensing one of the center nodes out of the stiffness matrix. When the constraint equations defining the rigid region were processed, a master node was named that no longer existed in the stiffness matrix, and the solution would terminate. This scenario would work as long as the constraint equations were processed in the right order. The ANSYS software, however, offered no means of controlling the order of constraint equation processing. The problem was circumvented by replacing the rigid region links between the pinhole and center nodes with a series of very stiff springs instead.

There was also a concern that adding large stiffness constants may adversely affect the condition of the element stiffness matrix, which would in turn adversely affect the reliability of the results. This was addressed by choosing a spring constant that was stiff enough to be considered rigid with respect to this region of the FEA model, but was no larger than the highest pivot term reported by the solver in previous solutions. In other words, the large terms added to the matrix for these stiff springs were no larger than the largest already there, and the condition of the matrix was not adversely affected.
5.2.2.3 Combined Frame - Body FEA Results

Figure 5-16 is a picture of the frame and body FEA model used for the frame twist analysis. The many colored arrows indicate the pressure applied to the inside faces of the body by the weight of the ore load. The spring elements representing the four struts can be seen in light blue. At the top of each spring element, rigid region constraint equations distribute the line-forces onto the appropriate nodes of the frame. At the lower ends of each strut spring, displacement boundary conditions constrain all nodal displacements.

The most pronounced shape of displacement observed with this frame analysis was torsion about the truck centerline. That is, the frame twists like a corkscrew in response to the opposing moments applied by a difference in the two front strut forces and the two
rear strut forces. In the FEA, front and rear strut force differences were applied as vertical displacement differences in the lower nodes of the front and rear strut springs.

According to the collected strut pressure data, the moments about the truck centerline for the front and rear struts do not balance. This means, there is a significant moment component coming from the fact that the ore load is placed slightly off-center in the body. Even though the moment arm of ore load resulting force is a little as 145mm (the dump body is 8m wide), this moment must be taken into consideration in order to capture the true frame torsion present. It was possible to capture this effect by offsetting the load shape slightly in the load application algorithm. This would require, however, integrating the load shape function to determine the appropriate amount to offset the load. Instead, time was saved by applying a force couple that balanced the front and rear moments. This couple was applied as line forces acting along both outer edges of the body floor, far away from any regions of particular interest.

Ideally, we would like to re-run this analysis with an offset load shape rather than a force couple correction. Unfortunately, the resources required to re-solve the FEA model are no longer available. The version of ANSYS used by Memorial University of Newfoundland is the University high option, and is limited to 32,000 nodes. This finite element model was assembled and solved on an unlimited version of the ANSYS software licensed for use at SCL’s Edmonton Research Center. The combined frame and dump body FEA model described here has over 930,000 nodes. Re-meshing the model to
fit under the 32,000 node restriction would have detrimental effects on the convergence of the results.

The effect that frame torsion had on the dump body was as expected. Frame torsion causes localized bending in some bolster-stringer intersections, which result in tensile stresses. Furthermore, this occurs most extensively near the hinge pivots. This result is supported, at least in Syncrude’s experience, by the fact that the bolster-stringer intersections in this region develop cracks first, regardless of the make or model of the haul truck. Under static conditions, parked fully loaded on uneven ground, the intersection between the sixth bolster from the front and the left-hand-side stringer had the greatest amount of tension present. To be more specific, the tension was present on the inside edge and the rearward-most rounded corner of the innermost bolster-stringer intersection (see Figure 3-2).

The bolster stiffeners in this hinge pin region are slightly different from those described earlier in that they are slightly smaller and are not tapered. Instead, they have a constant cross-section from the outer edge of the one stringer to the outer edge of the other. Outward from the stringers, these bolster stiffeners have a tapered cross-section like the rest. As described by Figure 5-17, the exaggerated results of the shell element model indicate the presence of localized bending stresses in this bolster-stringer intersection. The hypothesis presented earlier was that this bending would be reversed completely from that described in Figure 5-7, and would look similar to Figure 5-8. When subjected
to a realistic frame deflection, however, the results were in fact a combination of both.
Nonetheless, at the outer edge of this intersection, the bolster bottom plate is deformed
upward, which is the appropriate direction to produce tension in the material near the
weld toe.

The top and bottom results of the shell elements on either side of the stringer intersection
indicate the state of stress through the bolster, with the assumption of a linear variation
through the material thickness. From the trial analyses of Section 5.1, it was noted that
the stress results at the corner intersection of a shell element analysis were not
significantly different than the variation of stress through the thickness near the weld toe
in a solid element model of the same region. It was therefore concluded that the shell
element model does adequately represent this region, and the results obtained can be
interpreted as follows:
The top and bottom results on the inward side of the intersection are $-70 \text{ MPa}$ and $-170 \text{ MPa}$ respectively (see Figure 5-18). The interpretation of this is that superimposed onto 120 MPa of uniform, compressive membrane stress in this area is 50 MPa of a pure bending stress. The combined state of stress, however, in entirely compression. On the outer edge, where cracking commonly occurs, the situation is different. This time, the top and bottom results indicate $-168 \text{ MPa}$ and $+100 \text{ MPa}$ respectively. Again, a secondary bending stress is superimposed onto a compressive membrane stress, however, this time the bending stress of 134 MPa is great enough to overcome the 34 MPa of compression, producing tension near the weld toe. This tension is causing the crack propagation problems of the area.

Figure 5-18: Interpretation of Shell Element Model Results
Again, it should be noted that this was an analysis of a static situation only. To reiterate slightly, the above analysis indicated that the frame of a mining truck does deflect under normal operating conditions, resulting in a displacement of the dump body supports, which is a form of structural loading. In response to this support displacement, localized bending stresses in some bolster-stringer intersections near the hinge pivots reverse with sufficient magnitude to produce tensile stresses. As a fully loaded haul truck drives over uneven ground, the frame can be expected to deflect similar to this, but back and forth, causing the stress at the weld toe to alternate between tension and compression. In addition to this, under dynamic conditions, one would expect the peak tension to be greater than that seen here under static conditions. It is the presence of alternating tensile stresses greater than 100 MPa, at the toe of a weld with poor fatigue resistance, that is causing the extensive cracking problems observed in this area.
Chapter: 6 Conclusions and Future Directions

The static analysis presented in this work, models the frame deflection of a fully loaded haul truck, parked at the shovel on uneven ground, prior to commencing a haul run (similar to Figure 6-1). In addition, this analysis models the effect this deflection has on the dump body, and the results indicate the presence of tensile stresses in the floor stiffener intersections. Since this deflection is actually a twist along the truck frame, we can expect that it will twist back and forth, as the truck drives over uneven ground, resulting in an alternating state of compression and tension. The magnitudes observed would easily explain fatigue cracking if present in a dynamic environment; and it is expected that a dynamic analysis of this truck would produce stresses greater than observed here. In conclusion, frame deflections caused by normal service conditions are the primary cause of fatigue cracking in the bolster-stringer intersections of mining truck dump bodies in oil sand operations.

Figure 6-1: Haul Truck Parked at Shovel, Receiving Last Load Pass
The frame, being the backbone of the entire truck structure, is the most crucial, most studied, and most analyzed part of the trucks design. Changing frame designs to better suit the dump body is not something that is likely to happen. The haul body, being significantly cheaper, is much more likely to be modified. It is the recommendation of this work to account for movement in the haul body supports when analyzing or designing future mining truck haul bodies.

New and improved haul truck designs, however, will do nothing to reduce the cost of maintaining existing fleets. Many companies, such as SCL, have large fleets of mining trucks currently in service. What can be done to mitigate the cost of weld repairs to these floor stiffener intersections? Several feasible alternatives exist including: replacing the current dump body design with one chosen specifically for its ability to accommodate frame deflections, and modifying existing body designs to improve the fatigue strength of the floor stiffener intersections.

6.1 Entire Body Replacement

Most standard haul truck bodies have a traditional box-style bolster-stringer floor stiffening arrangement, which has been demonstrated to not respond well to the normal frame deflections of the truck during service. Other stiffening arrangements, however, may accommodate frame torsions better. One such body design, by the Chilean manufacturer Dicsa-Tricon, is called the DT-HiLoad (shown in Figure 6-1). The DT-
HiLoad is a lightweight design with an unconventional floor stiffening arrangement currently being considered by SCL’s truck maintenance group to replace the existing bodies for the entire 930E fleet.

The most notable difference in this design with respect to conventional designs is the reduction in the need for external wall stiffeners by utilizing the stiffness of curved plates. Although the floor does contain external stiffeners, they are of an I-Beam construction. Most significantly, the way these widthwise stiffeners intersect with the lengthwise stiffeners is different from traditional designs in that the intersection is not welded in place. Instead, reinforced contact pads are placed at the intersection (Figure 6-2). By allowing slight movements at this location, the cracking problems of traditional designs may be reduced.

Figure 6-2: DT-HiLoad Body Design - Close-up of Floor Stiffener Intersection
Syncrude Canada Limited has purchased one such body for trial purposes to see how this design will perform in oil sand mine operating conditions. In addition to this, there is a request from the truck maintenance group to investigate the relative performance of this new design when subjected to the same loading conditions. The recommendation for future work in this area is to conduct a FEA of this lightweight design, applying the same loading conditions studied earlier, and to compare the structural response of both designs. Together with the performance of the trial body soon to be in service, an educated decision should be possible as to which body design should be purchased as a replacement for the entire 930E fleet.

6.2 Modification of Existing Bodies

The other option to reduce the costs of weld repair would be to modify current designs. As stated before, localized bending in bolster-stringer intersections causes high stresses that the welds in the region are unable to withstand. Modifying the structural arrangement to reduce or eliminate this localized bending would be a cumbersome task, and one that is not feasible. Current cracking problems exist, however, not because high stresses exist in this region, but because a weld is located there as well. Intuitively, one could remedy the problem by removing the weld instead of the high stresses.

Although this is much easier said than done, the solution is quite ingenious. Simply cut out the troubled sections of the haul bodies and replace these sections with integral
one-piece components of the same geometry. In the corners currently referred to as the bolster-stringer intersection, localized bending will continue to cause high stresses. These components, however, would be fabricated without welding and would replace the fillet welds of the intersection with rounded corners. This way, the fatigue life of the region would be substantially enhanced. Such components would have to be welded into place, but they can be welded with full-penetration butt-welds at locations away from the localized bending. Under much lower stress conditions, the fatigue life of these welds ought to be satisfactory.

Figure 6-3: Modification Details
References

Appendix A

Weld Repair Costs
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## Appendix B

ANSYS Input Files

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<td>full_post_INPUT</td>
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</table>
! FEA of 930E Truck Box Structure

! Setting Analysis Options, Element types, and Material Properties
FINISH
/CLEAR
/CLEAR
/FILNAM.geom
/INPUT.2_1_setup_INPUT,,,,setup,0
! Error Message Suppression

! Creating Geometry and Saving Database
/INPUT.2_2_build_floor_INPUT,,,,0 ! Floor
/INPUT.2_3_build_wall_INPUT,,,,0 ! Wall
/INPUT.2_4_build_front_INPUT,,,,0 ! Front
/INPUT.2_5_build_canopy_INPUT,,,,0 ! Canopy
/INPUT.2_6_round_corners_INPUT,,,,0 ! Rounding Bolster Corners
/INPUT.2_7_SCL_mods_INPUT,,,,0 ! SCL Modifications

! Assigning Thickness and Material Properties to All Areas
/INPUT.3_1_assignprop_floor_INPUT,,,,0 ! Floor
/INPUT.3_2_assignprop_wall_INPUT,,,,0 ! Wall
/INPUT.3_3_assignprop_front_INPUT,,,,0 ! Front
/INPUT.3_4_assignprop_canopy_INPUT,,,,0 ! Canopy
/INPUT.3_5_add_guideline_INPUT,,,,0 ! Canopy
SAVE ! Saving geom.db
/EOF

! FE Meshing
/INPUT.4_1_FEA_manual_mesh_INPUT,,,,0 ! Meshing Routine

! Meshing
FINISH
/CLEAR
RESUME.geom.db
/NERR,0,10000, ! Error Message Suppression

! Boundary Conditions
*SET_hinge_type.2 ! 1=Bearing Forces 2=Rigid about Center
*SET_STRtype.3 ! 1=Distributed 2=Line 3=Rubber
*SET_UyPin,0,0 ! Uy Applied at Hinge Pin
*SET_UyNose,0,0 ! Uy Applied at Nose
*SET_Shim,0 ! 0=Off 1=On
*SET_Amt_Shim,1.0 ! Amount Of Steel Shim Added or Subtracted
*SET_Loadcell,0,0 ! 0=Off 1=On

/INPUT.4_3_FEA_support_INPUT,,,,0 ! Support BC's
INPUT,4,4_FEA_load_algorithm_INPUT,,home/dw11589/930E_Full,1,

-Symmetry Conditions-
/INPUT,4,6_FEA_symm_INPUT,,0   ! Symmetry BC's
/INPUT,4,6_FEA_antisymm_INPUT,,0 ! Anti-Symm. BC's

/FILNAM,BATCH
SAVE ! Saving FEA.db

/SOLU
/PVGCHECK,1 ! Pivot Check (Off=0) (On=1)
/SOLVE       ! Solve Current Load Step
/LSSOLVE,1,3,1,1 ! Solve Load Steps 1 thru 3, incr 1
/END

/DELETE,BATCH,amat,
/DELETE,BATCH,iseav,
/DELETE,BATCH,mmtr,
/DELETE,BATCH,stat,
/DELETE,BATCH,tri, ! Cleanup
/EOF !---------------------------------------

:post
------------------------------------------

/INPUT,5,1_post_StressPath_INPUT,,0   ! Bolster Path Routine
/INPUT,5,2_post_USUM_INPUT,,0         ! Plot USUM Routine
/EOF

------------------------------------------

/END

/FILEM, test
SAVE ! Saving test.db
/EOF

:here
FINISH
FINISH
/CLEAR
RESUME, test.db
/PPREP7
APLOT

------------------------------------------
Filename: 2_1_Setup_INPUT

Analysis Setup

:setup
/TITLE,Analysis Setup

/NOPR
KEYW,PR_SET,1
KEYW,PR_STRUCT,1
/COM,PReferences for GUI filtering have been set to display:
/COM, Structural

/PREP7
ET,1,SHELL93 ! Defining Shell Element Type
KEYOPT,1,4,0
KEYOPT,1,5,0
KEYOPT,1,6,0

! Defining Real Constants
R,3,3,...... ! 1/8" Exhaust Plenum
R,5,5,...... ! 5mm Thickness
R,8,8,...... ! 8mm Thickness
R,9,9,...... ! 9mm Thickness
R,12,12,..... ! 12mm Thickness
R,14,14,...... ! 14mm Thickness
R,16,16,...... ! 16mm Thickness
R,18,17,7,...... ! 5mm + 1/2" Thickness
R,19,19,...... ! 3/4" Thickness
R,21,20,7,...... ! 8mm + 1/2" Thickness
R,22,21,7,...... ! 9mm + 1/2" Thickness
R,25,25,...... ! 1" Thickness
R,29,28,575,..... ! 5/8"+1/2" Thickness or 1 1/8" Plate
R,35,35,...... ! 11/8" Thickness
R,38,38,...... ! 38mm Thickness
R,44,44,...... ! 3/4" + 1"
R,54,54,...... ! 1 1/8" + 1" FishPlate
R,63,63,6,...... ! 1 1/8" + 1" Thickness
R,90,00,...... ! 90mm Thickness

! Material Properties
! Material #1
! 690 MPa Tensile Strength
! 630 MPa Yield Strength
! Elongation in 50mm - 16%
! Modulus is Unknown
UIMP,1,EX,.,207000, ! Modulus in N/mm²
UIMP,1,DENS,.,0.0000786, ! Density in kg/mm³
UIMP,1,PRXY,..3,

! Material #2
! 1379 MPa Tensile Strength
! Yield Strength Unknown
! Elongation in 50mm - Unknown
! Modulus is Unknown
UIMP,2,EX,.,207000, ! Modulus in N/mm²
UIMP,2,DENS,.,0.0000786, ! Density in kg/mm³
UIMP,2,PRXY,.,0.3,

FINISH
/EOF
**Filename: 2_2_build_floor_INPUT**

```
! FEA of 93DE Truck Box Structure
! Floor Geometry Construction Routine

:build
FINISH
FINISH

! CLEAR
! NERRR,0, ! Warning
! Suppression
! /RESUME,setup.db
! /FILNAM,build_floor
! /RESUME,geom.db

/FILNAM,geom
/TITLE,Building Floor Geometry

/PREP7

! -----------------------------------------------
! --------- Floor Construction
! -----------------------------------------------
! Defined Parameters

*SET,bxwidth,8105
*SET,bxwidth,7915
*SET,tonnes,320

! Creating Keypoints

K,1,0,0,0,
K,2,bxwidth/2,0,0,
K,3,bxwidth/2,-bxlength,
K,4,0,0,-bxlength,

FLST,2,4,3
FITEM,2,1
FITEM,2,2
FITEM,2,3
FITEM,2,4
A,P51X
CM_,Y,AREA
ASEL,.,,1
CM_,Y1,AREA
CMSEL,S_,Y
CMSEL,S_,Y1
AATT,.,15,2,0
CMSELS_,Y
CMDELE_,Y
CMDELE_,Y1

! -----------------------------------------------
! Bolsters
! -----------------------------------------------

RH Item #16
! Keypoints

K,5,0,-340,0,
K,6,(bxwidth/2)-120,-115,0,
FLST,2,4,3
FITEM,2,1
FITEM,2,5
FITEM,2,6

FLST,3,1,5,ORDE,1 ! Rear Area
A,P51X
FITEM,3,2
AGEN,2,P51X,.,.,,-635,.,0
FLST,2,4,3
FITEM,2,6
FITEM,2,9
FITEM,2,8
FITEM,2,5
A,P51X ! Bottom Area

APLOT
/VIEW,1,1,1,1
/USER,1
/VIEW,1,-0.391990212388,-0.705334606237,0.590632514036
/ANG,1,174.710908189
/AUTO,1
/REP

RH Item #14
FLST,3,1,5,ORDE,1
FITEM,3,2
AGEN,2,P51X,.,.,,-1535,.,0! Copying Rear Area to Location
FLST,3,1,5,ORDE,1
FITEM,3,5
FLST,3,1,5,ORDE,1
FITEM,3,5
AGEN,2,P51X,.,.,,-350,.,0! Copying Area to other side
FLST,2,4,3
FITEM,2,13
FITEM,2,17
FITEM,2,16
FITEM,2,12
A,P51X ! Creating Bottom

FLST,3,3,5,ORDE,2 ! Item #12
FITEM,3,5
FITEM,3,7
AGEN,2,P51X,.,.,,-2740+1535,.,0
FLST,3,3,5,ORDE,2 ! Item #11
FITEM,3,5
FITEM,3,7
AGEN,2,P51X,.,.,,-3690+1535,.,0
FLST,3,3,5,ORDE,2 ! Item #10
FITEM,3,5
FITEM,3,7
AGEN,2,P51X,.,.,,-5035+1535,.,0
FLST,3,3,5,ORDE,2 ! Item #9
FITEM,3,5
FITEM,3,7
AGEN,2,P51X,.,.,,-5705+1535,.,0
```

112
ITEM.2,109  ! Creating Forward Stringer
A,P51X
FLST.2,15,5,ORDE.2
ITEM.2,14
ITEM.2,28
FLST.2,15,5,ORDE.2
ITEM.2,14
ITEM.2,28
FLST.3,2,5,ORDE.2
ITEM.3,8
ITEM.3,72
ASBA,P51X,P51X,!.KEEP  ! Dividing Bolster Areas
FLST.2,4,3
ITEM.2,148
ITEM.2,147
ITEM.2,149
ITEM.2,150
A,P51X
FLST.2,4,3
ITEM.2,145
ITEM.2,146
ITEM.2,152
ITEM.2,151
A,P51X
FLST.2,4,3
ITEM.2,136
ITEM.2,135
ITEM.2,141
ITEM.2,142
A,P51X
FLST.2,4,3
ITEM.2,133
ITEM.2,134
ITEM.2,144
ITEM.2,143
A,P51X
FLST.2,4,3
ITEM.2,137
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ITEM.2,131
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ITEM.2,123
ITEM.2,124
A,P51X
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ITEM.2,125
ITEM.2,126
ITEM.2,122
ITEM.2,121
A,P51X
FLST.2,4,3
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ITEM.2,119
ITEM.2,115
ITEM.2,116
A,P51X
FLST.2,4,3
ITEM.2,117
ITEM.2,118
ITEM.2,114
ITEM.2,113
A,P51X
FLST.3,5,5,ORDE.5
ITEM.3,15
ITEM.3,17
ITEM.3,19
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ITEM.3,23
ASBA, 72,P51X
FLST.3,5,5,ORDE.5
ITEM.3,14
ITEM.3,16
ITEM.3,18
ITEM.3,20
ITEM.3,22
ASBA, 6,P51X  ! Removing Bolster Holes in Front Stringer
LANG, 191, 146,90,0, 0.9878158211681047E-01
LANG, 187, 147,90,0, 0.1071625505009111
KL, 190, 5, ,
KL, 186, 5, ,
FLST.2,3,3
ITEM.2,154
ITEM.2,158
ITEM.2,111
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A,P51X
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ASBA, 24, 14  ! Chopping Stringer Edge
Angle Area
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ITEM.2,154
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A,P51X
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ITEM.2,119
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A,P51X
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A,P51X
FLST.2,4,3
ITEM.2,120
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ITEM.2,115
ITEM.2,116
A,P51X
FLST.2,4,3
K, 48*20.5,-370,-2740+50,
K, 48*20.5,-440,-2740-370,
K, 48*20.5,-440,-4090,
K, 48*20.5,0,-4090,
K, 48°20.5°, -27.4°50°,
IK, 970, 370°, -27.4°50°,
IK, 970, 440°, -27.4°370°,
IK, 970, 440°, -40°90°,
IK, 970, 0°, -40°90°,
IK, 970, 0°, -27.4°50°,

FLST, 2, 5, 3
ITEM, 2, 109
ITEM, 2, 111
ITEM, 2, 157
ITEM, 2, 159
A, P51X

Structure Side Area

ITEM, 3, 303
LGEN, 2, P51X, ..., 275, 0
FLST, 2, 1, 4, ORDE, 1
ITEM, 2, 287
FLST, 3, 1, 4, ORDE, 1
ITEM, 3, 38
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FLST, 2, 1, 4, ORDE, 1
ITEM, 2, 303
FLST, 3, 1, 4, ORDE, 1
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LSBL, 39, 43
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LSTR, 173, 164
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LDELETE, P51X, ..., 1

Pivot

ITEM, 3, 18
ASBA, P51X, P51X, , DELETE, KEEP
FLST, 2, 6, 5, ORDE, 6
ITEM, 2, 19
ITEM, 2, 21
ITEM, 2, 24
ITEM, 2, 25
ITEM, 2, 27
ITEM, 2, 118
DELE, P51X, ..., 1

Deleting

FLST, 3, 1, 5, ORDE, 1
ITEM, 3, 18
AGEN, 2, P51X, ..., -363, ..., 0
Otherside

Creating

ITEM, 2, 24
ITEM, 2, 160
ITEM, 2, 162
ITEM, 2, 164
ITEM, 2, 166
ITEM, 2, 167
A, P51X
FLST, 2, 4, 3
ITEM, 2, 165
ITEM, 2, 166
ITEM, 2, 167
A, P51X
FLST, 2, 1, 5, ORDE, 1
ITEM, 2, 18
FLST, 3, 2, 5, ORDE, 2
ITEM, 3, 9
ITEM, 3, 10
ASBA, P51X, P51X, , KEEP

Dividing

Outside Area

ITEM, 3, 3
FLST, 3, 2, 4, ORDE, 2
ITEM, 3, 295
ITEM, 3, 306
FLST, 3, 2, 4, ORDE, 2
ITEM, 3, 31
ITEM, 3, 33
LSBL, P51X, ..., 234, ..., 0
FLST, 3, 1, 4, ORDE, 1
ITEM, 3, 287
FLST, 3, 1, 4, ORDE, 1
ITEM, 3, 287
LGEN, 2, P51X, ..., 275, ..., 0
FLST, 3, 1, 4, ORDE, 1

FLST, 2, 4, 3
ITEM, 2, 160
ITEM, 2, 162
ITEM, 2, 164
ITEM, 2, 166
ITEM, 2, 172
ITEM, 2, 173
A, P51X
FLST, 2, 1, 5, ORDE, 1
ITEM, 2, 9
FLST, 3, 1, 5, ORDE, 1
ITEM, 3, 12
ASBA, P51X, P51X, , KEEP
FLST, 2, 1, 5, ORDE, 1
ITEM, 2, 10
FLST, 3, 1, 5, ORDE, 1
ITEM, 3, 13
ASBA, P51X, P51X, , KEEP

FLST, 2, 1, 5, ORDE, 1
ITEM, 2, 10
FLST, 3, 1, 5, ORDE, 1
ITEM, 3, 3
A, P51X
FLST, 2, 4, 3
ITEM, 2, 169
ITEM, 2, 160
A, P51X
FLST, 2, 4, 3
ITEM, 2, 169
ITEM, 2, 160
A, P51X
FLST, 2, 4, 3
ITEM, 2, 175
ITEM, 2, 174
ITEM, 2, 177
ITEM, 2, 169
A, P51X
FLST, 2, 4, 3
ITEM, 2, 23
ITEM, 2, 162
Creating Lines for Pivot

Indent

Creating Lines and Areas on Side for Mesh reasons

Sweeping Pivot Indent Across

Creating Lines and Areas on Other Side for Mesh reasons

Dividing Lines and Areas Reinforced Area

! Finish

Dividing Lines and Areas Reinforced Area

Merging Coincident Keypoints

NUMMRG.KP...
| FITEM,2,256 | FITEM,2,70 |
| A,PS1X | FITEM,2,253 |
| FLST,2,4,3 | FITEM,2,258 |
| FITEM,2,26 | A,PS1X |
| FITEM,2,30 | FLST,2,4,3 |
| FITEM,2,258 | FITEM,2,70 |
| FITEM,2,257 | FITEM,2,3 |
| A,PS1X | FITEM,2,252 |
| FLST,2,4,3 | FITEM,2,253 |
| FITEM,2,34 | A,PS1X |
| FITEM,2,259 | FLST,2,4,3 |
| FITEM,2,258 | FITEM,2,251 |
| A,PS1X | FITEM,2,256 |
| FLST,2,4,3 | FITEM,2,231 |
| FITEM,2,261 | A,PS1X |
| FITEM,2,260 | FLST,2,4,3 |
| FITEM,2,259 | FITEM,2,254 |
| A,PS1X | FITEM,2,232 |
| FLST,2,4,3 | FITEM,2,235 |
| FITEM,2,261 | A,PS1X |
| FITEM,2,260 | FLST,2,4,3 |
| FITEM,2,262 | FITEM,2,255 |
| A,PS1X | FITEM,2,237 |
| FLST,2,4,3 | FITEM,2,236 |
| FITEM,2,42 | A,PS1X |
| FITEM,2,254 | FLST,2,4,3 |
| FITEM,2,46 | FITEM,2,255 |
| FITEM,2,262 | FITEM,2,256 |
| FITEM,2,261 | A,PS1X |
| A,PS1X | FLST,2,4,3 |
| FLST,2,4,3 | FITEM,2,258 |
| FITEM,2,46 | FITEM,2,237 |
| FITEM,2,261 | A,PS1X |
| FITEM,2,260 | FLST,2,4,3 |
| FITEM,2,263 | FITEM,2,257 |
| FITEM,2,262 | FITEM,2,258 |
| A,PS1X | FITEM,2,239 |
| FLST,2,4,3 | FITEM,2,238 |
| FITEM,2,46 | A,PS1X |
| FITEM,2,264 | FLST,2,4,3 |
| FITEM,2,263 | FITEM,2,259 |
| A,PS1X | FITEM,2,240 |
| FLST,2,4,3 | FITEM,2,239 |
| FITEM,2,266 | FITEM,2,240 |
| FITEM,2,264 | FITEM,2,240 |
| FITEM,2,265 | A,PS1X |
| FITEM,2,264 | FLST,2,4,3 |
| A,PS1X | FITEM,2,259 |
| FLST,2,4,3 | FITEM,2,260 |
| FITEM,2,266 | FITEM,2,258 |
| A,PS1X | FITEM,2,261 |
| FLST,2,4,3 | FITEM,2,242 |
| FITEM,2,267 | A,PS1X |
| FITEM,2,256 | FLST,2,4,3 |
| A,PS1X | FITEM,2,241 |
| FLST,2,4,3 | FITEM,2,240 |
| FITEM,2,62 | A,PS1X |
| FITEM,2,267 | FLST,2,4,3 |
| FITEM,2,72 | FITEM,2,260 |
| FITEM,2,268 | FITEM,2,261 |
| FITEM,2,257 | FITEM,2,262 |
| A,PS1X | FITEM,2,243 |
| FLST,2,4,3 | FITEM,2,256 |
| FITEM,2,72 | FITEM,2,243 |

! Adding Lower Outside

Plate Areas
FITEM,2,-89
FITEM,2,91
FITEM,2,93
FITEM,2,95
FITEM,2,92
FITEM,2,194
FLST,3,2,5,ORDE,2
FITEM,3,289
FITEM,3,270
ASBA,P51X,P51X
FlST,3,2,5,0
FITEM,2,93
FITEM,2,95
FITEM,2,114
FITEM,2,92
FITEM,2,194
FLST,3,2,5,ORDE,2
FITEM,3,289
FITEM,3,270
ASBA,P51X,P51X

Bolster Areas

FLST,3,1,3,ORDE,1
FITEM,3,321
KGEN,2,P51X,,-164,-72,0
FLST,3,1,3,ORDE,1
KGEN,2,P51X,,-,0,-60,0
FLST,2,6,3
FITEM,3,321
FITEM,3,317
FITEM,3,320
FITEM,3,334
FITEM,3,325
FITEM,3,324
A,P51X

FLST,3,1,3,ORDE,1
FITEM,3,318
KGEN,2,P51X,,-164,-72,0
FLST,3,1,3,ORDE,1
KGEN,2,P51X,,-,0,-60,0
FLST,2,6,3
FITEM,2,318
FITEM,2,322
FITEM,2,323
FITEM,2,326
A,P51X

FLST,3,6,4,ORDE,0
FITEM,3,323
FITEM,3,229
FITEM,3,232
FITEM,3,233
FITEM,3,238
FITEM,3,239
LGEN,2,P51X,,-249,0,0
IFLST,2,6,4
IFITEM,2,255
IFITEM,2,551
IFITEM,2,599
IFITEM,2,623
IFITEM,2,626
IFITEM,2,618
IFITEM,2,625
IFITEM,2,551
IFITEM,2,599
AL,P51X

NUMMPG,KP,...
FLST,2,6,4
FITEM,2,623
FITEM,2,626
FITEM,2,618
FITEM,2,625
FITEM,2,551
FITEM,2,599
AL,P51X
FLST,2,6,4
FITEM,2,600
FITEM,2,601
FITEM,2,602
FITEM,2,605

FITEM,2,627
FITEM,2,621
AL,P51X

I Stiffeners
Inside Bolsters

KL,623,0,4,
KL,625,0,6,
FLST,3,1,3,ORDE,1
FITEM,3,328
KGEN,2,P51X,,-240,-255,0
KL,648,0,6,
KL,648,0,4,
FLST,3,1,3,ORDE,1
FITEM,3,334
KGEN,2,P51X,,-240,-255,0
LSTR,343,345
LSTR,345,344
LSTR,336,340
LSTR,340,339
FLST,2,4,4,ORDE,4
FITEM,2,623
FITEM,2,625
FITEM,2,648
FITEM,2,648
FLST,3,4,4,ORDE,4
FITEM,3,468
FITEM,3,476
FITEM,3,549
FITEM,3,550
LSBL,P51X,P51X,,KEEP
FLST,2,5,4
FITEM,2,551
FITEM,2,468
FITEM,2,476
FITEM,2,552
FITEM,2,632
AL,P51X
FLST,2,5,4
FITEM,2,505
FITEM,2,549
FITEM,2,550
FITEM,2,507
FITEM,2,615

I Pivot Areas

Pivot and Front Stringer
FLST,3,1,3,ORDE,1
FITEM,3,334
KGEN,2,P51X,,-140,-260,0
KWPLAN,-1,346,334,335
KWPPLAN,-1,346,334,335
PCIRC,60,0,360,
FLST,2,1,5,ORDE,1
FITEM,2,65
VEXT,P51X,,-2000,0,0,...
FLST,2,4,5,ORDE,4
FITEM,2,6
FITEM,2,16
FITEM,2,51
FITEM,2,53
ASBVP51X,1

-----------------------------

---- Correcting Angles at Ends of Corner Stringer
-----------------------------
FLST,2,3,5,ORDE,3
FITEM,2,231
FITEM,2,205
FITEM,2,242
ASBW,P51X
FLST,2,4,5,ORDE,4
FITEM,2,6
FITEM,2,16
FITEM,2,187
FITEM,2,192
ADELE,P51X,..,1
FLST,2,4,4
FITEM,2,655
FITEM,2,659
FITEM,2,653
FITEM,2,545
AL,P51X
! Correcting Rear End of
Corner STR
KWPLAN,-1, 112, 110, 156
wpno.,12,500000.
FLST,2,3,5,ORDE,3
FITEM,2,15
FITEM,2,301
FITEM,2,302
ASBW,P51X
FLST,2,4,5,ORDE,4
FITEM,2,16
FITEM,2,17
FITEM,2,31
FITEM,2,192
ADELE,P51X,..,1
FLST,2,4,4
FITEM,2,422
FITEM,2,545
FITEM,2,656
FITEM,2,403
FITEM,2,189
AL,P51X
! Correcting Front of
Stringer
FLST,2,3,5,ORDE,3
FITEM,3,223
FITEM,3,241
FITEM,3,259
AGEN,2,P51X,..,-375, ,0
FLST,2,3,5,ORDE,3
FITEM,2,16
FITEM,2,17
FITEM,2,31
ASBW,P51X
FLST,2,3,5,ORDE,3
FITEM,2,299
FITEM,2,270
FITEM,2,298
ADELE,P51X,..,1
FLST,2,6,5,ORDE,6
FITEM,2,162
FITEM,2,223
FITEM,2,241
FITEM,2,242
FITEM,2,259
FITEM,2,301
ADELE,P51X,
FLST,2,9,4,ORDE,9
FITEM,2,87
FITEM,2,404
FITEM,2,422
FITEM,2,568
FITEM,2,597
FITEM,2,598
FITEM,2,660
FITEM,2,668
FITEM,2,670
LDELE,P51X,..,1
LDELE, 672, ,1
LDELE, 440, ,1
LSTR, 253, 366
LSTR, 234, 365
NUMMRG,KP,
FLST,2,4,4
FITEM,2,96
FITEM,2,671
FITEM,2,65
FITEM,2,460
AL,P51X
FLST,2,4,4
FITEM,2,459
FITEM,2,65
FITEM,2,675
FITEM,2,87
AL,P51X
FLST,2,4,4
FITEM,2,671
FITEM,2,548
FITEM,2,669
FITEM,2,675
AL,P51X
! Correcting Front of
Corner STR
WPCSYS,-1,0
NUMMRG,ALL, ...
NUMCMP,AREA
NUMCMP,LINE
NUMCMP,KP
! Merging Coincident
Items
! Compressing Numbers
FINISH
!SAVE
/EOF

126
**Filename: 2_3_build_wall_INPUT**

! FEAO of 93DE Truck Box Structure
! Side Wall Construction Routine

:build

FINISH

FINISH

! CLEAR

! NERR, 0,

! RESUME, build_floor.db

! FILNAM, build_wall

! RESUME, geom.db

! FILNAM, geom

/TITLE, Building Wall Geometry

/PREP7

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/ANG, 1

/REP, FAST

/USER, 1

/VIEW, 1, 0.784420712192, -0.258767530301, 0.65869683011

/ANG, 1, -1.85612633420

/AUTO, 1

APLOT

!------------------------------- Wall Construction

!------------------------------- Wall Construction

! AFUN, DEG

WPSSTYLE, 0,

FLST, 3, 1, ORDE, 1

FITEM, 3, 346

KGEN, 2, P51X, ..., 21*20.5*sin(90-13), -21*20.5*cos(90-13), 0

FLST, 3, 1, ORDE, 1

FITEM, 3, 356

KGEN, 2, P51X, ..., 79*20.5*sin(39.5), 79*20.5*cos(39.5), 0

FLST, 3, 1, ORDE, 1

FITEM, 3, 354

KGEN, 2, P51X, ..., 123*20.5*sin(89.25), -123*20.5*cos(89.25), 0

FLST, 3, 1, ORDE, 1

FITEM, 3, 354

KGEN, 2, P51X, ..., 160*20.5*sin(77.5), -160*20.5*cos(77.5), 0

LSTR, 346, 355

LSTR, 356, 357

LSTR, 357, 358

LSTR, 358, 359

LSTR, 354, 359

FLST, 2, 23, 4

FITEM, 2, 246

FITEM, 2, 401

FITEM, 2, 402

FITEM, 2, 403

FITEM, 2, 404

FITEM, 2, 405

FITEM, 2, 406

FITEM, 2, 407

FITEM, 2, 408

FITEM, 2, 409

FITEM, 2, 410

FITEM, 2, 411

FITEM, 2, 412

FITEM, 2, 413

FITEM, 2, 414

FITEM, 2, 415

FITEM, 2, 416

FITEM, 2, 87

FITEM, 2, 662

FITEM, 2, 661

FITEM, 2, 660

FITEM, 2, 659

FITEM, 2, 658

AL, P51X

! Side Wall Plate

!------------------------------- Top Tapered Bolter

!------------------------------- Wall Construction

! Lines Near Tail End.

FLST, 2, 1, 4, ORDE, 1

FITEM, 2, 659

FLST, 3, 1, 4, ORDE, 1

FITEM, 3, 668

LSBL, P51X, P51X, ..., KEEP

LSTR, 392, 361

FLST, 3, 1, 3, ORDE, 1

FITEM, 3, 361

KGEN, 2, P51X, ..., 230, 0

LSTR, 360, 347

KL, 659, 29.5, 79, 0

FLST, 3, 1, 3, ORDE, 1

FITEM, 3, 361

KGEN, 2, P51X, ..., 230, 0

LSTR, 362, 361

FLST, 3, 1, 3, ORDE, 1

FITEM, 3, 354

KGEN, 2, P51X, ..., 89, 0

LSTR, 361, 360

FLST, 2, 1, 4, ORDE, 1

FITEM, 2, 668

FLST, 3, 1, 4, ORDE, 1

FITEM, 3, 668

LSBL, P51X, P51X, ..., KEEP

FLST, 2, 1, 4, ORDE, 1

FITEM, 2, 662

FLST, 3, 1, 4, ORDE, 1

FITEM, 3, 670

LSBL, P51X, P51X, ..., DELETE

! Horizontal Line

FLST, 3, 1, 3, ORDE, 1

FITEM, 3, 364

KGEN, 2, P51X, ..., 230, 0

LSTR, 364, 363

LSTR, 363, 362

FLST, 3, 3, 3, ORDE, 2

FITEM, 3, 357

FITEM, 3, 356

KGEN, 2, P51X, ..., 230, 0
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<td>369, 367, 366</td>
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<tr>
<td>FITEM,2,572</td>
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Using Workplane to divide lines

WPSTYLE,,,,0

NUMMRG,KP,,
LSTR, 371, 370
LSTR, 370, 374
LSTR, 374, 372
LSTR, 372, 371

Creating Lines

Creating Areas

Moving Workplane

Using Workplane to Divide Lines

Creating Lines
FLST,3,1,4,ORDE,1
ITEM,3,411
LSBL,P51X,P51X,..,KEEP
LDELE, 707,,1  ! Cleanup Constr. Line
KL,717,(2582-82.5*20.5)/2582,..
FLST,3,1,3,ORDE,1
ITEM,3,386
KGEN,2,P51X,230,,0
LSTR, 386, 386
FLST,2,1,4,ORDE,1
ITEM,2,717
FLST,3,1,4,ORDE,1
ITEM,3,707
LSBL,P51X,P51X,..,KEEP
LDELE, 716,,1  ! Trim Line to Right
Length
FLST,3,1,3,ORDE,1
ITEM,3,388
KGEN,2,P51X,230,,0
LSTR, 386, 387
LSTR, 387, 355
LSTR, 387, 389
LSTR, 386, 244
LSTR, 389, 262  ! Creating
FLST,2,7,4
ITEM,2,715
ITEM,2,87
ITEM,2,416
ITEM,2,415
ITEM,2,414
ITEM,2,721
ITEM,2,719
AL,P51X
FLST,2,4,4
ITEM,2,719
ITEM,2,720
ITEM,2,716
ITEM,2,707
AL,P51X
FLST,2,4,4
ITEM,2,721
ITEM,2,467
ITEM,2,467
ITEM,2,722
ITEM,2,707
AL,P51X
FLST,2,7,4
ITEM,2,430
ITEM,2,431
ITEM,2,432
ITEM,2,265
ITEM,2,717
ITEM,2,720
ITEM,2,722
AL,P51X  ! Creating
Areas
FLST,2,14,4
ITEM,2,721
ITEM,2,413
ITEM,2,412
ITEM,2,411
ITEM,2,410
ITEM,2,409
ITEM,2,408
ITEM,2,407
ITEM,2,406
FLST,2,700
ITEM,2,709
ITEM,2,708
ITEM,2,718
ITEM,2,719
AL,P51X  ! Lower Unstiffened Wall Area

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<td>Side Boards</td>
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*AFUN,DEG  ! Work in Degrees
FLST,3,1,3,ORDE,1
ITEM,3,359
KGEN,2,P51X,..,-327°20.5°sin(9),327°20.5°cos(9),0
LSTR, 357, 390
LSTR, 390, 359
FLST,3,1,3,ORDE,1
ITEM,3,390
KGEN,2,P51X,..,230,,0  ! Keypoints
LSTR, 368, 391
LSTR, 391, 387
LSTR, 391, 390  ! Lines
FLST,2,4,4
ITEM,2,727
ITEM,2,724
ITEM,2,728
ITEM,2,574
AL,P51X
FLST,2,4,4
ITEM,2,561
ITEM,2,573
ITEM,2,723
ITEM,2,724
AL,P51X
FLST,2,4,4
ITEM,2,574
ITEM,2,679
ITEM,2,723
ITEM,2,725
ITEM,2,727
AL,P51X
FLST,2,4,4
ITEM,2,726
ITEM,2,725
ITEM,2,682
ITEM,2,672
AL,P51X  ! Areas

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<td>Cleanup</td>
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ADELE, 295,,1  ! Deleting Unneeded Area
NUMMRG,ALL,..  ! Merging Coincident Items
NUMCMP,AREA
NUMCMP,LINE
NUMCMP,KP  ! Compressing Numbers
FINISH
SAVE
/E0F

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**Filename: 2_4_build_front_INPUT**

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<tr>
<th>FLST.3.1,3,ORDE,1</th>
<th>FITEM.3,728</th>
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<tr>
<td>FITEM.3,730</td>
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<td>FITEM.3,731</td>
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<td>LGEN,2,P51X, , , -0.4127500000E+04, , , 0</td>
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<td>LSTR, 392, 398</td>
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<td>LSTR, 395, 399</td>
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<td>Creating Lines</td>
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<td>FITEM.3,730</td>
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<td>LSLB,P51X,P51X, , , ,KEEP</td>
<td>Dividing Line on Side Wall</td>
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<td>/PREP7</td>
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<td>/USER, 1</td>
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<td>/VIEW, 1, 0.484264822294 , -0.192301274690 , -0.859526684785</td>
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<td>.................................- Top Bolster - Lines Only</td>
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<tr>
<td>.................................- Outside Bolster Construction</td>
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<td>.................................- Dividing Lines Near Top Edge</td>
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<th>FLST.3,1,3,ORDE,1</th>
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<td>KGEN,2,P51X, , , -12.5<em>20.5</em>sin(21.5-9), -12.5<em>20.5</em>cos(21.5-9), 0</td>
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<td>LSTR, 394, 393</td>
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<td>LSTR, 393, 392</td>
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<td>FLST.3,1,3,ORDE,1</td>
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<td>KGEN,2,P51X, , , 13.5<em>20.5</em>sin(9)-13.5<em>20.5</em>cos(9), 0</td>
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<td>LSTR, 392, 395</td>
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<tr>
<td>LSTR, 394, 396</td>
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<td>LDELE, 729, , ,</td>
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<td>Copying Lines into Middle</td>
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| FLST.3,4,4 | |
| FITEM.3,660 | |
| FITEM.3,740 | |
| AL,P51X | |
| FLST.2,4,4 | |
| FITEM.2,741 | |
| FITEM.2,744 | |
| FITEM.2,660 | |
| FITEM.2,745 | |
| AL,P51X | |
| FLST.2,4,4 | |
| FITEM.2,739 | |
| FITEM.2,745 | |
| FITEM.2,743 | |
| FITEM.2,671 | |
| AL,P51X | |
| FLST.2,4,4 | |
| FITEM.2,875 | |
| FITEM.2,671 | |
FLST,2,677
FLST,2,662
AL_P51X
LSTR, 363, 377
LSTR, 365, 387
FLST,2,4,4
FITEM,2,734
FITEM,2,662
FITEM,2,695
FITEM,2,697
AL_P51X
FLST,2,4,4
FITEM,2,714
FITEM,2,710
FITEM,2,697
FITEM,2,713
AL_P51X
FLST,2,4,4
FITEM,2,736
FITEM,2,713
FITEM,2,716
FITEM,2,716
AL_P51X
FLST,2,1,4,ORDE,1
FITEM,2,676
FLST,3,1,4,ORDE,1
FITEM,3,655
LSBL_P51X,P51X,..KEEP
FLST,2,1,5,ORDE,1
FITEM,2,192
FLST,3,1,4,ORDE,1
FITEM,3,749
LSBL_P51X,P51X,..KEEP
FLST,2,1,4,ORDE,1
FITEM,2,746
FLST,3,1,4,ORDE,1
FITEM,3,748
LSBL_P51X,P51X,..KEEP
FLST,2,9,4
FITEM,2,655
FITEM,2,677
FITEM,2,743
FITEM,2,748
FITEM,2,695
FITEM,2,710
FITEM,2,718
FITEM,2,715
FITEM,2,752
AL_P51X ! Areas & Lines for Wall Behind Bolster
FLST,3,1,4,ORDE,1
FITEM,3,730
LGEN,2,P51X,..-230,..0
! Line for Canopy Edge Stiffener

FLST,3,2,3,ORDE,2
FITEM,3,300
FITEM,3,-401
KGEN,2,P51X,..-10*20.5,..0
LSTR, 407, 408
KWPLAN,-1, 394, 393, 400
LSBW, 753
LDELE, 754, ..1
WPICYS,-1,0

FLST,3,2,3,ORDE,2
FITEM,3,355
KGEN,2,P51X,..-10*20.5,..0
LSTR, 410, 407
LSTR, 407, 406
LSTR, 408, 401
LSTR, 407, 3
LSTR, 410, 355
FLST,3,1,3,ORDE,1
FITEM,3,409
KGEN,2,P51X,..-16.5*20.5,..0
LSTR, 411, 410
LSTR, 411, 409
LSTR, 409, 400
FLST,2,1,4,ORDE,1
FITEM,2,728
FLST,3,1,4,ORDE,1
FITEM,3,760
LSBL_P51X,P51X,..KEEP ! Lines 4 Bolster
FLST,3,3,4,ORDE,3
FITEM,3,798
FITEM,3,792
FITEM,3,794
LGEN,2,PS1X,,-752.625,.,0
FLST,2,1,4,ORDE,1
FITEM,2,798
FLST,3,2,4,ORDE,2
FITEM,3,773
FITEM,3,775
LSBL,PS1X,PS1X,,KEEP
FLST,3,2,3,ORDE,2
FITEM,3,110
FITEM,3,112
LGRID,2,PS1X,,-6*20.5,-10*20.5,,0
LSTR,247,441
LSTR,441,438
LSTR,439,112
LSTR,229,440
LSTR,440,436
LSTR,437,110

LST,441,440
Lines
LST,112,441
LST,110,440

FLST,2,4,4
FITEM,2,809
FITEM,2,797
FITEM,2,812
FITEM,2,795
AL,PS1X
FLST,2,4,4
FITEM,2,805
FITEM,2,806
AL,PS1X
FLST,2,4,4
FITEM,2,794
FITEM,2,793
FITEM,2,792
AL,PS1X
FLST,2,4,4
FITEM,2,791
AL,PS1X
FLST,2,4,4
FITEM,2,796
FITEM,2,793
AL,PS1X
FLST,2,4,4
FITEM,2,790
FITEM,2,787
FITEM,2,793
AL,PS1X
FLST,2,4,4
FITEM,2,815
FITEM,2,814
FITEM,2,817
FITEM,2,816
AL,PS1X
FLST,2,4,4
FITEM,2,810
FITEM,2,775
AL,PS1X
FLST,2,4,4
FITEM,2,807
FITEM,2,806
AL,PS1X

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FLST,3,1,4,ORDE,1
FITEM,3,787
LGEN,2,PS1X,,148.3+23.55,,0
FLST,2,1,4,ORDE,1
FITEM,2,729
FLST,3,1,4,ORDE,1
FITEM,3,819

135
LSBL.P51X.P51X,.KEEP
LSSTR, 397, 4
LSSTR, 4, 442
FLST, 3.1, ORDE, 1
FITEM, 3, 821
FITEM, 2, 831
FITEM, 2, 829
FITEM, 2, 827
FITEM, 2, 825
FITEM, 2, 822
FITEM, 2, 829
AL.P51X
FLST, 2.4, 4
FITEM, 2, 832
FITEM, 2, 828
FITEM, 2, 830
FITEM, 2, 815
AL.P51X
FLST, 2.4, 4
FITEM, 2, 828
FITEM, 2, 729
FITEM, 2, 831
FITEM, 2, 829
AL.P51X
FLST, 2.4, 4
FITEM, 2, 827
FITEM, 2, 825
FITEM, 2, 822
FITEM, 2, 829
AL.P51X
FLST, 2.4, 4
FITEM, 2, 831
FITEM, 2, 824
FITEM, 2, 821
FITEM, 2, 826
AL.P51X
FLST, 2.4, 4
FITEM, 2, 823
FITEM, 2, 828
FITEM, 2, 826
FITEM, 2, 827
AL.P51X
FLST, 2.4, 4
FITEM, 2, 729
FITEM, 2, 819
FITEM, 2, 822
FITEM, 2, 821
FITEM, 2, 825
AL.P51X
FLST, 2.4, 4
FITEM, 2, 823
FITEM, 2, 819
FITEM, 2, 824
FITEM, 2, 825
AL.P51X
FLST, 2.4, 4
FITEM, 2, 729
FITEM, 2, 819
FITEM, 2, 822
FITEM, 2, 821
FITEM, 2, 825
AL.P51X
FLST, 2.4, 4
FITEM, 2, 823
FITEM, 2, 819
FITEM, 2, 824
FITEM, 2, 825
AL.P51X
FLST, 2.4, 4
FITEM, 2, 823
FITEM, 2, 819
FITEM, 2, 824
FITEM, 2, 825
AL.P51X
FLST, 2.4, 4
FITEM, 2, 823
FITEM, 2, 819
FITEM, 2, 824
FITEM, 2, 825
AL.P51X
FLST, 2.4, 4
FITEM, 2, 823
FITEM, 2, 819
FITEM, 2, 824
FITEM, 2, 825
AL.P51
! Bottom Area of Top Bolster
AL.P51X
FLST, 3.1, 3, ORDE, 1
FITEM, 3.4
KGEN, 2.P51X, ., 190, 0
KL, 729, (303.8-190)/(303.6, 2
FLST, 3.2, 3, ORDE, 2
FITEM, 3.405
FITEM, 3.447
KGEN, 2.P51X, ., 10000, 0
FLST, 2.4, 3
FITEM, 2.447
FITEM, 2.405
FITEM, 2.449
FITEM, 2.450
! Front Angle Plate
AL.P51X
AL.P51X
FLST, 2.1, 5, ORDE, 1
FITEM, 2.385
FLST, 3.1, 5, ORDE, 1
FITEM, 3.17
ASBA.P51X.P51X,. KEEP
ADELE, 387, 1
FLST, 2.1, 5, ORDE, 1
FITEM, 2.17
FLST, 3.1, 5, ORDE, 1
FITEM, 3.386
ASBA.P51X.P51X,. KEEP
FLST, 2.10, 5, ORDE, 10
FITEM, 2.347
FITEM, 2.348
FITEM, 2.354
FITEM, 2.355
FITEM, 2.361
FITEM, 2.362
FITEM, 2.368
FITEM, 2.369
FITEM, 2.377
FITEM, 2.378
FLST, 3.1, 5, ORDE, 1
FITEM, 3.386
!

136
ASBA,P51X,P51X,,KEEP
FLST,2,3,5,ORDE,3
FITEM,2,45
FITEM,2,170
FITEM,2,188
FLST,3,1,5,ORDE,1
FITEM,3,386
ASBA,P51X,P51X,,KEEP ! Dividing Areas

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```
! Areas on Ends of Bolsters

FLST,2,24,4
FITEN,2,872
FITEN,2,871
FITEN,2,980
FITEN,2,1038
FITEN,2,885
FITEN,2,1024
FITEN,2,1020
FITEN,2,884
FITEN,2,1026
FITEN,2,1013
FITEN,2,1009
FITEN,2,877
FITEN,2,1015
FITEN,2,1002
FITEN,2,998
FITEN,2,1004
FITEN,2,875
FITEN,2,991
FITEN,2,987
FITEN,2,993
FITEN,2,873
FITEN,2,975
FITEN,2,974
FITEN,2,874
AL,P51X

! Lip Internal Area

FLST,2,1,5,ORDE,1
FITEN,2,417
FLST,2,1,5,ORDE,1
FITEN,3,407
ASBA,P51X,P51X,,KEEP

! Subtracted Upper Bolster End Area

KWPLAN,-1, 535, 533, 480
WPSTYLE,0
FLST,2,3,5,ORDE,3
FITEN,2,414
FITEN,2,418
FITEN,2,420
ASBW,P51X
KWPAVE, 539
FLST,2,3,5,ORDE,3
FITEN,2,419
FITEN,2,423
ASBW,P51X
KWPAVE, 543
FLST,2,3,5,ORDE,3
FITEN,2,414
FITEN,2,424
FITEN,2,426
ASBW,P51X
KWPAVE, 547
FLST,2,3,5,ORDE,3
FITEN,2,419
FITEN,2,427
FITEN,2,431
ASBW,P51X

! Using WPlane to Cut Lip Areas

WPCSYS,-1,0
LSTR, 547, 493
LSTR, 543, 486
LSTR, 539, 483
LSTR, 535, 476
FLST,2,4,4
FITEN,2,886
FITEN,2,926
FITEN,2,912
FITEN,2,929

! Lip Inside Area

AL,P51X

FLST,2,7,4
FITEN,2,964
FITEN,2,880
FITEN,2,876
FITEN,2,965
FITEN,2,730
FITEN,2,961
FITEN,2,960
AL,P51X

FLST,2,4,4
FITEN,2,956
FITEN,2,952
FITEN,2,960
FITEN,2,959
AL,P51X

! Lip Outer Areas

KWPLAN,-1, 527, 467, 535
ASBW, 414
WPSTYLE,0

! Cut Outer Area w/ WPlane

LSTR, 518, 469
FLST,2,1,4,ORDE,1
FITEN,2,866
FLST,3,1,4,ORDE,1
FITEN,3,983
LSBL,P51X,P51X,,KEEP
FLST,2,13,4
FITEN,2,730
FITEN,2,1041
FITEN,2,885
FITEN,2,1032
FITEN,2,884
FITEN,2,1031

AL,P51X

FLST,2,4,4
FITEN,2,898
FITEN,2,920
FITEN,2,900
FITEN,2,922

AL,P51X

FLST,2,4,4
FITEN,2,921
FITEN,2,911
FITEN,2,905
FITEN,2,913

AL,P51X

FLST,2,4,4
FITEN,2,899
FITEN,2,897
FITEN,2,893

142
AL_P51X

--- Lip Gusset Areas ---

FLST, 2, 4, 4
FITEM, 2, 451
FITEM, 2, 467
FITEM, 2, 455
ASBW, P51X

FLST, 2, 5, 5, ORDE, 4
FITEM, 2, 446
FITEM, 2, 451
FITEM, 2, 463
FITEM, 2, 455

FLST, 2, 5, 4
FITEM, 2, 1001
FITEM, 2, 1000
FITEM, 2, 1003
FITEM, 2, 988

--- Top Plate Areas ---

FLST, 2, 4, 4
FITEM, 2, 1028
AL_P51X

--- Outside Bolster Gusset ---

WPSTYLE, 0, 0, -700, 5-700, 5
FLST, 2, 5, 4
FITEM, 2, 451
FITEM, 2, 463
FITEM, 2, 455

--- Bolster Gussets ---

[wikipedia]

--- Internal Bolster Gussets ---

*wafun, deg
KWPAVE, 398
wp, r, 0, 0, 0, 0, 0
KWPAVE, 508
wp, 0, 0, -503

--- Placing WPlane ---

FLST, 2, 3, 5, ORDE, 3
FITEM, 2, 454
FITEM, 2, 490
FITEM, 2, 491
ASBW, P51X

WPCSYS, -1, 0
KL, 756, 34*20, 5/3085.14
KWPLAN, -1, 510, 511, 462
FLST, 3, 1, 3, ORDE, 1
FITEM, 3, 510
KGEN, 2, P51X, -1000, 0

--- 2nd Center Gusset Area ---

--- Rounded Sections of Bolsters ---

[wikipedia]
FITEM,2,848
FITEM,2,850
FITEM,2,853
FITEM,2,843
FITEM,2,835
FITEM,2,860
FITEM,2,858
AL,P51X ! Replaced Area using proper line segments

<table>
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<tr>
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<tr>
<td>Adding Missing Gusset in Pivot Structure</td>
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KWPLAN,-1,  180,  183,  178
KWPAVE,   209
FLST,2,3,5,ORDE,3
FITEM,2,33
FITEM,2,129
FITEM,2,140
ASBW,P51X ! Using Workplane to Cut Areas

WPSTYLE,....,0
FLST,2,4,4
FITEM,2,1137
FITEM,2,1133
FITEM,2,1134
FITEM,2,362
AL,P51X

! Creating Gusset Area from Created lines

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<tr>
<td>-----------------------------------------------</td>
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<tr>
<td>Correction Necessary for correct mesh generation.</td>
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<tr>
<td>Old Area was not made up of proper lines to be</td>
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<td>attached to surrounding areas. Caused discontinuous</td>
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<td>mesh.</td>
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ADELE,  52
FLST,2,5,4
FITEM,2,151
FITEM,2,173
FITEM,2,155
FITEM,2,139
FITEM,2,156
AL,P51X

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<tr>
<td>-----------------------------------------------</td>
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<tr>
<td>Cleanup</td>
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</tbody>
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NUMMRG,ALL,,   ! Merging Coincident
items
NUMCMP,AREA
NUMCMP,LIN
NUMCMP,KP   ! Compressing Numbers

FINISH
/EOF
![Image](https://via.placeholder.com/150)

**Filename: 2_6_round_corners_INPUT**

```
!**********************************************************
! FEA of 530E Truck Box Structure
! Routine to Add Rounded Bolster Fillets to Geometry
!**********************************************************

FINISH

/TITLE, Adding Bolster Fillets

/PREP7
*AFUN, DEG
A PLOT
/AUTO, 1
/REP
/USER, 1
/VIEW, 1, 0.0091617178652, 0.375169699704, 0.175619875347
/LIG, 1, 179.4989010154
/LIG, 1, 0.5091609919, 0.563136024016
, 0.656485028234, 0.000000000000E+00
/ZOOM, 1, RECT, 0.086021, 0.815836, 0.967367, 0.098534

!----------------------------------------------------------
!----------------------------------------------------------
!----------------------------------------------------------
FLST, 2, 2, 5, ORDE, 2
FITEM, 2, 189
FITEM, 2, 201
ADELE, P51X, .1 ! Deleting STR Side Areas
AFILLT, 97, 100, 38, ! First Bolster from Front
AFILLT, 96, 101, 38,
AFILLT, 95, 98, 38,
AFILLT, 651, 115, 38,
AFILLT, 550, 96, 38, ! 38mm Bolster Fillets
ADELE, 220, .1 ! Deleting End Cap Area
LSTR, 70, 611 ! Creating Line in Middle
FLST, 2, 2, 4, 4
FITEM, 2, 83
FITEM, 2, 1136
FITEM, 2, 283
FITEM, 2, 2144
AL, P51X
FLST, 2, 2, 4, 4
FITEM, 2, 124
FITEM, 2, 83
FITEM, 2, 85
FITEM, 2, 1161
AL, P51X ! Creating New End Cap Areas
AFILLT, 282, 281, 38,
AFILLT, 274, 280, 38,
AFILLT, 264, 268, 38,
AFILLT, 109, 113, 38,
AFILLT, 86, 95, 38,
AFILLT, 65, 93, 38,
AFILLT, 580, 111, 38,
AFILLT, 559, 268, 38,
AFILLT, 558, 273, 38,
AFILLT, 557, 284, 38,
FLST, 2, 3, 4
FITEM, 2, 279
FITEM, 2, 225
FITEM, 2, 547
```

AL, P51X
FLST, 2, 3, 4
FITEM, 2, 243
FITEM, 2, 605
FITEM, 2, 1165
FITEM, 2, 1167
FITEM, 2, 220
AL, P51X
FLST, 2, 3, 4
FITEM, 2, 269
FITEM, 2, 1181
FITEM, 2, 221
FITEM, 2, 634
AL, P51X
FLST, 2, 3, 4
FITEM, 2, 1181
FITEM, 2, 221
FITEM, 2, 634
AL, P51X
FLST, 3, 2, 5, ORDE, 2
FITEM, 3, 284
FITEM, 3, 557
FITEM, 3, 587
ASBA, 85, P51X
FLST, 3, 2, 5, ORDE, 2
FLST, 2, 2, 4, 4
FITEM, 2, 1136
FITEM, 2, 1167
FITEM, 2, 634
AL, P51X
FLST, 2, 2, 4, 4
FITEM, 2, 120
FITEM, 2, 68
FITEM, 2, 72
FITEM, 2, 1190
AL, P51X ! Second Bolster
AFILLT, 283, 280, 38,
AFILLT, 277, 279, 38,
AFILLT, 265, 267, 38,
AFILLT, 210, 112, 38,
AFILLT, 89, 91, 38,
AFILLT, 572, 84, 38,
AFILLT, 571, 109, 38,
AFILLT, 570, 263, 38,
AFILLT, 568, 272, 38,
AFILLT, 567, 281, 38,
FLST, 2, 3, 4
FITEM, 2, 1189
FITEM, 2, 585
FITEM, 2, 237
AL, P51X
FLST, 2, 3, 4
FITEM, 2, 692
FITEM, 2, 1207
FITEM, 2, 214
AL, P51X
FLST, 2, 3, 4
FITEM, 2, 1162
FITEM, 2, 689
FITEM, 2, 75
AL, P51X
FLST, 2, 3, 4
FITEM, 2, 602
FITEM, 2, 1209
| ITEM,2,215 | LSTR, 621, 153 |
| AL,PS1X | FLST,2,5,4 |
| FLST,3,2,5,ORDE,2 | FITEM,2,530 |
| FITEM,3,578 | FITEM,2,766 |
| FITEM,3,579 | FITEM,2,791 |
| ASBA, 44,PS1X | FITEM,2,1145 |
| FLST,3,2,5,ORDE,2 | FITEM,2,187 |
| FITEM,3,281 | AL,PS1X |
| ASBA, 57,PS1X | FLST,2,5,4 |
| ADELE, 287,1 | FITEM,2,295 |
| ADELE, 287,1 | FITEM,2,274 |
| LSTR, 58,131 | FITEM,2,781 |
| FLST,2,4,4 | FITEM,2,1139 |
| FITEM,2,289 | AL,PS1X |
| FITEM,2,1210 | FLST,2,4,4 |
| FITEM,2,233 | FITEM,2,244 |
| FITEM,2,582 | FITEM,2,190 |
| AL,PS1X | FITEM,2,831 |
| FLST,2,5,4 | FITEM,2,186 |
| FITEM,2,254 | AL,PS1X |
| FITEM,2,1113 | FLST,2,4,4 |
| FITEM,2,1213 | FITEM,2,187 |
| FITEM,2,59 | FITEM,2,638 |
| AL,PS1X | FITEM,2,186 |
| AL,PS1X | FITEM,2,68 |
| AFILLT,81,82,38 | AL,PS1X |
| AFILLT,106,107,38 | ! STR Nose Area |
| AFILLT,80,83,38 | KWPLAN, 148, 70, 617 |
| AFILLT,51,76,38 | KWPANE, 612 |
| AFILLT,58,105,38 | ASBW, 14 |
| AFILLT,57,73,38 | KWPANE, 627 |
| ADELE, 256,1 | ASBW, 595 |
| LSTR, 50,66 | KWPANE, 630 |
| FLST,2,4,4 | ASBW, 14 |
| FITEM,2,58 | KWPANE, 633 |
| FITEM,2,1113 | ASBW, 595 |
| FITEM,2,252 | KWPANE, 149 |
| AL,PS1X | ASBW, 14 |
| FLST,2,4,4 | KWPANE, 639 |
| FITEM,2,58 | ASBW, 595 |
| FITEM,2,112 | KWPANE, 642 |
| FITEM,2,1222 | ASBW, 14 |
| FITEM,2,54 | KWPANE, 643 |
| AL,PS1X | ASBW, 595 |
| AL,PS1X | KWPANE, 71 |
| AFILLT,75,76,38 | ASBW, 14 |
| AFILLT,103,104,38 | KWPANE, 651 |
| AFILLT,74,77,38 | ASBW, 595 |
| AFILLT,58,72,38 | KWPANE, 320 |
| AFILLT,58,102,38 | ASBW, 14 |
| AFILLT,58,73,38 | KWPANE, 327 |
| ADELE, 256,1 | ASBW, 595 |
| LSTR, 42,69 | KWPANE, 83 |
| FLST,2,4,4 | ASBW, 14 |
| FITEM,2,49 | KWPANE, 659 |
| FITEM,2,1224 | ASBW, 595 |
| FITEM,2,197 | KWPANE, 126 |
| FITEM,2,197 | ASBW, 14 |
| AL,PS1X | KWPANE, 661 |
| FLST,2,4,4 | ASBW, 595 |
| FITEM,2,108 | KWPANE, 57 |
| FITEM,2,1227 | ASBW, 14 |
| FITEM,2,45 | KWPANE, 667 |
| FITEM,2,49 | ASBW, 595 |
| AL,PS1X | ! Using Cplane to Divide STR Bottom Area |
| LSTR, 616,229 | FLST,2,4,3 |
| LSTR, 617,247 | FITEM,2,153 |
| LSTR, 619,154 | FITEM,2,261 |
LSTR,  111,  109
LSTR,  24,   20
FLST,2,3,4
FITEM,2,1396
FITEM,2,166
FITEM,2,302
ALPSIX
FLST,2,3,4
FITEM,2,301
FITEM,2,1397
FITEM,2,299
ALPSIX
FLST,2,2,5,ORDE,2
FITEM,2,681
FITEM,2,691
AADD,PSIX
FLST,2,2,5,ORDE,2
FITEM,2,680
FITEM,2,692
AADD,PSIX

FINISH
ISAVE
/EOF
! FEA of 930E Truck Box Structure
! Routine to Incorporate Syncrude
! Modifications to Geometry
!----------------------------------------
FINISH
/TITLE. Incorporating Syncrude's Modifications
/PRER7
*AFUN,DIG

------------------------------------------
| Wear Package on Side Wall |
------------------------------------------
KWPLAN,-1, 218, 30, 236
FLST,2,4,5,ORDE,4
ITEM,2,293
ITEM,2,313
ITEM,2,316
ITEM,2,321
ASBW,P51X ! Used WPlane to divide Side Areas
ITEM,2 only cover back 1/3rd of Sidewall

------------------------------------------
View Commands

APLOT
/AUTO, 1
/REP
/USER, 1
/VIEW, 1, 0.1537497671045, 0.083576000405, 0.7997162840240
/ANG, 1, -1.72364133592
/LIG, 1, 1.1, 0.000, 0.282687364737, 0.461125582318, 0.841109948399, 0.000000000000E+00
/REPL0
/ZOOM, 1, RECT, 0.394496, 0.585044, 0.838009, 0.06774

! Flat Plate Between Forward Two Bolsters
! between STR's

LSTR, 351, 625
FLST,2,4,4
ITEM,2,668
ITEM,2,603
ITEM,2,1286
ITEM,2,1156
AL,P51X

------------------------------------------
Exhaust Plenum

------------------------------------------
KWPLAN,-1, 43, 47, 657
wcpoff,0.0,-430
WPSTYLE,......,0
FLST,2,17,5,ORDE,17
ITEM,2,74
ITEM,2,80
ITEM,2,83
ITEM,2,89
ITEM,2,91
ITEM,2,103

------------------------------------------
Dividing Bolster Areas

FLST,2,21,4
ITEM,2,159
ITEM,2,161
ITEM,2,162
ITEM,2,175
ITEM,2,562
ITEM,2,573
ITEM,2,582
ASBW,P51X
ASBW,95

------------------------------------------
Plenum Side Area

LGEN,2,213, , -150, , -150, , 0
LGEN,2,260, , -280, , , 0
LSTR, 754, 757
LSTR, 757, 759
LSTR, 759, 123
LSTR, 758, 756
LSTR, 756, 755
LSTR, 758, 353
FLST,2,4,4
ITEM,2,213
ITEM,2,260
ITEM,2,1195
ITEM,2,629
AL,P51X

------------------------------------------
Slanted Side Area

FLST,2,5,4
ITEM,2,228
ITEM,2,629
ITEM,2,1169
ITEM,2,179
ITEM,2,1455
AL,P51X

------------------------------------------
End Area

AL,P51X

156
FITEM, 2.59
FITEM, 2.128
FITEM, 2.139
FITEM, 2.140
FITEM, 2.660
FITEM, 2.662
FITEM, 2.665
FITEM, 2.671
FITEM, 2.674
FITEM, 2.676
ADELE, PS1X, ., .1
FLST, 2.2.5. ORDE, 2
FITEM, 2.672
FITEM, 2.673
ADELE, PS1X, ., .1

LSTR, 158, 167
ASBL, 149.8, ., KEEP
FLST, 2.3.5. ORDE, 3
FITEM, 2.54
FITEM, 2.140
FITEM, 2.203
AADD, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.1
FITEM, 2.5
FITEM, 2.49
AADD, PS1X
FLST, 2.3.5. ORDE, 2
FITEM, 2.68
FITEM, 2.70
AADD, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.146
FITEM, 2.147
FITEM, 2.154
AADD, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.3
FITEM, 2.47
FITEM, 2.57
AADD, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.627
FITEM, 2.630
FITEM, 2.659
AADD, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.29
FITEM, 2.63
FITEM, 2.64
AADD, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.4
FITEM, 2.62
FITEM, 2.199
AADD, PS1X

FITEM, 2.50
FITEM, 2.54
FITEM, 2.55
FITEM, 2.60
FITEM, 2.67
ADELE, PS1X
ASBW, 48
KWPAVE, 158
FLST, 2.12.5. ORDE, 10
FITEM, 2.2
FITEM, 2.46
FITEM, 2.51
FITEM, 2.66
FITEM, 2.139
FITEM, 2.140
FITEM, 2.146
FITEM, 2.149
FITEM, 2.154
FITEM, 2.165
ADELE, PS1X

LSTR, 158, 167
ASBL, 149.8, ., KEEP
FLST, 2.3.5. ORDE, 3
FITEM, 2.54
FITEM, 2.57
ADELE, PS1X, ., .1
FLST, 2.3.4. ORDE, 3
FITEM, 2.131
FITEM, 2.1344
FITEM, 2.1346
LCOMB, PS1X, ., .0
FLST, 2.3.4. ORDE, 3
FITEM, 2.130
FITEM, 2.1334
FITEM, 2.1338
LCOMB, PS1X, ., .0
FLST, 2.4.4
FITEM, 2.131
FITEM, 2.1347
FITEM, 2.130
FITEM, 2.132
AL, PS1X
FLST, 2.3.5. ORDE, 3
FITEM, 2.4
FITEM, 2.29
FITEM, 2.52
ADELE, PS1X, ., .1
FLST, 2.3.4. ORDE, 3
FITEM, 2.55
FITEM, 2.56
FITEM, 2.64
ADELE, PS1X, ., .1
FLST, 2.2.4. ORDE, 2
FITEM, 2.1359
FITEM, 2.1362
LOELE, PS1X, ., .1
FLST, 2.3.4. ORDE, 3
FITEM, 2.10
FITEM, 2.178
FITEM, 2.1348
LCOMB, PS1X, ., .0
FLST, 2.3.4. ORDE, 3
FITEM, 2.2
FITEM, 2.171
FITEM, 2.177
LCOMB, PS1X, ., .0
FLST, 2.3.4. ORDE, 3
FITEM, 2.144
FITEM, 2.1340
FITEM, 2.1349
LCOMB.P51X ,0
FLST,2,3,4,ORDE,3
FITEM,2,145
FITEM,2,1351
FITEM,2,1351
LCOMB.P51X ,0
FLST,2,4,4
FITEM,2,13
FITEM,2,10
FITEM,2,367
FITEM,2,2
AL.P51X
FLST,2,4,4
FITEM,2,144
FITEM,2,145
FITEM,2,147
FITEM,2,1325
AL.P51X
I Repairing Corner Areas
LSTR,20,92
LSTR,766,109
FLST,2,114
FITEM,2,9
FITEM,2,277
FITEM,2,1467
FITEM,2,1365
FITEM,2,1347
FITEM,2,1328
FITEM,2,367
FITEM,2,1367
FITEM,2,1358
FITEM,2,1366
FITEM,2,1325
AL.P51X
FLST,2,114
FITEM,2,1
FITEM,2,147
FITEM,2,6
FITEM,2,141
FITEM,2,150
FITEM,2,13
FITEM,2,153
FITEM,2,132
FITEM,2,152
FITEM,2,155
FITEM,2,29
AL.P51X
FLST,2,4,4
FITEM,2,353
FITEM,2,1
FITEM,2,146
FITEM,2,9
AL.P51X
I Creating New STR Areas
FITEM,2,163
FITEM,2,1366
FITEM,2,1325
FITEM,2,170
FITEM,2,1368
AL.P51X
FLST,2,5,4
FITEM,2,154
FITEM,2,128
FITEM,2,138
AL.P51X
I Stiffeners inside Rear Angle Bolster
FLST,2,3,4,ORDE,3

FITEM,2,157
FITEM,2,162
FITEM,2,1470
FLST,2,3,4,ORDE,3
FITEM,2,158
FITEM,2,165
FITEM,2,1472
FLST,2,3,4,ORDE,3
FITEM,2,156
FITEM,2,168
FITEM,2,1471
FLST,2,3,4,ORDE,3
I Cleanup
KWPLAN,-1,84,11,8
FLST,2,3,5,ORDE,3
FITEM,2,29
FITEM,2,46
FITEM,2,51
ASBW.P51X
KWPAVE,12
FLST,2,3,5,ORDE,3
FITEM,2,56
FITEM,2,66
FITEM,2,139
ASBW.P51X
KWPAVE,82
FLST,2,3,5,ORDE,3
FITEM,2,140
FITEM,2,146
FITEM,2,147
ASBW.P51X
KWPAVE,79
FLST,2,3,5,ORDE,3
FITEM,2,148
FITEM,2,149
FITEM,2,154
ASBW.P51X
I Using CPPlane to Divide STR Areas
FLST,2,3,4,ORDE,3
FITEM,2,159
FITEM,2,179
FITEM,2,1468
LCOMB.P51X,0

I-----------------------------------------------
I Area for 1° Fishplating
I-----------------------------------------------
KL,155.0.3,
KWPAVE,81
FLST,2,2,5,ORDE,2
FITEM,2,667
FITEM,2,668
ASBW,P51X
I Divided Rear STR Areas
KL,71,5,
KWPAVE,709
FLST,2,4,5,ORDE,4
FITEM,2,645
FITEM,2,646
FITEM,2,652
FITEM,2,653
ASBW,P51X
WPSTYLE,0
I Divided Areas between 5th and 6th Bolsters
FINISH
IEOF I-----------------------------------------------
FINISH

TITLE: Assigning Floor Thicknesses and Material Properties

/REP7
*APUN, DEG

------------------------------------------- Pivot Structure

CM_YAREA
ASEL... P51X
CM_Y1 AREA
CMSEL S_Y
CMSEL S_Y1
ATT, 1, 5, 1, 0
CMSEL Y
CMDELE Y
CMDELE Y1 ! Gusset Above Cutout - 5mm

FLST, 5, 2, 5, ORDE, 2
FITEM, 5, 11
FITEM, 5, 118
CM_Y AREA
ASEL... P51X
CM_Y1 AREA
CMSEL S_Y
CMSEL S_Y1
ATT, 1, 90, 1, 0
CMSEL S_Y
CMDELE Y
CMDELE Y1 ! Reinforced Section - 90mm total

FLST, 5, 8, 5, ORDE, 7
FITEM, 5, 137
FITEM, 5, 549
FITEM, 5, 679
FITEM, 5, 681
FITEM, 5, 688
FITEM, 5, 689
FITEM, 5, 693
CM_YAREA
ASEL... P51X
CM_Y1 AREA
CMSEL S_Y
CMSEL S_Y1
ATT, 1, 63, 1, 0
CMSEL S_Y
CMDELE Y
CMDELE Y1 ! Sides - 1.5" thick + 1" Fish Plating

FLST, 5, 6, 5, ORDE, 8
FITEM, 5, 138
FITEM, 5, 253
FITEM, 5, 254
FITEM, 5, 545
FITEM, 5, 546
FITEM, 5, 548
FITEM, 5, 668
FITEM, 5, 687
CM_YAREA
ASEL... P51X
CM_Y1 AREA
CMSEL S_Y
CMSEL S_Y1
ATT, 1, 38, 1, 0
CMSEL S_Y
CMDELE Y
CMDELE Y1 ! Inner Pieces of Side Walls - 1.5"

FLST, 5, 2, 5, ORDE, 2
FITEM, 5, 141
FITEM, 5, 142
CM_YAREA
ASEL... P51X
CM_Y1 AREA
CMSEL S_Y
CMSEL S_Y1
ATT, 1, 19, 1, 0
CMSEL S_Y
CMDELE Y
CMDELE Y1 ! Front Narrowing Section - 3/4"

FLST, 5, 7, 5, ORDE, 5
FITEM, 5, 128
FITEM, 5, 143
FITEM, 5, 144
FITEM, 5, 682
FITEM, 5, 686
CM_YAREA
ASEL... P51X
CM_Y1 AREA
CMSEL S_Y
CMSEL S_Y1
ATT, 1, 16, 1, 0
CMSEL S_Y
CMDELE Y
CMDELE Y1 ! Bottom Plates - 5/8"

------------------------------------------- Rear Stringer Structure

-------------------------------------------
FLST,5,2,5,ORDE,2
FITEM,5,140
FITEM,5,-149
CM_Y_AREA
ASEL,,P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y1
AATT, 1, 54, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1 ! Side Areas - 1 1/8" w/ 1" FishPlate

FLST,5,2,5,ORDE,2
FITEM,5,52
FITEM,5,54
CM_Y_AREA
ASEL,,P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y1
AATT, 1, 5, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1 ! Gusset Plates inside Rear Angle - 5mm

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CMSEL S, Y
CMSEL S, Y1
AATT, 1, 9, 1, 0
CMSEL S, Y
CMDELE Y1
! Last Bolster (Front) - 9mm

------------------------------------------

Floor Plate

------------------------------------------

FLST.S,54,5,ORDE,43
FITEM,5,3
FITEM,5,34
FITEM,5,37
FITEM,5,39
FITEM,5,43
FITEM,5,45
FITEM,5,50
FITEM,5,56
FITEM,5,59
FITEM,5,62
FITEM,5,65
FITEM,5,67
FITEM,5,89
FITEM,5,106
FITEM,5,126
FITEM,5,150
FITEM,5,153
FITEM,5,155
FITEM,5,157
FITEM,5,185
FITEM,5,191
FITEM,5,193
FITEM,5,194
FITEM,5,204
FITEM,5,262
FITEM,5,269
FITEM,5,271
FITEM,5,273
FITEM,5,275
FITEM,5,276
FITEM,5,285
FITEM,5,286
FITEM,5,343
FITEM,5,349
FITEM,5,350
FITEM,5,544
FITEM,5,547
FITEM,5,573
FITEM,5,682
FITEM,5,662
FITEM,5,665
FITEM,5,669
FITEM,5,700
FITEM,5,702
FITEM,5,705
FITEM,5,101
CM, Y, AREA
CMSEL S, Y
CMSEL S, Y1
AATT, 1, 9, 1, 0
CMSEL S, Y
CMDELE Y1
! 7th Bolster (Near Hoist) - 9mm

FLST.S,30,5,ORDE,26
FITEM,5,74
FITEM,5,80
FITEM,5,86
FITEM,5,88
FITEM,5,93
FITEM,5,111
FITEM,5,113
FITEM,5,161
FITEM,5,268
FITEM,5,261
FITEM,5,264
FITEM,5,266
FITEM,5,268
FITEM,5,274
FITEM,5,278
FITEM,5,280
FITEM,5,282
FITEM,5,293
FITEM,5,550
FITEM,5,556
FITEM,5,558
FITEM,5,561
FITEM,5,563
FITEM,5,566
FITEM,5,721
FITEM,5,733
CM, Y, AREA
CMSEL S, Y
CMSEL S, Y1
AATT, 1, 9, 1, 0
CMSEL S, Y
CMDELE Y1
! 8th Bolster (Near Hoist) - 9mm

FLST.S,18,5,ORDE,13
FITEM,5,86
FITEM,5,101
FITEM,5,114
FITEM,5,116
FITEM,5,159
FITEM,5,162
FITEM,5,189
FITEM,5,201
FITEM,5,259
FITEM,5,551
FITEM,5,552
FITEM,5,554
FITEM,5,555
CM, Y, AREA
CMSEL S, Y
CMSEL S, Y1
AATT, 1, 9, 1, 0
CMSEL S, Y
CMDELE Y1
! Floor Plate - 5/8" + 1/2" Wear Pkg. = 28.575mm

FLST.S,4,5,ORDE,4
FITEM,5,342
FITEM,5,356
FITEM,5,357

163
FRONT ANGLE PLATE AND FLOOR PLATE UNDER - 5/8"
FLST, 5, 2, S, ORDE, 2
FITEM, 5, 107
FITEM, 5, 109
CM, Y, AREA
ASEL, . . . P51X
CM, Y1, AREA
CMSEL, S, Y
CMSEL, S, Y1
AATT, 1, 3, 1, 0
CMSEL, S, Y
CMDELETE, Y
CMDELETE, Y1

-----------------------------
| Guide Pin Stiffened Region |
-----------------------------

CM, Y, AREA
ASEL, . . . 110
CM, Y1, AREA
CMSEL, S, Y
CMSEL, S, Y1
AATT, 1, 9, 1, 0
CMSEL, S, Y
CMDELETE, Y
CMDELETE, Y1
| 9mm Plate Between Bolsters |

FINISH
/EOF

------------------------------------------------------------
FILENAME: 3_2_assignprop_wall_INPUT

! FEA of 930E Truck Box Structure
! Thickness and Mat Prop Assignment Routine
! Side Structure

! TITLE Assigning Wall Thicknesses and Material Properties

/PREP7
*AFUN,DEG

------------- Wall Structure
-------------

FLST,5,6,5,ORDE,6
FITEM,5,289
FITEM,5,317
FITEM,5,691
FITEM,5,694
FITEM,5,697
FITEM,5,698
CM_Y AREA
ASEL,,P51X
CM_Y1 AREA
CMSEL_S_Y
CMSEL_S_Y1
AATT, 1, 8, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1 ! Side Sheet - 8mm

FLST,5,6,5,ORDE,6
FITEM,5,289
FITEM,5,290
FITEM,5,301
FITEM,5,690
FITEM,5,692
FITEM,5,695
FITEM,5,-696
CM_Y AREA
ASEL,,P51X
CM_Y1 AREA
CMSEL_S_Y
CMSEL_S_Y1
AATT, 1, 21, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1
! Side Sheet - 8mm +1/2" Wear Pkg.

FLST,5,23,5,ORDE,14
FITEM,5,290
FITEM,5,292
FITEM,5,294
FITEM,5,295
FITEM,5,297
FITEM,5,-300
FITEM,5,302
FITEM,5,-304
FITEM,5,307
FITEM,5,-312
FITEM,5,314
FITEM,5,-315

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/I All Wall Bolsters - 9mm

-------------
-------------
Filename: 3_3_assignprop_front_INPUT

! FEA of 930E Truck Box Structure
! Thickness and Mat Prop Assignment Routine
! Front Structure

FINISH

/TITLE: Assigning Front Thicknesses and Material Properties

/STOP

*AFUN,DEG

!----------------------------------------- Top Beam
!----------------------------------------- Front Sheet
!----------------------------------------- Bolsters

FLST,5,31,5,ORDE,20
FITEM,5,340
FITEM,5,344
FITEM,5,351
FITEM,5,358
FITEM,5,368
FITEM,5,371
FITEM,5,388
FITEM,5,408
FITEM,5,426
FITEM,5,428
FITEM,5,430
FITEM,5,432
FITEM,5,434
FITEM,5,441
FITEM,5,443
FITEM,5,496
FITEM,5,498
FITEM,5,510
FITEM,5,513
CM_Y,AREA
ASEL,,,P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y1
AATT,1,9,1,0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1 ! Top Beam - 9mm

-----------------------------------------

FLST,5,32,5,ORDE,7
FITEM,5,17
FITEM,5,187
FITEM,5,326
FITEM,5,335
FITEM,5,379
FITEM,5,397
FITEM,5,422
CM_Y,AREA
ASEL,,,P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y1
AATT,1,9,1,0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1 ! Front Sheet - 9mm No Wear Pkg.

-----------------------------------------

FLST,5,34,5,ORDE,20
FITEM,5,337
FITEM,5,338
FITEM,5,345
FITEM,5,347
FITEM,5,362
FITEM,5,354
FITEM,5,359
FITEM,5,381
FITEM,5,363
FITEM,5,367
FITEM,5,369
FITEM,5,370
FITEM,5,372
FITEM,5,375

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FILENAME: 3_4_assignprop_canopy_INPUT

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ASEL_P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y
AATT: 1, 5, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1
! All Plates - 5mm
! Incl. Gussets

---------------------
Canopy Braces
---------------------

FLST,5,4,5,ORDE,3
FITEM,5,539
FITEM,5,541
FITEM,5,543
CM_Y,AREA
ASEL_P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y
AATT: 1, 8, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1
! Square Tubing - 8mm

FLST,5,3,5,ORDE,3
FITEM,5,478
FITEM,5,529
FITEM,5,540
CM_Y,AREA
ASEL_P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y
AATT: 1, 18, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1
! Upper Reinforced Section - 5mm + 1/2" (17.7mm)

FLST,5,4,5,ORDE,4
FITEM,5,339
FITEM,5,341
FITEM,5,530
FITEM,5,535
CM_Y,AREA
ASEL_P51X
CM_Y1,AREA
CMSEL_S_Y
CMSEL_S_Y
AATT: 1, 22, 1, 0
CMSEL_S_Y
CMDELE_Y
CMDELE_Y1
! Lower Reinforced Section - 9mm + 1/2" (21.7mm)

---------------------
---------------------

FINISH

/EOF
TITLE, Incorporating Syncrude's Modifications

/AUXFUN, DEG

--- View Commands ---

APLOT
/USER, 1
/REP
/VIEW, 1, 0.153749767104, 0.580357600000, 0.790716784000
/JANG, 1, -172.36143592
/JLIG, 1, 1.11.000, 0.286267356737, 0.461125582318
/JANG, 1, -172.36143592
/Zoom, 1, 0.3944966, 0.5850444, 0.838009, 0.067742

--- Dividing Exhaust Plenum Side Area ---

KWPAVE, 744
LSBW, 1202
KWPAVE, 750
LSBW, 55
KWPAVE, 97
LSBW, 1202
KWPAVE, 748
LSBW, 55
KWPAVE, 33
LSBW, 1202
KWPAVE, 746
LSBW, 55
ADELE, 95, 1
WPSTYLE, 0

LSTR, 744, 782
FLST, 2, 5, 4
FITEM, 2, 55
FITEM, 2, 71
FITEM, 2, 218
FITEM, 2, 196
FITEM, 2, 1451
AL_P51X
LSTR, 750, 783
FLST, 2, 6, 4
FITEM, 2, 1423
FITEM, 2, 25
FITEM, 2, 1272
FITEM, 2, 1483
FITEM, 2, 1444
FITEM, 2, 1449
AL_P51X
LSTR, 97, 784
FLST, 2, 4, 4

FITEM, 2, 1453
FITEM, 2, 1273
FITEM, 2, 1485
FITEM, 2, 1484
AL_P51X
LSTR, 748, 785
FLST, 2, 4, 4
FITEM, 2, 1441
FITEM, 2, 1442
FITEM, 2, 1443
FITEM, 2, 1446
FITEM, 2, 1448
FITEM, 2, 1448
FITEM, 2, 1448
FITEM, 2, 1448
AL_P51X
LSTR, 33, 766
FLST, 2, 4, 4
FITEM, 2, 1486
FITEM, 2, 1485
FITEM, 2, 1316
FITEM, 2, 1454
AL_P51X
LSTR, 746, 787
FLST, 2, 4, 4
FITEM, 2, 1487
FITEM, 2, 1478
FITEM, 2, 1486
FITEM, 2, 703
FITEM, 2, 1435
FITEM, 2, 1415
FITEM, 2, 1447
FITEM, 2, 1432
AL_P51X
FLST, 5, 6, 5, ORDE, 7
FITEM, 5, 95
FITEM, 5, 645
FITEM, 5, 646
FITEM, 5, 652
FITEM, 5, 653
FITEM, 5, 676
FITEM, 5, 718
CM, Y_AREA
ASEL, 1, P51X
CM, Y1_AREA
CMSEL, S, Y
CMSEL, S, Y
AATT, 1, 3, 1, 0
CMDELE, S, Y
CMDELE, S, Y

--- Creating Guide Pin Geometry ---

NUMSTR, AREA, 750, ! Start New Area Numbers at 750
KWPLAN, -1, 755, 56, 351
KWPAVE, 756

170
FLST.5,7,5,ORDE.2
FITEM.5,758
FITEM.5,-764
CM_,Y,AREA
ASEL...PS1X
CM.,Y1,AREA
CMSEL.S.Y
CMSEL.S.Y1
AATT. 1, 16, 1, 0
CMSEL.S.Y
CMELE._Y
CMELE._Y1  ! 5/8" Plate - Guide Material

------------------ Dividing Forward STR for New BC

NUMSTR.KP.1000.
NUMSTR.LINE.2000,
NUMSTR,AREA.1000.
! Start New Area Numbers at 1000

KWPLAN.-1,  63,  327,  681
KL.1274,  5,  
KWPAVE, 1000

FLST.2,16,5,ORDE.2
FITEM.2,596
FITEM.2,-611
ASBW,PS1X

FLST.5,32,5,ORDE.2
FITEM.5,1000
FITEM.5,-1031
CM.,Y,AREA
ASEL...PS1X
CM.,Y1,AREA
CMSEL.S.Y
CMSEL.S.Y1
AATT. 1, 25, 1, 0
CMSEL.S.Y
CMELE._Y
CMELE._Y1  ! Restoring 1" Plate
Thickness

------------------

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<tr>
<td>ERASE</td>
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<td>View Settings</td>
</tr>
<tr>
<td>LINES</td>
<td></td>
<td>Manual Meshing Routine</td>
</tr>
</tbody>
</table>

PREP7

--- Bolster Stringer Joint Lines

--- Manual Mesh Sizing

--- Div's Down Bolster Side Edges

--- Div's Down Forward Bolster Side Edges
LELSIZE_22_,_23,1/_24
*ENDIF
*ENDIF
*ENDIF
CMSEL=Y1
CMDELE=Y1  ! Flip Bias on Some Lines

FLST,5,2,4,ORDE,2
FITEM,5,153
FITEM,5,1328
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,7;5,
IENSEL_Y1,...,10;5,
CMDEL_Y  ! Div's Small Near Bolster Corners
CMDELY1

FLST,5,9,4,ORDE,9
FITEM,5,297
FITEM,5,359
FITEM,5,1155
FITEM,5,1178
FITEM,5,1109
FITEM,5,1214
FITEM,5,1229
FITEM,5,1375
FITEM,5,1390
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,15;7,
IENSEL_Y1,...,17;7,
CMDEL_Y  ! Div's Small Near Bolster Corners
CMDELY1

FLST,5,7,4,ORDE,7
FITEM,5,1149
FITEM,5,1173
FITEM,5,1158
FITEM,5,1211
FITEM,5,1228
FITEM,5,1357
FITEM,5,1308
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,15;7,
IENSEL_Y1,...,20;7,
CMDEL_Y  ! Div's Small Near Bolster Corners
CMDELY1

FLST,5,2,4,ORDE,2
FITEM,5,147
FITEM,5,1325
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,2;1,
CMDELY1
CMDELY1  ! Div's on Rounded Corners (1st Rear Bolster)

FLST,5,4,4,ORDE,4
FITEM,5,13
FITEM,5,132
FITEM,5,367
FITEM,5,1347
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,5;1,
CMDELY1
CMDELY1  ! Div's on Rounded Corners (2nd Bolster)

FLST,5,14,4,ORDE,14
FITEM,5,26
FITEM,5,36
FITEM,5,42
FITEM,5,51
FITEM,5,61
FITEM,5,74
FITEM,5,80
FITEM,5,89
FITEM,5,176
FITEM,5,194
FITEM,5,208
FITEM,5,234
FITEM,5,240
FITEM,5,244
FITEM,5,280
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,10;1,
IENSEL_Y1,...,10;1,
CMDELY1
CMDELY1  ! Div's on Rounded Corners (Outside)

FLST,5,18,4,ORDE,17
FITEM,5,32
FITEM,5,38
FITEM,5,41
FITEM,5,43
FITEM,5,50
FITEM,5,52
FITEM,5,60
FITEM,5,62
FITEM,5,77
FITEM,5,86
FITEM,5,88
FITEM,5,139
FITEM,5,184
FITEM,5,235
FITEM,5,239
FITEM,5,278
FITEM,5,280
CM_Y,LINE
LSEL...,P51X
CM_Y,LINE
CMSEL=Y
LELSIZE_Y1,...,10;1,
IENSEL_Y1,...,10;1,
CMDELY1
CMDELY1  ! Div's on Rounded Corners (Outside)

FLST,5,2,2,4,ORDE,2
FITEM,2,365
FITEM,2,1333
LCOMB,P51X,.0
FLST,5,2,4,ORDE,2
FITEM,5,365
FITEM.5.1378
CM_Y,LINE
LSEL,...,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,...,10.1,
CMDEL_Y
CMDEL_Y1
FLST.5,1,4,ORDE.1
FITEM.5,1382
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSEL_Y
LESIZE_Y1,...,1.1,
CMDEL_Y
CMDEL_Y1
FLST.5.1,4,ORDE.1
FITEM.5,312
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSEL_Y
LESIZE_Y1,...,7.1,
CMDEL_Y
CMDEL_Y1  ! Sizing a Few Misc. Lines

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Bolster Lines Inside Stringer Box</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>

FLST.2,3,4,ORDE.3
FITEM.2,160
FITEM.2,174
FITEM.2,1409
LCOMP,P51X,.0
FLST.5,2,4,ORDE.2
FITEM.5,159
FITEM.5,160
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSEL_Y
LESIZE_Y1,...,4.1,
CMDEL_Y
CMDEL_Y1  ! Inside Bolster (Top) (2nd Bolster)

FLST.5,14,4,ORDE.14
FITEM.5,37
FITEM.5,255
FITEM.5,257
FITEM.5,259
FITEM.5,261
FITEM.5,263
FITEM.5,265
FITEM.5,267
FITEM.5,270
FITEM.5,271
FITEM.5,274
FITEM.5,301
FITEM.5,307
FITEM.5,319
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSEL_Y
LESIZE_Y1,...,4.1,
CMSEL_Y
CMDEL_Y  ! Inside Bolster (Top) (Rest of Bolsters)

FLST.5,4,4,ORDE.4
FITEM.5,2
FITEM.5,10
FITEM.5,130
FITEM.5,131
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSEL_Y
LESIZE_Y1,...,7.-5,
ILESIZE_Y1,...,10.-10.
CMSEL_Y  ! Div's Small Near Bolster Corners
CMDEL_Y  ! Larger in Center (inside Bolster Bottom)
CMDEL_Y1  ! (2nd Bolster)

FLST.5,28,4,ORDE.28
FITEM.5,218
FITEM.5,251
FITEM.5,-252
FITEM.5,254
FITEM.5,269
FITEM.5,305
FITEM.5,314
FITEM.5,320
FITEM.5,350
FITEM.5,362
FITEM.5,569
FITEM.5,648
FITEM.5,1141
FITEM.5,1151
FITEM.5,1157
FITEM.5,1168
FITEM.5,1174
FITEM.5,1180
FITEM.5,1192
FITEM.5,1197
FITEM.5,1203
FITEM.5,1209
FITEM.5,1218
FITEM.5,1227
FITEM.5,1233
FITEM.5,1374
FITEM.5,1376
FITEM.5,1383
CM_Y,LINE
LSEL,...,P51X
CMSEL_Y
LESIZE_Y1,...,7.-5,
ILESIZE_Y1,...,10.-10.
CMSEL_Y  ! Div's Small Near Bolster Corners
CMDEL_Y  ! Larger in Center (inside Bolster Bottom)
CMDEL_Y1  ! (Rest of Bolsters)

<table>
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<tr>
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<tbody>
<tr>
<td>Bolster Lines Between Two Stringers</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>

FLST.5,2,4,ORDE.2
FITEM.5,126
FITEM.5,137
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSEL_Y
LESIZE_Y1,...,7.1/3,
FLST, 5.2, 4, ORDE, 2
FITEM, 5, 140
FITEM, 5, 151
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 7, 1/3,
ILESIZE, Y, 10, 1/3,
CMDEL, Y
! Bolster Div's Inside Stringer (Top)
(1st Bolster)
CMDEL, Y
CMDEL, Y
FLST, 5.4, 4, ORDE, 4
FITEM, 5, 316
FITEM, 5, 317
FITEM, 5, 323
FITEM, 5, 324
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 10, 1/3,
ILESIZE, Y, 10, 1/3,
CMDEL, Y
! Bolster Div's Inside Stringer (Top)
(2nd Bolster)
CMDEL, Y
CMDEL, Y
FLST, 5.1, 4, ORDE, 1
FITEM, 5, 185
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 10, 1/3,
ILESIZE, Y, 10, 1/3,
CMDEL, Y
FLST, 5.6, 4, ORDE, 2
FITEM, 5, 1424
FITEM, 5, 1429
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 5, 1/3,
ILESIZE, Y, 5, 1/3,
CMDEL, Y
CMDEL, Y
FLST, 5.6, 4, ORDE, 6
FITEM, 5, 1413
FITEM, 5, 1414
FITEM, 5, 1416
FITEM, 5, 1417
FITEM, 5, 1421
FITEM, 5, 1422
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 5, 1,
ILESIZE, Y, 5, 1,
CMDEL, Y
CMDEL, Y
FLST, 5.4, 4, ORDE, 4
FITEM, 5, 241
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 10, 1/3,
ILESIZE, Y, 10, 1/3,
CMDEL, Y
CMDEL, Y
FLST, 5.2, 4, ORDE, 2
FITEM, 5, 260
FITEM, 5, 592
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 8, 3/1,
ILESIZE, Y, 8, 3/1,
CMDEL, Y
CMDEL, Y
FLST, 5.2, 4, ORDE, 2
FITEM, 5, 1196
FITEM, 5, 1200
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
ILESIZE, Y, 7, 3/1,
ILESIZE, Y, 10, 3/1,
CMDEL, Y
! Bolster Div's Inside Stringer (Bottom)
(1st Bolster)
CMDEL, Y
CMDEL, Y
FLST, 5.3, 4, ORDE, 3
FITEM, 5, 127
FITEM, 5, 148
FITEM, 5, 149
CM, Y, LINE
LSEL, ..., P51X
CM, Y, LINE
CMSEL, Y
CMSEL, S, Y
GET, 21, LINE, COUNT
SET, _20
* GET, _23, LINE, _22, ATTR, NDIV
IF:_23, NE, 0, THEN
LESIZE, _22, ..., _23, 1/2
ENDIF
ENDIF
ENDDO
CMSEL, S, Y
CMDELE, Y
FLST, 5.4, 4, ORDE, 4
FITEM, 5, 135
FITEM, 5, 136
FITEM, 5, 142
FITEM, 5, 143
CM, Y, LINE
LSEL, . . . PS1X
CM_Y1_LINE
CMSEL_Y
LESIZE_Y1, . . . 7.3/1,
-I-LESIZE_Y1, . . . 10.3/1,
! Bolster Div's Inside Stringer (Bottom)
CMDEL_Y ! (2nd Bolster)
CMDEL_Y

FLST.5.8.4.ORD.8
FITEM.5.295
FITEM.5.304
FITEM.5.309
FITEM.5.356
FITEM.5.1369
FITEM.5.1371
FITEM.5.1385
FITEM.5.1387
CM_Y1.LINE
LSEL, . . . PS1X
*GET_.z1.LINE_.COUNT
*SET_.z2.0
*DO_.z5.1_.z1
*SET_.z2.LSNEXT(.z2)
*GET_.z3.LINE_.z2.ATTR.NDIV
*GET_.z4.LINE_.z2.ATTR.SPAC
*IF_.z3.GT.0.THEN
*IF_.z4.NE.0.THEN
LESIZE_.z2,.z3.1/.z4
*ENDIF
*ENDIF
*ENDDO
CMSEL.S_Y1
CMDELE_Y1

FLST.5.1.4.ORD.1
FITEM.5.1232
CM_Y.LINE
LSEL, . . . PS1X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1, . . . 10.1/3,
-I-LESIZE_Y1, . . . 15.1/3,
CMDEL_Y
CMDEL_Y1

FLST.5.13.4.ORD.13
FITEM.5.205
FITEM.5.1408
FITEM.5.1409
FITEM.5.1419
FITEM.5.1420
FITEM.5.1430
FITEM.5.1431
FITEM.5.1436
FITEM.5.1437
FITEM.5.1442
FITEM.5.1443
FITEM.5.1452
FITEM.5.1457
CM_Y.LINE
LSEL, . . . PS1X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1, . . . 4.2,
-I-LESIZE_Y1, . . . 7.2,
CMDEL_Y
CMDEL_Y1

FLST.5.2.4.ORD.2
FITEM.5.1419
FITEM.5.1420
CM_Y1.LINE
LSEL, . . . PS1X
*GET_.z1.LINE_.COUNT
*SET_.z2.0
*DO_.z5.1_.z1
*SET_.z2.LSNEXT(.z2)
*GET_.z3.LINE_.z2.ATTR.NDIV
*GET_.z4.LINE_.z2.ATTR.SPAC
*IF_.z3.GT.0.THEN
*IF_.z4.NE.0.THEN
LESIZE_.z2,.z3.1/.z4
*ENDIF
*ENDIF
*ENDDO
CMSEL.S_Y1
CMDELE_Y1

FLST.5.13.4.ORD.13
FITEM.5.191
FITEM.5.686
FITEM.5.700
FITEM.5.1410
FITEM.5.1411
FITEM.5.1433
FITEM.5.1434
FITEM.5.1439
FITEM.5.1440
FITEM.5.1445
FITEM.5.1446
FITEM.5.1450
FITEM.5.1455
CM_Y.LINE
LSEL, . . . PS1X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1, . . . 6.2,
-I-LESIZE_Y1, . . . 8.2,
CMDEL_Y
CMDEL_Y1
FLST,5,9,4,ORDE,9
FITEM,5,191
FITEM,5,1433
FITEM,5,1434
FITEM,5,1439
FITEM,5,1440
FITEM,5,1445
FITEM,5,1446
FITEM,5,1450
FITEM,5,1455
CM_Y1,L1NE
LSEL,.,P51X
*GET_,z1,L1NE.,COUNT
*SET_,z2,0
*DO_,z5,1,1,2
*SET_,z2,LSNEX T(_z2)
*GET_.,z3,L1NE.,_z2,ATTR.NDIV
*GET_.,z4,L1NE.,_z2,ATTR.SPAC
*IF_.,z3,GT,0,THEN
*IF_.,z4,NE,0,THEN
LESIZE_,_z2,.,_z3,1/4
*ENDIF
*ENDDO
CMSEL,,Y1
CMDEL,,Y1
FLST,5,3,4,ORDE,13
FITEM,5,191
FITEM,5,686
FITEM,5,700
FITEM,5,1410
FITEM,5,1411
FITEM,5,1433
FITEM,5,1434
FITEM,5,1439
FITEM,5,1440
FITEM,5,1445
FITEM,5,1446
FITEM,5,1450
FITEM,5,1455
CM_Y1,L1NE
LSEL,.,P51X
CM_Y1,L1NE
CMSEL,,Y
LESIZE,,Y1,.,6,2
IELSEIZE,,Y1,.,8,2
CMDEL,,Y
CMDEL,,Y1
FLST,5,3,4,ORDE,9
FITEM,5,191
FITEM,5,1433
FITEM,5,1434
FITEM,5,1439
FITEM,5,1440
FITEM,5,1445
FITEM,5,1446
FITEM,5,1450
FITEM,5,1455
CM_Y1,L1NE
LSEL,.,P51X
*GET_,z1,L1NE.,COUNT
*SET_,z2,0
*DO_,z5,1,1,2
*SET_,z2,LSNEXT(_z2)
*GET_.,z3,L1NE.,_z2,ATTR.NDIV
*GET_.,z4,L1NE.,_z2,ATTR.SPAC
*IF_.,z3,GT,0,THEN
*IF_.,z4,NE,0,THEN
LESIZE_,_z2,.,_z3,1/4
*ENDIF
*ENDDO
CMSEL,,Y1
CMDEL,,Y1
FLST,5,4,4,ORDE,4
FITEM,5,1136
FITEM,5,1142
FITEM,5,1154
FITEM,5,1177
CM_Y1,L1NE
LSEL,.,P51X
CM_Y1,L1NE
CMSEL,,Y
LESIZE,,Y1,.,10,1,3
IELSEIZE,,Y1,.,15,1,3
CMDEL,,Y
CMDEL,,Y1
FLST,5,2,4,ORDE,2
FITEM,5,1154
FITEM,5,1177
CM_Y1,L1NE
LSEL,.,P51X
CM_Y1,L1NE
CMSEL,,Y
LESIZE,,Y1,.,11,1,1
IELSEIZE,,Y1,.,13,1,1
CMDEL,,Y
CMDEL,,Y1
FLST,5,2,4,ORDE,2
FITEM,5,1481
FITEM,5,1482
CM_Y1,L1NE
LSEL,.,P51X
CM_Y1,L1NE
CMSEL,,Y
LESIZE,,Y1,.,8,3
IELSEIZE,,Y1,.,13,3
CMDEL,,Y

! Bolster Div's Inside Stringer (Bottom)
CMDEL,,Y1 ! (Forward Bolsters)

==================================================================================================

! Bolster Lines Outside of Stringers
==================================================================================================

FLST,5,3,4,ORDE,3
FITEM,5,164
FITEM,5,169
FITEM,5,370
CM_Y1,L1NE
LSEL,.,P51X
CM_Y1,L1NE
CMSEL_1_Y  
LESIZE_1_Y1, .15,1/2,  ! Div's Bottom of Bolster
CMDEL_1_Y  
CMDEL_1_Y1  
FLST,5,4,4,ORDE,4  
FITEM,5,569  
FITEM,5,1143  
FITEM,5,1146  
FITEM,5,1160  
CM_1_LINE  
LSEL, ., P51X  
CM_1_LINE  
CMSEL_1_Y  
FLST,5,4,4,ORDE,4  
FITEM,5,368  
FITEM,5,369  
FITEM,5,327  
FITEM,5,1335  
CM_1_LINE  
LSEL, ., P51X  
CM_1_LINE  
CMSEL_1_Y  
LESIZE_1_Y1, .20,1/5,  ! Div's Bottom of Bolster
ILESIZE_1_Y1, .30,1/5,  ! 2nd Bolster
CMDEL_1_Y  
CMDEL_1_Y1  
FLST,5,20,4,ORDE,20  
FITEM,5,258  
FITEM,5,262  
FITEM,5,318  
FITEM,5,345  
FITEM,5,346  
FITEM,5,356  
FITEM,5,363  
FITEM,5,587  
FITEM,5,595  
FITEM,5,621  
FITEM,5,649  
FITEM,5,1143  
FITEM,5,1146  
FITEM,5,1160  
FITEM,5,1220  
FITEM,5,1221  
FITEM,5,1236  
FITEM,5,1377  
FITEM,5,1580  
FITEM,5,1584  
CM_1_LINE  
LSEL, ., P51X  
CM_1_LINE  
CMSEL_1_Y  
LESIZE_1_Y1, .30,1/5,  ! Div's Bottom of Bolster
ILESIZE_1_Y1, .35,1/5,  ! Except Hoist Bolsters
CMDEL_1_Y  
CMDEL_1_Y1  
FLST,5,2,4,ORDE,2  
FITEM,5,250  
FITEM,5,262  
CM_1_LINE  
LSEL, ., P51X  
*GET, _21,L1INE, COUNT  
*SET, _22,0  
*DO, _25,1, _21  
*SET, _22,LSNEXT(_22)  
*GET, _23,L1INE, _22,ATTR,NDIV  
*GET, _24,L1INE, _22,ATTR,SPAC  
*IF, _23,GT,0,THEN  
*IF, _24,NE,0,THEN  
LESIZE_22, _23,1/, _24  
*ENDIF  
*ENDIF  
*ENDDO  
CMSEL_S_Y1  
CMDELE_Y1  
FLST,5,8,4,ORDE,8  
FITEM,5,264  
FITEM,5,266  
FITEM,5,1164  
FITEM,5,1170  
FITEM,5,1181  
FITEM,5,1183  
FITEM,5,1193  
FITEM,5,1206  
CM_1_LINE  
LSEL, ., P51X  
CM_1_LINE  
CMSEL_1_Y  
LESIZE_1_Y1, .5,1,  
ILESIZE_1_Y1, .5,1,  ! Bolster Segment Between Hoist Pivot / Str
CMDEL_1_Y  
CMDEL_1_Y1  
FLST,5,8,4,ORDE,8  
FITEM,5,593  
FITEM,5,600  
FITEM,5,608  
FITEM,5,646  
FITEM,5,1163  
FITEM,5,1166  
FITEM,5,1167  
FITEM,5,1208  
CM_1_LINE  
LSEL, ., P51X  
CM_1_LINE  
CMSEL_1_Y  
LESIZE_1_Y1, .5,1,  
ILESIZE_1_Y1, .5,1,  ! Bolster Segment Inside Hoist Pivot
CMDEL_1_Y  
CMDEL_1_Y1  
FLST,5,5,4,ORDE,8  
FITEM,5,605  
FITEM,5,634  
FITEM,5,1140  
FITEM,5,1158  
FITEM,5,1185  
FITEM,5,1188  
FITEM,5,1194  
FITEM,5,1212  
CM_1_LINE  
LSEL, ., P51X  
CM_1_LINE  
CMSEL_1_Y  
LESIZE_1_Y1, .30-5-6,1/5,  
ILESIZE_1_Y1, .35-12,1/5,  ! Bolster Lines Outside Hoist Pivot
CMDEL_1_Y  
CMDEL_1_Y1  
FLST,5,3,4,ORDE,3  
FITEM,5,1185  
FITEM,5,1186  
FITEM,5,1194  
CM_1_LINE  
LSEL, ., P51X  
*GET, _21,L1INE, COUNT
SMRTSIZE,1 ! Fine Mesh Setting

MSHKEY,0
FLST,5,15,5,ORDE,15
FITEM,5,29
FITEM,5,46
FITEM,5,51
FITEM,5,-52
FITEM,5,54
FITEM,5,-57
FITEM,5,64
FITEM,5,66
FITEM,5,139
FITEM,5,-140
FITEM,5,146
FITEM,5,-149
FITEM,5,154
FITEM,5,165
FITEM,5,659
CM,_Y,AREA
ASEL,,P51X
CM,_Y1,AREA
CHKMSH,AREA'
CMSEL,S,_Y
AMESH,Y1
CMDEL,Y
CMDEL,Y1
CMDEL,Y2

!--------------------------------------------------
!----------- All Bolster Areas incl. Inside Stringer
!--------------------------------------------------

SMRTSIZE,6 ! Mesh Setting

MSHKEY,0 ! Rear Bolster (Angle)
FLST,5,14,5,ORDE,14
FITEM,5,1
FITEM,5,5
FITEM,5,7
FITEM,5,48
FITEM,5,-49
FITEM,5,65
FITEM,5,112
FITEM,5,203
FITEM,5,562
FITEM,5,630
FITEM,5,660
FITEM,5,666
FITEM,5,677
FITEM,5,678
FITEM,5,5
CM,_Y,AREA
ASEL,,P51X
CM,_Y1,AREA
CHKMSH,AREA'
CMSEL,S,_Y
AMESH,Y1
CMDEL,Y
CMDEL,Y1
CMDEL,Y2

!-----------------------------------------------
!----------- Front Stringer Structure
!-----------------------------------------------

SMRTSIZE,3 ! Fine Mesh Setting

MSHKEY,0
FLST,5,57,5,ORDE,30
FITEM,5,14
FITEM,5,15
FITEM,5,37
FITEM,5,39
FITEM,5,41
FITEM,5,43
FITEM,5,183
FITEM,5,342
FITEM,5,349
FITEM,5,586
FITEM,5,592
FITEM,5,-595
FITEM,5,612
FITEM,5,626
FITEM,5,628
FITEM,5,629
FITEM,5,631
FITEM,5,-644
FITEM,5,647
FITEM,5,651
FITEM,5,654
FITEM,5,658
FITEM,5,663
FITEM,5,664
FITEM,5,667
FITEM,5,668
FITEM,5,670
FITEM,5,675
FITEM,5,1000
FITEM,5,1031
CM,_Y,AREA

SMRTSIZE,1 ! 2nd Bolster from Back

MSHKEY,0
FLST,5,17,5,ORDE,16
FITEM,5,2
FITEM,5,4
FITEM,5,47
FITEM,5,50
FITEM,5,58
FITEM,5,60
FITEM,5,63
FITEM,5,68
FITEM,5,-70
FITEM,5,199
FITEM,5,251
FITEM,5,-252
FITEM,5,533
FITEM,5,627
FITEM,5,689
FITEM,5,661
FITEM,5,663
CM,_Y,AREA
ASEL,,P51X
CM,_Y1,AREA
CHKMSH,AREA'
CMSEL,S,_Y
AMESH,Y1
CMDEL,Y
CMDEL,Y1
CMDEL,Y2
MSHKEY,0
FLST,5,22,5,ORDE,19
FITEM,5,8
FITEM,5,-10
FITEM,5,12
FITEM,5,-13
FITEM,5,21
FITEM,5,-25
FITEM,5,27
FITEM,5,-28
FITEM,5,117
FITEM,5,119
FITEM,5,-120
FITEM,5,123
FITEM,5,-124
FITEM,5,127
FITEM,5,128
FITEM,5,130
FITEM,5,132
FITEM,5,134
FITEM,5,-136
CM,_Y,AREA
ASEL,,.,P51X
CM,_Y1,AREA
CHKMSH,'AREA'
CMSEL,S,_Y
AMESH_Y1
CMDEL_Y
CMDEL_Y1
CMDEL_Y2
CMDEL_Y1
CMDEL_Y2

| 6th Bolster |
| 7th Bolster |

MSHKEY,0
FLST,5,20,5,ORDE,16
FITEM,5,72
FITEM,5,73
FITEM,5,75
FITEM,5,-77
FITEM,5,102
FITEM,5,255
FITEM,5,570
FITEM,5,585
FITEM,5,587
FITEM,5,-991
FITEM,5,706
FITEM,5,-707
FITEM,5,714
FITEM,5,-715
FITEM,5,723
FITEM,5,-729
CM,_Y,AREA
ASEL,,.,P51X
CM,_Y1,AREA
CHKMSH,'AREA'
CMSEL,S,_Y
AMESH_Y1
CMDEL_Y
CMDEL_Y1
CMDEL_Y2
CMSEL_Y
CMSEL_Y1
CMSEL_Y2
CMDEL_Y
CMDEL_Y1
CMDEL_Y2

| 5th Bolster |
| 6th Bolster |

MSHKEY,0
FLST,5,22,5,ORDE,20
FITEM,5,78
FITEM,5,79
FITEM,5,81
FITEM,5,-82
FITEM,5,105
FITEM,5,256
FITEM,5,281
FITEM,5,313
FITEM,5,316
FITEM,5,567
FITEM,5,579
FITEM,5,581
FITEM,5,583
FITEM,5,-584
FITEM,5,708
FITEM,5,-710
FITEM,5,716
FITEM,5,-717
FITEM,5,725
FITEM,5,-727
CM,_Y,AREA
ASEL,,.,P51X
CM,_Y1,AREA
CHKMSH,'AREA'
CMSEL,S,_Y
AMESH_Y1
CMDEL_Y
CMDEL_Y1
CMDEL_Y2

| 7th Bolster |

MSHKEY,0
FLST,5,4,4,ORDE,3
FITEM,5,603
FITEM,5,1464
FITEM,5,-1466
CM,_Y,LINE
ASEL,,.,P51X
CM,_Y1,LINE
CMSEL_Y
CMSEL_Y1
CMSEL_Y2
CMSEL_Y
CMSEL_Y1
CMSEL_Y2

| 4.1, |

183
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
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<tbody>
<tr>
<td>CMDEL_ Y</td>
<td>Mesh Delimiting</td>
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<tr>
<td>CMDEL_ Y1</td>
<td>Mesh Delimiting</td>
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<td>MSHKEY,0</td>
<td>Mesh Key 0</td>
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<tr>
<td>FLST,5,30,5,ORDE,26</td>
<td>Front (9th) Bolster</td>
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<tr>
<td>FITEM,5,74</td>
<td>CM_ Y, AREA</td>
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<td>FITEM,5,80</td>
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<td>FITEM,5,86</td>
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<tr>
<td>FITEM,5,88</td>
<td>CMSEL_S, Y</td>
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<td>FITEM,5,93</td>
<td>AMESH_ Y1</td>
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<tr>
<td>FITEM,5,111</td>
<td>CMDEL_ Y</td>
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<td>FITEM,5,113</td>
<td>CMDEL_ Y1</td>
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<td>FITEM,5,161</td>
<td>CM_ Y, AREA</td>
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<tr>
<td>FITEM,5,258</td>
<td>ASEL, ..., 197</td>
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<td>FITEM,5,261</td>
<td>CM_ Y1, AREA</td>
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<td>FITEM,5,266</td>
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<td>FITEM,5,278</td>
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<td>FITEM,5,721</td>
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<td>FITEM,5,733</td>
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<td>CM_ Y, AREA</td>
<td>ASEL, ..., 163</td>
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<tr>
<td>ASEL ... P51X</td>
<td>CM_ Y1, AREA</td>
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<tr>
<td>CM_ Y1, AREA</td>
<td>CHKMSH, AREA’</td>
</tr>
<tr>
<td>CHKMSH, AREA’</td>
<td>CMSEL_S, Y</td>
</tr>
<tr>
<td>AMESH_ Y1</td>
<td>CMDEL_ Y</td>
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<tr>
<td>CMDEL_ Y</td>
<td>CMDEL_ Y1</td>
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<tr>
<td>CMDEL_ Y2</td>
<td>! 8th Bolster</td>
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<td>FLST,5,18,5,ORDE,13</td>
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<td>FITEM,5,162</td>
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<td>FITEM,5,189</td>
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<td>FITEM,5,201</td>
<td>ASEL, ..., 166</td>
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<td>FITEM,5,239</td>
<td>CM_ Y1, AREA</td>
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<td>FITEM,5,551</td>
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<tr>
<td>FITEM,5,552</td>
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<td>CMDEL_ Y</td>
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<td>CM_ Y, AREA</td>
<td>CMDEL_ Y2</td>
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<td>ASEL ... P51X</td>
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<td>CM_ Y1, AREA</td>
<td>ASEL, ..., 225</td>
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<td>CHKMSH, AREA’</td>
<td>CM_ Y1, AREA</td>
</tr>
<tr>
<td>CMSEL_S, Y</td>
<td>CHKMSH, AREA’</td>
</tr>
<tr>
<td>AMESH_ Y1</td>
<td>CMSEL_S, Y</td>
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<td>CMDEL_ Y</td>
<td>CMDEL_ Y1</td>
</tr>
<tr>
<td>CMDEL_ Y2</td>
<td>! 9th Bolster</td>
</tr>
</tbody>
</table>

* ! Sizing lines in Exhais Hole (8th bolster)

* ! Mesh Setting

* ! Wall Corner Section

* ! Exhaust Hole Regions

* ! Triangular Mesh on

-----
FLST,5,95,5,ORDE,36
FITEM,5,6
FITEM,5,16
FITEM,5,20
FITEM,5,32
FITEM,5,38
FITEM,5,61
FITEM,5,90
FITEM,5,52
FITEM,5,94
FITEM,5,145
FITEM,5,158
FITEM,5,160
FITEM,5,163
FITEM,5,164
FITEM,5,166
FITEM,5,182
FITEM,5,184
FITEM,5,186
FITEM,5,190
FITEM,5,192
FITEM,5,195
FITEM,5,198
FITEM,5,200
FITEM,5,202
FITEM,5,205
FITEM,5,238
FITEM,5,240
FITEM,5,250
FITEM,5,296
FITEM,5,305
FITEM,5,308
FITEM,5,334
FITEM,5,335
FITEM,5,376
FITEM,5,378
CM_Y,AREA
ASEL,,PS1X
CM_Y1,AREA
CHKMSH,'AREA'
CMSEL_S_Y
AMESH_Y2
CMDEL_Y
CMDEL_Y1
CMDEL_Y2 ! Quad Mesh on Rest of Corner Areas

----------------------------------------------- Canopy Support Beam
-----------------------------------------------
SMRTSIZE,6 ! Mesh Setting
FLST,5,34,5,ORDE,22
FITEM,5,325
FITEM,5,327
FITEM,5,340
FITEM,5,344
FITEM,5,351
FITEM,5,358
FITEM,5,358
FITEM,5,371
FITEM,5,398
FITEM,5,408
FITEM,5,426
FITEM,5,428
FITEM,5,430
FITEM,5,432
FITEM,5,434
FITEM,5,441
FITEM,5,-443
FITEM,5,496
FITEM,5,498
FITEM,5,-510
FITEM,5,513
FITEM,5,-514
CM_Y,AREA
ASEL,,PS1X
CM_Y1,AREA
CHKMSH,'AREA'
CMSEL_S_Y
AMESH_Y1
CMDEL_Y
CMDEL_Y1
CMDEL_Y2 ! Meshing Box Beam

FLST,5,8,4,ORDE,8
FITEM,5,732
FITEM,5,1042
FITEM,5,1068
FITEM,5,1073
FITEM,5,1075
FITEM,5,1077
FITEM,5,1079
FITEM,5,1081
CM_Y,LINE
LSEL,,PS1X
CM_Y1,LINE
CMSEL_Y
CMSEL_Y1
CMDEL_Y
CMDEL_Y1 ! 10 Divs on Fillet Lines

FLST,5,4,5,ORDE,4
FITEM,5,463
FITEM,5,511
FITEM,5,512
FITEM,5,515
CM_Y,AREA
ASEL,,PS1X
CM_Y1,AREA
CHKMSH,'AREA'
CMSEL_S_Y
AMESH_Y2
CMSEL_S_Y
AMESH_Y1
CMDEL_Y
CMDEL_Y1 ! Meshing Rounded Fillet Areas
CMDEL_Y2

IUI,MESH,OFF
FLST,5,8,5,ORDE,8
FITEM,5,336
FITEM,5,348
FITEM,5,355
FITEM,5,362
FITEM,5,451
FITEM,5,458
FITEM,5,464
FITEM,5,470
CM_Y,AREA
ASEL,,PS1X
CM_Y1,AREA
CHKMSH,'AREA'
CMSEL_S_Y
AMESH_Y1
CMSEL_S_Y
AMESH_Y1
CMDEL_Y
CMDEL_Y1 ! Meshing Fillet Side Areas
CMDEL_Y2

IUI,MESH,OFF
FLST,5,57,5,ORDE,40
FITEM.5.289
FITEM.5.291
FITEM.5.326
FITEM.5.329
FITEM.5.336
FITEM.5.344
FITEM.5.348
FITEM.5.351
FITEM.5.355
FITEM.5.358
FITEM.5.362
FITEM.5.368
FITEM.5.371
FITEM.5.375
FITEM.5.398
FITEM.5.408
FITEM.5.426
FITEM.5.429
FITEM.5.430
FITEM.5.432
FITEM.5.434
FITEM.5.441
FITEM.5.444
FITEM.5.451
FITEM.5.453
FITEM.5.457
FITEM.5.460
FITEM.5.464
FITEM.5.467
FITEM.5.470
FITEM.5.473
FITEM.5.474
FITEM.5.476
FITEM.5.498
FITEM.5.515
FITEM.5.517
FITEM.5.519
FITEM.5.521
FITEM.5.524
CM_.Y_AREA
ASEL_..P51X
CM_..Y1_AREA
CHKMSH,'AREA'
CMSEL_s.Y
AMESH_y2
CMDEL_y
CMDEL_y1
CMDEL_y2

---------------------------------------------
Front/Floor Corner

-------------------

SMRTSIZE,6       ! Mesh Setting
MSHKEY,0
FLST,5.405,ORDE,34
FITEM,5.15
FITEM,5.17
FITEM,5.31
FITEM,5.183
FITEM,5.184
FITEM,5.334
FITEM,5.335
FITEM,5.337
FITEM,5.338
FITEM,5.342
FITEM,5.343
FITEM,5.345
FITEM,5.349
FITEM,5.350
FITEM,5.352
FITEM,5.356
FITEM,5.357
FITEM,5.359
FITEM,5.363
FITEM,5.365
FITEM,5.370
FITEM,5.376
FITEM,5.380
FITEM,5.382
FITEM,5.383
FITEM,5.385
FITEM,5.386
FITEM,5.389
FITEM,5.393
FITEM,5.394
FITEM,5.514
FITEM,5.533
FITEM,5.586
FITEM,5.592
FITEM,5.594
CM_.Y_AREA
ASEL_..P51X
CM_..Y1_AREA
CHKMSH,'AREA'
CMSEL_s.Y
AMESH_y2
CMDEL_y
CMDEL_y1
CMDEL_y2

---------------------------------------------

SMRTSIZE,10      ! Mesh Setting
FLST,5.355,ORDE,14
FITEM,5.399
FITEM,5.407
FITEM,5.410
FITEM,5.425
FITEM,5.427
FITEM,5.429
FITEM,5.431
FITEM,5.433
FITEM,5.435
FITEM,5.436
FITEM,5.445
FITEM,5.446
FITEM,5.454

---------------------------------------------
Eyebrow of Canopy

---------------------------------------------

SMRTSIZE,3       ! Mesh Setting
MSHKEY,0
Reversed Some Area Normals on Canopy

Reversed Some Area Normals Inside Box
! Reversed Normals on Bolsters

FLST,5,19.5,ORDE,19
FITEM,5,11
FITEM,5,51
FITEM,5,64
FITEM,5,137
FITEM,5,139
FITEM,5,149
FITEM,5,165
FITEM,5,549
FITEM,5,625
FITEM,5,631
FITEM,5,632
FITEM,5,636
FITEM,5,642
FITEM,5,651
FITEM,5,656
FITEM,5,658
FITEM,5,669
FITEM,5,672
FITEM,5,674
CM_Y,AREA
ASEL,,P51X
CM_Y,AREA
CMSEL,S_Y
CMDDEL_Y
AREVERSE_Y1.0
CMDDEL_Y
FLST,5,11.5,ORDE,9
FITEM,5,8
FITEM,5,21
FITEM,5,24
FITEM,5,26
FITEM,5,123
FITEM,5,125
FITEM,5,128
FITEM,5,130
FITEM,5,133
CM_Y,AREA
ASEL,,P51X
CM_Y,AREA
CMSEL,S_Y
CMDDEL_Y
AREVERSE_Y1.0
CMDDEL_Y
FLST,5,10.5,ORDE,8
FITEM,5,12
FITEM,5,-13
FITEM,5,18
FITEM,5,20
FITEM,5,27
FITEM,5,117
FITEM,5,120
FITEM,5,-122
CM_Y,AREA
ASEL,,P51X
CM_Y,AREA
CMSEL,S_Y
CMDDEL_Y
AREVERSE_Y1.0
CMDDEL_Y
FLST,5,12.5,ORDE,12
FITEM,5,4
FITEM,5,7
FITEM,5,48
FITEM,5,49
FITEM,5,58
FITEM,5,60
FITEM,5,68
CM_Y1_AREA
CMSELS_Y
CMDEL_Y
AREVERSE_Y1,0
CMDEL_Y!

! Reversed Some Normals on STR's

|-----------------------------------------------| Correction
|-----------------------------------------------|

! Removing STR Area and Elements from the Inside of
! small Boilers in the hinge pivot structure...

FLST,2.2.5,ORDE,2
FITEM,2,686
FITEM,2,-687
ACLEAR,P51X ! Clearing Meshed Areas

FLST,2.2.5,ORDE,2
FITEM,2,686
FITEM,2,-687
ADELE,P51X ! Deleting Areas only

FINISH
FINISH

*SET,nodes,ndmrg(0,12)
*SET,elems,elmrg(0,12)
*SET,sol_time,(((3e-8)*(nodes**2))+0.0006*nodes+0.022)/60

/EOF

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Filename: 4_3_FEA_support_INPUT

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<tr>
<td>*APUN,RAD</td>
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<tr>
<td>DOFSEL,S,UY</td>
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<tr>
<td>DCUM,ADD,1.0, ! Set DOF Accumulation to ADD</td>
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<td>DOFSEL,ALL</td>
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<tr>
<td>*SET, disp, (UYpin-UyNose)/(-3490-(-7730))</td>
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<td>! Slope of Uy along Z</td>
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<td>*SET, intercept, UyPin-disp, (-3490)</td>
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| ~~~~~~~~~~~~~~~~ Hinge Support Conditions ~~~~~~~~~~~~~~~~ |

*IF, hinge typ=EQ.1,THEN

| FLST, 5.4,4,ORDEN,4 |
| FITEM, 5,325 |
| FITEM, 5,330 |
| FITEM, 5,339 |
| FITEM, 5,342 |
| LSEL, S,1 |
| NSSL, S,1 |
| *GET, count, NODE, 0, COUNT |
| *GET, Nindex, NODE, 0, MIN |
| *DO, index=0, count+10,1 |
| /GOPER ! Resume Print to Output |
| *GET, Zloc, NODE, Nindex, LOC.Z |
| D, Nindex, UY (disp)* (Zloc* intercept) |
| *GET, Next NODE, Nindex, NXTH |
| *IF, Next=EQ.0,EXIT |
| *SET, Nindex, Next |
| /NOPER ! Suspend Print to Output |
| *ENDDO |

| ALLSEL,ALL ! Bearing Force on Top of Pin |
| FLST, 2,2,4,4,ORDEN,4 |
| FITEM, 2,325 |
| FITEM, 2,328 |
| FITEM, 2,339 |
| FITEM, 2,342 |
| IDL, P51X, UY, UyPin |

| ! Bearing Force on Top of Pin |
| FLST, 2,2,4,4,ORDEN,4 |
| FITEM, 2,325 |
| FITEM, 2,328 |
| FITEM, 2,339 |
| FITEM, 2,340 |
| DL, P51X, UZ |

| ! Preventing Forward Movement |

*ELSEIF, hinge typ=EQ.2,THEN

*IF, CE_DONE, NE, 1, THEN

| N, 70000, 601*(584-601)/2, -197*(-364+197)/2, -3490, |
| KNODE, 0, 70000 |

| TYPE, 1 |
| MAT, 1 |
| REAL, 9 |
| ESY, 0 |

| KC, 2050, 5, |
| KC, 2051, 5, |
| KC, 2052, 5, |
| FLST, 3,3,3,ORDEN,2 |
| FITEM, 3,1019 |
| FITEM, 3,1021 |
| NPKT, 0, P51X |
| FLST, 2,8,1 |
| FITEM, 2,17 |
| FITEM, 2,70000 |
| FITEM, 2,70001 |
| FITEM, 2,70002 |
| FITEM, 2,70003 |
| E, P51X |

| ! Creating Element In Hinge (for CERig) |

| FLST, 2,2,1, |
| FITEM, 2,70000 |
| FITEM, 2,17 |
| FITEM, 2,240 |
| FITEM, 2,241 |
| FITEM, 2,242 |
| FITEM, 2,243 |
| FITEM, 2,244 |
| FITEM, 2,245 |
| FITEM, 2,246 |
| FITEM, 2,247 |
| FITEM, 2,248 |
| FITEM, 2,249 |
| FITEM, 2,250 |
| FITEM, 2,251 |
| FITEM, 2,252 |
| FITEM, 2,253 |
| FITEM, 2,254 |
| FITEM, 2,255 |
| FITEM, 2,256 |
| FITEM, 2,257 |
| FITEM, 2,258 |
| FITEM, 2,18 |
| CERIG, P51X, ALL, , , ! Outside Top-Rear |

| FLST, 2,2,1, |
| FITEM, 2,70000 |
| FITEM, 2,17 |
| FITEM, 2,315 |
| FITEM, 2,314 |
| FITEM, 2,313 |
| FITEM, 2,312 |
| FITEM, 2,311 |
| FITEM, 2,310 |
| FITEM, 2,309 |
| FITEM, 2,308 |
*GET, Nindex, NODE, 0, NUM, MIN
*DO, Index, 0, count+10, 1
!GOPR ! Resume Print to Output
*GET, Zloc, NODE, Nindex, LOC, Z
D, Nindex, UY, (dispstrp*(Zloc)+Intercept)
*GET, Next, NODE, Nindex, NXTTH
IF, Next, EQ, 0, EXIT
*SET, Nindex, Next
*/NOPT! Suspend Print to Output

*ENDDO
ALLSEL, ALL
*ELSEIF, STRtype, EQ, 3, THEN
FINISH
*/PREP7

*IF, Rub_DONE, NE, 1, THEN
! Material #2
UIMP, 2, EX, , 207000/100,
! Modulus in N/mm^2
! 1/100th of Steel
UIMP, 2, DENS, , 0.00000786,
! Density in kg/mm^3
UIMP, 2, ALPX, ,
UIMP, 2, REFT, ,
UIMP, 2, NUXY, ,
UIMP, 2, PRXY, , .5, .3,
UIMP, 2, OXY, ,
UIMP, 2, MU, ,
UIMP, 2, DAMP, ,

MAT, 2
ET, 2, SOLID95
KEYOPT, 2, 5, 0
KEYOPT, 2, 6, 0
KEYOPT, 2, 11, 0
EXTOPT, ESIZE, 1, 1,
EXTOPT, AGCLEAR, 0,
FLST, 5, 32.5, ORDE, 2
FLST, 2, 1000
FLST, 2, 1030
DA, P51X, UY, MyNose
! Distributed STR Support
*SET, Rub_DONE, 1

*ENDIF

!-----------------------------------------------!
! Stringer (STR) Support Conditions             !
!-----------------------------------------------!

*IF, STRtype, EQ, 1, THEN
FLST, 2, 32.5, ORDE, 2
FITEM, 2, 1000
FITEM, 2, 1031
DAP, P51X, UY, MyNose
! Distributed STR Support
*ELSEIF, STRtype, EQ, 2, THEN
FLST, 5, 16.4, ORDE, 16
FITEM, 5, 2002
FITEM, 5, 2009
FITEM, 5, 2012
FITEM, 5, 2015
FITEM, 5, 2018
FITEM, 5, 2021
FITEM, 5, 2024
FITEM, 5, 2027
FITEM, 5, 2030
FITEM, 5, 2033
FITEM, 5, 2036
FITEM, 5, 2039
FITEM, 5, 2040
FITEM, 5, 2042
FITEM, 5, 2046
FITEM, 5, 2049
LSEL, S, P51X
! Selecting STR CenterLines
NSLL, S, 1 ! Selecting nodes attached to Lines
*GET, count, NODE, 0, COUNT

*ENDIF

!-----------------------------------------------!
! Cylindrical (CYL) Support Conditions          !
!-----------------------------------------------!

*IF, CYLtype, EQ, 1, THEN
FLST, 1, 32.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF

!-----------------------------------------------!
! Circular (CIR) Support Conditions             !
!-----------------------------------------------!

*IF, CIRtype, EQ, 1, THEN
FLST, 1, 24.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF

!-----------------------------------------------!
! Rectangular (REC) Support Conditions          !
!-----------------------------------------------!

*IF, RECtype, EQ, 1, THEN
FLST, 1, 32.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF

!-----------------------------------------------!
! Diamond (DM) Support Conditions               !
!-----------------------------------------------!

*IF, DMtype, EQ, 1, THEN
FLST, 1, 24.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF

!-----------------------------------------------!
! Trapezoidal (TRA) Support Conditions          !
!-----------------------------------------------!

*IF, TRAtype, EQ, 1, THEN
FLST, 1, 32.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF

!-----------------------------------------------!
! Triangular (TRI) Support Conditions           !
!-----------------------------------------------!

*IF, TRItype, EQ, 1, THEN
FLST, 1, 24.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF

!-----------------------------------------------!
! Trapezoidal (TRA) Support Conditions          !
!-----------------------------------------------!

*IF, TRAtype, EQ, 1, THEN
FLST, 1, 32.5, ORDE, 2
FITEM, 1, 1000
FITEM, 1, 1031
CERIG, P51X, ALL, , , ! Inside Bottom-Front
*SET, CE_DONE, 1

*ENDIF
*IF, Shim, EQ, 1, THEN
! Adding Shim Displacements
! Shim Values From Optimum Slope...
*SET, deltamax, 4.5
*SET, shimslope, deltamax/(7730-3490)
*SET, shimin, deltamax/7730(7730-3490)
*SET, shimin, 1.0, 3.24976415
*SET, shimin, 2.0, 974929245
*SET, shimin, 3.1, 62488208
*SET, shimin, 4.2, 2748349
*SET, shimin, 5.2, 92478774

! Trial Shim Values
*SET, Shim_1, 0.0
*SET, Shim_2, 1.5
*SET, Shim_3, 2.0
*SET, Shim_4, 2.5
*SET, Shim_5, 3.0

! Trial Shim Values
*SET, Shim_1, AmI_Shrm
*SET, Shim_2, AmI_Shrm
*SET, Shim_3, AmI_Shrm
*SET, Shim_4, AmI_Shrm
*SET, Shim_5, AmI_Shrm

! Shim Displacement Routine
*GET, count, NODE, 0, COUNT
*GET, Nindex, NODE, 0, NUM, MIN
*DO, i, NODE, 1, count
  *GET, Zloc, NODE, Nindex, LOC, Z
  D, Nindex, UY, (shimslope*(Zloc)+shin)
*ENDDO

*ENDIF

*END

! Guide Pin Conditions

! ~~~~~~~~~~~~~~~~~ Guide Pin Conditions

FLST, 2, 1, 5, ORDE, 1
ITEM, 2, 763
/GO
DA, P51X, UX, 0 I Ux=0 on Guide Pin

! ~~~~~~~~~~~~~~~~~ Nose Load Cell

! ~~~~~~~~~~~~~~ Start Making Load Cell #1

|FLST, 2, 2, 6, ORDE, 2
|ITEM, 2, 593
|ITEM, 2, 595
|ACLEAR, P51X
|FLST, 2, 2, 5, ORDE, 2
|ITEM, 2, 593
|ITEM, 2, 595
|ADELE, P51X, 1

! Clearing and Deleting Side Areas

KWPLAN, -1, 153, 154, 1023
wpoff, 0.0, -25.4*

! Using CP plane to Cut Nose...

|FLST, 2, 2, 6, ORDE, 2
|ITEM, 2, 1
|ITEM, 2, 1
|VCLEAR, P51X
|FLST, 2, 2, 5, ORDE, 2
|ITEM, 2, 2, 1000
|ITEM, 2, 1001
|ACLEAR, P51X
|ACLEAR, 3
|ACLEAR, 1002
|ACLEAR, 183
|VCLEAR, 4

! Clearing Mesh to Operate on Geom

VSBW, 1 I Cutting Volume

|FLST, 2, 2, 3, ORDE, 2
|ITEM, 3, 153
|ITEM, 3, 1075
|KGEN, 2, P51X, ., 25.4*, ., 0 I Copy KP's

|LSTR, 1075, 1080
|LSTR, 153, 1079
|LSTR, 1079, 1080 | Box End Lines
|LSTR, 1079, 616
|LSTR, 1080, 621
|FLST, 2, 4, 4
|ITEM, 2, 2202
|ITEM, 2, 2063
|ITEM, 2, 251
|ITEM, 2, 166
|AL, P51X
|FLST, 2, 4, 4
|ITEM, 2, 244
|ITEM, 2, 2202
|ITEM, 2, 2055
|ITEM, 2, 2203
|AL, P51X
|FLST, 2, 5, 4
|ITEM, 2, 2203
|ITEM, 2, 1149
|ITEM, 2, 2002
|ITEM, 2, 2198
|ITEM, 2, 192
|AL, P51X
|FLST, 2, 4, 4
|ITEM, 2, 2002
|ITEM, 2, 2055
FITEM,2,2053
FITEM,2,2190
AL,P51X

! Patching Up Areas

K, 0.440, 0.7731464844E+04,
K, 0.440, 0.7655253802E+04,
K, 0.363.8, 0.7731464844E+04,
K, 0.363.8, 0.7655253802E+04,

LSTR, 1083, 1084
LSTR, 1084, 1082
LSTR, 1082, 1081
LSTR, 1081, 1083
LSTR, 1083, 1079
LSTR, 1080, 1084
LSTR, 1082, 1075
LSTR, 1081, 1084

FLST,2,4,4
ITEM,2,2209
ITEM,2,2208
ITEM,2,2204
ITEM,2,2205
AL,P51X
FLST,2,4,4
ITEM,2,2211
ITEM,2,2053
ITEM,2,2207
ITEM,2,2208
AL,P51X
FLST,2,4,4
ITEM,2,2210
ITEM,2,2206
ITEM,2,2190
AL,P51X
FLST,2,4,4
ITEM,2,2209
ITEM,2,2210
ITEM,2,2208
ITEM,2,2202
AL,P51X

! Creating Square Pipe Areas

FLST,5,4,5,ORDE,4
ITEM,5,1000
ITEM,5,1033
ITEM,5,1034
ITEM,5,1036
CM,Y,AREA
ASEL,...,P51X
CM,Y1,AREA
CMSEL,...Y
CMSEL,Y1
CMDELE,Y
CMDELE,Y1

! STR Side Areas
AATT, 1, 19, 1, 0
CMSEL,...Y
CMDELE,Y
CMDELE,Y1
FLST,5,5,5,ORDE,4
ITEM,5,1001
ITEM,5,1002
ITEM,5,1149
ITEM,5,1154
CM,Y,AREA
ASEL,...,P51X
CM,Y1,AREA
CMSEL,...Y
CMSEL,Y1
CMDELE,Y
CMDELE,Y1

! STR Bottom Areas
AATT, 25, 1, 0
CMSEL,...Y
CMDELE,Y
CMDELE,Y1

R,2,1.875,...
FLST,5,4,5,ORDE,2
ITEM,5,1158
ITEM,5,1161
CM,Y,AREA
ASEL,...,P51X
CM,Y1,AREA
CMSEL,Y
CMSEL,Y1
! Pipe Thickness
AATT, 1, 2, 1, 0
CMSEL,...Y
CMDELE,Y
CMDELE,Y1

FLST,5,4,4,ORDE,4
ITEM,5,2002
ITEM,5,2053
ITEM,5,2095
ITEM,5,2190
CM,Y,LINE
LSEL,...,P51X
CM,Y1,LINE
CMSEL,...Y
LESIZE,...Y1,4.1
CMDELE,Y
CMDELE,Y1

! Pipe Size Commands
AATT, 1, 10, 1
CMSEL,Y
CMDELE,Y
CMDELE,Y1

APLOT

MSHKEY,0
FLST,5,9,5,ORDE,6
ITEM,5,183
ITEM,5,1000
ITEM,5,1002
ITEM,5,1033
ITEM,5,1034
ITEM,5,1036
ITEM,5,1149
ITEM,5,1154
CM,Y,AREA
ASEL,...,P51X
CM,Y1,AREA
CHKMESH,AREA
CMSEL,...Y
AMESH,...Y1
CMDELE,Y
CMDELE,Y1
CMDELE,Y
CMDELE,Y1

! Re-Meshing Cleared Areas
FLST,5,4,4,ORDE,2
ITEM,5,2204
ITEM,5,1207
CM,Y,LINE
LSEL,...,P51X
CM,Y1,LINE
CMSEL,...Y
LESIZE,...Y1,4.1
CMDELE,Y

196
CMDEL_Y1  MSHAPE,0
MSHKEY,0
FLST,5,4,5,ORDE,2
FITEM,5,1158
CM_Y,AREA
ASEL,...,P51X
CM_Y1,AREA
CHKMSH_AREA
CMSELS_Y
AMESH_Y
CMDEL_Y
CMDEL_Y1
CMDEL_Y2  ! Meshing Pipe Areas
EXTOPT,ESIZE,1,1,
EXTOPT_ACLEAR,0
VSWEEP,33,1149,1150
VSWEEP,2,1001,1038
VSWEEP,4,1003,1046
VSWEEP,3,1002,1042
VSWEEP,34,1154,1155
! Re-Meshing Volumes
-----------------------------
! Start Making Load Cell #2
-----------------------------
ACLEAR, 592  ! Clearing STR Area
FLST,3,4,4,ORDE,2
! Copying Load Cell End Lines
FITEM,3,2204
FITEM,3,2207
LGEN,2,P51X,...,365.8-25.4,-74.7,46196-25.4,0
FLST,3,1,3,ORDE,1
FITEM,3,1087
KGEN,2,P51X,...,800,...,0
LSTR, 1089, 1087
FLST,2,4,4,ORDE,2
FITEM,2,2212
FITEM,2,2215
ADRAG,P51X,...,2216
! Dragging Load Cell Areas
KWPLAN,-1, 145, 110, 616
ADELE, 1592, 11 1 ! Deleting STR Area
FLST,2,4,5,ORDE,2
FITEM,2,1162
FITEM,2,-1165
ASBW,P51X
! Cutting Load Cell with Work Plane
FLST,2,4,5,ORDE,2
FITEM,2,1170
FITEM,2,-1173
ADELE,P51X,...,1
LDELE, 2216, 1
! Deleting Ends of Load Cell
LSTR, 145, 1095
LSTR, 1094, 110
LSTR, 1097, 229
LSTR, 1096, 616
FLST,2,4,4
FITEM,2,2216
FITEM,2,2229
FITEM,2,1139
FITEM,2,2219
AL,P51X
FLST,2,4,4
FITEM,2,2227
FITEM,2,2229
FITEM,2,2235
FITEM,2,2218
FITEM,2,2232
AL,P51X
FLST,2,5,4
FITEM,2,781
FITEM,2,724
FITEM,2,2216
FITEM,2,2227
FITEM,2,2217
AL,P51X
FLST,2,4,4
FITEM,2,2221
FITEM,2,2227
FITEM,2,2229
FITEM,2,2232
AL,P51X
FLST,2,4,4
FITEM,2,2219
FITEM,2,2217
AL,P51X
FLST,5,5,5,ORDE,3
FITEM,5,1162
FITEM,5,-1155
FITEM,5,1170
CM_Y,AREA
ASEL,...,P51X
CM_Y1,AREA
CMSELS_Y
CMSELS_Y1
AMESH_Y
CMSELS_Y
CMSELS_Y1
AATT, 1, 19, 1, 0
CMSELS_Y
CMDELE_Y
CMDELE_Y1  ! STR Sidewall Thickness
FLST,5,4,5,ORDE,2
FITEM,5,1166
FITEM,5,-1159
CM_Y,AREA
ASEL,...,P51X
CM_Y1,AREA
CMSELS_Y
CMSELS_Y1
AMESH_Y
CMSELS_Y
CMDELE_Y
CMDELE_Y1
! Load Cell Thickness
FLST,5,4,4,ORDE,4
FITEM,5,2227
FITEM,5,2229
FITEM,5,2231
FITEM,5,-2232
CM_Y,LINE
LSEL,...,P51X
CM_Y1,LINE
CMSELS_Y
CMSELS_Y1
LSIZE,ALL,4,1,1
CMSELS_Y
CMDELE_Y
CMDELE, Y1
FLST, 2, 4, 5, ORDE, 2
FITEM, 2, 1166
FITEM, 2, -1169
ACLEAR, P51X
FLST, 5, 4, 4, ORDE, 4
FITEM, 5, 2225
FITEM, 5, -2226
FITEM, 5, 2226
FITEM, 5, 2230
CM, Y, LINE
LSEL, ..., P51X
CM, Y, AREA
CMSEL, ..., Y1
FITEM, 5, 2226
FITEM, 5, 2228
FITEM, 5, 2230
CM, Y, LINE
LSEL, ..., P51X
CM, Y, AREA
CMSEL, ..., Y1
FITEM, 5, 2226
FITEM, 5, 2228
FITEM, 5, 2230
CM, Y, AREA
ASEL, ..., P51X
CM, Y, AREA
CHKMESH, 'AREA'
CMSEL, ..., Y
AMESH, ..., Y1
CMDELE, Y1
CMDELE, Y2! LSize for Load Cell #2

MSHKEY, 0
FLST, 5, 4, 5, ORDE, 2
FITEM, 5, 1166
FITEM, 5, -1169
CM, Y, AREA
ASEL, ..., P51X
CM, Y, AREA
CHKMESH, 'AREA'
CMSEL, ..., Y
AMESH, ..., Y1
CMDELE, Y1
CMDELE, Y2! Meshing Load Cell Areas

MSHKEY, 0
FLST, 5, 4, 5, ORDE, 3
FITEM, 5, 1162
FITEM, 5, -1164
FITEM, 5, 1170
CM, Y, AREA
ASEL, ..., P51X
CM, Y, AREA
CHKMESH, 'AREA'
CMSEL, ..., Y
AMESH, ..., Y1
CMDELE, Y1
CMDELE, Y2! Re-Meshing STR Sidewall

IFLST, 2, 2, 5, ORDE, 2
FITEM, 2, 1161
FITEM, 2, 1167
ACLEAR, P51X
! Clearing Mesh on Load Cell Areas
! Making into Channel Sections...
! Very Low Torsional Stiffness...

!----------------------------------------
! Start Making Load Cell #3
!----------------------------------------

ACLEAR, 621
! Clearing and Deleting STR Area for 3rd LC
ADELE, 621...

FLST, 3, 4, 5, ORDE, 2
FITEM, 5, 2226
FITEM, 3, 1158
FlST, 3, 4, 5, ORDE, 2
FITEM, 3, 1158

FITEM, 3, 1161
AGEN, 2, P51X, ..., 15, 8, 46, 40, 0, 48, 44, 46, 1, 0

FLST, 2, 4, 5, ORDE, 2
FITEM, 2, 1171
FITEM, 2, -1174
ACLEAR, P51X
! Clearing FE Mesh on LC Areas

FLST, 3, 3, 8
FITEM, 3, 718, 9, 8199, 0, 107, -294, 6,-
6672, 40, 301, 1715
FITEM, 3, 724, 2, 79, 96, 329, -298, 2,-
6877, 43, 45, 793
FITEM, 3, 718, 8, 88, 99, 7991, -436, 6,-
6666, 80, 42, 184

WP, P, P51X
FLST, 2, 4, 5, ORDE, 2
FITEM, 2, 1171
FITEM, 2, -1174
ASBW, P51X
! Using WPlane to Cut LC Areas

FLST, 2, 4, 5, ORDE, 4
FITEM, 2, 1176
FITEM, 2, 1178
FITEM, 2, 1180
FITEM, 2, 1182
ADELE, P51X, ..., 1! Deleting End Areas

LSTR, 1104, 1102
LSTR, 1104, 634
LSTR, 1103, 48
LSTR, 635, 1102
FLST, 2, 4, 4
FITEM, 2, 2220
FITEM, 2, 2249
FITEM, 2, 2223
FITEM, 2, 1242
AL, P51X
FLST, 2, 4, 4
FITEM, 2, 1251
FITEM, 2, 2220
FITEM, 2, 2221
FITEM, 2, 2222
AL, P51X
FLST, 2, 4, 4
FITEM, 2, 2222
FITEM, 2, 2242
FITEM, 2, 2224
FITEM, 2, 1173
AL, P51X
FLST, 2, 4, 4
FITEM, 2, 2246
FITEM, 2, 2224
FITEM, 2, 1288
FITEM, 2, 2223
AL, P51X
FLST, 2, 4, 4
FITEM, 2, 2242
FITEM, 2, 2246
FITEM, 2, 2249
FITEM, 2, 2251
AL, P51X ! Re-creating STR side area

FLST, 5, 5, 5, ORDE, 3
FITEM, 5, 1171
FITEM, 5, -1174
FITEM, 5, 1176
CM, Y, AREA

198
ASEL, _P51X
CM_Y, AREA
CMSEL_S, Y
CMSEL_S, Y1
AATT, 1, 19, 1, 0
CMSEL_S, Y
CMDELE_Y
CMDELE_Y1
FLST, 5, 4, 5, ORDE, 4
FITEM, 5, 1175
FITEM, 5, 1177
FITEM, 5, 1179
FITEM, 5, 1181
CM_Y, AREA
ASEL, _P51X
CM_Y1, AREA
CMSEL_S, Y
CMSEL_S, Y1
AATT, 1, 2, 1, 0
CMSEL_S, Y
CMDELE_Y
CMDELE_Y1 ! STR and LC Thicknesses...
FLST, 5, 4, 4, ORDE, 4
FITEM, 5, 2240
FITEM, 5, 2241
FITEM, 5, 2245
FITEM, 5, 2248
CM_Y, LINE
LSEL, _P51X
CM_Y1, LINE
CMSEL_Y
LESIZE_Y1, .10, 1
CMDELE_Y
CMDELE_Y1
FLST, 5, 4, 4, ORDE, 4
FITEM, 5, 2242
FITEM, 5, 2246
FITEM, 5, 2249
FITEM, 5, 2251
CM_Y, LINE
LSEL, _P51X
CM_Y1, LINE
CMSEL_S, Y1
LESIZE_ALL, 4, 1, 1
CMSEL_S, Y
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing Side Areas
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing Side Areas
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing Side Areas
FLST, 5, 1, 4, ORDE, 1
FITEM, 5, 2224
CM_Y, LINE
LSEL, _P51X
CM_Y1, LINE
CMSEL_Y
LESIZE_Y1, .4, 1
CMDELE_Y
CMDELE_Y1
MSHKEY, 0
ASEL, _P51X
CM_Y, AREA
ASEL, _P51X
CM_Y1, AREA
CHMKMSH_AREA:
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing STR Side Areas
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y:
CMDELE_Y2 ! Meshing STR Side Areas
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing STR Side Areas
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing STR Side Areas
CMSEL_S, Y
AMESH_Y1
CMDELE_Y
CMDELE_Y1
CMDELE_Y2 ! Meshing STR Side Areas
FLST, 3, 4, 5, ORDE, 4
FITEM, 3, 1175
FITEM, 3, 1177
FITEM, 3, 1179
FITEM, 3, 1181
AGEN, 2, P51X, .40, 3699, 8, 0
FLST, 2, 4, 5, ORDE, 4
FITEM, 2, 1178
FITEM, 2, 1180
FITEM, 2, 1182
FITEM, 2, 1183
ACLEAR, 681 ! Clearing Meshed Areas
ADELE, 681, 1 ! Deleting Pivot Area
KWPLAN, 1, 24, 201, 209
FLST, 2, 4, 5, ORDE, 4
FITEM, 2, 1176
FITEM, 2, 1180
FITEM, 2, 1182
FITEM, 2, 1183
ASBW, P51X
! Using WPlane to Cut LC Areas
FLST, 2, 4, 5, ORDE, 4
FITEM, 2, 1185
FITEM, 2, 1187
FITEM, 2, 1189
FITEM, 2, 1191
ADELE, P51X, .1 ! Deleting End Areas
LSTR, 1100, 206
LSTR, 24, 20
LSTR, 24, 1111
199
IR & Measuring Pivot Area

! Re-creating Pivot STR Areas

FLST, 5, 4, 5, ORDE, 4
FITEM, 5, 1178
FITEM, 5, 1180
FITEM, 5, 1182
FITEM, 5, 1184
CM, Y, AREA
ASEL, ..., P51X
CM, Y, AREA
CMSELS, _Y
CMSELS, _Y
AATT, 1, 63, 1, 0
CMSEL, _Y
CMDELE, _Y
CMDELE, Y1
FLST, 5, 4, 5, ORDE, 4
FITEM, 5, 1186
FITEM, 5, 1188
FITEM, 5, 1190
CM, Y, AREA
ASEL, ..., P51X
CM, Y, AREA
CMSELS, _Y
CMSELS, _Y
AATT, 1, 2, 1, 0
CMSEL, _Y
CMDELE, _Y
CMDELE, Y1
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
AATT, 1, 2, 1, 0
CMSEL, _Y
CMDELE, _Y
CMDELE, Y1
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
AATT, 1, 2, 1, 0
CMSEL, _Y
CMDELE, _Y
CMDELE, Y1
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
AATT, 1, 2, 1, 0
CMSEL, _Y
CMDELE, _Y
CMDELE, Y1
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
CMSELS, _Y
FITEM, 5, 2256
FITEM, 5, 2257
FITEM, 5, 2261
FITEM, 5, 2264
CM, Y, LINE
FILE: 4_4_FEA_load_algorithm_INPUT

FEA of 930E Track Box Structure
Oilsand Pressure Load Algorithm

FINISH

/TITLE,Oilsand Load Application Algorithm

*SET,Ka,0.5     ! Rankine Active Pressure Coefficient
*SET,tons,308.5 ! Payload (Short Tons)
*SET,density,1.6 ! Density (Metric tonnes / m^3)
*SET,G,9.81     ! Gravity (9.81 m/sec^2)
*SET,XPeak,0     ! X Location of Peak
*SET,ZPeak,2450 ! Z Location of Peak
*SET,mass,0.9071847*tons    ! Mass (Metric Tonnes)
*SET,rho,1000*density   ! Density (kg/m^3)

/REP7
ALLSEL,ALL
SFADELE,ALL,1,ALL
SFADELE,ALL,2,ALL
SFADELE,ALL,3,ALL
SFADELE,ALL,4,ALL
SFADELE,ALL,5,ALL
SFADELE,ALL,6,ALL ! Clearing All Pressures

*AFUN,DEG
LOCAL,99,0,0,0,-8105,0,9,0 ! Rotated Co-ordinate System
CSYS,99 ! Changing Active CS to Rotated CS

SFGRAD,PRES, X, .. ! Making Sure NO Pressure Gradients
SFGRAD,PRES, Y, ..
SFGRAD,PRES, Z, ..

FINISH

*DIM,TRACKER.ARRAY,10000,1,1,
*DIM,F1_INT,TABLE,2000,1,1,Xloc,height,
*DIM,FL_INT,TABLE,2000,1,1,Xloc,height,

plot
/VIEW, 1,1,1,1
/ANG, 1
/REP,FAST
/AUTO, 1
/REP
/USER, 1
/VIEW, 1, -0.573647192861, 0.458489757215, 0.678760665221
/ANG, 1, 3.440812295118
/REPLO
/NERR,0,10000, ! Error Message Suppression

-------------------------------------------------------------------
! Calling Proper Component Section
-------------------------------------------------------------------

FINISH

! Half Model Components Section
/INPUT,4_4_FEA_algorithm_comp_INPUT,./home/dw11589/930E_Full_half,
! Combined Full Model Components Section
!INPUT,4,4_FEA_algorithm_comp_INPUT,./home/dw11589/930E_Full_comb,

! Slice Components Section
!INPUT,4,4_FEA_algorithm_comp_INPUT,./home/dw11589/930E_Full,slice,

! Applying Load to Front Wall

*GET,numcomp,COMP,0,NCOMP
*IF,numcomp,GT,3,THEN

/PREP7

ALLSEL.ALL
CMSEL.S.Front ! Select Comp = Front
ALLSEL.BELOW.AREA ! Selecting Elements Below Selected Areas

INDEX = 0
*DO,Xloc,0.4200,100 ! Front Wall Intercept Calculations
    *DO,Zloc,-2000.0,50
        *IF,jumpout,EQ,1,CYCLE
            *GET,numcomp,COMP,0,NCOMP
            *IF,jumpout,LT,numcomp,CYCLE
                *GET,Xloc,COMP,ALL,1
                *SET,Jumpout,1
            *ELSE
                *IF,jumpout,GT,1,CYCLE
                    *SET,Jumpout,0
                *ENDIF
        *ENDIF
    *ENDIF
*ENDDO

INDEX = INDEX+1
FR_INT(INDEX,0,1) = Xloc
FR_INT(INDEX,1,1) = height

*ENDDO

! Speeding Up Do Loop

*GET,count,ELEM,0,COUNT
*GET,Index,ELEM,0[NUM,MIN

*DO,i,0,count+10,1
    *IF,elem(i,1).EQ,-1.CYCLE ! Skip if Element is Not Selected
        *GET,Xcen,ELEM,Index,CENT,X ! Calling Centroid Locations
        *GET,Ycen,ELEM,Index,CENT,Y
        *GET,Zcen,ELEM,Index,CENT,Z
    ! Pressure Calculations
        *GET,basepres,COMP,0,1
        *SET,Basepres,COMP,Index,basepres
    *ELSE
        *SET,jumpout,0 ! Preventing Negative Pressure
    *ENDIF
    height = FR_INT(Xcen) ! Height = f(Xlocation)
    *IF,jumpout,GT,0,THEN
        *SET,basepres,.rho*G*(1/(1000**3))*height
        *SET,horzpres,(basepres)*((1-Ycen/height))
    *ELSE
        *SET,horzpres,0 ! Preventing Negative Pressure
    *ENDIF

202
Pressure Combination
*SET, pressure, (vertpres*0.366501226) + (horzpresp*0.930417568)
*IF, pressure*1.0e6, GE, 0. THEN
   SF, E, index, 1, PRES, -pressure, . . ! Apply Pressure to Elem i
*ENDIF

!GOPR ! Resume Print to Output
*SET, E, left, (E, left, 1) ! Number of Elements Left
!NOPR ! Suspend Print to Output

*GET, Next, E, index, Next
*IF, Next, EQ, 0, EXIT
*SET, index, Next

*ENDDO
FINISH
*ENDIF

---------------------------------------------------------------------
| Applying Load to Floor                                          |
---------------------------------------------------------------------

!PREP7

/ALLSEL, ALL
CMSEL, S, Floor ! Select Comp = Floor
ALLSEL, BELOW, AREA ! Selecting Elements Below Selected Areas

INDEX = 0
*DO, Xloc, 0, 4200, 100 ! Front Wall Intercept Calculations
   *DO, Zloc, 3000, 8500, 100
      *IF, jumpout, EQ, 1, CYCLE
      *SET, surf, (22.229)*mass/density + 1024)*((1-(Xloc-XPeak)/(4854))**2)*((Zloc-ZPeak)/(6671)**2)
      *SET, floor, (0.158384*Zloc)
      *IF, surf, GT, floor, CYCLE ! Finding height up floor
         *IF, surf, LE, wall, THEN ! (topsurf / wall intercept)
            *SET, height, (0.158384*Zloc)
            *SET, jumpout, 1
      *ENDIF
      *IF, Zloc, GT, 8005.214, THEN
         *SET, height, 1257.901
         *SET, jumpout, 1
      *ENDIF
   *ENDDO
*SET, jumpout, 0
INDEX = INDEX + 1
FL_INT(INDEX, 0, 1) = Xloc
FL_INT(INDEX, 1, 1) = height
*ENDDO

*GET, count, E, index, 0, COUNT
*GET, E, index, E, index, 0, NUM, MIN

*DO, I, 0, count + 10, 1
   *IF, elem(i, 1), EQ, -1, CYCLE ! Skip if Element is Not Selected
      *GET, Xcent, E, index, CENT.X ! Calling Centroid Locations
      *GET, Ycent, E, index, CENT.Y
      *GET, Zcent, E, index, CENT.Z
      ! Pressure Calculations
      *SET, topsurf, ((22.229)*mass/density + 1024)*((1-(Xcent-XPeak)/(4854))**2)*((Zcent-ZPeak)/(6671)**2)
      *SET, column, (topsurf - Ycent)
      *IF, column, GT, 0, THEN
         *SET, vertpres, rho*G*(1/(1000**3)) * column
      *ELSE
         *SET, vertpres, 0 ! Preventing Negative Pressure
      *ENDIF
      height = FL_INT(Xcent) ! Height = F(Xlocation)
*IF, column, GT, 0, THEN
    *SET, basepres, K *rho *G, *height
    *SET, horzpres, (basepres, *1 - Ycent / height))
*ELSE
    *SET, horzpres, 0  ! Preventing Negative Pressure
*ENDIF

! Pressure Combination
*SET, pressure, (vertpres * 0.99768834) + (horzpres * 0.156434465)
*IF, pressure * 10e6, GE, 0, THEN
    SFE, Eindex, 1, PRES, -pressure, ...
    ! Apply Pressure to Elem i
*ENDIF

! GOPR
! Resume Print to Output
*SET, Elemlft, (Elemlft - 1)  ! Number of Elements Left
! NOPR
! Suspend Print to Output

*GET, Next, ELEM, Eindex, NEXT
*IF, Next, EQ, 0, EXIT
*SET, Eindex, Next
*enddo

FINISH

-------------------------------------------------------------------------------------
| Applying Load to Side Wall
-------------------------------------------------------------------------------------

/ PREP7

ALLSEl, ALL
CMSEl, 3, Side
ALLSEl, BELOW, AREA  ! Select Comp = Side
                          ! Selecting Elements Below Selected Areas
*GET, count, ELEM, 0, COUNT
*GET, Eindex, ELEM, 0, NUM, MIN

*DO, i, O, count + 10, 1
    *IF, elmg((i,1), EQ, -1, CYCLE  ! Skip if Element is Not Selected
    *GET, Xcent, ELEM, Eindex, CENT, X
    *GET, Ycent, ELEM, Eindex, CENT, Y
    *GET, Zcent, ELEM, Eindex, CENT, Z

    *SET, height, ((22.222 * mass / density + 1024) * (1 - (Xcent - Xpeak) / 4854) ** 2) / (1 - (Zcent - Zpeak) / 6671) ** 2)
    *SET, column, (height - Ycent)  ! Vertical Pressure Calculations
    *IF, column * 10e3, ST, 0, THEN
        *SET, basepres, K *rho *G, *height
        *SET, horzpres, (basepres, *1 - Ycent / height))
    *ELSE
        *SET, horzpres, 0  ! Preventing Negative Pressure
    *ENDIF

! Pressure Combination
*SET, pressure, horzpres
   *IF, pressure * 10e6, GE, 0, THEN
    SFE, Eindex, 1, PRES, -pressure, ...
    ! Apply Pressure to Elem i
*ENDIF

! GOPR
! Resume Print to Output
*SET, Elemlft, (Elemlft - 1)  ! Number of Elements Left
! NOPR
! Suspend Print to Output

*GET, Next, ELEM, Eindex, NEXT
*IF, Next, EQ, 0, EXIT
*SET, Eindex, Next
*enddo

FINISH
Applying Load to Side Angle Pieces

!PREP7

ALLSEL ALL
CMSEL S.Angle_S
ALLSEL BELOW AREA

! Select Comp = Side Angle
! Selecting Elements Below Selected Areas

! Speeding Up Do Loop

*GET,count,ELEM,0,COUNT
*GET,Eindex,ELEM,0,NUM,MIN

*DO,i,0,count+10,1

*IF,allnot(1),EQ,-1,CYCLE  ! Skip if Element is Not Selected

*GET,Xcen,ELEM,Eindex,CENT.X  ! Calling Centroid Locations
*GET,Ycen,ELEM,Eindex,CENT.Y
*GET,Zcen,ELEM,Eindex,CENT.Z

*SET, topsurf,((22.229*mass/density+1024)*(1-(Xcen-XPeak)4854)**2)*(1-(Zcen-ZPeak)6671)**2)

*SET, column, (topsurf-Ycen)  ! Vertical Pressure Calculations
*IF, column, GT, 0, THEN

  *SET, vertpres, rho*G*(1/(1000**3)) *column

  *ELSE

  *SET, vertpres, 0  ! Preventing Negative Pressure

  *ENDIF

*IF, column, GT, 0, THEN  ! Horizontal Approximation

  *SET, horzpres, K_a*rho*G*(1/(1000**3)) *column

  *ELSE

  *SET, horzpres, 0  ! Preventing Negative Pressure

  *ENDIF

*SET, pressure, (vertpres*0.707106781)+(horzpres*0.707106781)  ! Pressure Combination

*IF, pressure*106.6, GE, 0, THEN  ! Apply Pressure to Element

  SFE,Eindex,1,PRES,,-pressure,..  ! Apply Pressure to Element

*ENDIF

!!GOPR  ! Resume Print to Output

*SET,Elenleft,(Elenleft-1)  ! Number of Elements Left
!!NOPR  ! Suspend Print to Output

*GET,Next,ELEM,Eindex,NXTH
*IF,Next, EQ,0, EXIT

*GET,Eindex,Next

*enddo

FINISH

Applying Load to Front Angle Pieces

*GET,numcomp,COMP,0,NCOMP
*IF,numcomp,GT,3,THEN
.

PREP7

ALLSEL, ALL
CMSEL, S.Angle, F
ALLSEL, BELOW, AREA

! Select Comp = Front Angle
! Selecting Elements Below Selected Areas

! Speeding Up Do Loop

*GET, count, ELEM, 0, COUNT
*GET, Eindex, ELEM, 0, NUM, MIN

*DO, i, 0, count + 10, 1

IF, elmiq(i, 1), EQ, -1, CYCLE

! Skip if Element is Not Selected

*GET, Xcent, ELEM, Eindex, CENT, X
*GET, Ycent, ELEM, Eindex, CENT, Y
*GET, Zcent, ELEM, Eindex, CENT, Z

SET, topsurf, (22.293 * mass/density + 1024) * (1 - ((Xcent - XPeak) / 4854) ** 2) * (1 - ((Zcent - ZPeak) / 6671) ** 2)

SET, column, (topsurf - Ycent) ! Vertical Pressure Calculations

IF, column, GT, 0, THEN

SET, vertpres, rho * G * (1 / (1000 ** 3)) * column
ELSE

SET, vertpres, 0 ! Preventing Negative Pressure
ENDIF

IF, column, GT, 0, THEN

SET, horzpres, K * rho * G * (1 / (1000 ** 3)) * column
ELSE

SET, horzpres, 0 ! Preventing Negative Pressure
ENDIF

! Pressure Combination

SET, pressure, (vertpres * 0.8660254) + (horzpres * 0.5) ! 60 deg

IF, pressure * 10e6, GE, 0, THEN

SFE, Eindex, 1, PRES, -pressure, . . . , ! Apply Pressure to Elem
ELSE

! GOPR

 RESUME Print to Output
 SET, Elemlref, (Elemlref - 1) ! Number of Elements Left
 ! NOPR

 Suspend Print to Output

GET, Next, ELEM, Eindex, NXTH

IF, Next, EQ, 0, EXIT

SET, Eindex, Next

*enddo

FINISH

*ENDIF

ALLSEL, ALL

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deleting Parameters and Display Commands</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
</tbody>
</table>

EPILOT
MVIEW, 1, 1, 1, 1
JANG, 1
! Deleting Parameters

FR_INT=
FL_INT=
surf=
Xloc=
Zloc=
wall=
height=
jumpout=
lowelem=
highelem=
Xcent=
Ycent=
Zcent=
topsurf=
column=
vertpres=
height=
basepres=
horzpres=
presure=
Elemleft=

CMDELE,ANGLE_F
CMDELE,ANGLE_S
CMDELE,FLOOR
CMDELE,FRONT
CMDELE,SIDE           ! Deleting Components

CSYS,0                ! Returning to the Global Cartesian
                      ! Co-ordinate System

!EOF                    ! End of File Marker
FILE: 4_4_FEA_algorithm_comp_INPUT

<table>
<thead>
<tr>
<th>FEA of 930E Truck Box Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oilfield Pressure Load Algorithm</td>
</tr>
<tr>
<td>Select Components Subroutine</td>
</tr>
</tbody>
</table>

---

Creating Body Half Model

Floor, Front, and Side Components

---

FINISH

!FREP7!

**ALLSEL, ALL**

**FLST, 5, 54, 5, ORDE, 43**

**FITEM, 5, 3**

**FITEM, 5, 34**

**FITEM, 5, 37**

**FITEM, 5, 39**

**FITEM, 5, 43**

**FITEM, 5, 45**

**FITEM, 5, 53**

**FITEM, 5, 59**

**FITEM, 5, 62**

**FITEM, 5, 67**

**FITEM, 5, 89**

**FITEM, 5, 106**

**FITEM, 5, 126**

**FITEM, 5, 150**

**FITEM, 5, 153**

**FITEM, 5, 155**

**FITEM, 5, 157**

**FITEM, 5, 185**

**FITEM, 5, 191**

**FITEM, 5, 193**

**FITEM, 5, 194**

**FITEM, 5, 204**

**FITEM, 5, 262**

**FITEM, 5, 269**

**FITEM, 5, 271**

**FITEM, 5, 273**

**FITEM, 5, 275**

**FITEM, 5, 276**

**FITEM, 5, 285**

**FITEM, 5, 286**

**FITEM, 5, 343**

**FITEM, 5, 349**

**FITEM, 5, 350**

**FITEM, 5, 544**

**FITEM, 5, 547**

**FITEM, 5, 573**

**FITEM, 5, 582**

**FITEM, 5, 662**

**FITEM, 5, 685**

**FITEM, 5, 699**

**FITEM, 5, 700**

**FITEM, 5, 702**

**FITEM, 5, 705**

**ASEL, S, , P51X**

CM, Front, AREA ! Storing Areas as Component

**ALLSEL, BELOW, AREA**

! Selecting Elements Below Selected Areas

**SET, Elemlntf, (Elemlntf + elmiQ(0, 13))**

! Element Counter

**ALLSEL, ALL**

**FLST, 5, 12, 5, ORDE, 10**

**FITEM, 5, 187**

**FITEM, 5, 381**

**FITEM, 5, 384**

**FITEM, 5, 367**

**FITEM, 5, 388**

**FITEM, 5, 390**

**FITEM, 5, 392**

**FITEM, 5, 395**

**FITEM, 5, 397**

**FITEM, 5, 442**

**ASEL, S, , P51X**

CM, Side, AREA ! Storing Areas as Component

**ALLSEL, BELOW, AREA**

! Selecting Elements Below Selected Areas

**SET, Elemlntf, (Elemlntf + elmiQ(0, 13))**

! Element Counter

**ALLSEL, ALL**

**ASEL, S, , 377**

CM, Angle, F, AREA ! Storing Areas as Component

**ALLSEL, BELOW, AREA**

! Selecting Elements Below Selected Areas

**SET, Elemlntf, (Elemlntf + elmiQ(0, 13))**

! Element Counter

**FLST, 5, 18, 5, ORDE, 7**

**FITEM, 5, 32**

**FITEM, 5, 61**

**FITEM, 5, 60**

**FITEM, 5, 145**

**FITEM, 5, 208**

**FITEM, 5, 217**

**FITEM, 5, 378**

**ASEL, S, , P51X**

CM, Angle, S, AREA ! Storing Areas as Component

**ALLSEL, BELOW, AREA**

! Selecting Elements Below Selected Areas

CM, floor, AREA ! Storing Areas as Component

**ALLSEL, BELOW, AREA**
*SET,Elem.left,(Elem.left+elmigr(0,13))

! Element Counter

ALLSEL,ALL

FINISH

/EOF ! End of File Marker

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating Combined Frame and Body Full Model</td>
</tr>
<tr>
<td>! Floor, Front, and Side Components</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>:comb</td>
</tr>
</tbody>
</table>

FINISH

/PREP7

ALLSEL,ALL

FLST,5,108,5,ORDE,86

FITEM,5,283

FITEM,5,314

FITEM,5,-317

FITEM,5,319

FITEM,5,-323

FITEM,5,325

FITEM,5,333

FITEM,5,339

FITEM,5,342

FITEM,5,347

FITEM,5,369

FITEM,5,366

FITEM,5,406

FITEM,5,430

FITEM,5,-433

FITEM,5,435

FITEM,5,-437

FITEM,5,465

FITEM,5,471

FITEM,5,473

FITEM,5,-474

FITEM,5,484

FITEM,5,542

FITEM,5,549

FITEM,5,552

FITEM,5,555

FITEM,5,556

FITEM,5,557

FITEM,5,565

FITEM,5,-566

FITEM,5,567

FITEM,5,582

FITEM,5,597

FITEM,5,603

FITEM,5,591

FITEM,5,605

FITEM,5,610

ASEL,S,,P51X ! Selecting Floor Areas

CM,floor,AREA ! Storing Areas as Component

ALLSEL,BELOW,AREA

! Selecting Elements Below Selected Areas

*SET,Elem.left,elmigr(0,13) ! Element Counter

ALLSEL,ALL

FLST,5,5,5,ORDE,5

FITEM,5,597

FITEM,5,603

FITEM,5,595

FITEM,5,605

FITEM,5,610

ASEL,S,,P51X

CM,Side,AREA ! Storing Areas as Component

ALLSEL,BELOW,AREA

! Selecting Elements Below Selected Areas

*SET,Elem.left,(Elem.left+elmigr(0,13)) ! Element Counter

ALLSEL,ALL

FINISH

/EOF ! End of File Marker

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating Body Slice Model</td>
</tr>
<tr>
<td>! Floor, Front, and Side Components</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
</tbody>
</table>

FLST,5,7,5,ORDE,7

FITEM,5,191

FITEM,5,229

FITEM,5,323

FITEM,5,325

FITEM,5,551

FITEM,5,553

FITEM,5,555

ASEL,S,,P51X ! Selecting Floor Areas

CM,floor,AREA ! Storing Areas as Component

ALLSEL,BELOW,AREA

! Selecting Elements Below Selected Areas

*SET,Elem.left,elmigr(0,13) ! Element Counter

ALLSEL,ALL

FLST,5,5,5,ORDE,3

FITEM,5,211

FITEM,5,557

FITEM,5,585

ASEL,S,,P51X

CM,Angle_S,AREA ! Storing Areas as Component

ALLSEL,BELOW,AREA

! Selecting Elements Below Selected Areas

*SET,Elem.left,(Elem.left+elmigr(0,13)) ! Element Counter

ALLSEL,ALL

FINISH

/EOF ! End of File Marker
FITEM,5,1417
FITEM,5,1435
FITEM,5,1459
FITEM,5,1462
FITEM,5,1464
FITEM,5,1466
FITEM,5,1468
FITEM,5,1500
FITEM,5,1502
FITEM,5,1503
FITEM,5,1513
FITEM,5,1571
FITEM,5,1578
FITEM,5,1580
FITEM,5,1582
FITEM,5,1584
FITEM,5,1585
FITEM,5,1586
FITEM,5,1588
FITEM,5,1589
FITEM,5,1593
FITEM,5,1595
FITEM,5,1652
FITEM,5,1658
FITEM,5,1659
FITEM,5,1853
FITEM,5,1856
FITEM,5,1862
FITEM,5,1891
FITEM,5,1925
FITEM,5,1958
FITEM,5,1990
FITEM,5,1991
FITEM,5,1993
FITEM,5,1996
ASEL,S,,P51X ! Selecting Floor Areas
CM,flow,AREA ! Storing Areas as Component
ALLSEL BELOW AREA
! Selecting Elements Below Selected Areas
*SET,Elemleft, elmiqr(0,13) ! Element Counter

ALLSEL ALL
FLST,5,24,5,ORDE,20
FITEM,5,467
FITEM,5,661
FITEM,5,664
FITEM,5,667
FITEM,5,668
FITEM,5,670
FITEM,5,672
FITEM,5,675
FITEM,5,676
FITEM,5,677
FITEM,5,722
FITEM,5,1436
FITEM,5,1690
FITEM,5,1693
FITEM,5,1696
FITEM,5,1697
FITEM,5,1698
FITEM,5,1699
FITEM,5,1701
FITEM,5,1704
FITEM,5,1706
FITEM,5,1751
ASEL,S,,P51X ! Selecting Front Wall Areas
CM,Front,AREA ! Storing Areas as Component
ALLSEL BELOW AREA
! Selecting Elements Below Selected Areas
*SET,Elemleft, elmiqr(0,13) ! Element Counter

ALLSEL ALL
FLST,5,26,5,ORDE,18
FITEM,5,519
FITEM,5,569
FITEM,5,581
FITEM,5,597
FITEM,5,603
FITEM,5,970
FITEM,5,-972
FITEM,5,-974
FITEM,5,-978
FITEM,5,1548
FITEM,5,1598
FITEM,5,1610
FITEM,5,1626
FITEM,5,1632
FITEM,5,1981
FITEM,5,-1983
FITEM,5,1985
FITEM,5,-1989
ASEL,S,,P51X ! Selecting Side Wall Areas
CM,Side,AREA ! Storing Areas as Component
ALLSEL BELOW AREA
! Selecting Elements Below Selected Areas
*SET,Elemleft, elmiqr(0,13) ! Element Counter

ALLSEL ALL
FLST,5,2,5,ORDE,2
FITEM,5,657
FITEM,5,1636
ASEL,S,,P51X
CM,Angle_F,AREA ! Storing Areas as Component
ALLSEL BELOW AREA
! Selecting Elements Below Selected Areas
*SET,Elemleft, elmiqr(0,13) ! Element Counter

ALLSEL ALL
FLST,5,36,5,ORDE,14
FITEM,5,312
FITEM,5,341
FITEM,5,370
FITEM,5,425
FITEM,5,485
FITEM,5,487
FITEM,5,668
FITEM,5,1343
FITEM,5,1372
FITEM,5,1401
FITEM,5,1454
FITEM,5,1514
FITEM,5,-1526
FITEM,5,1687
ASEL,S,,P51X
CM,Angle_S,AREA ! Storing Areas as Component
ALLSEL BELOW AREA
! Selecting Elements Below Selected Areas
*SET,Elemleft, elmiqr(0,13) ! Element Counter

ALLSEL ALL
FINISH

/EOF ! End of File Marker

--------------------

210
**Filename: 4_5_FEA_symm_INPUT**

```plaintext
---
<table>
<thead>
<tr>
<th>TITLE</th>
<th>Applying Symmetry Boundary Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREP7</td>
<td>AFUN,DEG</td>
</tr>
<tr>
<td></td>
<td>---------------------------------------</td>
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<tr>
<td>ERASE</td>
<td></td>
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<td>REP</td>
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<td>USER, 1</td>
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<tr>
<td>VIEW, 1, 0.868057538878 , -0.230698620303 , -0.439653522647</td>
<td></td>
</tr>
<tr>
<td>JANG, 1, -7.459066690049</td>
<td></td>
</tr>
<tr>
<td>REPO</td>
<td></td>
</tr>
</tbody>
</table>

---
| FSTL,2,106,4,ORDE,102                      |
| ITEM,2,5                                   |
| ITEM,2,17                                  |
| ITEM,2,40                                  |
| ITEM,2,47                                  |
| ITEM,2,56                                  |
| ITEM,2,66                                  |
| ITEM,2,70                                  |
| ITEM,2,81                                  |
| ITEM,2,90                                  |
| ITEM,2,93                                  |
| ITEM,2,95                                  |
| ITEM,2,97                                  |
| ITEM,2,99                                  |
| ITEM,2,101                                 |
| ITEM,2,103                                 |
| ITEM,2,105                                 |
| ITEM,2,107                                 |
| ITEM,2,109                                 |
| ITEM,2,111                                 |
| ITEM,2,113                                 |
| ITEM,2,115                                 |
| ITEM,2,117                                 |
| ITEM,2,119                                 |
| ITEM,2,121                                 |
| ITEM,2,123                                 |
| ITEM,2,125                                 |
| ITEM,2,134                                 |
| ITEM,2,172                                 |
| ITEM,2,175                                 |
| ITEM,2,183                                 |
| ITEM,2,193                                 |
| ITEM,2,198                                 |
| ITEM,2,207                                 |
| ITEM,2,212                                 |
| ITEM,2,224                                 |
| ITEM,2,230                                 |
| DLPS1X, UX,0                               |
---
```
*IF, Loadcell, EQ, 1, THEN

<table>
<thead>
<tr>
<th>FLST, 2, 16, 4, ORDE, 12</th>
</tr>
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<tbody>
<tr>
<td>ITEM, 2, 2204</td>
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<tr>
<td>ITEM, 2, 2207</td>
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<td>ITEM, 2, 2212</td>
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<td>ITEM, 2, 2215</td>
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<tr>
<td>ITEM, 2, 2221</td>
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<td>ITEM, 2, 2233</td>
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<tr>
<td>ITEM, 2, 2235</td>
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<tr>
<td>ITEM, 2, 2236</td>
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<tr>
<td>ITEM, 2, 2238</td>
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<tr>
<td>ITEM, 2, 2244</td>
</tr>
<tr>
<td>ITEM, 2, 2250</td>
</tr>
<tr>
<td>ITEM, 2, 2254</td>
</tr>
<tr>
<td>DL, P51X, ROTY, 0</td>
</tr>
</tbody>
</table>

*ENDIF

FINISH
FINISH

; EOF

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>----------------------------------------------------------------------</td>
</tr>
</tbody>
</table>

DL, P51X, ROTZ, 0
TITLE: Applying Anti-symmetry Boundary Conditions

PREP7

*AFUN, DEG

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td>View Settings</td>
<td>Anti-Symmetry Conditions</td>
</tr>
</tbody>
</table>

ERASE
APLOT
WPSSTYLE,...,0
AUTO, 1
REP
USER, 1
VIEW, 1, 0.868057538878, -0.230609820303, -0.439685322647
ANG, 1, -7.49589869049
REPLO

FLST, 2, 105, 4, ORDER, 150
FITM, 2, 236
FITM, 2, 238
FITM, 2, 246
FITM, 2, 258
FITM, 2, 268
FITM, 2, 281
FITM, 2, 300
FITM, 2, 306
FITM, 2, 322
FITM, 2, 367
FITM, 2, 377
FITM, 2, 394
FITM, 2, 406
FITM, 2, 727
FITM, 2, 728
FITM, 2, 733
FITM, 2, 780
FITM, 2, 810
FITM, 2, 914
FITM, 2, 817
FITM, 2, 855
FITM, 2, 859
FITM, 2, 869
FITM, 2, 885
FITM, 2, 886
FITM, 2, 938
FITM, 2, 943
FITM, 2, 944
FITM, 2, 946
FITM, 2, 950
FITM, 2, 952
FITM, 2, 953
FITM, 2, 957
FITM, 2, 960
FITM, 2, 961
FITM, 2, 974
FITM, 2, 982
FITM, 2, 1020
FITM, 2, 1025
FITM, 2, 1032
FITM, 2, 1033
FITM, 2, 1038
FITM, 2, 1041
FITM, 2, 1045
FITM, 2, 1137
FITM, 2, 1130
FITM, 2, 1152
FITM, 2, 1172
FITM, 2, 1175
FITM, 2, 1179
FITM, 2, 1196
FITM, 2, 1207
FITM, 2, 1225
FITM, 2, 1226
FITM, 2, 1326
FITM, 2, 1343
FITM, 2, 1350
FITM, 2, 1364
FITM, 2, 1370
FITM, 2, 1389
FITM, 2, 1489
FITM, 2, 1491
FITM, 2, 1497
FITM, 2, 1499
FITM, 2, 1509
FITM, 2, 1512
FITM, 2, 230
DLPS15X, ROTX, 0

214
*IF, Loadcell,EQ,1,THEN

FLST,2,16,4,ORDE,12
FITEM,2,2204
FITEM,2,2207
FITEM,2,2212
FITEM,2,2215
FITEM,2,2221
FITEM,2,2223
FITEM,2,2235
FITEM,2,2236
FITEM,2,2238
FITEM,2,2244
FITEM,2,2250
FITEM,2,2254
DL,P51X,احتم.0

FLST,2,16,4,ORDE,12
FITEM,2,2204
FITEM,2,2207
FITEM,2,2212
FITEM,2,2215
FITEM,2,2221
FITEM,2,2223
FITEM,2,2235
FITEM,2,2236
FITEM,2,2238
FITEM,2,2244
FITEM,2,2250
FITEM,2,2254
DL,P51X,احتم.0

*ENDIF

FINISH
/EOF
**Filename: 5_1_post_StressPath_INPUT**

<table>
<thead>
<tr>
<th>FEA of 930E Truck Box Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolster Stress Plot</strong></td>
</tr>
<tr>
<td><strong>FINISH</strong></td>
</tr>
<tr>
<td><strong>CLEAR</strong></td>
</tr>
</tbody>
</table>

---------- Reading Database and Results Files

**RESUME,July_18_4Loadcells.db.**

**/GRAPHICS FULL**

**/POST1**

**INRES, FILE,July_18_4Loadcells,rst,**

**SET,1, LAST,1,**

**! Load Step #, Last Substep, Scale=1**

**/EOF**

**LCDEF,1,1,**

**LCDEF,2,2,**

**LCDEF,3,3,**

**LCDEF,4,4,**

**LCASE,1,**

**LCOPER,ADD,4,**

**/TITLE,LOAD CASE 5: Twist + Ore Load**

**LCWRITE,5,**

**/SET,1, LAST,1,**

**LCOPER,ADD,4,**

**/TITLE,LOAD CASE 6: Inverted Twist + Ore Load**

**LCWRITE,6,**

**LCASE,2,**

**LCOPER,ADD,4,**

**/TITLE,LOAD CASE 7: Uniform Frame Displacement + Ore Load**

**LCWRITE,7,**

**/SET,2, LAST,1,**

**LCOPER,ADD,4,**

**/TITLE,LOAD CASE 8: Inverted Uniform Frame Displacement + Ore Load**

**LCWRITE,8,**

**LCASE,5,**

**LCOPER,ADD,2,**

**/TITLE,LOAD CASE 9: Twist + OreLoad - Uniform + Uyin=0 UyNosa=-2.0**

**LCWRITE,9,**

**LCASE,6,**

**LCOPER,ADD,2,**

**/TITLE,LOAD CASE 10: Inverted Twist + OreLoad + Uniform... Uyin=0 UyNosa=+2.0**

**LCWRITE,10,**

**| Rotating Co-ordinate System to Match Bolster Plate**

**CSKP,11,0,119,60,39,1,1,**

**| Rotating Co-ordinate System to**

**RSYS,11 | align w/ Bottom of Bolster**

|---------------------------------|
| **ALLSEL,ALL**

| FLST,5,16,5,ORDE,14 |
| FITEM,5,96 |
| FITEM,5,-97 |
| FITEM,5,99 |
| FITEM,5,-101 |
| FITEM,5,114 |
| FITEM,5,116 |
| FITEM,5,159 |
| FITEM,5,162 |
| FITEM,5,189 |
| FITEM,5,201 |
| FITEM,5,551 |
| FITEM,5,-562 |
| FITEM,5,554 |
| FITEM,5,-555 |
| ASELR, .PS1X |
| CM,Bolster1,AREA |

| ALLSEL,ALL |

| FLST,5,28,5,ORDE,24 |
| FITEM,5,74 |
| FITEM,5,80 |
| FITEM,5,86 |
| FITEM,5,93 |
| FITEM,5,111 |
| FITEM,5,113 |
| FITEM,5,161 |
| FITEM,5,261 |
| FITEM,5,264 |
| FITEM,5,266 |
| FITEM,5,268 |
| FITEM,5,274 |
| FITEM,5,278 |
| FITEM,5,280 |
| FITEM,5,282 |
| FITEM,5,293 |
| FITEM,5,550 |
| FITEM,5,556 |
| FITEM,5,556 |
| FITEM,5,558 |
| FITEM,5,-561 |
| FITEM,5,563 |
| FITEM,5,-566 |
| FITEM,5,721 |
| FITEM,5,733 |
| ASELR, .PS1X |
| CM,Bolster2,AREA |

| ALLSEL,ALL |

| FLST,5,30,5,ORDE,25 |
| FITEM,5,84 |
| FITEM,5,108 |
| FITEM,5,260 |
| FITEM,5,283 |
| FITEM,5,265 |
| FITEM,5,267 |
| FITEM,5,272 |
| FITEM,5,277 |
| FITEM,5,279 |
| FITEM,5,283 |
| FITEM,5,-284 |
CMSEL.A,Bolster6
CMSEL.A,Bolster7
CMSEL.A,Bolster8
CMSEL.A,Bolster9

ALLSEL,BELOW,AREA

A:PLOT
/AUTO,1
/REP
AVPRIN,0,0,

quick
ILCASE,10
SET,1,2,3,-5,
SHELL,TOP
AVPRIN,0,0,
ETABLE,SXTOP,S,X
SHELL.bot
AVPRIN,0,0,
ETABLE,SXBOT,S,X
SADD,SEC_BEND,SXTOP,SXBOT,1,-1,0,
P:LETAB,SEC_BEND,AVG

/EOF

---------------------------------------------------------------------

--------------- Defining Path Locations
---------------------------------------------------------------------

I here
I:PADEL,ALL ! Delete All Paths
ILCASE,1, ! Read Load Case

PATH,Bolster,2,30,200. ! Defining Path
! 2 path points, 30 Data sets, 200 Data Points
I:PPATH,2,0,3840,-115,-4400-(4670-4400)/2,0,
I:PPATH,1,0,-340,-4400-(4670-4400)/2,0,
I/TITLE,Path Functions Down Centerline of Fifth Bolster

FLST,2,2,1
FITEM,2,42,488
FITEM,2,38,828
IPPATH,P51X,1
I:IPDEF,STAT
I/TITLE,Path Functions Down Centerline of Fifth Bolster Filler

I:PPATH,2,0,3840,-115,-7440-(7690-7440)/2,0,
I:PPATH,1,0,-340,-7500-(7690-7500)/2,0,
I/TITLE,Path Functions Down Centerline of FRONT Bolster Filler

FLST,2,2,1
FITEM,2,43,399
FITEM,2,42,420
IPPATH,P51X,1
I:IPDEF,STAT
I/TITLE,Path Functions Down Centerline of FRONT Bolster Filler

I:PPATH,2,0,1030,-440+100,-7730,0,
! FEA of 930E Truck Box Structure
! Rubber Pad Representation
! Reaction Force Collection Routine

FINISH
/CLEAR
/NERRR,0,, \ Warning Supression

--------- Reading Database and Results Files 
---------
RESUME,June_25_Shim.db
/GRAPHICS,FULL

::POST1
INRES,
FILE,June_25_Shim.rst,

SET,1,LAST,1, \ Base Load Step

--------- Selecting Rubber Pad Volumes 
---------

ALLSEL,ALL
ALLSEL,BELOW,VOLU

ESEL,S,MAT,2
EPLT
/AUTO,1
/REP
/AUSER,1
/MVIEW,1,0.475551822770,0.322430127329,0.8184673539465
/ANG,1,6.72302175464
/LEIG,1,1.16000,0.812507096498,-0.550663422625,-0.191392133977,0.00000000000000E+00
/REPLT
/ZOOM,1,RECT,1.187651,-0.473591,0.626680,-0.021810
*SET_ZF,1
AVPRIN,0,0
*
/SFACE_ZF
PLNSL,U,Y,0,1
*
/DScale,1,1,0
/REPLT
*
/EOF
INSEL_S,LOC,Y,-465.5,-465.3 ' Selecting Bottom

INSEL_R,LOC,Y,-440.5,-439.5 ' Selecting Top Nodes

*GET,count,NODE,0,COUNT
*GET,Nindex,NODE,0,NUM,MIN
*DIM,REACTION,ARRAY,count,5,1
*DO,index,1,count+10,1

/GOPR ! Resume Print to Output
*GET,Rforce,NODE,Nindex,RF,FY
*GET,StressY,NODE,Nindex,S,Y
! Element Nodal Stress
REACTION(index,1,1)=index
REACTION(index,2,1)=Nindex
REACTION(index,3,1)=NZ(Nindex)
REACTION(index,4,1)=NX(Nindex)
!REACTION(index,5,1)=Rforce
REACTION(index,5,1)=StressY
*GET,Next,NODE,Nindex,NXTH
!IF,Next,EQ,0,EXIT
*SET,Nindex,Next

/NOPR ! Suspend Print to Output

*ENDDO
*CFOPEN,Reaction_Rubber_Top,
*CFOPEN,Reaction_Rubber_SY_Top,
*WRITE,REACTION(1,1),REACTION(1,1),REACTION(1,2),REACTION(1,3),REACTION(1,4),REACTION(1,5),
*Index,F4.0,Node,F6.0,Stress,F12.2
Xloc,F10.2,SY,F12.2
*CFCLOS
Count=
Nindex=
Index=
Rforce=
Next=
REACTION=

ALLSEL_ALL
/EOF
Filename: 5_7_post_LoadCells_INPUT

FEA of SRGE Truck Box Structure

Load Cell Study Algorithm...

FINISH

Warnings Suppression

Reading Database and Results Files

RESUME,July_18_4Loadcells.db.

GRAPHICS,FULL.

/POST1
INRES,
FILE,July_18_4Loadcells.rst.

SET,1,LAST,1,

Creating Load Cell Component Areas

ALLSEL,ALL
FLST,5,4,5,ORDE,4
FITEM,5,1184
FITEM,5,1186
FITEM,5,1188
FITEM,5,1190
ASEL,S,,P51X
CM,Loadcell AREA

ALLSEL,ALL
FLST,5,4,5,ORDE,4
FITEM,5,1175
FITEM,5,1177
FITEM,5,1179
FITEM,5,1181
ASEL,S,,P51X
CM,Loadcell AREA

ALLSEL,ALL
FLST,5,4,5,ORDE,4
FITEM,5,1175
FITEM,5,1177
FITEM,5,1179
FITEM,5,1181
ASEL,S,,P51X
CM,Loadcell AREA

ALLSEL,ALL
FLST,5,4,5,ORDE,2
FITEM,5,1161
FITEM,5,1163
ASEL,S,,P51X
CM,Loadcell AREA

ALLSEL,ALL
FLST,5,4,5,ORDE,2
FITEM,5,1161
FITEM,5,1163
ASEL,S,,P51X
CM,Loadcell AREA

ALLSEL,ALL
FLST,5,4,5,ORDE,2
FITEM,5,1161
FITEM,5,1163
ASEL,S,,P51X
CM,Loadcell AREA

ALLSEL,ALL
ICMSEL,S,Loadcell1
ICMSEL,S,Loadcell2
ICMSEL,S,Loadcell3
ICMSEL,S,Loadcell4

Combining Load Sets..

LCDEF,1,1,
LCDEF,2,2,
LCDEF,3,3,
LCDEF,4,4,
LCASE,1,
LCOPER,ADD,4,
/TITLE,LOAD CASE 5: Twist + Ore Load
LCWRITE,5,,/.
SET,1,LAST,-1,
LCOPER,ADD,4,
/TITLE,LOAD CASE 6: Inverted Twist + Ore Load
LCWRITE,6,,/.
LCASE,2,
LCOPER,ADD,4,
/TITLE,LOAD CASE 7: Uniform Frame Displacement + Ore Load
LCWRITE,7,,/.
SET,2,LAST,-1,
LCOPER,ADD,4,
/TITLE,LOAD CASE 8: Inverted Uniform Frame Displacement + Ore Load
LCWRITE,8,,/.
LCASE,5
LCOPER,ADD,2,
/TITLE,LOAD CASE 9: Twist + Ore Load - Uniform...
Upin=0 UyNose=-2.0
LCWRITE,9,,/.
LCASE,6
LCOPER,ADD,2,
/TITLE,LOAD CASE 10: Inverted Twist + Ore Load + Uniform...
Upin=0 UyNose=+2.0
LCWRITE,10,,/.
Filename: 6_1_submodel_Main_INPUT

! Sub-model of Bolster-Stringer Intersection

/INPUT,6_2_submodel_geom_INPUT,...,0 ! Creating Sub-model Solid Geometry
SAVE ! Saving sub_geom.db
/EOF

mesh
FINISH
FINISH
/CLEAR
RESUME,sub_geom.db
/INPUT,6_3_submodel_mesh_INPUT,...,0 ! Meshing with Solid Elements
SAVE ! Saving sub_mesh.db
/EOF

/INPUT,6_4_submodel_tran_INPUT,...,0 ! Results Transfer Routine
/SAVE ! Saving sub_modl.db
/EOF

! [load sets??]
! Solve
**Filename: 6_2_submodel_geom_INPUT**

```
! Sub-model Geometry Creation Routine

FINISH
FINISH
/CLEAR
RESUME.geom.db
/TITLE, Building Sub-Model Geometry
/FILNAME, sub_geom

/END

KWPLAN,-1,  175, 19, 723
KL,1357,0.5, ,
KL,1335,0.5, ,
KWPAVE,  1018 ! Moving Work Plane

FLST,2,5,ORDE,5
FITEM,2,120
FITEM,2,122
FITEM,2,686
FITEM,2,686
FITEM,2,688
ASBW,F51X ! Cutting Areas

KWPAVE,  1019 ! Moving Work Plane

FLST,2,2,5,ORDE,2
FITEM,2,19
FITEM,2,117
ASBW,F51X ! Cutting Areas

KWPLAN,-1,  1018,  727,  726
KWPAVE,  1019 ! Moving Work Plane

ASBW,  1038 ! Cutting Area

FLST,5,9,9,ORDE,9
FITEM,5,119
FITEM,5,121
FITEM,5,1035
FITEM,5,1036
FITEM,5,1039
FITEM,5,1040
FITEM,5,1043
FITEM,5,1045
FITEM,5,1047
ASEL,S, ,P51X ! Selecting Areas

ALLSEL,BELOW,AREA

FLST,3,1,4,ORDE,1 ! STR Lower Edge Lines
FITEM,3,2071
LGEN,2,P51X, ,38*(33.3/109),-38*(103.8/109), ,0
FLST,3,1,4,ORDE,1
FITEM,3,2059
LGEN,2,P51X, ,38, ,0
KWPLAN,-1,  1021,  727,  1029
LARC,1032,1030,727,38+38,

FLST,5,3,5,ORDE,3
FITEM,5,1039
FITEM,5,1040
FITEM,5,1047
ASEL,U, ,P51X
ASEL,INVE ! Inverting Selection

FLST,2,761,5,ORDE,29
FITEM,2,1
FITEM,2,-18
FITEM,2,20
FITEM,2,106
FITEM,2,108
FITEM,2,110
FITEM,2,-116
FITEM,2,118
FITEM,2,123
FITEM,2,-595
FITEM,2,612
FITEM,2,-684
FITEM,2,687
FITEM,2,689
FITEM,2,-719
FITEM,2,721
FITEM,2,-729
FITEM,2,732
FITEM,2,733
FITEM,2,750
FITEM,2,-764
FITEM,2,1000
FITEM,2,-1034
FITEM,2,1037
FITEM,2,1039
FITEM,2,-1042
FITEM,2,1044
FITEM,2,1046
FITEM,2,-1047
ADELE,P51X, ,1 ! Deleting Unselected Areas

ALLSEL,ALL
FLST,2,20,4,ORDE,5
FITEM,2,48
FITEM,2,57
FITEM,2,428
FITEM,2,-444
FITEM,2,1502
LDELE,P51X, ,1 ! Deleting Unused Lines

FLST,3,1,4,ORDE,1 ! STR Upper Edge Lines
FITEM,3,2071
LGEN,2,P51X, ,38*(33.3/109),38*(103.8/109), ,0
FLST,3,1,4,ORDE,1
FITEM,3,1016
KGEN,2,P51X, ,38, ,0
LSTR,  1003,  1001
LSTR,  1003,  1018
LSTR,  1018,  1033
LSTR,  1001,  727
LSTR,  1001,  177
LSTR,  1002,  1019
LSTR,  1019,  1031
LSTR,  177,  1030
LSTR,  727,  1032 ! Creating Lines for STR Areas

NUMMRG,KP, , , ! Merging Coincident keypoints
```

224
%% End of job

%% Start of job

% The end of the job

%% End of job

%% Start of job

% The end of the job

%% End of job

%% Start of job

% The end of the job

%% End of job

%% Start of job

% The end of the job

%% End of job
Filename: 6_3_submodel_mesh_INPUT

! Sub-model Meshing Routine

/TITLE Meshing Sub-model Volume with Solid
Elements
/FILNAME sub_mesh
/REPEAT

KWPAVE, 1106
wpooff,0,0,20
ALLSEL,ALL
FLST,2,6,6,ORDE,4
ITEM,2,33
ITEM,2,36
ITEM,2,51
ITEM,2,-54
VSBW,P51X ! Cutting Bolster Volumes ! To Help With Meshing

! Selecting Corner Piece Only

FLST,5,2,4,6,ORDE,22
ITEM,5,1
ITEM,5,4
ITEM,5,7
ITEM,5,12
ITEM,5,-13
ITEM,5,18
ITEM,5,-19
ITEM,5,24
ITEM,5,26
ITEM,5,30
ITEM,5,-31
ITEM,5,33
ITEM,5,-34
ITEM,5,47
ITEM,5,-50
ITEM,5,54
ITEM,5,-55
ITEM,5,60
ITEM,5,-61
ITEM,5,66
ITEM,5,68
ITEM,5,72
VSEL,,P51X
FLST,5,4,6,ORDE,4
ITEM,5,19
ITEM,5,24
ITEM,5,33
ITEM,5,54
ITEM,5,56
VSEL,,P51X
ALLSEL,BELOW,VOLU

! Meshing Corner Piece Only

! LSizel Intersection Region

FLST,5,2,4,ORDE,2
ITEM,5,2251
ITEM,5,2273
CM_Y,LINE

LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,5.1, ! Weld Toe Through Thickness
CMDEL_Y
CMDEL_Y1
FLST,5,3,4,ORDE,3
ITEM,5,2277
ITEM,5,2279
ITEM,5,2286
CM_Y,LINE
LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,5.0,5, ! Weld Depth
CMDEL_Y
CMDEL_Y1
FLST,5,4,4,ORDE,4
ITEM,5,2005
ITEM,5,2036
ITEM,5,2055
ITEM,5,2113
CM_Y,LINE
LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,2.1, ! Bolster Thickness
CMDEL_Y
CMDEL_Y1
FLST,5,1,4,ORDE,1
ITEM,5,2150
CM_Y,LINE
LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,8.0,5, ! STR Thickness
CMDEL_Y
CMDEL_Y1
FLST,5,1,4,ORDE,1
ITEM,5,2154
CM_Y,LINE
LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,5.0,5, ! Weld Throat Top
CMDEL_Y
CMDEL_Y1
FLST,5,2,4,ORDE,2
ITEM,5,2178
ITEM,5,2200
CM_Y,LINE
LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,5.2, ! Weld Throat Bottom
CMDEL_Y
CMDEL_Y1
FLST,5,2,4,ORDE,2
ITEM,5,2278
ITEM,5,2200
CM_Y,LINE
LSEL,,P51X
CM_Y,LINE
CMSEL_Y
LESIZE_Y1,,3.1, ! Weld Height
CMDEL_Y
VSWEEP.84,1301,1308
VSWEEP.79,1288,1290

!SweepingBolsterTransitionRegions
FLST,5,3,4,OROE,3
FITEM,5,2319

!SelectingVolumes
ALLSEL,ALL

EXTOPT,ESIZE,20.0, !20 Sweep Divisions
EXTOPT,ACLEAR,1 !Clear Source Areas
ET,2,SOLID95 !Solid 95 Element

VSWEEP,18,1078,1074
VSWEEP,26,1107,1108
VSWEEP,60,1227,1224
VSWEEP,13,1048,1052
VSWEEP,58,1215,1216
VSWEEP,30,1114,1116

!Sweep Meshing Intersection Region

FLST,5,1,4,OROE,1
FITEM,5,2190
CM_Y_LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1., 5,2, !Pie Section Line Sizing
CMDEL_Y
CMDEL_Y1
FLST,5,1,4,OROE,1
FITEM,5,2227
CM_Y_LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1., 5,0.5, !Pie Section Line Sizing
CMDEL_Y
CMDEL_Y1
EXTOPT,ESIZE,5.2, !Sweep Divisions, Ratio
EXTOPT,ACLEAR,1
VSWEEP,31,1132,1134

!Sweeping Pie Section

FLST,5,1,4,OROE,1
FITEM,5,2246
CM_Y_LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1., 5,2, !Crescent Section Line Sizing
CMDEL_Y
CMDEL_Y1
FLST,5,1,4,OROE,1
FITEM,5,2268
CM_Y_LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1., 5,0.5, !Crescent Section Line Sizing
CMDEL_Y
CMDEL_Y1
FLST,5,1,4,OROE,1
FITEM,5,2215
CM_Y_LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1., 10,1, !Crescent Section Line Sizing
CMDEL_Y
CMDEL_Y1
EXTOPT,ESIZE,5.2, !Sweep Divisions, Ratio
EXTOPT,ACLEAR,1
VSWEEP,4,1190,1189

!Sweeping Crescent Section

FLST,5,2,4,ORDE,2

FLST,5,14,6,ORDE,14
FITEM,5,1
FITEM,5,5
FITEM,5,13
FITEM,5,18
FITEM,5,26
FITEM,5,30
FITEM,5,31
FITEM,5,47
FITEM,5,55
FITEM,5,59
FITEM,5,78

CM_Y_LINE
LSEL...,P51X
CMSEL_Y
LESIZE_Y1., 2.1, !Outside Thickness Divs, Ratio
CMDEL_Y
CMDEL_Y1
FLST,5,3,4,ORDE,3
FITEM,5,2355
FITEM,5,2356
FITEM,5,2365
FITEM,5,2366
CM_Y_LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL_Y
LESIZE_Y1., 10,3, !Transition Divs, Ratio
CMDEL_Y
CMDEL_Y1

EXTOPT,ESIZE,20.0, !20 Sweep Divisions
EXTOPT,ACLEAR,1 !Clear Source Areas
VSWEEP,84,1301,1298
VSWEEP,79,1288,1290

!Sweeping Bolster Transition Regions

FLST,5,3,4,ORDE,3
FITEM,5,2319
FITEM.5,2329
FITEM.5,2349
CM_Y1.LINE
LSEL...,P51X
CM_Y1.LINE
CMSEL...,Y
LESIZE_Y1,...20.1/3,...LSIZE: Bolster Outside Length
CM_CY1.LINE
CMSEL...,Y
FLST.5,2,4,ORDE,2
FITEM.5,2073
FITEM.5,2087
CM_Y1.LINE
LSSEL...,P51X
CM_Y1.LINE
CMSEL...,Y
LESIZE_Y1,...1,1,...LSIZE: on Outside Edge
CMDEL...,Y
CMDEL...,Y
VSWEEP,73,1254,1258
VSWEEP,78,1282,1278
! Sweeping Bolster Outside Volumes

---------------------------------------------
--- Meshing Upper Straight Section Only
---------------------------------------------

ALLSEL,ALL
FLST.5,28,6,ORDE,27
FITEM.5,1
FITEM.5,4
FITEM.5,5
FITEM.5,13
FITEM.5,15
FITEM.5,16
FITEM.5,18
FITEM.5,26
FITEM.5,27
FITEM.5,29
FITEM.5,31
FITEM.5,43
FITEM.5,44
FITEM.5,46
FITEM.5,47
FITEM.5,51
FITEM.5,55
FITEM.5,57
FITEM.5,58
FITEM.5,60
FITEM.5,73
FITEM.5,75
FITEM.5,76
FITEM.5,77
FITEM.5,78
FITEM.5,79
FITEM.5,81
FITEM.5,82
FITEM.5,84

VSEL...,P51X
ALLSEL.BELOW.VOLU...Selecting Volumes

---------------------------------------------
--- Selecting Volumes
---------------------------------------------

VSWEEP,46,1186,1184
VSWEEP,5,1123,1125
VSWEEP,15,1032,1070
VSWEEP,16,1074,1075
VSWEEP,44,1175,1176
VSWEEP,43,1171,1172
VSWEEP,29,1116,1117
VSWEEP,57,1216,1221
VSWEEP,58,1224,1225
VSWEEP,27,1108,1111
VSWEEP,61,1290,1295
VSWEEP,82,1298,1297
VSWEEP,76,1258,1274
VSWEEP,76,1278,1277
! Sweeping Commands

---------------------------------------------
--- Reflecting Mesh to Other Side
---------------------------------------------

ALLSEL,ALL
FLST.2,36,6,ORDE,17
FITEM.2,2
FITEM.2,3
FITEM.2,7
FITEM.2,12
VDELE.P51X,,1
ADELE, 1006,,1
FLST,2,4,4,ORDE,4
FITEM,2,2010
FITEM,2,2011
FITEM,2,2147
FITEM,2,2148
LDELE.P51X,,1 ! Deleting Other Side Volumes, etc.

KWPAVE, 1033
CSYS,4 ! Move CPlane and set active CS to CPlane

FLST,3,42,6,ORDE,17
FITEM,3,1
FITEM,3,4
FITEM,3,6
FITEM,3,13
FITEM,3,-18
FITEM,3,25
FITEM,3,31
FITEM,3,39
FITEM,3,-40
FITEM,3,42
FITEM,3,-44
FITEM,3,46
FITEM,3,47
FITEM,3,55
FITEM,3,60
FITEM,3,73
FITEM,3,-84
VSYMM.Z,P51X,,0,0 ! Reflect Volumes and Mesh

NSEL,S,LOC.Z,-1,1 ! Selecting Center Nodes
NUMMRG,NODE,, ! Merging Co-incident Nodes
NUMMRG,KP,, ! Merging Co-incident KP's, Lines, Areas
ALLSEL,ALL
NUMMRG,KP,, ! Merging Co-incident KP's, Lines, Areas
NUMCMP,ELEM ! Compressing Element Numbers
NUMCMP,NODE ! Compressing Node Numbers
WPSTYLE,,0 ! Turn Off CPlane Display

! Change Active Coordinate System to Global Coordinate System
CSYS,0

FINISH
FINISH

---------------------------------------------------------------------------------------------------

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/TITLE Performing Cut Boundary Interpolation
/FILENAME sub_mod1
/PREP7

NUMOFF.NODE 200000
! Offset Node Number by 200000

---------------------
| Selecting Cut Boundary Nodes
---------------------

FLST.5,44,5,ORDE,44
FITEM.5,1044
FITEM.5,1045
FITEM.5,1049
FITEM.5,1050
FITEM.5,1053
FITEM.5,1056
FITEM.5,1057
FITEM.5,1058
FITEM.5,1063
FITEM.5,1065
FITEM.5,1070
FITEM.5,1075
FITEM.5,1076
FITEM.5,1078
FITEM.5,1083
FITEM.5,1217
FITEM.5,1221
FITEM.5,1225
FITEM.5,1226
FITEM.5,1230
FITEM.5,1233
FITEM.5,1236
FITEM.5,1239
ASEL.S,.,P51X
ASEL.S,.,P51X

NSLA.S,1
! Selecting Nodes Attached to Areas
NWRITE,sub_boI_NODE,0
! Writing sub_boI_node

ALLSEL.ALL

FITEM.5,1045
FITEM.5,1049
FITEM.5,1050
FITEM.5,1053
FITEM.5,1056
FITEM.5,1065
FITEM.5,1070
FITEM.5,1075
FITEM.5,1076
FITEM.5,1078
FITEM.5,1083
FITEM.5,1217
FITEM.5,1225
FITEM.5,1226
FITEM.5,1230
FITEM.5,1233
FITEM.5,1236
ASEL.U,.,P51X
ASEL.U,.,P51X

NSLA.S,1
! Selecting Nodes Attached to Areas
NWRITE,sub_slr_NODE,0
! Writing sub_slr_node

ALLSEL.ALL

FLST.5,24,5,ORDE,24
FITEM.5,1021
FITEM.5,1034
FITEM.5,1044
FITEM.5,1046
FITEM.5,1050
FITEM.5,1056
FITEM.5,1065
FITEM.5,1070
FITEM.5,1075
FITEM.5,1076
FITEM.5,1078
FITEM.5,1083
FITEM.5,1125
FITEM.5,1129
FITEM.5,1142
FITEM.5,1151
FITEM.5,1158
FITEM.5,1164
FITEM.5,1167
FITEM.5,1169
FITEM.5,1172
FITEM.5,1176
FITEM.5,1184
FITEM.5,1192
FITEM.5,1193
FITEM.5,1197
ASEL.S,.,P51X
ASEL.S,.,P51X

NSLA.S,1
! Selecting Nodes Attached to Areas
NWRITE,sub_str2_NODE,0
! Writing sub_str2_node

ALLSEL.ALL
FINISH

--------- Performing Cut Boundary Interpolation

RESUME, May_31_Rubber.db ! Shell Element File

FLST, 5, 54, 5, ORDE, 30
ITEM, 5, 11
ITEM, 5, 18
ITEM, 5, 21
ITEM, 5, 23
ITEM, 5, 24
ITEM, 5, 26
ITEM, 5, 27
ITEM, 5, 33
ITEM, 5, 36
ITEM, 5, 53
ITEM, 5, 71
ITEM, 5, 117
ITEM, 5, 125
ITEM, 5, 129
ITEM, 5, 131
ITEM, 5, 133
ITEM, 5, 137
ITEM, 5, 138
ITEM, 5, 151
ITEM, 5, 153
ITEM, 5, 155
ITEM, 5, 253
ITEM, 5, 254
ITEM, 5, 259
ITEM, 5, 49
ITEM, 5, 689
ITEM, 5, 693
ITEM, 5, 1032
ASEL, S, ., P51X
FLST, 5, 7, 5, ORDE, 5
ITEM, 5, 33
ITEM, 5, 129
ITEM, 5, 122
ITEM, 5, 53
ITEM, 5, 71
ITEM, 5, 117
ITEM, 5, 125
ITEM, 5, 129
ITEM, 5, 131
ITEM, 5, 133
ITEM, 5, 137
ITEM, 5, 138
ITEM, 5, 151
ITEM, 5, 153
ITEM, 5, 155
ITEM, 5, 253
ITEM, 5, 254
ITEM, 5, 259
ITEM, 5, 689
ITEM, 5, 693
ITEM, 5, 1032
ASEL, U, ., P51X
ASEL, U, ., 143
ALLSEL, BELOW, AREA
    ! Selecting Required Areas and Elements Only

/POST1
INRES,
FILE, May_31_Rubber, rst,
    ! Read in Results
SET, FIRST
/TITLE, Performing Cut Boundary Interpolation

FLST, 5, 6, 5, ORDE, 4
    ! Interpolation on Bolster
ITEM, 5, 19
ITEM, 5, 117
ITEM, 5, 119
ITEM, 5, 122
ASEL, R, ., P51X
ALLSEL, BELOW, AREA
    ! Selecting Bolster Elements Only
CBDOF, sub_bol, NODE, sub_bol, CBDO, 0, .1

ALLSEL, ALL
FLST, 5, 54, 5, ORDE, 30

CBDOF, ., ., 0, .1
    ! Ensuring Active CS of Global CS

CSYS, 0
    ! Interpolation Command
FINISH

/READ7
/INPUT, sub_mod, cbdo, 1.0
/INPUT, sub_mod, cbdo, CB1, 0
FINISH

--- 233 ---
FILENAME: 7_1_frame_Main_INPUT

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| FEA of 930E Frame Displacements |
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_filename: 7_2_frame_geom_INPUT

---

*930E Frame Geometry Creation Routine*

/title 930E Frame Geometry

---

**Setup**

/NOFR
KEYW,PR_SET,1
KEYW,PR_STRUCT,1
/GO

/APREP7

ET,1,SHELL,93 ! Defining Shell Element Type
KEYOPT,1,4,0
KEYOPT,1,5,0
KEYOPT,1,6,0

! Defining Real Constants

IR,3,3,.... 1/8" Exhaust Plenum
IR,5,5,..... 5mm Thickness
IR,9,8,..... 8mm Thickness
IR,9,9,..... 9mm Thickness

! Material Properties

! 660 MPa Tensile Strength
! 620 Mpa Yield Strength
! Elongation in 50mm - 18%
! Modulus is Unknown

UIMP,1,EX,207000, ! Modulus in N/mm^2
UIMP,1,DENS,0.00000786, ! Density in kg/mm^3
UIMP,1,ALPF,....
UIMP,1,REFT,....
UIMP,1,NUXY,....
UIMP,1,PRXY,....
UIMP,1,GXY,....
UIMP,1,MU,....
UIMP,1,DAMP,....

---

Timeline Torsion Tubes and Rear Section

---

K,0,-280.5-640,-3400-240,
! KP at Center of Rear Torsion Tube

wpct,0.0,90
KWP,AVE,1
PCIRC,300,0.360, ! Rear T-Tube Circle
ADELE,1
WPCSYS,1
FLST,3,4,4,ORDE,2
FITEM,3,1
FITEM,3,4
LGEN,2,P51X,191,0
WPSTYLE,0
FLST,3,2,3,ORDE,2
FITEM,3,7
FITEM,3,9

---

KGEN,2,P51X,0.457,0
LSTR,3,7
LSTR,6,2
LSTR,9,5
LSTR,4,8
LSTR,7,10
LSTR,9,11

! Lines to Main Rail

WPSTYLE,1
wpct,0.0,90
KWP,AVE,1
CSYS,4
K,3240.470,
KWP,AVE,12
PCIRC,353.52,0.360, ! Center T-Tube Circle
ADELE,1

FLST,3,2,3,ORDE,2
FITEM,3,14
FITEM,3,16
KGEN,2,P51X,0.813-1043281654,0
LSTR,17,14
LSTR,18,16

! Lines to Main Rail

CSYS,0
FLST,3,1,3,ORDE,1
FITEM,3,17
KGEN,2,P51X,460-535.52,0
FLST,3,1,3,ORDE,1
FITEM,3,16
KGEN,2,P51X,0.113,0
KWP,AVE,1
CSYS,4
LSTR,20,19
KWP,AVE,1
CSYS,4

! active CS is in plane of Main Rail

wpct,240.0,227.0
PCIRC,1522,0.360,
CSYS,4
FLST,3,4,4,ORDE,2
FITEM,3,22
FITEM,3,25
FITEM,3,30
LGEC,2,P51X,-273.930+25,0
PCIRC,1522+60,0.360,
FLST,3,4,4,ORDE,2
FITEM,3,30
FITEM,3,33
LGEC,2,P51X,-273.930+25,0
FLST,2,2,5,ORDE,2
FITEM,2,1
FITEM,2,2
ADELE,P51X

! Pivot and Rear Strut Pin Holes

ADELE,21
KDELE,20

! Deleting Construction Line

CSYS,4
K,15.0*30.3227,0
K,735.227,0
K,735.227+664.0,
LSTR,20,37
LSTR,37,38
LSTR,38,34
LSTR,20,29
LSTR,31,35

! Rear Frame Lines
Center Portion of Bumper and Front Tube

Extruding Main Rails

Front Main Rail

Extrude Rear Hole Areas

Closing Main Rails
\textbf{Strut Attachment Areas}

\begin{verbatim}
| STRUT | 104 | 139 | 101 |
\end{verbatim}

\textbf{CSYS,4}

\begin{verbatim}
K, -305, 119.19
K, -192.5.17*19.19
K, .-95.7.19+185+265.
\end{verbatim}

\textbf{FLST,3.1.0,ORDE,1}

\textbf{FITEM,3.101}

\textbf{KGEN,2.P51X, .92.5, .0,0}

\textbf{LSTR, 101, 167}

\textbf{LSTR, 101, 167}

\textbf{LSTR, 165, 165}

\textbf{LSTR, 165, 164}

\textbf{LSTR, 164, 163}

\textbf{LSTR, 163, 104}

\textbf{wprot, 0.90, 0.0}

\textbf{KWPAVE, 165}

\textbf{FLST, 2.3.5, ORDE, 3}

\textbf{FITEM, 2.44}

\textbf{FITEM, 2.100}

\textbf{FITEM, 2.111}

\textbf{ASBW, P51X}

\textbf{KWPAVE, 165}

\textbf{FLST, 2.3.5, ORDE, 3}

\textbf{FITEM, 2.130}

\textbf{FITEM, 2.132}

\textbf{FITEM, 2.133}

\textbf{ASBW, P51X}

\textbf{LSTR, 167, 100}

\textbf{LSTR, 163, 51}

\textbf{FITEM, 2.291}

\textbf{FITEM, 2.161}

\textbf{FITEM, 2.283}

\textbf{AL, P51X}

\textbf{LSTR, 169, 165}

\textbf{LSTR, 172, 166}

\textbf{FITEM, 2.283}

\textbf{FITEM, 2.285}

\textbf{FITEM, 2.286}

\textbf{FITEM, 2.287}

\textbf{FITEM, 2.288}

\textbf{AL, P51X}

\textbf{FLST, 2.4.4}

\textbf{FITEM, 2.293}

\textbf{FITEM, 2.280}

\textbf{FITEM, 2.294}

\textbf{FITEM, 2.295}

\textbf{AL, P51X}

\textbf{FLST, 2.4.4}

\textbf{FITEM, 2.132}

\textbf{FITEM, 2.294}

\textbf{FITEM, 2.279}

\textbf{FITEM, 2.278}

\textbf{AL, P51X}

\textbf{FLST, 2.3.4}

\textbf{FITEM, 2.278}

\textbf{FITEM, 2.168}

\textbf{FITEM, 2.290}

\textbf{AL, P51X}

\textbf{LSTR, 174, 166}

\textbf{LSTR, 165, 168}

\textbf{FLST, 2.3.4}

\textbf{FITEM, 2.302}

\textbf{FITEM, 2.286}

\textbf{FITEM, 2.284}

\textbf{AL, P51X}

\textbf{FLST, 2.3.4}

\textbf{FITEM, 2.303}

\textbf{FITEM, 2.286}

\textbf{FITEM, 2.293}

\textbf{AL, P51X}

\textbf{KWPAVE, 173}

\textbf{wprot, 355/2, 0.0}

\textbf{FLST, 3.7.5, ORDE, 5}

\textbf{FITEM, 3.130}

\textbf{FITEM, 3.132}

\textbf{FITEM, 3.133}

\textbf{FITEM, 3.137}

\textbf{FITEM, 3.140}

\textbf{ARSYM, X, P51X, .0,0}

\textbf{NUMMRRG, KP, .0,0}

\textbf{Merging Coincident Items}
Deleting Unneeded Areas on Centerline

Adding To Fillet Areas on Strut Mounts

Returning WPlane and Active CS to Global Cartesian

/EOF
930E Frame FEA Meshing Routine

TITLE, 930E Frame FEA Mesh

Defining Material Thicknesses

!PREP7

! Defining Real Constants
R,13,12.7, 12.7mm Thickness
R,15,13.7, 13.7mm Thickness
R,25,25, 25mm Thickness
R,26,26, 26mm Thickness
R,30,30.5, 30.5mm Thickness
R,32,32, 32mm Thickness
R,33,33, 33mm Thickness
R,36,36, 36mm Thickness
R,38,38, 38mm Thickness
R,41,41, 41mm Thickness
R,42,42, 42mm Thickness
R,45,45, 45mm Thickness
R,46,46, 46mm Thickness
R,51,51, 51mm Thickness
R,127,127, 127mm Thickness

Rear Section

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<tr>
<th>FLST, 5, 4, 5, ORDE, 2</th>
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<tbody>
<tr>
<td>FITEM, 5, 1</td>
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<tr>
<td>FITEM, 5, 4</td>
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<tr>
<td>CM, Y, AREA</td>
</tr>
<tr>
<td>ASEL, ... P51X</td>
</tr>
<tr>
<td>CM, Y, AREA</td>
</tr>
<tr>
<td>CMSEL, S, Y</td>
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<td>CMSEL, S, Y</td>
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<tr>
<td>AATT, 1, 28, 1, 0</td>
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<tr>
<td>CMSEL, S, Y</td>
</tr>
<tr>
<td>CMDELE, Y</td>
</tr>
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<td>CMDELE, Y, Y, Y,</td>
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</table>

<table>
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<tr>
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<tr>
<td>CMDELE, Y</td>
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<tr>
<td>CMDELE, Y, ! Outer Rear Torsion Tube</td>
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<table>
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Perimeter Areas Rear Section

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<td>FITEM, 5, 63</td>
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<td>FITEM, 5, -68</td>
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<td>CM, Y, AREA</td>
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<td>ASEL, ... P51X</td>
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<td>AATT, 1, 38, 1, 0</td>
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<tr>
<td>CMDELE, Y</td>
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<td>CMDELE, Y</td>
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Pin Hole Inside Areas

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<td>ASEL, ... P51X</td>
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<td>CM, Y, AREA</td>
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<td>CMSEL, S, Y</td>
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<td>AATT, 1, 28, 1, 0</td>
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<tr>
<td>CMDELE, Y</td>
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<td>CMDELE, Y</td>
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Side Areas

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<td>FITEM, 5, 55</td>
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<tr>
<td>FITEM, 5, -57</td>
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<td>AATT, 1, 45, 1, 0</td>
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<tr>
<td>CMSEL, S, Y</td>
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CMDELE,_Y Top and Bottom Plate Thickness
CMDELE,_Y1
FLST,5.2,5,ORDE,2
FITEM,5.43
FITEM,5.125
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 45, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Side Plate Thickness
CMDELE,_Y1
FLST,5.3,5,ORDE,3
FITEM,5.5
FITEM,5.58
FITEM,5.59
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 32, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Casting Side Thickness
CMDELE,_Y1
FLST,5.8,5,ORDE,4
FITEM,5.15
FITEM,5.18
FITEM,5.69
FITEM,5.72
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 30, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Center Torsion Tube
CMDELE,_Y1
FLST,5.2,5,ORDE,2
FITEM,5.122
FITEM,5.124
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 33, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Casting Near Horse Collar
CMDELE,_Y1
FLST,5.4,5,ORDE,4
FITEM,5.86
FITEM,5.102
FITEM,5.105
FITEM,5.107
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 33, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Lower Section
CMDELE,_Y1
FLST,5.4,5,ORDE,4
FITEM,5.46
FITEM,5.101
FITEM,5.104
FITEM,5.108
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 41, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Lower transition Region
CMDELE,_Y1
FLST,5.4,5,ORDE,4
FITEM,5.7
FITEM,5.97
FITEM,5.109
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 46, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Areas Around Main Rail
CMDELE,_Y1
FLST,5.4,5,ORDE,4
FITEM,5.113
FITEM,5.114
FITEM,5.116
FITEM,5.117
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 46, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

CMDELE,_Y Casting Near Horse Collar
CMDELE,_Y1
FLST,5.4,5,ORDE,4
FITEM,5.119
FITEM,5.120
FITEM,5.121
CM_Y,AREA
ASEL...,P51X
CM_Y1,AREA
CMSEL_S,Y
CMSEL_S,Y1
AATT, 1, 25, 1, 0
CMSEL_S,Y
CMDELE,_Y
CMDELE,_Y1

245
CMSEL.S._Y
CMDELE.Y
CMDELE.Y1  ! Top Collar Top and Bottom Plates

FLST,5,4,5,ORDE,2
FITEM,5,110
FITEM,5,121
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 19, 1, 0
CMDELE.Y
CMDELE.Y1  ! Circular Cutout Pipe

FLST,5,2,5,ORDE,2
FITEM,5,99
FITEM,5,103
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 33, 1, 0
CMDELE.Y
CMDELE.Y1  ! Top Collar Side Plates

FLST,5,13,5,ORDE,10
FITEM,5,44
FITEM,5,100
FITEM,5,110
FITEM,5,112
FITEM,5,129
FITEM,5,131
FITEM,5,133
FITEM,5,136
FITEM,5,143
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 30, 1, 0
CMDELE.Y
CMDELE.Y1  ! Areas Near Strut Mount

FLST,5,8,5,ORDE,7
FITEM,5,115
FITEM,5,130
FITEM,5,138
FITEM,5,139
FITEM,5,141
FITEM,5,145
FITEM,5,147
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 36, 1, 0
CMDELE.Y
CMDELE.Y1  ! Strut Support Fillets

FLST,5,5,5,ORDE,5
FITEM,5,44
FITEM,5,131
FITEM,5,133
FITEM,5,134
FITEM,5,143
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 38, 1, 0
CMDELE.Y
CMDELE.Y1  ! Strut Mount Outside Face Areas

FLST,5,2,5,ORDE,2
FITEM,5,137
FITEM,5,144
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 51, 1, 0
CMDELE.Y
CMDELE.Y1  ! Top Strut Mount Areas

FLST,5,2,5,ORDE,2
FITEM,5,132
FITEM,5,142
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 127, 1, 0
CMDELE.Y
CMDELE.Y1  ! Bottom Strut Mount Areas

-------------------------------------------------------------------------------------------------
| Front Section |

-------------------------------------------------------------------------------------------------
| Top and Bottom of Main Rail |

FLST,5,2,5,ORDE,2
FITEM,5,123
FITEM,5,127
CM._YAREA
ASEL.,..P51X
CM._Y1AREA
CMSEL.S._Y
CMSEL.S._Y1
AATT. 1, 33, 1, 0
CMDELE.Y
CMDELE.Y1  ! Strut Support Fillets
CMDELE._Y  ! Sides of Main Rail
CMDELE._Y1  FLST,5.2,5,ORDE,2
FLST,5.2,5,ORDE,2
FITEM,5,89
FITEM,5,95
CM_Y,AREA
CM_Y1,AREA
ASEL,,,PS1X
CM, Y1,AREA
CMSEL,S,Y
CMSEL,S,Y1
AATT, 1, 33, 1, 0
CMSEL,S,Y
CMDELE._Y
CMDELE._Y1  ! Top and Bottom of Tapered Section
R,13,12,7, . . . , 12.7 mm Thickness
FLST,5,2,5,ORDE,2
FLST,5,2,5,ORDE,2
FITEM,5,14
FITEM,5,21
CM_Y,AREA
CM_Y1,AREA
ASEL,,.,PS1X
ASEL,,.,PS1X
CMSEL,S,Y
CMSEL,S,Y1
AATT, 1, 13, 1, 0
CMSEL,S,Y
CMDELE._Y
CMDELE._Y1  ! Top and Bottom of Tapered Section
FLST,5,4,5,ORDE,4
FITEM,5,19
FITEM,5,22
FITEM,5,87
FITEM,5,98
CM_Y,AREA
CM_Y1,AREA
ASEL,,.,PS1X
ASEL,,.,PS1X
CMSEL,S,Y
CMSEL,S,Y1
AATT, 1, 13, 1, 0
CMSEL,S,Y
CMDELE._Y
CMDELE._Y1  ! Sides of Front Section
FLST,5,2,5,ORDE,2
FITEM,5,26
FITEM,5,28
CM,,Y,AREA
ASEL,,.,PS1X
CM_Y1,AREA
CMSEL,S,Y
CMSEL,S,Y1
AATT, 1, 19, 1, 0
CMSEL,S,Y
CMDELE._Y
CMDELE._Y1  ! Top and Bottom of Front Section
FLST,2,2,5,ORDE,2
FITEM,2,31
FITEM,2,38
ADELETE,PS1X
LDELETE, 103,,1
FLST,2,4,4,ORDE,2
FITEM,2,85
FITEM,2,77
LCOMB,PS1X,,0
FLST,2,2,5,ORDE,2
FITEM,2,104
FITEM,2,118
LCOMB,PS1X,,0
FLST,2,4,4
FITEM,2,104
FITEM,2,266
FITEM,2,101
FITEM,2,117
AL,PS1X
FLST,2,2,5,ORDE,2
FITEM,2,82
FITEM,2,83
FITEM,2,255
AL,PS1X  ! Repairing Front T-Tube
CMDELE._Y1  ! Top and Bottom of Tapered Section
FLST,5,10,5,ORDE,7
FITEM,5,20
FITEM,5,23
FITEM,5,25
FITEM,5,30
FITEM,5,31
FITEM,5,37
FITEM,5,40
CM_Y,AREA
CM_Y1,AREA
ASEL,,.,PS1X
ASEL,,.,PS1X
CMSEL,S,Y
CMSEL,S,Y1
AATT, 1, 19, 1, 0
CMSEL,S,Y
CMDELE._Y
CMDELE._Y1  ! Thickness Front T-Tube
FLST,5,8,5,ORDE,5
FITEM,5,27
FITEM,5,29
FITEM,5,32
FITEM,5,36
FITEM,5,41
CM_Y,AREA
CM_Y1,AREA
ASEL,,.,PS1X
ASEL,,.,PS1X
CMSEL,S,Y
CMSEL,S,Y1
AATT, 1, 13, 1, 0
CMSEL,S,Y
CMDELE._Y
CMDELE._Y1  ! Thickness Front Bumper
ADELETE, 60,,1
FLST,2,4,5,ORDE,4
FITEM,2,42
FITEM,2,45
FITEM,2,47
FITEM,2,52
ADELETE,PS1X  ! Deleting False Areas
Free Meshing

/VIEW_1,1.1.1
/AANG, 1
/AПLOT
/AUTO
/REP,FAST  ! View Commands

WPSTYI'E,.,,,1
/MSHКEY,5
/FLST,5,163,5,ORDE,2
/FITEM,5,1
/FITEM,5,163
/CM,_Y,AREA
/ASEL,.,.,51X
/CM,_Y,AREA
/CHKMSH,'AREA'
/CMSEL,5,_,Y
/AMESH,_,Y1
/CMDEL,_,Y
/CMDEL,_,Y1
/CMDEL,_,Y2  ! Free Meshing All Areas

/FLST,3,163,5,ORDE,2
/FITEM,3,1
/FITEM,3,163
/ARSYMIX,51X,.,0,0  ! Reflect Model

/NUMMRG,ALL,.,.  ! Merge Coincident Items...

*SET, nodes,ndlnqr(0,12)
*SET, elems,elmqr(0,12)
*SET, sol_mins, ((0.6  
8)*(nodes**2)+0.0005*nodes+0.022)

/EOF
Filename: 7_4_frame_loads_INPUT

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<td>*SET,RFpres,40.9</td>
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<td>*SET,LFpres,60.9</td>
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<td>DOFSEL,S,FX,FY,FZ,MX,MY,MZ</td>
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<td>FITEM,5.214</td>
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<td>ASEL,S,,P51X</td>
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<tr>
<td>! Define Elements between Co-incident Nodes</td>
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<td>*GET,Nmax,NODE,0,NUM,MAX</td>
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<td>D,100000,UYS,0, Nmax,1</td>
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<td>*SET,Nmax Uy=0 On Top of Springs</td>
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<table>
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<td>*GET,count,NODE,0,COUNT # of Selected Nodes</td>
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ALLSEL, BELOW AREA
NSLAS, S.1 ! Selecting Left Rear Strut Pin Nodes

! Strut Force in Newtons
*SET, LRfstrut, LRpres*(100**2)*9.81*3.14/4*(0.305**2)
*GET, count, NODE, 0, COUNT ! # of Selected Nodes
*SET, fnode, LRfstrut/count ! Newtons/node

F.ALL, FY, fnode ! Applying Force to Nodes
*SET, fnode
*SET, count

ALLSEL, ALL

---------------------------------------------------------------------------
| Right Front Strut Mount 
---------------------------------------------------------------------------

! Strut Force in Newtons
*SET, RFfstrut, RFpres*(100**2)*9.81*3.14/4*(0.400**2)

KSEL, S., 177
NSLK, S ! Selecting Point Node

! Applying Forces to Point Node
*AFUN, DEG
F.ALL, FY, RFfstrut*COS(9)
F.ALL, FZ, RFfstrut*SIN(9)

ALLSEL, ALL

---------------------------------------------------------------------------
| Left Front Strut Mount 
---------------------------------------------------------------------------

! Strut Force in Newtons
*SET, LFfstrut, LFpres*(100**2)*9.81*3.14/4*(0.400**2)

KSEL, S., 343
NSLK, S ! Selecting Point Node

! Applying Forces to
Point Node
*AFUN, DEG
F.ALL, FY, LFfstrut*COS(9)
F.ALL, FZ, LFfstrut*SIN(9)

ALLSEL, ALL

---------------------------------------------------------------
| Constraining to Improve Numerical Stability 
---------------------------------------------------------------

*IF, firstpas, NE, 1, THEN
FLST, 2, 2, 3, ORDE, 2 ! Ux=0 On Side Keypoints
ITEM, 2, 84
ITEM, 2, 110
DK, P51X, 0., 0., UX, . . . .

FLST, 2, 2, 3, ORDE, 2 ! Uz=0 Near Rear Body Pin
ITEM, 2, 31
ITEM, 2, 212
DK, P51X, 0., 0., UZ, . . . .

*ENDIF
FINISH
**Filename: 7_5_frame_post_INPUT**

930E Frame FEA Post Processing Routine

---

/TITLE, 930E Frame FEA Post Processing

---

Defining Paths Along Main Rails

---

*WRITE,L.Path(1,1),L.Path(1,2),L.Path(1,3),L.Path(1,4),L.Path(1,5),..,
     (F12.4,F12.1,F12.4,F12.4,F12.4,F12.4)
*CFCLOSE

---

Combining Load Cases to Check Linearity

---

/EOF

---


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<td>LCDEF.3.3</td>
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<td>LCASE.1</td>
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<td>LCOPER.ADD.2</td>
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<td>LCOPER.ADD.4</td>
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/TITLE Load Case 10: Added Strut Pressures

LCWRITE.10, ..,

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<td>FITEM.5.214</td>
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<td>ASEL.S, P51X</td>
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<td>Selecting Main Rail Area</td>
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<td>ASEL.BELLO.</td>
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<td>PATH.R.Path(2,30,40), FPATH.F51X,1</td>
<td>Path on Right Rail</td>
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PDEFF.STAT
AVPRIN.0.0.
PDEFF.,U,Y,AVG Mapping Results to Path

PAGET,L.Path,TABL Storing Path Items in Array

---

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<td>FITEM.2.14252</td>
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<td>PATH.L.Path(2,30,40), PPATH.F51X,1 Path on Left Rail</td>
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</table>

PDEFF.STAT
AVPRIN.0.0.
PDEFF.,U,Y,AVG Mapping Results to Path

PAGET,L.Path,TABL Storing Path Items in Array

---

Writing Path Data to Text File

---

/EOF

---

\*CFOPEN,XL_Set_10_R_Path.txt,

\*CFOPEN,XL_H25_D125_R_Path.txt,

\*WRITE,R.Path(1,1),R.Path(1,2),R.Path(1,3),R.Path(1,4),R.Path(1,5),
     (F12.4,F12.1,F12.4,F12.4,F12.4,F12.4)
\*CFCLOSE

---

\*CFOPEN,XL_H25_D125_L_Path.txt,

---

251
**Filename: 8_1_full_Main_INPUT**

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<td>!load</td>
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<tr>
<td>/CLEAR,START</td>
<td>Clear and Start New</td>
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<td>RESUME,joined.db</td>
<td>Call in Database</td>
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<td>/FINLAM,loaded</td>
<td>! Apply One Load</td>
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<td>/FINLAM,loaded</td>
<td>I Save Joined Database</td>
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<td>/EOF</td>
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<td>Creating Strut Support Springs</td>
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<td>!strut</td>
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<td>/CLEAR,START</td>
<td>Clear and Start New</td>
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<td>RESUME,loaded.db</td>
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<td>! Set Strut Displacements as Parameters</td>
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252
### Joining Both FEA Models into One

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### Cutting Main Rails for Rubber Pad Support

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Re-Meshing Frame Main Rail Areas

Creating Rubber Pad Connection

PREP7

255
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| AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X | AL.P51X |
| FITEM, 2.2280 | FITEM, 2.2275 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2248 | FITEM, 2.2248 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.3976 | FITEM, 2.2286 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2248 | FITEM, 2.2248 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2286 | AL.P51X |
| FLST, 2.4.4, " | FITEM, 2.2220 | FITEM, 2.2276 | FITEM, 2.3988 | FITEM, 2.2275 | FITEM, 2.2277 | FLST, 2.4.4, " | FITEM, 2.2279 | FITEM, 2.3986 | FITEM, 2.2167 | FLST, 2.4.4, " | FITEM, 2.2279 | FITEM, 2.3986 | FITEM, 2.2167 | FLST, 2.4.4, " | FITEM, 2.2279 | FITEM, 2.3986 |
| AL.P51X | FLST, 2.3.4, " | FITEM, 2.2279 | FITEM, 2.2209 | FITEM, 2.2277 | FLST, 2.4.4, " | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2279 | FITEM, 2.3986 | FITEM, 2.2167 | FLST, 2.4.4, " | FITEM, 2.2279 | FITEM, 2.3986 | FITEM, 2.2167 | FLST, 2.4.4, " | FITEM, 2.2279 | FITEM, 2.3986 |
| FITEM, 2.2276 | FITEM, 2.2226 | FITEM, 2.3990 | FITEM, 2.2261 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2276 | FITEM, 2.2226 | FITEM, 2.3990 | FITEM, 2.2261 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2276 | FITEM, 2.2226 | FITEM, 2.3990 | FITEM, 2.2261 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2276 |
| FLST, 2.4.4, " | FITEM, 2.2278 | FITEM, 2.3983 | FITEM, 2.2252 | AL.P51X | FLST, 2.4.4, " | FLST, 2.4.4, " | FITEM, 2.2278 | FITEM, 2.3983 | FITEM, 2.2252 | AL.P51X | FLST, 2.4.4, " | FLST, 2.4.4, " | FITEM, 2.2278 | FITEM, 2.3983 | FITEM, 2.2252 | AL.P51X | FLST, 2.4.4, " |
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| FLST, 2.4.4, " | FITEM, 2.2284 | FITEM, 2.3992 | FITEM, 2.2281 | FLST, 2.4.4, " | FITEM, 2.2284 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2284 | FITEM, 2.3992 | FITEM, 2.2281 | FLST, 2.4.4, " | FITEM, 2.2284 | AL.P51X | FLST, 2.4.4, " | FITEM, 2.2284 | FITEM, 2.3992 |
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UIMP.3.EX, 270000/1000, ! Material #3 = Rubber
UIMP.3.DENS., 7.86e-06/100,
UIMP.3.ALPX, ...
UIMP.3.REFT, ...
UIMP.3.NUXY, ...
UIMP.3.PRXY, 0.3,
UIMP.3.GXY, ...
UIMP.3.MU, ...
UIMP.3.DAMP, ...
VATT. 3, 13, 3, 0 ! Setting Volume Attributes

---

! Defining Nodes in Centers of Circles
FITEM.4,19195
FITEM.4,19207
FITEM.4,87831
FITEM.4,10463
NGEN.2,2000000,P51X, ...,167/2, ...,1,
FLST.4,4,1,ORDE,4
FITEM.4,1121
FITEM.4,5091
FITEM.4,10716
FITEM.4,14586
NGEN.2,2000000,P51X, ...,152/2, ...,1,
FLST.5,811,1,ORDE,5
FITEM.5,19207
FITEM.5,19210
FITEM.5,19430
FITEM.5,19505
FITEM.5,2019207
NSEL.R, ..,P51X
*GET,count,NOOE,0,COUNT
*GET,Nindex,NOOE,0,NUM,MIN
*GET,Nmaster,NOOE,0,NUM,MAX
*DO,index,0,count+10,1
E.Nindex,Nmaster
*GET Next, NODE,Nindex,NTH
*IF,Next, EQ,Nmaster,EXIT
*SET,Nindex,Next
*ENDDO
ALLSEL.ALL,NOOE ! Select All Nodes

---

! Right-Hinge Body Outer-Side Wagon Wheel
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FITEM.5,19210
FITEM.5,19430
FITEM.5,19505
FITEM.5,2019207
NSEL.R, ..,P51X
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*GET,Nindex,NOOE,0,NUM,MIN
*GET,Nmaster,NOOE,0,NUM,MAX
*DO,index,0,count+10,1
E.Nindex,Nmaster
*GET Next, NODE,Nindex,NTH
*IF,Next, EQ,Nmaster,EXIT
*SET,Nindex,Next
*ENDDO
ALLSEL.ALL,NOOE ! Select All Nodes

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! Right-Hinge Body Inner-Side Wagon Wheel
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CP.12.UY.2087831.2014686
CP.13.UZ.2087831.2014686
CP.14.ROTY.2087831.2014686
CP.15.ROTZ.2087831.2014686

! Left Inner
CP.16.UX.2104653.2010716
CP.17.UY.2104653.2010716
CP.18.UZ.2104653.2010716
CP.19.ROTY.2104653.2010716
CP.20.ROTZ.2104653.2010716

*SET.count
*SET.Nindex
*SET.Nmaster
*SET.index
*SET.Next

ALLSEL,ALL
FINISH

/EOF
**Filename: 8_3_full_struts_INPUT**

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! Creating Strut Supports...
!----------------------------------------

/PREP7

!----------------------------------------
! Rear Strut Rigid Regions
!----------------------------------------

FLST.5,8,5,ORDE,4
FITEM.5,73
FITEM.5,-76
FITEM.5,208
FITEM.5,211
ASEL,R,P51X
ALLSEL,BELLOW,AREA

FLST.3,2,3,ORDE,2
FITEM.3,28
FITEM.3,292
KGEN,2,P51X, .,305/2,-152/2,. ,0

LSTR. 292, 1221
LSTR. 1221, 221
LSTR. 28, 1220
LSTR. 1220, 126

FLST.2,3,4
FITEM.2,2339
FITEM.2,507
FITEM.2,2340
AL.P51X

FLST.2,3,4
FITEM.2,2342
FITEM.2,199
FITEM.2,2341
AL.P51X

FLST.5,2,5,ORDE,2
FITEM.5,1154
FITEM.5,-1155
CM,Y,AREA
ASEL,. ,P51X
CM,Y,AREA
CMSEL,. Y
CMSEL,.Y1
AATT,. 1, 13, 1, 0
CMSEL,. Y
CMDELE,. Y
CMDELY,. Y1
MESH,. 0

FLST.5,2,5,ORDE,2
FITEM.5,1154
FITEM.5,-1155
CM,Y,AREA
ASEL,. ,P51X
CM,Y,AREA
CHMKS,. AREA'
CMSEL,. Y
AMESH,.Y1
CMDELE,. Y
CMDELY,. Y1
CMDELY,. Y2
FLST.2,362,1,ORDE,11
FITEM.2,2104658
FITEM.2,1144
FITEM.2,-1167
FITEM.2,5030
FITEM.2,-5053
FITEM.2,6307
FITEM.2,-6570
FITEM.2,2104678
FITEM.2,2104699
FITEM.2,2104727
FITEM.2,2104753
CERIG,P51X,. ALL, , 

FLST.3,302,1,ORDE,11
FITEM.2,2104654
FITEM.2,10739
FITEM.2,-10762
FITEM.2,14625
FITEM.2,14648
FITEM.2,15902
FITEM.2,-16165
FITEM.2,2104656
FITEM.2,-2104677
FITEM.2,2104700
FITEM.2,-2104726
CERIG,P51X,. ALL, , 

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FLST.2.2,1,ORDE,2
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FITEM.2,104655
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FITEM.3,292
KGEN,2,P51X, ,305/2,-152/2,. ,0

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LSTR. 1221, 221
LSTR. 28, 1220
LSTR. 1220, 126

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AL.P51X
FLST.2.3,4
FITEM.2,2342
FITEM.2,199
FITEM.2,2341
AL.P51X

FLST.5,2,5,ORDE,2
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FITEM.5,-1155
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CM,Y,AREA
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CMSEL,.Y1
AATT,. 1, 13, 1, 0
CMSEL,. Y
CMDELE,.Y
CMDELY,. Y1
MESH,. 0

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FITEM.5,-1155
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ASEL,. ,P51X
CM,Y,AREA
CHMKS,. AREA'
CMSEL,. Y
AMESH,.Y1
CMDELE,. Y
CMDELY,. Y1
CMDELY,. Y2

ALLSEL, ALL
R.2999,10000, ,1 , 10000 N/mm Reduced
Spring Constant

FLST.4,2,1,ORDE,2
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FITEM.4,2104655
IR
NGEN,2,1000000,P51X,.,-1500-850,. ,1

! Rigid Region Master Nodes
TYPE,. 4
MAT,. 1
REAL,. 2999
ESYS,. 0
SENUM,. TSHAP.LINE

! Element type Settings

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FITEM.2,3104654
E,P51X

FLST.2.2,1
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FITEM.2,3104655
E,P51X

D,3104654,. ALL, , ,
D,3104654,. dispLR,. ,UY, , ,

! Left Rear Strut Displacement

D,3104655,. ALL, , ,
D,3104655,. dispPR,. ,UY, , ,

! Right Rear Strut Displacement
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<td>FLST,2.5,4</td>
<td></td>
</tr>
<tr>
<td>FITEM,2,2346</td>
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<tr>
<td>FITEM,2,2357</td>
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<tr>
<td>FITEM,2,2348</td>
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<tr>
<td>FITEM,2,2349</td>
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</tr>
<tr>
<td>FITEM,2,2350</td>
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</tr>
<tr>
<td>AL.P51X</td>
<td>! Creating Areas</td>
</tr>
<tr>
<td>FLST,5.2,5.ORDE,2</td>
<td></td>
</tr>
<tr>
<td>FITEM,5.1156</td>
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<tr>
<td>FITEM,5.-1157</td>
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<tr>
<td>CM_Y.AREA</td>
<td></td>
</tr>
<tr>
<td>ASEL,.,.P51X</td>
<td></td>
</tr>
<tr>
<td>CM_Y1.AREA</td>
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</tr>
<tr>
<td>CMSSEL_S.._Y</td>
<td></td>
</tr>
<tr>
<td>CMSSEL_S.._Y1</td>
<td></td>
</tr>
<tr>
<td>AATT, 1, 13, 1, 0</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>FLST,2.314,1.ORDE,42</td>
<td></td>
</tr>
<tr>
<td>FITEM,2.3104661</td>
<td></td>
</tr>
</tbody>
</table>
I Right FootStrut Offset

D.4104660,dispRF*COS(9),... UY,
D.4104660,dispRF*SIN(9),... UZ,

I Left Front Strut Displacement
D.4104660,... ALL,...
D.4104660,dispLF*COS(9),... UY,
D.4104660,dispLF*SIN(9),... UZ,

I Right Front Strut Displacement
D.4104660,... ALL,...
D.4104660,dispRF*COS(9),... UY,
D.4104660,dispRF*SIN(9),... UZ,

L.PLOT

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Additional Restraints to Improve Stability</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
</tbody>
</table>

FLST.2.2.3,ORDE.2
FITEM.2.3104661
FITEM.2.3104660

![Image](http://example.com/image.jpg)

I Left Front Strut Rigid Region

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Strut Spring Elements</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
</tbody>
</table>

ALLSEL,ALL

*AFUN,DEG

I Rigid Region Master Nodes
I Copy Nodes down from Rear Strut

FLST.4.2.1,ORDE.2
FITEM.4.3104661,IL
FITEM.4.3104660,IR
NGEN.2,1000000,P51X,...,2500*COS(9),-
2500*SIN(9),1,

TYPE, 4
MAT, 1
REAL, 2899
ESYS, 0
SECNUM,
TSHAP.LINE

I Element type Settings

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FINISH</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
</tbody>
</table>

FLST.2.2.1
FITEM.2,3104660
FILE: 8_4_full_adjust_INPUT

! Combined 930E Frame and Dump Body FEA Model

FINISH
/SOLU ! Set Strut Displacements

/TITLE, Load Set 1: Cre Load Only

*SET, fmtdiff, 0 ! Newtons
*SET, reardiff, 0 ! Newtons
*SET, dispLF, (fmtdiff/2)/100000
*SET, dispRF, (fmtdiff/2)/100000
*SET, dispLR, (reardiff/2)/100000
*SET, dispRR, (reardiff/2)/100000

! Left Front Strut Displacement
D.4104661, . . . ALL, . . .
D.4104661, dispLF*COS(9), . . . UY . . .
D.4104661, dispLF*SIN(9), . . . UZ . . .

! Right Front Strut Displacement
D.4104660, . . . ALL, . . .
D.4104660, dispRF*COS(9), . . . UY . . .
D.4104660, dispRF*SIN(9), . . . UZ . . .

! Left Rear Strut Displacement
D.3104654, . . . ALL, . . .
D.3104654, dispLR, . . . UY . . .
D.3104655, . . . ALL, . . .
D.3104655, dispRR, . . . UY . . .

LSWRITE, 1,
SFEDELE, ALL, ALL, PRES

/TITLE, Load Set 2: Rack Front Difference Only

*SET, fmtdiff, 271155 ! Newtons
*SET, reardiff, 0 ! Newtons
*SET, dispLF, (fmtdiff/2)/100000
*SET, dispRF, (fmtdiff/2)/100000
*SET, dispLR, (reardiff/2)/100000
*SET, dispRR, (reardiff/2)/100000

! Left Front Strut Displacement
D.4104661, . . . ALL, . . .
D.4104661, dispLF*COS(9), . . . UY . . .
D.4104661, dispLF*SIN(9), . . . UZ . . .

! Right Front Strut Displacement
D.4104660, . . . ALL, . . .
D.4104660, dispRF*COS(9), . . . UY . . .
D.4104660, dispRF*SIN(9), . . . UZ . . .

! Left Rear Strut Displacement
D.3104654, . . . ALL, . . .
D.3104654, dispLR, . . . UY . . .
D.3104655, . . . ALL, . . .
D.3104655, dispRR, . . . UY . . .

LSWRITE, 2,

/TITLE, Load Set 3: Rack Rear Difference Only

*SET, fmtdiff, 0 ! Newtons
*SET, reardiff, 326134 ! Newtons
*SET, dispLF, (fmtdiff/2)/100000
*SET, dispRF, (fmtdiff/2)/100000
*SET, dispLR, (reardiff/2)/100000
*SET, dispRR, (reardiff/2)/100000

! Left Front Strut Displacement
D.4104661, . . . ALL, . . .
D.4104661, dispLF*COS(9), . . . UY . . .
D.4104661, dispLF*SIN(9), . . . UZ . . .

! Right Front Strut Displacement
D.4104660, . . . ALL, . . .
D.4104660, dispRF*COS(9), . . . UY . . .
D.4104660, dispRF*SIN(9), . . . UZ . . .

! Left Rear Strut Displacement
D.3104654, . . . ALL, . . .
D.3104654, dispLR, . . . UY . . .
D.3104655, . . . ALL, . . .
D.3104655, dispRR, . . . UY . . .

LSWRITE, 3,

/TITLE, Load Set 4: Load to One side Only

*SET, fmtdiff, 5 ! Newtons
*SET, reardiff, 5 ! Newtons
*SET, dispLF, 5 ! Newtons
*SET, dispRF, 5 ! Newtons
*SET, dispLR, 5 ! Newtons
*SET, dispRR, 5 ! Newtons

! Left Front Strut Displacement
D.4104661, . . . ALL, . . .
D.4104661, dispLF*COS(9), . . . UY . . .
D.4104661, dispLF*SIN(9), . . . UZ . . .

! Right Front Strut Displacement
D.4104660, . . . ALL, . . .
D.4104660, dispRF*COS(9), . . . UY . . .
D.4104660, dispRF*SIN(9), . . . UZ . . .

! Left Rear Strut Displacement
D.3104654, . . . ALL, . . .
D.3104654, dispLR, . . . UY . . .
D.3104655, . . . ALL, . . .
D.3104655, dispRR, . . . UY . . .

LSWRITE, 4,
FINISH
/EOF
Combining 930E Frame and Dump Body FEA Model
Post Processing Routine...

-----------------------------

------------------------------- Read in Results File
-------------------------------

RESUME Aug_24.db;
!GRAPHICS,FULL

/POST1
INRES,
FILE Aug_24.res,

!SET,1,LAST,1, Load Step #, Last
Substep, Scale=1

|----------------------- Combining Load Cases to Check Linearity |
|-----------------------

!SET,2,LAST,5/1.557555,
ILCWRITE,1, ...
!SET,3,LAST,5/1.63067,
ILCWRITE,2, ...
ILCOPER,ADD,1 ...

/TITLE,LOAD CASE 3: Combined Results
ILCWRITE,3, ...
ILCDEF,4,4 ! Frame FEA Load Case Operations
/EOF

|----------------------- Selecting Which Bolster to Study |
|-----------------------

ALLSEL,ALL
FLST,5,382,5,ORDE,153
FITEM,5,385
FITEM,5,388
FITEM,5,391
FITEM,5,394
FITEM,5,399
FITEM,5,405
FITEM,5,407
FITEM,5,408
FITEM,5,410
FITEM,5,416
FITEM,5,439
FITEM,5,441
FITEM,5,442
FITEM,5,469
FITEM,5,479
FITEM,5,481
FITEM,5,483
FITEM,5,531
FITEM,5,532
FITEM,5,535
FITEM,5,541
FITEM,5,543
FITEM,5,548
FITEM,5,552
FITEM,5,554
FITEM,5,557
FITEM,5,564
FITEM,5,573
FITEM,5,593
FITEM,5,596
FITEM,5,601
FITEM,5,830
FITEM,5,832
FITEM,5,852
FITEM,5,854
FITEM,5,861
FITEM,5,863
FITEM,5,865
FITEM,5,867
FITEM,5,871
FITEM,5,907
FITEM,5,910
FITEM,5,939
FITEM,5,941
FITEM,5,946
FITEM,5,957
FITEM,5,958
FITEM,5,981
FITEM,5,986
FITEM,5,999
FITEM,5,997
FITEM,5,1001
FITEM,5,-1009
FITEM,5,1012
FITEM,5,-1013
FITEM,5,1312
FITEM,5,-1312
FITEM,5,-1313
FITEM,5,1315
FITEM,5,-1316
FITEM,5,1318
FITEM,5,1321
FITEM,5,1323
FITEM,5,-1324
FITEM,5,1329
FITEM,5,1339
FITEM,5,1355
FITEM,5,1358
FITEM,5,1359
FITEM,5,-1361
ASEL.R.,,P51X ! Selecting Main Rail Areas

ALLSEL.BELOW,AREA

ASEL.R.,,P51X ! Selecting Main Rail Areas
FLST,2,2,1
FITEM,2,151976
FITEM,2,153615
PATH.LPath,2,30,40,
PPATH,P51X,1 ! Path on Left Rail

PDEF,STAT
AVPRIN,0,0,
PDEF. _U,Y,AVG ! Mapping Results to Path

PAGET.L.Path,TABL ! Storing Path Items in Array

ASEL.R.,,P51X ! Selecting Main Rail Areas
FLST,2,2,1
FITEM,2,152758
FITEM,2,153550
PATH.RPath,2,30,40,
PPATH,P51X,1 ! Path on Right Rail

PDEF,STAT
AVPRIN,0,0,
PDEF. _U,Y,AVG ! Mapping Results to Path

PAGET.R.Path,TABL ! Storing Path Items in Array

-----------------------------------------------
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-----------------------------------------------
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Writing Path Data to Text File

-----------------------------------------------
-----------------------------------------------
-----------------------------------------------
-----------------------------------------------

/EOF

*CFOPEN,XL.couple_R_Path.txt,
*WRITE_RPath(1,1),RPath(1,2),RPath(1,3),RPath(1,4),RPath(1,5),...
(F12.4,F12.1,F12.4,F12.1,F12.4)
*CFCLOSE

*CFOPEN,XL.couple_L_Path.txt,
*WRITE_LPath(1,1),LPath(1,2),LPath(1,3),LPath(1,4),LPath(1,5),...
(F12.4,F12.1,F12.4,F12.1,F12.4)
*CFCLOSE

/EOF

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-----------------------------------------------

Defining Paths Along Main Rails
-----------------------------------------------
-----------------------------------------------
-----------------------------------------------
-----------------------------------------------

I:	est
ILCASE.3
ISET,4,LAST,1,

ALLSEL,ALL
FLST,5,36,5,ORDE,8
FITEM,5,1011
FITEM,5,1015
FITEM,5,1029
FITEM,5,1045
FITEM,5,1059
FITEM,5,1061
FITEM,5,1064
FITEM,5,1067

-----------------------------------------------
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End of File