University of Southern Queensland

Faculty of Engineering and Surveying

Analysis of a Sheet Metal Bucket Elevator Head

In conjunction with

DOWNFIELDS ENGINEERING PTY LTD

A dissertation submitted by

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In fulfilment of the requirements of

Courses ENG4111 and ENG4112 Research Project

Towards the degree of

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Abstract

This dissertation reports the analysis of a currently designed sheet metal head manufactured by Downfields. The analysis was primarily evaluated by assessment of finite element results.

The documentation covers a brief summary of the background and manufacture followed by testing then finally the analysis. Testing was to compare variation between zinc coated and uncoated steel as well as the comparison of simple samples with finite element models. The final analysis covers worst-case scenario loadings with structural variations caused by wear and corrosion.

This analysis allows a better understanding of the behaviour of the structure in loaded situations and opens the opportunity for assisting in future new design changes.

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Table of Contents

List of Figures

List of Tables

Chapter 1.0 Introduction

This dissertation analyses the strength and durability of a bucket elevator head manufactured by Downfields Engineering Pty Ltd. The head is the top most component of a vertical bucket elevator and such contains the complete drive assembly. This means that all start-up and running torques are confined to this area. This analysis utilises computer simulation software with a finite element approach to predict head behaviour under worst-case scenario loadings.

1.1 Client Introduction

Downfields is a privately owned company. The owner, Keith Schelberg, is also the founder and managing director. It was founded in 1976 on a grain property 20 km north west of Dalby. The company grew and relocated to Toowoomba in 1980. Now in 2005, Downfields employees 30 staff and continue to manufacture a wide range of grain handling and aeration equipment. A list of handling equipment includes bucket elevators, screw conveyors, drag conveyors, distributor vales, and slide gates to just name a few.

Not only does Downfields build equipment but it also designs complete storage, processing facilities and is committed to always improving design and efficiency.

1.2 Client Brief

Downfields have only one manufacturing plant located in Toowoomba but manufacture for clients all over Australia and also some overseas, such as China. They have found that quality and durability are an important part of having a good product and reputation.

One of the most important items of equipment for Downfields is the bucket elevator. This is because it is their most prominent article, fewer competitors and many years of experience. At Downfields elevators are economically manufactured by profiling, pressing and welding sheet metal. The sheet metal assemblies create both the structure and sealed enclosure of an elevator. See Figure 1-1 for a typical configuration.

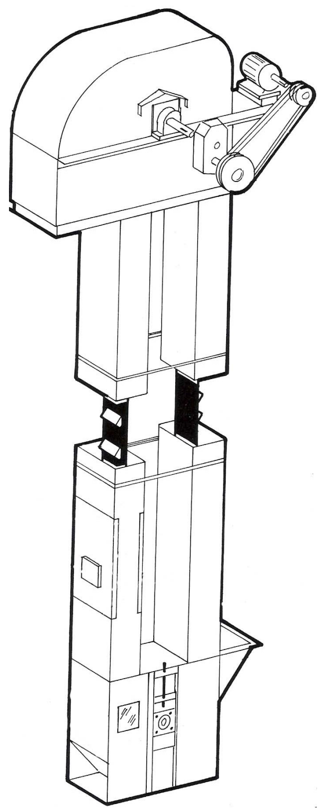

Figure 1-1 Bucket Elevator

(Courtesy of Downfields)

The head is one of the major structural elements of the overall elevator. It supports the weight of buckets and belt, and also accommodates the drive and anti-runback back device. Corrosion and wear can also affect the durability depending on the environment in which the elevator is operated.

1.3 Background Information

The author of this dissertation had been an employee of Downfields for a period of seven and a half years. During the course of employment it was noticed that an increase of client demands in areas of the following:

- Higher elevators. This allows grain to be spouted over greater distances, from elevator or fill taller silos. Increasing the height also increases loads on head bearings and brackets due to longer belt and more buckets.
- Larger Capacity elevators. To increase capacity either more buckets or larger sized buckets are used. A larger drive power is required to assist in this increase.
- Larger drives. The larger drive can be because an increase in hight, capacity or capability to start with fully loaded buckets. A larger drive transmits greater reactions back to mounts welded to the head assembly.
- Corrosive environments. Feedlots use elevators for conveying reconstituted (moistened) grain. The moisture in the grain allows grain, husk and dust to stick to the inside of the sheet metal structure. This rapidly increases the rate of corrosion inside the elevator.

Also other areas of the elevator noticed:

- Wear inside the head. The continual 'rubbing' of the grain against the steel slowly wears it away. The wearing occurs in known regions of the structure. These regions are the nose and/or throat of the head where the grain strikes because it is centrifugally discharged from the buckets.
- Optimum bracket design. There are a varying number of different styles used to support bearings, backstop or drive unit. They can be made from either a thicker profile or thinner pressed section. Brackets can also be attached by having a thickening plate, between the bracket and head structure, or an extended bracket that continues to the base flange.

Bucket elevators are one of Downfields most important pieces of equipment. The author had chosen the elevator head then after discussions with Downfields a specific model was chosen. Refer to section 3.2 for more details on the elevator selected.

1.4 Project Objectives

1) Research
    - Background of bucket elevators
    - Materials used
    - Methods of manufacture
    - Styles of brackets used
2) Test materials used
3) Conduct analysis of each style of bracket
4) Conduct analysis of elevator head as a unit
5) Conduct analysis of head with effects of corrosion and wear
6) Conclude on overall safety factors of current design

Chapter 2.0 Elevator Background

2.1 Elevator History

Bucket elevators are no new invention, according to (Colijn 1985, p. 330)

> *The bucket elevator is probably the oldest known form of conveyor, Its history can be traced back to the days of Babylon where wicker baskets lined with a natural pitch and fastened to ropes operating over wooden sheaves turned by slaves, were used for the elevating of water into irrigation ditches.*

The Concept of the elevator has been around for many years. Variations that have changed to the elevator are its method of manufacture and types of materials used. As new materials are developed and quality materials become more readily available, then changes in design have been made to adapt to these materials. New technology has improved both design and manufacturing procedures. Computer technology has helped reduce design time, reduce rework and understanding the behaviour of materials under different loadings. New technologies in manufacture have reduced manufacturing time, costs, weight and increased tolerances. These changes have allowed increase discharge height and greater capacities to be obtained.

2.2 Elevator uses

An elevator is ideally used where the product needs to be elevated and consume only a small amount of ground area. Conveyed products are mostly granular solids, which range from powders to rocks. Limitations depend on how easily product can be loaded into and discharged from the bucket. Large granular products create difficulty loading and sticky products discharging. For products that are fragile and easily crushed, slower conveyance speeds are used.

2.3 Parts of an elevator

The elevator has five main areas being the head, legging, boot, belt & buckets, elevator access and elevator support. Each of these areas can be broken into smaller areas as listed below.

The head consists of:

- Main structural sheet metal frame
- Covers with or without wear liners
- Throat wiper
- Head pulley and lagging
- Drive Shaft
- Bearings
- Gearbox and Motor or Gearbox, coupling (belts, chain, etc.) and motor
- Backstop

Legging consists of

- Sheet metal trunking
- Flange connections
- Inspection windows and access doors

Boot consists of

- Main Structural sheet metal frame
- Inlet chute with or without wear liner
- Boot pulley and shaft
- Bearings
- Pulley take-up for belt tensioning

Belt & buckets consist of

- Belt with holes
- Buckets

- Bolts, spacer washers and anti-loosen nuts
- Belt joiners

Elevator access consists of

- Stairs or ladders with cages
- Intermediate platforms with handrails
- Distributor or valve access platforms with handrails
- Platform to elevator connection
- Head Platform with handrails

Elevator support consist of

- Elevator attachment lugs
- Guy ropes
- Concrete piers into the ground

Or

- Structural tower in which the elevator is supported or hung
- Connections between elevator and tower

Chapter 3.0 The Elevator Head

3.1 Assembly

The head of an elevator has a greater number and some of the most important functions for conveying the material. These functions consist of

- Supporting the weight of buckets, belt and material.
- Restraining the drive so electrical energy can be converted into mechanical energy to elevate material.
- Allow access and/or inspection to throat wiper, pulley lagging, belt and buckets.
- Enclose the conveying system so elements of the environment cannot contaminate the material.
- Enclose the material so waste isn't created and dust cannot escape to the outside environment.
- Remove and separate the material from the buckets.
- Absorb impact of the material as well as converge it towards its final destination.
- Due to intermittent stopping, the head has to stop the belt running backwards.

All these functions are combined into the one main head sheet metal structure. Most individual functions are accomplished by components that attach to the main frame. See Figure 3-1 and Figure 3-2 for component details.

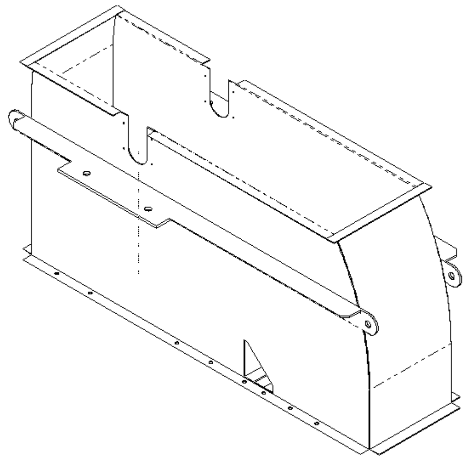

Figure 3-1 Elevator Head Assembled

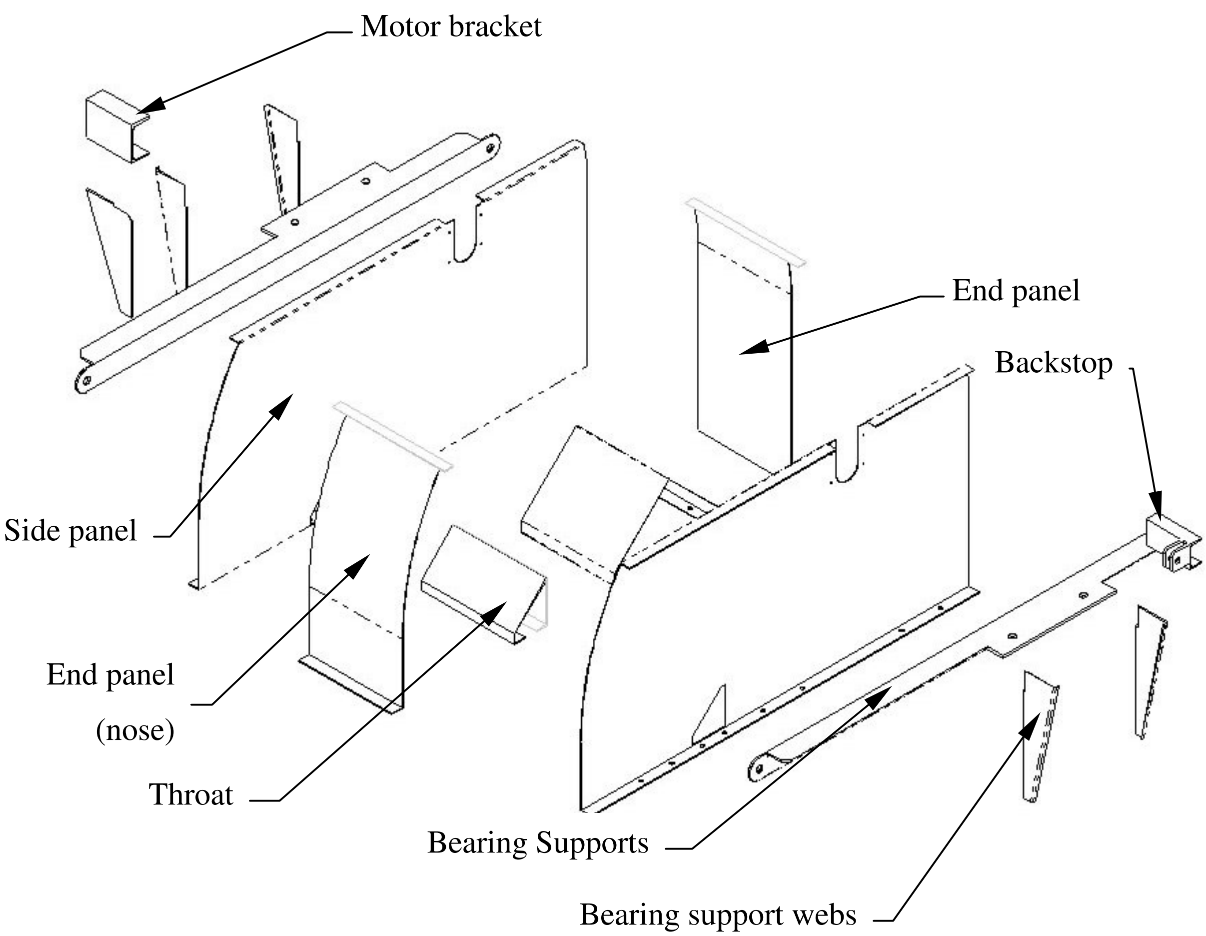

Figure 3-2 Head Structure Exploded view

3.2 Head Selection

Selecting the size and model of elevator was done with Downfields assistance. The elevator chosen was one of the largest models made using a 3mm sheet metal structure. This choice was to be a model that was expected to have high stress concentrations. The general specifications of the chosen elevator are as follows.

Downfields model No.:	SPS300
Motor power:	15 kW
Gearbox ratio:	20:1
Capacity:	20 tonnes per hour
Conveyed material:	Wheat @ 750 Kg/m^3
Discharge height:	26.5m

Chapter 4.0 The Design of the head

4.1 Materials

Elevators can be made using different types of materials. Materials of the structure and brackets also can be different types as well.

The materials used to construct the head structure vary depending on conveyed material, cost and appearance, which are specified by the customer. These materials can range from galvanised, mild steel or stainless steel sheet. Galvanised is the most common material used by Downfields. Mild steel is used when a painted finish is required and stainless steel for when high moisture or corrosive materials are being conveyed. Since galvanised sheet was the most common it was used in the analysis for the head structure. Mechanical properties of the galvanised sheet were unavailable so testing strips were compared with mild steel ones to check their comparison. For more information on testing refer to section Chapter 6.0 Sheet Metal Joint Test Samples.

Bracket material normally matches that of the head structure, but for a galvanised head, mild steel is used. They are constructed by using standard plate and structural sections, which are unavailable in a galvanised finish. During the fabrication process a large amount of welding is done in the bracket areas, which melts and burns away the galvanised coating. Due to the unavailability and fabrication process brackets are made from standard mild steel plate and structural sections then painted, for a galvanised head structure construction.

A list of the materials used in this analysis is,

- 3.0mm galv – AS1397/G2 Z275
- 3.0mm HR – 250 grade AS1594/ GD HA1
- 5.0mm plate – 250 grade AS1594 GR HA250
- Channel & Angle – 300PLUS

These material specification types were given by Downfields (refer to appendix D.1 Material Grades on page 62). Note sheet refers to 3mm or less and plate refers to 4mm or greater.

4.1.1 Galvanised Sheet

Galvanised sheet is a mild steel sheet coated with a layer of zinc both sides. These layers are applied using a hot dip process. This material has the advantages of reduced fabrication time and durability. According to Abbott (1997, p. 3) extreme Australian weather conditions from hot sun, heavy wind and rain conditions encourage the use of galvanised sheet. The analysis of the sheet metal structure in this dissertation primarily used the galvanised coated sheet.

The specification for this sheet is 3.0mm galv – AS1397/G2 Z275 and the code refers to the following,

G – indicate that mechanical properties have been achieved or modified by in-line heat treatment prior to hot dipping.
2 – Commercial forming.
Z – It is a zinc coating.
275 – the mass of zinc in grams per m^2 for both sides.
(AS 1397-2001, pp 6-7)

This grade doesn't specify the minimum mechanical properties of the galv sheet because it is a formability grade not a structural grade. The formable G2 grade has less carbon as shown in Table 1 than the structural G250 grade, which gives it more flexibility. For this reason test were conducted to compare the galv with mild steel sheet.

	Carbon %	Manganese %	Phosphorus %	Sulfur %
G250, G1	0.12	0.50	0.040	0.035
G2	0.10	0.45	0.030	0.030
HA1	0.13	0.50	0.030	0.030

Table 1 Galv Sheet Required Chemical Composition
(Adapted from AS 1397 – 2001, Table 2.1, p 9. &
AS 1594 – 2002, Table 2.2, p 11.)

Since the galv material is made with a mild steel centre and layered with zinc this can change the overall mechanical properties, but according to (AS 1397 – 2001, p 10.)

> *It is international practice to tensile test zinc-coated sheet and strip with the coating intact, and to calculate the strength using the cross-sectional area of the steel base metal only, since the contribution made by the zinc coating is so small that, for practical purposes, it can be ignored. The strength value obtained is close to the strength of the base material itself.*

For this reason the contribution of the zinc layers were also ignored in the head structure models.

4.1.2 Mild Steel Sheet

The purpose of considering mild steel in this analysis was for comparison with the galvanised sheet. Mild steel specification was 3.0mm HR – 250 grade AS1594/ GD HA1 which refers to the following, H – indicates that it has been hot rolled

A – indicates the reoxidation practice is aluminium killed

1 – indicates that it is for commercial forming

(AS 1594-2002, pp 6-8)

The specification of HA1 is a formable grade and not a structural grade, but the supplier had specified that it is a 250 grade, which shows similar chemical compositions, as shown in Table 1, to the structural grade 250. This indicates that its mechanical properties are 250Mpa for the minimum yield strength and 350Mpa for minimum tensile strength (AS 1594 – 2002, Table 3.1, p 15.).

4.1.3 Mild Steel Plate

The mild steel plate is used as webs or thickening plates on the head structure. Its specification was 5.0mm plate – 250 grade AS1594 GR HA250, which refers to the following,

H – indicates that it has been hot rolled

A – indicates the reoxidation practice is aluminium killed

250 – indicates that it is a structural grade and the number represents the nominal minimum yield strength.

(AS 1594-2002, pp 6-8)

Since this material is a structural grade 250 then it has a minimum yield stress of 250MPa and a Minimum tensile strength of 350MPa (AS 1594 – 2002, Table 3.1, p 15.).

4.1.4 Channel and Angle

Channels and angles are a structural grade 300PLUS, which have a minimum yield stress of 320MPa and a tensile strength of 440MPa (AS 3679.1-300).

4.2 Fabrication Processes

A brief overview of the fabrication processes shows how the head is made. Then each process is explained more deeply. The processes used to construct the sheet metal head weldment are shearing, punching, pressing and welding. First items are shared to gain overall sizes prior to the next processes. Any item requiring holes or to be shaped are punched in the turret punch. After items are punched they are pressed and finally all combined together by welding the joints.

4.2.1 Shearing

Shearing is done using a guillotine shown Figure 4-1. The first cut is made using the side gauge and about 6mm is trimmed off the end of the sheet (Smith 1993, p. 319). This allows the sheared sheet to be square and leaves a datum edge to measure the next cut. Following cuts are made by either measuring from the datum or the datum edge is pushed against a stop of preset distance. The advantages of using a guillotine are

- Cuts are straight
- Cuts are quick
- No material waste from the cutting
- Using a NC (numerically controlled) back stop saves measuring time and increases accuracy

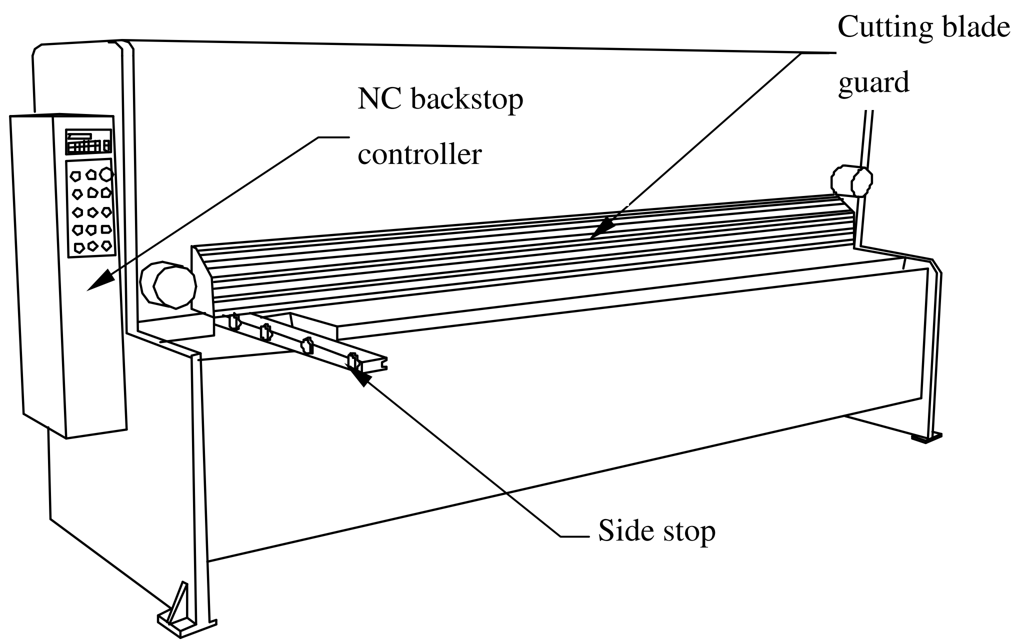

Figure 4-1 Downfields Guillotine

4.2.2 Punching

Punching is done with a CNC (computer numerically controlled) turret punch shown in Figure 4-2. This machine has 9 tool stations, as shown in Figure 4-3, which hold different size and shape punches. Sheet is placed into clamps, which moves and locates the sheet under a designated punch. The accuracy of this machine is 0.3mm, which allows precise location of boltholes and shaping.

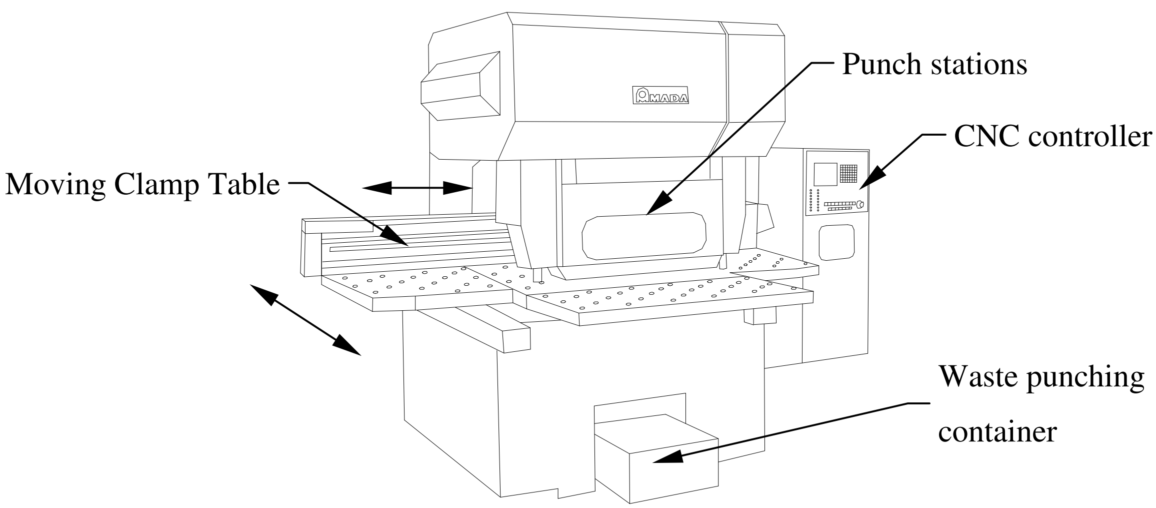

Figure 4-2 Downfields Turret Punch

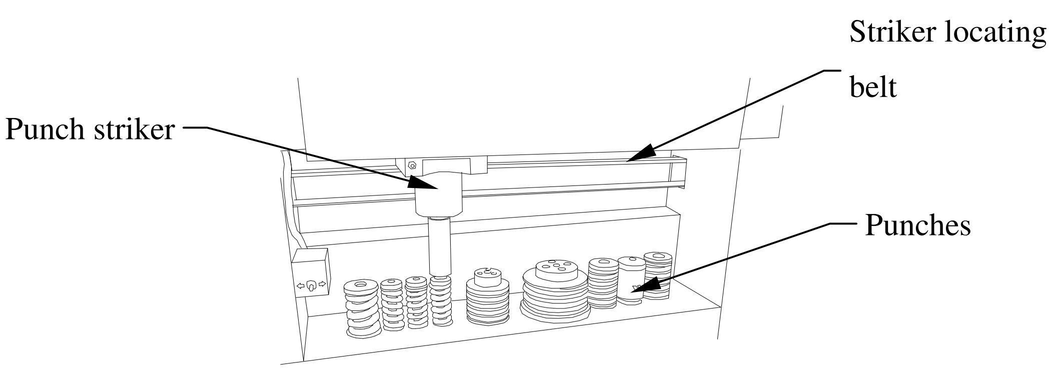

Figure 4-3 Punch Stations

Punch shapes range from round, square and slotted as shown in Figure 4-4. Sheared sheets can be shaped by nibbling with a round punch to create arcs or punching with a square punch to create rectangular cut-outs. Nibbled arcs leave a jagged edge but these edges are normally located at a welded joint and don't pose a problem. Advantage of this process is quickness, accuracy and repeatability through the use of programmes.

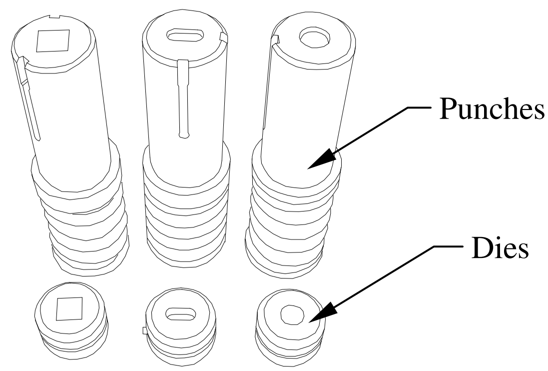

Figure 4-4 Punch and Dies

4.2.3 Pressing

All pressing is done in hydraulic brake press with a down stoke punch as shown in Figure 4-5.

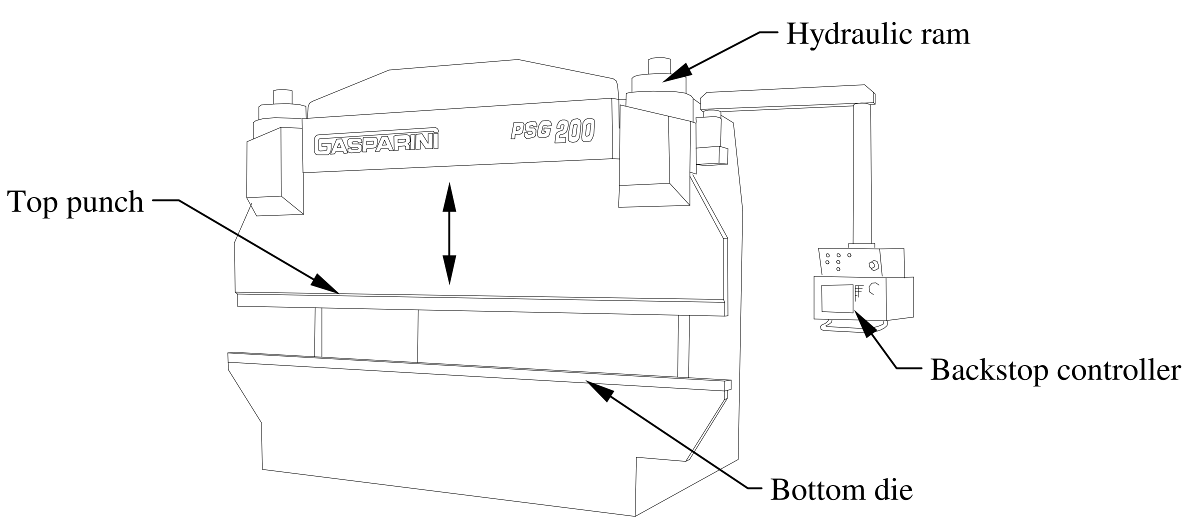

Figure 4-5 Downfields Break Press

The tooling used in the press is a vee die and gooseneck punch as shown in Figure 4-6. A gooseneck punch allows for a number of closely located bends on the same item (Smith 1993, p. 348). The closely located bends are on the bearing support web brackets. Advantages of a pressed joint is that they are quicker to create than a welded joint, they don't induce buckling due to heat and the galvanised coating isn't removed during the process. Not all joints in the main structure can be pressed so welding of joints is still required.

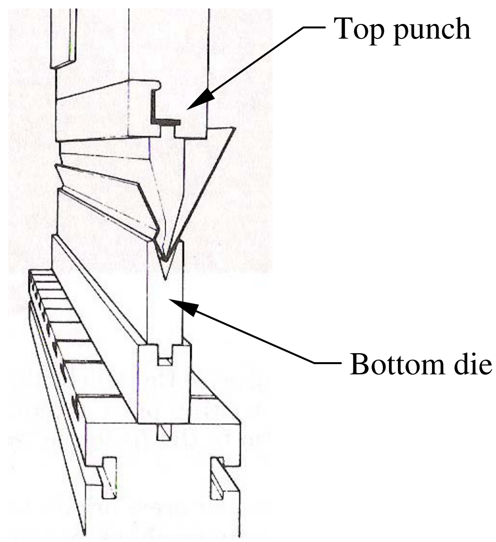

Figure 4-6 Brake press with gooseneck tooling

(Source: Smith 1993, p. 348)

4.2.4 Welding

Welding is done by a process commonly known as Metal Inert Gas (MIG) welding or formally known as Gas Metal Arc Welding (GMAW). The main advantages with this process over others are (Norrish 1992, p. 14).

- Low heat input
- Continuous operation
- High deposition rate
- No heavy slag – reduced post-weld cleaning
- Low hydrogen – reduces risk of cold cracking.

Most sheet metal welds are made using a corner-to-corner weld. Brackets are attached by either a stich weld or fillet weld. The choices of weld types are due to

- Loading on joint, high loaded joints require larger fillets.
- Hold tolerances. Reduced heat distortion by reducing the amount of weld.
- Sealing the structure – a small continuos fillet welds are used.
- Reduce weld time, stitching is used
- Stitching is used to avoid too much removal of the galvanized coating.

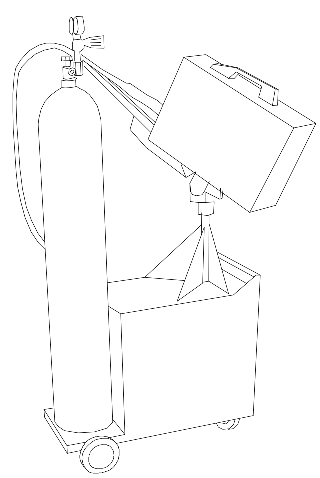

Figure 4-7 Downfields MIG Welder

Chapter 5.0 FEA Software

A non-destructive analysis was the best approach in understanding the durability of the elevator head. Finite element analysis (FEA) is a type of computer software that is a non-destructive method of analysis.

The advantages of a non-destructive analysis are no proto-type costs, experiment costs, difficulties in measuring result and availability of FEA software. Results from FEA could be compared with historical cases to assure some areas of analysis. The purpose of this report is to identify areas of weakness and likely hood of failure at the end of its life.

5.1 Choice of FEA analysis

Choosing to analysis using a non-destructive approach required a mathematical method to be used. Analytical or numerical methods are two mathematical approaches used to find these values. The analytical method suits plain geometry articles where experimentation has been done to find an equivalent equation. The numerical approach was chosen due to the complexity in the sheet metal structure. In this chapter we will cover the purpose of using FEA with its advantages, elements, the basic mathematics and the choice of software.

5.1.1 Purpose

The Finite Element Analysis (FEA) is a numerical method used to determine the deflection, stress and buckling behaviours of an article. These behaviours are hard to visually see and measure accurately. This method can help determine factors of safety on existing articles and also locations of structural weakness. Advantages of this information are to increase understanding in design and reduce potential costs later on (Adams 1999, p. 130). The finite element numerical method is based on the assumption that any function defining a domain may be approximated using a finite number of smaller elements (Steele 1989 p. 5).

5.1.2 Elements

When analysing deflection, stress and buckling behaviours of an article it is meshed into smaller elements. There are three different types of elements: beams, shells or solids. Shells can have a shape of triangular or quadrilateral and solids tetrahedron, pentahedron or hexahedron as shown in Figure 5-1. Each of these can also be broken into either a linear shaped element, known as h-elements, or a quadratic shaped element known as p-elements as shown in Figure 5-2. Purpose for these elements is.

- Beams are one-dimensional elements. They are used for objects that have uniform cross-sections.
- Shells are two-dimensional elements. These are used for plates and other thin walled structures.
- Solids are three-dimensional elements and are used in 3D models with complex geometry in all directions.

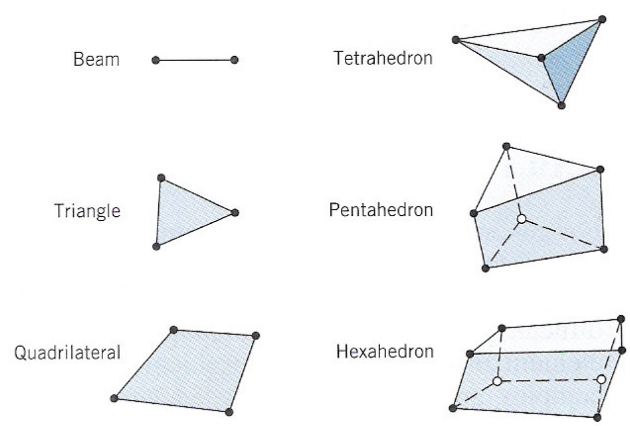

Figure 5-1 Elements

(Source: Juvinall, 2000, p. 222)

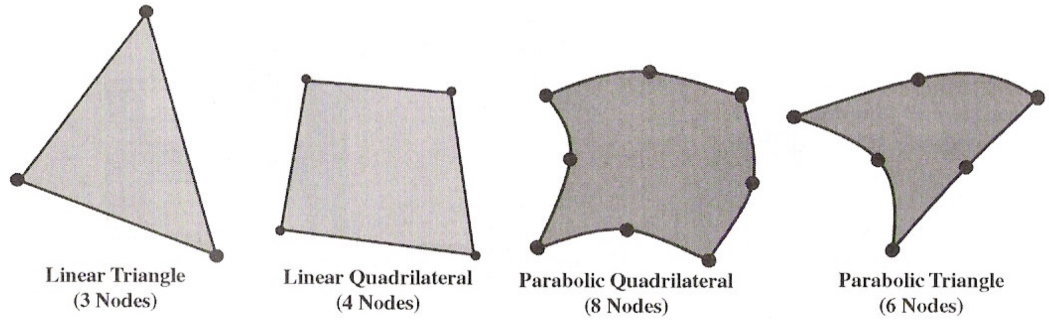

Figure 5-2 Linear h-elements & Parabolic p-elements

(Source: Adams, 1999, p. 142)

Elements have boundaries and nodes. Beams one boundary, shell three or four and solids six to twelve. At the end or intersection of each boundary are nodes. Displacement and strain calculations are evaluated along each of these boundaries. For a linear h-element analysis each boundary is considered a straight line. A quadratic p-element boundary has an extra node at the midpoint of each boundary. This extra node allows the boundaries to have a bi-directional curvature that allows that element to have a curve shape. Quadratic elements take longer to solve but can return a more accurate answer when analysing a object that has many curved surfaces or curved in nature. Shell elements can also have a quadrilateral or triangular shape. Quadrilateral shapes are usually more accurate than a triangular shape with similar density (Adams 1999, p. 141).

For the analysis of the bucket elevator head quadrilateral linear shell elements were chosen. These elements suited the head structure because it is made using thin, uniform thickness material. Brackets consist of uniform thickness plates and sectioned material also. Majority of the material is flat, which is why a linear element was chosen and quadrilateral shape due to easer to mesh and increased accuracy.

5.1.3 Basic Mathematics

An element relates to an applied load by stretching or compressing each of its boundaries. These boundaries can be idealised as a spring that change in length depending on its stiffness and the applied force. The boundary stiffness is denoted by the symbol [K] and applied force {F}.

Objects are analysed in a static state. Loads applied to an object create strain but don't create momentum. This is why elements require to be restrained if they weren't they'd either move or rotate in free space. Constraints are given to only a few nodes in a whole mesh. Constraints are commonly known as degrees of freedom, and nodes can be constrained by displacement in any of the three axes and rotation about the tree axis. Constraints are denoted by the symbol {d}.

The element stiffness [K], displacement {d} and applied {F} for each element are related in the following equation.

$$\{F\} = [K]\{d\} \tag{5-1}$$

Therefore for an object meshed with *n* elements must be applied *n* time creating a matrix of values. The software solver solves the displacement of each node in the {d} matrix. Stress and strain values can then be evaluated by the changes in boundary lengths.

5.1.4 Software

The computer solver software chosen to solve the mathematical solution for the meshed elevator head was ANSYS 9.0. The reasons why this software was chosen are.

- Availability at USQ,
- Previous use of this software,
- Capability of modelling shell elements,
- Have pre-processor (for model construction) and postprocessor (for output analysis),
- Modelling able to be programmed.

Being able to programme ANSYS saved a lot of modelling time. Programmes had many advantages.

- Make small changes without having to remodel the whole item.
- Amounts of programme can be reused for other models.
- The model can be shared with others.
- The modelling approach can be analysed by others.
- Being able to repeat the same results.

Chapter 6.0 Sheet Metal Joint Test Samples

A small test of the material involved was tested and results compared with FEA results to confirm material properties prior to modelling, loading scenarios and other structural variations to identify model parameters.

These tests were to analysis a pressed and welded sheet metal joint to confirm that the bending moments are transferred across the joint with no losses.

To gain an understanding of real life behaviours, testing small samples is a start. By testing in a controlled environment, where only one condition is changing, helps increase accuracy of the tested results. A sheet metal structure consists of flat sheets connected by welded and pressed joints so four different test samples were required.

- Mild steel flat sheet,
- Galvanised flat sheet,
- Welded corners and
- Pressed corners.

The flat sheet samples were required was to determine weather the galvanised coating assisted in the strength of the material or could be ignored. To measure the behaviour, deflection of sample was chosen rather than strain. Measuring deflection has advantages due to cost and simplicity.

See Appendix B for testing procedure.

6.1 Flat Strip Test Results

Results from this test showed that the galvanised material deflected slightly more than the mild steel strip. The reason for the greater deflection was most likely due to the zinc coating. Both samples measured the same thickness of 2.95mm; means the galvanised material has less mild steel due to the zinc layers of zinc on both sides. Since the zinc has lower modulus of elasticity and the galvanised has less mild steel, this would contribute to slightly increased deflections. Even though the galvanised material did deflect more than the mild steel sample, the increase was only small in comparison.

ANSYS results matched closely to the tested samples. These results were in between the mild steel and galvanised deflections, except for the 10Kg loading. The reason for this difference was unknown but since all deflections in the analysis were less than 15mm then the possible reason wasn't studied further.

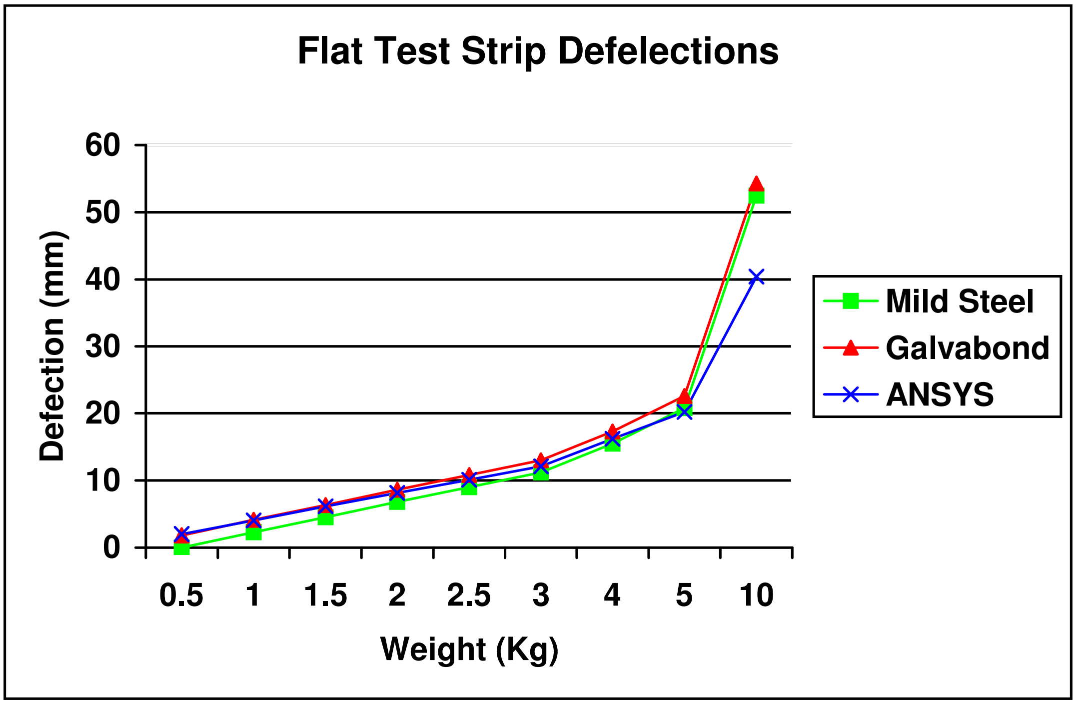

Figure 6-1 Flat Test Strip Deflections

ANSYS results under the 15mm deflection matched closely to the galvanised steel test results. This gave comfort that ANSYS results, for the galvanised material, in a more complex model. From the conclusion of these results the analysis was done as 3mm mild steel sheet metal properties.

6.2 Corner Test Results

Results from these tests showed insignificant variations between the welded and pressed corner samples. Variations of 1 to 2mm occurred between the two samples. These differences could be due to inaccuracies caused with manual measuring. With little variation meant both joints could be considered to behave the same.

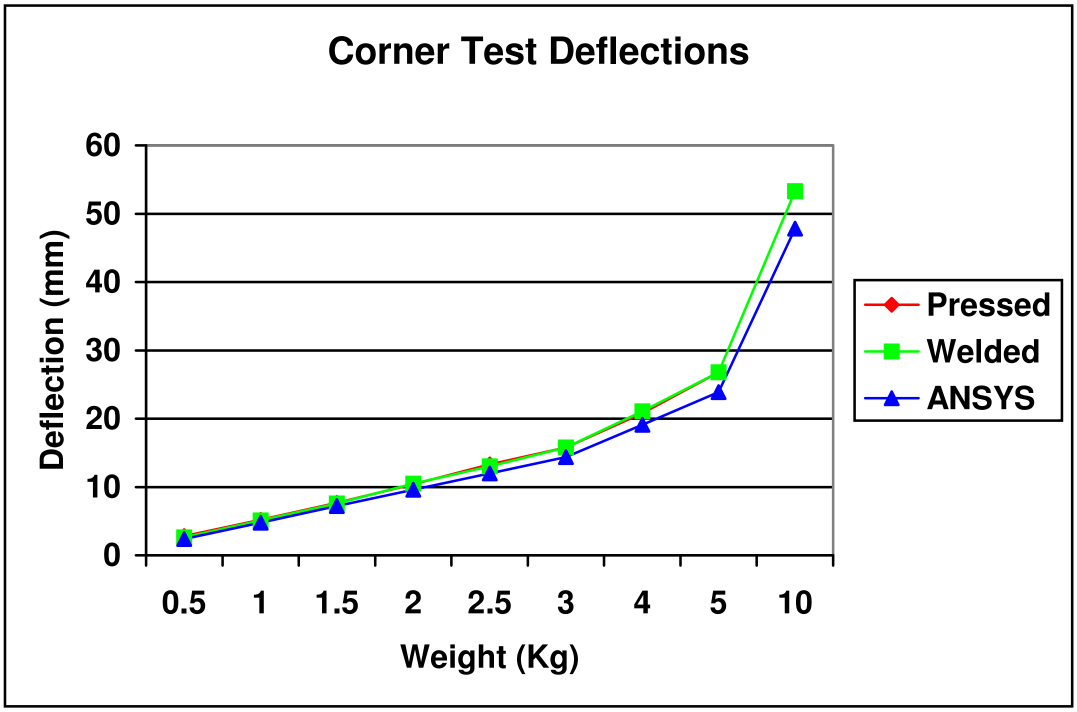

Figure 6-2 Corner Test Deflections

The results compared with ANSYS showed a slight increase in deflection. This variation could be a result of the different properties of the galvanised material or the bending moment partly being absorbed in the joint. It would be more likely to be the difference in material properties, as these small variations appear to match the flat strip sample results. Since the variation in deflection in the area under 15mm overall deflection was negligible then the joints were classed as stiff. A stiff joint, being one were all moments from one side of the joint are transferred to the other. This concluded that the ANSYS results of a more complex model with joints should give relatively accurate results.

Chapter 7.0 FEA Analysis

Two types of failure that is detrimental to the functioning if the elevator is deflection and tearing of the structure. Deflections are only a concern in the head structure. Large deflections in the area of the head pulley will cause the pulley to rub against the casing. This rubbing will deteriorate the belt and if a spark is generated, there is a high potential of an explosion. Tearing of the structure, which is sheet metal, is caused from high stress concentrations. This type of failure is very detrimental to the safe functioning of the elevator. Both types of failure would require the replacement of the head structure.

In these analyses, two loading scenarios were looked at. A jammed boot and motor in reverse are the most likely extremes on the head structure. In both scenarios the brackets receive the full start up torque from the motor. This full start up torque is about 278% of the normal running torque.

7.1 Loading Cases

7.1.1 Jammed Boot

A jam occurs from overload at the boot inlet. The occurrence of a jam can happen several times during the lifetime of the elevator. This case locks the pulley and shaft from rotating that diverts the full loading from the motor to the motor bracket. Starting of the elevator in this state imposes the full start up torque on the bracket. The conveyed material is to be removed from the elevator prior to starting but an operator could try starting the elevator in the jammed state to see if it would clear.

7.1.2 Motor in Reverse

A motor in reverse engages the backstop unit, which locks the head shaft from rotating. The backstop is supplied fitted to the head shaft; this is to avoid the possibilities of incorrect fitting or the unit not being fitted at all. Since it is mandatory for a conveyor to have an anti-runback device is why these precautions are taken. During installation an electrician cannot determine the exact direction the motor will run and a physical test is required. If the electrician has read the elevator instructions then unbolting the backstop prior to this test is done. The possibility of this not happening is small but it has happened before. A physical test is only supposed to be a short jolt of power so a visual check to confirm the direction of the motor is correct. If the backstop hasn't been disconnected and the motor is wired in reverse then the start-up load will be shared between both motor and backstop brackets. During a test of the motor direction the maximum start up torque shouldn't be reached but for the analysis the maximum torque was used. There should be no other structural variations for this scenario since the only time it will happen is during installation.

7.2 Structural Variations

Variations to the sheet metal structure occur during the life of the elevator head. The predominant variations are wear and corrosion. Both cases reduce the thickness of the metal that in turn can affect the structural capability of the whole head. Thickness of the metal varies over the surface so material thickness selected will only represent the average. Time taken to reach the selected cases varies depending on amount of use and material conveyed, so a prediction of the life would be hard to determine.

7.2.1 Wear

Wear occurs mainly on the nose of the elevator but for this analysis both front and rear end panels where modelled with the reduced thickness. This case occurs to all elevator heads, larger amounts of material conveyed increases the amount of wear. Liners are used in this area to avoid wearing of the structure, but the unawareness of a warn-out liner is highly possible. 1mm was used as the average for a worn end penal.

7.2.2 Corrosion

Corrosion or commonly known as rusting, only occurs on the inside of the structure due to moist product sticking and corroding over time. The corrosion mainly occurs to the side panels since end panels are kept clean by the continual passing of conveyed material. It is rare for a galvanised or mild steel elevator to convey moist material. When an elevator is designed for this purpose then another steel such as stainless steel is used instead. Elevators have been installed with no intension of conveying this type of material but have changed during the life of the conveyor. For this reason corrosion was considered in the analysis. In this analysis an average of 2mm reduction in material thickness was used, on the side panels to simulate corrosion.

7.3 Motor Bracket Analysis

The purpose of the motor bracket is to restrain the motor and gearbox from rotation around the shaft. The purpose of this analysis was to identify if there were high stress in the web section and around the area of stitch welds that connect the web to the head.

7.3.1 Model

This bracket was initially modelled as a shell model. The shell type of model was chosen since it was used to analysis the head in section 7.5 on page 41. A model of the bracket consists of a channel and web. The channel is connected to the head by its end section and the web spans between the channel and head side panel. Connection between the web and channel is fully welded and between the side panel and web stitch welded. A cross section of an angle passes between the web and channel that was omitted for this analysis.

7.3.2 Constraints

Constraints were placed on both the web and channel. For the web, stitch welds were established as several points along the edge of the web. These constraints were restrained in x, y and z directions. Rotations weren't fixed since the web is connected to shee t metal that has the ability to flex. Constraining the rotation could over restrain the model and give less accurate result. The channel was only constrained along its bottom toe. These constraints were in the x, y and z directions, and this still allowed it to rotate about this edge. The purpose of this was to simulate the load path through the web. This was because the web was the component being observed for this analysis.

7.3.3 Loadings

The motor and gearbox unit is mounted directly to the head shaft. To restrain the unit from rotating around the head shaft another plate of a banjo shape is bolted to it. At the far end of this plate is a short section of channel that is smaller then the channel on the motor bracket. This channel of the banjo plate is located inside the motor bracket channel. Rubber strips are used to fill the gapes between the two channels. This type of connection allows minor vibrations to be absorbed and no axial loadings applied to the gearbox. Loadings applied to the motor bracket are from the banjo plate's channel. Loads were applied along a line that is collinear to the edge of the banjo plate's channel. The magnitude of these loads were of a jammed boot load case as described in section 7.1 on page 30. This case was used since the jammed boot case loadings are greater than those from the motor in reverse load case.

7.3.4 First Model Results

The results of this FEA report showed high stress concentrations in the corner of the channel. Since the internal corners of a channel have an internal radius this would effect the concentration in this area.

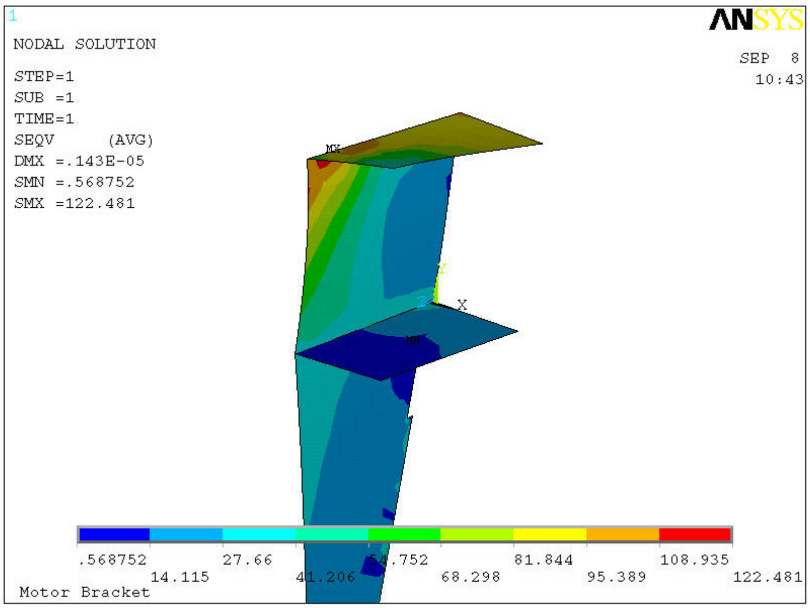

Figure 7-1 Motor Bracket Shell Model FEA Results

To model the internal radius accurately the bracket needed to be modelled as a solid. Since the high stress location was in the channel component, this changed the area of observation from the web to the channel. The next model was of the channel only. The channel needed to be constrained to stop it from rotating, so the end that connects to the head was constrained along the edges of the top and bottom toes. These constrains were in x, y and z directions.

7.3.5 Second Model Results

In the channel only model FEA results showed that the high stress point was not in the corner and there were no alarming levels in the channel. The highest stress points were at the connection between the channel and head. These stress areas are more accurately analysed when the bracket is modelled with the head structure. Other areas in the bracket reached stress level of 40 MPa, which is well below the yielding limit of 250 MPa. This showed that this member has a good safety factor at maximum start up torque.

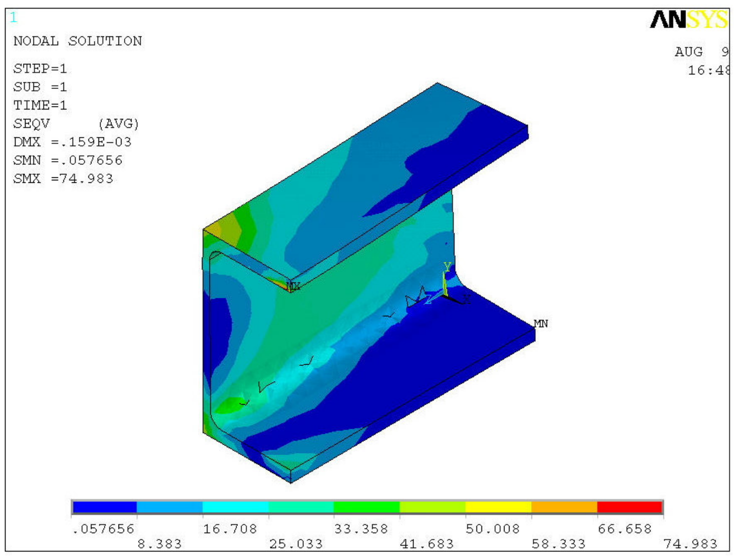

Figure 7-2 Motor Bracket Channel FEA Results

Since the channel was confirmed adequate the web of this motor bracket needed to be considered again. Both components were modelled as solids. Constrains on the channel were placed again on the bottom toe only so the load line goes through the web. The stitch welds on the web were established as a string of constraints in 30mm segments on bother edges of the web.

7.3.6 Third Model Results

Results from this FEA model showed very high stress concentrations in the area of the absent angle section.

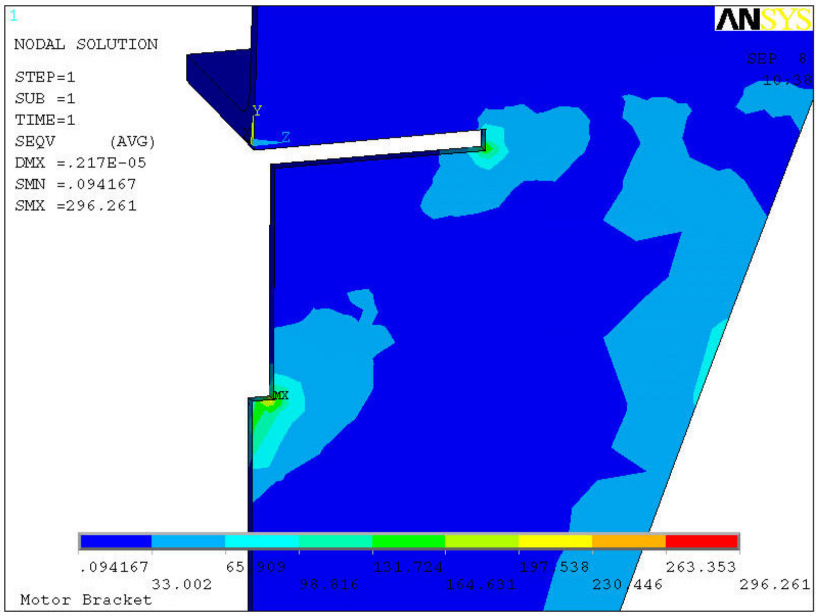

Figure 7-3 Motor Bracket with Omitted Angle FEA Results

Since the angle fills this area in practice the web was redrawn with this area filled in.

7.3.7 Forth Model

The final FEA results gave high stress concentrations where the channel is connected to the sheet metal structure. Since this area will be analysed with the whole head these extreme values were ignored. The area with the next highest stress levels were in both channel and web. In the channel, concentrations were in the toe with the applied load and in the area of stitch welds of the web. These concentrations reached levels of 120MPa, which is still well with in the yielding limit of 250MPa.

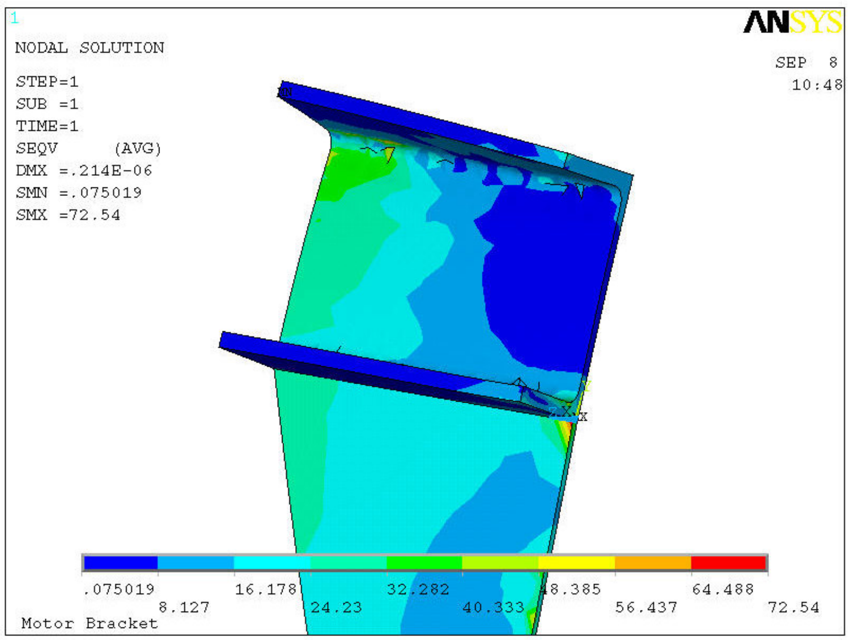

Figure 7-4 Motor Bracket Final FEA Results

7.4 Backstop Bracket Analysis

The purpose of a backstop is to stop the buckets and belt running backwards. A belt able to run backwards would cause a jam, if full of material and also be a safety hazard to a maintenance personal working on the elevator. Loads required to restrain the belt are transferred back to the head structure via the backstop bracket. This analysis was to observe the how this behaves under maximum load.

7.4.1 Model

This bracket is modelled as a channel with two lugs attached. Since this bracket is similar to the motor bracket it was modelled as a solid.

7.4.2 Constraints

One end of the channel is attached to the head structure. It needed to be fully constrained at this end so the edges of the top and bottom toes were restrained in x, y and z directions.

7.4.3 Loadings

The backstop is fitted to the end of the head shaft, opposite end to the motor and gearbox unit. A banjo shaped plate, which is similar in shape but smaller than the motor unit's banjo plate, is bolted to the backstop. The other end of the banjo plate is pinned to the lugs on the backstop bracket. The magnitude of this load is from the motor in reverse and explained in section 7.1.2 on page 31.

7.4.4 First Model Results

FEA results showed high stress concentrations at the channel to head connection and base of lugs. Since the channel to head connection would be more accurate in the whole head model only the stress concentrations at the base of the lugs was considered.

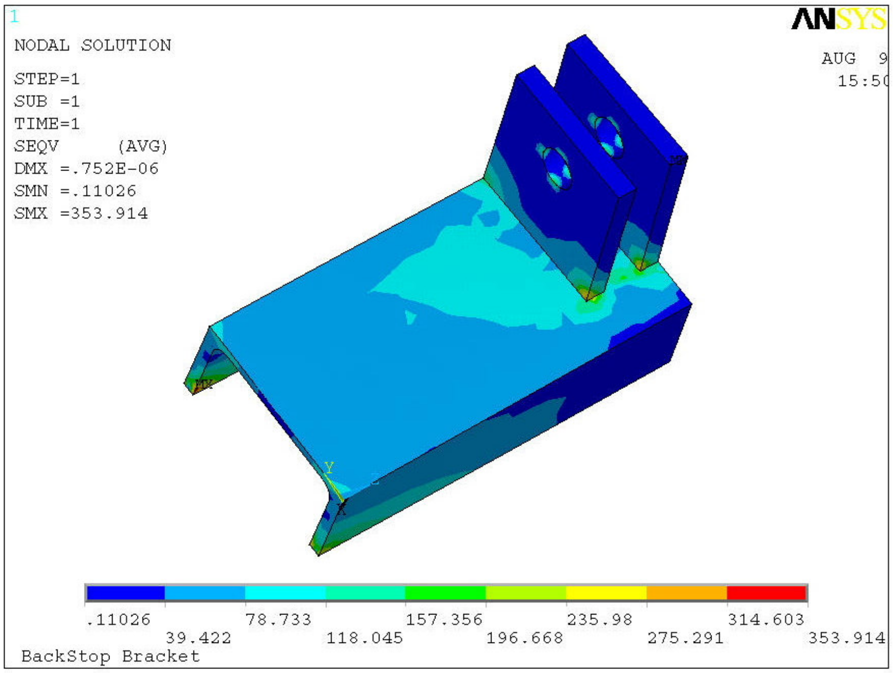

Figure 7-5 Backstop Bracket FEA Results

Fillets were added to give a more accurate representation at the base of the lugs. The lugs are welded along the sides as well as each end. Since the concentrations were located at the base of the lug then only a fillet was added in this area. This fillet was to reduce the concentration of the stresses in this area.

7.4.5 Second Model Results

The fillets encountered a higher stress concentration than the previous model as shown in Figure 7-6. This increase was unexpected and suggests a better modelling approach to simulate the welds is required.

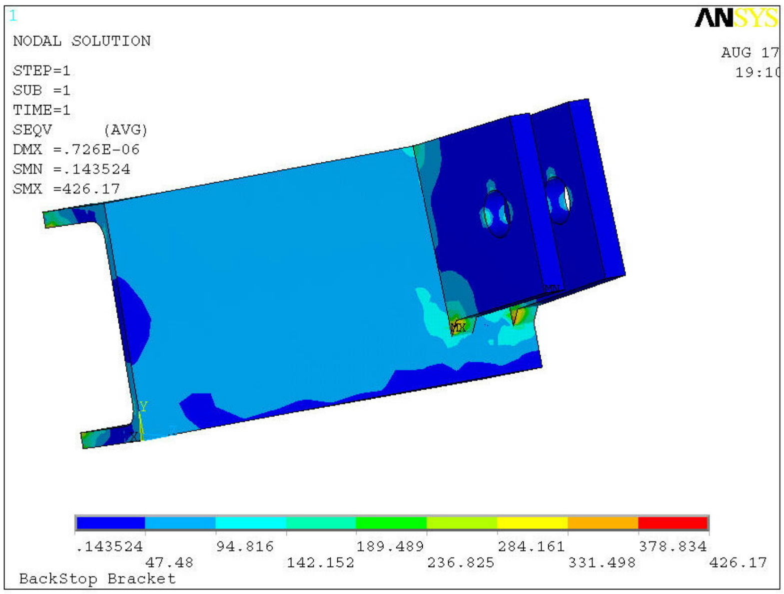

Figure 7-6 Backstop Bracket with Weld Fillet FEA Results

The results suggest that failure did occur for a fully constrained bracket then this would be the area it would begin.

7.5 Whole Head Analysis

The analysis of the head structure is the most important of all. All loading scenarios and structural variations were considered in this analysis.

7.5.1 Model

Majority of the head structure is sheet metal, which lent itself to a shell model. Both previously modelled brackets were also added as shells. The head throat and shedder plates were omitted for simplicity during initial analysis.

7.5.2 Constraints

The head structure is normally bolted to a structural platform with bolt through the bottom flange. To simulate the bolts point constraints were used limiting x, y and z directional movement. When meshing the bottom flange with constraints mid way, caused an error. So constraints where located on the inner edge of the flange, near the bolting locations.

7.5.3 Loadings

Loadings for the jammed boot case had full load start up torque on the motor bracket. For the motor in reverse, the full start up torque was shared between both the backstop and motor bracket. In both cases the applied load was located on the web of the channel. If loading were applied to the flange of the shell brackets, high stress concentrations would occur in the corners of the brackets. Since the head structure was the item of analysis and the brackets had already been modelled was why loads were added to the web section of these channels.

In both loading scenarios the downward loading caused by the buckets, belt and conveyed material was also applied to he bearing supports.

7.5.4 Jammed Boot Initial Condition First Model

Stress concentrations were located above and below the motor bracket. Above the bracket the top flange was distorted showing that it contributed to constraining the bracket. Behind the bracket is a thickening plate that helps distribute the loading to the head structure. The high stress concentrations below the motor bracket was where this thickening plate terminates as shown in Figure 7-7.

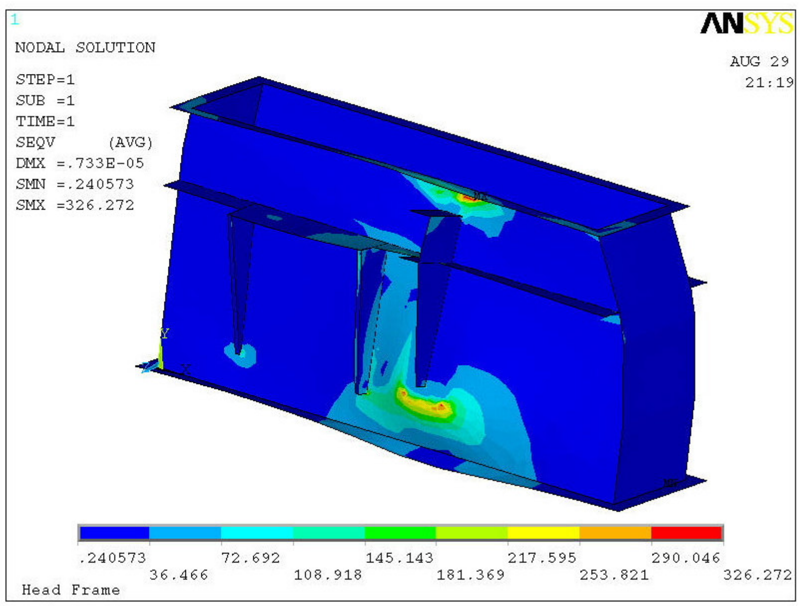

Figure 7-7 FEA results - omitted throat

The concentrations below the motor bracket were not far from the omitted throat panels. This prompted for the requirement of another model with the throat panels added.

7.5.5 Jammed Boot Initial Condition Second Model

With the addition of the throat panels high stress levels were concentrated in a corner where the side and throat panels are welded together as shown in Figure 7-8. These stresses are located in a small area only as shown in the insert of Figure 7-8. The applied loadings to the bearing supports didn't incur high stress levels. Maximum deflections reached during this scenario were 1.6mm.

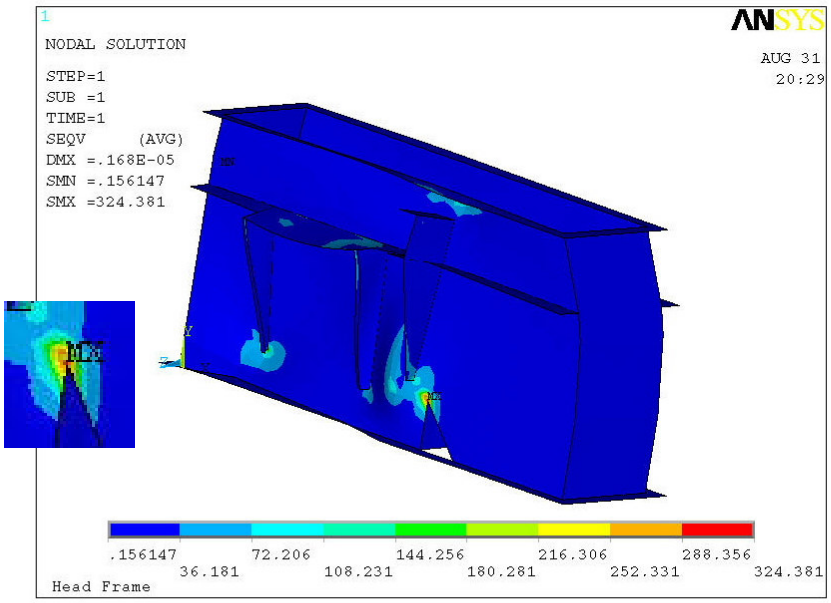

Figure 7-8 FEA results with throat panels

Since the area above the yield strength was very small and below the tensile strength suggests that failure wasn't likely to occur under a jammed boot initial condition scenario. Deflections reached in this scenario also were not great enough to effect the functioning of the elevator.

7.5.6 Jammed Boot With Wearing Model

The thickness of the end panels had no effect on the high stress levels as shown in Figure 7-9 compared with the previous model in Figure 7-8.

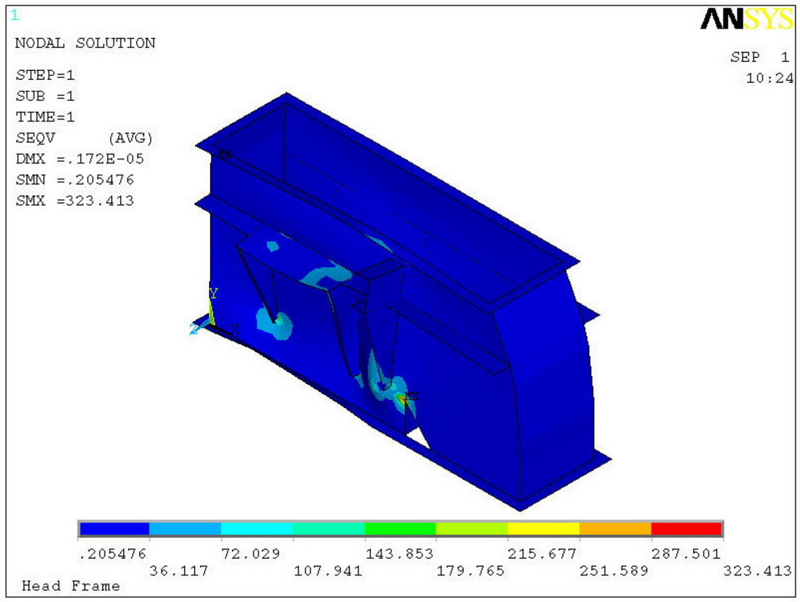

Figure 7-9 FEA results with worn end panels

Even though worn end panels affect spillage and waste of the conveyed material, it has no effect on the structural strength.

7.5.7 Jammed Boot With Corrosion Model

Results showed that the 2mm reduction in side panel thickness increased the stress from 324Mpa to 2490MPa as shown in Figure 7-10. Not only was stress increase but also deflections reached 13mm.

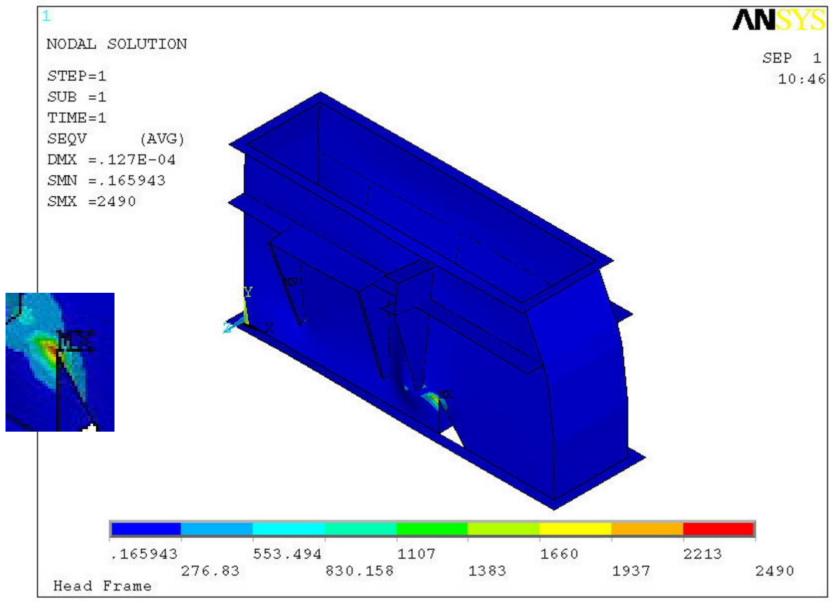

Figure 7-10 FEA results with corrosion

A stress increase of 8 times was well above the tensile strength of steel and failure is certain. The size of the area, that isn't dark blue shown in the insert of Figure 7-10, is large and above the tensile strength of the material. Failure would occur in this region and be destructive. The large deflections would continue once failure of the structure due to tearing had begun. For this analysis the large stress values conclude the reason of failure and not the deflections alone.

7.5.8 Motor in Reverse Model

The highest concentrations where all located on the backstop side of the structure. These stresses reached a magnitude of 500MPa as shown in Figure 7-11. Stress levels were just above the tensile strength of the angle, which is 440MPa.

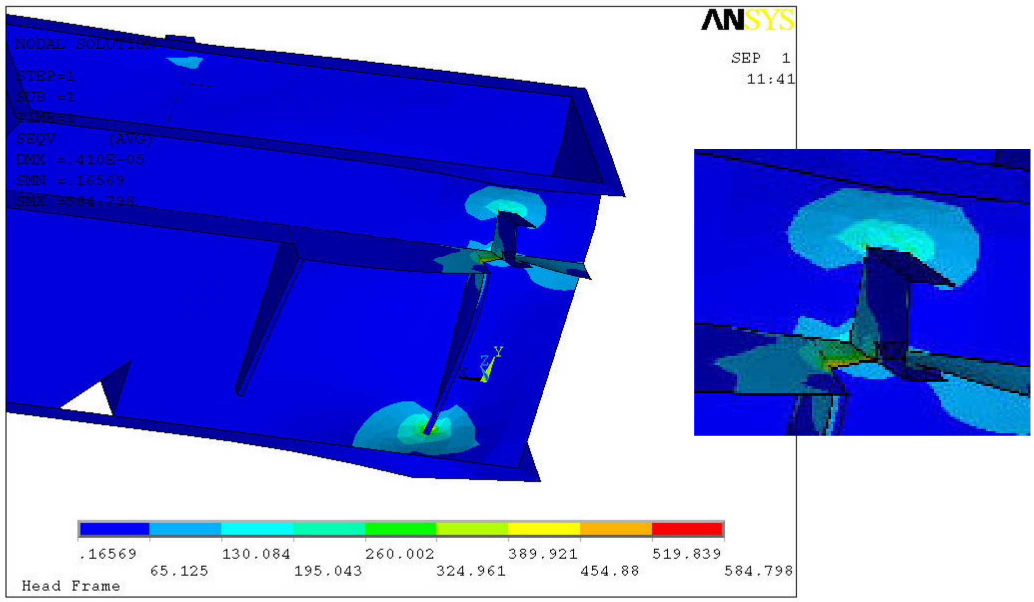

Figure 7-11 FEA results with motor in reverse

Since stress level were above the tensile strength levels then failure was likely to occur and redesign in this area is advisable.

Chapter 8.0 Conclusion

Finite element method proved a good way of analysing the elevator head. It has showed the load paths and where high stress concentrations are. This process has allowed an elimination of several areas of concern and also reassured which areas need redesigning. The conclusion has been broken into the following sections; brackets, wear corrosion, jammed boot and motor in reverse.

8.1 Brackets

The overall design of the motor and backstop brackets was sound.

Stresses in the motor bracket were well below the limits of the materials used. This design suited the 15 kW motor and gearbox, which suggested that it could be used on any size or style of elevator head.

Stresses in the backstop bracket did reach the tensile strength of the material but only in a very small area. Since the area is small, the likely hood of this scenario happening or reaching predicted loadings and the head in its initial condition suggests failure is unlikely. For this reason existing elevators would have and adequately designed bracket but a future redesign in this area would be recommended. A recommendation of extending the length of the lugs over the full face of the channel is a suggestion.

8.2 Wear

Wear on the end panels had no effect in increasing areas with stress concentrations. The stress concentrations caused by a jammed boot scenario were located on the side panels, where as wearing occurred in the end panels. Since they are two different areas the variations of the wearing didn't affect the side panel. Even though wearing didn't affect the mechanical strength of the head it still effects the functioning of the elevator. Small holes are created from wearing and conveyed material leaks to the outside. This problem was not considered in this dissertation but can be considered in future redesigns.

8.3 Corrosion

Corrosion had a major impact on the stress concentrations caused by a jammed boot scenario. Since corrosion causes a structural variation to the side panel and the stress concentrations are located in this area, was why an increase in stress concentrations occurred. This area of high concentrations was above the tensile strength of the sheet metal. Failure when the thickness reaches 1mm is likely and would occur prior to reaching this thickness. Since stainless steel is used instead of galvanized steel for corrosive applications then this type of failure would be avoided. In the case of an existing galvanized head to be used for a corrosive application then it would be strongly recommended not to. Using this type of head would reduce its life expectancy causing costly down time and replacement.

8.4 Jammed Boot

Results from the jammed boot scenario reported within limits, except when corrosion was involved and this was discussed in section 8.3 . Stress concentrations, from this loading condition, were caused in small areas located on the side panel near the top of the throat. Since the area that was above the tensile strength of the sheet metal was small, failure was unlikely to occur. This scenario only occurs a few times during the life of the elevator reassuring failure would be unlikely (in a non-corrosive application).

8.5 Motor in Reverse

Results from the motor in reverse loading scenario showed high stress concentrations in the area around were the backstop bracket attached to the head structure. In this area stress levels were above the yield strength and small areas were above the tensile strength of the material involved. This suggested that permanent deflections in this area would occur and failure due to the bracket tearing was possible. An Extra web plate to restrain the backstop, similar to the motor bracket, is recommended. Since an extra web plate in this area would be close to the bearing support web plate causing a manufacturing problem than a redesign in this area is recommended.

8.6 Future Work

The only major area requiring future work is the backstop bracket area. New designs for this area can be easily remodelled and analysed by modifying an existing programme. This will assist in choosing from a multiple number of design options. Other issues important in the design decision are manufacturability, cost and time. As durability of the elevator is one of the most important assets to Downfields then finite element analysis can help maintain this asset.

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Appendix A   Project Specification

TITLE: Analysis of the Head of a Sheet Metal, Bucket Elevator

ORIGINATOR: Scott Janke

MAJOR: Mechanical Engineering

SPONSOR: Downfields Engineering
Faculty of Engineering and Surveying, U.S.Q.

SUPERVISORS: Chris Snook
Keith Schelberg, Manager, Downfields Engineering

PROJECT DESCRIPTION:

Downfields are a Toowoomba based company who manufacture bucket elevators. Their clients are located all over Australia and some overseas, such as China.

There are some clients requesting higher and increased capacity bucket elevators. This increases the loadings applied to the head and an analysis hadn't been established to determine capability of the existing sheet metal design.

Areas to be addressed:

1) Research
    - Background of bucket elevators
    - Materials used
    - Styles of brackets used

2) Test materials used
3) Conduct analysis of each style of bracket
4) Conduct analysis of elevator head as a unit
5) Conduct analysis of head with effects of corrosion and wear
6) Conclude on overall safety factors of current design

AUTHORISATION

Student's Signature: ……………………. Date: ……………….

Supervisor's Signature: ………………… Date: ………………..

Appendix B   Sample Tests

B.1   Testing Procedure

TITLE: Testing deflection of sheet metal with welded, pressed and flat samples

DRAWINGS:

INTRODUCTION: Measure deflection on four samples with know weights. Sample 1 – flat strip of 3mm HRCQ, 2 – flat strip of 3mm galvabond, 3 – ‘L’ shape welde d 3mm galvabond, 4 – ‘L’ shaped pressed 3mm galvabond.

BILL OF MATERIAL AND TOOLS:

- 4 sample pieces
- Workbench with vice.
- Bench vice for holding flat samples
- Secondary vice for holding datum timber
- Drill press vice.
- Vernier callipers
- Weights
- String
- Ø5mm drill bit
- Drill press
- Hammer & Centre punch
- Stele capped boots
- Safety glasses
- Marker
- Ruler
- Nail

METHOD OF SETUP AND TESTING:

1. Scribe mark on the two flat strips 270mm from end in centre with marker and ruler.
2. Scribe mark on welded and pressed samples 200mm from bend using marker and ruler.
3. Mark clamp lines 20mm in form the opposite end of the sample with marker and ruler.
4. Centre-pop each mark with hammer and centre pop punch.
5. Put Ø5mm drill bit in the drill press and wear safety glasses. Clamp sample in the drill press vice and drill holes on centre pop locations. Repeat this for each sample.

SETTING UP FLAT SAMPLES

1. Clamp drill press vice vertically in bench vice.
2. Clamp flat sample into drill press vice.
3. Locate secondary vice next to bench vice.
4. Clamp timber into secondary vice for datum referencing.
5. Thread string through hole in sample and tie two knots at the end of string that is on the topside of sample.
6. Tie nail on the other end of string so length is about 300 mm off ground.

TESTING OF FLAT SAMPLES

1. Measure and record distance, with vernier callipers, between sample (at the location of hole) and the datum timber.
2. Thread string and nail through hole in weight, align nail horizontally and lower weight until its full weight is supported by sample.
3. Measure and record again at the same location.

4. Continue steps 13 and 14 until all weight variation are measured. Then replace sample with other flat sample.

SETUP OF ‘L’ SHAPED SAMPLES

1. Remove weights, string, sample and drill press vice.
2. Clamp ‘L’ shaped sam ple into bench vice at the clamp line.
3. Clamp another piece of timber on datum timber so the measuring distance below hole in sample is about 75mm.
4. Thread string through hole in sample and tie two knots at the end of string that is on the topside of sample.
5. Tie nail on the other end of string so length is about 300 mm off ground.

TESTING OF ‘L’ SHAPED SAMPLES

1. Measure and record distances, with vernier callipers, between sample (at the location of hole) to the clamped datum.
2. Thread string and nail through hole in weight, align nail horizontally and lower weight until its full weight is supported by sample.
3. Measure and record both distances again at the same locations.
4. Continue steps 23 and 24 until all weight variation are measured. Then replace sample with other ‘L’ shaped sample.

B.2 Test Results

Weight (Kg)	Distance (mm)	Deflection (mm)	ANSYS (mm)
0.0	114.4		
0.5	112.6	1.8	2.0
1.0	110.3	4.1	4.0
1.5	108.1	6.3	6.1
2.0	105.8	8.6	8.1
2.5	103.6	10.8	10.1
3.0	101.4	13	12.1
4.0	97.1	17.3	16.2
5.0	91.8	22.6	20.2
10.0	60.1	54.3	40.4

Table 2 Mild Steel Flat Strip Test Results

Weight (Kg)	Distance (mm)	Deflection (mm)	ANSYS (mm)
0.0	103.4		
0.5	101.2	2.2	2.0
1.0	98.9	4.5	4.0
1.5	96.4	7	6.1
2.0	94.2	9.2	8.1
2.5	92.2	11.2	10.1
3.0	89.7	13.7	12.1
4.0	85.3	18.1	16.2
5.0	80.1	23.3	20.2
10.0	33.7	69.7	40.4

Table 3 Galvanised Steel Flat Strip Test Results

Weight (Kg)	Distance (mm)	Deflection (mm)	ANSYS (mm)
0.0	49.6		
0.5	46.8	2.8	2.4
1.0	44.4	5.2	4.8
1.5	41.9	7.7	7.2
2.0	39.2	10.4	9.6
2.5	36.3	13.3	12.0
3.0	33.8	15.8	14.4
4.0	28.8	20.8	19.1
5.0	22.8	26.8	23.9
10.0	nr		47.8

Table 4 Galvanised Steel Pressed Corner Test Results

Weight (Kg)	Distance (mm)	Deflection (mm)	ANSYS (mm)
0.0	96.6		
0.5	94	2.6	2.4
1.0	91.5	5.1	4.8
1.5	89	7.6	7.2
2.0	86.1	10.5	9.6
2.5	83.6	13	12.0
3.0	80.8	15.8	14.4
4.0	75.5	21.1	19.1
5.0	69.8	26.8	23.9
10.0	43.3	53.3	47.8

Table 5 Galvanised Steel Welded Corner Test Results

Appendix C Calculations

C.1 Loading on Head Shaft

Mass of belt and buckets fully loaded.

$M_{buckets}$ = 1.92 Kg .... mass of each pressed metal bucket

M_{Belt} = 3.2 Kg/m ..... mass of 320mm wide belt per unit length

ρ_{Grain} = 750 Kg/m^3 .. average density of grain

V_{Bucket} = 4.24 L .... water line volume of each bucket

α_{Over} = 1.2 .... Bucket over fill factor

x = 0.2 m .... Bucket spacing

D_{Height} = 26 m............. Elevator discharge height

g = 9.81 .... Gravity

<u>For a linear one meter section</u>

$$L_{belt} = 2 \times M_{Belt} = 2 \times 3.2 = 6.4 \text{ Kg/m}$$

$$L_{Buckets} = 1/x \times 2 \times M_{buckets} = 1/0.2 \times 2 \times 1.92 = 19.2 \text{ Kg/m}$$

$$L_{Grain} = \alpha_{Over} \times (V_{Bucket} \times 10^{-3} \times 1/x \times \rho_{Grain}) = 1.2 \times (4.24 \times 10^{-3} \times 1/0.2 \times 750) = 19.08 \text{ Kg/m}$$

$$L_{Total} = L_{belt} + L_{Buckets} + L_{Grain}$$

$= 6.4 + 19.2 + 19.08$

$= 44.68$ Kg/m

For a 26m discharge height elevator

$M_{Total} = L_{Total} \times D_{Height}$

$= 44.68 \times 26$

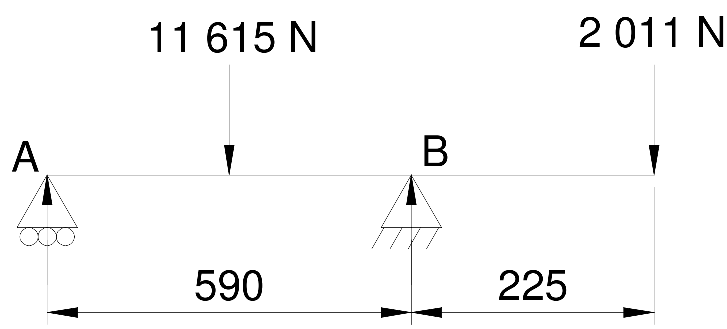
$= 1184$ Kg

$P1 = M_{Total} \times g$

$= 1184 \times 9.81$

$= 11.615$ kN

Bearing Loadings



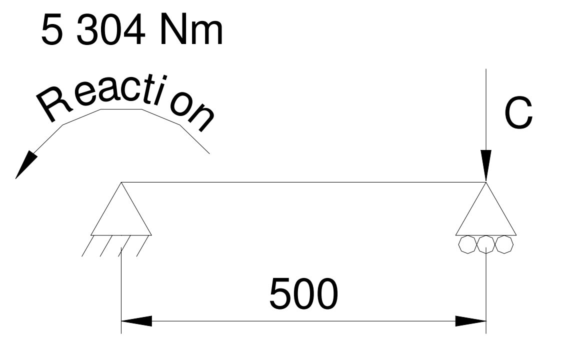
$$0.59\,B = (0.59/2) \times 11\,615 - (0.59 + 0.225) \times 2\,011 \quad \textbf{(C - 1)}$$

$B = 8\,585$ N

$$A = 11\,615 + 2\,011 + 8\,585 \quad \textbf{(C - 2)}$$

$= 5\,041$ N

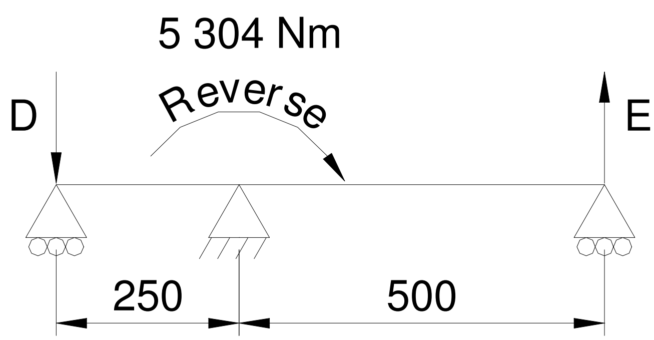
C.2 Loadings on Gearbox Bracket



C = 5 304/0.05 **(C - 3)**

= 10 605 N

C.3 Loading on Backstop Bracket



D = 0.5 x 5 304/0.25 **(C - 4)**

= 10 608 N

E = 0.5 x 5 304/0.5 **(C - 5)**

= 5 304 N

Appendix D Correspondence

D.1 Material Grades

Keith Schelberg

From: Tanya Duncan [tduncan@downfields.com.au]
Sent: Wednesday, 2 March 2005 10:32 AM
To: 'kschelberg@downfields.com.au'
Subject: grades

5mm plate - 250 grade (AS/NZS 1594 GR HA250 Lasergrade)

3.0 mm HR - 250 grade (AS1365-Blackform or AS1594/ GD HA1 Skinpassed)

3.0 mm galv - AS1397/ G2 Z275

Regards,

Tanya Duncan

DOWNFIELDS ENGINEERING
Factory: 19-29 Enterprise Street. TOOWOOMBA
Postal: P.O. Box 6095. TOOWOOMBA WEST. QLD. 4350. AUSTRALIA
Internet: www.downfields.com.au
Email: tduncan@downfields.com.au
Ph: (61) 07 46 344 622
Fax: (61) 07 46 331 049

D.2 Gearbox Outputs

Scott,

Good to hear from you! keep up the good work.

Take the full load torque of the motor as (kw x 9550) / RPM, in this case 97.65Nm and multiply that by the 278% or just 2.8 which equals 273Nm.

Now multiply it by ratio of 20 and also by 0.97 for the approximate efficiency and you have the peak output torque of 5304Nm.

Have I explained that clearly...... make a bad e-mail teacher I do!

Cheers

DB

Kind Regards

David Brown

****

ESM Australia
5/12 Billabong Street
Stafford, Queensland 4053
AUSTRALIA
P + 61 (0) 7 3856 3100
F + 61 (0) 7 3856 3056
M + 61 (0) 4 16 223 194
E davidbrown@esm.com.au

-----Original Message-----
From: Scott & Rebecca (mailto:sdrijanke@ezweb.com.au)
Sent: Wednesday, 25 May 2005 11:13 AM
To: davidbrown@esm.com.au
Subject: Starting torque calulation of a MRCI 140 G box

Dear David,

I need help to calculate the maximum output torque at start up so I can design the attaching brackets.

I'm doing my final year project as a bachelor of engineering (mechanical). It is the analysis of a sheet metal bucket elevator head that is manufactured by Downfield Engineering in Toowoomba. At the end of 2004 you had sent me a catalogue (G02) as requested by Keith Schelberg. Thank you once again for sending me this. The details of the drive used in design are as follows.

The gearbox chosen is:

Part No - MRCI 140 - 160L

i = 20

P1 = 15 kW

n2 = 70 min^-1

M2 = 196 daNm

fs = 1.7

page 95 of catalogue G02

The motor chosen is:

TECO

415 Volt 3 phase 50Hz class F TEFC squirrel cage motor

Power = 15 kW

Full load speed = 1467 rpm

Frame no = D160L

Efficiency 100% load = 91.1%

Power factor 100% load cosØ = 85.2%

D.O.L start current = 705% FLC

D.O.L. start torque = 278% FLT

Pull up torque = 218% FLT

Pull out torque = 312% FLT

Rotor inertia G.D^2 = 0.411 Kg.m^2

Max load inertia G.D^2 = 37.70 Kg.m^2

Could you please help me by giving me the equations and calculations to find the maximum starting torque, in the case if the elevator is jammed or overfull. Also I've had difficulty trying to find the gearbox efficiency, so could you please tell me this. Thank you for this David your help will be very much appreciated. You can try and call me on Ph. 46 33 7595 or fax on Fax. 46 33 7595 but best to email if possible, as I'm not always home.

Regards

Scott Janke

Appendix E ANSYS Programs

E.1 Motor Bracket Shell Model

```
/Title, Motor Bracket  - Shell Model
/Prep7

        !Properties
Et,1,SHELL63
R,1,5,5,5,5
R,2,6,6,6,6
R,3,9.5,9.5,9.5,9.5
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Channel
K,1,75,0
K,2,0,0
K,3,0,150
K,4,75,150
K,5,75,0,205
K,6,0,0,205
K,7,0,150,205
K,8,75,150,205
A,3,4,8,7
A,2,3,7,6
A,1,2,6,5

/VIEW,1,1,1,1
APLOT

        !Web
K,9,0,0,85
K,10,0,-8,85
K,11,0,-8,8
K,12,0,-92,8
K,13,0,-92,0
K,14,0,-400,0
K,15,0,-400,50
A,9,10,11,12,13,14,15,6

/VIEW,1,1,1,1

        !Join
AGLUE,ALL
```

```
    !Load points
HPTCreate,AREA,1,20,COORD,15,150,195
HPTCreate,AREA,1,21,COORD,15,150,185
HPTCreate,AREA,1,22,COORD,15,150,175
HPTCreate,AREA,1,23,COORD,15,150,165
HPTCreate,AREA,1,24,COORD,15,150,155
HPTCreate,AREA,1,25,COORD,15,150,145

    !Loads
KSEL,S,HPT,,20,25
FK,ALL,FY,1768

    !Restraints
HPTCreate,LINE,15,26,COORD,0,-100
HPTCreate,LINE,15,27,COORD,0,-150
HPTCreate,LINE,15,28,COORD,0,-200
HPTCreate,LINE,15,29,COORD,0,-250
HPTCreate,LINE,15,30,COORD,0,-300
HPTCreate,LINE,15,31,COORD,0,-350

HPTCreate,LINE,8,32,COORD,25,0
HPTCreate,LINE,8,33,COORD,50,0

HPTCreate,LINE,1,34,COORD,25,150
HPTCreate,LINE,1,35,COORD,50,150

    !Restraints
KSEL,S,HPT,,26,33
KSEL,A,KP,,1,2
KSEL,A,KP,,14
DK,ALL,UX,0,,,UY,UZ

KSEL,S,HPT,,34,35
KSEL,A,KP,,3,4,
DK,ALL,UY,0
ALLSEL

    !Asign Material Thickness
ALLSEL
ASEL,S,AREA,,1
ASEL,A,AREA,,6
AATT,1,3,1,0,-1

ASEL,S,AREA,,5
AATT,1,2,1,0,-1

FINISH
/EOF
```

E.2 Motor Bracket Channel only

```
/Title, Motor Bracket Channel Only
/Prep7

        !Properties
Et,1,SOLID45
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Channel
K,1,0,0
K,2,75,0
K,3,75,9.5
K,4,16,9.5
K,5,6,19.5
K,6,6,130.5
K,7,16,140.5
K,8,75,140.5
K,9,75,150
K,10,0,150

L,1,2
L,2,3
L,3,4
LARC,4,5,3,10
L,5,6
LARC,6,7,8,10
L,7,8
L,8,9
L,9,10
L,10,1

AL,ALL
VOFFSET,1,205,20

/VIEW,1,1,1,1
VPLOT

        !Load Line Hardpoints
HPTCREATE,AREA,9,80,COORD,16.5,140.5,145
HPTCREATE,AREA,9,81,COORD,16.5,140.5,150
HPTCREATE,AREA,9,82,COORD,16.5,140.5,155
HPTCREATE,AREA,9,83,COORD,16.5,140.5,160
HPTCREATE,AREA,9,84,COORD,16.5,140.5,165
HPTCREATE,AREA,9,85,COORD,16.5,140.5,170
HPTCREATE,AREA,9,86,COORD,16.5,140.5,175
```

```
HPTCREATE,AREA,9,87,COORD,16.5,140.5,180
HPTCREATE,AREA,9,88,COORD,16.5,140.5,185
HPTCREATE,AREA,9,89,COORD,16.5,140.5,190
HPTCREATE,AREA,9,90,COORD,16.5,140.5,195
HPTCREATE,AREA,9,91,COORD,16.5,140.5,200

        !Restraints
DL,42,,UX,0
DL,42,,UY,0
DL,42,,UZ,0
DL,3,,UX,0
DL,3,,UY,0
DL,3,,UZ,0
DL,9,,UX,0
DL,9,,UY,0

        !Loads
KSEL,S,HPT,,80,91
FK,ALL,FY,842
ALLSEL
/PBC,ALL,1

        !Meshing
VMESH,ALL

/EOF
```

E.3 Motor Bracket Omitted Angle

```
/Title, Motor Bracket Omitted Angle
/Prep7

        !Properties
Et,1,SOLID45
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Channel
K,1,0,0
K,2,75,0
K,3,75,9.5
K,4,16,9.5
K,5,6,19.5
K,6,6,130.5
K,7,16,140.5
K,8,75,140.5
K,9,75,150
K,10,0,150

L,1,2
L,2,3
L,3,4
LARC,4,5,3,10
L,5,6
LARC,6,7,8,10
L,7,8
L,8,9
L,9,10
L,10,1

AL,ALL
VOFFSET,1,205,20

        !Web
K,40,0,0,85
K,41,0,-8,85
K,42,0,-8,8
K,43,0,-92,8
K,44,0,-92,0
K,45,0,-400
K,46,0,-400,50
A,40,41,42,43,44,45,46,21
VOFFSET,13,-5
```

```
/VIEW,1,1,1,1
VPLOT

        !Join
VADD,1,2

        !Welding Hardpoints
HPTCREATE,LINE,35,51,COORD,0,-100
HPTCREATE,LINE,35,52,COORD,0,-110
HPTCREATE,LINE,35,53,COORD,0,-120
HPTCREATE,LINE,35,54,COORD,0,-225
HPTCREATE,LINE,35,55,COORD,0,-235
HPTCREATE,LINE,35,56,COORD,0,-245
HPTCREATE,LINE,35,57,COORD,0,-255
HPTCREATE,LINE,35,58,COORD,0,-360
HPTCREATE,LINE,35,59,COORD,0,-370
HPTCREATE,LINE,35,60,COORD,0,-380
HPTCREATE,LINE,35,61,COORD,0,-390

HPTCREATE,LINE,43,63,COORD,5,-100
HPTCREATE,LINE,43,64,COORD,5,-110
HPTCREATE,LINE,43,65,COORD,5,-120
HPTCREATE,LINE,43,66,COORD,5,-225
HPTCREATE,LINE,43,67,COORD,5,-235
HPTCREATE,LINE,43,68,COORD,5,-245
HPTCREATE,LINE,43,69,COORD,5,-255
HPTCREATE,LINE,43,70,COORD,5,-360
HPTCREATE,LINE,43,71,COORD,5,-370
HPTCREATE,LINE,43,72,COORD,5,-380
HPTCREATE,LINE,43,73,COORD,5,-390

        !Load Line Hardpoints
HPTCREATE,AREA,9,80,COORD,16.5,140.5,145
HPTCREATE,AREA,9,81,COORD,16.5,140.5,150
HPTCREATE,AREA,9,82,COORD,16.5,140.5,155
HPTCREATE,AREA,9,83,COORD,16.5,140.5,160
HPTCREATE,AREA,9,84,COORD,16.5,140.5,165
HPTCREATE,AREA,9,85,COORD,16.5,140.5,170
HPTCREATE,AREA,9,86,COORD,16.5,140.5,175
HPTCREATE,AREA,9,87,COORD,16.5,140.5,180
HPTCREATE,AREA,9,88,COORD,16.5,140.5,185
HPTCREATE,AREA,9,89,COORD,16.5,140.5,190
HPTCREATE,AREA,9,90,COORD,16.5,140.5,195
HPTCREATE,AREA,9,91,COORD,16.5,140.5,200


        !Restraints
```

```
KSEL,S,HPT,,51,73
DK,ALL,UX,0,,,UY,UZ
ALLSEL

DL,42,,UX,0
DL,42,,UY,0
DL,42,,UZ,0
DL,3,,UX,0
DL,3,,UY,0
DL,3,,UZ,0
DL,9,,UX,0
DL,9,,UY,0

        !Loads
KSEL,S,HPT,,80,91
FK,ALL,FY,842
ALLSEL
/PBC,ALL,1

        !Meshing
VMESH,ALL

/EOF
```

E.4 Motor Bracket Solid Web

```
/Title, Motor Bracket Solid Web
/Prep7

        !Properties
Et,1,SOLID45
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Channel
K,1,0,0
K,2,75,0
K,3,75,9.5
K,4,16,9.5
K,5,6,19.5
K,6,6,130.5
K,7,16,140.5
K,8,75,140.5
K,9,75,150
K,10,0,150

L,1,2
L,2,3
L,3,4
LARC,4,5,3,10
L,5,6
LARC,6,7,8,10
L,7,8
L,8,9
L,9,10
L,10,1

AL,ALL
VOFFSET,1,205,20

        !Web
K,40,0,-400
K,41,0,-400,50

A,1,21,41,40
VOFFSET,13,5
/VIEW,1,1,1,1
VPLOT

        !Join
VADD,1,2
```

```
    !Welding Hardpoints
HPTCREATE,LINE,33,50,COORD,0,-90
HPTCREATE,LINE,33,51,COORD,0,-100
HPTCREATE,LINE,33,52,COORD,0,-110
HPTCREATE,LINE,33,53,COORD,0,-120
HPTCREATE,LINE,33,54,COORD,0,-225
HPTCREATE,LINE,33,55,COORD,0,-235
HPTCREATE,LINE,33,56,COORD,0,-245
HPTCREATE,LINE,33,57,COORD,0,-255
HPTCREATE,LINE,33,58,COORD,0,-360
HPTCREATE,LINE,33,59,COORD,0,-370
HPTCREATE,LINE,33,60,COORD,0,-380
HPTCREATE,LINE,33,61,COORD,0,-390

HPTCREATE,LINE,37,62,COORD,5,-90
HPTCREATE,LINE,37,63,COORD,5,-100
HPTCREATE,LINE,37,64,COORD,5,-110
HPTCREATE,LINE,37,65,COORD,5,-120
HPTCREATE,LINE,37,66,COORD,5,-225
HPTCREATE,LINE,37,67,COORD,5,-235
HPTCREATE,LINE,37,68,COORD,5,-245
HPTCREATE,LINE,37,69,COORD,5,-255
HPTCREATE,LINE,37,70,COORD,5,-360
HPTCREATE,LINE,37,71,COORD,5,-370
HPTCREATE,LINE,37,72,COORD,5,-380
HPTCREATE,LINE,37,73,COORD,5,-390

    !Load Line Hardpoints
HPTCREATE,AREA,9,80,COORD,16.5,140.5,145
HPTCREATE,AREA,9,81,COORD,16.5,140.5,150
HPTCREATE,AREA,9,82,COORD,16.5,140.5,155
HPTCREATE,AREA,9,83,COORD,16.5,140.5,160
HPTCREATE,AREA,9,84,COORD,16.5,140.5,165
HPTCREATE,AREA,9,85,COORD,16.5,140.5,170
HPTCREATE,AREA,9,86,COORD,16.5,140.5,175
HPTCREATE,AREA,9,87,COORD,16.5,140.5,180
HPTCREATE,AREA,9,88,COORD,16.5,140.5,185
HPTCREATE,AREA,9,89,COORD,16.5,140.5,190
HPTCREATE,AREA,9,90,COORD,16.5,140.5,195
HPTCREATE,AREA,9,91,COORD,16.5,140.5,200


    !Meshing
VMESH,ALL

FINISH
```

```
/SOLU
        !Restraints
KSEL,S,HPT,,50,73
DK,ALL,UX,0,,,UY,UZ
ALLSEL

DL,42,,UX,0
DL,42,,UY,0
DL,42,,UZ,0
DL,3,,UX,0
DL,3,,UY,0
DL,3,,UZ,0
DL,9,,UX,0
DL,9,,UY,0

        !Loads
KSEL,S,HPT,,80,91
FK,ALL,FY,842
ALLSEL
/PBC,ALL,1

/EOF
```

E.5 Backstop Bracket Without Fillet Welds

```
/Title, BackStop Bracket Without Fillets
/Prep7

        !Properties
Et,1,SOLID45
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Channel
K,1,0,0
K,2,50,0
K,3,50,6.7
K,4,12.2,6.7
K,5,4.2,14.7
K,6,4.2,85.3
K,7,12.2,93.3
K,8,50,93.3
K,9,50,100
K,10,0,100
/VIEW,1,1,1,1
VPLOT

L,1,2
L,2,3
L,3,4
LARC,4,5,3,8
L,5,6
LARC,6,7,8,8
L,7,8
L,8,9
L,9,10
L,10,1
AL,ALL
VOFFSET,1,195

        !Lugs
K,21,0,25,195
K,22,-80,25,195
K,23,-80,100,195

L,20,21
L,21,22
L,22,23
L,23,20
LSEL,S,LINE,,31,34
```

```
AL,ALL
VOFFSET,13,10
ALLSEL

        !Hole in lug
K,30,-55,62.5,195

CIRCLE,30,10

LSEL,S,LINE,,43,46
AL,ALL
VOFFSET,19,-10
ALLSEL

        !Join
VSBV,2,3
VGEN,2,4,,,0,0,-30
VADD,1,2,4

        !Meshing
VMESH,ALL

FINISH
/SOLU
        !Restraints
LSEL,S,LINE,,1
LSEL,A,LINE,,3
LSEL,A,LINE,,7
LSEL,A,LINE,,9
DL,ALL,,UX,0
DL,ALL,,UY,0
DL,ALL,,UZ,0

        !Loads
KSEL,S,KP,,28,29
KSEL,A,KP,,31
KSEL,A,KP,,33,35
KSEL,A,KP,,41,42
KSEL,A,KP,,44
KSEL,A,KP,,45,47
FK,ALL,FY,982
ALLSEL

/VIEW,1,1,1,1
/PBC,ALL,1
VPLOT
FINISH
/EOF
```

E.6 Backstop Bracket With Fillet Welds

```
/Title, BackStop Bracket With Fillets
/Prep7

        !Properties
Et,1,SOLID45
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Channel
K,1,0,0
K,2,50,0
K,3,50,6.7
K,4,12.2,6.7
K,5,4.2,14.7
K,6,4.2,85.3
K,7,12.2,93.3
K,8,50,93.3
K,9,50,100
K,10,0,100
/VIEW,1,1,1,1
VPLOT

L,1,2
L,2,3
L,3,4
LARC,4,5,3,8
L,5,6
LARC,6,7,8,8
L,7,8
L,8,9
L,9,10
L,10,1

AL,ALL
VOFFSET,1,195

        !Lug
K,21,0,25,195
K,22,-80,25,195
K,23,-80,100,195


L,20,21
L,21,22
L,22,23
```

```
L,23,20

LSEL,S,LINE,,31,34
AL,ALL
VOFFSET,13,10
ALLSEL

        !Hole in lug
K,30,-55,62.5,195

CIRCLE,30,10

LSEL,S,LINE,,43,46
AL,ALL
VOFFSET,19,-10
ALLSEL

        !Join
VSBV,2,3
VGEN,2,4,,,0,0,-30
VADD,1,2,4

        !Weld on lugs
K,53,-6,25,195
K,54,0,19,195
K,55,-6,25,185
K,56,0,19,185
K,57,-6,25,165
K,58,0,19,165
K,59,-6,25,155
K,60,0,19,155

V,53,54,21,21,55,56,25,25
V,57,58,38,38,59,60,50,50
VADD,1,2,3
        !Meshing
VMESH,ALL

FINISH
/SOLU
        !Restraints
LSEL,S,LINE,,1
LSEL,A,LINE,,3
LSEL,A,LINE,,7
LSEL,A,LINE,,9

DL,ALL,,UX,0
DL,ALL,,UY,0
```

```
DL,ALL,,UZ,0

          !Loads
KSEL,S,KP,,28,29
KSEL,A,KP,,31
KSEL,A,KP,,33,35
KSEL,A,KP,,41,42
KSEL,A,KP,,44
KSEL,A,KP,,45,47

FK,ALL,FY,982
ALLSEL

/VIEW,1,1,1,1
/PBC,ALL,1
VPLOT

FINISH
/EOF
```

E.7 Head Jammed Boot Without Throat

```
/Title, Head Frame Without Throat
/Prep7

        !Properties
Et,1,SHELL63
R,1,3,3,3,3
R,2,5,5,5,5
R,3,8,8,8,8
R,4,11,11,11,11
R,5,12,12,12,12
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Side Panel
K,1,0,0
K,2,295,0
K,3,295,539
K,4,0,539
A,1,2,3,4

K,5,805,0
K,6,805,539
A,2,5,6,3

K,7,1050,0
K,8,1050,189
K,200,975,189
K,201,975,539
A,5,7,8,200,201,6

K,9,1750,0
K,10,1750,267
K,11,1716,539
K,202,1125,539
K,203,1125,189
K,204,1050,539
A,7,9,10,11,202,203,8
A,8,200,201,204
A,8,203,202,204

K,12,0,629
K,13,1689,629
A,4,11,13,12

K,205,975,629
```

```
K,206,1050,629
K,207,1050,779
K,208,975,779
A,205,206,207,208

K,20,945,629
K,21,1080,629
K,22,1080,829
K,23,945,829
A,20,205,208,207,206,21,22,23

K,24,1569,874
K,25,15,874
K,26,0,737
A,12,20,23,22,21,13,24,25,26

/VIEW,1,1,1,1
APLOT

K,210,0,0,-416
K,211,295,0,-416
K,212,295,539,-416
K,213,0,539,-416
A,210,211,212,213

K,214,805,0,-416
K,215,805,539,-416
A,211,214,215,212

K,216,1750,0,-416
K,217,1750,267,-416
K,218,1716,539,-416
A,214,216,217,218,215

K,219,0,629,-416
K,220,1689,629,-416
A,213,219,220,218

K,221,200,629,-416
K,222,250,629,-416
K,223,250,729,-416
K,224,200,729,-416
A,221,222,223,224

K,225,1569,874,-416
K,226,15,874,-416
K,227,0,737,-416
A,219,221,224,223,222,220,225,226,227
```

```
        !End Panels
A,9,216,217,10
A,10,217,218,11
A,11,218,220,13
A,13,220,225,24
A,1,210,227,26
A,26,227,226,25

        !Bottom Flange
K,41,-50,0,50
K,42,1800,0,50
K,43,1800,0,-466
K,44,-50,0,-466

A,41,42,43,44
A,1,9,216,210

ASBA,23,24

        !Top Flange
K,45,-35,874,50
K,46,1619,874,50
K,47,1619,874,-466
K,48,-35,874,-466

A,45,46,47,48
A,25,24,225,226

ASBA,23,24

        !Angles
K,54,1689,629,90
K,55,0,629,90
K,56,805,629,90
K,57,805,629,40
K,58,295,629,40
K,59,295,629,90
K,60,295,629,160
K,61,805,629,160

A,12,13,54,56,57,58,59,55
A,57,58,60,61

K,62,1689,629,-506
K,63,0,629,-506
K,64,805,629,-506
K,65,805,629,-456
```

```
K,66,295,629,-456
K,67,295,629,-506
K,68,295,629,-576
K,69,805,629,-576

A,219,220,62,64,65,66,67,63
A,65,66,68,69

        !Bearing Supports
K,70,295,629,0
K,71,295,129,0
K,72,295,129,35
K,73,310,629,160
K,74,310,129,35
A,60,70,71,72
A,60,72,74,73

K,75,805,629,0
K,76,805,129,0
K,77,805,129,35
K,78,790,629,160
K,79,790,129,35
A,61,75,76,77
A,61,77,79,78

K,80,295,629,-416
K,81,295,129,-416
K,82,295,129,-451
K,83,310,629,-576
K,84,310,129,-451
A,68,80,81,82
A,68,82,84,83

K,85,805,629,-416
K,86,805,129,-416
K,87,805,129,-451
K,88,790,629,-576
K,89,790,129,-451
A,69,85,86,87
A,69,87,89,88

        !Motor Bracket
K,92,1050,779,205
K,93,1050,629,205
K,94,1050,629,90
K,95,975,629,90
K,96,975,629,205
K,97,975,779,205
```

```
K,99,1050,229,0
K,100,1050,229,50

A,206,207,92,93
A,93,94,95,96
A,207,92,97,208
A,93,206,99,100

AGLUE,ALL
        !Asign Material Thickness
ALLSEL
ASEL,S,AREA,,51
ASEL,A,AREA,,61
AATT,1,2,1,0,-1

ASEL,S,AREA,,41,46
ASEL,A,AREA,,52
ASEL,A,AREA,,54,55
ASEL,A,AREA,,57,58
ASEL,A,AREA,,63,64
ASEL,A,AREA,,70
AATT,1,3,1,0,-1

ASEL,S,AREA,,8,9
ASEL,A,AREA,,49,50
ASEL,A,AREA,,39
ASEL,A,AREA,,47
AATT,1,4,1,0,-1

ASEL,S,AREA,,71,72
AATT,1,5,1,0,-1
ALLSEL

        !Restraints

        !Hold down bolts
!HPTCreate,LINE,1,121,COORD,150,0,0
HPTCreate,LINE,5,122,COORD,325,0,0
HPTCreate,LINE,5,123,COORD,775,0,0
HPTCreate,LINE,8,124,COORD,950,0,0
HPTCreate,LINE,13,125,COORD,1125,0,0
HPTCreate,LINE,13,126,COORD,1225,0,0
HPTCreate,LINE,13,127,COORD,1362,0,0
HPTCreate,LINE,13,128,COORD,1500,0,0
HPTCreate,LINE,13,129,COORD,1638,0,0

!HPTCreate,LINE,42,132,COORD,150,0,-416
HPTCreate,LINE,45,133,COORD,325,0,-416
```

```
HPTCreate,LINE,45,134,COORD,775,0,-416
HPTCreate,LINE,48,135,COORD,950,0,-416
HPTCreate,LINE,48,136,COORD,1125,0,-416
HPTCreate,LINE,48,137,COORD,1225,0,-416
HPTCreate,LINE,48,138,COORD,1362,0,-416
HPTCreate,LINE,48,139,COORD,1500,0,-416
HPTCreate,LINE,48,140,COORD,1638,0,-416

HPTCreate,LINE,71,142,COORD,0,0,-131
HPTCreate,LINE,71,143,COORD,0,0,-289
HPTCreate,LINE,66,144,COORD,1750,0,-131
HPTCreate,LINE,66,145,COORD,1750,0,-289

        !Motor bracket load points
HPTCreate,AREA,51,147,COORD,1050,769,195
HPTCreate,AREA,51,149,COORD,1050,769,185
HPTCreate,AREA,51,151,COORD,1050,769,175
HPTCreate,AREA,51,153,COORD,1050,769,165
HPTCreate,AREA,51,155,COORD,1050,769,155
HPTCreate,AREA,51,157,COORD,1050,769,145

        !Backstop bracket load points
!HPTCreate,AREA,40,158,COORD,250,720,-610
!HPTCreate,AREA,40,159,COORD,250,720,-600
!HPTCreate,AREA,40,160,COORD,250,720,-580
!HPTCreate,AREA,40,161,COORD,250,720,-570

        !Bearing loading points
HPTCreate,AREA,71,170,COORD,420,629,68
HPTCreate,AREA,71,171,COORD,680,629,68
HPTCreate,AREA,72,172,COORD,420,629,-503
HPTCreate,AREA,72,173,COORD,680,629,-503

        !Restraints
KSEL,S,HPT,,120,145
DK,ALL,UX,0,,,UY,UZ
ALLSEL

        !Loads
KSEL,S,HPT,,146,157
FK,ALL,FY,1768

KSEL,S,HPT,,170,171
FK,ALL,FY,-4293
KSEL,S,HPT,,172,173
FK,ALL,FY,-2520
ALLSEL
```

```
      !Meshing
AMESH,ALL
/PBC,ALL,1

FINISH
EOF
```

E.8 Head Jammed Boot With Throat

```
!This Programme Includes the Throat panels
/Title, Head Frame With Throat
/Prep7

        !Properties
Et,1,SHELL63
R,1,3,3,3,3
R,2,5,5,5,5
R,3,8,8,8,8
R,4,11,11,11,11
R,5,12,12,12,12
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Side Panel
K,1,0,0
K,2,295,0
K,3,295,539
K,4,0,539
A,1,2,3,4

K,5,805,0
K,6,805,539
A,2,5,6,3

K,7,1050,0
K,8,1050,189
K,200,975,189
K,201,975,539
A,5,7,8,200,201,6

K,9,1750,0
K,10,1750,267
K,11,1716,539
K,202,1125,539
K,203,1125,189
K,204,1050,539
K,228,1100,0
K,229,1100,170
K,230,1250,0
A,7,228,229,230,9,10,11,202,203,8
A,8,200,201,204
A,8,203,202,204

K,12,0,629
```

```
K,13,1689,629
A,4,11,13,12

K,205,975,629
K,206,1050,629
K,207,1050,779
K,208,975,779
A,205,206,207,208

K,20,945,629
K,21,1080,629
K,22,1080,829
K,23,945,829
A,20,205,208,207,206,21,22,23

K,24,1569,874
K,25,15,874
K,26,0,737
A,12,20,23,22,21,13,24,25,26

/VIEW,1,1,1,1
APLOT

K,210,0,0,-416
K,211,295,0,-416
K,212,295,539,-416
K,213,0,539,-416
A,210,211,212,213

K,214,805,0,-416
K,215,805,539,-416
A,211,214,215,212

K,216,1750,0,-416
K,217,1750,267,-416
K,218,1716,539,-416
K,231,1100,0,-416
K,232,1100,170,-416
K,233,1250,0,-416
A,214,231,232,233,216,217,218,215

K,219,0,629,-416
K,220,1689,629,-416
A,213,219,220,218

K,221,200,629,-416
K,222,250,629,-416
K,223,250,729,-416
```

```
K,224,200,729,-416
A,221,222,223,224

K,225,1569,874,-416
K,226,15,874,-416
K,227,0,737,-416
A,219,221,224,223,222,220,225,226,227

        !End Panels
A,9,216,217,10
A,10,217,218,11
A,11,218,220,13
A,13,220,225,24
A,1,210,227,26
A,26,227,226,25

        !Bottom Flange
K,41,-50,0,50
K,42,1800,0,50
K,43,1800,0,-466
K,44,-50,0,-466

A,41,42,43,44
A,1,9,216,210

ASBA,23,24

        !Top Flange
K,45,-35,874,50
K,46,1619,874,50
K,47,1619,874,-466
K,48,-35,874,-466

A,45,46,47,48
A,25,24,225,226

ASBA,23,24

        !Angles
K,54,1689,629,90
K,55,0,629,90
K,56,805,629,90
K,57,805,629,40
K,58,295,629,40
K,59,295,629,90
K,60,295,629,160
K,61,805,629,160
```

```
A,12,13,54,56,57,58,59,55
A,57,58,60,61

K,62,1689,629,-506
K,63,0,629,-506
K,64,805,629,-506
K,65,805,629,-456
K,66,295,629,-456
K,67,295,629,-506
K,68,295,629,-576
K,69,805,629,-576

A,219,220,62,64,65,66,67,63
A,65,66,68,69

        !Bearing Supports
K,70,295,629,0
K,71,295,129,0
K,72,295,129,35
K,73,310,629,160
K,74,310,129,35
A,60,70,71,72
A,60,72,74,73

K,75,805,629,0
K,76,805,129,0
K,77,805,129,35
K,78,790,629,160
K,79,790,129,35
A,61,75,76,77
A,61,77,79,78

K,80,295,629,-416
K,81,295,129,-416
K,82,295,129,-451
K,83,310,629,-576
K,84,310,129,-451
A,68,80,81,82
A,68,82,84,83

K,85,805,629,-416
K,86,805,129,-416
K,87,805,129,-451
K,88,790,629,-576
K,89,790,129,-451
A,69,85,86,87
A,69,87,89,88
```

```
        !Motor Bracket
K,92,1050,779,205
K,93,1050,629,205
K,94,1050,629,90
K,95,975,629,90
K,96,975,629,205
K,97,975,779,205
K,99,1050,229,0
K,100,1050,229,50

A,206,207,92,93
A,93,94,95,96
A,207,92,97,208
A,93,206,99,100

        !Throat
A,228,229,232,231
A,232,233,230,229

        !Asign Material Thickness
ALLSEL
ASEL,S,AREA,,53
ASEL,A,AREA,,62
AATT,1,2,1,0,-1

ASEL,S,AREA,,47,48
ASEL,A,AREA,,54
ASEL,A,AREA,,56,57
ASEL,A,AREA,,65
ASEL,A,AREA,,71
AATT,1,3,1,0,-1

ASEL,S,AREA,,8,9
ASEL,A,AREA,,39
ASEL,A,AREA,,43,46
ASEL,A,AREA,,49
ASEL,A,AREA,,51,52
ASEL,A,AREA,,59,60
ASEL,A,AREA,,64
AATT,1,4,1,0,-1

ASEL,S,AREA,,72,73
AATT,1,5,1,0,-1
ALLSEL

        !Restraints

        !Hold down bolts
```

```
HPTCreate,LINE,5,122,COORD,325,0,0
HPTCreate,LINE,5,123,COORD,775,0,0
HPTCreate,LINE,8,124,COORD,950,0,0
HPTCreate,LINE,191,125,COORD,1125,0,0
HPTCreate,LINE,191,126,COORD,1225,0,0
HPTCreate,LINE,16,127,COORD,1362,0,0
HPTCreate,LINE,16,128,COORD,1500,0,0
HPTCreate,LINE,16,129,COORD,1638,0,0

HPTCreate,LINE,48,133,COORD,325,0,-416
HPTCreate,LINE,48,134,COORD,775,0,-416
HPTCreate,LINE,51,135,COORD,950,0,-416
HPTCreate,LINE,192,136,COORD,1125,0,-416
HPTCreate,LINE,192,137,COORD,1225,0,-416
HPTCreate,LINE,54,138,COORD,1362,0,-416
HPTCreate,LINE,54,139,COORD,1500,0,-416
HPTCreate,LINE,54,140,COORD,1638,0,-416

HPTCreate,LINE,77,142,COORD,0,0,-131
HPTCreate,LINE,77,143,COORD,0,0,-289
HPTCreate,LINE,72,144,COORD,1750,0,-131
HPTCreate,LINE,72,145,COORD,1750,0,-289

        !Motor bracket load points
HPTCreate,AREA,53,147,COORD,1050,769,195
HPTCreate,AREA,53,149,COORD,1050,769,185
HPTCreate,AREA,53,151,COORD,1050,769,175
HPTCreate,AREA,53,153,COORD,1050,769,165
HPTCreate,AREA,53,155,COORD,1050,769,155
HPTCreate,AREA,53,157,COORD,1050,769,145

        !Bearing loading points
HPTCreate,AREA,72,170,COORD,420,629,68
HPTCreate,AREA,72,171,COORD,680,629,68
HPTCreate,AREA,73,172,COORD,420,629,-503
HPTCreate,AREA,73,173,COORD,680,629,-503

        !Restraints
KSEL,S,HPT,,120,145
DK,ALL,UX,0,,,UY,UZ
ALLSEL

        !Loads
KSEL,S,HPT,,146,157
FK,ALL,FY,1768

KSEL,S,HPT,,170,171
FK,ALL,FY,-4293
```

```
KSEL,S,HPT,,172,173
FK,ALL,FY,-2520
ALLSEL

          !Meshing
AMESH,ALL
/PBC,ALL,1

FINISH
/EOF
```

E.9 Head Jammed Boot With Wearing

```
!This Program Includes the Throat panels
!And looks at wear on the end panels
/Title, Head Frame Wearing
/Prep7

        !Properties
Et,1,SHELL63
R,1,3,3,3,3
R,2,5,5,5,5
R,3,8,8,8,8
R,4,11,11,11,11
R,5,12,12,12,12
R,6,1,1,1,1
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Side Panel
K,1,0,0
K,2,295,0
K,3,295,539
K,4,0,539
A,1,2,3,4

K,5,805,0
K,6,805,539
A,2,5,6,3

K,7,1050,0
K,8,1050,189
K,200,975,189
K,201,975,539
A,5,7,8,200,201,6

K,9,1750,0
K,10,1750,267
K,11,1716,539
K,202,1125,539
K,203,1125,189
K,204,1050,539
K,228,1100,0
K,229,1100,170
K,230,1250,0
A,7,228,229,230,9,10,11,202,203,8
A,8,200,201,204
A,8,203,202,204
```

```
K,12,0,629
K,13,1689,629
A,4,11,13,12

K,205,975,629
K,206,1050,629
K,207,1050,779
K,208,975,779
A,205,206,207,208

K,20,945,629
K,21,1080,629
K,22,1080,829
K,23,945,829
A,20,205,208,207,206,21,22,23

K,24,1569,874
K,25,15,874
K,26,0,737
A,12,20,23,22,21,13,24,25,26

/VIEW,1,1,1,1
APLOT

K,210,0,0,-416
K,211,295,0,-416
K,212,295,539,-416
K,213,0,539,-416
A,210,211,212,213

K,214,805,0,-416
K,215,805,539,-416
A,211,214,215,212

K,216,1750,0,-416
K,217,1750,267,-416
K,218,1716,539,-416
K,231,1100,0,-416
K,232,1100,170,-416
K,233,1250,0,-416
A,214,231,232,233,216,217,218,215

K,219,0,629,-416
K,220,1689,629,-416
A,213,219,220,218

K,221,200,629,-416
```

```
K,222,250,629,-416
K,223,250,729,-416
K,224,200,729,-416
A,221,222,223,224

K,225,1569,874,-416
K,226,15,874,-416
K,227,0,737,-416
A,219,221,224,223,222,220,225,226,227

        !End Panels
A,9,216,217,10
A,10,217,218,11
A,11,218,220,13
A,13,220,225,24
A,1,210,227,26
A,26,227,226,25

        !Bottom Flange
K,41,-50,0,50
K,42,1800,0,50
K,43,1800,0,-466
K,44,-50,0,-466

A,41,42,43,44
A,1,9,216,210
ASBA,23,24

        !Top Flange
K,45,-35,874,50
K,46,1619,874,50
K,47,1619,874,-466
K,48,-35,874,-466

A,45,46,47,48
A,25,24,225,226

ASBA,23,24

        !Angles
K,54,1689,629,90
K,55,0,629,90
K,56,805,629,90
K,57,805,629,40
K,58,295,629,40
K,59,295,629,90
K,60,295,629,160
K,61,805,629,160
```

```
A,12,13,54,56,57,58,59,55
A,57,58,60,61

K,62,1689,629,-506
K,63,0,629,-506
K,64,805,629,-506
K,65,805,629,-456
K,66,295,629,-456
K,67,295,629,-506
K,68,295,629,-576
K,69,805,629,-576

A,219,220,62,64,65,66,67,63
A,65,66,68,69

        !Bearing Supports
K,70,295,629,0
K,71,295,129,0
K,72,295,129,35
K,73,310,629,160
K,74,310,129,35
A,60,70,71,72
A,60,72,74,73

K,75,805,629,0
K,76,805,129,0
K,77,805,129,35
K,78,790,629,160
K,79,790,129,35
A,61,75,76,77
A,61,77,79,78

K,80,295,629,-416
K,81,295,129,-416
K,82,295,129,-451
K,83,310,629,-576
K,84,310,129,-451
A,68,80,81,82
A,68,82,84,83

K,85,805,629,-416
K,86,805,129,-416
K,87,805,129,-451
K,88,790,629,-576
K,89,790,129,-451
A,69,85,86,87
A,69,87,89,88
```

```
        !Motor Bracket
K,92,1050,779,205
K,93,1050,629,205
K,94,1050,629,90
K,95,975,629,90
K,96,975,629,205
K,97,975,779,205
K,99,1050,229,0
K,100,1050,229,50

A,206,207,92,93
A,93,94,95,96
A,207,92,97,208
A,93,206,99,100

        !Throat
A,228,229,232,231
A,232,233,230,229

        !Backstop Bracket
!K,101,250,629,-416
!K,102,250,729,-416
!K,103,250,729,-611
!K,104,250,629,-611
!K,105,250,629,-506
!K,106,200,629,-506
!K,107,200,629,-611
!K,108,200,729,-611
!K,109,200,729,-416

!A,101,102,103,104
!A,104,105,106,107
!A,102,103,108,109

AGLUE,ALL

        !Asign Material Thickness
ALLSEL
ASEL,S,AREA,,53
ASEL,A,AREA,,62
AATT,1,2,1,0,-1

ASEL,S,AREA,,47,48
ASEL,A,AREA,,54
ASEL,A,AREA,,56,57
ASEL,A,AREA,,65
ASEL,A,AREA,,71
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```
AATT,1,3,1,0,-1
ASEL,S,AREA,,8,9
ASEL,A,AREA,,39
ASEL,A,AREA,,43,46
ASEL,A,AREA,,49
ASEL,A,AREA,,51,52
ASEL,A,AREA,,59,60
ASEL,A,AREA,,64
AATT,1,4,1,0,-1
ASEL,S,AREA,,72,73
AATT,1,5,1,0,-1
ASEL,S,AREA,,17,20
ASEL,A,AREA,,22
ASEL,A,AREA,,70
AATT,1,6,1,0,-1
ALLSEL

        !Restraints

        !Hold down bolts
!HPTCreate,LINE,1,121,COORD,150,0,0
HPTCreate,LINE,5,122,COORD,325,0,0
HPTCreate,LINE,5,123,COORD,775,0,0
HPTCreate,LINE,8,124,COORD,950,0,0
HPTCreate,LINE,191,125,COORD,1125,0,0
HPTCreate,LINE,191,126,COORD,1225,0,0
HPTCreate,LINE,16,127,COORD,1362,0,0
HPTCreate,LINE,16,128,COORD,1500,0,0
HPTCreate,LINE,16,129,COORD,1638,0,0

!HPTCreate,LINE,44,132,COORD,150,0,-416
HPTCreate,LINE,48,133,COORD,325,0,-416
HPTCreate,LINE,48,134,COORD,775,0,-416
HPTCreate,LINE,51,135,COORD,950,0,-416
HPTCreate,LINE,192,136,COORD,1125,0,-416
HPTCreate,LINE,192,137,COORD,1225,0,-416
HPTCreate,LINE,54,138,COORD,1362,0,-416
HPTCreate,LINE,54,139,COORD,1500,0,-416
HPTCreate,LINE,54,140,COORD,1638,0,-416

HPTCreate,LINE,77,142,COORD,0,0,-131
HPTCreate,LINE,77,143,COORD,0,0,-289
HPTCreate,LINE,72,144,COORD,1750,0,-131
HPTCreate,LINE,72,145,COORD,1750,0,-289

        !Motor bracket load points
HPTCreate,AREA,53,147,COORD,1050,769,195
HPTCreate,AREA,53,149,COORD,1050,769,185
```

```
HPTCreate,AREA,53,151,COORD,1050,769,175
HPTCreate,AREA,53,153,COORD,1050,769,165
HPTCreate,AREA,53,155,COORD,1050,769,155
HPTCreate,AREA,53,157,COORD,1050,769,145

        !Backstop bracket load points
!HPTCreate,AREA,40,158,COORD,250,720,-610
!HPTCreate,AREA,40,159,COORD,250,720,-600
!HPTCreate,AREA,40,160,COORD,250,720,-580
!HPTCreate,AREA,40,161,COORD,250,720,-570

        !Bearing loading points
HPTCreate,AREA,72,170,COORD,420,629,68
HPTCreate,AREA,72,171,COORD,680,629,68
HPTCreate,AREA,73,172,COORD,420,629,-503
HPTCreate,AREA,73,173,COORD,680,629,-503

        !Restraints
KSEL,S,HPT,,120,145
DK,ALL,UX,0,,,UY,UZ
ALLSEL

        !Loads
KSEL,S,HPT,,146,157
FK,ALL,FY,1768

KSEL,S,HPT,,170,171
FK,ALL,FY,-4293
KSEL,S,HPT,,172,173
FK,ALL,FY,-2520
ALLSEL

        !Meshing
AMESH,ALL
/PBC,ALL,1

FINISH
/EOF
```

E.10 Head Jammed Boot With Corrosion

```
!This Programme Includes the Throat panels
!And looks at  rust on side panels
/Title, Head Frame Corrosion
/Prep7

        !Properties
Et,1,SHELL63
R,1,3,3,3,3
R,2,5,5,5,5
R,3,8,8,8,8
R,4,11,11,11,11
R,5,12,12,12,12
R,6,1,1,1,1
R,7,6,6,6,6
R,8,9,9,9,9
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Side Panel
K,1,0,0
K,2,295,0
K,3,295,539
K,4,0,539
A,1,2,3,4

K,5,805,0
K,6,805,539
A,2,5,6,3
K,7,1050,0
K,8,1050,189
K,200,975,189
K,201,975,539
A,5,7,8,200,201,6

K,9,1750,0
K,10,1750,267
K,11,1716,539
K,202,1125,539
K,203,1125,189
K,204,1050,539
K,228,1100,0
K,229,1100,170
K,230,1250,0
A,7,228,229,230,9,10,11,202,203,8
A,8,200,201,204
```

```
A,8,203,202,204

K,12,0,629
K,13,1689,629
A,4,11,13,12

K,205,975,629
K,206,1050,629
K,207,1050,779
K,208,975,779
A,205,206,207,208
K,20,945,629
K,21,1080,629
K,22,1080,829
K,23,945,829
A,20,205,208,207,206,21,22,23

K,24,1569,874
K,25,15,874
K,26,0,737
A,12,20,23,22,21,13,24,25,26

/VIEW,1,1,1,1
APLOT

K,210,0,0,-416
K,211,295,0,-416
K,212,295,539,-416
K,213,0,539,-416
A,210,211,212,213

K,214,805,0,-416
K,215,805,539,-416
A,211,214,215,212

K,216,1750,0,-416
K,217,1750,267,-416
K,218,1716,539,-416
K,231,1100,0,-416
K,232,1100,170,-416
K,233,1250,0,-416
A,214,231,232,233,216,217,218,215

K,219,0,629,-416
K,220,1689,629,-416
A,213,219,220,218

K,221,200,629,-416
```

```
K,222,250,629,-416
K,223,250,729,-416
K,224,200,729,-416
A,221,222,223,224

K,225,1569,874,-416
K,226,15,874,-416
K,227,0,737,-416
A,219,221,224,223,222,220,225,226,227

        !End Panels
A,9,216,217,10
A,10,217,218,11
A,11,218,220,13
A,13,220,225,24
A,1,210,227,26
A,26,227,226,25

        !Bottom Flange
K,41,-50,0,50
K,42,1800,0,50
K,43,1800,0,-466
K,44,-50,0,-466

A,41,42,43,44
A,1,9,216,210
ASBA,23,24

        !Top Flange
K,45,-35,874,50
K,46,1619,874,50
K,47,1619,874,-466
K,48,-35,874,-466

A,45,46,47,48
A,25,24,225,226
ASBA,23,24

        !Angles
K,54,1689,629,90
K,55,0,629,90
K,56,805,629,90
K,57,805,629,40
K,58,295,629,40
K,59,295,629,90
K,60,295,629,160
K,61,805,629,160
```

```
A,12,13,54,56,57,58,59,55
A,57,58,60,61

K,62,1689,629,-506
K,63,0,629,-506
K,64,805,629,-506
K,65,805,629,-456
K,66,295,629,-456
K,67,295,629,-506
K,68,295,629,-576
K,69,805,629,-576

A,219,220,62,64,65,66,67,63
A,65,66,68,69

        !Bearing Supports
K,70,295,629,0
K,71,295,129,0
K,72,295,129,35
K,73,310,629,160
K,74,310,129,35
A,60,70,71,72
A,60,72,74,73

K,75,805,629,0
K,76,805,129,0
K,77,805,129,35
K,78,790,629,160
K,79,790,129,35
A,61,75,76,77
A,61,77,79,78

K,80,295,629,-416
K,81,295,129,-416
K,82,295,129,-451
K,83,310,629,-576
K,84,310,129,-451
A,68,80,81,82
A,68,82,84,83

K,85,805,629,-416
K,86,805,129,-416
K,87,805,129,-451
K,88,790,629,-576
K,89,790,129,-451
A,69,85,86,87
A,69,87,89,88
```

```
	!Motor Bracket
K,92,1050,779,205
K,93,1050,629,205
K,94,1050,629,90
K,95,975,629,90
K,96,975,629,205
K,97,975,779,205
K,99,1050,229,0
K,100,1050,229,50

A,206,207,92,93
A,93,94,95,96
A,207,92,97,208
A,93,206,99,100

	!Throat

A,228,229,232,231
A,232,233,230,229

	!Backstop Bracket
!K,101,250,629,-416
!K,102,250,729,-416
!K,103,250,729,-611
!K,104,250,629,-611
!K,105,250,629,-506
!K,106,200,629,-506
!K,107,200,629,-611
!K,108,200,729,-611
!K,109,200,729,-416

!A,101,102,103,104
!A,104,105,106,107
!A,102,103,108,109

AGLUE,ALL

	!Asign Material Thickness
ALLSEL
ASEL,S,AREA,,53
ASEL,A,AREA,,62
AATT,1,2,1,0,-1

ASEL,S,AREA,,47,48
ASEL,A,AREA,,54
ASEL,A,AREA,,56,57
ASEL,A,AREA,,65
ASEL,A,AREA,,71
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AATT,1,3,1,0,-1

ASEL,S,AREA,,39
ASEL,A,AREA,,49
AATT,1,4,1,0,-1

ASEL,S,AREA,,72,73
AATT,1,5,1,0,-1

ASEL,S,AREA,,4
ASEL,A,AREA,,15
ASEL,A,AREA,,17,20
ASEL,A,AREA,,22
ASEL,A,AREA,,50
ASEL,A,AREA,,55
ASEL,A,AREA,,58
ASEL,A,AREA,,61
ASEL,A,AREA,,63
ASEL,A,AREA,,70
ASEL,A,AREA,,74,76
AATT,1,6,1,0,-1

ASEL,S,AREA,,8,9
ASEL,A,AREA,,51,52
AATT,1,7,1,0,-1

ASEL,S,AREA,,43,46
ASEL,A,AREA,,59,60
ASEL,A,AREA,,64
AATT,1,8,1,0,-1

ALLSEL

        !Restraints

        !Hold down bolts
!HPTCreate,LINE,1,121,COORD,150,0,0
HPTCreate,LINE,5,122,COORD,325,0,0
HPTCreate,LINE,5,123,COORD,775,0,0
HPTCreate,LINE,8,124,COORD,950,0,0
HPTCreate,LINE,191,125,COORD,1125,0,0
HPTCreate,LINE,191,126,COORD,1225,0,0
HPTCreate,LINE,16,127,COORD,1362,0,0
HPTCreate,LINE,16,128,COORD,1500,0,0
HPTCreate,LINE,16,129,COORD,1638,0,0

!HPTCreate,LINE,44,132,COORD,150,0,-416
HPTCreate,LINE,48,133,COORD,325,0,-416
```

```
HPTCreate,LINE,48,134,COORD,775,0,-416
HPTCreate,LINE,51,135,COORD,950,0,-416
HPTCreate,LINE,192,136,COORD,1125,0,-416
HPTCreate,LINE,192,137,COORD,1225,0,-416
HPTCreate,LINE,54,138,COORD,1362,0,-416
HPTCreate,LINE,54,139,COORD,1500,0,-416
HPTCreate,LINE,54,140,COORD,1638,0,-416

HPTCreate,LINE,77,142,COORD,0,0,-131
HPTCreate,LINE,77,143,COORD,0,0,-289
HPTCreate,LINE,72,144,COORD,1750,0,-131
HPTCreate,LINE,72,145,COORD,1750,0,-289

        !Motor bracket load points
HPTCreate,AREA,53,147,COORD,1050,769,195
HPTCreate,AREA,53,149,COORD,1050,769,185
HPTCreate,AREA,53,151,COORD,1050,769,175
HPTCreate,AREA,53,153,COORD,1050,769,165
HPTCreate,AREA,53,155,COORD,1050,769,155
HPTCreate,AREA,53,157,COORD,1050,769,145

        !Backstop bracket load points
!HPTCreate,AREA,40,158,COORD,250,720,-610
!HPTCreate,AREA,40,159,COORD,250,720,-600
!HPTCreate,AREA,40,160,COORD,250,720,-580
!HPTCreate,AREA,40,161,COORD,250,720,-570

        !Bearing loading points
HPTCreate,AREA,72,170,COORD,420,629,68
HPTCreate,AREA,72,171,COORD,680,629,68
HPTCreate,AREA,73,172,COORD,420,629,-503
HPTCreate,AREA,73,173,COORD,680,629,-503

        !Restraints
KSEL,S,HPT,,120,145
DK,ALL,UX,0,,,UY,UZ
ALLSEL

        !Loads
KSEL,S,HPT,,146,157
FK,ALL,FY,1768
KSEL,S,HPT,,170,171
FK,ALL,FY,-4293
KSEL,S,HPT,,172,173
FK,ALL,FY,-2520
ALLSEL

        !Meshing
```

```
AMESH,ALL
/PBC,ALL,1

FINISH
/EOF
```

E.11 Head Motor In Reverse

```
!This Programme Includes the Throat panels
!and bactstop bracket
/Title, Head Frame Motor in Reverse
/Prep7

        !Properties
Et,1,SHELL63
R,1,3,3,3,3
R,2,5,5,5,5
R,3,8,8,8,8
R,4,11,11,11,11
R,5,12,12,12,12
R,6,7,7,7,7
Mp,ex,1,200e9
Mp,nuxy,1,0.3

        !Side Panel
K,1,0,0
K,2,295,0
K,3,295,539
K,4,0,539
A,1,2,3,4

K,5,805,0
K,6,805,539
A,2,5,6,3

K,7,1050,0
K,8,1050,189
K,200,975,189
K,201,975,539
A,5,7,8,200,201,6

K,9,1750,0
K,10,1750,267
K,11,1716,539
K,202,1125,539
K,203,1125,189
K,204,1050,539
K,228,1100,0
K,229,1100,170
K,230,1250,0
A,7,228,229,230,9,10,11,202,203,8
```

```
A,8,200,201,204
A,8,203,202,204

K,12,0,629
K,13,1689,629
A,4,11,13,12

K,205,975,629
K,206,1050,629
K,207,1050,779
K,208,975,779
A,205,206,207,208

K,20,945,629
K,21,1080,629
K,22,1080,829
K,23,945,829
A,20,205,208,207,206,21,22,23

K,24,1569,874
K,25,15,874
K,26,0,737
A,12,20,23,22,21,13,24,25,26

/VIEW,1,1,1,1
APLOT

K,210,0,0,-416
K,211,295,0,-416
K,212,295,539,-416
K,213,0,539,-416
A,210,211,212,213

K,214,805,0,-416
K,215,805,539,-416
A,211,214,215,212

K,216,1750,0,-416
K,217,1750,267,-416
K,218,1716,539,-416
K,231,1100,0,-416
K,232,1100,170,-416
K,233,1250,0,-416
A,214,231,232,233,216,217,218,215
K,219,0,629,-416
K,220,1689,629,-416
A,213,219,220,218
```

```
K,221,200,629,-416
K,222,250,629,-416
K,223,250,729,-416
K,224,200,729,-416
A,221,222,223,224

K,225,1569,874,-416
K,226,15,874,-416
K,227,0,737,-416
A,219,221,224,223,222,220,225,226,227

        !End Panels
A,9,216,217,10
A,10,217,218,11
A,11,218,220,13
A,13,220,225,24
A,1,210,227,26
A,26,227,226,25
        !Bottom Flange
K,41,-50,0,50
K,42,1800,0,50
K,43,1800,0,-466
K,44,-50,0,-466

A,41,42,43,44
A,1,9,216,210

ASBA,23,24

        !Top Flange
K,45,-35,874,50
K,46,1619,874,50
K,47,1619,874,-466
K,48,-35,874,-466

A,45,46,47,48
A,25,24,225,226

ASBA,23,24

        !Angles
K,54,1689,629,90
K,55,0,629,90
K,56,805,629,90
K,57,805,629,40
K,58,295,629,40
K,59,295,629,90
K,60,295,629,160
```

```
K,61,805,629,160

A,12,13,54,56,57,58,59,55
A,57,58,60,61

K,62,1689,629,-506
K,63,0,629,-506
K,64,805,629,-506
K,65,805,629,-456
K,66,295,629,-456
K,67,295,629,-506
K,68,295,629,-576
K,69,805,629,-576

A,219,220,62,64,65,66,67,63
A,65,66,68,69

        !Bearing Supports
K,70,295,629,0
K,71,295,129,0
K,72,295,129,35
K,73,310,629,160
K,74,310,129,35
A,60,70,71,72
A,60,72,74,73

K,75,805,629,0
K,76,805,129,0
K,77,805,129,35
K,78,790,629,160
K,79,790,129,35
A,61,75,76,77
A,61,77,79,78

K,80,295,629,-416
K,81,295,129,-416
K,82,295,129,-451
K,83,310,629,-576
K,84,310,129,-451
A,68,80,81,82
A,68,82,84,83

K,85,805,629,-416
K,86,805,129,-416
K,87,805,129,-451
K,88,790,629,-576
K,89,790,129,-451
A,69,85,86,87
```

```
A,69,87,89,88

        !Motor Bracket
K,92,1050,779,205
K,93,1050,629,205
K,94,1050,629,90
K,95,975,629,90
K,96,975,629,205
K,97,975,779,205
K,99,1050,229,0
K,100,1050,229,50

A,206,207,92,93
A,93,94,95,96
A,207,92,97,208
A,93,206,99,100

        !Throat
A,228,229,232,231
A,232,233,230,229

        !Backstop Bracket
K,103,250,729,-611
K,104,250,629,-611
K,105,250,629,-506
K,106,200,629,-506
K,107,200,629,-611
K,108,200,729,-611

A,223,103,104,222
A,223,103,108,224
A,105,104,107,106

AGLUE,ALL

        !Asign Material Thickness
ALLSEL
ASEL,S,AREA,,57
ASEL,A,AREA,,60
ASEL,A,AREA,,67
AATT,1,2,1,0,-1

ASEL,S,AREA,,50,51
ASEL,A,AREA,,58
ASEL,A,AREA,,61,63
ASEL,A,AREA,,68
ASEL,A,AREA,,77
AATT,1,3,1,0,-1
```

```
ASEL,S,AREA,,8,9
ASEL,A,AREA,,46,49
ASEL,A,AREA,,55,56
ASEL,A,AREA,,65,66
ASEL,A,AREA,,71
AATT,1,4,1,0,-1

ASEL,S,AREA,,78,79
AATT,1,5,1,0,-1

ASEL,S,AREA,,44
ASEL,A,AREA,,53
AATT,1,6,1,0,-1

ALLSEL

        !Restraints

        !Hold down bolts
!HPTCreate,LINE,1,121,COORD,150,0,0
HPTCreate,LINE,5,122,COORD,325,0,0
HPTCreate,LINE,5,123,COORD,775,0,0
HPTCreate,LINE,8,124,COORD,950,0,0
HPTCreate,LINE,205,125,COORD,1125,0,0
HPTCreate,LINE,205,126,COORD,1225,0,0
HPTCreate,LINE,16,127,COORD,1362,0,0
HPTCreate,LINE,16,128,COORD,1500,0,0
HPTCreate,LINE,16,129,COORD,1638,0,0

!HPTCreate,LINE,44,132,COORD,150,0,-416
HPTCreate,LINE,48,133,COORD,325,0,-416
HPTCreate,LINE,48,134,COORD,775,0,-416
HPTCreate,LINE,51,135,COORD,950,0,-416
HPTCreate,LINE,206,136,COORD,1125,0,-416
HPTCreate,LINE,206,137,COORD,1225,0,-416
HPTCreate,LINE,54,138,COORD,1362,0,-416
HPTCreate,LINE,54,139,COORD,1500,0,-416
HPTCreate,LINE,54,140,COORD,1638,0,-416

HPTCreate,LINE,77,142,COORD,0,0,-131
HPTCreate,LINE,77,143,COORD,0,0,-289
HPTCreate,LINE,72,144,COORD,1750,0,-131
HPTCreate,LINE,72,145,COORD,1750,0,-289

        !Motor bracket load points

HPTCreate,AREA,57,147,COORD,1050,769,195
```

```
HPTCreate,AREA,57,149,COORD,1050,769,185
HPTCreate,AREA,57,151,COORD,1050,769,175
HPTCreate,AREA,57,153,COORD,1050,769,165
HPTCreate,AREA,57,155,COORD,1050,769,155
HPTCreate,AREA,57,157,COORD,1050,769,145

        !Backstop bracket load points
HPTCreate,AREA,60,158,COORD,250,720,-610
HPTCreate,AREA,60,159,COORD,250,720,-600
HPTCreate,AREA,60,160,COORD,250,720,-580
HPTCreate,AREA,60,161,COORD,250,720,-570

        !Bearing loading points
HPTCreate,AREA,78,170,COORD,420,629,68
HPTCreate,AREA,78,171,COORD,680,629,68
HPTCreate,AREA,79,172,COORD,420,629,-503
HPTCreate,AREA,79,173,COORD,680,629,-503

        !Restraints
KSEL,S,HPT,,120,145
DK,ALL,UX,0,,,UY,UZ
ALLSEL

        !Loads
KSEL,S,HPT,,146,157
FK,ALL,FY,1768

KSEL,S,HPT,,170,171
FK,ALL,FY,-4293
KSEL,S,HPT,,172,173
FK,ALL,FY,-2520

KSEL,S,HPT,,158,161
FK,ALL,FY,2652

ALLSEL

        !Meshing
AMESH,ALL
/PBC,ALL,1

FINISH
/EOF
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