University of Southern Queensland

Faculty of Engineering and Surveying

REDESIGN AND ANALYSIS OF JANKE BROS. F500P PARALLELOGRAM PLANTING UNIT

A dissertation submitted by

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Towards the degree of

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Abstract

Janke Bros Engineering (Australia) is a progressive manufacturing company specialising in minimum tillage machinery for the agricultural market. They specialise in the customisation of machines to suit the customers farming practices, this enables the grower to purchase a machine that will do several separate operations with minimal fuss.

Currently they manufacture two main lines of direct drill planters, a fixed tyne unit and a parallelogram unit. The parallelogram unit gains the majority of the attention from customers. The features that appeal to the customers are the ability for the parallelogram to follow the contours of the ground and the leading coulter disc that is able to cut the trash ahead of the tyne.

In the current market place there is a trend towards minimum tillage farming, which incorporates the use of double and single disc openers. However disc openers are not able to work in dry conditions, they are not able to reach through the dry crust to the moisture below where a direct drill tyne is able to. To obtain the best of both worlds Janke intend to redesign the current F500P parallelogram unit to have interchange-ability. This would enable the customer to remove the leading coulter and tyne, replacing it with either a single or double disc opener, depending on the planting conditions.

The design process involved:

- Design the double/Single disc unit, using as many of Jankes current range of products as possible, and the new attachment system.
- The newly designed disc opener and attachment is to be tested on a finite element analysis (FEA) package. Allowing a better visualisation of the attachment method and eliminate the need to redesign the attachment system after testing.
- A prototype can be constructed and tested in the field, enabling Janke to produce the new design for the next winter crop planting (April-May 2005).

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Andrew John Alexander Ruhle

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Signature

Date

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I would like to thank Dr. Amar Khennane for his constant support and guidance on this project. Your guidance on the finite element analysis enabled me to achieve the objectives, with out your help it would not have been possible to complete this project, and I cannot thank you enough for your time and knowledge.

I would also like to thank Janke Bros Engineering for providing me with the project topic; it has been a valuable learning experience over the past several months.

Thanks also to my family and friends who have supported me during this period of time.

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Glossary of Terms

Aggregates - Refers to the individual sand, silt and clay particles bound together to form larger clusters. Aggregates may be spherical, block, plate, prism or columns.

Controlled traffic - Refers to the continued use of a single set of tracks that machinery use.

Coulter disc - Disc leading the planting tyne in order to cut the trash and stubble.

Direct drill tyne - The use of a tyne designed to create minimal soil disturbance while moving through the soil.

Fallowed country - Refers to the spelling of a field between seasons in the aim of improving soil structure and moisture content.

FEA - Finite Element Analysis

Grub Screw - A bolt or stud used as a clamp to hold an object in place.

Integrated pest management - A system used by farmers to aid in the control of pests and diseases on their property.

IPM - Integrated Pest Management.

Minimum Tillage - A farming system in which a crop is planted in the residue from a previous crop with minimal soil disturbance created during the season.

Moisture content -	The percentage of water in the soil with respect to the level of void spaces and soil particles present.
Organic matter -	Crop residue that is present in the soil, it aids in the development and improvement of soil structure.
Runoff -	Water flow on the soil surface.
Soil Structure -	Refers to the arrangement of particles into aggregates.
Stubble -	Residue of the previous crop still standing in the field.
Sub-Soil layers -	Soil layers that are located below the topsoil.
Tillage -	The mechanical stirring or turning of the soil profile.
Topsoil -	Refers to the layer of soil that is on top of the soil profile, this layer is the more fertile soil of the profile.
Zero-Tillage -	A farming system in which a crop is planted in the residue from a previous crop without soil tillage.

Chapter 1

Introduction

1.1 Introduction

Janke Bros (Australia) is a progressive manufacturing company specialising in minimum tillage machinery for the agricultural market. They specialise in the customisation of machines to suit the customers’ farming practices and this enables the grower to purchase a machine that is capable of several separate operations with minimal effort.

Currently they manufacture two main lines of direct drill planters, a fixed tyne unit and a parallelogram unit. The parallelogram unit varies from a light 120lb breakout to a 500lb breakout unit; this particular unit gains the majority of the attention from customers. The features that appeal to the customers are the ability for the parallelogram to follow the contours of the ground and the leading coulter disc that is able to cut the trash ahead of the tyne.

This chapter will introduce the problem raised by Janke Bros., the objectives of the project, the methodology and an overview of the dissertation.

1.2 Problem Statement

In the current market place there is a trend towards minimum tillage farming, which incorporates the use of double and single disc openers. However disc openers are not able to work in dry conditions, they are not able to reach through the dry crust to the moisture below where as a direct drill tyne is able to. To obtain the best of both worlds, Janke Bros intend to redesign the current F500P parallelogram unit to have interchange-ability. This would enable the customer to remove the leading coulter and tyne, replacing it with either a single or double disc opener, depending on the planting conditions.

The new design is intended to be placed into production in time for the 2005 winter planting season, therefore the unit must comply with the customers' standards. That is, the machine must be a sturdy and reliable unit. Janke Bros pride themselves on their reputation of producing reliable machines that are designed to withstand Australia's rugged conditions. The challenge is to design and construct a machine that is exactly what the customer want - this is achieved by closely listening to the growers needs.

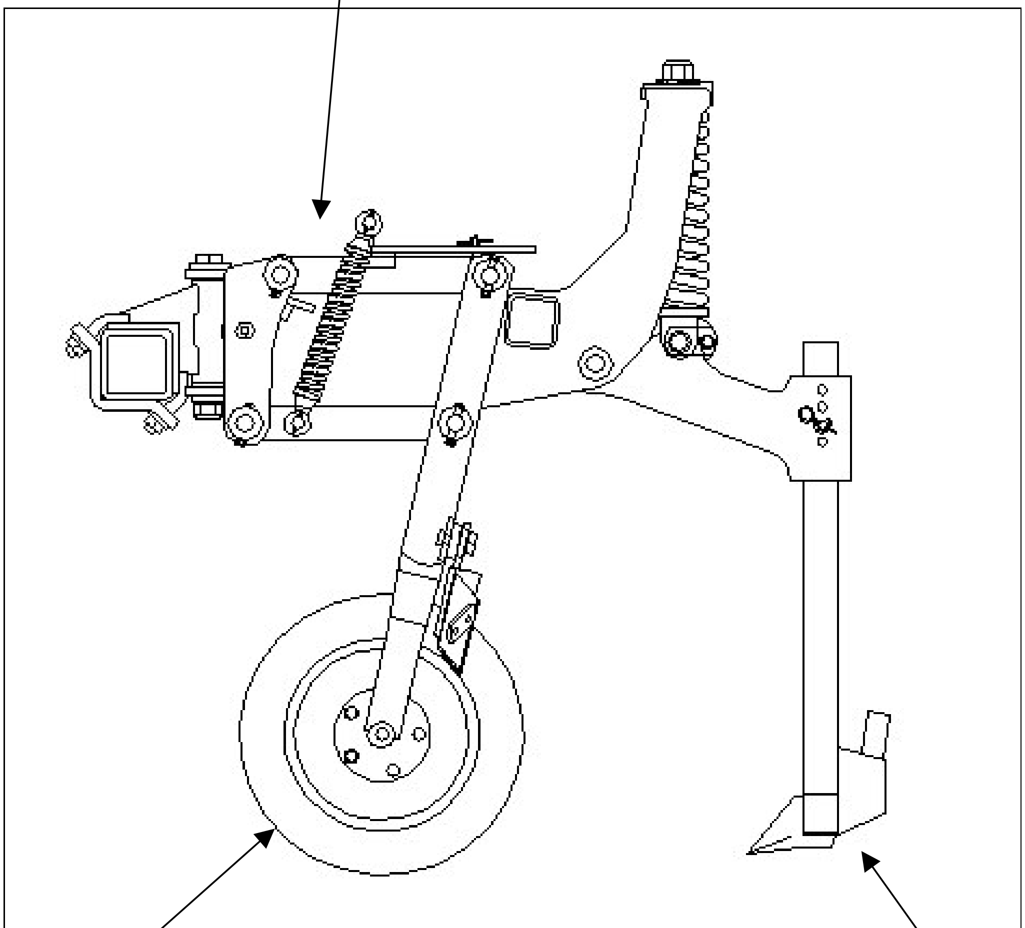


Figure 1.1) Current Janke Bros F500P Parallelogram Planting Unit

1.3 Objectives

The redesign process will involve:

- Design the double/single disc unit, using as many of Janke Bros current range of products as possible, and the new attachment system.

- The newly-designed disc opener and attachment is to be tested on a finite element analysis (FEA) package. Allowing a better visualisation of the attachment method and eliminate the need to redesign the attachment system after testing.
- A prototype can be constructed and tested in the field, enabling Janke to produce the new design for the next winter crop planting (April-May 2005).

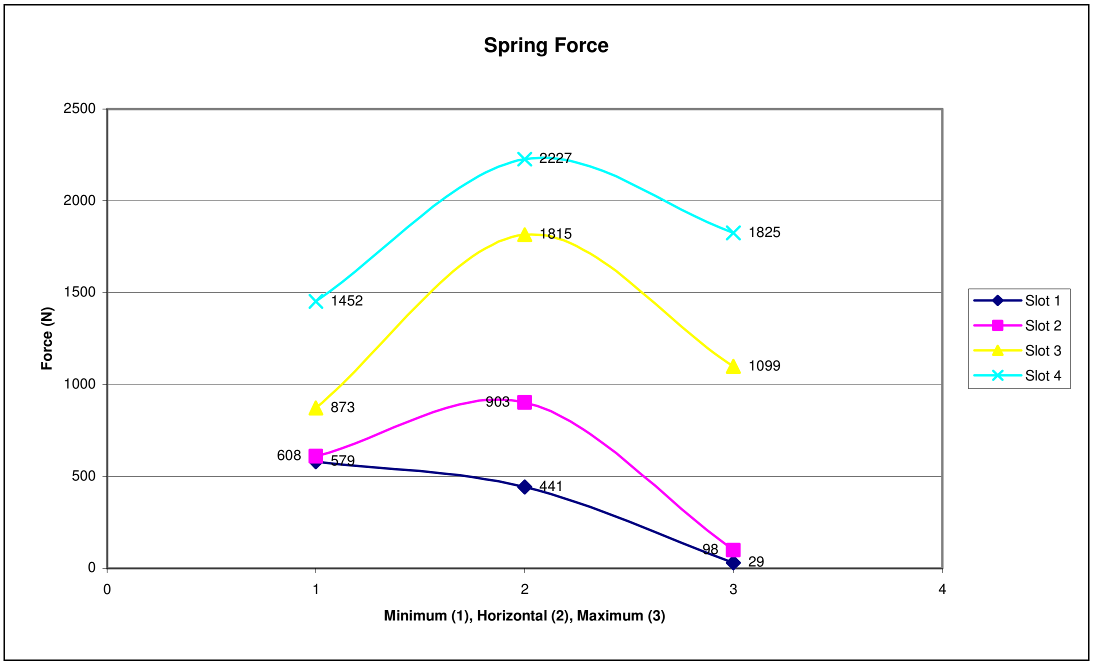
1.4 Project Methodology

The initial designing of the F500P parallelogram was not commenced until early March, this was due to the inaccessibility of the engineers at Janke Engineering as they were pre-occupied with the construction of orders for the up-coming winter plant.

The design of the current F500P design was obtained in AutoCAD format, therefore the redesign and drafting of the unit was performed in AutoCAD. Janke Bros Engineering provided the relevant drawings and dimensions of the F500P unit and their current range of double disc openers as aids to the redesign process.

Before the prototype was constructed and field-tested it was intended that the design be modelled in a Finite Element Analysis package. This step was to save time for the future as the analysis will outline whether or not the design will fail under working conditions. However the prototype was constructed before the modelling was complete, but this did not affect the project objectives. The Finite Element Analysis package that was used was for this project was Abaqus/CAE software, which is one of the world-leading FEA packages.

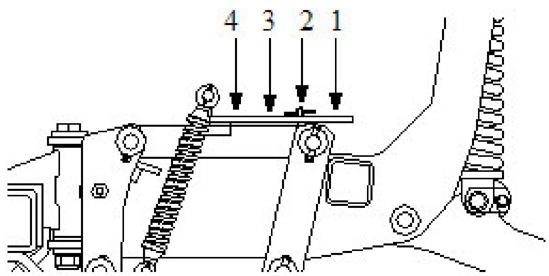
The field testing was performed in the Darling Downs (Bongeen region), which largely consists of Black Self-mulching Vertisol soils, which are generally easily workable soils. Therefore, the field-testing that was carried out will not be a representation of all the possible soil types and conditions that Janke machines may encounter. However, the testing will provide a strong indication of whether the new design will withstand the majority of field conditions that may be encountered. This was achieved by extensively testing the range of different levels of force that may act upon the F500P unit. The down forces created by the springs on the parallelogram are represented in the graph below.



Graph 1.1) Representing the spring force at different spring settings.

Each Parallelogram unit is constructed with 4 spring settings, the spring is set by changing the position of the slots, (1 2 3 4), along the top of the parallelogram. The X-axis represents the parallelogram at different working positions, maximum, horizontal and the minimum lift height. The horizontal lift is the optimum working position as it produces the highest spring force and also it enables the greatest movement up and down.

Slot Positions



Horizontal Lift

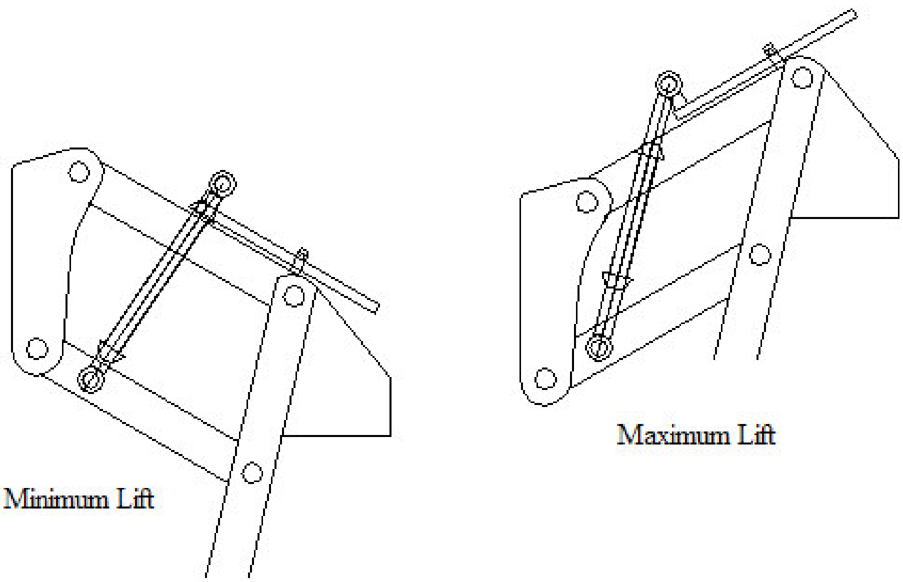


Figure 1.2) Parallelogram lift height and load slots

These are the general working conditions of the machine in the paddock, the forces that are experienced by the unit in the paddock may vary from these values. The variations may be a result of the tyne or disc contacting either a stone or log; this will result in a sharp increase of force exerted of the attachment system. This situation was taken into consideration while designing and testing the unit; otherwise the machine would not withstand the required field conditions.

1.5 Overview of Dissertation

Chapter 2 will introduce the background information on minimum tillage practices, it will cover the reasons behind the adoption of these practices in the Australian agricultural industry and the advantages and disadvantages of minimum tillage.

Chapter 3 covers the literature that was researched in order to gain greater knowledge about minimum tillage and direct drill and disc opening planting systems.

The design process will be discussed in the 4^{th} chapter; it involves the discussion of the features of the attachment system and the double disc opener.

The finite element analysis of the design is covered in chapter 5, each step of the finite element analysis process is explained in detail.

Chapter 6 explains the need for field testing of the new double disc opener design and the attachment system, it will cover the factors that were examined during testing and the process that was followed.

The 7^{th} chapter discusses the result obtained from the finite element analysis and the field-testing of the attachment system and the double disc opener.

The dissertation is wrapped up in chapter 8, the conclusion presents an overview of the project process and the results obtained from the modelling and testing, also the further work that may be undertaken is discussed.

Chapter 2

Background

2.1 Introduction

Over the last 20 to 30 years the agricultural industry has been heavily involved in the issue of sustainability. One of the concepts at the forefront of this issue is minimum or zero tillage practices, which involve the adoption of minimum tillage planting methods either as direct drill tynes or disc openers. This project was intended to investigate the possibility of developing a unit that is interchangeable between these two methods.

Figure 2.1) Map of Australia Representing location of Janke Bros Engineering.

The project was initiated by Janke Brothers Engineering, one of the leading manufacturers of tillage and planting equipment in Australia. Janke Bros. Engineering is located at Mt Tyson, approximately 30 minutes west of Toowoomba. They specialise in planters, cultivators and hydraulic chisel ploughs. Their chisel ploughs range from a 120lb to a 500lb break out. Their Universal minimum till system is designed to conserve fuel, moisture, organic material and soil structure in order to lower soil erosion and increase fertility. This chapter will introduce the background of minimum tillage and a background on the current disc openers available in the industry.

2.2 Minimum Tillage

Minimum tillage is the practice of conserving soil moisture by the reduction of conventional tillage and the disturbance of the soil. This is achieved by adopting alternative methods of pest control, hence the implementation of an Integrated Pest Management (IPM) program.

Essentially there are two key alternative methods to conventional tillage, one is the utilisation of available chemicals to control undesired weeds and pests in the paddock, while the other is the use of direct drill planting systems to minimise soil disturbance during planting.

Conventionally, the soil was tilled 3 – 4 times between seasons to control problem weeds and prepare the seed bed for planting,.For each working, the soil would loose approximately 25mm of moisture. This results in the soil moisture content becoming diminished between seasons. For minimal rainfall areas this loss in available soil moisture could prove to be very costly to the health of the emerging crop.

Figure 2.2) Use of Chemicals to control weeds

The use of chemicals to control problem weeds enables the grower to eliminate the need to disturb the soil; therefore the soil moisture loss can be reduced. The use of chemical application as a weed control, however, is not limited to fallowed country. During planting the grower can choose to apply a pre-emergence band spray over the planted area. This will kill any weed in the vicinity of the emerging plant to reduce competition, which enables the crop to gain the full potential of soil moisture. The mature crop is also susceptible to competition for soil moisture from weeds. Conventionally the grower would cultivate between the crop rows in order to kill the weeds, resulting in the reduction of soil moisture levels. Now, chemical sprays can be applied between the rows by shielded sprayers, this allows the grower to conserve the valuable moisture in the soil, which can be utilised by the crop.

Agricultural chemicals have been developed over the years so they can target one specific plant group, whether it is, for example, dicotyledon or monocotyledon, annual or perennial.

Figure 2.3) Broad acre spraying of crop

Certain crops have also been developed so that they can withstand knockdown herbicides; this allows the grower to broadacre spray the entire crop with a knockdown chemical and kill only the weeds, not the crop.

The planting process must disturb the soil in order for the seed to be placed in the soil. This, however, can be reduced by the utilisation of direct drill planting systems. Direct drill planting systems may come in the form of either tynes or discs, however, discs usually create the least disturbance if designed and operated correctly.

Conventional tynes are designed to lift and upturn the soil during working, This exposes the soil moisture from below to the sun and moisture is evaporated, which results in the reduction of the soil moisture. Direct drill tynes are designed to cut through the soil with minimal disturbance from lifting or upturning, as a result, the soil layers are not mixed and minimal moist soil is exposed to evaporation. Direct drill, tyne-based planters only consist of the planting tynes, whereas conventional planters consist of planting tynes plus additional tynes for weed control.

Planting discs are usually found in two different configurations-either as double disc openers or as a single disc opener. Both systems have advantages and disadvantages over each other. The discs are designed to cut a furrow in the soil so that the seed and fertiliser can be placed, The furrow is then covered and pressed without disturbing the soil. Discs usually cause very minimal layer mixing or moisture exposure during working and for that reason they are ideal for minimal tillage applications.

2.3 Adoption of Minimum Tillage

In the past growers did not see the benefits or function that minimal tillage had on their property, they did not consider the effect cultivation had on the local environment and the possible land degradation issues that were involved in farming. Soil conservation and sustainability has been one the most popular topics of research over the past several years and large in-roads have been created into these topics. Growers are now being educated on the importance of sustainable farming by taking into consideration the future use of the land so that it will remain as productive cultivation.

Sustainable farming and minimal tillage can be linked together as they are both initiatives to promote the protection of the soil structure and health. This includes the aim to increase the soil fertility, aggregate structure and the soil productivity. They are both incorporated by growers with the intention of prolonging the life of the soil as a productive agricultural resource.

Minimal tillage involves the retention of stubble from the previous crop, the new crop is usually planted straight into the stubble as the stubble is slowly decomposing and will disappear during the season. By retaining the stubble between seasons the fallowed country is protected from damaging rainfall and erosion. Bare fallowed ground is highly susceptible to soil erosion - when heavy rain falls, the rain drops collide with the top soil aggregates and destroy the soil structure into smaller particles. This in turn creates a sealed or hard surface on the topsoil, which allows the surface water to begin flowing across the ground. The flowing surface water collects the small soil particles and carries them away. This form of erosion can be eliminated or at least minimised by minimal till and stubble retention. The stubble that covers the fallowed country slows the heavy raindrops, therefore protecting the soil aggregates from degradation, furthermore the roots of the plants assist in protecting the soil structure in the sub-soil layers from eroding.

Figure 2.4) Retention of Stubble in the field

The retention of the stubble allows the accumulation of organic matter within the soil, keeping in mind that organic matter is one of the foremost important building blocks of the soil structure. Without organic matter in the soil the soil structure would degrade, and this would affect the productivity of the soil. Soil organisms also feed off the organic matter. These organisms, along with the organic matter, work to increase the aeration of the soil. Plant roots need air to breathe, therefore soils with good aeration are beneficial to plant growth.

Conventional tillage practices require high horse power tractors to pull them through the soil. This is a slow process, as the force required cannot be exerted at high speeds. Minimal tillage practices involve lower powered machinery, as they are not disturbing the soil. Instead, they are usually applying chemicals, and as a result they are able to travel at much greater speeds.

The production efficiencies of the enterprise are increased by the reduction of labour, fuel and machinery costs by the adoption of minimal tillage practices. This is achieved by the smaller machinery needed, the faster working speeds, and the lower man-hours to finish the job.

Direct drill planters can also be pulled at faster speeds than the conventional planting units. This enables the grower to plant the majority of their crop in the optimum planting zone/time as a greater area of land can be covered in a given period of time.

Controlled traffic and tramline farming is an extension of sustainable agriculture and minimum tillage. Tramline or controlled traffic refers to the continued use of a single set of tracks that machinery use.

Figure 2.5) Controlled traffic and Tramline farming methods

Many farmers have taken this concept one step further and extended the wheel axles so that the tractor runs on the same wheel track spacings as their combine harvester.

Figure 2.6) Tramline Farming by extending wheel axles

Through research and trails it has been found that approximately 80% of all compaction from machinery is caused in the first passing. Therefore if the compaction can be concentrated to a small proportion of the field, then the remaining soil will produce greater yields due to increased soil structure.

2.4 Advantages and Disadvantages

Advantages of minimal tillage include:

- Stubble Retention
  - *Reduced runoff*
  - *Erosion control*
  - *More productive land*

- Reduced Evaporation
  - *Higher yields*

- Increased Organic Matter/Organism Levels
  - *Improved soil structure*
  - *Improved soil aeration*
  - *Improved soil fertility*

- Production Efficiencies Increased
  - *Fuel, labour, machinery*

Disadvantages of minimum tillage include:

- Weed Resistance
  - *Herbicide groups*
  - *Active constituents*

- Management of Rodents
  - *Mice*

- *Habitat and food year-round*

- Bacteria/ Nematode Infestations
    - *Minimal paddock spelling*

- Reduced Machinery Hours
    - *Repair costs, fuel, labour*

- Quality Seed Drills
    - *Stubble clearance*
    - *Seed placement accuracy*
    - *Limited by conditions*

2.5 Existing Disc Openers

The disc opener concept is not a new development in the agricultural industry. Since producers have begun practising minimum and zero tillage, the disc opener system has been at the forefront of the move towards sustainable farming. There are already various companies designing and constructing such systems. The concept has been researched and tested over the years and proven to be a major factor in minimum and zero tillage.

Various models and designs of disc opener systems were researched in order to develop a unit that would be competitive in the agricultural market. Such designs included:

Figure 2.7) John Deere double disc opener

Figure 2.8) John Deere Air Drill Single Disc openers

Figure 2.9) Kinze double disc opener

Figure 2.10) Kinze double disc opener

Figure 2.11) Excel Agriculture double disc opener

Figure 2.12) Excel Agriculture Stubble Warrior single disc opener

Figure 2.13) Daybreak single disc opener

Figure 2.14) Daybreak single disc opener

This research, along with visiting several field days, enabled me to gain the knowledge needed to create a design that was within the industry standard.

Chapter 3

Literature Review

3.1 Grains Research and Development Corporation August 2000, *Direct drill – choosing the right seeding package*, Kingston, ACT.

The main objective of the seeding system is to create an optimum environment for the seed, in particular to achieve accurate seed placement and optimum soil-seed contact. See table 1 for three factors that have been found to influence how this is achieved :

1) Equipment Design	2) System Set up & Operation	3) Soil Condition
Implement Frame Contour Following Ability Tyne Design Ground Opener Seed & Fertiliser Banding Unit Furrow Closing Device	Tyne Layout & Row Spacing Tillage Depth Operating Depth	Texture Structure Moisture Residue Conditions

Table 3.1) Factors that effect direct drill planting systems

The equipment design is the relevant information for the redesign of the Janke F500P parallelogram unit as the system set-up and operation is at the farmers' desire and the soil conditions cannot be controlled.

Together these factors determine:

- Furrow shape and size
- Amount of lateral soil throw and available soil tilth left in the furrow
- Placement and separation of seeds and fertiliser
- Extent of loosening or compaction/smearing below the seed zone
- Degree of seed-soil and seed-residue contact
- Quality of soil cover over seeds

Ground Opener Design

The amount of lateral soil throw and soil disturbance has been found to be influenced by four factors:

1. Opener width – The wider the opener the greater the soil disturbance
2. Opener working depth – Deeper working results in increased clod size
3. Opener angle of approach – Greater rake angles result in less soil disturbance and finer tilth
4. Operating speeds – Faster working speeds result in minimal increase in soil disturbance, finer tilth and greater lateral soil throw

Furrow Closing Devices:

It is important to maintain a good seed-soil contact for optimum seed germination. This can be achieved by using finger tyne harrows, rotary prickle chains or press wheels. In comparison to finger tyne harrows or rotary prickle chains, press wheels provide a much improved seed-soil contact and seed depth control. The pressing action improves the uniformity and speed of crop establishment in dry soil conditions.

3.2 Desbiolles, J, Agricultural Machinery Research and Design Centre, *Mechanics and Features of Disc Openers in Zero-Till Applications,* University of SA, South Australia.

Zero-till disc openers produce low soil disturbance characteristics. This minimises weed seed germination, soil layer mixing, stubble incorporation and moisture evaporation at planting.

Disc openers are regarded as having superior seed placement quality, however, not all disc openers provide such advanced performance.

Seeding uniformity is highly dependant on:

1) Design
2) Operation
3) Soil Conditions

Planter Disc Geometries:

Angled disc (Single disc opener):

The discs are set vertical with a small sweep angle of 5-8°, this allows the seed and fertiliser shoots to trail behind in the shadow of the disc. The soil disturbance created by this system is a function of the sweep angle, cutting depth and disc diameter.

Undercut disc (Single disc opener):

The disc is usually tilted sideways from the vertical of up to 20°, the disc also has a sweep angle of 5-8°. Simply lowering the working height of the implement frame can increase the shadow of the disc; this is the result of the tilt angle on the disc.

Penetration Ability:

Ground penetration is a very important issue with disc openers, the available machine weight and disc geometry are the factors that dictate the penetration ability. To ensure the discs penetrate equally, the weight distribution from front to back and centre to wings of the implement must be designed to allow equal penetration. However, the heavier the machine, the greater the ground compaction. Compaction may occur from excessive disc load on the soil/disc contact area along the cutting edge.

Increased penetration can be achieved by:

- Reducing the contact area (eg. using thinner discs, smaller diameters)

- Using positively tilted discs (i.e. undercut designs)

Soil Disturbance Aspects:

Soil conditions, operation settings and design features are all issues that influence the degree of lateral soil throw caused by the discs. Cleaner wheels is a design aspect that is adopted to control soil throw by stopping soil from being entrained by the disc. The effectiveness of a cleaner wheel can vary with the depth of cut, speed of operation and position relative to the disc.

Opportunities With Disc Openers:

Modern disc opener technology offers a wide range of capabilities to cater for many soil conditions and can provide an effective basis for low soil disturbance direct seeding, with opportunities for high work output. Various disc seeder designs aim to increase seedbed utilisation; this may also assist with reaching an optimal crop yield without the weed seed stimulation associated with soil disturbance.

Down pressure is the key feature of disc implements to ensure adequate disc penetration, however the down pressure requirements can vary across a range of soil conditions. Hydraulic systems have the ability to optimise the down pressure wheel loading while in motion according to the soil conditions. This enables the unit to avoid the disc running out of the furrow in hard patches or the depth wheel sinking/bulldozing in soft patches.

3.3 Price, T, December 1999,*What Should My No-Till Planter Look Like,* Darwin

Actual performance of the no-till planter depends on the soil type, moisture content, residue and how all of these conditions interact with the machine.

Accurate Depth Control:

Rear press wheels are usually used to provide depth control, which helps to ensure even plant emergence. The press wheels are usually either mounted on a trailing arm or on a parallelogram linkage. Common depth control systems include skid plates, side gauge wheels, rear press wheels and gauge wheels. It is preferred that both the press wheel pressure and the depth can be changed independently of each other.

Seed Firming:

This is usually carried out by semi-pneumatic rubber wheels which range from 25 x 150mm to 25 x 250mm in size, or solid plate wheels which are not as wide (6mm).
Seed firming devices are used to press the seed into the bottom of the furrow to obtain quality seed-soil contact.

Seed Covering:

These devices are used to cover the seed with moist soil to protect the moisture from evaporating from around the seed. Such devices include single covering discs, double covering discs, paddles, knives, loop or trailing drag chains and spring tynes.

Chapter 4

Design process and final unit

4.1 Introduction

The two main design aspects of the project involved the double disc opener and the attachment system. On the existing parallelogram unit, the coulter disc shank is an entire side arm for the parallelogram as seen below.

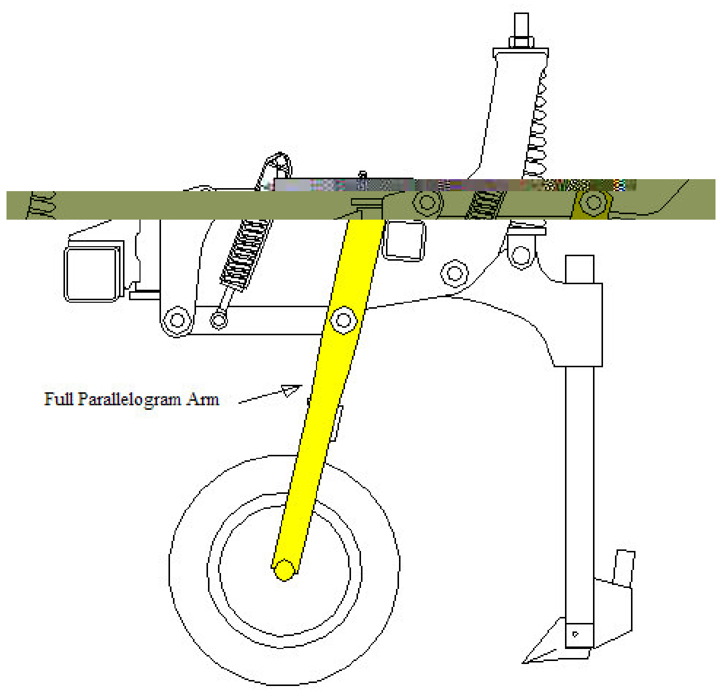


Figure 4.1) Janke Bros Engineering F500P Parallelogram.

The project was created in order to create an attachment so the tyne and the coulter disc could be removed easily and a double disc opener positioned in the attachment system.

4.2 Design process

4.2.1 Current design

Janke Bros had previously begun designing a double disc opener unit, but not for the interchange ability between tyne and disc. They were designing a single purpose unit. Therefore it was possible to build off Janke Bros design, but redesign it to the project specifications. It was possible to adopt several features of the current design.

4.2.2 Existing features used

The side arms that are attached to the depth wheels are consistent with Janke Bros current system. It was decided to use this system because the depth gauge for the unit proved to be an efficient design and would suit the redesigned unit.

The same disc geometry was adopted for the new design. This enabled the design to use Janke Bros current axles; which are constructed as a separate item in the factory and attached to the frame later. Therefore, the new design was drawn to fit the axles for both the discs and the depth wheel axles. The axle mounts had to contain the same geometry as the current design. This included the same mounting hole and the same distance from the disc axle, because the depth wheel must run in the same position. The anchor hole for the depth gauge was required to be at the same distance from the disc axle otherwise the depth settings on the gauge would become invalid and a new design would need to be created.

The scraper that was used on the current design was also be utilised for the new design, and the frame has been designed in order for the scraper to fit. The reason for continuing use of the scraper design is that it consists of a John Deere scraper system. This system mounted on a Janke Bros-designed extension arm and attached to the rear of the frame.

The furrow closing devices were not required to be developed as this was outside of the project specification. However, the frame was designed to accommodate for the design and attachment of the furrow closing system at a later date by Janke Bros' engineers.

4.2.3 Attachment system

The positioning of the attachment system was decided to be along the side arm of the parallelogram. As seen below, the attachment has three grub screws to hold the shank firmly. Furthermore the pin was included in the design so that if the grub screws happen to come loose, the pin can prevent the shank from sliding up and damaging the unit.

Figure 4.2) Coulter disc

The attachment was positioned in the centre of the parallelogram so that the coulter disc runs directly in line with the tyne, and so that the double disc plants in the same line as the tyne.

A new shank for the coulter disc would be required to fit the attachment system, as the current shank did not angle into the centre of the disc. The mud scraper was repositioned to the attachment so it could be easily removed if necessary.

4.2.4 Double disc opener

The design process of the double disc opener was the product of visits to several agricultural field days. These included Toowoomba Ag Show, Moree Cotton Trade Show and the Toowoomba Farm Fest. This enabled a rough mental design to be constructed before the design was created using AutoCAD.

AutoCAD is the drafting software that students are encouraged to learn by the University of Southern Queensland. Subsequently, the design of the unit was created in AutoCAD, which is also the same drafting software used by Janke Bros. Drawings acquired from Janke Bros were able to be easily loaded.

Janke Bros were able to provide AutoCAD drawings for several components of the current design and of the F500P parallelogram unit. However the drawings for the existing double disc opener were all hand-drafted and therefore some of the components needed to be redrawn in AutoCAD (drawings are available in Appendix B).

The drawings that were received from Janke Bros included the current disc opener, depth wheels and arms, disc geometry, axles for discs and depth wheels, the depth gauge and all its components, seed tubes, coulter disc and shank, F500P parallelogram unit, etc.

The design needed to be a sturdy and reliable unit so it would withstand the harsh conditions that may be encountered in Australia. That is the reason 6mm thick material was used for the frame. Other designs on the market use a smaller material, such as the John Deere Maxemerger (3mm) and the Excel Double disc unit (5mm).

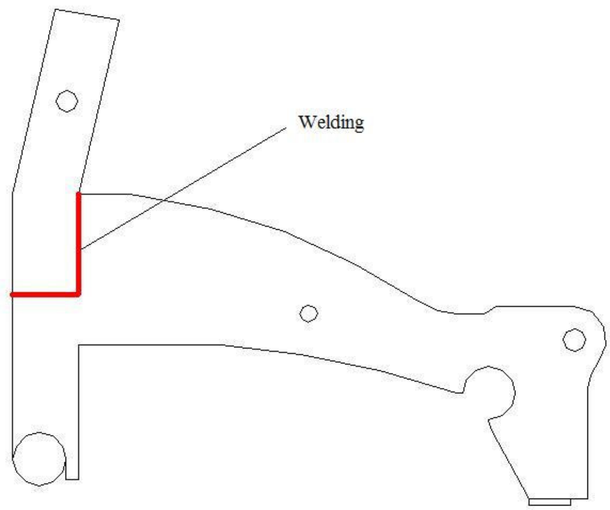


Figure 4.3) Representation of the shank attachment to the frame

The shank on the frame was extended further down. If it was welded on the top of the frame, there would be a high chance of the shank failing around the weld due to a concentration of stresses around the weak spot. The shank was constructed out of Bisalloy steel; Janke Bros construct all the shanks used on their equipment out of Bisalloy because it has greater strength than mild steel. The shank extends up further and includes the pinhole, however, it is not portrayed in the diagram below.

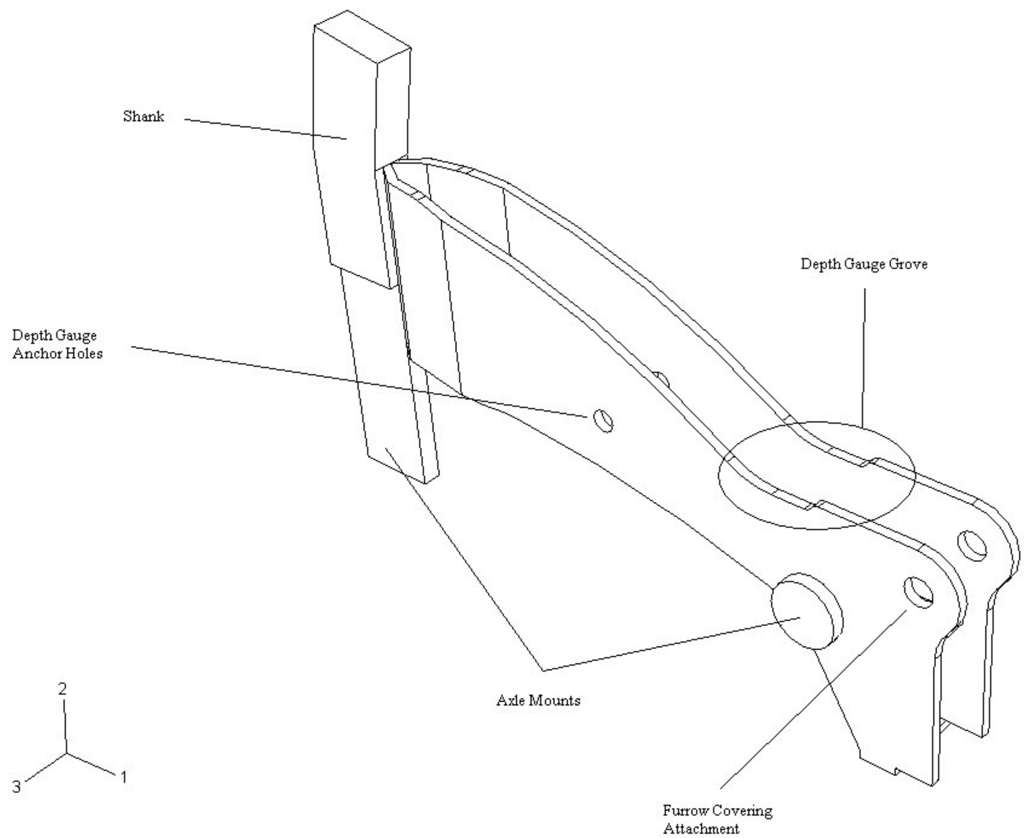


Figure 4.4) Features of the double disc opener design

The axle mounts at the front of the frame are for the discs. The axles are welded onto the lower shank during the design and drafting. The disc axle was set at coordinates (0,0), which enabled other features that had the same geometry as the current double disc unit to be located easily. The axle mounts at the rear of the frame are for the depth wheel arms; the depth wheel axles are situated at coordinates (340,50) from the disc axles. The same geometry was used for the wheels so the current design of the arms could be used in the new design.

The depth gauge anchor hole was positioned at coordinates (203.6,110) from the disc axle, which is the same geometry as Janke Bros current disc opener. This allows the use of the current depth gauge system. The groves on the top of the frame permit the depth gauge to move without hindrance from the frame as the positioning of the depth gauge system can be seen in the figure below.

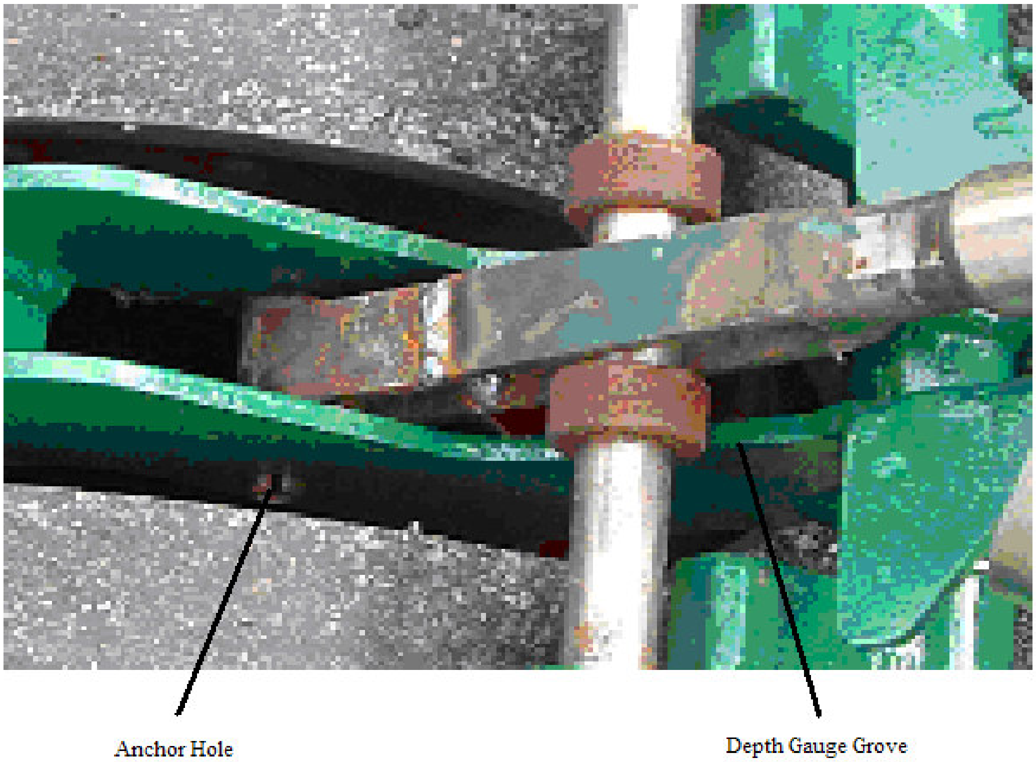


Figure 4.5) Depth gauge system

The reason the frame was constructed out of two beams that run side-by-side was that it was necessary for the placement of the seed tube between the two beams. The seed tube runs from above the frame down to approximately 5-7cm from the bottom of the furrow created by the discs directly behind the main shank.

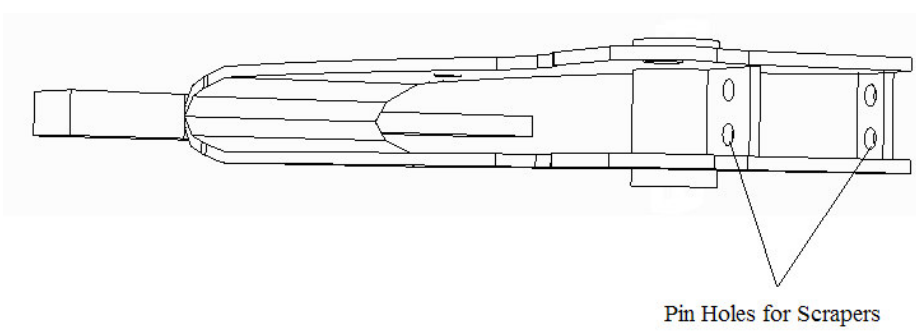


Figure 4.6) Location of pin holes on the double disc opener for the mud scrapers

The disc scrapers are the current design of Janke Bros (Drawings available in Appendix B), the design involves the use of John Deere's current scraper attached to an extension arm designed by Janke Bros. The arms reach forward so the scraper runs on the side of the disc on either side.

The furrow covering attachment holes were added into the design for the future design of the necessary components needed. This was however outside of the project specifications and therefore was not continued further in the design process.

4.3 Ergonomics

The ergonomics of the design became a major factor in the design of the unit. If the unit was designed with poor ergonomics, then the farmer may experience greater "down time" in the field when problems may occur with the double disc opener. One problem that double disc openers are renowned for is the failure of the bearings in the discs due to dust and moisture. The depth wheel must be removed in order to detach the failed disc bearing. If it is difficult to remove the depth wheels in order to access the discs, then the time needed to repair the problem is increased. The attachment of the current depth wheel arm is a very efficient system - the arms are mounted on the axles and held in place by washers and a cotter pin.

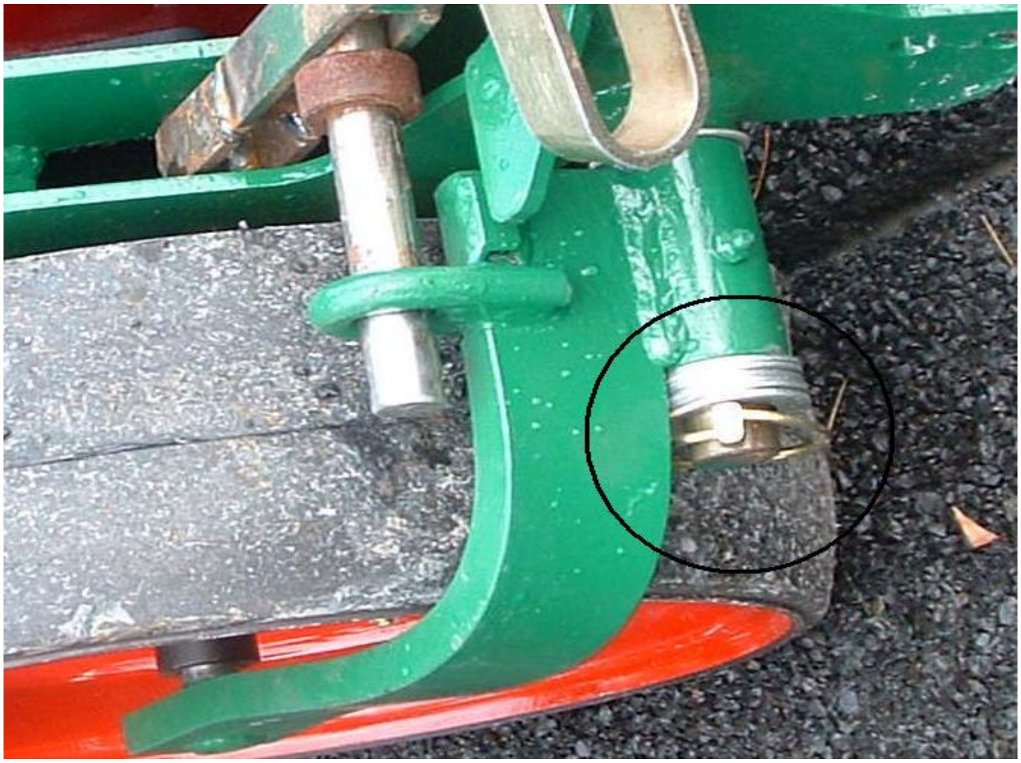


Figure 4.7) Depth wheel arms held in place by cotter pins

This allows the operator to simply remove the pin and washers and slide the arm off to expose the disc and bearing housing.

Ergonomics was also a major factor in the decision to design the attachment system using three grub screws and a pin. Even though the changeover between the tyne unit and disc opener may only happen once annually, the system still needed to be efficient. A 12m (40’) implement that is set at 0.76m (30”) row settings would contain 16 individual units. The task of changing the systems over if the attachment was an inefficient design would be significantly extended.

Figure 4.8) Attachment system

The design allows the operator to simply loosen the grub screws, remove the pin and slide the shank out. The pin enables the operator to position the shank of either the coulter disc or disc opener unit and insert the pin to hold it while they tighten the grub screws when changing over.

Chapter 5

Solid Modelling and Finite Element Analysis

5.1 Introduction

The Finite Element Analysis (FEA) of the project was incorporated so that the design would not have to be changed if it failed during field-testing. Also providing the opportunity to monitor the concentration of stresses in the design.

Janke Bros Engineering do not perform large amounts of Finite Element Analysis on their current implements and therefore do not have a powerful FEA modelling software package. The small amount performed is modelled on CAD Key Software, for the size of the company it is not viable to purchase a software package or licence, and the cost of training personnel.

Abaqus/CAE was the chosen Finite Element Analysis package to be used for the modelling of the project; Abaqus is a very powerful package and proved to be ideal for the problem at hand. Abaqus/CAE has been the leading provider in advanced Finite Element Analysis software packages in the world since 1978; it provides solutions for explicit, linear, non-linear and multi-body dynamic problems. The package allows the user to create the model from scratch and build the project through various steps to visualisation of the end result. The modules that are included in the process consist of the part, property, step, load, mesh, job and the visualisation modules.

This chapter will explain the process followed and the values and properties entered into the software to gain the results received.

5.2 Process for Each Module

5.2.1 Part Module

The part module allows the operator to create individual parts that are to be analysed, the part can be created from scratch or imported from other applications as a finite element mesh or geometric representation.

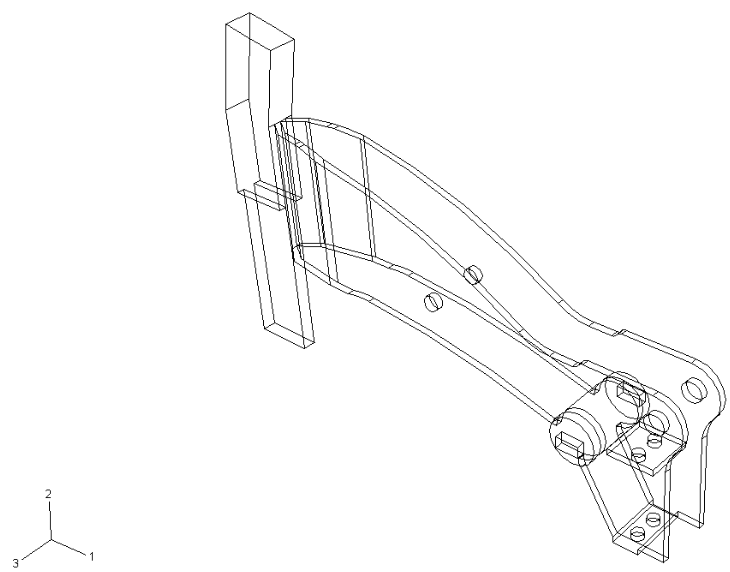


Figure 5.1) 3D drawing of the new double disc opener design

5.2.2 Property Module

The property module is used to define the material properties of the desired material whether it be metal, rubber, plastic or otherwise. This module was used to create a material named “steel”, the properties of the material entered into Abaqus were:

Elastic

Young’s Modulus = 200 000

Possion’s Ration = 0.3

Plastic

YEILD STRESS	**PLASTIC STRAIN**
300	0
350	0.025
375	0.1
394	0.2
400	0.35

Table 5.1) Yield stress and plastic strain of the material tested

And set as Isotropic (Hardening)

5.2.3 Assembly Module

The assembly module involves the process of assembling the various parts and creating sets. This module was not needed for the project as only one frame was created. This did not affect the analysis as Abaqus detects that there is a singular part and did not request any features associated with this step.

5.2.4 Step Module

The step module is used to define the different steps in the analysis, this must be performed before the loads and boundary conditions are applied or the contacts within the model are defined. The loads, boundary conditions and the interactions are then specified to the desired step for it to be applied to. The outputs required are specified in this module, the operator can choose various outputs, depending one what can be analysed on the model and what results the operator wish to obtain. The steps created included:

Field Output Request

Static Step

F-OUTPUT-1

Analysis:

Stresses
Strains
Displacement/Velocity/Acceleration
Forces/Reactions

(CF, LE, PE, PEEQ, PEMAG, RF, S, U)

History Output Request

H-OUTPUT-1

Analysis:

Energy

(ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPO, ALLSE, ALLVP, ALLWK, ETOTAL)

5.2.5 Interaction Module

The interaction module allows the user to define the mechanical and thermal interactions between surfaces of an assembly and its environment. Interactions may include contact between two surfaces and constraints such as rigid body constraints. This module is a very important module in the modelling process, as the mechanical contact between components of the assembly is not recognised by Abaqus/CAE unless it is defined in the interaction module. However, as the project model consists of only one part instance the interaction module becomes void, and Abaqus/CAE recognises that the model does not need contacts specified in this module.

5.2.6 Load Module

The load module enables the operator to create loads, define boundary conditions and specify fields. This module is linked to the step module as the loads and boundary conditions are step dependant, therefore the analysis step that they are activated in must be specified.

There were two loads applied to the model:

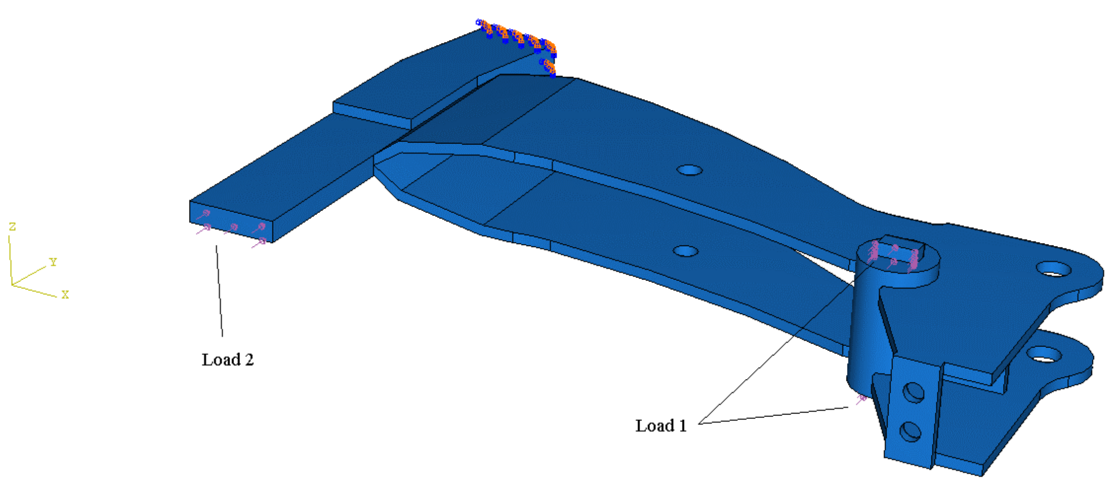


Figure 5.2) Location of the loads applied to the frame

LOAD 1 - Load created by depth wheels

Type - Pressure
Distribution - Uniform
Magnitude - 2227 N / 140 mm^2 = 15.91 N/mm^2
Amplitude - (Ramp)

Load - (STATIC, GENERAL)

LOAD 2 - Load created by discs

Type - Pressure
Distribution - Uniform
Magnitude - 2227 N / 600 mm^2 = 3.71 N/mm^2
Amplitude - (Ramp)

Load - (STATIC, GENERAL)

The loads were acquired by weighing the down force of the springs on the parallelogram; this was achieved by lifting the unit at different heights using an overhead crane. The parallelogram was lifted at the rear of the unit and raised as seen below.

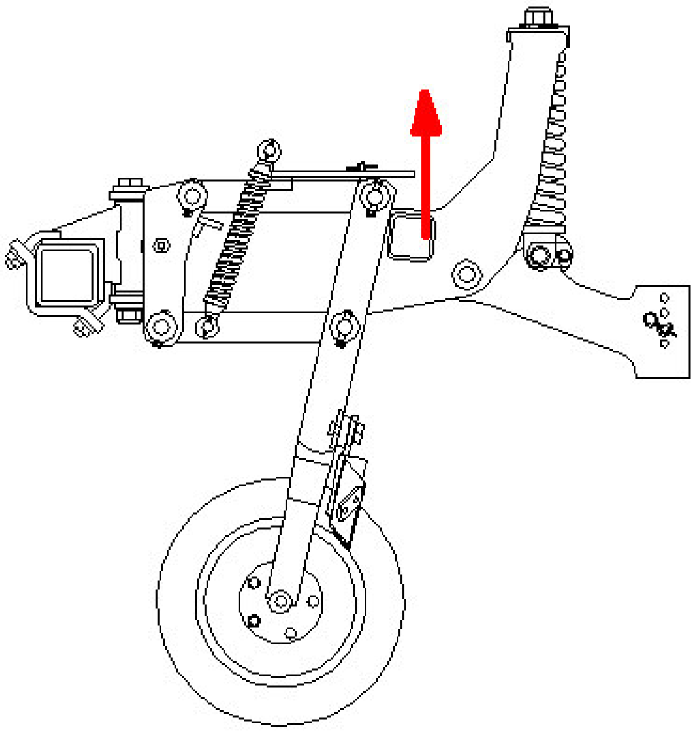
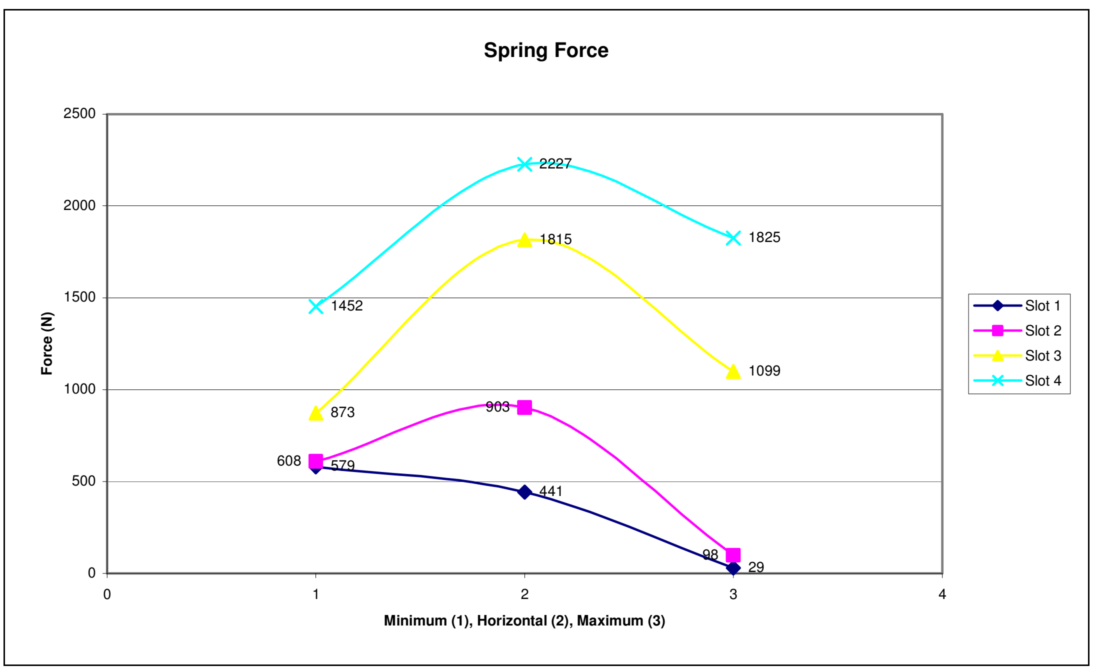


Figure 5.3) The position the parallelogram was lifted at

The down forces created by the springs on the parallelogram are represented in the following graph and table.



Graph 5.2) Representing the spring force at different spring settings.

Calculated Forces				
	Slot 1	Slot 2	Slot 3	Slot 4
Minimum	579	608	873	1452
Horizontal	441	903	1815	2227
Maximum	29	98	1099	1825

Table 5.3) Forces created by springs on parallelogram

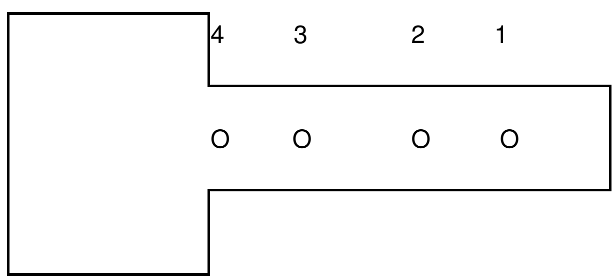
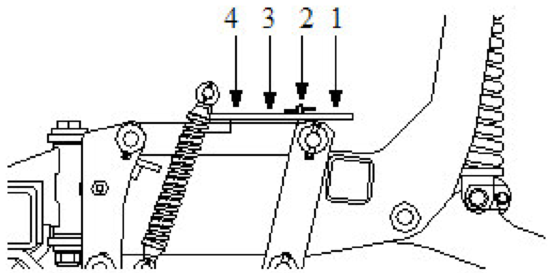


Figure 5.4) Slot positions on parallelogram

Each parallelogram unit is constructed with 4 spring settings, the spring is set by changing the position of the slots, 1 2 3 4, along the top of the parallelogram. The X-axis represents the parallelogram at different working positions:, maximum, horizontal and the minimum lift height.

Slot Positions



Horizontal Lift

Figure 5.5) Horizontal lift position and slot positions of the parallelogram

The highest down force setting was on the 4th slot position while running the parallelogram arms at horizontal; therefore this was the maximum force that the unit can withstand. Higher spikes may occur during working resulting from the unit striking objects in the field, so the attachment and disc opener were designed to handle such increases in force.

The boundary condition was also specified in the load module as the frame was restricted at the top of the shank at the point that the attachment system would reach to.

The boundary Condition set was:

Type	-	Symmetry/Antisymmetry/Encastre
Set as	-	Encastre

ENCASTRE: Fully built-in (U1 = U2 = U3 = UR1 = UR2 = UR3 = 0).

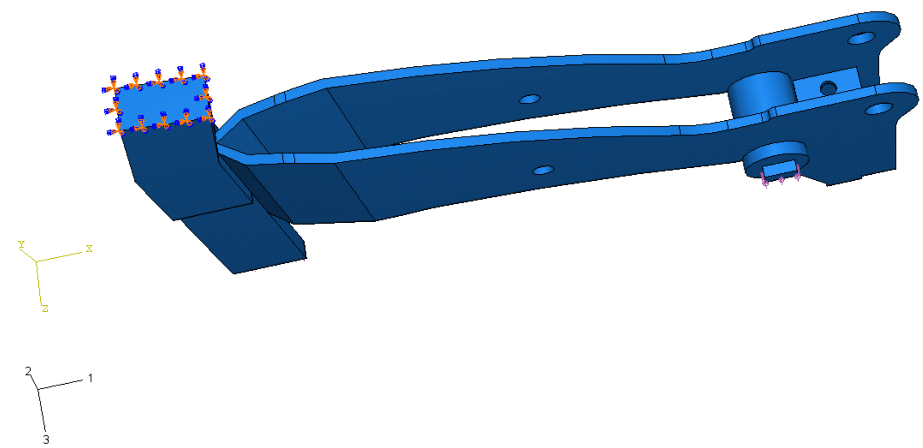


Figure 5.6) Boundary condition set in Abaqus/CAE

5.2.7 Mesh Module

The mesh module generates the finite element mesh for the model, the meshing technique, the element shape and the element type are defined in this module. Abacus/CAE contains several different meshing techniques depending on the model being meshed. Meshing the assembly can be divided into separate processes including, ensuring the model/assembly can be meshed, assigning the mesh attributes, seeding the part instances/model and completing the mesh of the assembly/model. The mesh characteristics were:

Seeding	-	Global Element Size	-	3.0
Mesh Controls	-	Tet	-	Free
Mesh Type	-	Standard 3D Stresses		
	-	Linear		
	-	Tet (4-node linear Tetrahedron)		

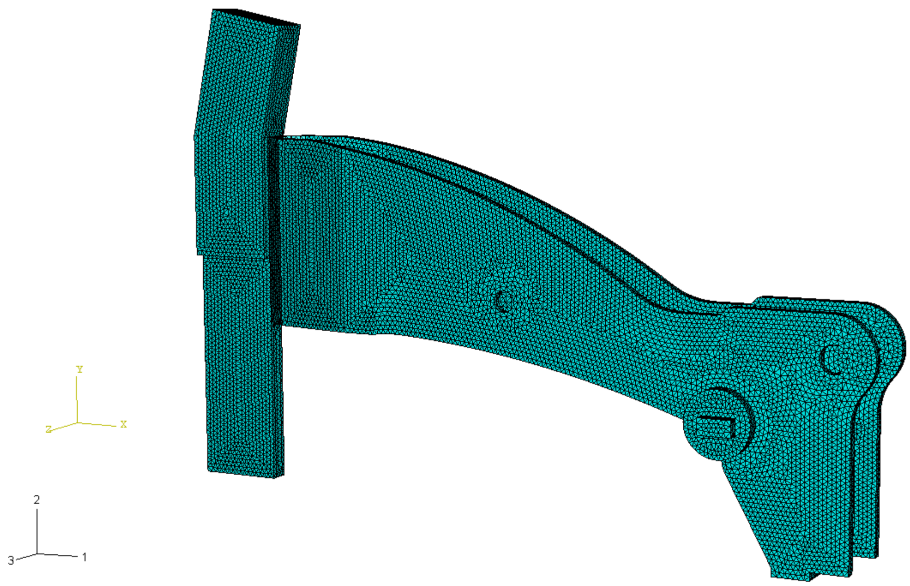


Figure 5.7) The double disc opener Frame Meshed

5.2.8 Job Module

The job module allows the user to create a job that is connected with the model after the analysis has been created and then to submit the job for analysis.

The submitted job was for a full finite element analysis for the model of the frame created for the project.

5.2.9 Visualisation module

The visualisation module or results of the analysis enable the user to read the output database and results that Abaqus/CAE created during the analysis of the job module.

The contour plots that were generated for the frame model included the Von Mises stresses, maximum principal stresses (Tensile) and the minimum principal stresses (Compressive).

The Von Mises Stresses contour plot was created as shown below:

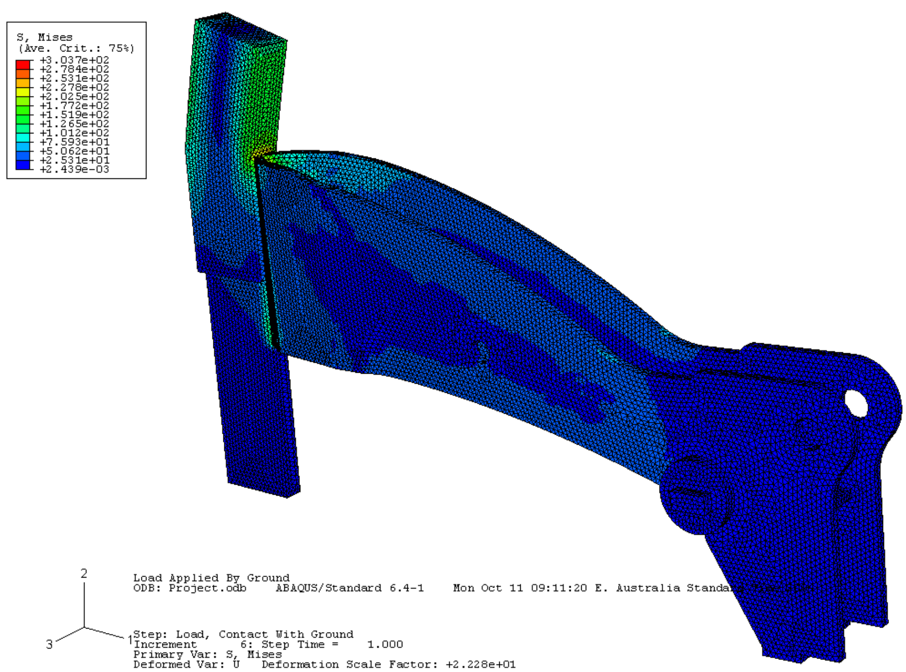


Figure 5.8) Contour plot of stresses

The majority of the stresses occur at the top of shank, as a result of the lever action caused by the depth wheels at the rear of the frame. There is also a concentration of stresses at the bottom of the frame that connects onto the shank; this is also due to the tensile stresses from the depth wheels.

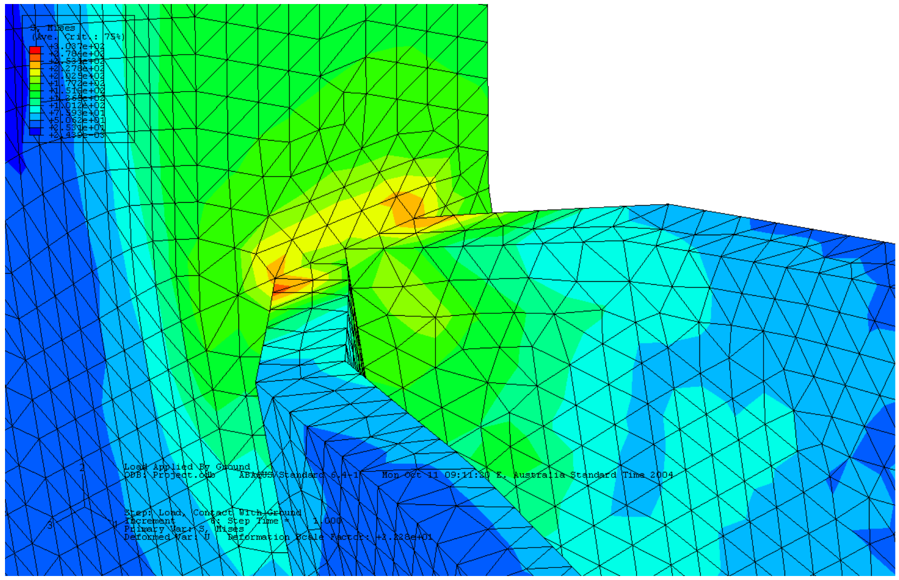


Figure 5.9) Concentration of stresses on top edge of the frame

As seen in figure 5.9, there was a concentration of stresses at the joint of the shank and the frame. This was caused by the acute angle located in that area and the compression forces, the stresses reach a hight of 3.037E+02, which is represented by the red contours.

The maximum principal stress contour plot was created:

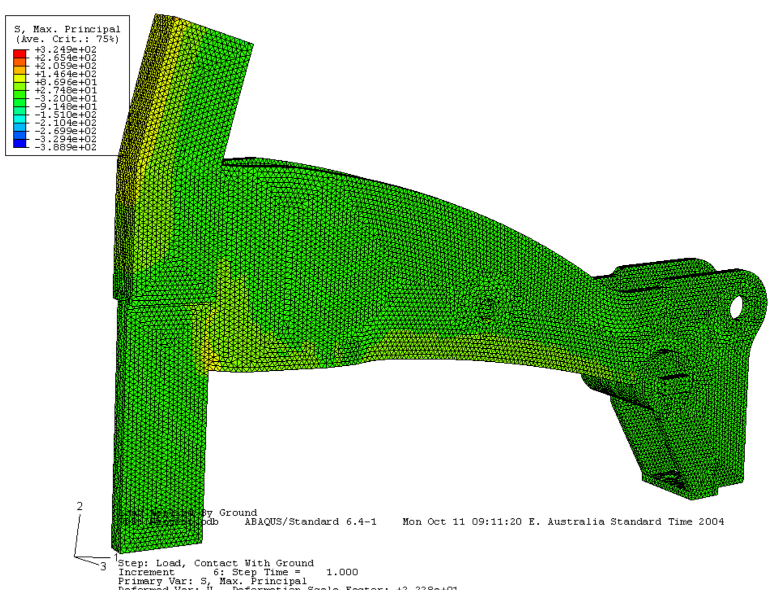


Figure 5.10) Maximum principal stress contour plot

The maximum principal stress contour plot represents the tensile stresses that will occur in the frame during working, the positioning of the stresses are expected as the depth wheel force is pushing upwards at the rear of the frame. As portrayed in figure 5.10, the stresses are located at the front of the shank and along the lower edge of the frame, the stress reached was equal to 1.464E+02, which is represented by the yellow contours and the green represents zero tensile stresses.

The minimum principal stress contour plot is shown in figure 5.11:

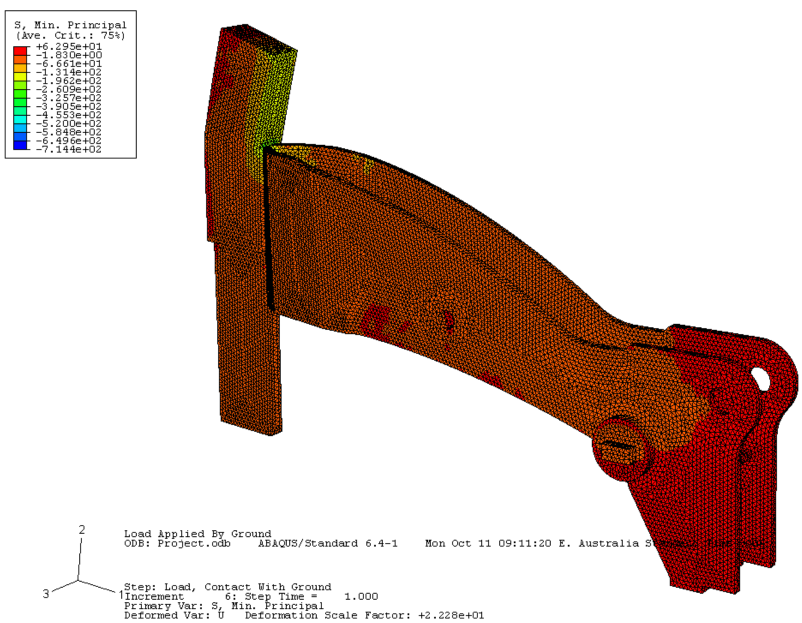


Figure 5.11) Minimum principal stress contour plot

The minimum principal stress contour plot represents the compressive stresses that will occur in the frame while it is working, the positioning of the compressive stresses in the frame are expected as they are opposite to the tensile stresses. The entire shank is under compression as the forces of the discs are pushing upwards through the beam. The compressive stresses are also visible at the rear of the shank due to the upward force of the depth wheels, the stress reached –2.609E+02, which is represented by the yellow and orange, and the red represents zero compressive stresses.

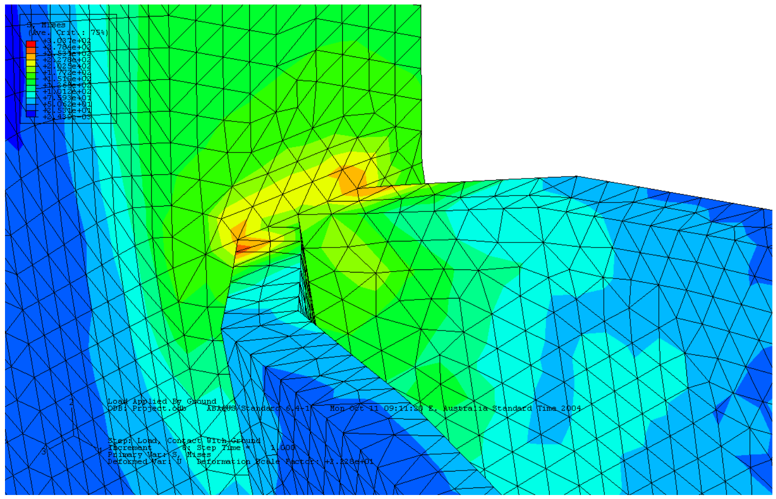


Figure 5.12) Concentration of stresses

Due to the concentration of the compressive stresses reaching 3.037E+02 at this particular point it was decided that a modification maybe made to the design in an attempt to eliminate the high stress concentration.

A flange was added to the top and bottom of the frame attaching the frame to the shank and a support brace was also added to the inside of the frame to aid in preventing deformation of the frame.

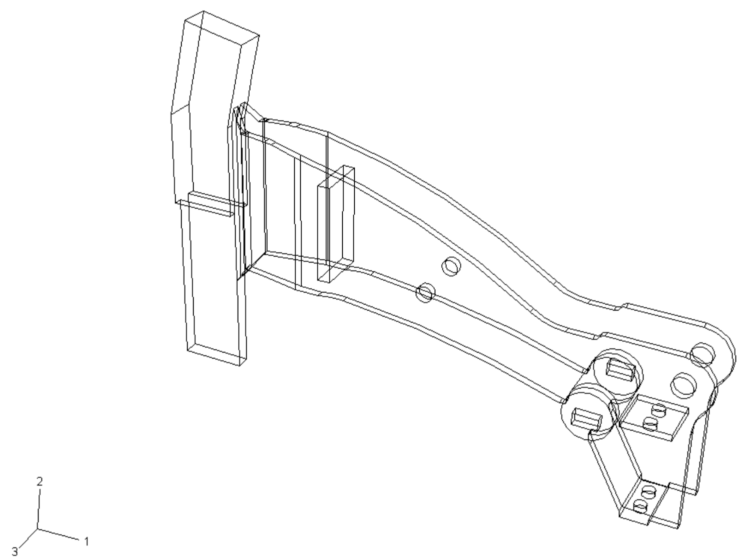


Figure 5.13) Modified Frame design to incorporate flanges and a brace

The addition of the extra support items increased the strength of the frame and reduced the concentration of stresses at the weaker points, with stress now only reached a hight of 2.123E+02. There are still concentrations of stresses at the top of the frame, however the frame is not likely to fail under working conditions.

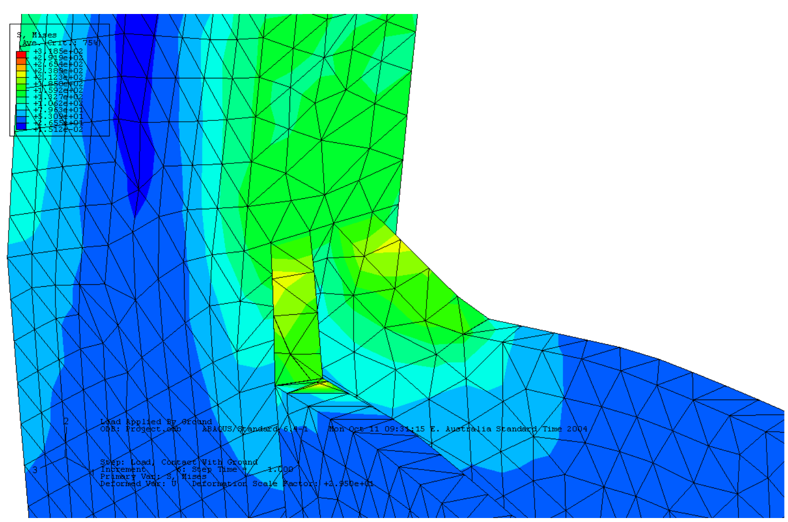


Figure 5.14) Stress contour plot

The minimum principal stress countor plot for the frame with flanges and brace:

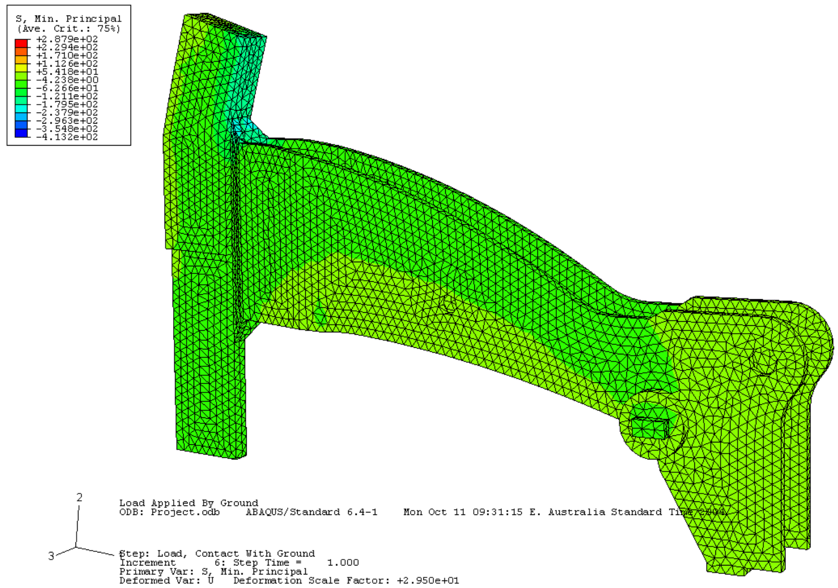


Figure 5.15) Minimum principal stress contour plot of modified design

The minimum principal stresses now only reach –1.795E+02

The maximum principal stress countor plot for the frame with flanges and brace is illustrated in figure 5.16:

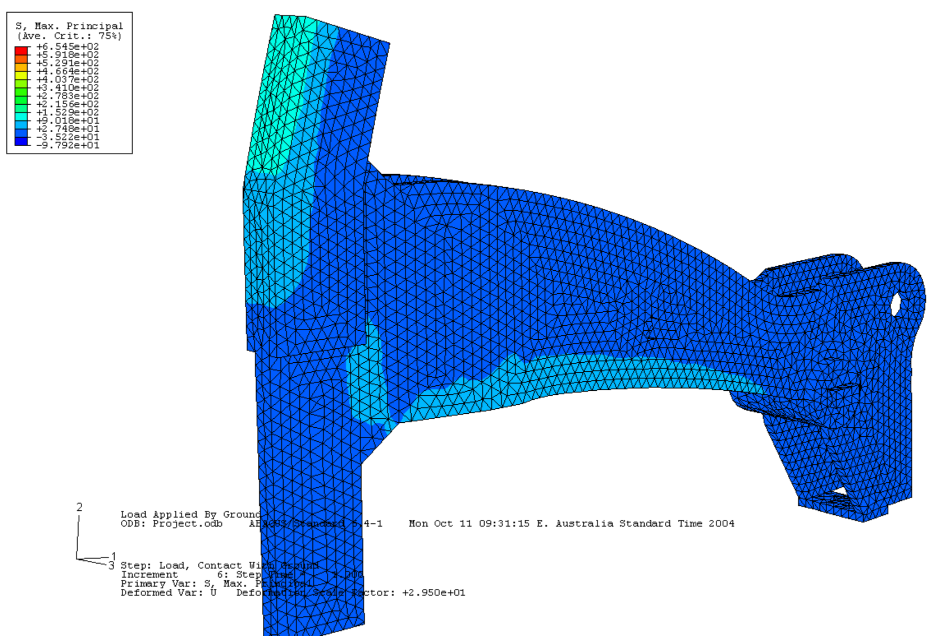


Figure 5.16) Maximum principal stress contour plot of modified design

The maximum principal stresses reached 9.018E+01

5.3 Conclusion

The results found that the original design would satisfy the requirements for the double disc opener to operate in Australia's harsh agricultural conditions. However the presence of concentrated stresses at a vital position on the frame may result in minor modifications to be the design if need be. The modifications are not essential but create a stronger more reliable unit; however the flange located on the top of the frame will disrupt the placing of the seed tube, therefore a new seed tube attachment system may need to be developed. The internal brace can be added to the original design quite easily without the need to redesign the seed tube or the attachment system.

The entire frame, attachment system and separate features were not modelled in Abaqus/CAE finite element analysis for various reasons which are as follows. The features such as the depth wheel arms and the depth gauge were not modelled as they have already been tested and trialed by Janke Bros. Any further testing would be unnecessary as Janke Bros standards of testing and pride in the reliability of the their products is sufficient to assume that the components will not fail.

The attachment system was not modelled as the contact surfaces between the attachment, the shank and the pin proved to be very difficult to model in Abaqus/CAE. The time period in which Abaqus/CAE was acquired and utilised resulted in a very short period in which to learn and acquire the necessary knowledge and skills to create a model and analyse the project on Abaqus/CAE. The interaction module in Abaqus/CAE is a vital component of the model and if the surfaces and contact characteristics are not specified correctly, the software does not analysis the model correctly and fails to produce accurate results. The full assembly was attempted, however the contact surfaces could not be specified correctly due to the inexperience in using Abaqus/CAE. The software could easily model and analysis the frame and attachment system, however the experience required to create such an assembly could not be gained in such a short period.

Chapter 6

Field Testing

6.1 Introduction

The field-testing of the unit was an integral part of the design and testing process of the project, it enabled the testing of the unit in working conditions simular to that of which may be encounter in the Australian agricultural industry. The finite element analysis allowed the design to be model in order to see whether the unit will fail under the applied loads that will be experienced during operation. However, the software package does not take into consideration external influences on the machine that may affect the performance of the unit.

The loads used during the finite element analysis were static loads; this gave a reasonably accurate representation of whether the unit will fail. However, the loads experienced during general working conditions in the field are dynamic loads and therefore change continuously. The change may be caused by the parallelogram continually moving up and down, resulting in the force created by the springs to change over time. Also the unit may strike objects during working and create a sharp increase in the load applied by the springs.

The Australian environment does not frequently provide a perfect seedbed to plant in, occasionally the seedbed can be quite hard and the disc openers may experience forces pushing the disc to the side slightly. The disc following a softer seam of soil (eg.

avoiding wheel tracks), causing the unit to twist to the side slightly will cause loads to form on the side of the unit.

The field testing was performed using Janke Bros current double disc opener unit, due to a shortage of time available on the factory floor, Janke Bros were not able to produce a prototype disc opener. However they were able to construct two parallelogram units with the new attachment system.

The field-testing was performed in the Darling Downs (Bongeen region), which largely consists of Black Self-mulching Vertisol soils, which are generally easily workable soils. Therefore the field-testing that was carried out will not be a representation of all the possible soil types and conditions that Janke Bros machines may encounter. However the testing will provide a strong indication of whether the new design will withstand the majority of field conditions that maybe encountered. This was achieved by extensively testing the range of different levels of force that may act upon the F500P unit.

This chapter will aim at providing an explanation in the need for the field testing, what the testing was trying to achieve and the process in which the testing was performed.

6.2 Aim

The general aim of the field-testing was to take into consideration the external influences that may affect the performance of the disc opener and the attachment system. Since the attachment system was not modelled in the finite element analysis the field-testing was the only indication of whether the attachment system would fail or not.

6.3 Field Trial Process

Although Janke Bros did not construct a prototype of the double disc opener unit they did construct two parallelogram units with the new attachment system. One of the parallelogram units was set up with the conventional tyne and the coulter disc attached with the new system, and the second parallelogram was set up with the current double disc opener.

The two units were mounted on a 4x4 inch RHS beam that was attached to a standard CAT III – 3-point hitch; this allowed the two systems to be tested simultaneously. Therefore enabling comparisons to be easily developed between the two separate planting systems and to ensure that both systems received identical tests.

Figure 6.1) Linkage system and bar that the two units were mounted on

The two units were constructed identically to how they would be set up in the field by the operator. As seen in figure 6.2, the units were run around for approximately three hours in order to extensively evaluate the reliability and efficiency of the design. The springs were set on the highest setting, which was the fourth slot and running the parallelogram arms approximately parallel to the ground. This load will be the maximum force that the machine will experience as this is the highest setting available on this design, therefore if the design could withstand this testing it will perform to the industry standards.

Figure 6.2) Field-testing the double disc opener and the attachment system

External factors that may influence the reliability and efficiency of the unit include dust and moisture, rocks and sticks, general wear and tear, etc. The area that the testing was performed was on the Darling Downs (Bongeen region), and therefore there are no rocks or sticks present in the soil in order to test these external factors. To simulate such disturbances caused by striking objects in the field, the tractor was moved from side to side slightly in an attempt to mimic the side ward forces that objects cause when struck.

The dust and moisture will affect the efficiency and ergonomics of the design of the attachment system and the depth wheel arms. During working, the machine creates dust; especially in dry areas that consist of finer soils that produce dust easily when disturbed. This fine dust manages to lodge itself around the shank in the attachment system and around the pins in the depth wheel arms and attachment. Once moisture reaches the fine dust it acts like an adhesive and the shank or pins become very difficult to remove. Running the unit around and allowing dust to accumulate between the attachment system and the shank achieved this; once the testing was completed the two systems were then removed and replaced in order to examine the degree of difficulty to perform the change over. Also the depth wheel arms were removed to see how the dust affected the pins that were holding the arms in place.

Figure 6.3) Assessing the units during testing

The grub screws in the attachment system shown in figure 6.4 were included in the design in order to clamp the shank firmly into place and to remove any movement of the shank. However the possibility of the grub screws causing the rear of the disc opener unit to kick out to one side had to be determined. This would result in the increase of loading applied to the disc opener and attachment system and the deterioration of the furrow and seedbed created by the discs.

Figure 6.4) Attachment system and double disc opener

6.4 Conclusion

The field-testing of the unit enabled the affects that various external influences may have on the new attachment system to be seen. Unfortunately, the double disc opener could not be field-tested, however the finite element analysis of the frame is sufficient to be confident in the reliability of the design.

Several external influences impacting on the double disc opener could still be examined, the depth wheel arms used on the current disc opener are the same as the arms on the new disc opener design. Therefore they could still be tested concerning the ergonomics and efficiency with respect to the dust and moisture affecting the removal of the cotter pin.

The field-testing also provided the chance to observe the difference between the furrows created by the tyne and the disc opener, and to find out if the disc opener will produce a suitable seedbed for seed germination.

Chapter 7

Discussion of Results

7.1 Introduction

Results were gained for the final design and dimensioning of the double disc opener and the attachment system. Also the finite element analysis of the double disc opener was completed and field-testing of the design was carried out and completed.

The design was modelled on the Abaqus/CAE finite element analysis package; this software is one of the world's leading packages in FEA modelling. Abaqus was chosen for its capacity to handle a model of this size with ease.

The field-testing enabled testing of the design of the disc opener and the attachment system in areas where the FEA could not. All aims of the field-testing were reached during the process and the prototype performed as expected during testing.

This chapter will present the results gained from the finite element analysis and the field-testing performed on the double disc opener and attachment system.

7.2 Finite Element Analysis Results

The finite element analysis of the design was intended to investigate the possibility of the frame failing under loading; the testing was a static load test, however produced sufficient results to determine the reliability of the design. The concentration of stress levels and any stress areas above the maximum limit for the material were determined by the analysis.

Stress concentrations were found on the back of the shank of the disc opener at the top of the frame, the stress levels were quite high. Since the analysis was a static analysis, and the design would encounter dynamic loading in the field, it was decided that modifications could be added. Flanges were attached to the upper and lower edges of the frame attaching the shank; also a brace was included in the design between the two frame sides as illustrated below.

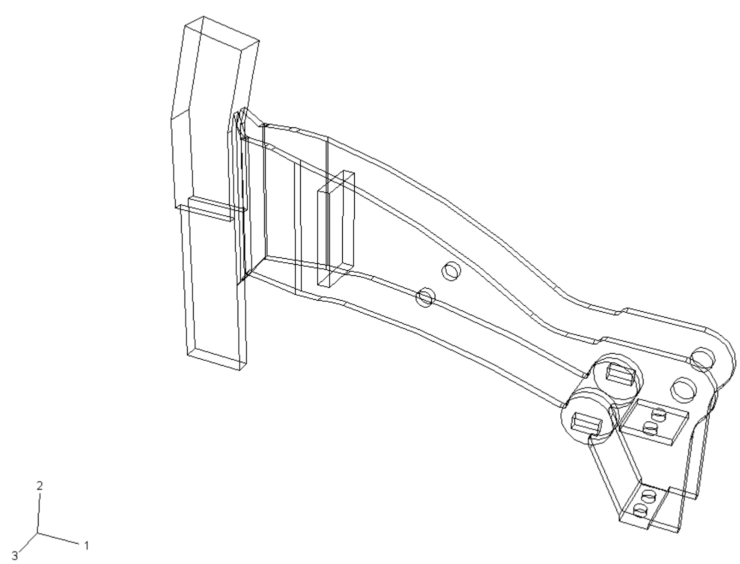


Figure 7.1) 3D drawing of double disc opener design

The flanges aided in distributing the stresses that were concentrated in the regions, the brace limited the deformation of the frame sides, resulting in the reduction of stresses on the upper edge of the frame.

The stresses that were determined include the Von Mises stresses, the maximum principal stresses, which are the tensile stresses, and the minimum principal stresses, which are the compression stresses. Contour plots were created for both the original and the modified disc opener design for the three stresses; the plots can be viewed in appendix C.

The original design would however be sufficient to withstand any field condition that it may be operated in; therefore the design was retained, as the flanges were disruptive to other features of the design. The brace can be easily included in the original design as it can be positioned around the seed tube that is located directly behind the shank.

7.3 Field Testing Results

The furrow created by the double disc opener was examined during the field-testing to view whether the discs were creating the desired seedbed and furrow. The disturbance of the seedbed by the planting method causes the evaporation of the soil moisture to increase. The pore spaces between the soil aggregates increases resulting in an increase of air movement through the soil resulting in the transition of soil moisture from the soil to the air and released into the atmosphere. Also the more soil seed contact that is achieved directly increases the germination rate of the crop, therefore if the seedbed has a well-structured furrow, then adequate soil seed contact will be achieved. The figures below illustrate the degree of disturbance and the difference between the furrows created by the conventional tyne and the double disc opener unit.

Figure 7.2) Furrow created by Janke Bros direct drill planting tyne

Figure 7.3) Furrow created by double disc opener

As seen in figures 7.2, 7.3 and 7.4, the double disc opener does not disturb the soil to the degree that the tyne unit does, enabling the operator to maximise the soil moisture efficiency to encourage a successful gemination. However, the double disc opener does not out-perform the tyne system in all conditions, the disc opener cannot plant at the same depths as the tyne system whilst chasing moisture.

Figure 7.4) Soil disturbance created by either unit

The field-testing also aimed at determining the affects external influences had on the design and other factors that may have an effect on the performance of the unit. The grub screws were examined to view whether they may change the alignment of the disc opener in the attachment system, and no visible changes to the positioning of the disc opener after the field-testing was completed could be found.

The attachment system and the disc opener were also tested for the affect that striking an object would have on the unit, after close inspection, no damage could be located on the discs or the unit.

The dust and moisture that accumulated between the disc opener/coulter disc shank and the attachment system did not affect the removal of the disc opener or the coulter disc.

Chapter 8

Summary and Conclusions

8.1 Achievement of Objectives

The objects set at the time of the projects commencement included:

- Design the double/single disc unit, using as many of Janke Bros current range of products as possible, and the new attachment system.

- The newly designed disc opener and attachment is to be tested on a finite element analysis (FEA) package. Allowing a better visualisation of the attachment method and eliminate the need to redesign the attachment system after testing.

- A prototype can be constructed and tested in the field, enabling Janke Bros to produce the new design for the next winter crop planting (April-May 2005)

The attachment system and double disc opener frame required was created using AutoCAD drafting software, as seen throughout the dissertation the attachment system consists of the parallelogram arms folded in and attached together. Three grub screws are position on the front of the attachment system to aid in holding the shank firmly in place, a pin was also included in the design of the attachment system to assist the operator while changing the disc opener and the coulter disc over.

The disc opener frame contained two sets of axles for the discs and the depth wheels, the anchor hole for the depth gauge and the groves for the gauge to move were also included in the design. The disc opener and coulter disc shanks were designed to fit the attachment system, which needed to be 50mmx25mm BIS alloy steel. The shank for the coulter disc was modified to be compatible with the new attachment system. The disc frame also includes an area at the rear of the design to accommodate for the attachment of a furrow closing devise.

The software used to model and analyse the design was Abaqus/CAE, the double disc opener frame was modelled and analysed in the finite element analysis package. Due to difficulties using the software, the attachment system was not modelled in Abaqus/CAE, this however did not effect the modelling of the disc frame. The frame was found to contain sufficient strength to withstand the load applied by the springs on the parallelogram. There were concentrations of stresses found on the design, modifications were developed to eliminate the concentrations but the original design was retained, as the modifications were not overly necessary.

Janke Bros did not construct the prototype of the double disc opener design; nonetheless the attachment system prototype was constructed and tested using Janke Bros current double disc opener design. The current disc opener was modified to accommodate the attachment system, allowing extensive testing of the design into the reliability and efficiency of the design.

8.2 Further work

The field-testing of the design was performed over approximately a three hour period; further testing may be performed over a longer period of time to determine the reliability of the design after wear and tear and the possibility of fatigue failure.

The design is a prototype, and further design work may be continued on the unit to improve the efficiency and for the construction of the design in the factory and the ergonomics of the design for the operator. Other features that were used from the existing design may also be modified to improve the operator's efficiency and reliability.

Furrow closing devices must be designed by Janke Bros in the future in order for the double disc opener to be operated correctly. Also a single disc opener may be developed as single disc openers and double disc openers each have their own advantages and disadvantages, and perform differently in varying conditions.

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Appendix B: Drafting Drawings of Disc opener and other components, Janke Bros. Engineering, Mt Tyson, Queensland, Australia.

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APPENDIX A

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Andrew John Ruhle**

TOPIC: Redesign and analysis of parallelogram planting unit

SUPERVISORS: Dr. Amar Khennane
Guido Strangherlin, Janke Bros

ENROLMENT: ENG 4111 – S1, D, 2004;
ENG 4112 – S2, D, 2004

PROJECT AIM: The project aims to modify and analyse Janke Bros current parallelogram planting unit design in order to accommodate either a tyne, single disc or double disc opener system.

PROGRAMME: **Issue A, 23 March 2004**

1. Research the background on current minimum tillage practises adopted by Australian producers.
2. Design the new planting unit attachment system, utilising as many of Janke Bros current range of products.
3. Test and analyse new design on a Finite Element Analysis package.
4. Construct a prototype unit and perform field trails in order to test durability of unit.

As time permits:

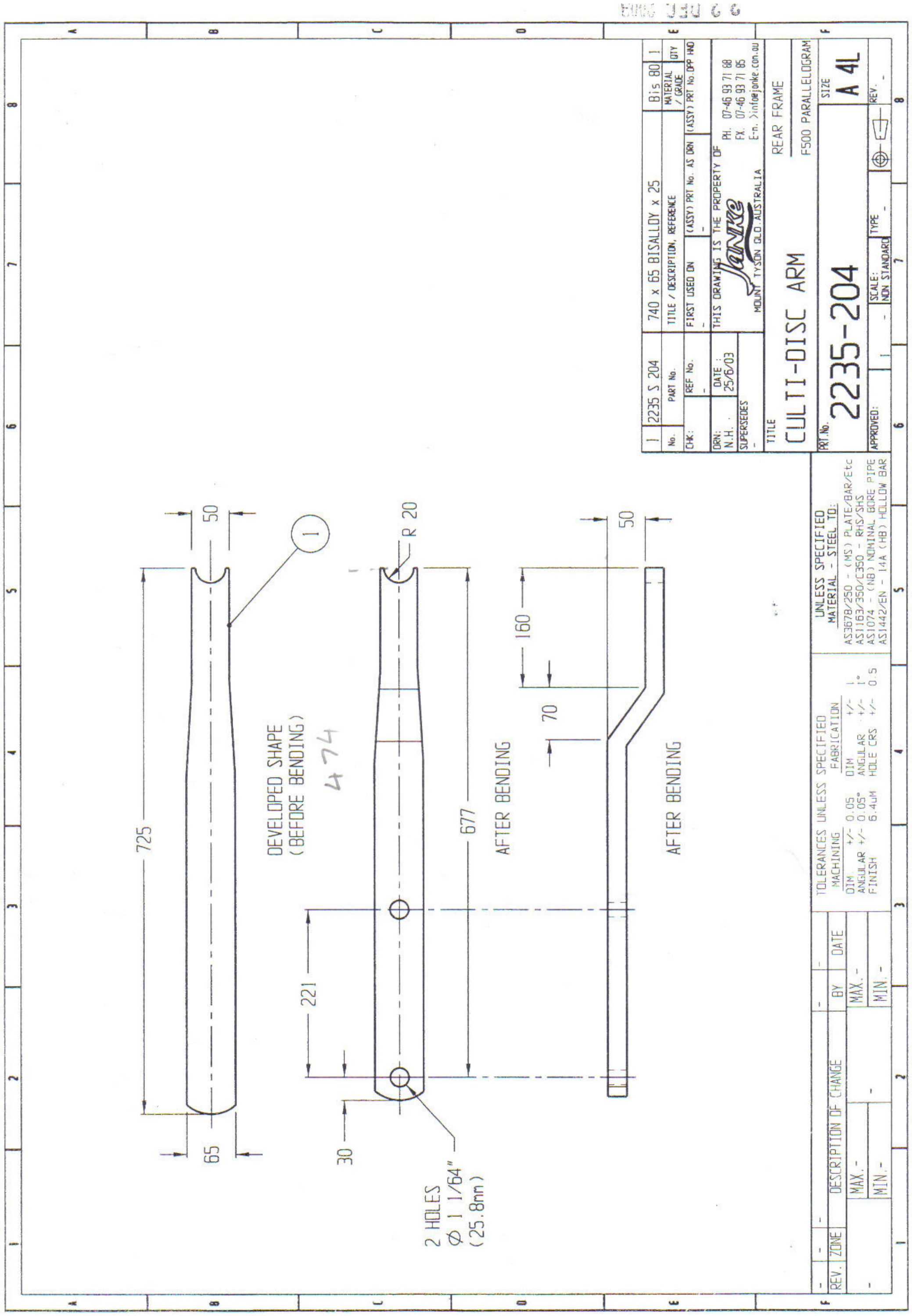
5. If unit fails, redesign, construct and analyse if necessary.

AGREED:

___________(Student) ______________, ____________(Supervisors)

___/___/___ ___/___/___ ___/___/___

APPENDIX B



740 x 65 BISALLOY x 25
Bis 80
2235 S 204
DEVELOPED SHAPE
(BEFORE BENDING)
AFTER BENDING
AFTER BENDING
2 HOLES
Ø 1 1/64"
(25.8mm)
R 20
725
677
221
160
70
50
50
65
30
REAR FRAME
F500 PARALLELOGRAM
CULTI-DISC ARM
2235-204
MOUNT TYSON QLD AUSTRALIA
A 4L
DATE: 25/6/03
UNLESS SPECIFIED
MATERIAL - STEEL TO:
TOLERANCES UNLESS SPECIFIED
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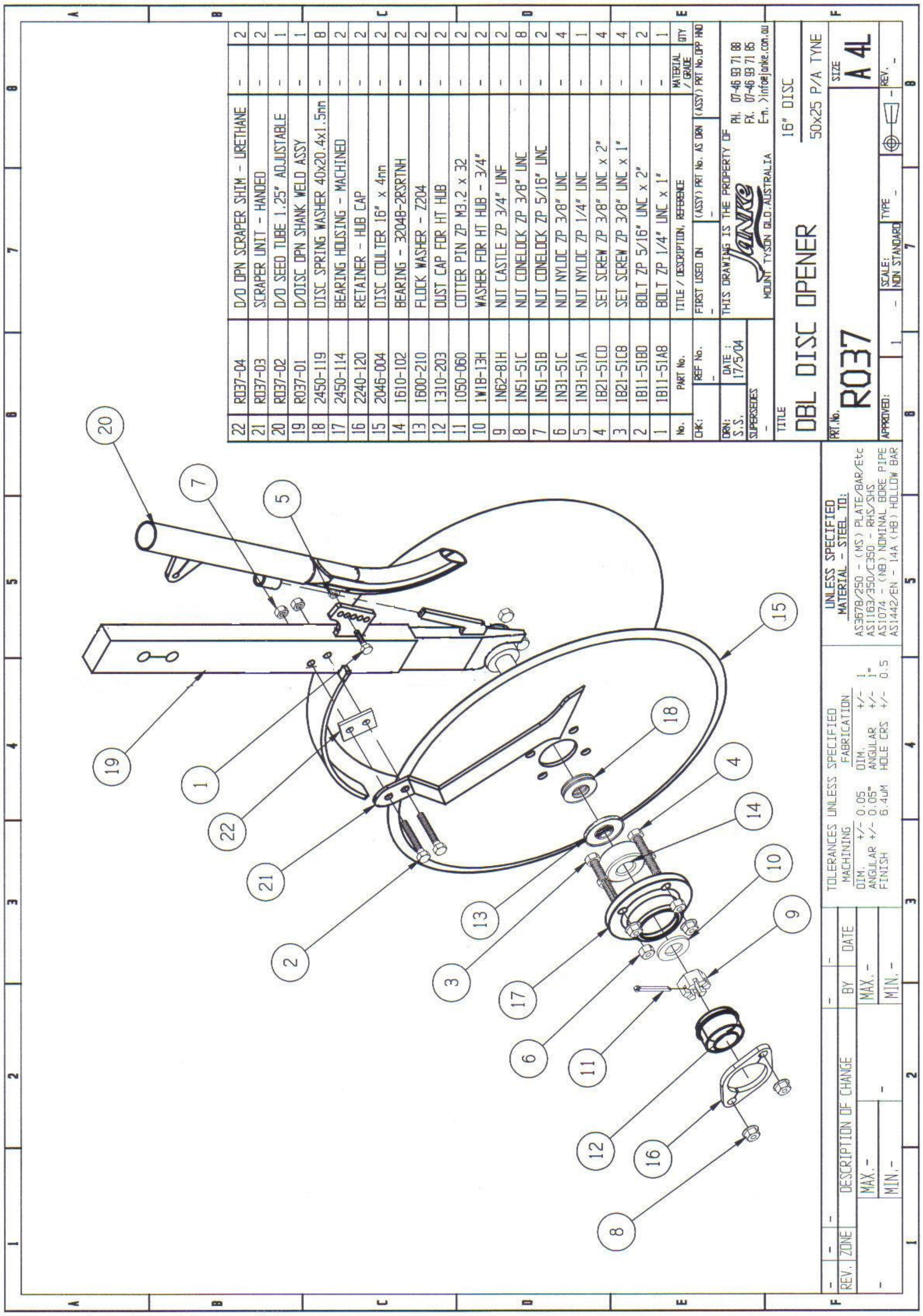
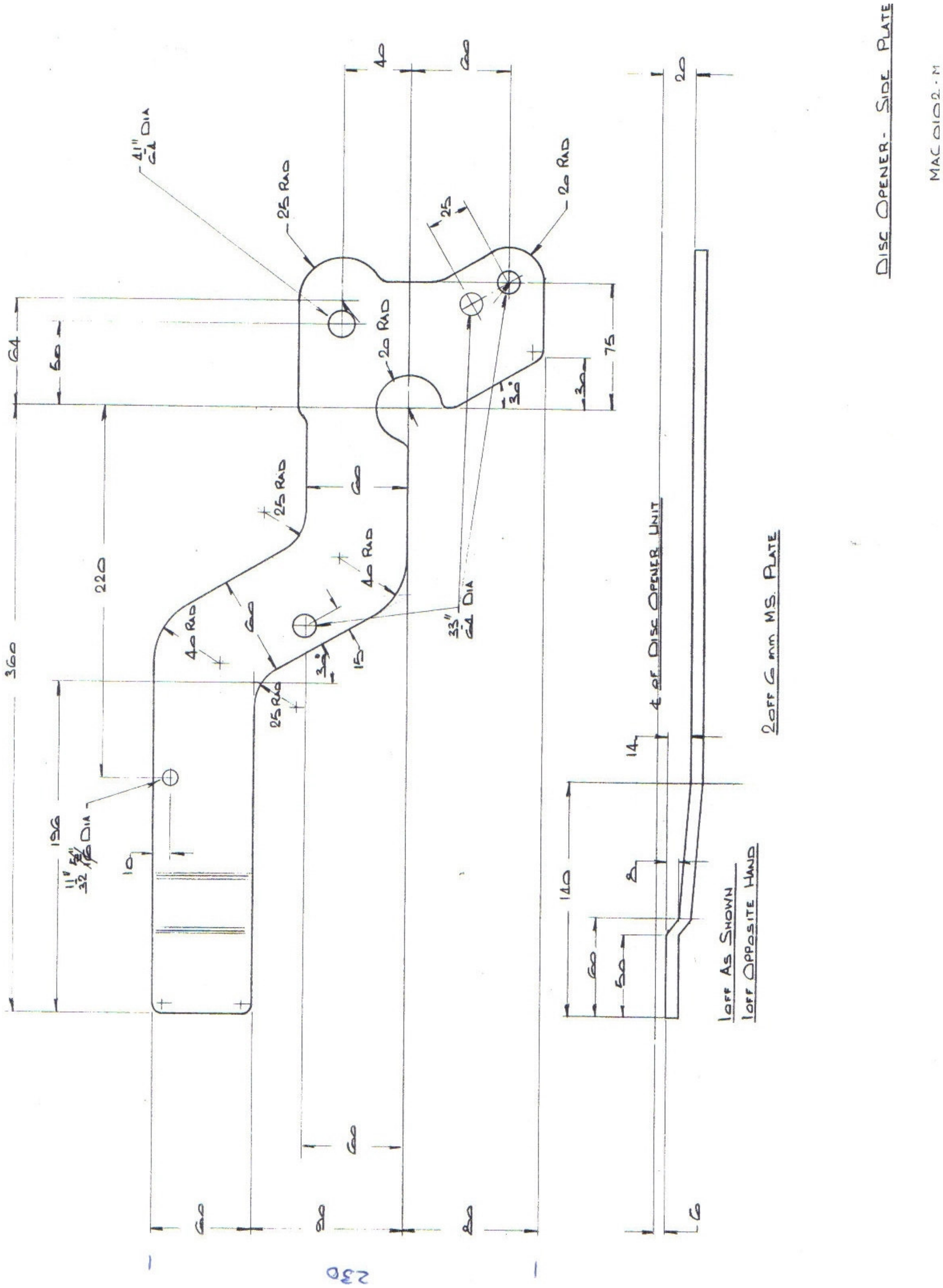


22 R037-04 D/O OPN SCRAPER SHIM - URETHANE - 2
21 R037-03 SCRAPER UNIT - HANDED - 2
20 R037-02 D/O SEED TUBE 1.25" ADJUSTABLE - 1
19 R037-01 D/DISC OPN SHANK WELD ASSY - 1
18 2450-119 DISC SPRING WASHER 40x20.4x1.5mm - 8
17 2450-114 BEARING HOUSING - MACHINED - 2
16 2240-120 RETAINER - HUB CAP - 2
15 2046-004 DISC COULTER 16" x 4mm - 2
14 1610-102 BEARING - 3204B-2RSRTNH - 2
13 1600-210 FLOCK WASHER - 7204 - 2
12 1310-203 DUST CAP FOR HT HUB - 2
11 1050-060 COTTER PIN ZP M3.2 x 32 - 2
10 1W18-13H WASHER FOR HT HUB - 3/4" - 2
9 1N62-81H NUT CASTLE ZP 3/4" UNF - 2
8 1N51-51C NUT CONELOCK ZP 3/8" UNC - 8
7 1N51-51B NUT CONELOCK ZP 5/16" UNC - 2
6 1N31-51C NUT NYLOC ZP 3/8" UNC - 4
5 1N31-51A NUT NYLOC ZP 1/4" UNC - 1
4 1B21-51CD SET SCREW ZP 3/8" UNC x 2" - 4
3 1B21-51CB SET SCREW ZP 3/8" UNC x 1" - 4
2 1B11-51BD BOLT ZP 5/16" UNC x 2" - 2
1 1B11-51AB BOLT ZP 1/4" UNC x 1" - 1
No. PART No. TITLE / DESCRIPTION, REFERENCE MATERIAL / GRADE QTY
THIS DRAWING IS THE PROPERTY OF Janke MOUNT TYSON QLD. AUSTRALIA
PH. 07-46 93 71 88
FX. 07-46 93 71 85
E-m. info@janke.com.au
DRN: S.S.
DATE: 17/5/04
TITLE DBL DISC OPENER
16" DISC 50x25 P/A TYNE
PRT. No. R037
SIZE A 4L
SCALE: NON STANDARD
UNLESS SPECIFIED MATERIAL - STEEL TO:
AS3678/250 - (MS) PLATE/BAR/Etc
AS1163/350/C350 - RHS/SHS
AS1074 - (NB) NOMINAL BORE PIPE
AS1442/EN - 14A (HB) HOLLOW BAR
TOLERANCES UNLESS SPECIFIED
DESCRIPTION OF CHANGE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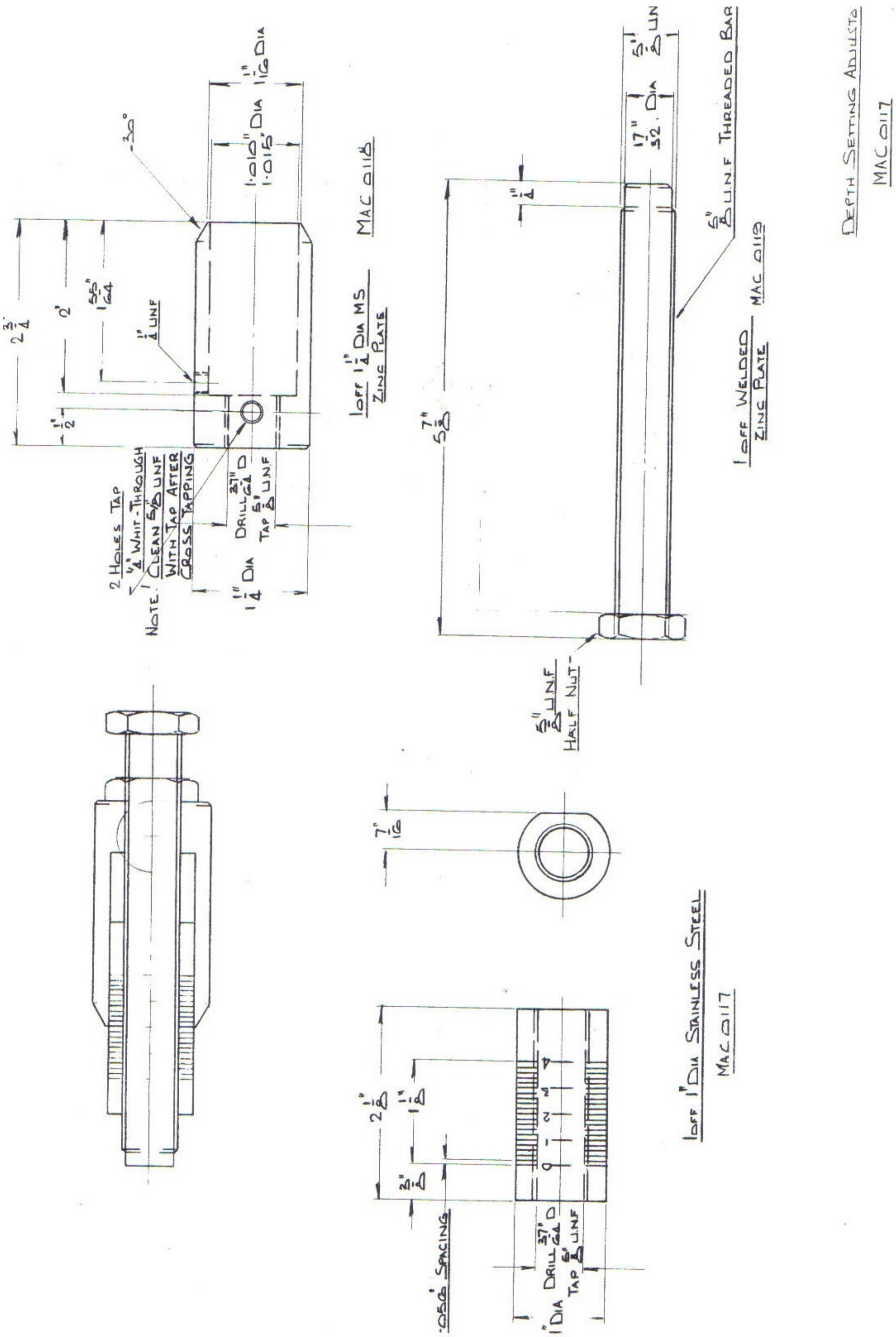
1OFF AS SHOWN
1OFF OPPOSITE HAND
℄ OF DISC OPENER UNIT
25 RAD
20 RAD
40 RAD
230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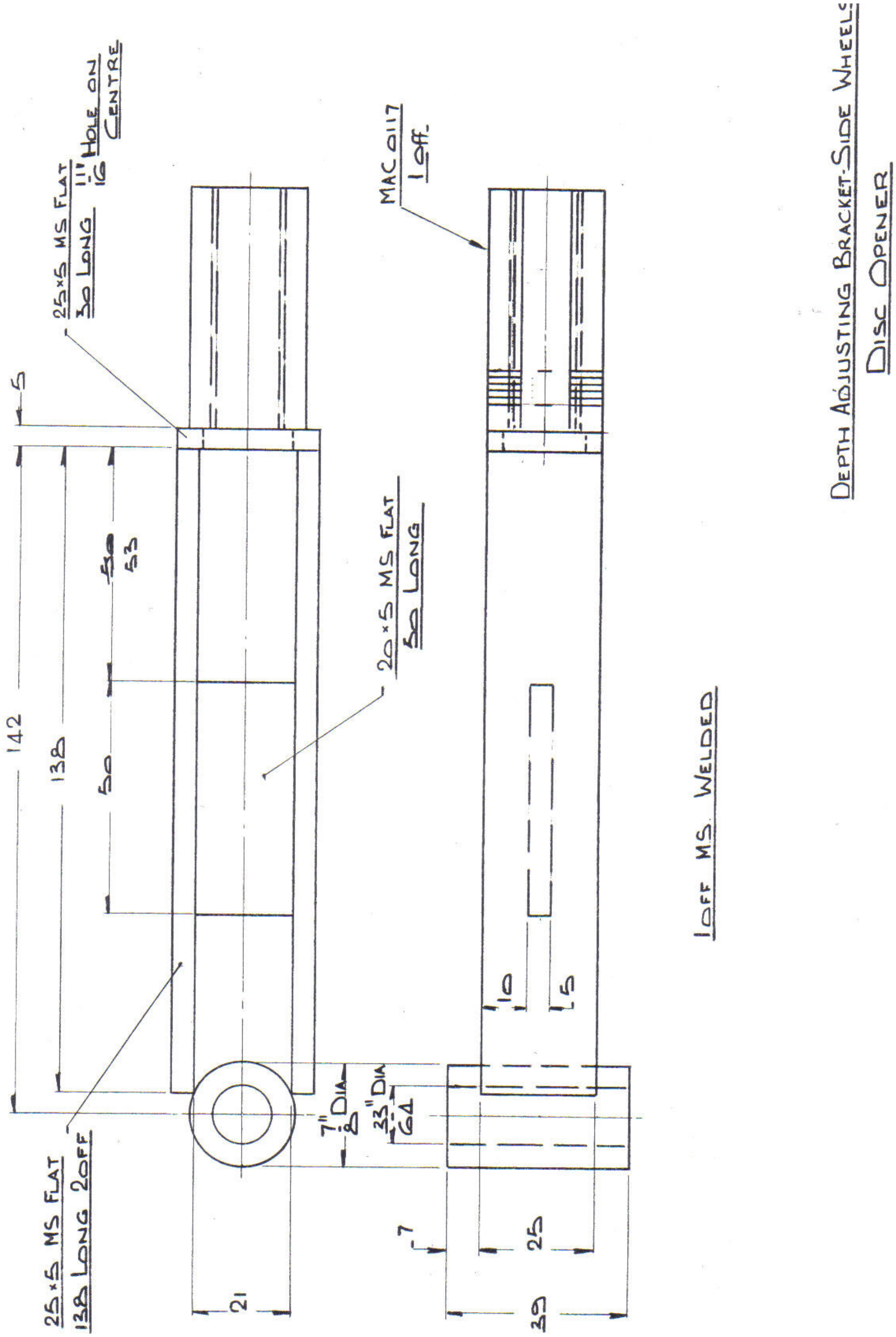
MAC 0117
1 OFF 1 1/4" DIA MS
ZINC PLATE
MAC 0118
NOTE: CLEAN 5/8 UNF
WITH TAP AFTER
CROSS TAPPING
1 OFF WELDED
ZINC PLATE
MAC 0119
5/8" UNF THREADED BAR
5/8" UNF
HALF NUT
1 OFF 1" DIA STAINLESS STEEL
MAC 0117
·0506" SPACING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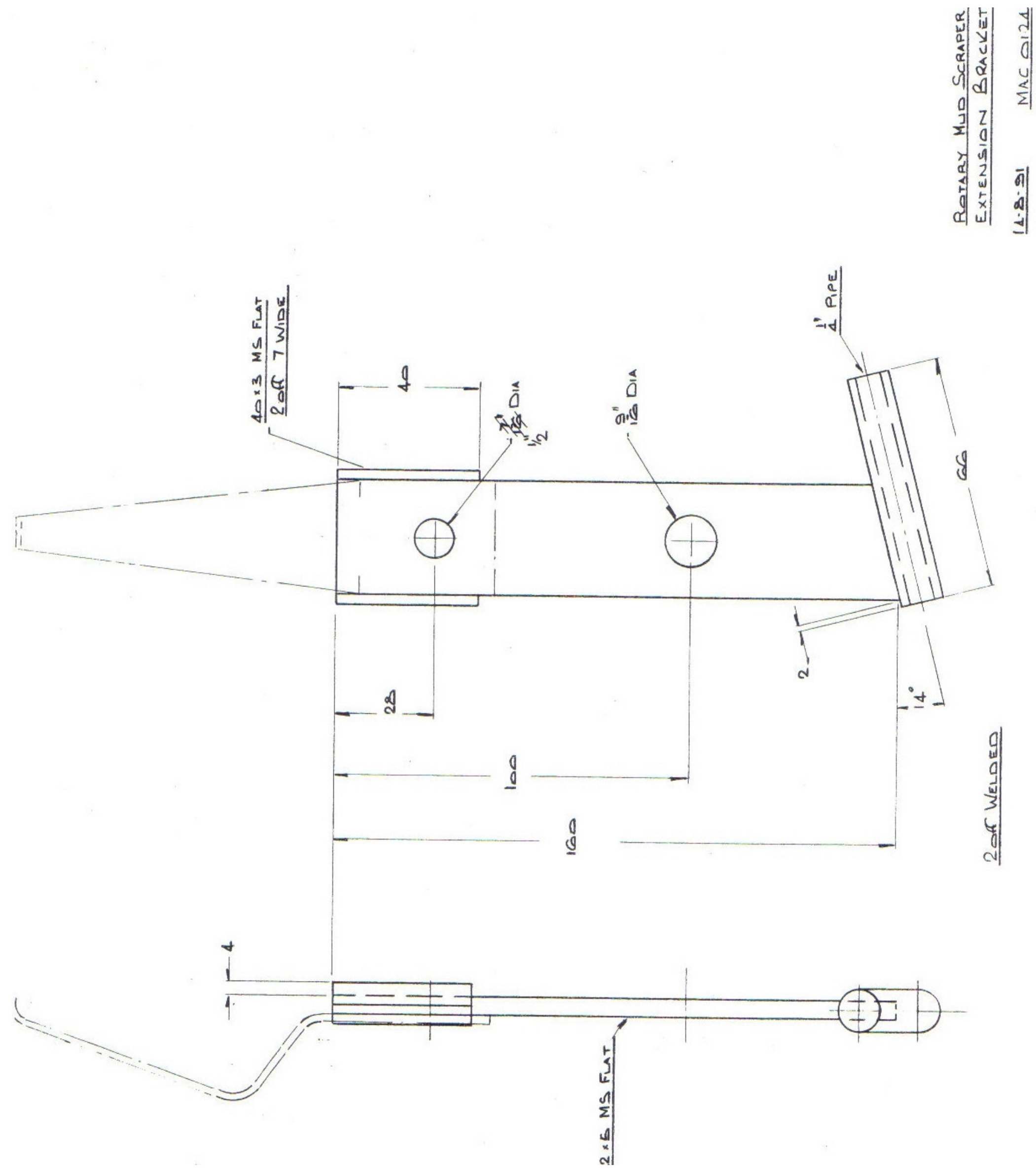
DISC OPENER
1 OFF MS. WELDED
MAC 0117
1 off
25×5 MS FLAT
30 LONG
11" HOLE ON
16 CENTRE
20×5 MS FLAT
50 LONG
25×5 MS FLAT
138 LONG 2 OFF
7" DIA
8
33" DIA
64
142
138
50
53
5
10
25
21
39
7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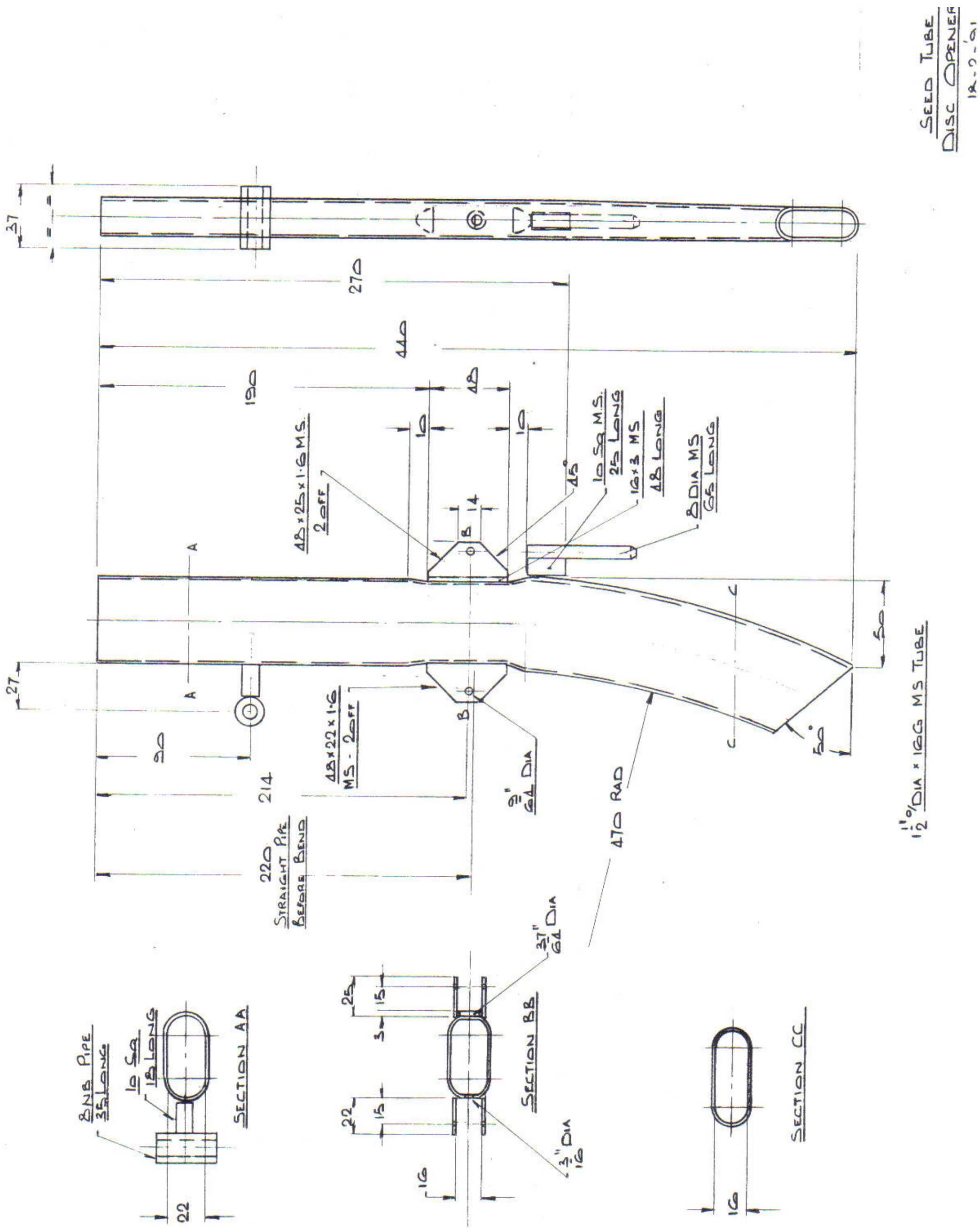
EXTENSION BRACKET
16·8·91
MAC 0124
40x3 MS FLAT
2off 7 WIDE
40
1/2" DIA
9/16" DIA
1" PIPE
66
2
14°
28
100
160
2off WELDED
4
2x6 MS FLAT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DISC OPENER
12-2-'91
37
270
440
190
48
10
10
48 x 25 x 1.6 M.S.
2 OFF
45°
14
10 SQ MS
25 LONG
16 x 3 MS
48 LONG
8 DIA MS
65 LONG
A
B
C
27
50
90
214
48 x 22 x 1.6
MS - 2 OFF
9/64" DIA
470 RAD
50°
1 1/2" O/DIA x 16G MS TUBE
220
STRAIGHT PIPE
BEFORE BEND
8NB PIPE
35 LONG
10 SQ
18 LONG
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22
15
16
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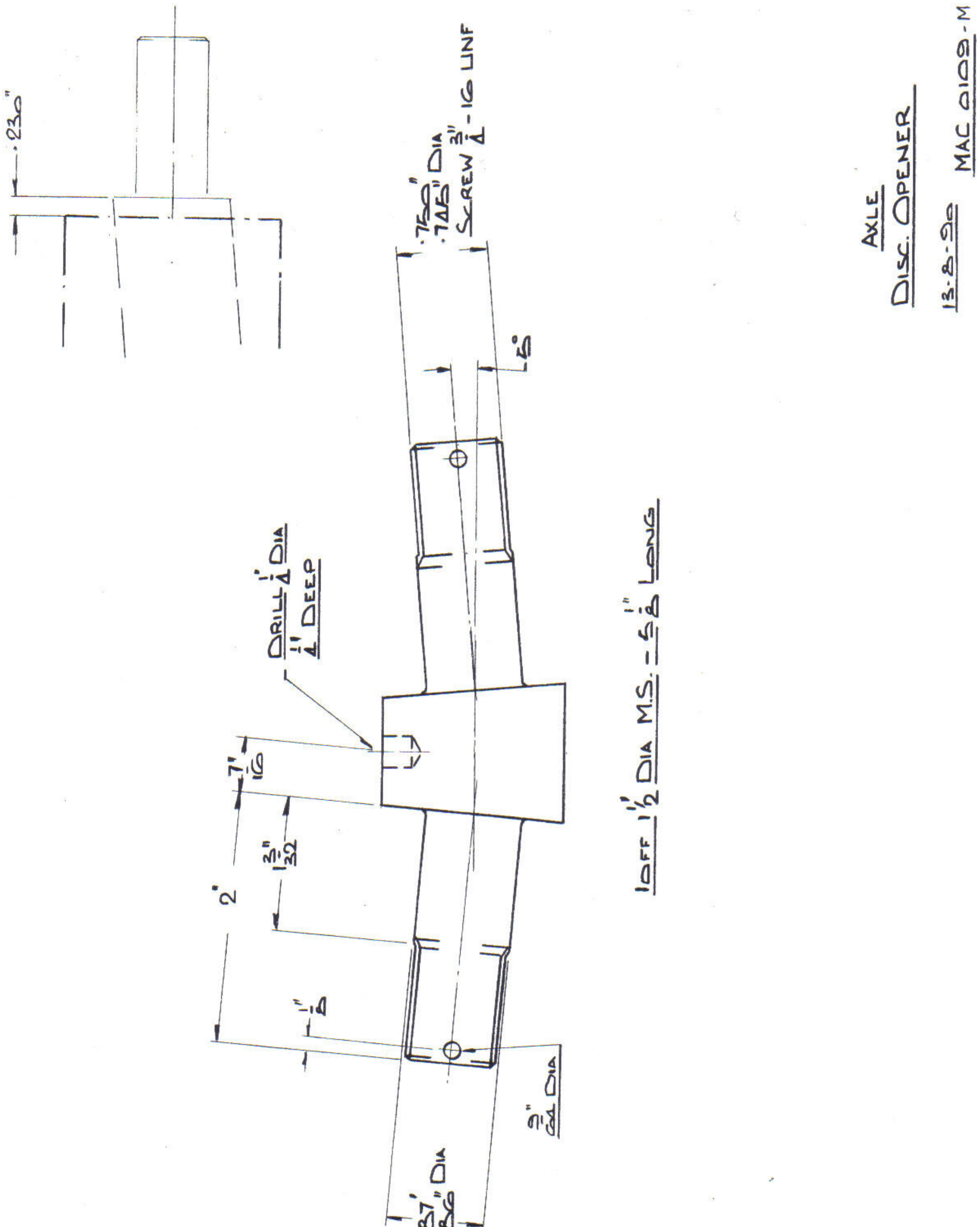
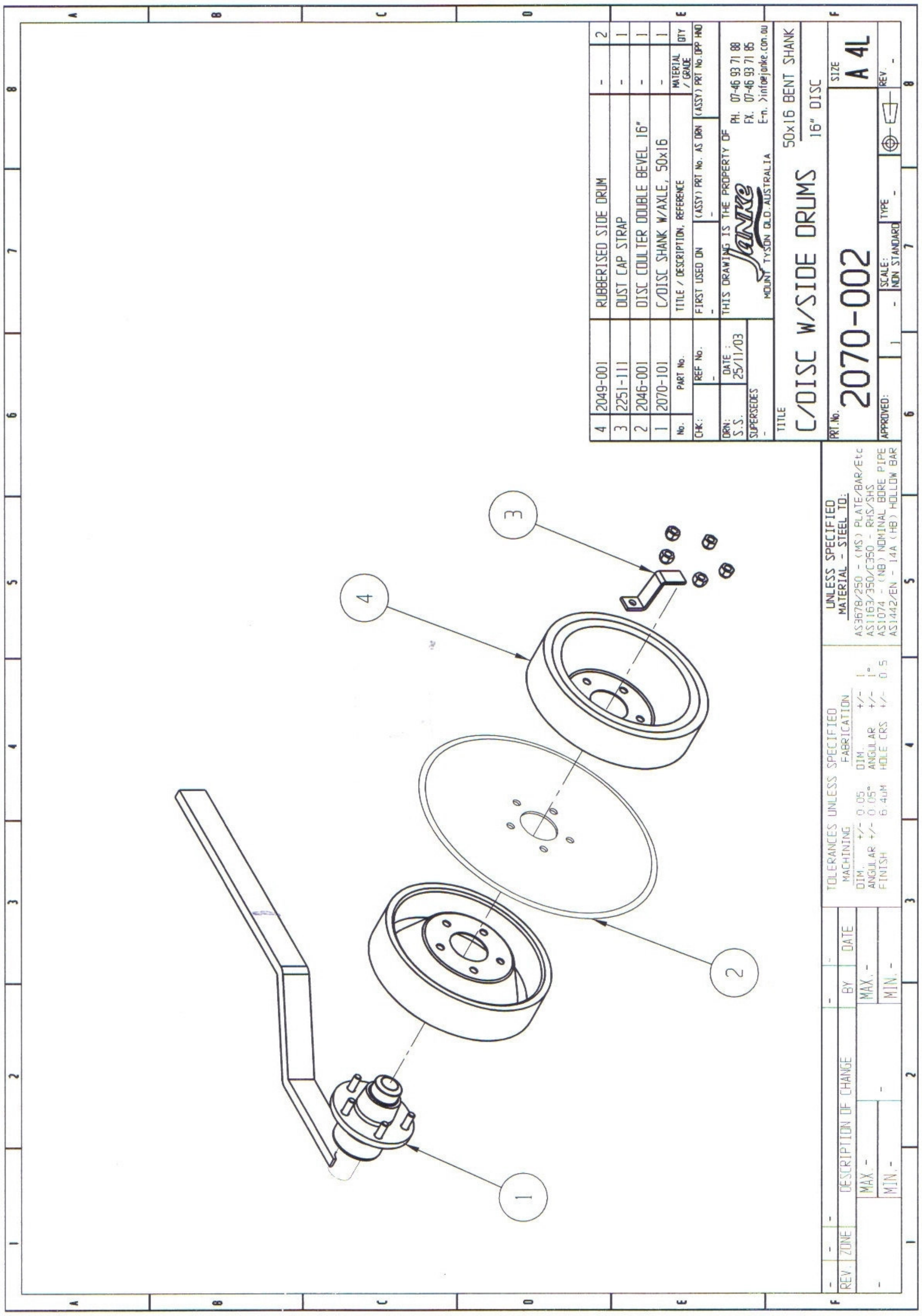
3/16" DIA
SECTION BB
SECTION CC
16


AXLE
DISC. OPENER
13-8-90
MAC 0109-M
1 OFF 1½ DIA M.S. - 5⅛ LONG
DRILL ¼ DIA
¼ DEEP
SCREW ¾ - 16 UNF
.750 .745 DIA
.787 .786 DIA
.230
6°
2
1 3/32
7/16
⅛
3/64 DIA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DRN: S.S. DATE: 25/11/03
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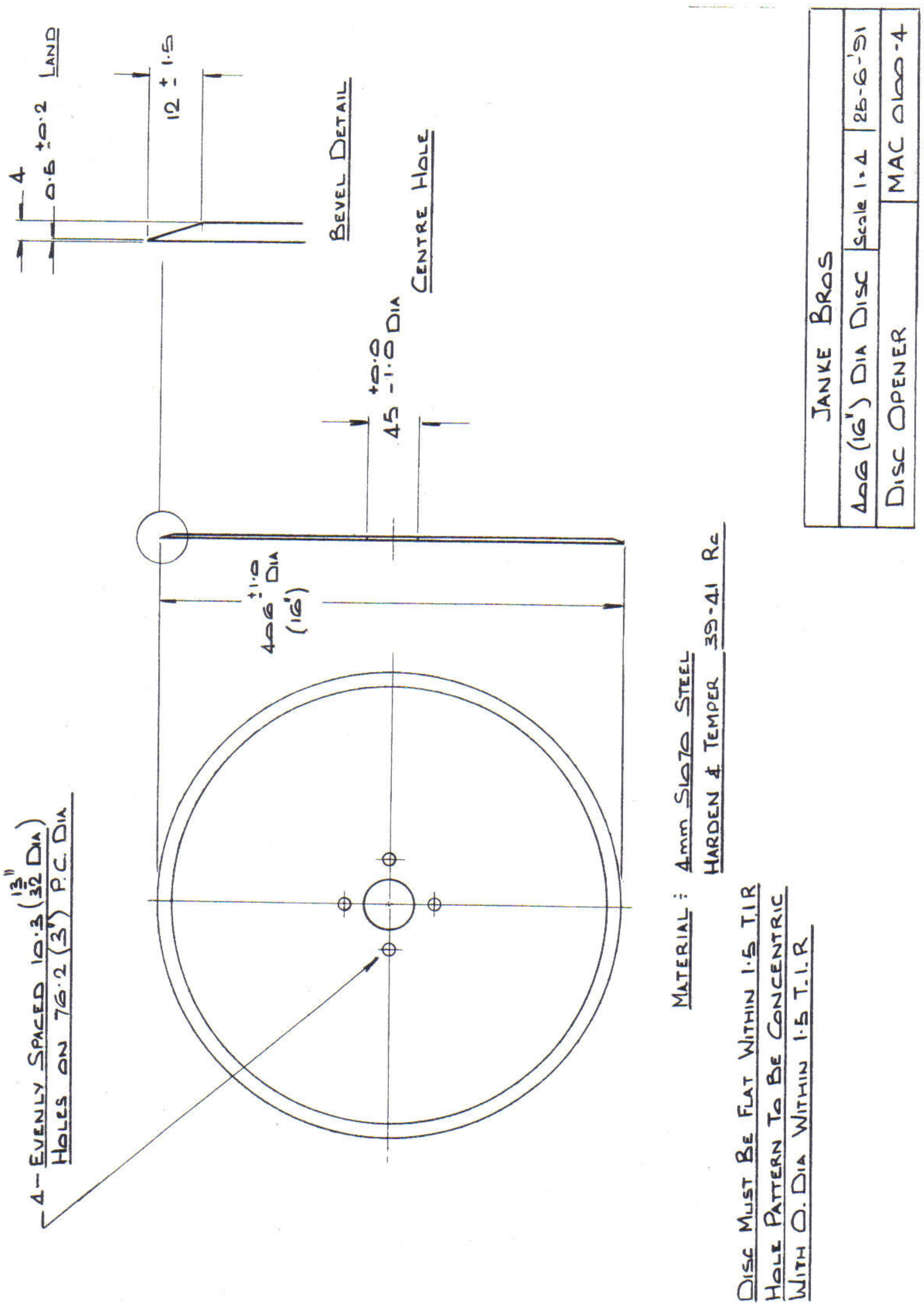
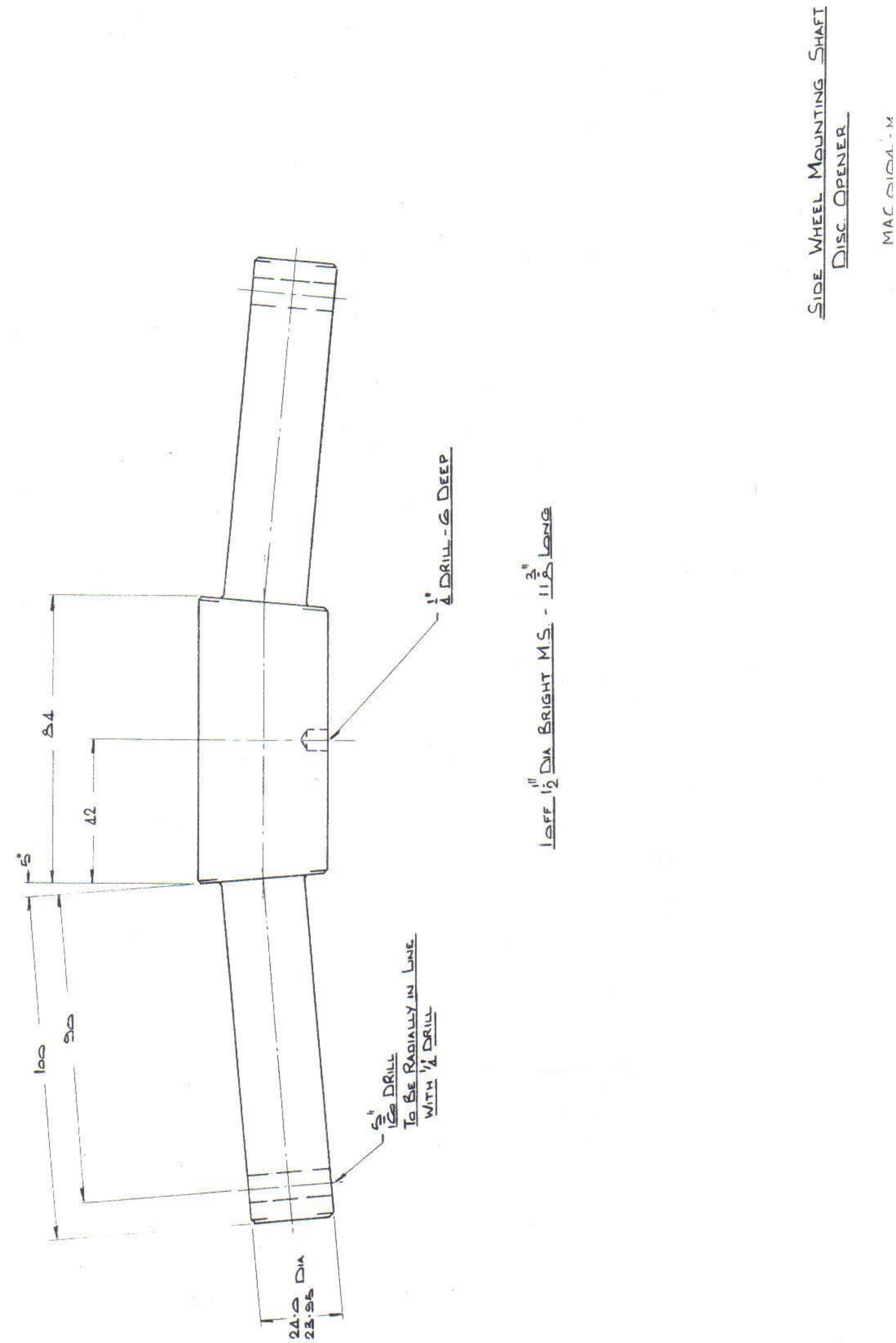
Janke
MOUNT TYSON QLD AUSTRALIA
PH. 07-46 93 71 88
FX. 07-46 93 71 85
E-m. >info@janke.com.au
TITLE
C/DISC W/SIDE DRUMS
50x16 BENT SHANK
16" DISC
PRT.No.
2070-002
SIZE A 4L
APPROVED: - SCALE: NON STANDARD TYPE - REV -
UNLESS SPECIFIED
MATERIAL - STEEL TO:
AS3678/250 - (MS) PLATE/BAR/Etc
AS1163/350/C350 - RHS/SHS
AS1074 - (NB) NOMINAL BORE PIPE
AS1442/EN - 14A (HB) HOLLOW BAR
TOLERANCES UNLESS SPECIFIED
MACHINING
DIM. +/- 0.05
ANGULAR +/- 0.05°
FINISH 6.4uM
FABRICATION
DIM. +/- 1
ANGULAR +/- 1°
HOLE CRS +/- 0.5
REV ZONE DESCRIPTION OF CHANGE BY DATE
MAX. - MAX. -
MIN. - MIN. -


4 – Evenly Spaced 10.3 (13/32" Dia)
Holes on 76.2 (3") P.C. Dia
4
0.6 ±0.2 Land
12 ± 1.5
Bevel Detail
45 +0.0 -1.0 Dia
Centre Hole
406 ±1.0 Dia
(16")
Material: 4mm 5070 Steel
Harden & Temper 39-41 Rc
Disc Must Be Flat Within 1.5 T.I.R
Hole Pattern To Be Concentric
With O. Dia Within 1.5 T.I.R
Janke Bros
406 (16") Dia Disc
Scale 1:4
26-6-'91
Disc Opener
MAC 0100-4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DISC OPENER
1/4" DRILL - 6 DEEP
1 OFF 1 1/2" DIA BRIGHT M.S. - 11 3/8" LONG
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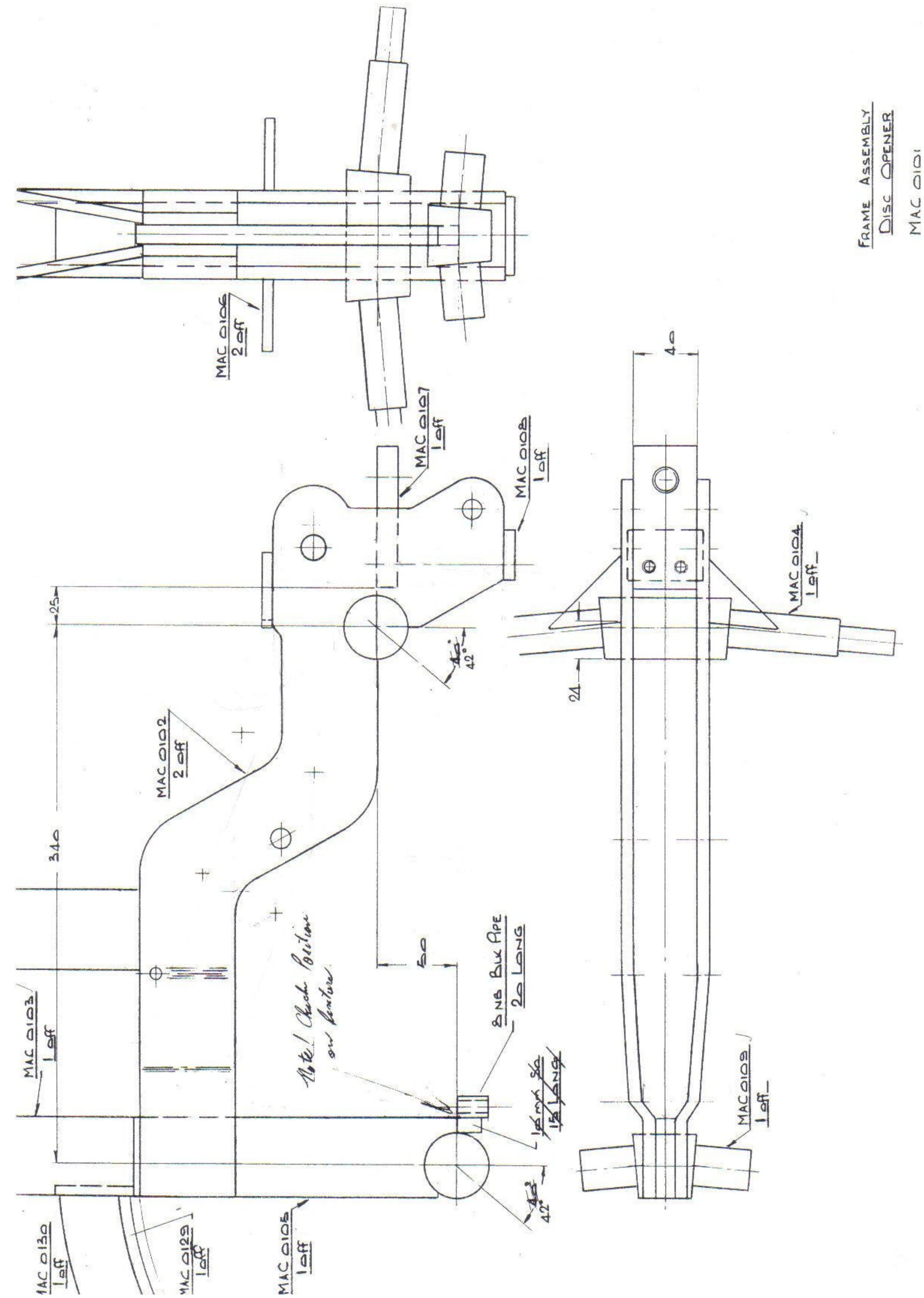
5°
100
90
5/16" DRILL
TO BE RADIALLY IN LINE
WITH 1/2" DRILL
24.0
23.95 DIA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MAC 0101
MAC 0106
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MAC 0107
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MAC 0108
1 off
MAC 0104
1 off
MAC 0102
2 off
MAC 0103
1 off
MAC 0109
1 off
MAC 0105
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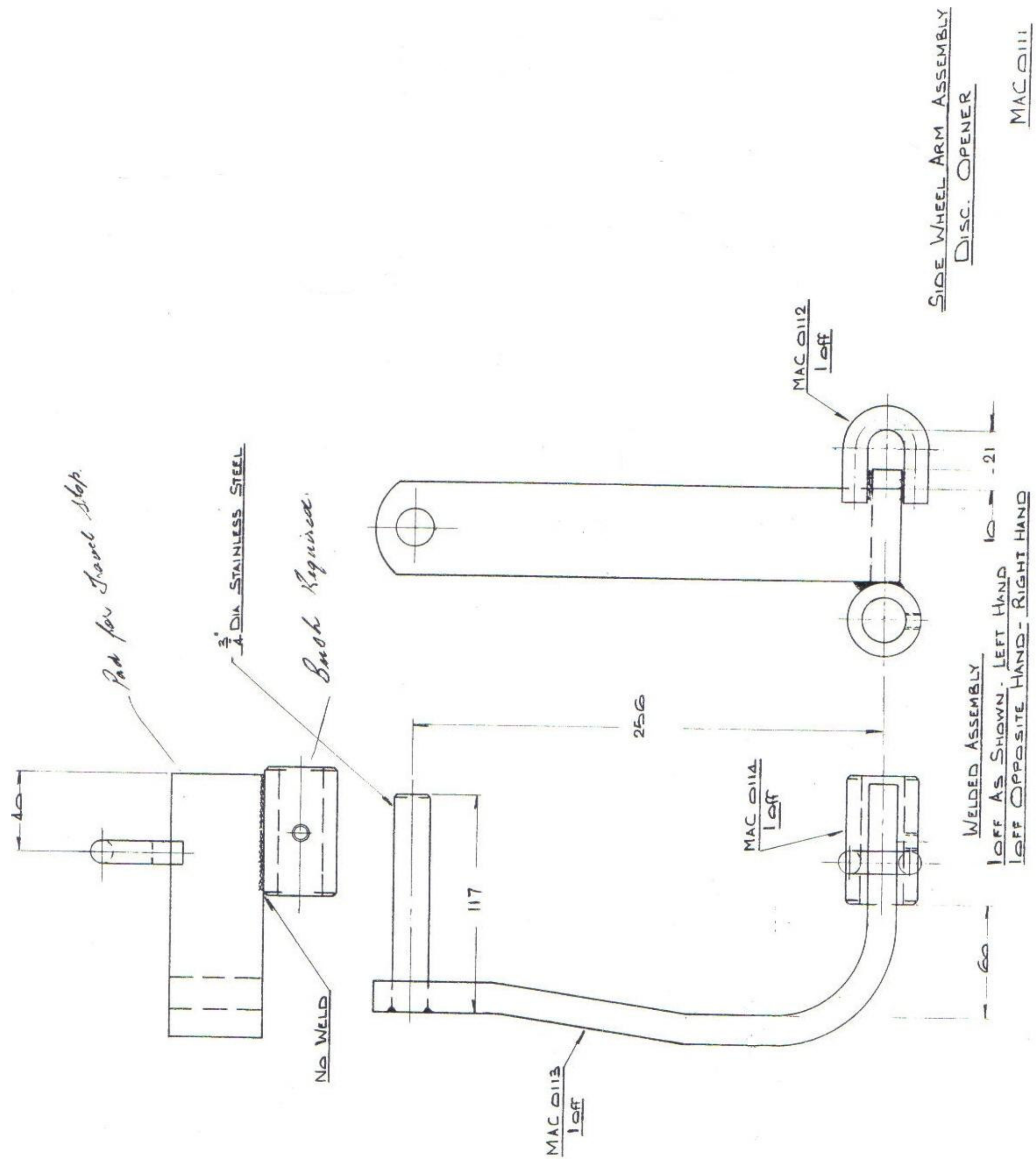
MAC 0130
1 off
MAC 0129
1 off
8 NB BLK PIPE
20 LONG
340
25
40
24
50
42°


SIDE WHEEL ARM ASSEMBLY
DISC. OPENER
MAC 0111
MAC 0112
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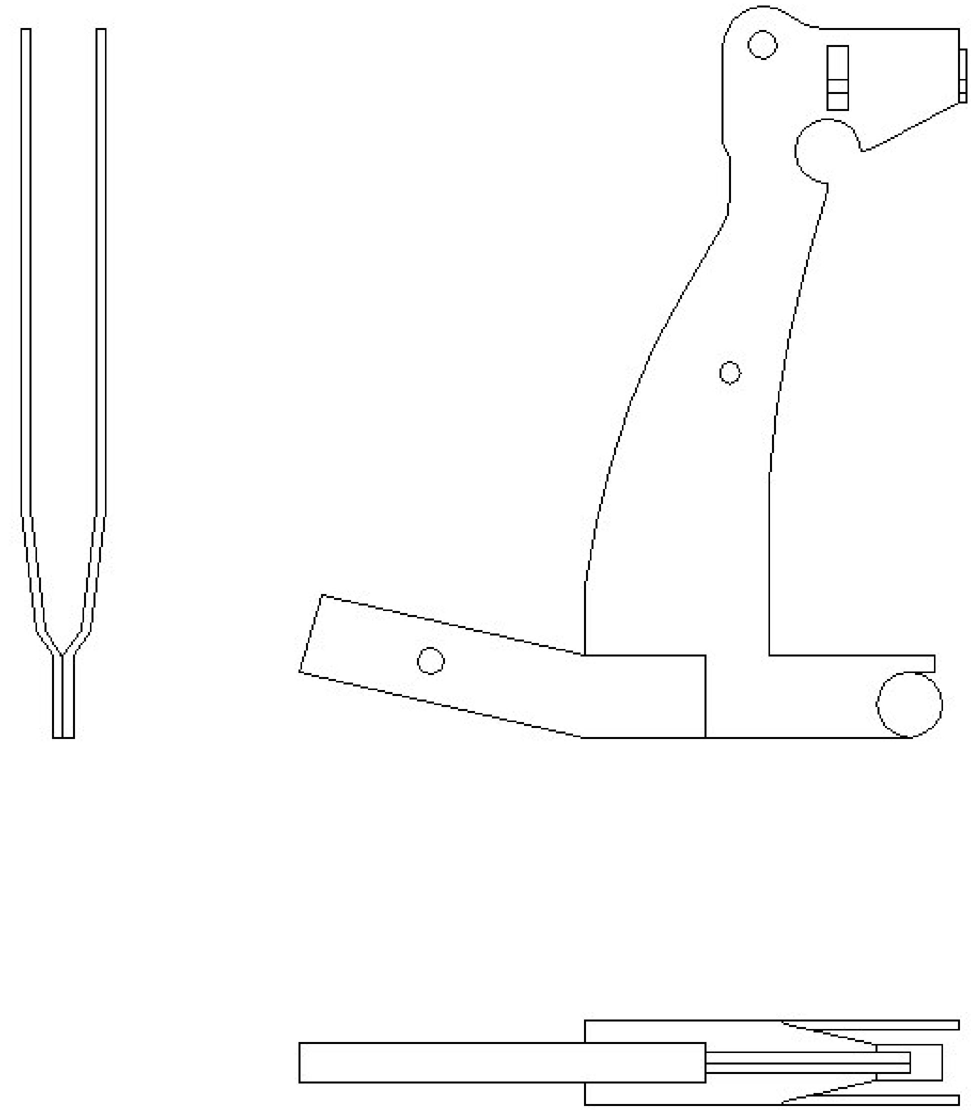
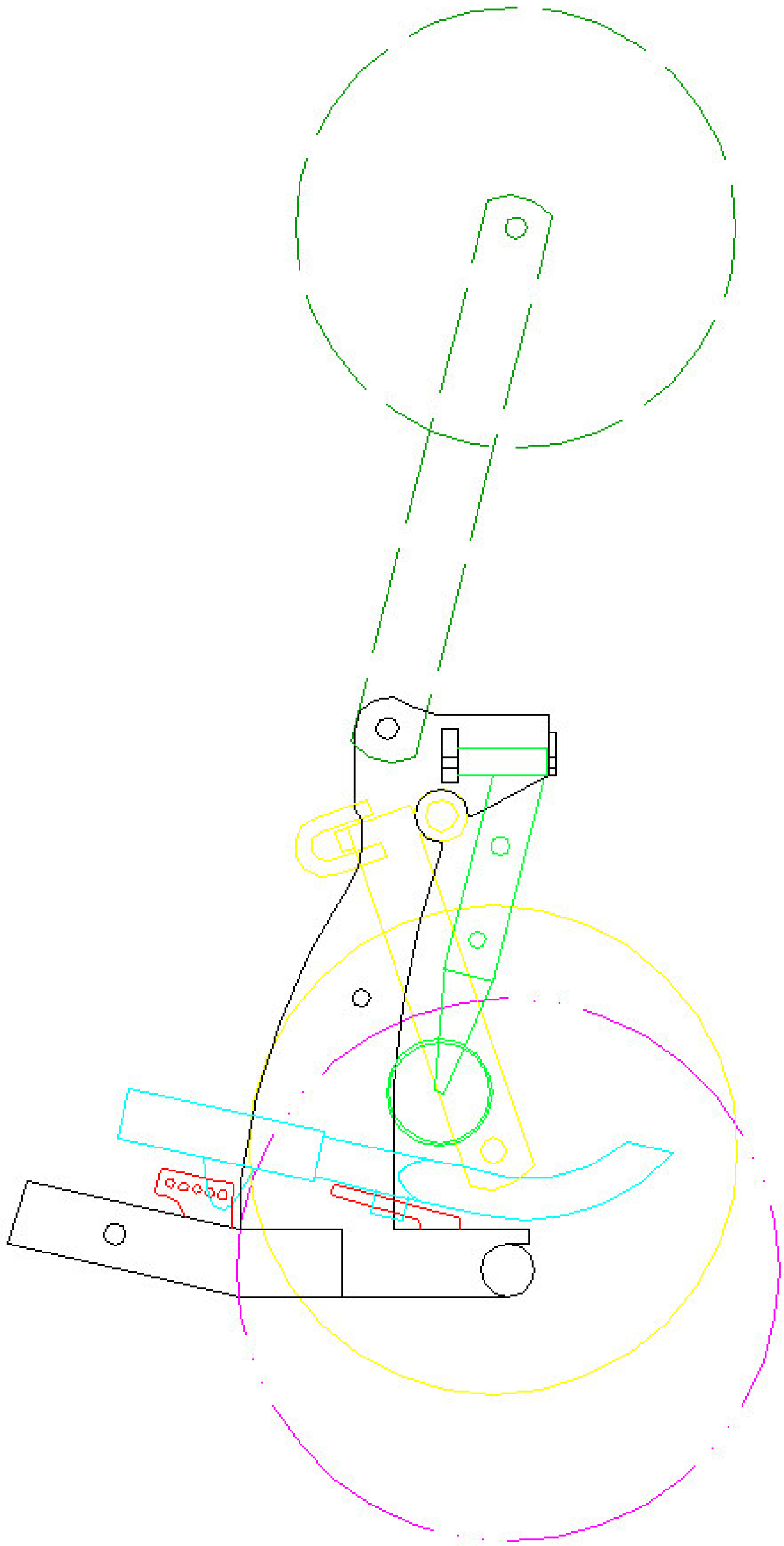
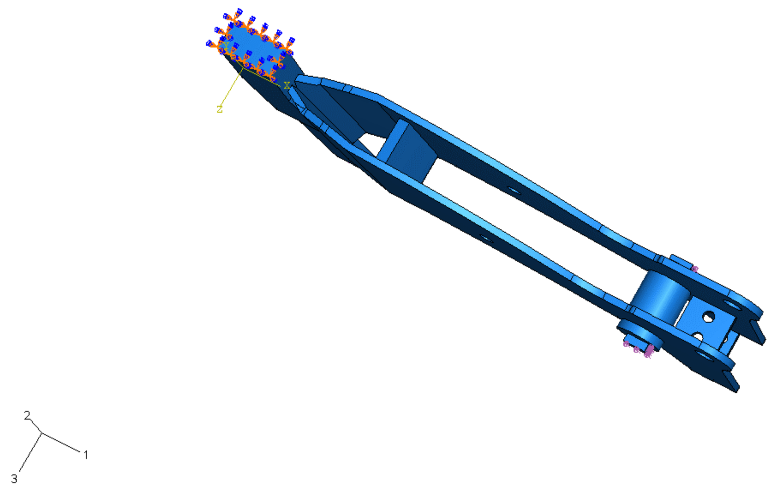
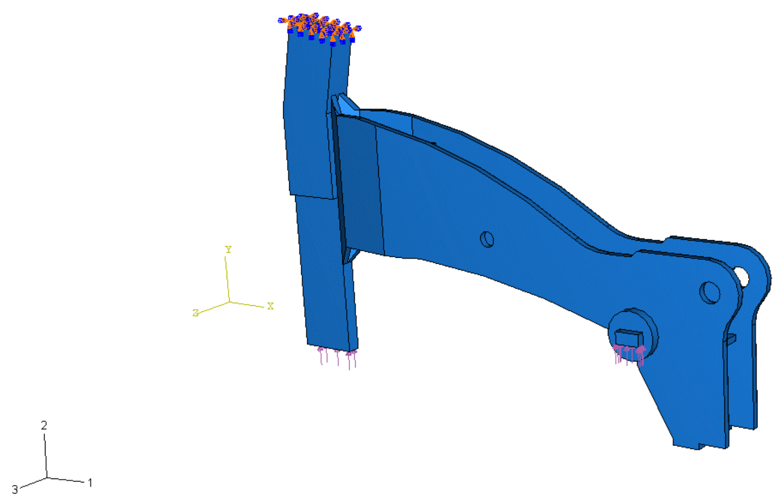
Pad for Travel Stop
3/4" DIA STAINLESS STEEL
Bush Required
No WELD
40
256
117
21
10
60
MAC 0114
1 off
MAC 0113
1 off
WELDED ASSEMBLY
1 OFF AS SHOWN. LEFT HAND
1 OFF OPPOSITE HAND - RIGHT HAND





APPENDIX C


Z
X
2
1
3


Y
Z
X
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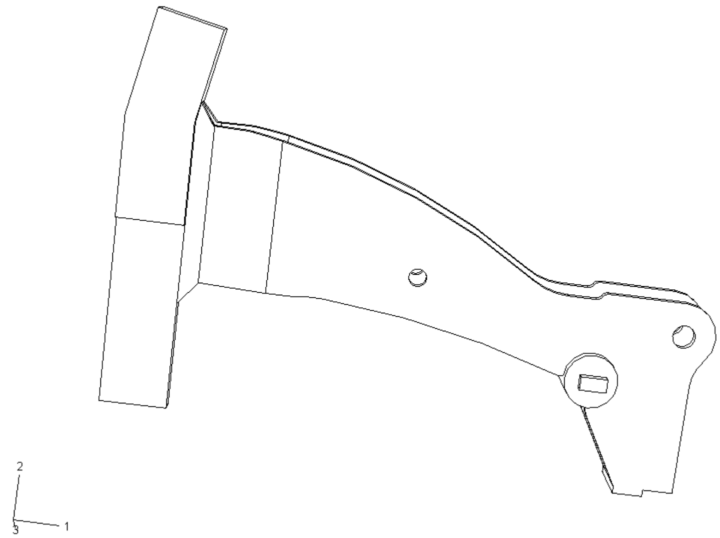
1
3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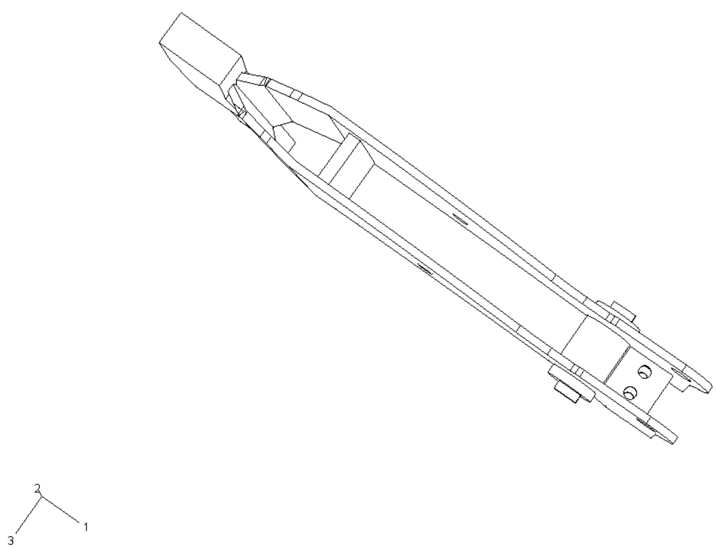
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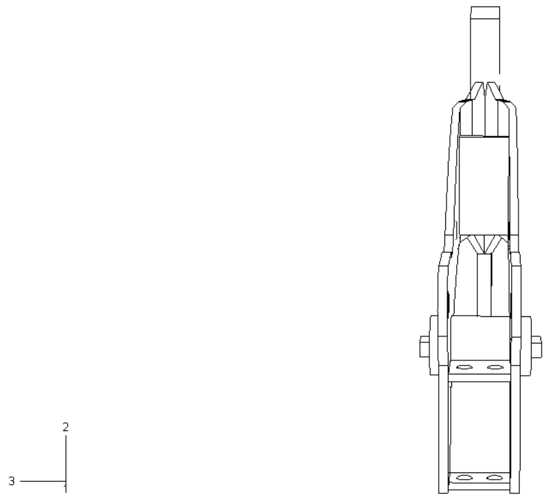
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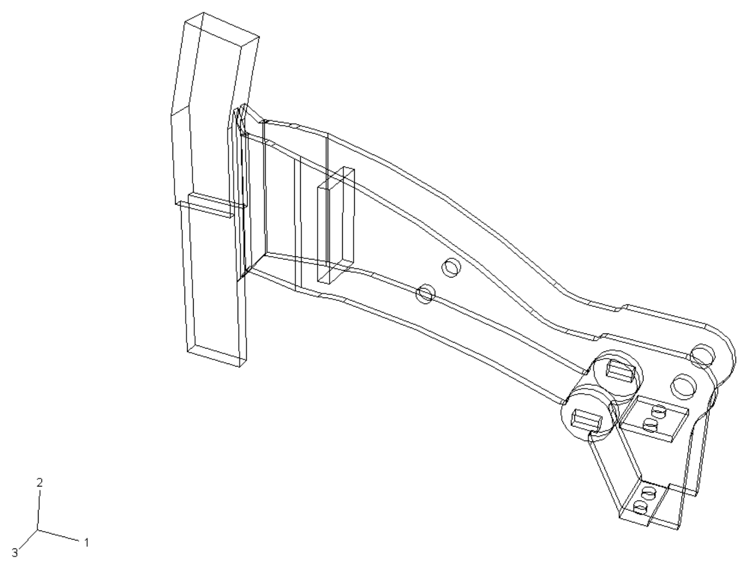
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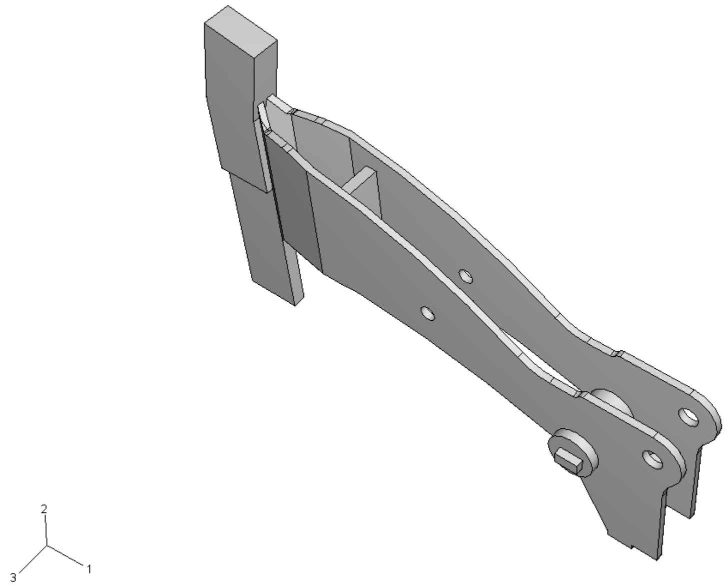
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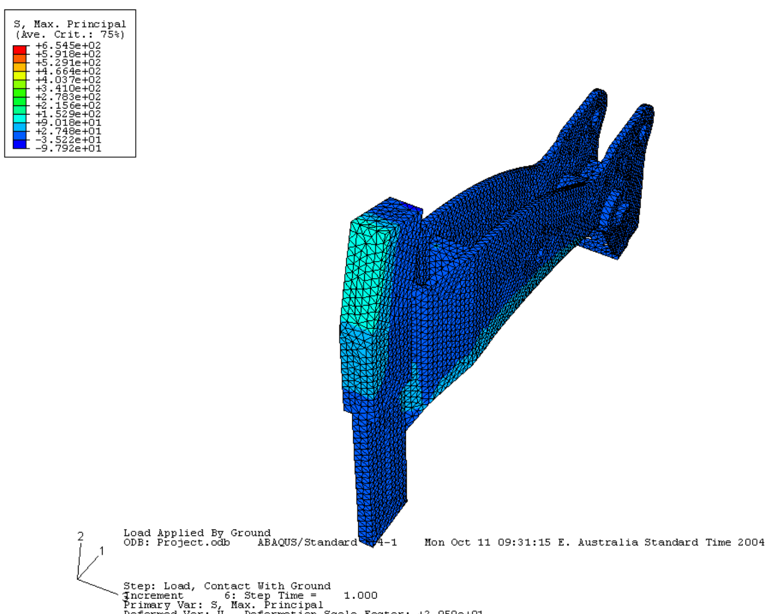
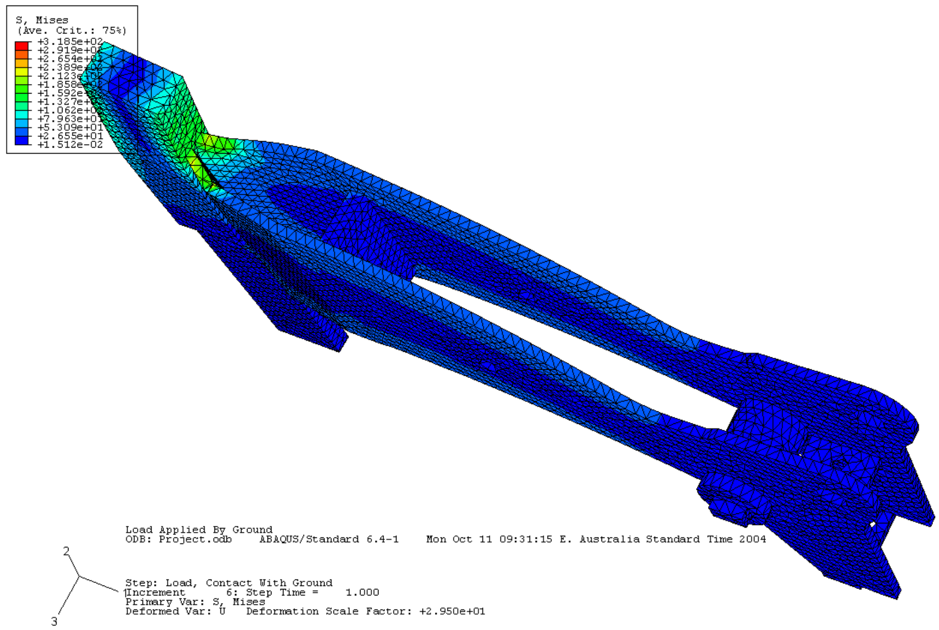

S, Max. Principal
(Ave. Crit.: 75%)
+6.545e+02
+5.918e+02
+5.291e+02
+4.664e+02
+4.037e+02
+3.410e+02
+2.783e+02
+2.156e+02
+1.529e+02
+9.018e+01
+2.748e+01
-3.522e+01
-9.792e+01
2
1
Load Applied By Ground
ODB: Project.odb ABAQUS/Standard 4-1 Mon Oct 11 09:31:15 E. Australia Standard Time 2004
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
Primary Var: S, Max. Principal
Deformed Var: U Deformation Scale Factor: +2.950e+01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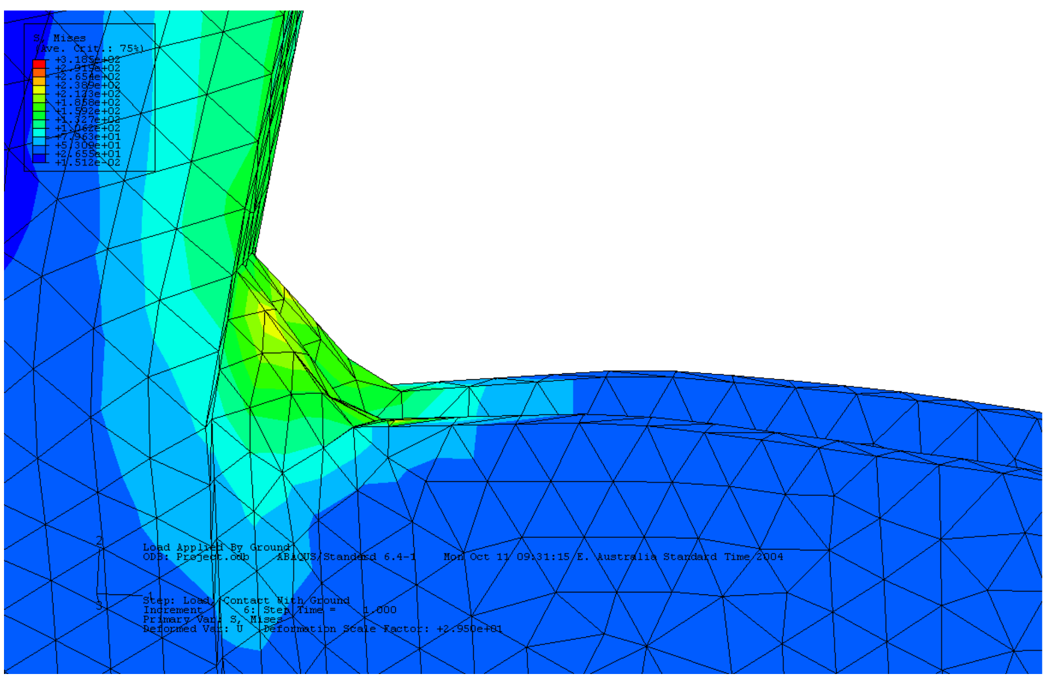
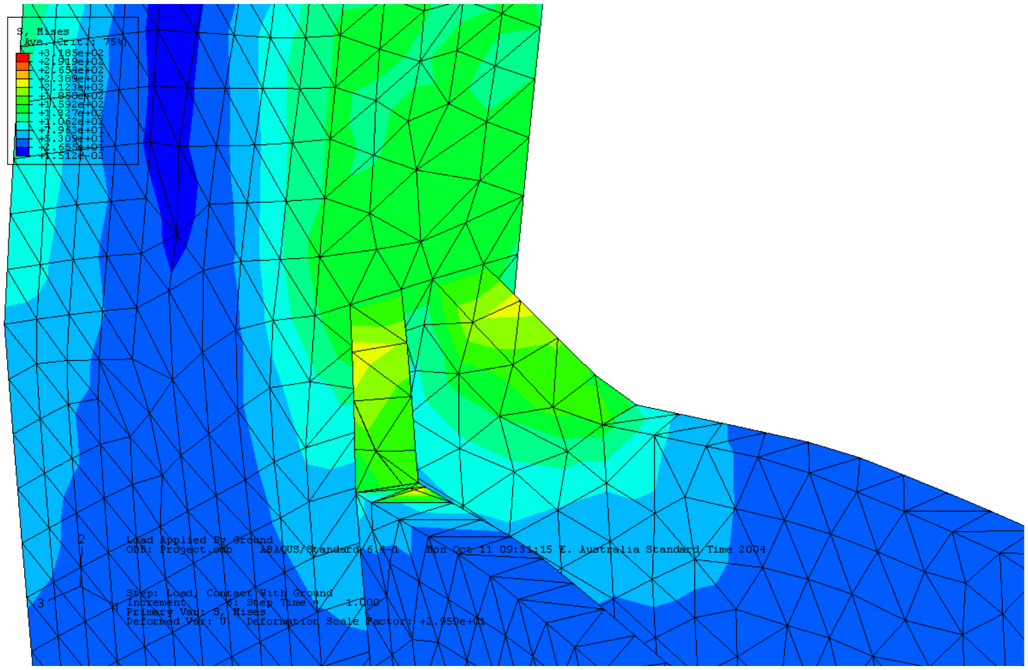
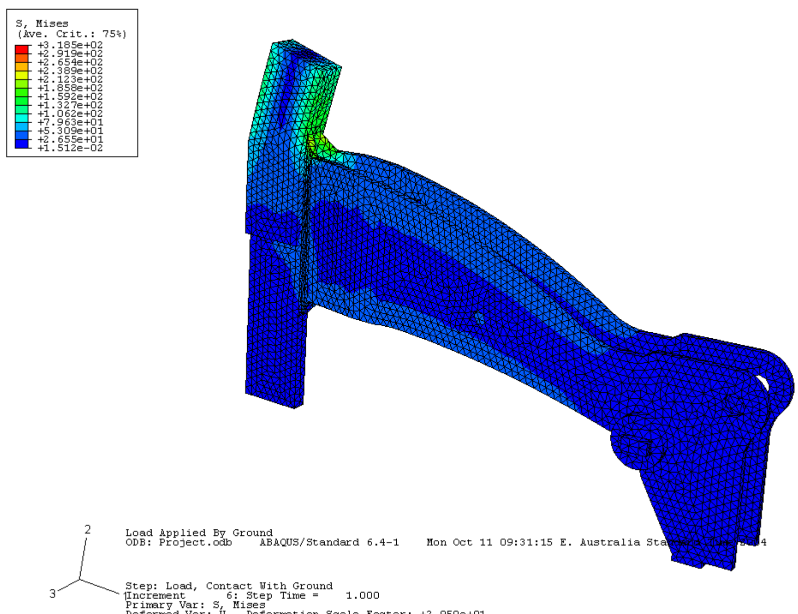
+2.919e+02
+2.654e+02
+2.389e+02
+2.123e+02
+1.858e+02
+1.592e+02
+1.327e+02
+1.062e+02
+7.963e+01
+5.309e+01
+2.655e+01
+1.512e-02
Load Applied By Ground
ODB: Project.odb ABAQUS/Standard 6.4-1 Mon Oct 11 09:31:15 E. Australia Standard Time 2004
2
3
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
Primary Var: S, Mises
Deformed Var: U Deformation Scale Factor: +2.950e+01



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Load Applied By Ground
ODB: Project.odb ABAQUS/Standard 6.4-1 Mon Oct 11 09:31:15 E. Australia Standard Time 2004
Step: Load, Contact With Ground
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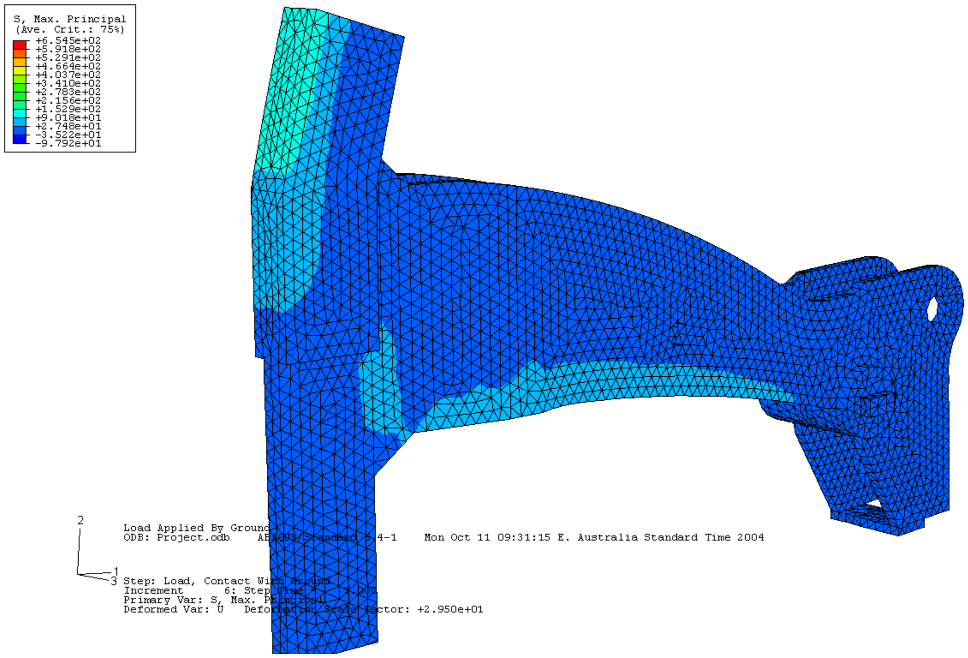
Deformed Var: U Deformation Scale Factor: +2.950e+01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+5.291e+02
+4.664e+02
+4.037e+02
+3.410e+02
+2.783e+02
+2.156e+02
+1.529e+02
+9.018e+01
+2.748e+01
-3.522e+01
-9.792e+01
Load Applied By Ground
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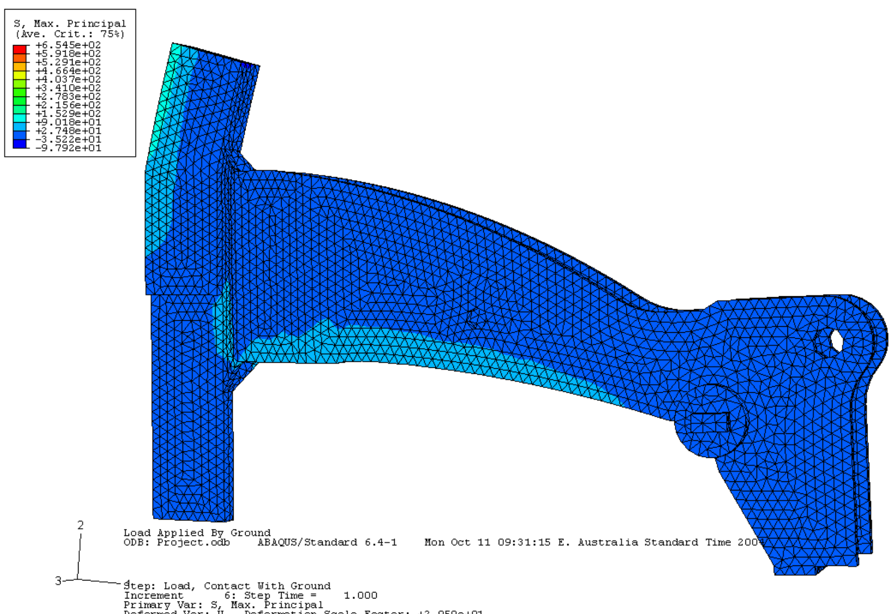
Step: Load, Contact With Ground
Deformed Var: U Deformation Scale Factor: +2.950e+01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+5.291e+02
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+2.783e+02
+2.156e+02
+1.529e+02
+9.018e+01
+2.748e+01
-3.522e+01
-9.792e+01
Load Applied By Ground
ODB: Project.odb ABAQUS/Standard 6.4-1 Mon Oct 11 09:31:15 E. Australia Standard Time 200
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
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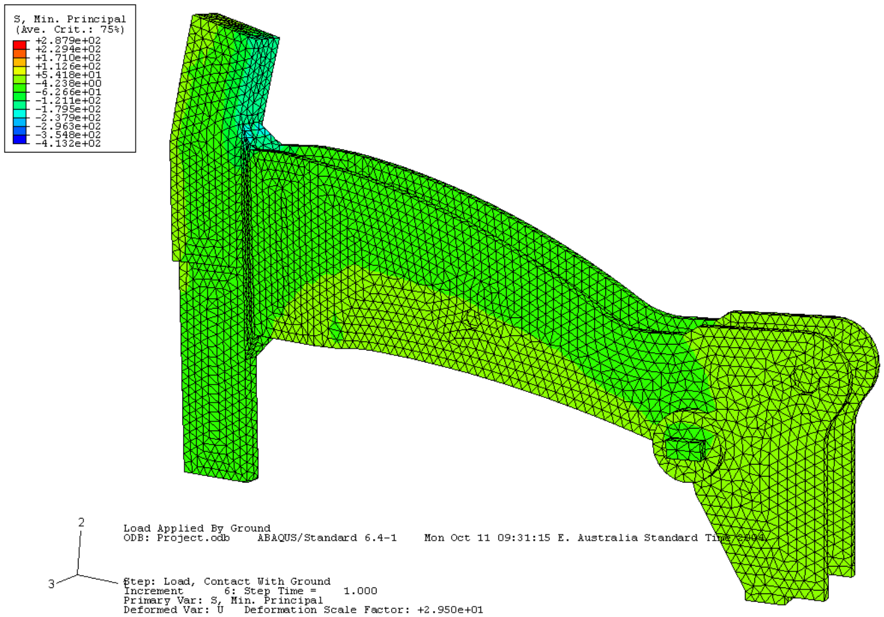
Deformed Var: U Deformation Scale Factor: +2.950e+01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+2.294e+02
+1.710e+02
+1.126e+02
+5.418e+01
-4.238e+00
-6.266e+01
-1.211e+02
-1.795e+02
-2.379e+02
-2.963e+02
-3.548e+02
-4.132e+02
Load Applied By Ground
ODB: Project.odb ABAQUS/Standard 6.4-1 Mon Oct 11 09:31:15 E. Australia Standard Time 2004
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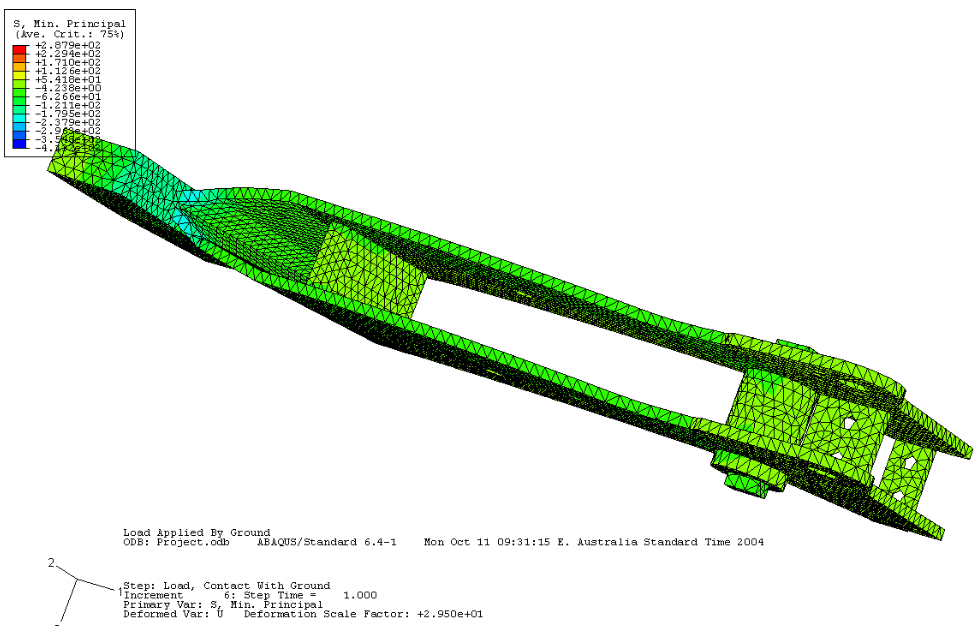
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
Primary Var: S, Min. Principal
Deformed Var: U Deformation Scale Factor: +2.950e+01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+1.126e+02
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-4.238e+00
-6.266e+01
-1.211e+02
-1.795e+02
-2.379e+02
Load Applied By Ground
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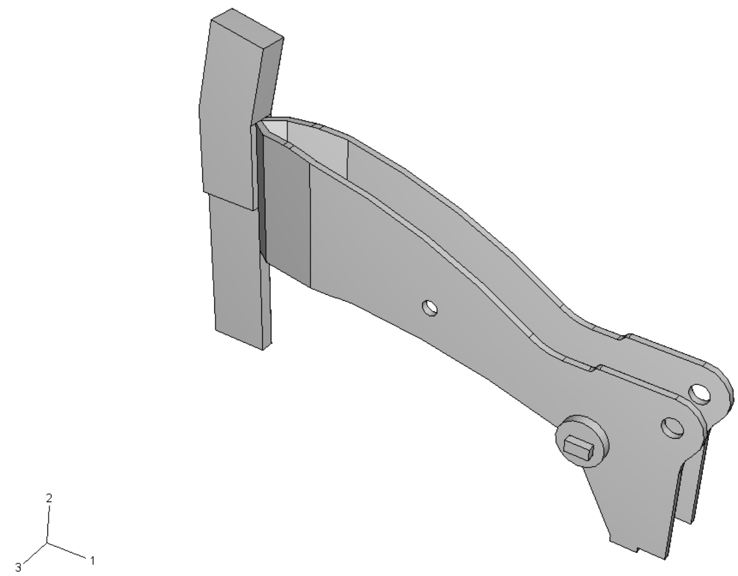
Primary Var: S, Min. Principal
Deformed Var: U Deformation Scale Factor: +2.950e+01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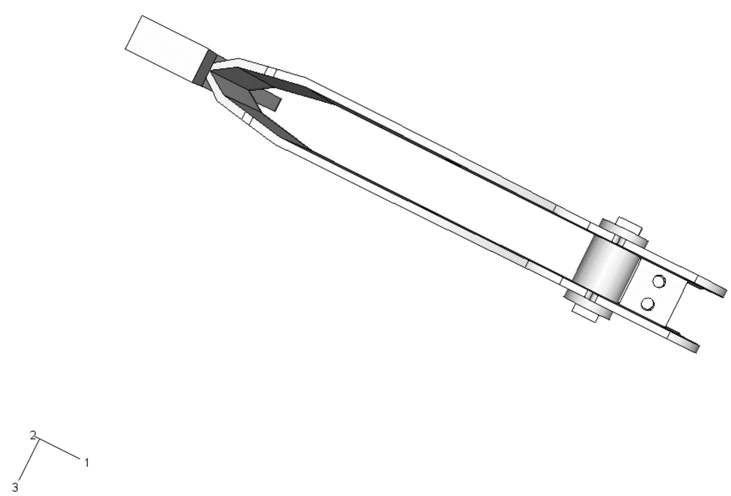
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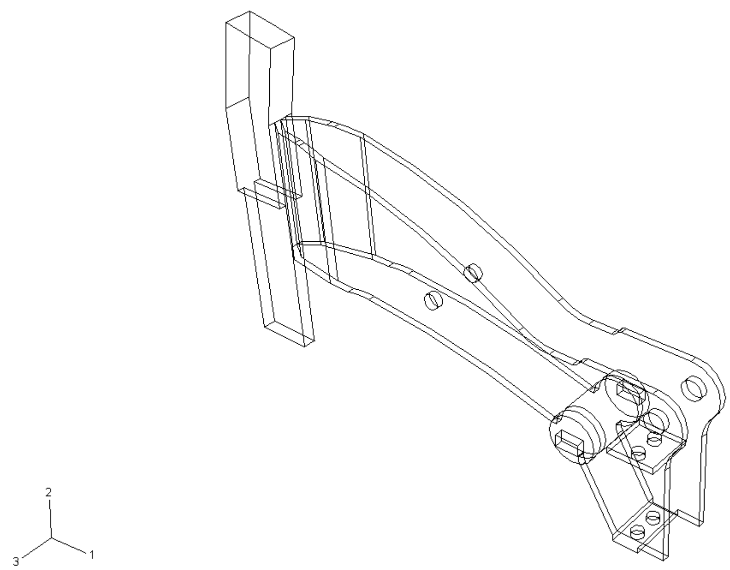
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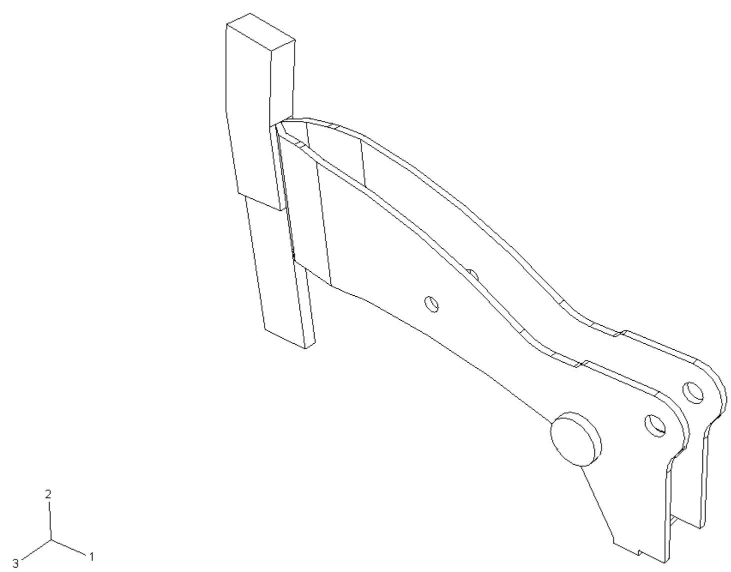
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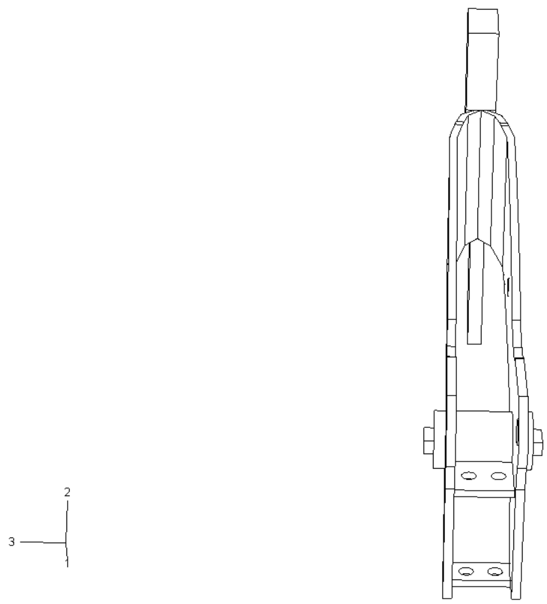
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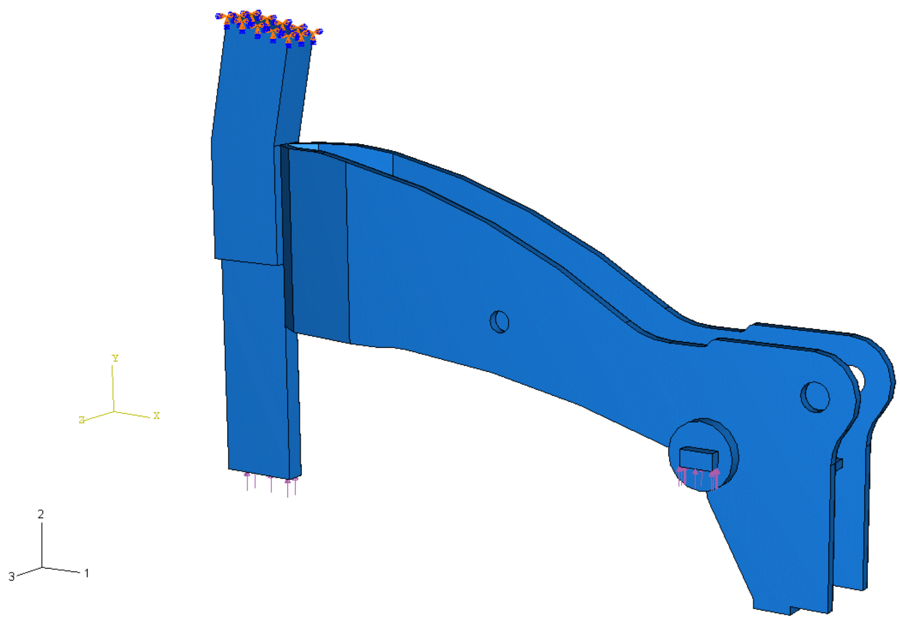
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Z
X
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3
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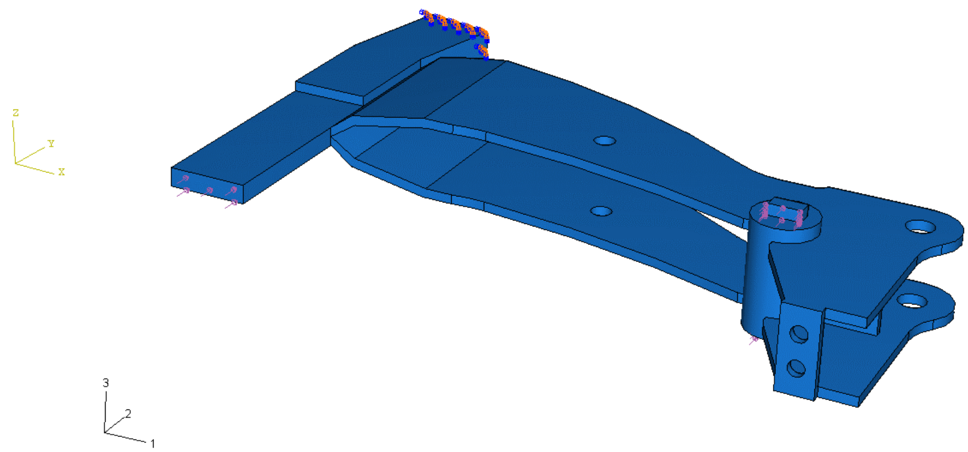
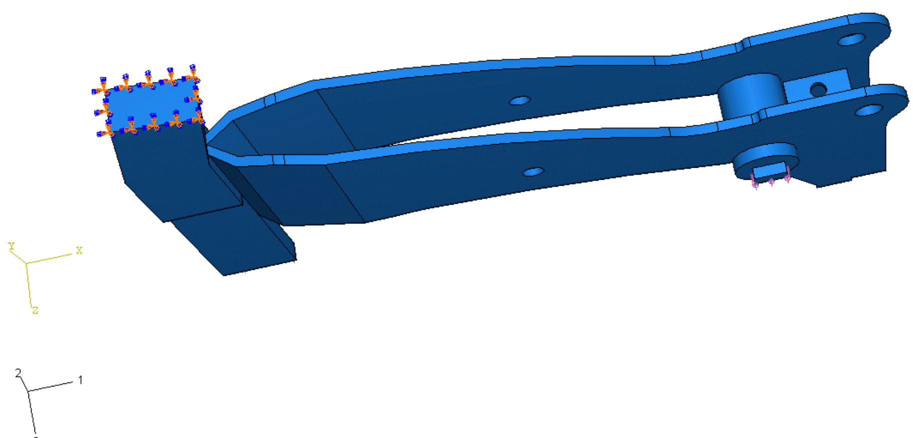
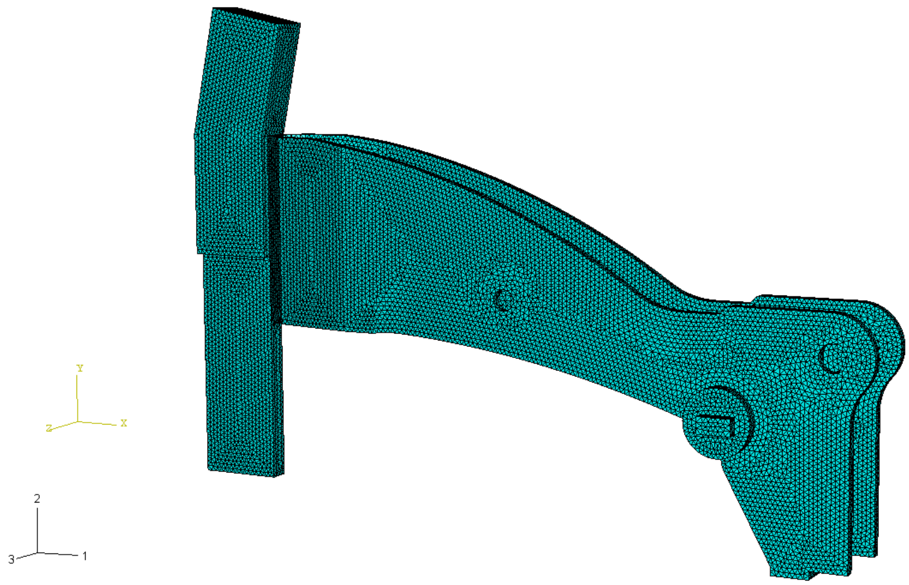


Z
Y
X
3
2
1



Y
X
Z
2
1
3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Z
X
2
3
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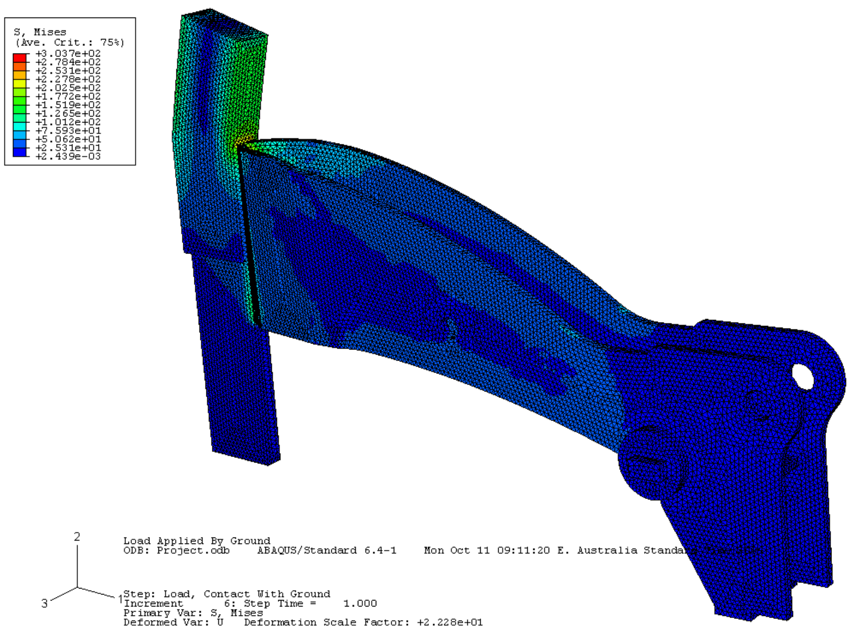
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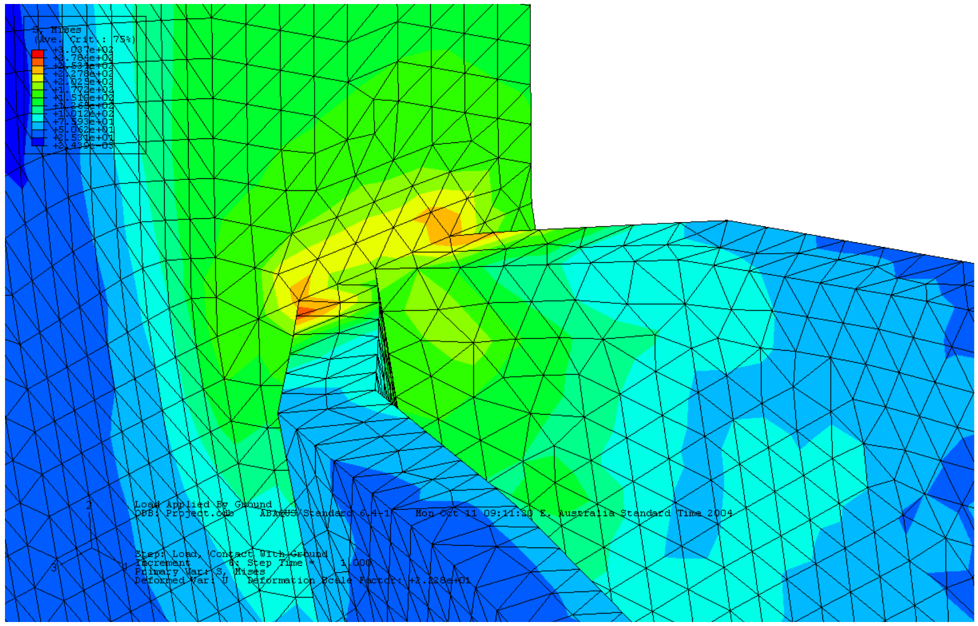
+1.772e+02
+1.519e+02
+1.265e+02
+1.012e+02
+7.593e+01
+5.062e+01
+2.531e+01
+2.439e-03
2
3
1
Load Applied By Ground
ODB: Project.odb ABAQUS/Standard 6.4-1 Mon Oct 11 09:11:20 E. Australia Standa
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
Primary Var: S, Mises
Deformed Var: U Deformation Scale Factor: +2.228e+01


S, Mises
(Ave. Crit.: 75%)
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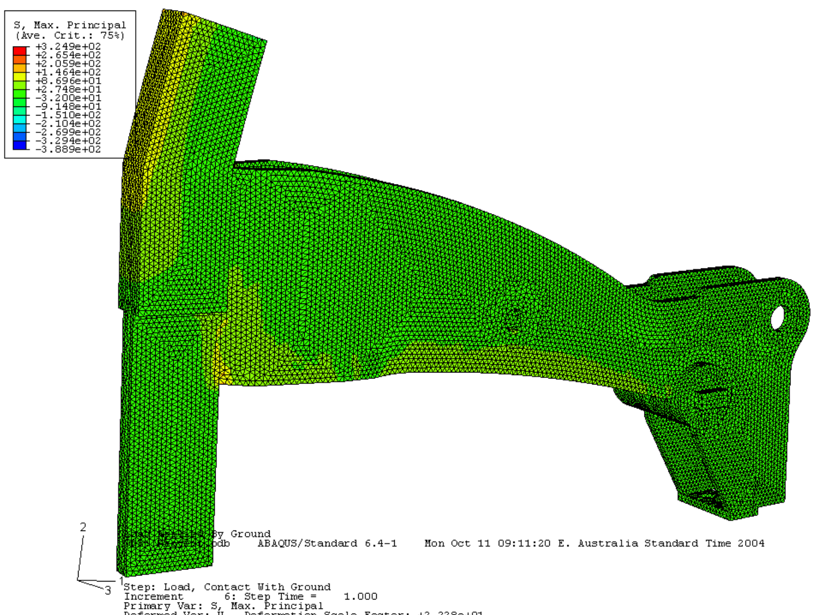
Step: Load, Contact With Ground
Primary Var: S, Mises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(Ave. Crit.: 75%)
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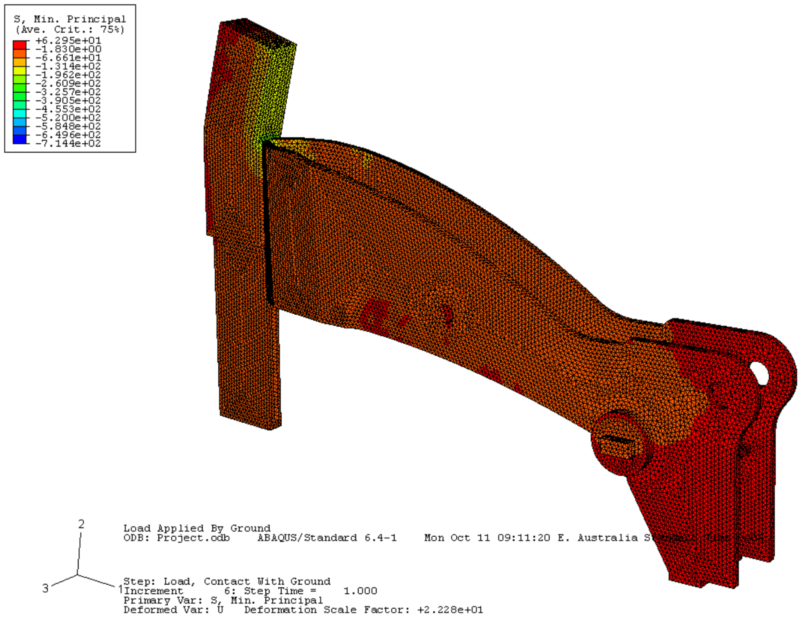
+2.654e+02
+2.059e+02
+1.464e+02
+8.696e+01
+2.748e+01
-3.200e+01
-9.148e+01
-1.510e+02
-2.104e+02
-2.699e+02
-3.294e+02
-3.889e+02
2
3
ABAQUS/Standard 6.4-1 Mon Oct 11 09:11:20 E. Australia Standard Time 2004
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
Primary Var: S, Max. Principal
Deformed Var: U Deformation Scale Factor: +2.228e+01


S, Min. Principal
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2
3
1
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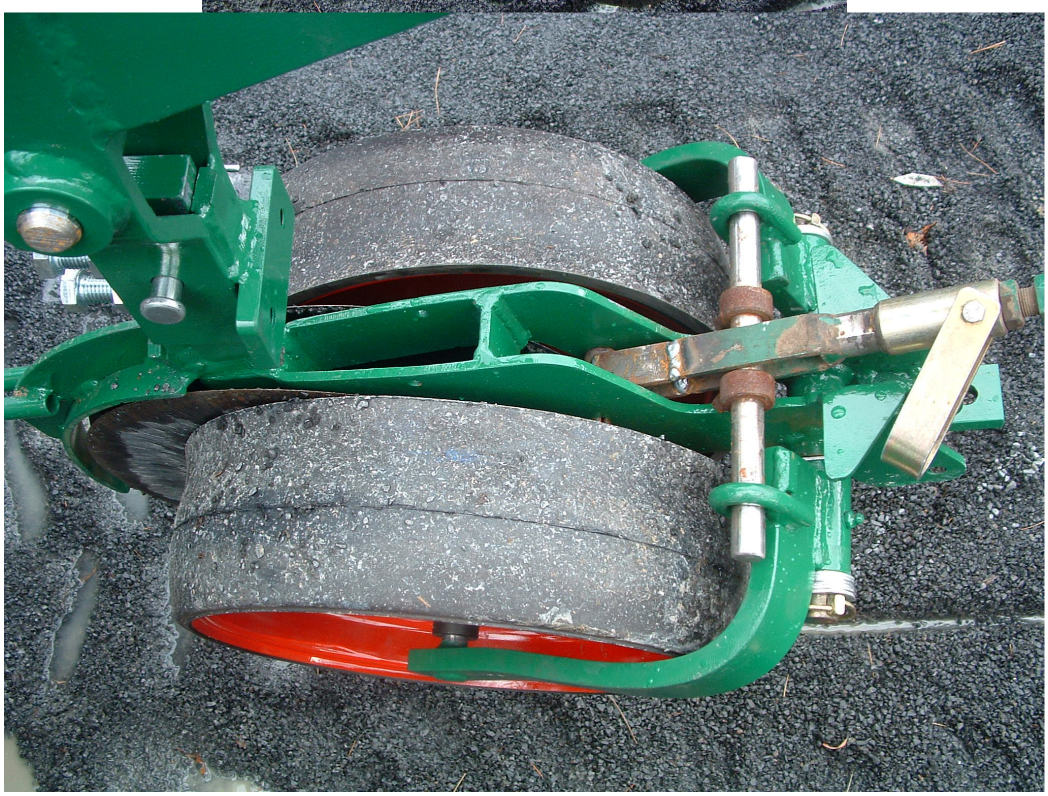
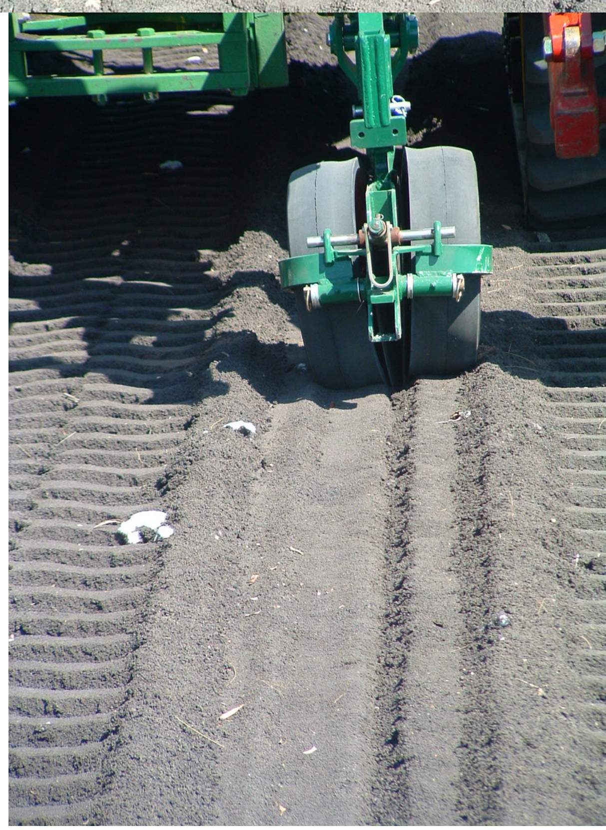
ODB: Project.odb ABAQUS/Standard 6.4-1 Mon Oct 11 09:11:20 E. Australia S
Step: Load, Contact With Ground
Increment 6: Step Time = 1.000
Primary Var: S, Min. Principal
Deformed Var: U Deformation Scale Factor: +2.228e+01

APPENDIX D




8420T
JOHN DEERE



APPENDIX E

Frame Without Modifications Output File

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1 ABAQUS VERSION 6.4-1      DATE 11-Oct-2004      TIME 10:09:24     PAGE    1
 For use at None under academic license

 from ABAQUS, Inc.
 Load Applied By Ground
 Contact With Ground
 STEP    1     INCREMENT     1     STEP TIME    0.00


                S T E P     1    S T A T I C   A N A L Y S I S


        Contact With Ground

    AUTOMATIC TIME CONTROL WITH -
        A SUGGESTED INITIAL TIME INCREMENT OF                     0.100
        AND A TOTAL TIME PERIOD OF                                1.00
        THE MINIMUM TIME INCREMENT ALLOWED IS                     1.000E-05
        THE MAXIMUM TIME INCREMENT ALLOWED IS                      1.00

    LINEAR EQUATION SOLVER TYPE        DIRECT SPARSE

 CONVERGENCE TOLERANCE PARAMETERS FOR FORCE
    CRITERION FOR RESIDUAL FORCE     FOR A NONLINEAR PROBLEM                 5.000E-03
    CRITERION FOR DISP.    CORRECTION IN A NONLINEAR PROBLEM                 1.000E-02
    INITIAL VALUE OF TIME AVERAGE FORCE                                      1.000E-02
    AVERAGE FORCE    IS TIME AVERAGE FORCE
    ALTERNATE CRIT. FOR RESIDUAL FORCE     FOR A NONLINEAR PROBLEM           2.000E-02
    CRITERION FOR ZERO FORCE     RELATIVE TO TIME AVRG. FORCE                1.000E-05
    CRITERION FOR RESIDUAL FORCE     WHEN THERE IS ZERO FLUX                 1.000E-05
    CRITERION FOR DISP.    CORRECTION WHEN THERE IS ZERO FLUX                1.000E-03
```

CRITERION FOR RESIDUAL FORCE FOR A LINEAR INCREMENT	1.000E-08
FIELD CONVERSION RATIO	1.00
CRITERION FOR ZERO FORCE REL. TO TIME AVRG. MAX. FORCE	1.000E-05
CRITERION FOR ZERO DISP. RELATIVE TO CHARACTERISTIC LENGTH	1.000E-08
VOLUMETRIC STRAIN COMPATIBILITY TOLERANCE FOR HYBRID SOLIDS	1.000E-05
AXIAL STRAIN COMPATIBILITY TOLERANCE FOR HYBRID BEAMS	1.000E-05
TRANS. SHEAR STRAIN COMPATIBILITY TOLERANCE FOR HYBRID BEAMS	1.000E-05
SOFT CONTACT CONSTRAINT COMPATIBILITY TOLERANCE FOR P>P0	5.000E-03
SOFT CONTACT CONSTRAINT COMPATIBILITY TOLERANCE FOR P=0.0	0.100
DISPLACEMENT COMPATIBILITY TOLERANCE FOR DCOUP ELEMENTS	1.000E-05
ROTATION COMPATIBILITY TOLERANCE FOR DCOUP ELEMENTS	1.000E-05

TIME INCREMENTATION CONTROL PARAMETERS:

FIRST EQUILIBRIUM ITERATION FOR CONSECUTIVE DIVERGENCE CHECK	4
EQUILIBRIUM ITERATION AT WHICH LOG. CONVERGENCE RATE CHECK BEGINS	8
EQUILIBRIUM ITERATION AFTER WHICH ALTERNATE RESIDUAL IS USED	9
MAXIMUM EQUILIBRIUM ITERATIONS ALLOWED	16
EQUILIBRIUM ITERATION COUNT FOR CUT-BACK IN NEXT INCREMENT	10
MAXIMUM EQUILIB. ITERS IN TWO INCREMENTS FOR TIME INCREMENT INCREASE	4
MAXIMUM ITERATIONS FOR SEVERE DISCONTINUITIES	12
MAXIMUM CUT-BACKS ALLOWED IN AN INCREMENT	5
MAXIMUM DISCON. ITERS IN TWO INCREMENTS FOR TIME INCREMENT INCREASE	6
CUT-BACK FACTOR AFTER DIVERGENCE	0.2500
CUT-BACK FACTOR FOR TOO SLOW CONVERGENCE	0.5000
CUT-BACK FACTOR AFTER TOO MANY EQUILIBRIUM ITERATIONS	0.7500
CUT-BACK FACTOR AFTER TOO MANY SEVERE DISCONTINUITY ITERATIONS	0.2500
CUT-BACK FACTOR AFTER PROBLEMS IN ELEMENT ASSEMBLY	0.2500
INCREASE FACTOR AFTER TWO INCREMENTS THAT CONVERGE QUICKLY	1.500
MAX. TIME INCREMENT INCREASE FACTOR ALLOWED	1.500
MAX. TIME INCREMENT INCREASE FACTOR ALLOWED (DYNAMICS)	1.250
MAX. TIME INCREMENT INCREASE FACTOR ALLOWED (DIFFUSION)	2.000
MINIMUM TIME INCREMENT RATIO FOR EXTRAPOLATION TO OCCUR	0.1000

MAX. RATIO OF TIME INCREMENT TO STABILITY LIMIT 1.000
FRACTION OF STABILITY LIMIT FOR NEW TIME INCREMENT 0.9500

PRINT OF INCREMENT NUMBER, TIME, ETC., EVERY 1 INCREMENTS

RESTART FILE WILL BE WRITTEN EVERY 1 INCREMENTS

THE MAXIMUM NUMBER OF INCREMENTS IN THIS STEP IS 100

LINEAR EXTRAPOLATION WILL BE USED

CHARACTERISTIC ELEMENT LENGTH 5.18

PRINT OF INCREMENT NUMBER, TIME, ETC., TO THE MESSAGE FILE EVERY 1 INCREMENTS

EQUATION ARE BEING REORDERED TO MINIMIZE WAVEFRONT

COLLECTING MODEL CONSTRAINT INFORMATION FOR OVERCONSTRAINT CHECKS

COLLECTING STEP CONSTRAINT INFORMATION FOR OVERCONSTRAINT CHECKS

INCREMENT 1 STARTS. ATTEMPT NUMBER 1, TIME INCREMENT 0.100

EQUILIBRIUM ITERATION 1

AVERAGE FORCE 1.26 TIME AVG. FORCE 1.26
LARGEST RESIDUAL FORCE -1.470E-09 AT NODE 27794 DOF 2
INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP. 0.201 AT NODE 1121 DOF 2
INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP. 0.201 AT NODE 1121 DOF 2
INSTANCE: FRAME-1

THE FORCE EQUILIBRIUM RESPONSE WAS LINEAR IN THIS INCREMENT

ITERATION SUMMARY FOR THE INCREMENT: 1 TOTAL ITERATIONS, OF WHICH
0 ARE SEVERE DISCONTINUITY ITERATIONS AND 1 ARE EQUILIBRIUM ITERATIONS.

TIME INCREMENT COMPLETED	0.100	,	FRACTION OF STEP COMPLETED	0.100
STEP TIME COMPLETED	0.100	,	TOTAL TIME COMPLETED	0.100

RESTART INFORMATION WRITTEN IN STEP 1 AFTER INCREMENT 1

INCREMENT 2 STARTS. ATTEMPT NUMBER 1, TIME INCREMENT 0.100

EQUILIBRIUM ITERATION 1

AVERAGE FORCE 2.64 TIME AVG. FORCE 1.95

LARGEST RESIDUAL FORCE	-2.751E-10	AT NODE	51	DOF 2
INSTANCE: FRAME-1				
LARGEST INCREMENT OF DISP.	0.201	AT NODE	1121	DOF 2
INSTANCE: FRAME-1				
LARGEST CORRECTION TO DISP.	2.242E-11	AT NODE	3355	DOF 3
INSTANCE: FRAME-1				

THE FORCE EQUILIBRIUM RESPONSE WAS LINEAR IN THIS INCREMENT
TIME INCREMENT MAY NOW INCREASE TO 0.150

ITERATION SUMMARY FOR THE INCREMENT: 1 TOTAL ITERATIONS, OF WHICH
0 ARE SEVERE DISCONTINUITY ITERATIONS AND 1 ARE EQUILIBRIUM ITERATIONS.

TIME INCREMENT COMPLETED	0.100	,	FRACTION OF STEP COMPLETED	0.200
STEP TIME COMPLETED	0.200	,	TOTAL TIME COMPLETED	0.200

RESTART INFORMATION WRITTEN IN STEP 1 AFTER INCREMENT 2

```
 INCREMENT     3 STARTS. ATTEMPT NUMBER  1, TIME INCREMENT  0.150

           EQUILIBRIUM ITERATION     1

AVERAGE FORCE                    4.60      TIME AVG. FORCE       2.83
LARGEST RESIDUAL FORCE               -1.182E-09      AT NODE              52       DOF  2
  INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.           0.302           AT NODE              1121    DOF  2
  INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP.          -1.682E-11      AT NODE              3355    DOF  3
  INSTANCE: FRAME-1
      THE FORCE     EQUILIBRIUM RESPONSE WAS LINEAR IN THIS INCREMENT
      TIME INCREMENT MAY NOW INCREASE TO   0.225

ITERATION SUMMARY FOR THE INCREMENT:   1 TOTAL ITERATIONS, OF WHICH
  0 ARE SEVERE DISCONTINUITY ITERATIONS AND  1 ARE EQUILIBRIUM ITERATIONS.

TIME INCREMENT COMPLETED          0.150    ,  FRACTION OF STEP COMPLETED      0.350
STEP TIME COMPLETED               0.350    ,  TOTAL TIME COMPLETED            0.350

   RESTART INFORMATION WRITTEN IN STEP   1  AFTER INCREMENT     3


 INCREMENT     4 STARTS. ATTEMPT NUMBER  1, TIME INCREMENT  0.225

           EQUILIBRIUM ITERATION     1

AVERAGE FORCE                    7.54      TIME AVG. FORCE       4.01
LARGEST RESIDUAL FORCE               12.9            AT NODE              165     DOF  1
  INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.           0.453           AT NODE              1121    DOF  2
  INSTANCE: FRAME-1
```

```
LARGEST CORRECTION TO DISP.        3.094E-04      AT NODE            514     DOF  2
  INSTANCE: FRAME-1
       FORCE     EQUILIBRIUM NOT ACHIEVED WITHIN TOLERANCE.

            EQUILIBRIUM ITERATION     2

AVERAGE FORCE                  7.54       TIME AVG. FORCE       4.01
LARGEST RESIDUAL FORCE             -3.275E-03     AT NODE            165     DOF  3
  INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.          0.453         AT NODE            1121    DOF  2
  INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP.         7.090E-05     AT NODE            514     DOF  2
  INSTANCE: FRAME-1
       THE FORCE     EQUILIBRIUM EQUATIONS HAVE CONVERGED
       TIME INCREMENT MAY NOW INCREASE TO   0.338

ITERATION SUMMARY FOR THE INCREMENT:              2 TOTAL ITERATIONS, OF WHICH
  0 ARE SEVERE DISCONTINUITY ITERATIONS AND  2 ARE EQUILIBRIUM ITERATIONS.

TIME INCREMENT COMPLETED          0.225    ,  FRACTION OF STEP COMPLETED      0.575
STEP TIME COMPLETED               0.575    ,  TOTAL TIME COMPLETED            0.575

    RESTART INFORMATION WRITTEN IN STEP   1  AFTER INCREMENT     4


 INCREMENT     5 STARTS. ATTEMPT NUMBER  1, TIME INCREMENT  0.338

            EQUILIBRIUM ITERATION     1

AVERAGE FORCE                  11.9       TIME AVG. FORCE       5.60
LARGEST RESIDUAL FORCE             -27.9          AT NODE            22449   DOF  1
  INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.          0.681         AT NODE            1121   DOF  2
```

```
 INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP.        2.009E-03     AT NODE          1146   DOF  2
 INSTANCE: FRAME-1
       FORCE     EQUILIBRIUM NOT ACHIEVED WITHIN TOLERANCE.

            EQUILIBRIUM ITERATION     2

AVERAGE FORCE                  11.9      TIME AVG. FORCE      5.60
LARGEST RESIDUAL FORCE             -2.203E-02     AT NODE          22449   DOF  1
 INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.         0.681          AT NODE          1121   DOF  2
 INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP.        1.604E-04     AT NODE          101   DOF  3
 INSTANCE: FRAME-1
       THE FORCE     EQUILIBRIUM EQUATIONS HAVE CONVERGED

ITERATION SUMMARY FOR THE INCREMENT:   2 TOTAL ITERATIONS, OF WHICH
 0 ARE SEVERE DISCONTINUITY ITERATIONS AND  2 ARE EQUILIBRIUM ITERATIONS.

TIME INCREMENT COMPLETED          0.338    ,  FRACTION OF STEP COMPLETED            0.913
STEP TIME COMPLETED               0.913    ,  TOTAL TIME COMPLETED                  0.913

   RESTART INFORMATION WRITTEN IN STEP   1  AFTER INCREMENT     5


 INCREMENT     6 STARTS. ATTEMPT NUMBER  1, TIME INCREMENT  8.750E-02

            EQUILIBRIUM ITERATION     1

AVERAGE FORCE                  13.1      TIME AVG. FORCE      6.86
LARGEST RESIDUAL FORCE             -0.308        AT NODE     22449          DOF  1
 INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.         0.177         AT NODE     1121           DOF  2
```

```
 INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP.       5.247E-04     AT NODE      1146           DOF  2
 INSTANCE: FRAME-1
       FORCE     EQUILIBRIUM NOT ACHIEVED WITHIN TOLERANCE.

            EQUILIBRIUM ITERATION     2

AVERAGE FORCE                     13.1      TIME AVG. FORCE       6.86
LARGEST RESIDUAL FORCE            -5.256E-06     AT NODE           22449   DOF  1
 INSTANCE: FRAME-1
LARGEST INCREMENT OF DISP.        0.177         AT NODE            1121   DOF  2
 INSTANCE: FRAME-1
LARGEST CORRECTION TO DISP.       8.339E-07      AT NODE           1146   DOF  2
 INSTANCE: FRAME-1
       THE FORCE     EQUILIBRIUM EQUATIONS HAVE CONVERGED

ITERATION SUMMARY FOR THE INCREMENT:   2 TOTAL ITERATIONS, OF WHICH
 0 ARE SEVERE DISCONTINUITY ITERATIONS AND  2 ARE EQUILIBRIUM ITERATIONS.

TIME INCREMENT COMPLETED  8.750E-02,    FRACTION OF STEP COMPLETED         1.00
STEP TIME COMPLETED             1.00    ,      TOTAL TIME COMPLETED                  1.00

   RESTART INFORMATION WRITTEN IN STEP   1  AFTER INCREMENT     6


       THE ANALYSIS HAS BEEN COMPLETED



   ANALYSIS SUMMARY:
   TOTAL OF          6  INCREMENTS
                     0  CUTBACKS IN AUTOMATIC INCREMENTATION
                     9  ITERATIONS
```

```
  9  PASSES THROUGH THE EQUATION SOLVER OF WHICH
  6  INVOLVE MATRIX DECOMPOSITION, INCLUDING
  0  DECOMPOSITION(S) OF THE MASS MATRIX
  1  REORDERING OF EQUATIONS TO MINIMIZE WAVEFRONT
  0  ADDITIONAL RESIDUAL EVALUATIONS FOR LINE SEARCHES
  0  ADDITIONAL OPERATOR EVALUATIONS FOR LINE SEARCHES
 17  WARNING MESSAGES DURING USER INPUT PROCESSING
  0  WARNING MESSAGES DURING ANALYSIS
  0  ANALYSIS WARNINGS ARE NUMERICAL PROBLEM MESSAGES
  0  ANALYSIS WARNINGS ARE NEGATIVE EIGENVALUE MESSAGES
  0  ERROR MESSAGES


JOB TIME SUMMARY
  USER TIME (SEC)          =  144.70
  SYSTEM TIME (SEC)        =  12.600
  TOTAL CPU TIME (SEC)     =  157.30
  WALLCLOCK TIME (SEC)     =     268
```

Frame Without Modifications Input File

```
*Heading
 Load Applied By Ground
** Job name: Project Model name: Model-1
*Preprint, echo=NO, model=NO, history=NO, contact=NO
**
** PARTS
**
*Part, name=frame
*End Part
**
** ASSEMBLY
**
*Assembly, name=Assembly
**
*Instance, name=frame-1, part=frame
```

MAJORITY OF THIS SECTION WAS DELETED AS IT WAS TOO LONG

```
** Region: (FrameSection:Picked)
*Elset, elset=_PickedSet26, internal, generate
     1,  155111,       1
** Section: FrameSection
*Solid Section, elset=_PickedSet26, material=Steel
1.,
*End Instance
*Nset, nset=_PickedSet126, internal, instance=frame-1
  177,   178,   179,   180,   184,   185,  2776,  2777,  2778,  2779,  2780,  2781,  2782,
2827,  2828,  2829


*Elset, elset=__PickedSurf37_S1, internal, instance=frame-1
 987, 1028, 1080, 1097, 3904, 3922, 3929, 3953, 8629
*Elset, elset=__PickedSurf37_S2, internal, instance=frame-1
  960,  1015,  1064,  1078,  8722, 11175
*Surface, type=ELEMENT, name=_PickedSurf37, internal
__PickedSurf37_S3, S3
__PickedSurf37_S4, S4
__PickedSurf37_S2, S2
__PickedSurf37_S1, S1
*End Assembly
**
** MATERIALS
**
*Material, name=Steel
*Elastic
200000., 0.3
*Plastic
```

```
300.,    0.
350., 0.025
375.,   0.1
394.,   0.2
400.,  0.35
**
** BOUNDARY CONDITIONS
**
** Name: Fixed Type: Symmetry/Antisymmetry/Encastre
*Boundary
_PickedSet126, ENCASTRE
** ----------------------------------------------------------------
**
** STEP: Load
**
*Step, name=Load
Contact With Ground
*Static
0.1, 1., 1e-05, 1.
**
** LOADS
**
** Name: applied forces   Type: Pressure
*Dsload
_PickedSurf36, P, 15.91
** Name: applied_load_2   Type: Pressure
*Dsload
_PickedSurf37, P, 7.423
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=1
**
** FIELD OUTPUT: F-Output-1
**
*Output, field
*Node Output
CF, RF, U
*Element Output
LE, PE, PEEQ, PEMAG, S
**
** HISTORY OUTPUT: H-Output-1
**
*Output, history, variable=PRESELECT
*El Print, freq=999999
*Node Print, freq=999999
*End Step
```