Score Crush Slitter Insert

by

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Mechanical Engineering Technology
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Slitter Insert for Slitter/ Rewinder - Frame
James J. Lins
ABSTRACT

In the material processing industry there is a common need to process bulk roll material into thinner useable strips. Some examples of the materials slit are adhesive bandages and invisible tape. This process is competed using a slitter that was designed around 1950 and few improvements have been made since.

The persons charged with the new design are James Lins and Nikolas Ilg. The project will be broken down into two parts. Mr. Lins will be tasked with designing the stationary parts of the insert with the primary member being the frame. Mr. Ilg will be tasked with designing the moving parts of the insert with the primary members being the fork, knife, and the associated bearing. When completed, both projects must work together seamlessly in order to meet the customer’s needs.

The survey was given to Tim and Peter Underhill of Cincinnati Knife Outlet. While they are not the project sponsor, they are the primary contact for selling the slitter inserts. The survey results have shown that the most important criterion is removing the blade while the insert is still attached to the machine. The second most important criterion is the egress and ingress of the blade in general. Lastly, making the design compatible with the existing air cylinder was also considered important. Once the initial design was reviewed with the customer, the project was taken back to the drawing board and a primarily new design was begun. With this new design, the compatibility with the air cylinder is not possible. This is because the air cylinder becomes part of the molded halves of the frame. The customer and sponsor both agreed that this second design was the way to go, even if it did not meet an original design objective.

The first design objective was to produce a cost effective direct replacement design based on the industry standard while improving on the maintainability of the insert. Every effort will be made using a design for assembly analysis to eliminate any unnecessary parts of the assembly. With the elimination of parts from the assembly, strides will be made towards achieving the next objective which is keeping costs to a minimum. The primary design objective, which is rarely stated but should always be kept to the forefront of the mind, is safety. The final design must not compromise the safety of the operators or users of the inserts in order to properly fulfill product objectives.

Three frame concept designs were created and a weighted decision matrix was completed in order to select the correct design. Therefore, it has been omitted from the report since the final design was initiated outside of the three concepts based on a design review with the project sponsor.

The project sponsor and customer also desired that the final mass produced product be injection molded in order to achieve desired dimensional stability and reduce costs. For the purpose of the prototype, the pieces for the frame will be machined. The change in manufacturing processes has caused major discrepancies with the initial budget estimates as noted.

The initial schedule has been revised, but only minimally. There was only one date that moved from the initial projected deadlines and that was proof of design which was moved one week earlier. This was done in hopes of project completion early enough to allow small scale production to begin prior to tech expo. Unfortunately due to unforeseen circumstances, specifically issues with prototype production, the desired date was not met and testing did not occur until after tech expo.
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BACKGROUND AND RESEARCH

INTRODUCTION

There are many products used on a daily basis that begin as bulk material in roll form. Some of the materials are things like adhesive bandages, invisible tape, and paper. Once the material has been brought to its final processing location, it is fed through a machine called a slitter/rewinder. The final width of the product is determined by the distance between the $\frac{1}{2}''$ wide slitter inserts lined up on the dovetail of the machine. The current industry standard was originally designed around 1959 (1). While there have been attempts to redesign the insert by Cincinnati Knife Outlet Co, Inc in order to overcome the problems with the standard design, the cost of the redesigned modular unit along with the number of units to changeover for large end users like 3M’s Scotch® brand has made it difficult to sell.

Figure 1 - Current design, industry standard
The industry standard for slitter inserts (Figure 1) has many shortcomings to its design. The main issues with the current frame design are friction, ease of blade removal, number of parts, ease of setup on machine, and premature air cylinder failure.

**RESEARCH**

Research for the project was relatively straight forward. Existing patents, such as that shown in Appendix A, were used to help guide the concept designs and to ensure no infringement would occur. The basic concept of the unit work, air being applied to lower the cutter blade against the material underneath, did have to be carried over for the product to work correctly.

Appendix A also shows the meeting minutes from meetings with the project sponsor, John Paselsky and separate meetings with Tim Underhill. These meetings were invaluable in the process of developing the survey.

The meeting with Tim Underhill proved to be the most helpful since he currently holds the patent for the “Lisa” slitter insert design. This allowed for specific features from both the original design and the “Lisa” to be analyzed with someone with firsthand experience.

Figure 2 - Cincinnati Knife Outlet's "Lisa" (2)
FEATURES

In conversations with Dean Arthur, John Paselsky, and Tim Underhill, important features for the new design were gathered and organized. The meeting minutes are shown in Appendix B. This list helped to achieve a better understanding of the improvements that the customer wished to obtain with the new design. It also helped to develop a more useful survey which in the end would help create a product that truly fit the customer’s needs.

CUSTOMER SURVEY

Appendix C contains the results from the survey of Tim and Peter Underhill of Cincinnati Knife. While the project sponsor is John Paselsky, his primary concern with the project was the development of a product that Mr. Underhill would find useful and be able to sell to his customers. Therefore a determination was made that the voice of the customer in this case must come from the Underhills. The results were relatively close to what was expected in the conversations previously had with the Underhills, but there were also some concerns with the results. The primary concern was with removal of the blade while the insert is still attached to the machine. If it was determined that this is an attainable goal through proper frame and mechanism design, then more in depth research had to be completed to insure that the unit will not allow workers to violate OSHA standards for safety while changing the blades. It was determined that in order to properly follow safe operating procedures, a machine would have to be locked out prior to the blade change which negated the concern. The next question on the survey that showed immediate attention required was blade removal. This feature took considerable time to build stability into the design for repeatability and accuracy, but still allow a more time efficient way to remove the blade for routine maintenance such as a re-grind. The third and final section of the survey that also rated a mean of five was compatibility with the existing air cylinder. Even if a frame design could have been developed that reasonably made it disposable, the customers indicated the desire to use the current air cylinder was strong. The use of the current air cylinder would have limited the number of parts that could be eliminated from the insert assembly due to their current interaction.

Since the original concept designs were brought before Mr. Paselsky and the Underhills, there has been an allowance in the final design to not use the current air cylinder. It was the combined decision that with the approved final design the disposability is more important than the use of the current air cylinder for marketability.

ANALYSIS OF SURVEY RESULTS

A quality function deployment was used to turn the survey results into useable numbers for determining the importance of engineering features and improvement ratios to shift the customer satisfaction. The QFD can be seen with all relevant numbers in Appendix D. The most important feature in order to achieve customer satisfaction was determined to be low-maintenance. The second feature with the highest absolute importance was the quick release of the axle. This feature might allow the blade to be removed while the insert is still attached to the machine, but minimally this feature was expected to allow for easier change of the blade. Both were considered very important to the customer.

FRAME DESIGN OBJECTIVES

The objectives for the frame design are presented in a straightforward manner from the QFD. The frame had to be developed in a manner that easily facilitated maintenance. The main concern with developing an easily maintainable insert was the standard concern of any design, safety. There were no concessions made on safety in order to ease maintenance. The next objective was a quick release of the axle. While this was not directly frame related, the design of the frame could not hinder the release that was be designed into the mechanisms of the unit. The third primary design objective
was clearance to allow the blade to be removed while the insert is still attached to the machine. While there were constraints of the blades relationship to the dovetail feature as well as an anvil located underneath the blade, serious consideration was made while designing the mechanism to frame interaction to allow for this to occur.

DESIGN PROCESS

CONCEPT DESIGN

In Appendix G there are the drawings that were initially presented to the project advisor. Each was conceptualized while trying to allow more air into the unit while reducing the number of parts and surface contact with the knife. The first concept did not allow more air in, but it was believed there would not be enough of a reduction in the surface contact with the knife. The second concept was deemed to be the better of the two through a weighted decision matrix by its use of polymers, reduction in surface contact, and use of a solid fork support for the knife. When the concept was brought to the customer, he encouraged the pursuit of a disposable design with a few of the same features. Since none of the concepts were used, but instead some ideas were taken from the second concept, the weighted decision matrix has been omitted.

FINAL DESIGN

In Appendix H there are pictures of the three dimensional model of the product created using Autodesk Inventor. There is also an exploded view of the crush score slitter insert assembly in Figure 3. There it is clearly shown how the fork is set into the frame and then the wheel and knife assembly can be inserted and removed from the insert. It also gives a clear picture how the air cylinder was integrated into the halves of the frame instead of the current separate part that is used. The CAD drawings can be found in Appendix K. These drawings were vital for dimensional comparison to the prototype products, but were not in fact used in the traditional sense for production. Software called MasterCAM was used to take the parametric 3D models and, with a set of skillful hands, create the G code that could be downloaded to NC machines for machining.
**DESIGN ANALYSIS**

Design analysis of the frame was done using ANSYS Workbench®. The loading conditions input into the software were determined in conversations with the design advisor and Mr. Paselsky. The primary frame forces to be analyzed were the air pressure being applied to the pressure vessel, the reactionary force applied to the frame by the dovetail after the blade is extended, and the force of the attachment feature. It was determined that the attachment feature only had to overcome the weight of the unit when static. The other two forces were analyzed at 150psi (inducing a 150lb reactionary force), 90psi, and 80psi. The results, including graphics, can be seen in Appendix I.

Once the analysis was run in the computer, factors of safety were determined. The only point determined to be of concern was the 150psi force in the air cylinder. Due to a minor oversight in the original modeling there were multiple sharp corners that met at a single point, which left a design factor of 1.75. This is shown in Figure 4. With the smoothing of transition between surfaces the stress concentration was reduced and a safety factor of over 10 was achieved. It may seem that more time could have been spent to reduce material or otherwise cut costs since the safety factor is so large, but stress was not the only concern. The initial analysis indicated that the large flat area in the pressure vessel was prone to a deflection of .013 in. While this is a relatively small amount of deflection, Mr. Paselsky desired to reduce this deflection, possibly by the use of an acetyl that contained a filler material.
MATERIAL AND COMPONENT SELECTION

With the desire to mold the production model of the frame, the prototype was made from a variation of DuPont Delrin®. The material’s inherent properties lend it to being molded relatively easily. It also has bearing properties which will aid in the smooth action of the mechanisms. Since Delrin® allowed too much deflection in the simulation, the decision was made to use 20% glass filled Delrin® which has more rigidity.

For the prototype being built, it was necessary to source components off the shelf if possible. The only piece in the frame that needed to be sourced commercially was the spring for the retention device. While that was the only off the shelf component used in its native form, the raw material for the frame body was also purchased in a mill finish sheet for machining. In Appendix J a complete bill of materials is listed for the completed slitter insert.

PROTOTYPE PRODUCTION

With a completed design and materials on order from various suppliers, multiple visits were made to Northpointe in order to discuss any final small changes that needed to be made to make machining easier. There were also multiple meetings with the MasterCAM programmer to make sure the design intent was being followed and addressing any areas of concern.

After the G code was produced by the program, the machine time began. After a short orientation in the shop as well as the necessary safety lectures, raw materials were fixtured into the NC machining center. Figure 5 shows the sheet of glass filled Delrin® being machined into the two halves of the frame. Since the material was only available in 3/8” thick stock, machining was necessary after the outlines were milled in order to release the halves from the stock. This was accomplished by turning the piece over, re-clamping the sheet, and then going over it with another mill until the halves were released. The bearing properties of the material and its smooth surface finish made it very difficult to maintain flatness on the table of the machine.

Figure 5 - Frame being machined
**FABRICATION AND ASSEMBLY ISSUES**

Due to the aforementioned issues maintaining flatness while releasing the halves from the stock, there was relative dimensional instability in the parts produced. This was not critical to the design since maintaining the 1/2” width was not an absolute necessity and the stress analysis showed that at the desired width, the parts would still be successful and the absolute dimensions can be achieved with the injection molding that the parts will be produced by for marketability. Figure 6 shows the halves of the frame before being removed from the stock material.

Along with the dimensional instability of the frame, the use of cold rolled steel for the fork caused issues for the assembly. The fork had to be made from three pieces that were hand welded together, as opposed to the desired method of investment casting, and the machining of them released residual stresses contained in the material from the cold working processes.

The first prototype body was milled from plain Delrin® for testing fitment as well as testing the adhesive purchased for the project since enough scrap was available from Northpointe and therefore the expensive glass filled stock could be saved for later iterations. On the recommendation of a large epoxy manufacturer, a special kind of epoxy was purchased that was marketed for the acetyl and glass filled acetyl bonding markets. Since Delrin® is an acetyl; it seemed the most logical choice.

From the first frame, many lessons were learned about the fitment and epoxy characteristics. There were small adjustments made to the frame, specifically depths of cuts, in order prevent binding due to the dimensional tolerances of the prototype parts. The biggest setback came from the epoxy. Even though it is marketed specifically for applications such as this, there was no significant adhesion achieved. Multiple attempts were taken specifically following the manufacturer’s instructions and even trying the recommended heat curing, but to no avail. At that time the decision was made to abandon the epoxy for the time being and use fasteners and RTV silicon to produce the desired seal. Once that was proven effective, the epoxy manufacturer was contacted and it was admitted that their product may not have been the best for this application.

A third and final prototype was machined out with a couple more small adjustments made to clearance dimensions to produce the testing unit. With this third prototype, testing was done to insure that the blade could be changed out with the unit still attached to the machine, as well as the whole unit being removed from the machine quickly.

**TESTING**

Since the crush score slitter insert was designed to eventually become a commercially viable product, the testing was relatively straight forward. It had to be compatible with the existing machinery, had to function properly, and had to be marketable. The first two criteria can be measured in the list of proof of design requirements shown in Appendix L. The cutting of material was done at an OEM manufacturer of printing press lines that also cut the printed material to the desired width. While the initial date of April 25th was not met, when the unit was installed on the machine, it functioned exactly as desired and cut properly all the way up to the machine’s maximum speed of 900 ft/min.
PROJECT MANAGEMENT

**BUDGET**

A revised budget is shown in Table 1 for just the frame portion of the design. A complete project budget can be seen in Appendix E. While the is a fully sponsored project, it is not reflected in the budget since the invoice for parts has not been given to and subsequently paid by the customer.

<table>
<thead>
<tr>
<th>Designed Components</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material (Delrin)</td>
<td>$63.61</td>
</tr>
<tr>
<td>Machining</td>
<td>N/A</td>
</tr>
<tr>
<td>Spring</td>
<td>$1.24</td>
</tr>
<tr>
<td>Retention Block</td>
<td>N/A</td>
</tr>
<tr>
<td>Industrial Adhesive</td>
<td>$105.95</td>
</tr>
<tr>
<td>Frame Total</td>
<td>$344.08</td>
</tr>
</tbody>
</table>

Table 1 - Frame budget

**SCHEDULE**

Major milestones for the project can be found in Table 2. The complete schedule can be found in Appendix F. Many of the dates typically found in the winter quarter have been moved back, with the approval of our advisor since the project was changed late in the autumn quarter. There has been a major change in the schedule which was the movement of the proof of design from the first of May to the 27th of May.

**CONCLUSIONS AND RECOMMENDATIONS**

Since the ultimate desire is for the newly designed crush score slitter inserts to be a commercially viable product, even though the prototyping of the product is complete, the unit itself will continue to be developed.

The first issue that needs to be addressed is the epoxy. If the original manufacturer cannot supply a suitable epoxy, then a new manufacturer needs to be sourced. It was also discussed that a shop should be found that could potentially ultrasonically weld the halves of the frame instead of using epoxy. After the bonding issues have been addressed, a design must be generated that more closely resembles what the final molded product will look and function like. While these are not large changes, there were concessions made for ease of machining and reduction of machining time that changed some features. After the changes are made, it will be possible to work alongside engineers at Northpointe to produce the mold for the injection molding process.

Once the molds are produced and the first units are sold, it is believed that these units will truly sell themselves and may eventually be able to inherit a large share of the market for replacement sales.
REFERENCES
Appendix A – Research

Patent Research

United States Patent

Mastriani et al.

3,977,284
Aug. 31, 1976

Abstract

This invention relates to compact slitting mechanism units structured so as to enable a plurality of such units to be positioned in abutting, close, parallel relation, for narrow width cutting, slitting or other operations, said units including pressure chambers and knife holding and aligning mechanisms with structural features enabling knife elements and actuator cylinder mechanisms of the units to be mounted in essentially unitary axially aligned relation, and having novel means for mounting and actuating the knives and for enabling removal and replacement of any knife of any unit without disassembly of parts, in a safe convenient and simple manner, the pressure chamber-knife-holding mechanism assemblies being structured of equal widths, to facilitate side-by-side positioning of plural assemblies thereof, enabling narrow width contacting operations to be performed on surfaces to be slit or otherwise worked so contacted thereby.

16 Claims, 11 Drawing Figures
COMPACT SLITTING MECHANISM

BACKGROUND OF THE INVENTION

The application is a continuation-in-part of copending application Ser. No. 872,433, filed Dec. 6, 1973, for "Compact Slitting Mechanism" assigned to the same assignee as the instant application, now U.S. Pat. No. 3,921,488.

This invention relates to mechanisms for recirculating in multiple unit form, for procedures such as scoring, slitting and cutting materials. An object of the invention is to overcome the disadvantages of complexity, inaccuracy and of opaque structures intended for such uses, wherein the knife positioning and actuating mechanisms were bulky, unwieldy, complex structures, making use and replacement thereof difficult, and unsafe, inaccurate, procedure and not adapted for simple and efficient assembly in multiple unit groups in close parallel arrangement.

The present invention provides a novel, safe, highly efficient, compact mechanism for achieving narrow slitting, scoring, cutting and other procedures to be achieved in a simple, safe, accurate and convenient manner due to novel structural features of pressure clamps, knife holders and actuators powered thereby for actuation in straight line, plural unit arrangements, so that an assembly of any desired number of such actuator units may be achieved in multiple side-by-side scoring, essentially unitary assembly as desired and enabling ready insertion or removal of the knife of any of the assembly units without interfering with the others or with the multiple unit arrangement.

The invention provides novel means for mounting knifes and their actuators as essentially integral units, each knife being essentially fully exposed to the ambient atmosphere, for cool running and for reducing friction to a minimum, at the same time facilitating cleaning and further enabling individual knives and holders to be readily viewed and removed and replaced in a safe, simple and convenient manner. The invention further enables the actuated knife mechanism to be of sturdy structure so that they may be assembled in essentially unitarily plural continuous side-by-side arrangements while enabling individual units to be subjected and aided simply, safely and without requiring complex components of parts as is required in prior structures in the art.

The invention further provides novel means for positioning each knife in its holder in a novel seating and holding arrangement, the knife insertion and removal path being clearly visible to the user at all times; any knife may be readily withdrawn from and re-inserted into its unit safety and without exercise of special dexterity or having to guess where the removal and re-insertion paths and areas are located.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are illustrated, by way of example, in the drawings, wherein similar reference characters indicate like parts, and whereas:

FIG. 1 is a side elevational view of a mechanism unit embodying the invention,
FIG. 2 is an elevational view of part of a pneumatic or other cable for powering the mechanism,
FIG. 3 is a top plan view showing, in dotted lines, a plurality of mechanism units embodying the invention,
FIG. 4 is a fragmentary side elevational view of an essential unitary side-by-side arrangement, taken at line 3--3 of FIG. 1,
FIG. 5 is a fragmentary side elevational view of a knife holder which may be used in accordance with the invention, showing, schematically, the (slotted) knife wheel axle 20 about to be inserted into (or just removed from) the slotted end of knife holder 22,
FIG. 6 is a similar view, showing the axle as being partially inserted into (or removed from) the slotted end of the knife holder,
FIG. 7 is a perspective view of a knife holding member embodying the invention,
FIG. 8 is a fragmentary side elevational view of a further form of the invention,
FIG. 9 is a vertical, partly sectional, elevation view of another form of the invention,
FIG. 10 is a fragmentary elevation view of part of a pneumatic or other power cable for use therewith, and
FIG. 11 is a top plan view, taken at line 11--11 of FIG. 9.

DESCRIPTION OF PREFERRED EMBODIMENTS

As shown in the drawings, FIG. 1 the invention comprises a C-shaped knife casing 10, preferably formed unilaterally of suitable metal or other material (or of a number of parts secured together) to define a pair of parallel spaced arms 11, 12, provided with the cut-out axial keying portion 13 or other means, for facilitate of mounting the casing 10 and its power source 37, as single units or in multiple units (FIG. 2) in a side-by-side, essentially unitary, relation on a beam or other part of the machine, in connection with which the invention is used, received in said cut-out keying portion 13. A movable link 14 and adjustable pin 16 cooperate with said portion 13 for so mounting the parts on a beam or other part of a machine on which U.S. Pat. No. 3,921,488 was issued on Nov. 25, 1975 for keying the mechanism thereto.

The upper casing arm 11 is preferably foreshortened at the free end 16 thereof inwardly of the free end 17 of the lower arm 12. In addition thereto, the foreshortened end 16 of said upper arm is preferably angularly upwardly, outwardly, inclined as at 18 (FIG. 1) to facilitate movement of the slotted or axle 20 of the knife 21 in a direct path of insertion or removal thereof relative to the knife holder 22 (FIGS. 4, 5, 6). The knife holder 22 (shown in perspective in FIG. 7) may be formed of a block of solid metal or of several parts, to define a closed, relatively solid, end portion 25, with beveled, spaced, parallel sides or arms 24, 25 extending therefrom, for a purpose presently explained. Said beveled arm members 24, 25 are provided with vertical entry slots 26, 27 adjacent their free ends (FIGS. 4--7) of a width that at their upper ends (FIGS. 4) substantially equal to or slightly less than the diameter of the shaft or axle 20 of the knife, so as to preferably require some force in the knife insertion and removal operations. The knife may then be moved down in the slots to register with the enlarged, that is wider than entry slot 27, (FIG. 5) seating portion 29, proportioned to receive and hold the axle preferably firmly and frictionally (FIG. 6). The slot is provided with the narrow lower end 30 (FIG. 4) below seating portion 29; the knife insertion/removal path is thus always visible.

The knife holder parts described above are preferably made of springy material so that the operation of inserting and removing the knife is safe, simple and...
Carolina Knife Co. manufactures a complete line of Score Slitting Knives for paper, film, non-woven and textile converting equipment, including Arrow, Ashton, Cameron, Didde-Graphics, Dusenbury, Johnstone, Schreiber, and others.

**Available in 52100 or D-2 steel.** Through hardened for maximum wear characteristics.

**American made.** We offer quick delivery - most sizes available from stock.

**Click Here** to download this information in print document form, or check out our technical diagrams below.

---

**Only the blades**

From pictures these appear to be useable in the same design frames as currently available from Cincinnati Knife (since it says industry standard this is a reasonable assumption)

If so issues with mating frame are:
- Fork wear
- Heat
- Quality
- Too many parts (including fasteners)

**Benefit:**
- Made in USA

---

http://www.cknife.com/score_cut_blades.htm

12/10/07
Carolina Knife Company
INTERVIEWS/MEETINGS

Meeting 11-14-07 (CAS)
Attendees: Dean A. Arthur
Nik Ilg
Jim Lins

- Must research existing stock slitters
- Cost target will be developed with Northpointe
- Want production to be moved back to US
- Reduction of friction is necessary
- Reduction in the number of breakages
- Minimize the number of fasteners

Meeting 11-28-07 (CAS)
Attendees: Dean A. Arthur
Nik Ilg
Jim Lins

- Patent research must be done
- Need to develop improvement measurable (examples)
  o $10 price
  o Dull blade replacement < 5 mins.
  o Piston movement < .5”
  o Heat @ operating temp 150°F
  o # Parts < 10
  o # Different parts < 6

Catbridge supplies a number of industry standard slitting components
Price not listed

1/11/08
Score Slitting Holders, Blades, Bearings & Accessories
Catbridge Machinery

From pictures appears to have same design as currently available from Cincinnati Knife (since it says industry standard this is a reasonable assumption)

If so issues are:
Fork wear
Heat
Quality
Not made in USA
Too many parts (including fasteners)
Appendix A9

Meeting 12-18-07 (Northpointe Machine) (5)
Attendees: John Paselsky (President)
Nik Ilg
Jim Lins

2 Problems with current design
- Air cylinder housing cracks from fatigue and hammer hits
- Heat

New design
- ½” width of unit must be maintained
- Other primary constraint is knife centerline in relation to dovetail feature
- Other than those two constraints, unit is a relatively from scratch design
- Keep minds open to possibly making the design disposable
- John’s design ideas
  o Easily removable/ replaceable
  o Low cost
  o High quality
  o Minimum number of parts
  o Methods of fastening
    ▪ Heat staking
    ▪ Industrial adhesives
  o Don’t be afraid to have secondary operations performed
- Possible manufacturing techniques
  o Die casting
  o Investment casting
  o Injection molding
- Next meeting with John need research and design concepts with recommendations

Meeting 1-11-08 (Cincinnati Knife) (1)
Attendees: Tim Underhill (President)
Nik Ilg
Jim Lins

- Units currently being sourced from places like China and Korea (approx. $70)
- Original design circa 1959

- Common widths of machines currently in use
  o 120” for older machines
  o 2m for newer machines
- Industry term for the machine is a slitter/ rewinder
- A big user of units is 3M (for scotch tape)
- Another big use is Band Aids™
- Approximate full speed is 2200 linear ft/min but can be up to 5000 linear ft/min
- Removal of blade from unit while still on machine may not be as big of an issue due to OSHA and lockout/ tag out requirements
- Need to investigate bearing removal for blade regrinds, intervals range from weeks to 8hr shift
- Reduction of variation in setup of machines can possibly be addressed in new design
- The blades (for Cincinnati Knife products) are currently sourced from Cleveland, OH
- Keep in mind possibility of disposable knives
- Possibility of using a “turnstyle” head attached to machine for insertion of setups that were completed outside of machine.
- Possible modifications of current design to allow for disposability (would have to meet selling price of approx. $55)
- If not disposable, ease of interchange
- The failures of the air cylinders are most often due to hammer hits in order to accurately position unit on dovetail

- Main problems with current design
  - Fork issues
    - Blade riding on fork.
    - Heat and friction
    - Fork is first failure point
  - Setup for widths greater than $\frac{1}{2}$”
    - Repeated hammer hits crack air cylinders
    - Accuracy largely determined by operator who completes setup and his gauge accuracy and repeatability.
  - Air cylinder issues
    - In current design only one piston is used in air cylinder which may induce binding
## APPENDIX B - FEATURES

<table>
<thead>
<tr>
<th>Category</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Easy to maintain</td>
</tr>
<tr>
<td>C</td>
<td>15 parts or less</td>
</tr>
<tr>
<td>O</td>
<td>Easy to setup on rail</td>
</tr>
<tr>
<td>O</td>
<td>Easy blade removal</td>
</tr>
<tr>
<td>O,S</td>
<td>Ability to remove blade while still attached to machine</td>
</tr>
<tr>
<td>C</td>
<td>Disposable frame</td>
</tr>
<tr>
<td>O,C</td>
<td>Compatible with existing blade</td>
</tr>
<tr>
<td>O,C</td>
<td>Disposable blade</td>
</tr>
<tr>
<td>O,R</td>
<td>Good heat dissipation</td>
</tr>
<tr>
<td>R</td>
<td>Minimum heat generation</td>
</tr>
<tr>
<td>O,R</td>
<td>No steel-on-steel contact</td>
</tr>
<tr>
<td>C</td>
<td>Uses existing air cylinder</td>
</tr>
<tr>
<td>C</td>
<td>Comparable life to existing design</td>
</tr>
<tr>
<td>C</td>
<td>Made in USA</td>
</tr>
<tr>
<td>O</td>
<td>Attaches to existing dovetail</td>
</tr>
</tbody>
</table>
APPENDIX C – SURVEY RESULTS

Crush Score Slitter Machine Insert
Customer Survey

We are Mechanical Engineering seniors at the University of Cincinnati working on a new design for a crush score slitter insert. Please take a moment to respond to this survey so that we may determine which areas to focus on in the design of the new machine insert.

What is important to you for the design of a new slitter insert? Please circle the appropriate answer.  
1 = low importance  5 = high importance

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ease of setup for widths greater than 1/2&quot;</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (1)</td>
<td>N/A (0)</td>
<td>4.0</td>
</tr>
<tr>
<td>2 Ease of blade removal</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (0)</td>
<td>5 (2)</td>
<td>N/A (0)</td>
<td>5.0</td>
</tr>
<tr>
<td>Ability to remove blade while slitter insert is still attached to machine</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (0)</td>
<td>5 (2)</td>
<td>N/A (0)</td>
<td>5.0</td>
</tr>
<tr>
<td>4 Disposability of slitter insert</td>
<td>1 (0)</td>
<td>2 (1)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>2.5</td>
</tr>
<tr>
<td>5 Compatibility with existing blade</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (1)</td>
<td>5 (1)</td>
<td>N/A (0)</td>
<td>4.5</td>
</tr>
<tr>
<td>6 Heat dissipation</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (1)</td>
<td>N/A (0)</td>
<td>4.0</td>
</tr>
<tr>
<td>7 Disposable blade</td>
<td>1 (0)</td>
<td>2 (1)</td>
<td>3 (0)</td>
<td>4 (1)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>3.0</td>
</tr>
<tr>
<td>8 Compatibility with existing air cylinder</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (0)</td>
<td>5 (2)</td>
<td>N/A (0)</td>
<td>5.0</td>
</tr>
<tr>
<td>9 Ease of maintenance</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (1)</td>
<td>N/A (0)</td>
<td>4.0</td>
</tr>
<tr>
<td>10 Life of slitter insert</td>
<td>1 (0)</td>
<td>2 (1)</td>
<td>3 (0)</td>
<td>4 (1)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Are you satisfied with the current slitter insert? Please circle the appropriate answer.  
1 = very unsatisfied  5 = very satisfied

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ease of setup for widths greater than 1/2&quot;</td>
<td>1 (1)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
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<tr>
<td>2 Ease of blade removal</td>
<td>1 (1)</td>
<td>2 (1)</td>
<td>3 (0)</td>
<td>4 (0)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>1.5</td>
</tr>
<tr>
<td>Ability to remove blade while slitter insert is still attached to machine</td>
<td>1 (1)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>2.0</td>
</tr>
<tr>
<td>4 Disposability of slitter insert</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (2)</td>
<td>4 (0)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>3.0</td>
</tr>
<tr>
<td>5 Compatibility with existing blade</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (1)</td>
<td>N/A (0)</td>
<td>4.0</td>
</tr>
<tr>
<td>6 Heat dissipation</td>
<td>1 (1)</td>
<td>2 (0)</td>
<td>3 (1)</td>
<td>4 (0)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>2.0</td>
</tr>
<tr>
<td>7 Disposable blade</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (1)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>3.5</td>
</tr>
<tr>
<td>8 Compatibility with existing air cylinder</td>
<td>1 (0)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (0)</td>
<td>5 (2)</td>
<td>N/A (0)</td>
<td>5.0</td>
</tr>
<tr>
<td>9 Ease of maintenance</td>
<td>1 (1)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (1)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>2.5</td>
</tr>
<tr>
<td>10 Life of slitter insert</td>
<td>1 (1)</td>
<td>2 (0)</td>
<td>3 (0)</td>
<td>4 (1)</td>
<td>5 (0)</td>
<td>N/A (0)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Please approximate the number of replacement slitter insert units you order per year
0-20 (0)  20-50 (0)  50-100 (0) 100+ (2)

What would be a reasonable target price for a disposable slitter insert with a comparable life to those available today?
$10-20 (1) $25-35 (1) $40-50 (0) $55-70 (0) $22.50

Thank you very much for participating in this survey. The results will be very beneficial throughout the design process.

Appendix C1
## APPENDIX D – QFD

### Material

<table>
<thead>
<tr>
<th>Ease of setup for widths greater than 1/2&quot;</th>
<th>9</th>
<th>9</th>
<th>9</th>
<th>4.0</th>
<th>2.0</th>
<th>4</th>
<th>2.0</th>
<th>1.3</th>
<th>10.4</th>
<th>0.11</th>
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<tbody>
<tr>
<td>Ease of blade removal</td>
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<td>9</td>
<td>9</td>
<td>9</td>
<td>5.0</td>
<td>1.5</td>
<td>5</td>
<td>3.3</td>
<td>1.5</td>
<td>25.0</td>
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<td>3</td>
<td>9</td>
<td>9</td>
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<td>2.0</td>
<td>4</td>
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<td>15.0</td>
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<td>3</td>
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<td>1</td>
<td>3</td>
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<td>1.3</td>
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<td>0.07</td>
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<td>1</td>
<td>1</td>
<td>9</td>
<td>4.0</td>
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<td>2.5</td>
<td>1.5</td>
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<td>Disposible blade</td>
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<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3.0</td>
<td>3.5</td>
<td>3.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Compatibility with existing air cylinder</td>
<td>3</td>
<td>9</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>1.0</td>
<td>1.3</td>
<td>6.5</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>3</td>
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<tr>
<td>Life of slitter insert</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>3.0</td>
<td>2.5</td>
<td>4</td>
<td>1.6</td>
<td>1.0</td>
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<tr>
<td>Absolute Importance</td>
<td>1.8</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Relative importance</td>
<td>0.08</td>
<td>0.05</td>
<td>0.03</td>
<td>0.20</td>
<td>0.432</td>
<td>0.04</td>
<td>0.98</td>
<td>0.19</td>
<td>0.421</td>
<td>0.13</td>
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</tbody>
</table>

### Improvement (Absolute weight) ratio

### Relative weight

### Improvement (%)
# APPENDIX E – BUDGET

<table>
<thead>
<tr>
<th>Designed Components</th>
<th>Cost (unit)</th>
<th>Cost (Extended)</th>
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<tbody>
<tr>
<td>Frame - James Lins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material (Delrin)</td>
<td>$63.61</td>
<td>$190.83</td>
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<tr>
<td>Machining</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Spring</td>
<td>$5.52</td>
<td>$11.04</td>
</tr>
<tr>
<td>Retention Block</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Industrial Adhesive</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Frame Total</td>
<td></td>
<td>$201.87</td>
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<tr>
<td>Mechanisms - Nikolas Ilg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blade</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Bushing</td>
<td>$9.51</td>
<td>$9.51</td>
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<tr>
<td>Detent Axle</td>
<td>$4.00</td>
<td>$24.00</td>
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<tr>
<td>Fork</td>
<td>$18.72</td>
<td>$112.32</td>
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<tr>
<td>Bearing</td>
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<td>$18.00</td>
</tr>
<tr>
<td>Air Cylinder Gasket</td>
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<tr>
<td>Mechanism Total</td>
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<td>$163.83</td>
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<tr>
<td>Overall Total</td>
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<tr>
<td>Sponsorship (Northpointe)</td>
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<td>$365.70</td>
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<tr>
<td>Total Cost to Students</td>
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<td>$0.00</td>
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<tr>
<td>Month</td>
<td>February</td>
<td>March</td>
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<td>Week 4</td>
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<td>Week 5</td>
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<td>Week 6</td>
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<td>Week 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**APPENDIX F – SCHEDULE**

- **Proof of Design**
- **Concept Designs**
- **Design Review, Design choice**
- **Detail Design:**
  - Frame - Jim Lins
  - External mounting
  - Internal features
  - Fasteners
  - Manufacturability review/ Process selection
  - Material Selection
  - Ease of setup feature
- **Mechanisms - Nikolas Ilg**
  - Interface with air cylinder
  - Plunger
  - Interface with frame
  - Blade removal
- **Finite Element Analysis**
- **Design Review**
- **Design Freeze**
- **Final Finite Element Analysis (if necessary)**
- **Detail drawings**
- **Work on report**
- **Design Presentation**
- **Design Report Due**
- **Order Production Materials**
- **Spring break**
- **Obtain final feedback from end user**
- **Build individual parts**
- **Assemble parts**
- **Proof of Design to Advisor**
- **Tech Expo**
- **Oral Presentation**
- **Project Report Due**
CURRENT KNIFE AND BEARING
W/ BRASS THRUST WASHER

SOLID
- DELRIN
- NYLON 6/6
- NYLATRON
- ERTALYTE
- ERTALYTE TX
APPENDIX I – FEA RESULTS

2. Introduction

The ANSYS CDM (Computer-Aided Engineering) software program was used in conjunction with 3D CAD (Computer-Aided Design) solid geometry to simulate the behavior of mechanical bodies under the multiastructural loading conditions. ANSYS automated FEA (Finite Element Analysis) technologies from ANSYS Inc. to generate the results listed in this report.

Each scenario presented below represents one complete engineering simulation. The definition of a simulation indicates linear factor about a design such as material properties per body, contact behavior between bodies (in an assembly), and types and magnitudes of loading conditions. The results of a simulation provide insight into how the bodies may perform and how the design might be improved. Multiple scenarios allow comparison of results given different loading conditions, materials or geometric configurations.

Convergence and alert criteria may be defined for any of the results and can serve as guides for evaluating the quality of calculated results and the acceptability of values in the context of known design requirements.

- Solution history provides a means of assessing the quality of results by examining how values change during successive iterations of solution refinement. Convergence criteria set a specific limit on the allowable change in a result between iterations. A result meeting this criteria is said to be "converged."
- Alert criteria define "allowable" ranges for result values. Alert ranges typically represent known aspects of the design specification.

All values are presented in the "U.S. Customary (in, lbm, ft, °F, ksi, °F, kcal)" unit system.

Notice

Do not accept or reject a design based solely on the data presented in this report. Evaluate designs by considering this information in conjunction with experimental test data and the practical experience of design engineers and analysts. A quality approach to engineering design usually mandates physical testing as the final means of validating structural integrity to a measured precision.
3. Scenario 1

3.1. "Model"

"Model" obtains geometry from the Inventor part "D:\CAD\AM\5.9\DuttaPolastic.Flame.ipt".

- The bounding box for the model measures 4.60 by 3.26 by 0.2 m along the global x, y, and z axes, respectively.
- The model has a total mass of 0.12 kg.
- The model has a total volume of 0.20 m³.

Table 3.1.1. Bodies

<table>
<thead>
<tr>
<th>Name</th>
<th>Material</th>
<th>Nonlinear Material Effects</th>
<th>Bounding Box (m)</th>
<th>Mass (kg)</th>
<th>Volume (m³)</th>
<th>Nodes</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;DuttaPolastic.Flame&quot;</td>
<td>Concrete Composite</td>
<td>Yes</td>
<td>0.65, 0.26, 0.3</td>
<td>0.12</td>
<td>0.20</td>
<td>300</td>
<td>6000</td>
</tr>
</tbody>
</table>

3.1.1. Mesh

- "Mesh", associated with "Model" has an overall relevance of 0.
- "Mesh" contains 10627 nodes and 5600 elements.

No mesh controls specified.

3.2. "Air Pressure - 150 PSI"

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Air Pressure - 150 PSI" contains all loading conditions defined for "Model" in this scenario.

3.2.1. Structural Loading

Table 3.2.1. Structural Loads

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Magnitude</th>
<th>Vector</th>
<th>Reaction Force</th>
<th>Reaction Force Vector</th>
<th>Reaction Moment</th>
<th>Reaction Moment Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Pressure&quot;</td>
<td>Pressure</td>
<td>150.0 psi</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

3.2.2. Structural Supports

Table 3.2.2.1. Structural Supports

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Reaction Force</th>
<th>Reaction Force Vector</th>
<th>Reaction Moment</th>
<th>Reaction Moment Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Fixed Support&quot;</td>
<td>Fixed Surface 433.14 lbf</td>
<td>[-2.50 x 10^7 lbf x, 24.52 lbf y, 433.49 lbf z]</td>
<td>243.63 lbf-in</td>
<td>242.99 lbf-in x, -56.68 lbf-in y, -7.17 lbf-in z</td>
<td></td>
</tr>
</tbody>
</table>

3.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for "Model" given loading conditions defined in "Air Pressure - 150 PSI".

- Thermal expansion calculations use a constant reference temperature of 71.6 °F for "DuttaPolastic.Flame.ipt". Theoretically, at a uniform temperature of 71.6 °F no strain results from thermal expansion or contraction.

3.3.1. Structural Results

Table 3.3.1. Values

<table>
<thead>
<tr>
<th>Name</th>
<th>Figure</th>
<th>Scope</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Minimum Occurs On</th>
<th>Maximum Occurs On</th>
<th>Alert Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Equivalent Stress&quot;</td>
<td>3.1.1</td>
<td>&quot;Model&quot;</td>
<td>1.3 x 10^-13 ps</td>
<td>1.6 x 10^-13 ps</td>
<td>displace frame.ipt</td>
<td>displace frame.ipt</td>
<td>Passed: Maximum Below: 0.000, 0.0 psi</td>
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<tr>
<td>&quot;Maximum Shear Stress&quot;</td>
<td>None</td>
<td>&quot;Model&quot;</td>
<td>1.2 x 10^-13 ps</td>
<td>2.0 x 10^-13 ps</td>
<td>displace frame.ipt</td>
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<td>Passed: Maximum Below: 0.000, 0.0 psi</td>
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<tr>
<td>&quot;Total Deformation&quot;</td>
<td>3.1.2</td>
<td>&quot;Model&quot;</td>
<td>6.0 in</td>
<td>1.3 x 10^-12 in</td>
<td>displace frame.ipt</td>
<td>displace frame.ipt</td>
<td>Passed: Maximum Below: 0.002 in</td>
</tr>
</tbody>
</table>

- Convergence tracking not enabled.
Loading Conditions (Air cylinder)

Finite Element Analysis
Maximum Stress
# APPENDIX J – BILL OF MATERIAL

<table>
<thead>
<tr>
<th>Item</th>
<th>Part Number</th>
<th>QTY</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>4WALR</td>
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<td>DETENT, AXLE</td>
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<tr>
<td>2</td>
<td>6700ZZ</td>
<td>1</td>
<td>BEARING, BALL</td>
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<td>3</td>
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<td>FRAME, DISPOSABLE ‘B’</td>
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<td>708-102</td>
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<td>FORK</td>
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<td>9001T12</td>
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