Phase 3 Report
New Holland Quick Change Knife

Team 9
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Executive Summary

New Holland, the sponsor for this senior design project, is a company based out of New Holland, Pennsylvania who designs, manufactures, and sells industrial farm equipment. The focus of this project is the disc mower, a machine in which a number of rotating discs with knives attached cut and lay crop on the ground. The objective is to create a quick release connection between the knife and the disc on New Holland’s disc mower. The knife is currently connected with a bolt and specialized nut. The changing procedure of the knives is lengthy and awkward and they may be changed as often as every day. Some of New Holland’s competitors already boast a quick-change knife, which increases the need for New Holland to design and implement such a connection. This project will not only benefit New Holland as a company but will also increase their customers’ satisfaction with the disc mower.

The first step in generating an effective solution was identifying New Holland, Agricultural Equipment Dealers, and farmers as the main customers. They were kept in mind while generating and evaluating possible designs. Also, constraints, such as aspects of the current design that cannot be modified, were provided by New Holland. A list of customer wants was developed, with the top wants being to secure the knife, reduce the knife changing time, and make the design user-friendly.

A great deal of time went into benchmarking and research. Many patents were reviewed including not only disc mowers, but more common lawn mowers as well. By talking to dealers, a quick-change knife on the market was found, which was a bent piece of metal bolted to the underside of a disc, which acts as a leaf spring to hold the knife in place. This spring plate design has many advantages, including being simple and making the knife able to be easily changed.

Based on this spring plate on the market, a similar design was used to secure the knife on the New Holland disc. To change the knife a specialized tool, similar to a pry bar, is used to deflect the spring plate, which is bolted on the underside of the disc, enough to release the knife. The metal plate also has a nub welded onto it that fits in the hole in the knife to hold it steady.

The next step is to incorporate our selected concept into a design that will fit with New Holland’s product. Three parts will need to be designed to create the spring plate. First, there is the plate. It will have the necessary bends to fit within the shell and bolt holes for mounting. The second part is the nub, which the blade will be secured to and fit upon. It will be welded to the plate and the extending nub will provide the surface for the knife to rotate on and securing fit into the shell. The third part is the disc insert, which the nub fits into. This part provides a pocket for the nub to set in, securing the blade.

To validate the chosen design, each of the metrics and target values were satisfied. The cost of manufacturing the spring plate is $2.69. This cost includes the amount of material needed, heat treatments, and manufacturing processes. New Holland will be continuing this project by field testing the design for two seasons and hopefully putting the quick change connection into production in 2005.
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Introduction

New Holland, the sponsor for this senior design project, is a company based out of New Holland, Pennsylvania who designs, manufactures, and sells agricultural tractors, combine harvesters, hay and forage equipment, grape harvesters and industrial equipment. The focus of this project is the disc mower, a machine in which a number of rotating discs with knives attached cut and lay crop on the ground (See below). Multiple discs are aligned on a cutter bar and two knives are attached to each disc by a bolt and a specialized nut (See Appendix A-1,2,3). As the disc rotates at speeds near 3000 revolutions per minute, the knives cut the crop upon impact.

The goal of this project is to create a quick release connection between the knife and the disc on New Holland’s disc mower. These knives wear significantly when mowing in harsh conditions such as fields full of anthills. Therefore they may need to be changed as often as every other day, and the changing procedure is lengthy and awkward. To remove the knife, first a tool is used to keep the discs from rotating while loosening the bolt, then the bolt is unscrewed with a socket and wrench, and the specialized nut is removed from under the disc, finally allowing the knife to be released. To replace the knife, the procedure is reversed.

The objective is to create a more user-friendly connection between the knife and the disc on a disc mower that will decrease changing time and effort at a minimal cost. Some of New Holland’s competitors boast a quick-change knife, which increases the need for New Holland to design and implement such a connection. This project will not only benefit New Holland as a company but will also increase their customers’ satisfaction with the disc mower.
As a solution to this problem, a spring plate was designed to secure the knife while decreasing the changing time. The design uses the spring properties of a steel alloy plate, which is attached underneath the disc, to hold the knife in place. To change the knife a specialized tool, similar to a pry bar, is used to deflect the spring plate enough to release the knife.

The plan of this report will be to first discuss the design process, including our customers, design criteria, concept solutions, and evaluations. The chosen design concept will then be described in depth along with the manufacturing process and cost analysis. The verification testing will be outlined and explained, and finally a hand-off package will be included to facilitate New Holland with continuing this project in the future.
Method

Team Management

The team is based on mutual respect. It was decided at the start of the project to address all issues as they arose with the entire team present. Since the team is only three members, all meetings, decisions, and actions were taken with all members present.

Available Resources

A five hundred dollar account was allotted at the beginning of the project, funded by the University. The University also offered a machine shop, rapid prototyping, and computer-aided drafting tools. New Holland made available many resources including a machine shop, rapid prototype machine, finite element analysis, and testing facilities.

Schedule

A tentative schedule was created at the start of the project to ensure enough time to finish within the given constraints. Our final schedule (see Appendix B) shows how the project progressed through the three stages.

Phase I, Synthesize Concept, consisted of concept generation and making a project plan. Customers and their wants were recognized; these were weighted and converted into metrics. Research lead to benchmarks and target values. The concepts generated were then graded based on these metrics and target values to find the best solutions.

In Phase II, Design Concept, a solution was chosen. This solution went through the process of being designed, checking calculations of feasibility, and being built as a prototype. This solution was presented at the Phase II review shown on the schedule. However, phase II was extended past its original schedule so that a different design could be considered. The new design went through the same process as the first solution. It was then agreed upon to freeze the improved design to move to Phase III.

Phase III, Prototype Concept, consisted of verifying that the solution met all the requirements of the problem. Three prototypes were built. A check was run through a series of tests to be sure the metrics were all satisfied. A hand off package was finalized to give to the sponsor.

Customers

The first step in generating an effective solution to this problem was to decide who the main customers were. It was important to keep them in mind at all times while generating and evaluating possible design concepts.

New Holland is obviously the main customer, and as the manufacturers of the disc mower, they will be profiting from this improvement to the disc-knife connection. It is
also important to fulfill the company’s needs and wants because they invested the time, money, and effort into sponsoring this project. Melanie Harkcom, a design engineer in the Hay Tools division at New Holland, is the main contact and sponsor of the project. She is also the engineer that will be taking over the design process when it is passed on to New Holland. Ed Priepke is also greatly involved as an advisor because he has worked at New Holland for a number years and has also been involved with several University of Delaware of senior design projects.

Farm equipment dealers are also customers. At Ag-Industrial, a Case-New Holland dealer, representatives agree that with the current connection, the knife is difficult to change. Triple H is a European dealer handling mainly Krone, Keeverland, Greenland, and other European brands. Jim Miller, an operator and mechanic at this facility, also felt that the current bolted connection was in need of improvement. These dealers are important customers because they perform maintenance on disc mowers and maintain a close working relationship with the company.

The farmers and operators are also important customers, as they will be the ones using and buying the equipment. Buddy Dixon, who owns a farm in lower Delaware, expressed his concern with the time consuming current connection and looks forward to a quick release alternative.

Constraints

The following constraints were provided by New Holland and must be adhered to:

- The knife must be able to rotate back behind the shell for protection if it hits rock, at least a $270^\circ$ rotation.
- Some discs rotate clockwise and some counter clockwise. The connection must be able to handle both.
- After the blade is worn on one side, it is flipped over to use the other side. Ideally, there should be the same connection on each knife regardless of the orientation of the knife.
- The new connection must work with the lifter, bolt guard, and disc. As little modification to each is desirable, and if modifications are necessary they should also be included in the scope of this problem (See Appendix C for New Holland disc assembly).
- The cutting edge of the knife cannot be modified.
- The knife height cannot be modified.
- The lowest most point under the knife cannot go any lower, currently this is the bottom surface of the specialized nut.
- All clearances under the knife must be considered.
Wants

The customers gave a list of their top wants. From this, each want was weighted based on how many customers requested it and the priority of the customer. The top three wants are as follows:

- Reduced changing time: This is the top concern. With a reduction in changing time, farmers can get back to their crops without wasting much time.
- User friendly: This want is fairly broad as it could include changing time, the number of tools needed to change the knife, and even the cost. It stands alone as a want to show the importance of the user feeling comfortable with the connection.
- Total cost: A design that is cost beneficial is desired.

Appendix D gives the entire list of wants and their relative weight.

Benchmarking

A lot of time went into benchmarking. Many patents were reviewed. These patents included not only disc mowers, but more common lawn mowers as well.

An Internet search for "quick-release" mechanisms led to solutions such as A-pins and cotter pins. Quick release mechanisms in other applications such as roller skates and bicycle wheels also led to interesting concepts. Hardware stores were also a good resource for other types of connections currently being used.

Agricultural dealers were also a great source of information. At Triple H, Jim Miller explained the concept behind Kevernland's design (See Appendix E-1,2,3). Basically, a bent piece of metal is bolted to the underside of the disc and acts as a leaf spring to hold the knife in place. The metal has a nub built into it that fits in the hole in the knife to hold it steady.

Metrics/Target Values

From the wants and constraints, a set of weighted metrics and target values were derived to evaluate each concept.

- The main concern of this project is to hold the knife securely, so the pre-load force is the number one metric. The target value was set at 100 pounds. This came from discussions with the sponsor and research on the types of loads the knife sees.
- The purpose of this project is not only to hold the knife securely, but also to be able to change it in a fraction of the current time needed to change a knife. Therefore, seconds are the next metric. The time needed to change a knife in its current design was found to be around one and a half minutes. This time was divided by two since the goal is half the current time, making the target value 45 seconds.
• Of course, pleasing the customers/farmers who will be using it is also a main concern. In order to satisfy the want of user friendly, the metrics seconds, number of tools, number of parts, and dollars were considered. To avoid adding extra time hunting and using several tools, the target value was set at only one tool. The number of parts should also be kept to a minimum. There are currently only three parts. The target value was set at less than or equal to five parts. This allows for extra blots or connectors.
• The cost target value was set by New Holland to be $2.50 per connection. The solution of course cannot interfere with anything under the disc.
• The target value for interference is set at none.
• The angle of rotation must be at least 270° so the knife can be protected if it hits a rock or other obstacle.
• The number of changes to the system also needs to be kept to minimum. Less than ten system changes is the goal.
• The degree of symmetry is the final metric. It is an advantage to have one design regardless of the spin of the disc.

Concept Generation/Evaluation

Many concepts were generated from brainstorming sessions, and ideas from other applications. Many of these can be found in Appendix F-1 through 5. Initial concepts included pins such as H-pins and cotter pins. However, there was concern with the wear that the pin would have to endure and the shear strength of the pin. They may not be able to withstand the loads that the knife and disc see. Bolts, such as half-threaded and double lead bolts, were also considered. These may not decrease the changing time enough, and it was decided another concept might do better. Many patents involved types of slide and lock blades. This would entail modifying the knife and disc so that the knife would slide into the disc and lock into place in a slot of some sort. These designs seemed to be very intricate and expensive and would also require modifications to the knife and disc. A clamping devise was another concept. Similar to the Kevenland, a piece of metal would be clamped to the disc via a hinge, spring, or using the metal itself as a spring.
Results

Concept Selection

All of the concepts generated were judged using the weighted metrics. Having the best results, Kevernland’s spring plate concept was chosen. The spring plate is the simplest of all of the designs. It is only a single piece that bolts to the disc. There are no exposed areas of the spring plate above the disc needing protection from crop wear. And most importantly, minimal modifications to the disc would be necessary to incorporate this concept into the current design.

Since Kevernland’s concept is going to be used, New Holland's legal department searched for a patent on their design. The results found were that there is no patent on their design. This legally allowed us to move forward with this concept without infringing on any patents.

Prototype Design

The next step is to incorporate our selected concept into a design that will fit with New Holland’s product. The shell was first examined in order to determine how this concept could be adapted. Immediate concerns surrounded the limited amount of space that there was to work with. Clearances between the shell, cutter bar, and rotating shaft are all extremely tight. To overcome this constraint, the design of the spring plate will have to fit close to the contour of the shell before bending into the proper position to secure the blade. To conform to the symmetry constraint, the parts will lie on the axis in which the knife mounting holes and shell center are on. Therefore, the part is usable for either clockwise or counterclockwise rotation of the shell. The mounting holes will need to be located near the center of the shell to allow for an adequate moment arm. There must be enough leverage available to impose the necessary deflection. Upon completion of visual inspection and idea generation, a preliminary shape was sketched for the designing process. Other design specifications include a pre-sprung load to secure the blade, a required deflection of .015m, and a material that will not yield under the stresses that will be applied to the part.

Three parts will need to be designed to create the spring plate. First, there is the plate. It will have the necessary bends to fit within the shell and bolt holes for mounting. It will also have an open hole in the end that will secure the knife (See Appendix G-1). This hole is for welding in the second part. The second part is the nub, which the blade will be secured to and fit upon. It will be welded to the plate and the extending nub will provide the surface for the knife to rotate on and securing fit into the shell (See Appendix G-2). The third part is the disc insert, which the nub fits into. This part provides a pocket for the nub to set in, securing the blade (See Appendix G-3). Drawings of the assembly of the nub and spring plate and the entire assembly in the New Holland disc can be found in Appendices G-4 and G-5.
The preliminary design was created using AutoCAD. Using the complete current design, also in AutoCAD format, the created shape was designed within the existing shell and cutter bar. Fit could be insured by visual inspection of all the parts assembled together. Also, 10B38 spring steel was preliminarily chosen for the spring plate and the nub due to the need for a higher yield strength. The preliminary choice of material for the disc insert is 4140 steel alloy, since that is what the current insert is made from. Once the part was adjusted to properly fit, the design was sent to New Holland. New Holland has a Finite Element Analysis department, which creates a computer simulation of applied loads and the resulting stresses. The results from their analysis created a model that revealed the locations of the highest stress points (See Appendix I). It also revealed the highest produced stress of 3480MPa, which is based on an inputted applied load of 2670N. This was located in an extremely small area near the bolt holes. Since these stress concentrations are so small, they will not have any significant effect in causing failure. The highest stress seen over the broadest area to be concerned with is 1293MPa, located near at the bend near the bolt holes. These results were based on a .018m deflection and the 1293MPa stress seen is below the yield strength of 10B38 spring steel, which is 1482MPa. This shows that the spring plate will not yield under the deflection it will see during use.

In order to have confidence in the FEA results, a simplified model of the design was created to perform calculations. The part was taken as a fixed-end cantilever beam with the load applied at the end. By modeling it as a beam, the bending stresses will be able to be found, but any torsion the actual part would see will be ignored. Any stress concentrations due to bends, corners, and holes will also be ignored. These simplifications will account for some of the difference between the calculated results and the FEA results. The resulting force required for the .015m deflection was found to be 2797N. The pre-sprung load was also found to be 957N, based on 0.0015m interference. The bending force required was calculated using the distance from the end of the part to the to the mounting holes, which is about .110m. The pre-sprung load force was calculated from the end of the part to the bend before the bolt holes, which is about .073m, since this is where the majority of this deflection will take place. The stress at the mounting holes was then calculated for both the maximum load and the pre-sprung load using the length from the end to the holes as the moment arm. These were found to be 1538MPa and 349MPa respectively, giving an applied stress of 594MPa. The calculated necessary bending force is relatively close in comparison to the FEA results and the calculated bending stresses are within 25% of the FEA results. These similar results give strong confidence in the choice of 10B38 spring steel for the plate and nub (See Appendix H for calculations).

Material Selection

Based on the results from the simplified stress analysis and FEA results, it is evident that the choice of 10B38 spring steel has the properties needed for the applications of the plate and nub. This material, as stated before, has high yield strength and is also heat treatable and weldable. This is necessary so that after forming the metal into the shape of the plate, it can be heat-treated to restore its original high strength. It also must be
weldable so that the plate and nub can be welded together. After reviewing all the results and discussing the matter with New Holland, it was decided that 10B38 spring steel will indeed be the material of choice for the plate and nub since it meets the necessary strength requirements. The disc insert will be made from 4140 steel alloy, which is not quite as strong as the 10B38 spring steel since it will see lower forces and stresses than the other parts. The current insert design is also made from this material, which has proven acceptable to this application. Material properties of both alloy steels can be found in Appendix J.

Manufacturing

There will be two different sets of manufacturing processes used. One set will be for the making the prototypes, which will use less costly methods due to the few that will be produced. The other will be for actual productions, which will involves more costly mass production equipment.

Producing the prototypes will involve using breaks to make the bends and curvature of the plate. Prior to bending, the blanks will be cut out using their 3-D laser router and will then be annealed to prevent breakage during cutting of the blank and forming. Once it has been formed, a hole for the nub, that will secure the blade, will be machined. The nub will be made using a lathe and will then be welded into place, but this procedure first requires preheating of the material to prevent any heat damage. The disc insert will also be made on the lathe and then welded to the shell using the same procedure as the nub. After assembly is complete, the parts will undergo a heat treatment to give the material the required strength properties.

When producing this part in mass quantities, dies will be used to form the plate. Dies are a costly expense, but are justified by the quantities that will be produced. The nub and disc insert will be made using automated CNC lathes. As before, the material will first need to be annealed before forming and preheated before welding. The rest of the proceeding steps remain the same.

Cost Analysis

Another calculation that was completed in our design analysis was the additional cost of the spring plate per unit. First, the cost of manufacturing each one was computed and found to be $2.69. This cost includes the amount of material needed, heat treatments, and manufacturing processes. Next, the assembly cost was considered by including the cost of the two bolts, nuts, and washers, which are required to attach the spring plate to the disc. This cost came to a total of $0.30, bringing the total cost of the leaf spring assemble to $2.99.

In order to calculate the additional cost of the spring plate, the current bolted connection cost had to be evaluated. Through talks with New Holland, this price was found to be $2.15 and includes the bolts, nuts, and protectors currently being used to attach the knife. Finally, the difference between the spring plate assembly cost and the current bolted connection cost is $0.84.
connection cost was taken in order to show the additional cost of this part to New Holland. This additional cost was found to be $0.84.

This price per unit is higher than specified in the target values, which was a total cost of $2.50. However, with re-examination of the material selection, refining of the manufacturing processes, and production of the spring plate assembly in large quantities, the price per unit will decrease enough to meet the desired target value.

Verification Testing

The testing required for this project consisted of fulfilling each of the wants, or desirable qualities that the chosen design must satisfy. This was done by verifying that the prototype met the metrics and target values chosen at the beginning of the design process. If the prototype design did not meet a specific target value, then a recommendation for improvement was developed to correct the design’s shortcomings. The following chart is a list of the wants, metrics, target values, tested prototype results, and design improvement recommendations if needed. Each specific test and its results are described in depth after the chart.

<table>
<thead>
<tr>
<th>Wants</th>
<th>Metric</th>
<th>Target Value</th>
<th>Prototype</th>
<th>Design Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secure Knife</td>
<td>Pre-load (lbs)</td>
<td>100</td>
<td>215</td>
<td>N/A</td>
</tr>
<tr>
<td>Reduce Changing Time</td>
<td>Seconds</td>
<td>90</td>
<td>15</td>
<td>N/A</td>
</tr>
<tr>
<td>User Friendly</td>
<td>No. Tools</td>
<td>1</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>No. Parts</td>
<td>&lt;= 5</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Fit/Clearances</td>
<td>Interference</td>
<td>None</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Knife Rotation</td>
<td>Angle of Rotation (º)</td>
<td>270</td>
<td>270</td>
<td>N/A</td>
</tr>
<tr>
<td>Total Cost</td>
<td>Dollars</td>
<td>2.50</td>
<td>2.69</td>
<td>Refine Manufacturing Process</td>
</tr>
<tr>
<td>Design Adaptation</td>
<td>No. Changes to Current Design</td>
<td>&lt;10</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>Fits CW/CCW Discs</td>
<td>Degree of Symmetry</td>
<td>Perfectly Symmetric</td>
<td>Perfectly Symmetric</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The highest priority want for this project was to secure the knife, for safety and crop cutting reasons. The pre-load applied to the spring plate prototype was chosen as the metric to measure this want because the steel plate had to impose an upward force to secure the knife in place on the disc. Discussion with the sponsor and research into the type of loads that the spring plate would see, lead to a target value of 100 pounds of pre-
load. The spring plate was intentionally interfered with the disc so that when it was bolted in place it would be deflected 1.5 mm. The interference can be seen on a close up assembly drawing of the spring plate and disc (See Appendix K-1). By the simple calculation performed above in the Results section (See Prototype Design, Page 10), the pre-load applied to the knife by the spring plate was found to be 957 N or 215 pounds. Therefore, our tested prototype value exceeded our target value and design improvements were not needed.

Another important want was to reduce the changing time of the knives on the disc mower. The metric chosen to measure this want was seconds of the total cycle change time, which includes removing the knife from the disc and securing it back into operating position. After twenty trials of removing and replacing the knife on the disc mower with current bolted connection, the average changing time was found to be 90 seconds. The target changing time chosen was 45 seconds, half of the current changing time. With the prototype spring plate design, the knife was removed and replaced a total of fifty times to compute an average changing time, which improved to 15 seconds, thirty seconds below the target value. This satisfied the metric by being less than the target value, and therefore, design improvements were not needed.

Making the design user-friendly was a want with several metrics that could measure it, including seconds to change the knife, number or tools, and number or parts. Since the seconds to change the knife had already been verified for another want, the number of tools and parts were chosen as additional metrics to satisfy user-friendliness. The number of tools used on the current design is three, including the pry bar used to keep the discs from rotating while loosening the bolt, the socket, and the wrench. The target value was set as one because it was a the teams’ desire as well as New Holland’s to reduce the amount of hardware and tools that needed to be carried around on the disc mower. With the prototype design, only one tool is needed. It is a specialized tool that is similar to a pry bar (See Appendix K-2). Therefore, the target value of one tool was met and no design improvements were needed. The number of parts on the current bolted connection is three, including the bolt, specialized nut, and bolt protector used to keep certain bolts from wearing. The target value was chosen to be less than or equal to five, which was decided after the benchmarking process. Through research, it was found that a type of clamping mechanism was most likely going to be the chosen design, and this type of design would include a total of five parts, a clamp, two bolts and two nuts. The prototype followed this prediction exactly. The spring plate is the major part of the design and it is attached to the disc with two bolts and two nuts, a total of five parts (See Appendix K-3). The number of parts on the prototype meets the target value exactly, which means that design improvements are once again not needed.

Another want or constraint that the design had to satisfy was to have no interference with other hardware while the disc rotates. The target value was then naturally set to be no interference. Unfortunately, with the model of cutter bar that our team was working with, there was interference on one spot of the discs rotation. However, when the spring plate was installed at New Holland in a newer model disc mower, there was no interference. After clearing the issue with the sponsor, the small issues with interference that were
occurring will not be a problem with the current and future models of New Holland disc mowers. Therefore, the target value was met and no design improvements are needed.

An aspect of the current design that was required to stay the same was that the knife is able to rotate around the bolted connection. This is done so that if a rock or other hard object strikes the knife while it is in operation, it is able to rotate underneath the disc for protection. The current design rotates approximately 300°, but in order for the knife to be completely underneath the disc a rotation of only 270° is needed, and therefore, this angle was set as the target value. The prototype allows for 270° of rotation, which protects the knife and eliminates the need for design improvements.

The total cost of the design is a large concern for New Holland because it must be cost effective to the company. $2.50 is the target value that was set by New Holland, and our prototype spring plate design comes to a total cost of $2.69. This includes $0.70 for the plate, $0.64 for the nub, and $1.35 for the heat treatment as explained above (See Cost Analysis, Page 12). This number is $0.19 over the target value, but by continually refining the manufacturing processes and eventually mass producing the parts, it is very likely that the cost will be brought down to within the originally set limits.

Another want that New Holland expressed was to make the spring plate design adaptable to their disc and cutter bar. The metric chosen to measure this want was the number of modifications to the disc assembly, and the target values was set to less than ten after conferring with the sponsors. The prototype design only needs to have three modifications made to the assembly for adaptation purposes. The first of these are the holes that need to be drilled into the disc where the spring plate attaches. The second modification is that the disc insert that is currently welded into the disc must be modified. This insert was also designed as part of this project because it needed to have a seat in it for the nub of the spring plate to fit into (See Appendix G-3). The last modification is that the lifter mechanism that is used to left crop must be modified because it currently attaches at the bolt, which also attached the knife. The disc insert that was designed corrects this problem on the disc itself because it was design with grooves in it for the lifter to screw in. However, the lifter itself must still be modified. Appendix K-4 identifies each of the design modifications.

The discs on the New Holland disc mowers rotate both clockwise and counter clockwise. This is done so that when a disc wears from crop constantly rubbing on one side, its rotation direction can be reversed, exposing an unworn face of the disc. This prolongs the life of the discs on the mower. In order for the prototype design to accommodate for both rotation directions, the prototype must be perfectly symmetric, which is the target value for the degree of symmetry metric. As can be seen in Appendix K-5, the two spring plates that are assembled on a disc are perfectly symmetric, thus satisfying the target value and eliminating the need for design improvements.
Hand off Package

Future Testing

Team 9 strived to verify the validity of the design with the resources available. At this point in the design stage, it is not possible to test the spring plate on a full mower due to minor changes to a spacer. Therefore, New Holland will conduct further testing at their facilities. They also have to ability to test in real field conditions.

One of the safety tests is a toughness test. The mower will be run through piles of wood and rocks. This test is to confirm that the spring plate can handle impact without breaking. It will also prove that the plate is not too brittle and will not crack under such circumstances.

The design will also be put through an actual field test. This will verify that the spring plate is still functional after a pre-determined number of hours. It will also show to what extent the design collects crop and mud. The durability will be examined as well.

Drawing Package

The design consists of three new parts: the spring plate, the nub, and the disc insert. Detailed, dimensioned drawings of each part are included as Appendix G-1, 2, and 3, respectively. Appendix G-4 gives the assembly, with the nub weld into the spring plate. The entire system, including the disc, cutter bar, and spring plate are shown in Appendix G-5.

Future Design Modifications

Generally, the spring plate fits well into the rest of the system. To fit the curvature of the disc better, the top corners of the spring plate should be rounded. Also, some of the material used as a spacer between the disc assembly and cutter bar will be removed for a better fit.

Time Line

New Holland will conduct their field tests, likely beginning this coming May, for the next two years. The quick-change knife could be put into production as early as 2005.
References

Many of the references are experts in the area of disc mowers and farm equipment in general.

Melanie Harkcom- Design Engineer, New Holland
Ed Priepke- Design Engineer, New Holland
Levi- Field Engineer- New Holland
Jim Miller- Dealer/Mechanic- Triple H
Representative from Ag-Industrial Co.- Dealer
Dr. Wilkins- Advisor, University of Delaware

Reference Websites

www.newholland.com
www.howtouseaquickrelease.html
www.avibank.com/pindet.html
www.rickethockey.com/frames.html
www.innovative-dsgn-sol.tripod.com
www.usinventionpatenting.com

Numerous patents and drawings were also provided by New Holland for reference research.
Appendix A - New Holland Disc Mower Pictures

1. Cutter Bar

2. New Holland Disc

3. Current Bolted Connection
Appendix B- Schedule

<table>
<thead>
<tr>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
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<td>12/16</td>
<td>12/23</td>
<td>12/30</td>
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- **Problem Statement**
- Customers
- Wants
- Constraints
- **Benchmarking**
- Concept Generation
- 9/26
- **Concept Selection**
- Feasibility Model
- Build Prototype
- 11/23
- **Concept Selection**
- Feasibility Model
- Build Prototype
- 11/28
- Verification of Metrics
- Hand off Package
- 12/8
Appendix C- New Holland Disc Assembly Drawing
### Appendix D - Wants, Metrics, and Target Values

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<tr>
<th>Wants/Constraints</th>
<th>Metrics</th>
<th>Target Values</th>
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<tr>
<td>Secure Knife</td>
<td>Pre Load (Pounds)</td>
<td>100 lbs</td>
</tr>
<tr>
<td>Reduce Changing Time</td>
<td>Seconds</td>
<td>45 s</td>
</tr>
<tr>
<td>User Friendly</td>
<td>No. Tools</td>
<td>1</td>
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<tr>
<td></td>
<td>No. Parts</td>
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<tr>
<td>Fit/Clearances</td>
<td>Interference</td>
<td>None</td>
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<tr>
<td>Knife Rotation</td>
<td>Angle of Rotation</td>
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<tr>
<td>Total Cost</td>
<td>Dollars</td>
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<tr>
<td>Design Adaptation</td>
<td>No. Changes to Current Design</td>
<td>&lt;10</td>
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<tr>
<td>Fits CW/ CCW Discs</td>
<td>Degree of Symmetry</td>
<td>Perfect</td>
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Appendix E- Kevernland Photograph.

1. Kevernland Disc

2. Kevernland Clamp

3. Close-up of Kevernland Clamp
Appendix F- Possible Design Solutions

1. Hinged Clamp- Possible Design Solution

2. Bolted Clamp- Possible Design Solution

3. Slotted Knife- Possible Design Solution
Appendix F Continued- Possible Design Solutions

4. Side Clamp Design assembled in New Holland Disc

5. Side Clamp
Appendix G- Drawing package

1. Spring Plate Design
2. The nub to be welded into the spring plate.
3. Disc insert to be welded into the New Holland Disc
4. Spring plate with nub assembly.
5. New Holland disc with one spring plate assembled.
Appendix H - Calculations

Force required for .015m deflection (using mild steel):
- modeled as a straight, fixed-end cantilever beam
- ignored torsion

\[ y = \frac{F l^3}{3EI} \quad I = \frac{bh^3}{12} \]

\[ I = 4 \times 10^{-4} \text{ mm}^4 \]

\[ y = .015 \text{ mm} \quad E = 206.8 \text{ GPa}, \quad b = .075 \text{m h} = .004 \text{m} \]

Lengths were taken at the bend where most of the bending will most likely occur

Solving for \( F \) using a .015m deflection:

\[ F = 2797 \text{ N} = 629 \text{ lbf} \]

Pre-Sprung Load:
\( y = .0015 \text{m} \), \( l = .073 \text{m} \)

\[ F_{\text{preload}} = 957 \text{N} = 215 \text{lbf} \]

Stress Calculation:

\[ \sigma = \frac{Mc}{I} \]

\[ \sigma_{\min} = \frac{4 E - 10}{(957)(.073)(.002)} = 349 \text{ MPa} \]

\[ \sigma_{\max} = \frac{4 E - 10}{(2797)(.110)(.002)} = 1538 \text{ MPa} \]

\[ \sigma_o = 594 \text{ MPa} \]

- below 10B38 yield strength (1482 MPa)
Appendix I- Finite Element Analysis

Analysis done with 600 lb load downward at the free end of the plate resulting in a displacement on .73”
## Appendix J- Material Properties

### Material Properties

**1. Steel Alloy 10B38**

<table>
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<th>Property</th>
<th>Steel Alloy 10B38</th>
<th>Unit</th>
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<tr>
<td>Yield Strength</td>
<td>1482 MPa</td>
<td>215 ksi</td>
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<tr>
<td>Modulus of Elasticity</td>
<td>207 GPa</td>
<td>30 x 10^6 psi</td>
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<tr>
<td>Density</td>
<td>7.83 g/cm^3</td>
<td>0.283 lb/in^3</td>
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</table>

**2. Steel Alloy 4140**

Oil-quenched and tempered (@315°C)

<table>
<thead>
<tr>
<th>Property</th>
<th>Steel Alloy 4140</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Yield Strength</td>
<td>1570 MPa</td>
<td>228 ksi</td>
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<tr>
<td>Tensile Strength</td>
<td>1720 MPa</td>
<td>250 ksi</td>
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<tr>
<td>Percent Elongation</td>
<td>11.5%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>207 GPa</td>
<td>30 x 10^6 psi</td>
</tr>
<tr>
<td>Density</td>
<td>7.85 g/cm^3</td>
<td>0.283 lb/in^3</td>
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<tr>
<td>Fracture Toughness</td>
<td>60 MPa/m</td>
<td>55 ksi/in</td>
</tr>
</tbody>
</table>

Composition (wt%): 96.8 Fe (min), 0.40 C, 0.90 Cr, 0.20 Mo, 0.9 Mn
Appendix K - Verification Testing

1. Side view of disc assembly. Circled section shows the intentional interference.

2. Tool used to remove knife

3. Five parts shown along with the knife and overturned disc.
4. Circled portions show modifications to the disc assembly.

5. Top view of spring plate/disc assembly showing symmetry.