Dean Kelley
Forrest Fanara
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Forest Concepts - Sub-millimeter Rotary Shear Clearing Plates

Introduction:

Over the course of our college careers, we have completed many interesting projects that have required ourselves to think in new ways to solve problems. The project that we undertook for Forest Concepts, designing a new clearing plate for their sub-millimeter rotary shear system, gave us the opportunity to use the problem-solving strategies that we have developed throughout our education, along with our skills in creative and technical design.

Forest Concepts is working with Washington State University to produce biofuel from reclaimed biomass. To convert this biomass into fuel most efficiently, it is important for the chemical reaction that the material be processed into small particles to increase the overall surface area. To achieve this, Forest Concepts has developed a rotary shear that is capable of shredding wood chips into sub-millimeter particles. The problem they face is that the small particles quickly clog the cutting device and cause it to fail. To combat this, they have attempted to develop a set of clearing plates to remove the material. While their plates aid in removing material, it only allows the machine to operate approximately 10 to 20 hours before it fails.

Our goal is to design a clearing plate that can extend the life of the rotary shear. On top of this goal, we also wanted to design a plate that could be replaced more efficiently, and enable the cutting shears to be run in reverse.

The following report describes the methods and processes used to complete this project and the unanticipated problems that caused delays in the progress of the project. An analysis of each individual team member's contributions is also covered. Lastly, a description on how standards were used in the process of completing the senior design project.

Body:

When starting the project, the team focused on the issue of friction that occurs on the clearing plate. Since the clearing plate rests on the bushing of the blade there is an immense amount of friction force on the tip. To overcome this friction and increase the strength of the clearing plate it

was decided that a steel material would be used. However, steel has a relatively high friction coefficient, so metal coating plating was researched. The team emailed about six or seven companies for different plating types to get an estimate on the cost of plating. Only two companies responded to the quote requests. One company stated that coating 192 clearing plates with Nye-Tef the cost would be $816 and the other company quoted a total cost for hard chrome being $1,142.40. It would have been excellent to have the other companies respond to our inquiries so more comparisons could have occurred; however, with the two estimates it was clear that the plating option was too expensive. Thankfully, a small amount of time was spent in plating, so it did not affect with the team's timeline.

The next delay that the team encountered was when the design of the new clearing plate began. During the beginning of the project the team only had meetings on school assigned days and worked in the senior design center. However, for the first month of school in spring semester the design center was not updated to the newest edition of SolidWorks. The SolidWorks that Washington State University provides is the 2016 SP 2 edition, Forest Concepts used the 2016 SP 5 edition. Both editions were not compatible with each other or with the 2015 version in the lab. Therefore, the work that the team performed at home could not be shared during meeting or continued at school due to the compatibility issue. The impact of this issue led to little progression on the design of the clearing plate and somewhat loss in motivation to working on the project at school. There were a few resolutions to this issue. First was saving it in a 2015 SolidWorks compatible STL file; however, this caused the large assembly file to lose all mating and required that someone from the team remate all parts. Another alternative we found was streaming the team's home computers to the member's respective surface tablet. This allowed us to access the models and work in a productive manner. The only problem with this method is that streaming requires a lot of bandwidth which caused lag when working. One resolution to that was working from home and messaging each other online.

One major issue that is continuing is the faulty Wi-Fi service in the senior design center. The Wi-Fi in the room is terrible which leads to continuing drops of service throughout every meeting. Supposedly the wireless router is behind a metal beam which is causing this to happen. The impact of this happening is loss in motivation and irritation due to the inability of working forward on the project. Unfortunately; there hasn't really been a resolution to this issue and the team is just working through it and getting as much work done as possible.

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The team consists of Ian Aupperle, Loren Bonner, Forrest Fanara, and Dean Kelley who all contributed to the design project. The Gantt Chart was not followed extensively, but it was used as a somewhat roadmap or guide to help with the design process of the project.

The first team member being discussed is Ian Aupperle. Ian has dedicated a total of _____ hours towards the project. At the beginning of the semester he researched and found quotes on the possibility of metal coating on the clearing plates. After the idea was deemed unfeasible, Ian ran SolidWorks simulations with alternative materials using the same fixtures and clearing plate profile that was provided by Forest Concepts. After the current model was studied, he began working with Forrest in researching flow simulations in SolidWorks with the hopes of running an abrasion/erosion plot. However, through much research, it was found that it could not be done accurately. Meanwhile, he also researched alternative materials and ran stress simulations on a current clearing plate design with custom materials. When the spacers were found impossible to use because of tolerance issues, the sponsor suggested to look into Smalley Springs, 3D metal printing. He also suggested performing a sensitivity analysis with the different materials. So, Ian researched these topics and found that the springs and 3D metal printing wasn't an option. And since the 1095 spring steel was superior to every other alternative material a sensitivity analysis wasn't required. Ian then started on the sponsor report outline so the paper can become as organized as possible. Ian also contributed with ideas for the poster. He also heavily contributed to the class and sponsor report. Karen requested that all groups construct 3 Power Point slides that gives a general description of our project which Ian created. He also helped develop the Powerpoint, setting up the visual aid model, and practiced the presentation with the group for a long period of time.

The next team member being discussed is Dean Kelley. Dean had dedicated ___ hours toward the project over the course of the semester. In the early stages of the project, he aided in researching different materials and pricing for electroplating before the team decided against plating due to cost. Dean primarily spent a large portion of this time working with Forrest on clearing plate designs, plate mounting designs, and running simulations to test the designs for different materials. After early attempts to understand how Forest Concepts set up their static study simulations, he devised a method to more accurately calculate results by setting up non-penetrating fixtures that would contain the clearing plate models. Dean had produced several

different clearing plate designs that proved to handle the stress well in the simulations. Ultimately, a clearing plate design produced by Dean was used as the product that would be presented to Forest Concepts. He had several plate mounting designs that were considered before the team ultimately decided on Forrest's design using hitch-pins. Dean contributed to the presentation PowerPoint slides pertaining to rotary shear applications, and the setup, configuration, and analysis of SolidWorks simulations.

The third team member being discussed is Forrest Fanara. Forrest has dedicated a total of _____ hours towards the project. The first task Forrest worked on was running the existing simulations that Forest Concepts provided with their prototype clearing plate files to get an idea of the factor of safety, stress, and deformation that the original clearing plate design was subjected to. Next, he worked on improving the team contract, and building our time sheet that makes use of google forms, and logs times into an Excel spreadsheet. He then focused on getting quotes from plating companies and successfully got a quote on hard chrome plating all 192 clearing plates. At several of the early team meetings the team ran into problems with SolidWorks being the wrong version in the design studio, so Forrest used time outside of team meetings to import the file as an STL and rebuild the entire assembly into an older version of SolidWorks. He also contributed by researching fatigue studies in SolidWorks as well as using particle injections in flow simulations to model abrasion, after much research these methods were not used due to fact that SolidWorks is not intended for abrasion simulation. To get an idea of the abrasion resistance of materials the Brinell hardness of each material was compared instead. Forrest participated in all the conferences with the sponsor, and was the main point of contact with the sponsor throughout the project. He also filled out the majority of the assessments while the team helped with input on the assessments. Forrest assisted Dean with designing multiple different clearing plate designs and mounting systems, and ultimately Deans design was used for the final clearing plate. Forrest designed the hitch pin mounting system, based on input from the sponsor, that was used in the final design while utilizing a mounting location that Dean had come up with in a previous design iteration. Forrest also designed the final C-clip spacer concept that utilizes 3D printing with a high-resolution 3D printer so that tolerance stacking is not an issue. Forrest also contacted Bruce from DS&T, and set up a meeting so that the team could get a quote on the cost of waterjet cutting each clearing plate. Bruce from DS&T was also nice enough to produce a prototype of our final clearing plate for free. In order to get Bruce the materials and information he needed to waterjet cut the final prototype Forrest created a part drawing to bring in during the meeting with Bruce,

and eventually converted the part file to a DXF file in order for it to be waterjet cut. Forrest researched several different materials with the help of Ian, and they both ran simulations on them to determine the best material for the job, Fully Hardened 1095 Steel. Forrest researched several different suppliers, and the team all pitched in to purchase a few sheets of 1095 steel, so that a prototype could be made. Forrest also pitched in and researched the hardening process and what goes into the process from a material science standpoint. Forrest also helped design the poster, presentation, PowerPoint, and worked on several parts of the paper. Finally, Forrest designed the model of the cutters and clearing plates that can be seen below. He made the wooden base and attaching rods, and the entire team helped during the 3D printing process of the clearing plates and cutters.

The last team member being discussed is Loren Bonner. Loren has contributed a total of ___ hours toward this project. As with a lot of other team members, the first thing Loren did was research on alternate clearing methods (there were none), different types of material strengthening methods such as metal coatings and analyzing what needs to be improved upon on the original clearing plate system. After the group was done with researching, Loren created the first new mounting system design with a new approach to securing clearing plates. As the rest of the group started to work on a clearing plate system that uses double sided plates, Loren continued to work on the single sided system for shredders that use single sided blades. During the process of developing a single sided clearing plate system that is practical, Loren took a few closer looks at what is causing a lot of the damage during the shredding process which was the friction of the clearing plates on the blades. This is where Loren first came up with the idea of spacers between the clearing plates and the cutting blades. Some time was spent trying to figure out how to use full sized plate spacers between the clearing plates but unfortunately, they were

not practical. Forrest came up with the final design for the spacers which was the 3-D printed plastic C-clip design. Loren finished the single sided clearing plate design which has a similar, but superior, mounting method as the double-sided design. The double-sided design went on to be the main design and the single sided design is presented as an alternate method when the shredder cannot run in reverse.

For more information on what was done by each team member see the attached Excel file that covers the hours spent on the project by each team member, what was worked on, total time spent on the project, and percentage of total hours each team member contributed.

We thought about the safety of the operator of the rotary shear machine. Therefore, safety standards had to be researched for this project. The color coding on the clearing plates was to give the operator some contrast between the clearing plate and cutters so he/she does not injure themselves to the exposed cutter. However, according to the OSHA standard uncer 29 CFR 1910.144, “there are specific color-coding requirements for items such as safety cans or other portable containers of flammable liquids and for devices such as emergency stop buttons, switches, and bars, but beyond that, the standard does not specify what machines or portions of machines need to be color-coded” (Podojil & Fairfax). Later, the standard states that it is up to the employer/manufacturer to color code sections of the machine. Therefore, it would be recommended by us to color code the clearing plates where the blades are exposed to help protect the user/operator. Since the machine uses rotating cutters, the OSHA standard 1910.145 must be upheld. This standard states that there must be a form of accident protection through the use of a danger, caution, and/or warning sign. Therefore, we recommend on the machine that a warning sign of some type be posted.

Conclusion:

In conclusion, this entire team learned a lot throughout this senior design project. Some of the key things learned throughout this process are the importance of hard work, communication among team members, professionalism when speaking with the sponsor and outside entities, and the importance of documenting your work while it’s being completed. One of the biggest issues we ran into was trying to go back and document our design progression at the very end when the report needed to be written. In the future, it would be extremely beneficial to write the report for a

project as it's being completed instead of waiting till after the project has been completed like we did. One of our proudest moments in the completion of this project was moving from our design and analysis into the production of our first prototype clearing plate by networking with DS&T to get the prototype waterjet cut.

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References:

Podojil, John F., and Richard E. Fairfax.*United States Department of Labor*. OSHA, n.d. Web. 28 Apr. 2017. <https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24636>.

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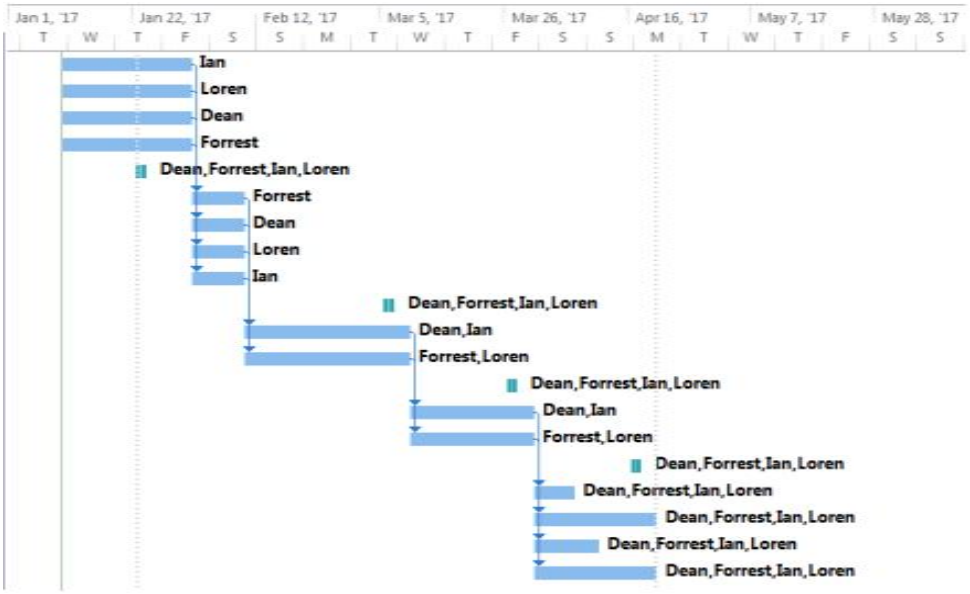
Proposed Timeline:

Task Name	Duration	Start	Finish	Resource Names
Research Possible Alternative Designs	16 days	Tue 1/10/17	Tue 1/31/17	Ian
Researching Plating/Coating	16 days	Tue 1/10/17	Tue 1/31/17	Loren
Researching Manufacturing Methods	16 days	Tue 1/10/17	Tue 1/31/17	Dean
Researching Materials	16 days	Tue 1/10/17	Tue 1/31/17	Forrest
Assesment 1	1 day	Mon 1/23/17	Mon 1/23/17	Dean,Forrest,Ian,Loren
Researching Tip Geometry	7 days	Wed 2/1/17	Thu 2/9/17	Forrest
Researching Edge Geometry	7 days	Wed 2/1/17	Thu 2/9/17	Dean
Researching Interface with Bushing	7 days	Wed 2/1/17	Thu 2/9/17	Loren
Researching/Designing Multiple Component Clearing Plates	7 days	Wed 2/1/17	Thu 2/9/17	Ian
Assesment 2	1 day	Mon 3/6/17	Mon 3/6/17	Dean,Forrest,Ian,Loren
Generating Clearing Plate Prototypes in SolidWorks	20 days	Fri 2/10/17	Thu 3/9/17	Dean,Ian
Prototyping Alternative Mounting Methods in SolidWorks	20 days	Fri 2/10/17	Thu 3/9/17	Forrest,Loren
Assesment 3	1 day	Mon 3/27/17	Mon 3/27/17	Dean,Forrest,Ian,Loren
Conducting/Interpreting FEA on Prototype Plates	15 days	Fri 3/10/17	Thu 3/30/17	Dean,Ian
Conducting/Interpreting FEA on Prototype Mounts	15 days	Fri 3/10/17	Thu 3/30/17	Forrest,Loren
Assesment 4	1 day	Mon 4/17/17	Mon 4/17/17	Dean,Forrest,Ian,Loren
Creating Poster	5 days	Fri 3/31/17	Thu 4/6/17	Dean,Forrest,Ian,Loren
Production/Testing	15 days	Fri 3/31/17	Thu 4/20/17	Dean,Forrest,Ian,Loren
Generating/Preparing for Presentation	7 days	Fri 3/31/17	Mon 4/10/17	Dean,Forrest,Ian,Loren
Generating Reports	15 days	Fri 3/31/17	Thu 4/20/17	Dean,Forrest,Ian,Loren



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Actual Timeline:

Task Name	Duration (Days)	Start	Finish
Ran Existing Simulations and Redisigned Assembly in Older SolidWorks Version	29	12/21/16	1/19/17
Researching Plating/Coating	7	1/12/17	1/19/17
Researching Alternative Clearing Methods	7	1/12/17	1/19/17
Designing Mounting Brackets	63	1/19/17	3/23/17
Researched Solidworks Analysis Methods	8	1/27/17	2/4/17
Single Sided Clearing Plate Design	70	1/26/17	4/6/17
Spacer Design	51	2/23/17	4/15/17
Researched Materials	61	1/24/17	3/26/17
Double Sided Clearing Plate Design	35	2/4/17	3/11/17
Double Sided Clearing Plate Analysis	54	3/7/17	4/30/17
Waterjet Cutting Prototype	24	3/13/17	4/6/17
Cost Analysis	4	3/26/17	3/30/17
Designing Display Model	15	4/8/17	4/23/17
Creating Poster	15	4/2/17	4/17/17
Creating PowerPoint and Presentation	25	4/2/17	4/27/17
Generating Reports	38	3/26/17	5/3/17

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Timesheet of Logged Hours: