Spring 2016

H.F. Hauff Pruner Cutting System

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Recommended Citation

Gibson, Daniel J., "H.F. Hauff Pruner Cutting System" (2016). *All Undergraduate Projects*. 17.
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H.F. Hauff Pruner: Cutting System

Daniel Gibson

Partners:
Erich Heilman - Housing and Ergonomics
Thomas Wilson - Power and Transmission

Table of Contents

INTRODUCTION

Motivation

Founded in 1947, H.F. Hauff Company Inc. of Yakima, Washington has been a nation-wide manufacturer and distributor of specialized agricultural equipment. The company is constantly striving to provide quality, dependable products using innovative technological advancements and the highest engineering standards. The company's president, Neil Hauff, is the driver behind this innovation. Neil's efforts towards perfection and customer satisfaction are the motivation behind this project.

Neil Hauff was approached by a Greek organic orchardist, Emmanuel Maniadakis. Emmanuel approached Neil with his Pellenc Treelion D45-900 battery-powered pruner and he explained the issues he has with the current design.

After operating for a long time, the linear actuator which provides cutting force becomes too hot for the operator to hold the housing surrounding the actuator, even when wearing gloves. The current reach of the pruner is also not sufficient. The single-finger trigger is difficult to operate when wearing gloves and causes discomfort on the operator's finger after pruning for a long time. Emmanuel would prefer a four-finger trigger (hand trigger) similar to the triggers found on pneumatic tools. With the current pruner, a cut is made by holding down the trigger until a cut is made and then letting go of the trigger. Emmanuel needs a cut to be made by only pressing the trigger once, momentarily.

The new design will eliminate the heat issue with the current pruner actuator and housing. The new design will also have a longer reach. The single-finger trigger system will be replaced with a new trigger system that is more comfortable for the operator and easier to operate with gloves. For the new design, a cut will be made by pressing the trigger once, momentarily. However, Emmanuel is satisfied with the current power supply system, a 44 V DC battery belt.

Function Statement

Function statement #1 applies to the new pruner design in its entirety. Function statement #2 applies to the cutting system of the new pruner design.

1. H.F. Hauff Pruner (Entire Pruner):

- A device is needed which can cut branches all day without overheating.

2. H.F. Hauff Pruner: Cutting System:

- A device is needed cut through apple tree branches, such as those found in an apple orchard.

Design Requirements

The design requirements for the pruner, as a whole, are as follows:

- The power system must use a 44 V DC power supply (as per customer)
- The power system must be able to supply a force to the pruner blade which can cut at minimum a 1.60-in diameter branch.
- The weight of all power system components must be no greater than 7 lbs.
- The power system components must be able to fit inside a 1.60-in inner-diameter housing.
- At least 50% of the power system components' weight must be positioned directly over the trigger system for ergonomic balance.
- When the power system is operating at a pruning rate of 250 1.60-in diameter branches/ hour, the components must not exceed a temperature of 110 degrees F.
- The pruner power system must provide at least 450 lbs of force to the pruner blade.
- The cutting power system must supply cutting force for 6 hours when pruning at a rate of 300 1.60-in diameter branches/ hour.
- After a cut is initiated by the operator, the cut cycle must be no longer than 2.0 seconds. (as per customer)
- The cut cycle must be initiated by a single, momentary pull of the trigger. (as per customer)
- The trigger must be designed so 4 fingers are used to operate it. (Hand trigger) (as per customer)
- The cost of all power system components must be no greater than $500.

The design requirements for the cutting system of the pruner are as follows:

- As requested by the customer, the cutting system must employ a blade and anvil assembly - as found on manual tree loppers.
- The blade must cut through a branch with a maximum diameter of 1.60 inches.
- As requested by the customer, the blade and anvil must be made of nickel titanium (nitinol).
- The blade and anvil must have a geometry capable of producing the maximum shear at the branch's maximum width.
- The cutting system must be capable of disassembly in less than three minutes with a common size screw driver.
- The cutting system must weigh less than 3 pounds.
- The cutting system must not exceed, in any position of the cutting cycle, the boundaries of a 6-in x 6-in x 6-in cube.
- As requested by the customer, the blade and anvil geometry is to be based on the design found on the Fiskars PowerGear manual tree lopper.

Engineering Merit

It is most important that the new pruner design is ergonomic. This is going to be achieved through overall weight, balance (weight kept near the handle), and a re-designed trigger system. However, the new design must also adhere to the design requirements regarding power capability, operating temperature, and reach of the pruner. For the cutting system, it is most important that it produces enough shear to cut through the branch. This is to be achieved through linkages and geometry of the blade and anvil. To determine the amount of shear force the blade can produce, the equation $F = \tau_{ult}A$ (τ_{ult} is the ultimate shear strength of the branch and A is the cross-sectional area of the blade edge) is utilized.

Scope of Effort

The scope of this document is focused on the cutting system of the automated tree pruner for the H.F. Hauff Company. Effort is mostly directed towards the geometry of the blade and the mating anvil. This is for two reasons: 1) The geometry determines how well a branch can be cut - with a blade shaped to generate an asymmetric shear and an anvil shaped to prevent the branch from sliding out of the cut; and 2) With a specified material desired by the customer, it is possible to know exactly how much a certain volume of material will cost.

Success Criteria

The cutting system for the pruner will be successful if it cuts through branches with diameter of at least 1.750 inches, if the blades retain sharpness for at least 700 hours of continuous operation, and if it cuts through the entire thickness of the branch in one cutting cycle.

DESIGN & ANALYSIS

Approach

While the main issue of this project is to have a device to cut through a branch in one cutting cycle, the first step is to have a branch be able to fit into that device.

Design Description

The design of the cutting system fuses the linkage-rod power transmission of the Treelion pruner with the blade and anvil geometry of the Fiskars PowerGear. The minimal use of linkages in the Treelion allows for a more compact shape. The “hooked” anvil shape of the Fiskars prevents the branch from slipping out of the cut, reducing the need to “push” the pruner into the branch to finish the cut.

The original intention was to design a blade and anvil from scratch. This decision was made so that the geometry could be customized to fulfill the objectives of this project. For the blade, a simple rectangular shape with a slight curve for a blade edge served as the foundation for the design. Through testing and calculations, the curve could be optimized through linearly offsetting. The anvil has a hook-like shape to prevent the branch from slipping out of the cut. The result of this process is shown in Figure 1, which shows the cutting system open and closed with a 1.60-in circle as reference for the branch.

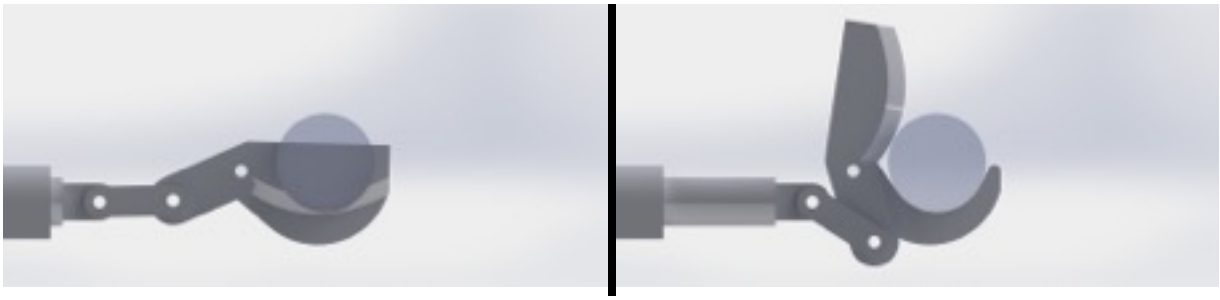


Figure 1

An idea to add to the design in Figure 1 was to create a four-bar linkage, in hopes to amplify the force of the actuator. This idea was abandoned due to the amount of space required to fit the four-bar linkage. After encountering complications with the custom blade geometry (not getting the right clearance to fit a tree branch or not cutting through the entire branch), it was decided to take the blade and anvil from a consumer tree lopper. This way, the electric pruner would utilize a proven blade and anvil geometry. The result of this effort is shown in Figure 2.

Figure 2

Benchmark

The benchmark for this project is a French-made electric tree pruner (Pellenc Treelion D45-900) that is currently in production for similar applications. This tree pruner is a powered by an electric, linear actuator which drives a rod which pulls the blade into the anvil. To cut a 1.60-in diameter branch, the Treelion requires multiple cutting cycles. Since the desired operation is to cut through a branch in one cycle, the blade and anvil geometry of the Treelion is discarded in favor of a new design.

Performance Predictions

The cutting system is designed to operate with an electric linear actuator which supplies 600 pounds of force. This will allow the blade to cut through the widest portion of the 1.50-inch diameter branch. Should failure occur, it will be at the pin holding the blade to the anvil. The situation that would cause this is if the blade is unable to cut through a particular branch, causing a high load from the actuator and a high reaction from the branch to shear the pin.

Description of Analysis

The analyses performed are stress calculations of the blade, anvil, linkages, and pins to be sure the dimensions to not allow for yield at the designated design factor.

Scope of Testing and Evaluation

Testing and evaluation of the cutting system consists of placing the blade and anvil in a jig and placed in a tensile tester. This allows for testing of the amount of force required to cut through a 1.50-inch diameter branch. The jig is also used to test the stress experienced in the linkages. For overall pruner testing, the cutting system is assembled to the full automated pruner and put through endurance tests to ensure the pruner operates for the required time amount.

Analysis

The green sheets mentioned are found in Appendix A.

Green Sheet A-1

This green sheet calculates the amount of force that is transferred from the driving rod to the branch. The 600 pound tensile load pulls on a pin, connected to a linkage pair, which pulls on another pin, connected to the blade, which rotates the blade to apply the load to the branch. This resulting force was found to be 635 pounds, which exceeds the 500 pound force required to cut through the branch

Green Sheet A-2

This green sheet calculates the dimensions of the linkages and the two pins the linkages are held by. Using the various forces found from A-1 and the equation $\sigma = F / A$, it was found that AISI 1018 linkage would yield with a thickness of 0.014 inches. So a standard thickness of 1/8 inches was selected. The two pins (in double shear) used the equation $\tau = F / 2A$ to obtain yielding diameters of 0.10 inches. So the standard diameter of 1/4 inches was selected.

Green Sheet A-3

This green sheet calculates the diameter of the pin that holds the blade to the anvil. It is at this location in which the most stress is experienced if the pruner is unable to cut through an object.

Using the single shear equation of $\tau = F / A$, the yielding diameter was determined to be 0.21 inches. So a standard diameter of 1/4 inches was selected. This is the location designed to fail should the pruner generate excessive loads when unable to cut through a branch.

Device

The device is a pruner blade and anvil which operate using a linear driving rod. This comes in direct association with the other two systems of the automated pruner: Housing/Ergonomics (driving rod) and Power/Transmission (cutting system housing and driving rod housing).

Device Assembly

The device consists of one blade, one anvil, two linkages, and three pins. The blade is pinned to the anvil to allow for blade rotation, while the anvil is held firmly in the cutting system housing. The linkages transmit the force from the driving rod to the blade, and they connect to each component with pins.

Technical Risk Analysis, Failure Mode Analysis, Safety Factors, Operation Limits

The cutting system is designed with a 1.5 safety factor. Should a branch require more than the 600 pounds of force delivered by the linear actuator, the blade will cease to cut through the branch. However, since the cutting system is the most easily accessible portion of the pruner and has inexpensive pins, the pin holding the blade to the anvil is designed to fail should excessive loads be experienced when unable to cut through a branch.

METHODS & CONSTRUCTION

Construction

The cutting system is to be manufactured in collaboration with the H.F. Hauff Company. Making use of their facilities, the three components of the cutting system will be made using a laser cutter. This operation will be used because the parts are very thin and the geometries would be difficult to produce using a CNC mill.

Descriptions

The main components of the cutting system are the blade and anvil. The design of these are based on the blade and anvil of a Fiskars PowerGear tree pruner. As such, the dimensions of the parts are fairly freeform and difficult to callout. The laser cutter has ease with producing these shapes based off of the cutting code programmed into it.

The minor component of the cutting system is the linkage pair. These would be simple to produce using even a manual mill, but the laser cutter expedites the manufacturing process and, if necessary, can produce a higher quantity at a quicker rate.

Drawing Tree and Drawing ID's

The drawing tree, as seen in Appendix B, exhibits the three components of the cutting system as well as the parts required for the other two systems of the automated pruner. Labelling for the drawings of the cutting system are as such:

- C0: Exploded view of cutting system assembly with bill of materials
- C1: Blade Drawing
- C2: Anvil Drawing
- C3: Linkage Drawing
- B5: Blade Housing - Back
- B6: Blade Housing - Front

Manufacturing Issues

A variety of issues occurred when producing the required parts, starting when the partnered company dropped their manufacturing support. Over half of the way through the school term, the pruner team was left to machine the necessary parts.

Due to time constraints, the housing for the impact drill needed to be produced through additive manufacturing. Completing the two halves of the blade housing took two weeks. This was accomplished by generating the CNC programs with computer aided manufacturing (HSMWorks) and a CNC mill. There was a difficult period of trial-and-error to attain the correct tool feeds and spindle speeds because the type of aluminum was unknown. Since these housing parts were not designed by the correct team member (resulting in undesirable performance), they will need to be redone in the beginning weeks of the Spring term. Hopefully the CAD/CAM course will not require the CNC mills during this time so that the new parts can be machined. For the short term, small support members of aluminum have been welded to the blade housing.

The partnered company did produce a few parts: the blade, anvil, and linkage pair. This was done using their laser cutting table. Unfortunately, they were unable to acquire the nickel titanium material and used, instead, stainless steel. Testing will show if the material change is a detriment to the performance of the cutting action. The parts were produced to the correct dimensions, but the sharp edge on the blade was anything but. It was necessary to grind the edge down to improve results. The anvil was also given a ground edge to increase ease of cutting (the branch tries to wedge itself between the blade and anvil, bending the two components).

TESTING METHOD

Introduction

Testing is performed on the blade and anvil of the cutting system to ensure the 1.50-inch diameter branch is cut through at the desired force. This force occurs when the blade is cutting through the widest portion of the branch. The force at this moment is the highest force experienced by the cutting system and determines the type of linear actuator required. A test is performed on the linkages to ensure they do not yield under normal pruner operation. After this isolated testing, the cutting system will be assembled to the automated pruner for endurance testing.

Method / Approach

The idea for these tests is to seclude the cutting system from the rest of the automated pruner to isolate performance, and then to test the pruner in its fully assembled form. With the cutting system separated, it is possible to measure the force required to cut through a 1.50-inch branch using just the blade and anvil in a tensile tester. It is also possible to measure the force required to cause the pin, which holds the blade to the anvil, to fail. This is the intended failure location of the pruner should excessive loads be experienced when unable to cut through a branch. This location was selected because: 1) The pin already experiences the most stress in the pruner; and 2) The pin is easy and inexpensive to replace, should failure occur.

Test Procedure

To test the maximum cutting force required of a 1.50-inch diameter branch, the blade and anvil are attached to a jig and placed in a tensile tester. This allows for testing of the amount of force required to cut through a 1.50-inch diameter branch. The jig is also used to test the stress experienced in the linkages. For overall pruner testing, the cutting system is assembled to the full automated pruner and put through endurance tests to ensure the pruner operates for the required time amount.

BUDGET / SCHEDULE / PROJECT MANAGEMENT

Proposed Budget

The budget for the cutting system is roughly 500 U.S. dollars. This includes nickel titanium for the blade and anvil, AISI 1018 steel for the linkages, and grooved clevis pins to hold everything together. The nickel titanium is the most expensive of these items. As such, parts using this material receive extra attention in design to ensure that money is not wasted. The complete list of the automated pruner's budget is located in Appendix D.

Proposed Schedule

The proposed schedule can be seen in the Gantt Chart of Appendix E.

Project Management

This project is managed by the Central Washington University Mechanical Engineering Technology students: Daniel Gibson, Erich Heilman, and Thomas Wilson. Supervision is provided by Neil Hauff and Casey McFarlen of the H.F. Hauff Company. Additional supervision is provided by Matt Burvee, Roger Beardsley, Greg Lyman, Charles Pringle, and Dr. Craig Johnson of Central Washington University.

CONCLUSION

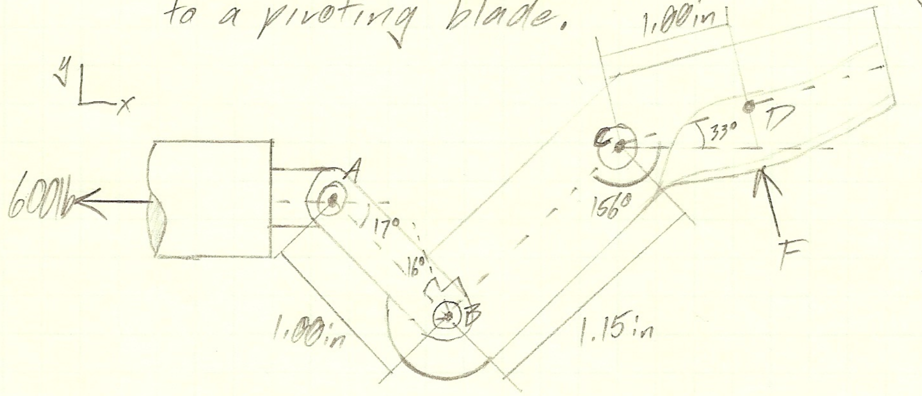
The proposed design for the cutting system of the automated pruner - being produced under the supervision of the H.F. Hauff Company - will function as outlined in the requirements listed above. Given a load of 600 pounds by the actuator, the cutting system will be able to cut through apple orchard branches of at least 1.50 inches with minimal fatigue to the components of the system. The nickel titanium material of the blade increases durability - reducing the amount of grinding required to maintain sharpness. In the event an object placed into the cutting system exceeds the applicable cutting force, the pin holding the blade to the anvil will fail. This is the most reasonable outcome since this pin is less expensive than the other components of the cutting system and is easy to access and replace. The failure of this pin will reduce stress buildup or failure of the other components, allowing them continued use.

ACKNOWLEDGEMENTS

Neil Hauff, Casey McFarlen, Matt Burvee, Greg Lyman, Ted Bramble, Charles Pringle, Craig Johnson, Roger Beardsley, Darryl Fuhrman, Erich Heilman, Thomas Wilson, Martha Gibson, John Gibson, Gretchen Gibson, Jillian Gibson, Melanie Bell, Steven Linden, Carlos Bonilla, Antonia Simonis-Paul, Benoit Porte, Santiago Garcia, Roldan Guillen Jr., Frédéric Reaud, Valerie Harris, Paula Ferguson, William Fitzpatrick, Janice Park, Lazslo Lak, Derrick Acosta, Rocco Botte, Shawn Chatfield, Garrett Hunter, Eric Baudour, Kevin Buschong, Bryan Abou Chacra

A-1 | Daniel Gibson | H.F. Hauff Pruner | 11-20-15

Given: A rod pulls with 600 lb on a linkage pair attached to a pivoting blade.

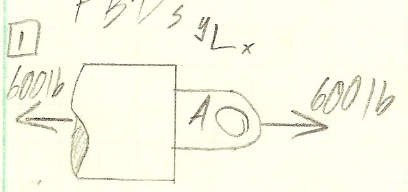


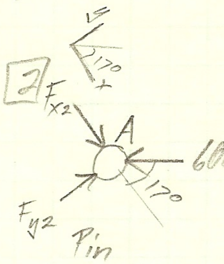
The blade reacts on the branch at D. The angle configuration shown in the figure is where the most force is required when cutting the branch. Pin C is fixed and the rod only moves on an x-axis.

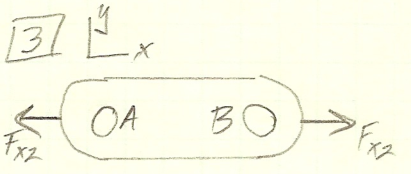
Find: Force applied to branch
Dimensions of linkages
Dimensions of pins

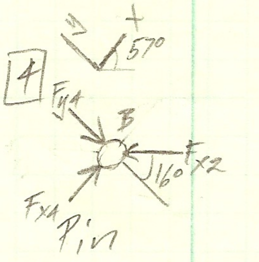
Sol'n: Force applied to branch (F)

FBDs







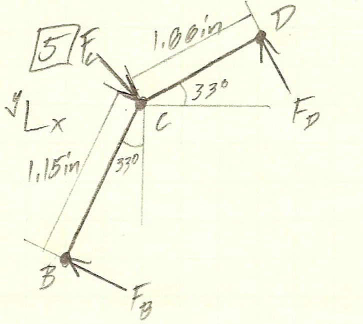


$\boxed{2}$ $\xrightarrow{+}\Sigma F_x=0$: $F_{x2}-(600\text{ lb})\cos(17°)=0$
$F_{x2}=573.7829\text{ lb}\rightarrow$

$+\uparrow\Sigma F_y=0$: $F_{y2}-(600\text{ lb})\sin(17°)=0$
$F_{y2}=175.4230\text{ lb}\uparrow$

$\boxed{4}$ $\xrightarrow{+}\Sigma F_x=0$: $F_{x4}-(573.7829\text{ lb})\sin(16°)=0$
$F_{x4}=158.1560\text{ lb}\rightarrow$

$+\uparrow\Sigma F_y=0$: $-F_{y4}+(573.7829\text{ lb})\cos(16°)=0$
$F_{y4}=551.5555\text{ lb}\downarrow$



$\circlearrowleft+\Sigma M_C=0$: $-F_B(1.15\text{ in})+F_D(1.00\text{ in})=0$ $\quad F_B=F_{y4}$

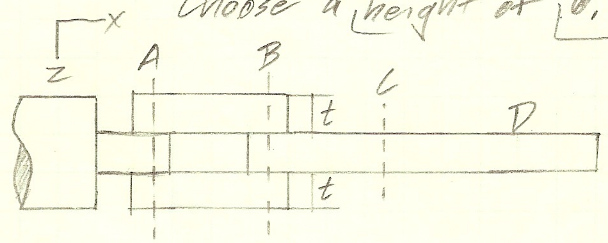
$$F_D=\frac{(551.5555\text{ lb})(1.15\text{ in})}{(1.00\text{ in})}$$

$F_D=634.2888\text{ lb}$

$\boxed{F=634\text{ lb}}$

Linkage Dimensions

Choose AISI 1018 steel and design to yield strength ($s_y = 49$ ksi) WolframAlpha
Choose a height of 0.625 in



FBD - One Linkage

Safety Factor of 1.5

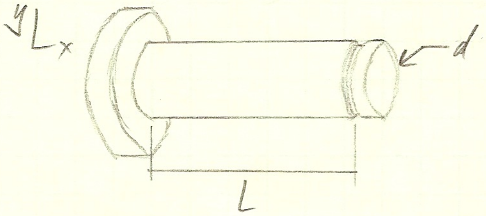
$$F = (1.5)(287\text{ lb})$$

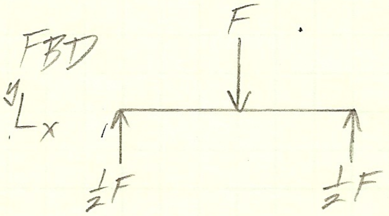
$$\sigma = \frac{F}{A} \qquad \sigma = s_y$$
$$s_y = \frac{F}{th} \Rightarrow t = \frac{F}{s_y h} \qquad A = bh$$
$$t = \frac{(1.5)(287\text{ lb})}{(49000\ \frac{\text{lb}}{\text{in}^2})(0.625\text{ in})} \qquad b = t$$
$$\boxed{t = 0.01406\text{ in}}$$

Choose a standard thickness of 0.125 in for the linkages. Consider using a cheaper material with a lower yield strength.

Pin Dimensions

Choose Clevis Pins
Choose AISI 1018 steel and design to yield strength ($s_y = 49$ ksi) WolframAlpha
Use a Safety Factor of 1.5





Pin A (Double Shear)

$$\tau = \frac{F}{2A} \qquad F = (1.5)(600\text{ lb})$$
$$s_y = \frac{F}{2(\frac{\pi}{4}d^2)} \qquad \tau = s_y$$
$$d = \sqrt{\frac{2F}{\pi s_y}} \qquad A = \frac{\pi}{4}d^2$$
$$d = \sqrt{\frac{2(1.5)(600\text{ lb})}{\pi(49000\ \frac{\text{lb}}{\text{in}^2})}}$$
$$\boxed{d = 0.1081\text{ in}}$$

Pin B (Double Shear)

$$d = \sqrt{\frac{2F}{\pi s_y}} \qquad F = (1.5)F_{x2}$$
$$d = \sqrt{\frac{2(1.5)(573.7829\text{ lb})}{\pi(49000\ \frac{\text{lb}}{\text{in}^2})}}$$
$$\boxed{d = 0.1057\text{ in}}$$

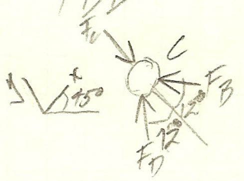
Assume thicknesses of rod connection and blade are 0.15 in.

$$L = 2(0.125\text{ in}) + (0.15\text{ in})$$
$$\boxed{L = 0.40\text{ in}}$$

For both pins A and B, use a standard diameter of 0.25 in and a usable length of 0.40 in. Consider using a cheaper material.

Pin C (Single Shear)

FBD



$$+\uparrow \Sigma F_y = 0: \quad F_D \cos 12° + F_B \cos 12° - F_C = 0$$

$$F_C = (F_D + F_B)\cos 78° = [(551.5555\ lb) + (634.2888\ lb)]\cos 12°$$

$$F_C = 1159.9308\ lb$$

$$\boxed{F_C = 1160\ lb}$$

$$\tau = \frac{F}{A} \qquad F = (1.5)(1160\ lb)$$

$$S_y = \frac{F}{\frac{\pi}{4}d^2} \qquad \tau = S_y$$

$$d = \sqrt{\frac{4F}{\pi S_y}} \qquad A = \frac{\pi}{4} d^2$$

$$d = \sqrt{\frac{4(1.5)(1160\ lb)}{\pi(49000\ \frac{lb}{in^2})}}$$

$$d = 0.2126\ in$$

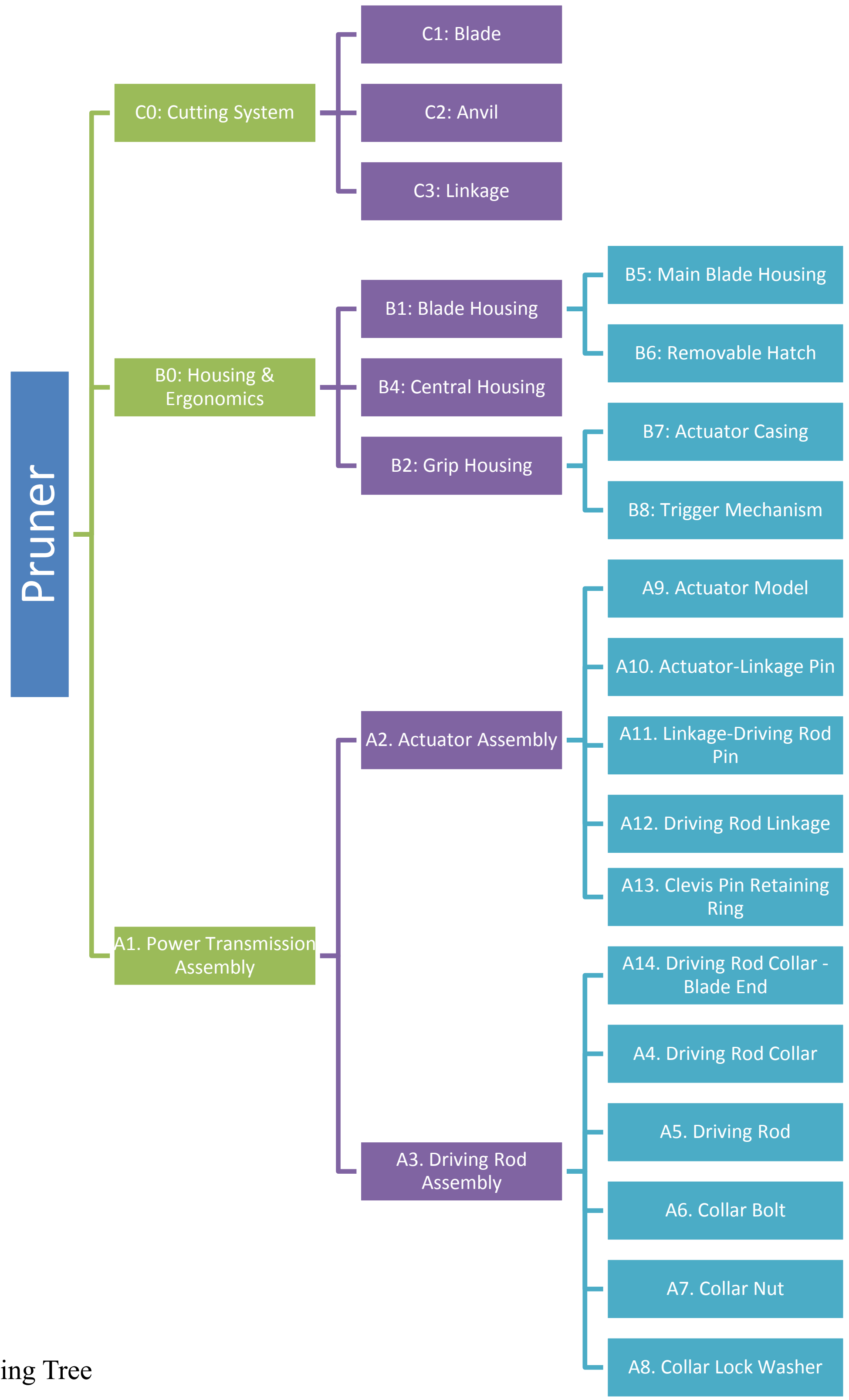
Assume thicknesses of blade and anvil are 0.15 in

$$L = (0.15 + 0.15)\ in$$

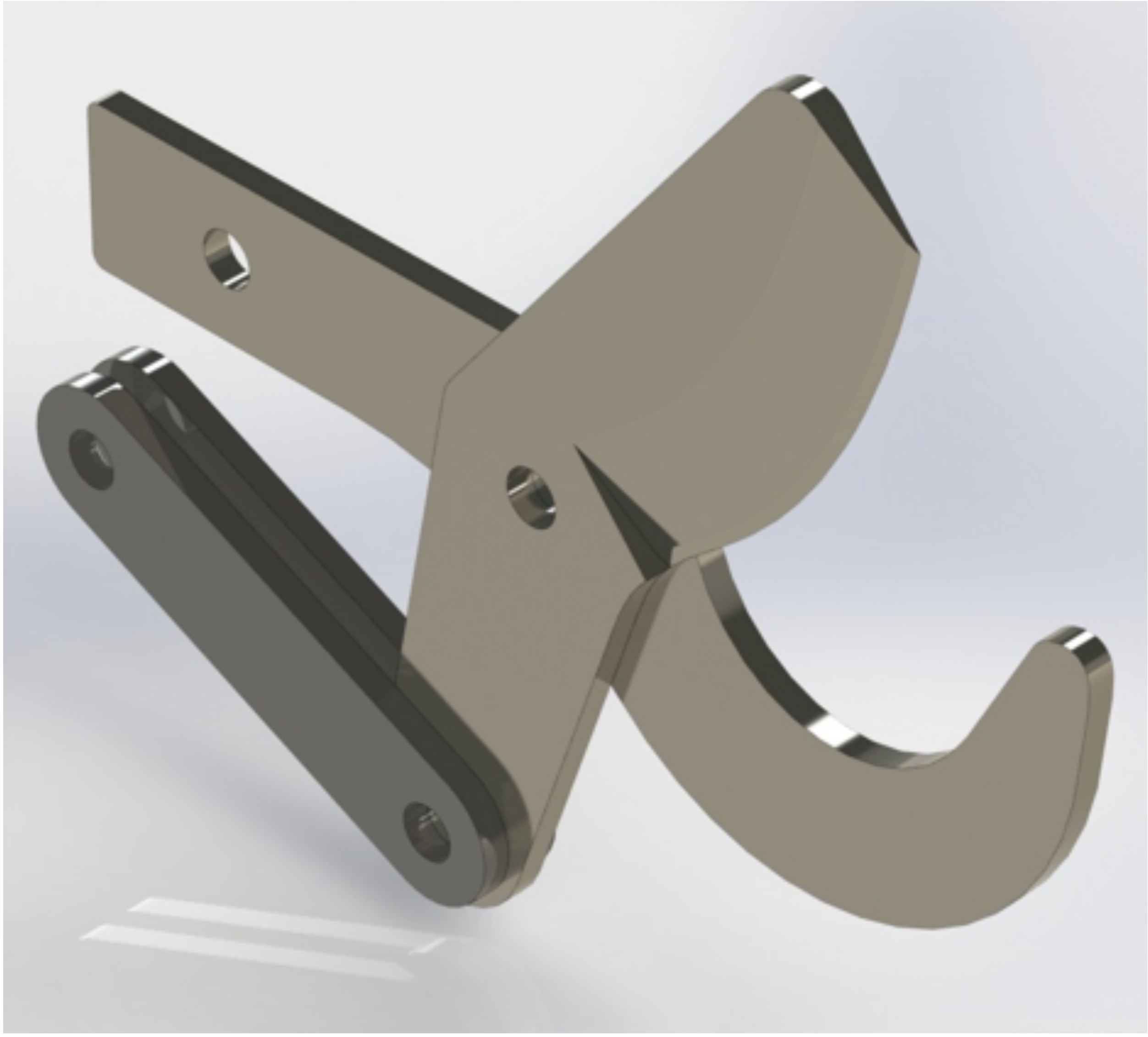
$$L = 0.30\ in$$

For pin C, use a standard diameter of 0.25 in and a usable length of 0.30 in.

Appendix B – Drawings

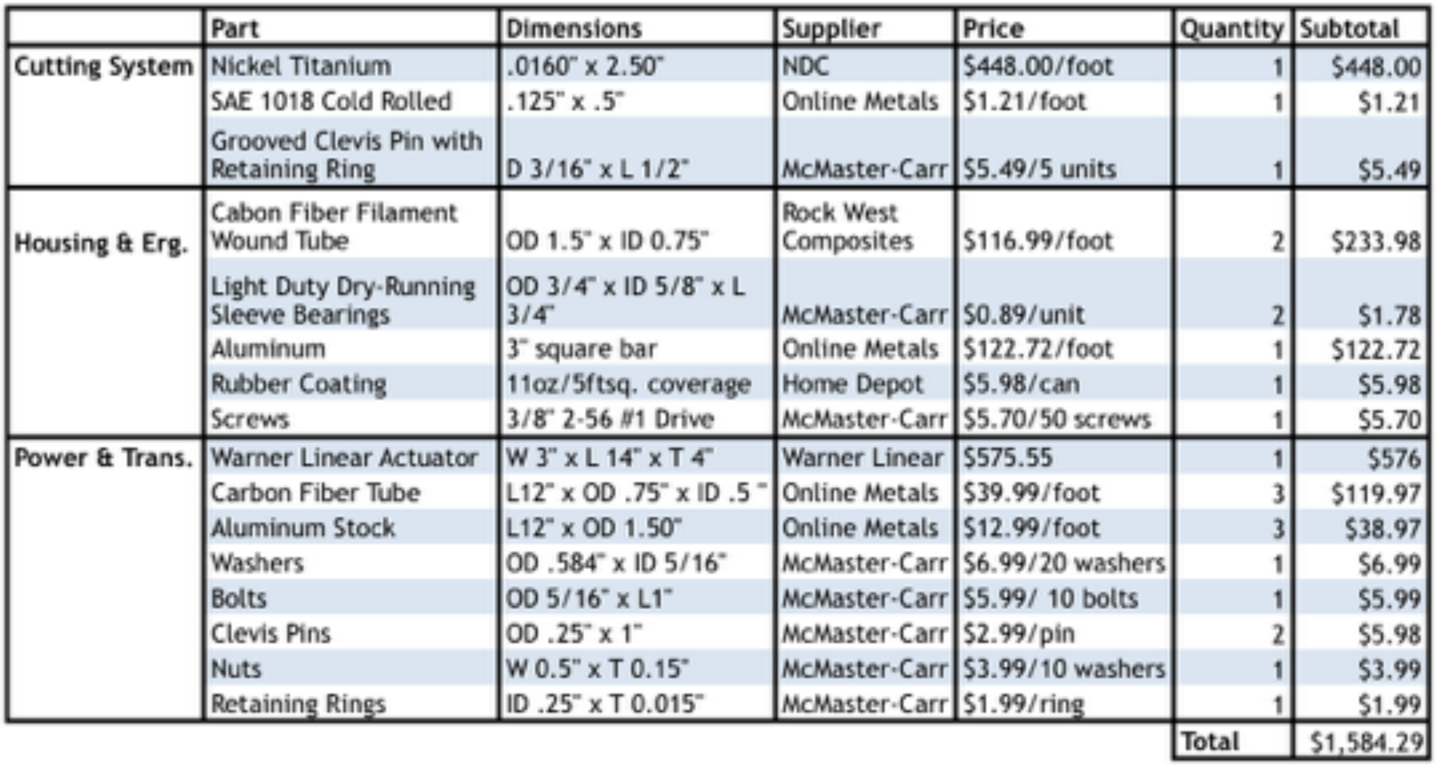


Drawing Tree



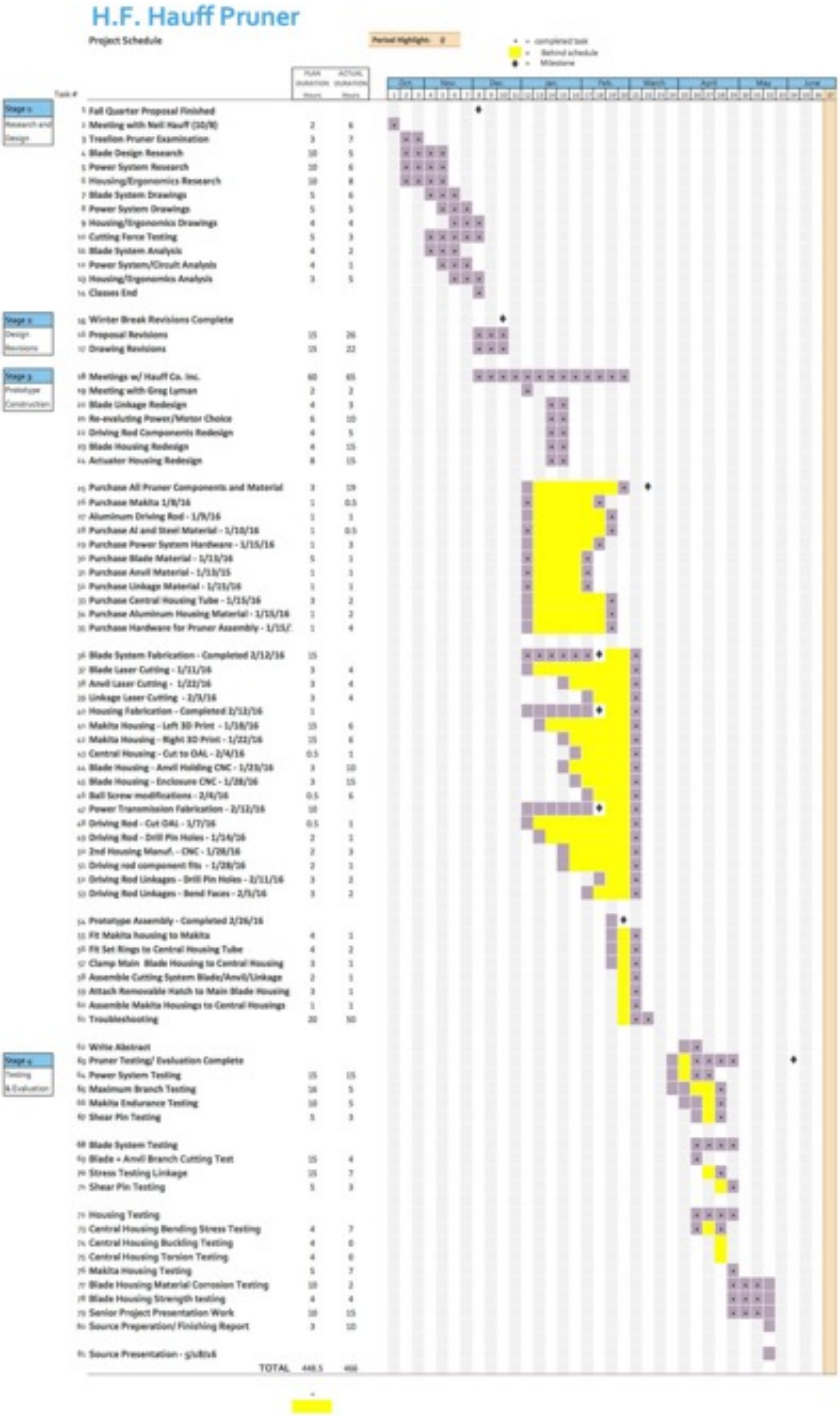
Rendering of Cutting System

Appendix D – Budget



	Part	Dimensions	Supplier	Price	Quantity	Subtotal
Cutting System	Nickel Titanium	.0160" x 2.50"	NDC	$448.00/foot	1	$448.00
	SAE 1018 Cold Rolled	.125" x .5"	Online Metals	$1.21/foot	1	$1.21
	Grooved Clevis Pin with Retaining Ring	D 3/16" x L 1/2"	McMaster-Carr	$5.49/5 units	1	$5.49
Housing & Erg.	Cabon Fiber Filament Wound Tube	OD 1.5" x ID 0.75"	Rock West Composites	$116.99/foot	2	$233.98
	Light Duty Dry-Running Sleeve Bearings	OD 3/4" x ID 5/8" x L 3/4"	McMaster-Carr	$0.89/unit	2	$1.78
	Aluminum	3" square bar	Online Metals	$122.72/foot	1	$122.72
	Rubber Coating	11oz/5ftsq. coverage	Home Depot	$5.98/can	1	$5.98
	Screws	3/8" 2-56 #1 Drive	McMaster-Carr	$5.70/50 screws	1	$5.70
Power & Trans.	Warner Linear Actuator	W 3" x L 14" x T 4"	Warner Linear	$575.55	1	$576
	Carbon Fiber Tube	L12" x OD .75" x ID .5 "	Online Metals	$39.99/foot	3	$119.97
	Aluminum Stock	L12" x OD 1.50"	Online Metals	$12.99/foot	3	$38.97
	Washers	OD .584" x ID 5/16"	McMaster-Carr	$6.99/20 washers	1	$6.99
	Bolts	OD 5/16" x L1"	McMaster-Carr	$5.99/ 10 bolts	1	$5.99
	Clevis Pins	OD .25" x 1"	McMaster-Carr	$2.99/pin	2	$5.98
	Nuts	W 0.5" x T 0.15"	McMaster-Carr	$3.99/10 washers	1	$3.99
	Retaining Rings	ID .25" x T 0.015"	McMaster-Carr	$1.99/ring	1	$1.99
					Total	$1,584.29

Appendix E – Schedule



H.F. Hauff Pruner

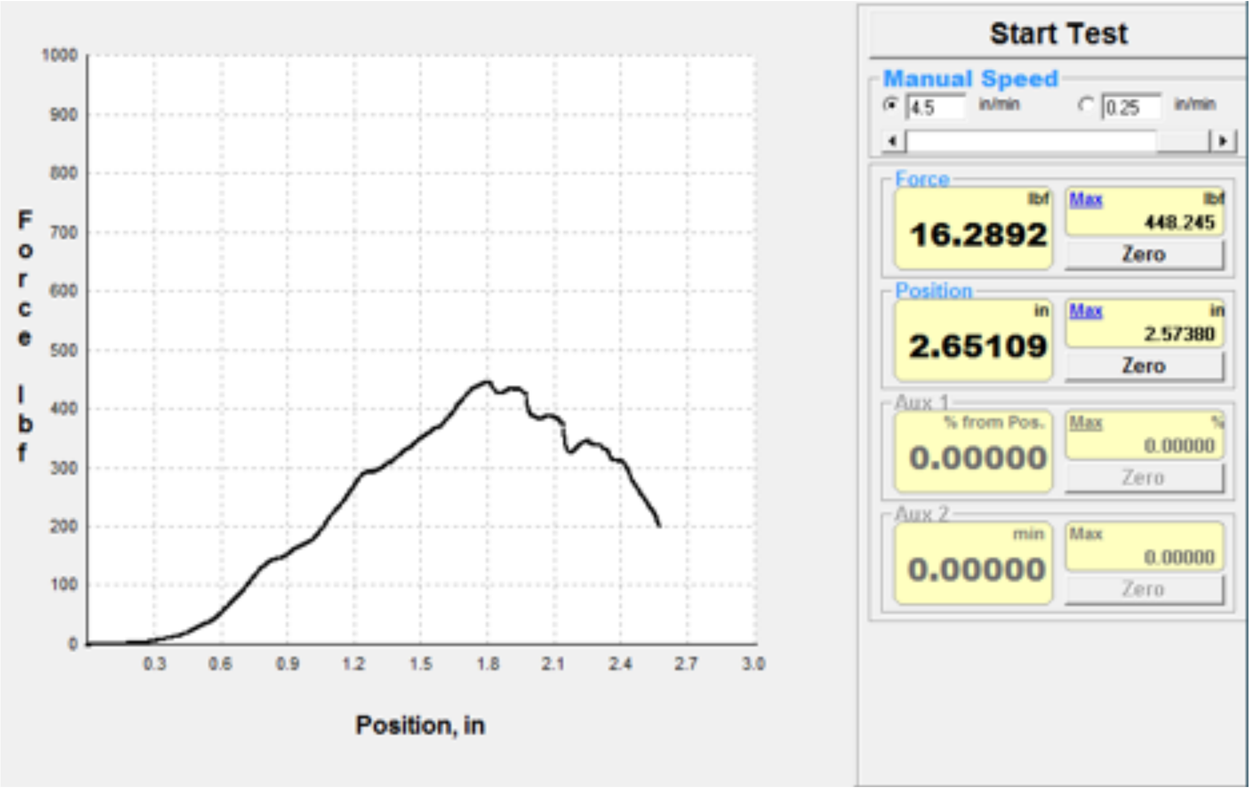
Project Schedule

Period Highlight: 8

- ✓ = completed task
- 🟨 = Behind schedule
- ◆ = Milestone

Stage	Task #	Task	PLAN DURATION Hours	ACTUAL DURATION Hours
Stage 1 Research and Design	1	Fall Quarter Proposal Finished		
	2	Meeting with Neil Hauff (10/8)	2	6
	3	Treelion Pruner Examination	3	7
	4	Blade Design Research	10	5
	5	Power System Research	10	6
	6	Housing/Ergonomics Research	10	8
	7	Blade System Drawings	5	6
	8	Power System Drawings	5	5
	9	Housing/Ergonomics Drawings	4	4
	10	Cutting Force Testing	5	3
	11	Blade System Analysis	4	2
	12	Power System/Circuit Analysis	4	1
	13	Housing/Ergonomics Analysis	3	5
	14	Classes End		
Stage 2 Design Revisions	15	Winter Break Revisions Complete		
	16	Proposal Revisions	15	26
	17	Drawing Revisions	15	22
Stage 3 Prototype Construction	18	Meetings w/ Hauff Co. Inc.	60	65
	19	Meeting with Greg Lyman	2	2
	20	Blade Linkage Redesign	4	3
	21	Re-evaluting Power/Motor Choice	6	10
	22	Driving Rod Components Redesign	4	5
	23	Blade Housing Redesign	4	15
	24	Actuator Housing Redesign	8	15
	25	Purchase All Pruner Components and Material	3	19
	26	Purchase Makita 1/8/16	1	0.5
	27	Aluminum Driving Rod - 1/9/16	1	1
	28	Purchase Al and Steel Material - 1/10/16	1	0.5
	29	Purchase Power System Hardware - 1/15/16	1	3
	30	Purchase Blade Material - 1/13/16	5	1
	31	Purchase Anvil Material - 1/13/15	1	1
	32	Purchase Linkage Material - 1/11/16	1	1
	33	Purchase Central Housing Tube - 1/15/16	3	2
	34	Purchase Aluminum Housing Material - 1/15/16	1	2
	35	Purchase Hardware for Pruner Assembly - 1/15/	1	4
	36	Blade System Fabrication - Completed 2/12/16	15	
	37	Blade Laser Cutting - 1/11/16	3	4
	38	Anvil Laser Cutting - 1/21/16	3	4
	39	Linkage Laser Cutting - 2/3/16	3	4
	40	Housing Fabrication - Completed 2/12/16	1	
	41	Makita Housing - Left 3D Print - 1/18/16	15	6
	42	Makita Housing - Right 3D Print - 1/22/16	15	6
	43	Central Housing - Cut to OAL - 2/4/16	0.5	1
	44	Blade Housing - Anvil Holding CNC - 1/23/16	3	10
	45	Blade Housing - Enclosure CNC - 1/28/16	3	15
	46	Ball Screw modifications - 2/4/16	0.5	6
	47	Power Transmission Fabrication - 2/12/16	10	
	48	Driving Rod - Cut OAL - 1/7/16	0.5	1
	49	Driving Rod - Drill Pin Holes - 1/14/16	2	1
	50	2nd Housing Manuf. - CNC - 1/28/16	2	3
	51	Driving rod component fits - 1/28/16	2	1
	52	Driving Rod Linkages - Drill Pin Holes - 2/11/16	3	2
	53	Driving Rod Linkages - Bend Faces - 2/1/16	3	2
	54	Prototype Assembly - Completed 2/26/16		
	55	Fit Makita housing to Makita	4	1
	56	Fit Set Rings to Central Housing Tube	4	2
	57	Clamp Main Blade Housing to Central Housing	3	1
	58	Assemble Cutting System Blade/Anvil/Linkage	2	1
	59	Attach Removable Hatch to Main Blade Housing	3	1
	60	Assemble Makita Housings to Central Housings	1	1
	61	Troubleshooting	20	50
Stage 4 Testing & Evaluation	62	Write Abstract		
	63	Pruner Testing/ Evaluation Complete		
	64	Power System Testing	15	15
	65	Maximum Branch Testing	16	5
	66	Makita Endurance Testing	10	5
	67	Shear Pin Testing	5	3
	68	Blade System Testing		
	69	Blade + Anvil Branch Cutting Test	15	4
	70	Stress Testing Linkage	15	7
	71	Shear Pin Testing	5	3
	72	Housing Testing		
	73	Central Housing Bending Stress Testing	4	7
	74	Central Housing Buckling Testing	4	6
	75	Central Housing Torsion Testing	4	6
	76	Makita Housing Testing	5	7
	77	Blade Housing Material Corrosion Testing	10	2
	78	Blade Housing Strength testing	4	4
	79	Senior Project Presentation Work	10	15
	80	Source Preperation/ Finishing Report	3	10
	81	Source Presentation - 5/18/16		
		TOTAL	448.5	466

Appendix F – Testing Data



Manual Speed

● 4.5 in/min ○ 0.25 in/min

Force

lbf 16.2892

Max lbf 448.245

Position

in 2.65109

Max in 2.57380

Aux 1

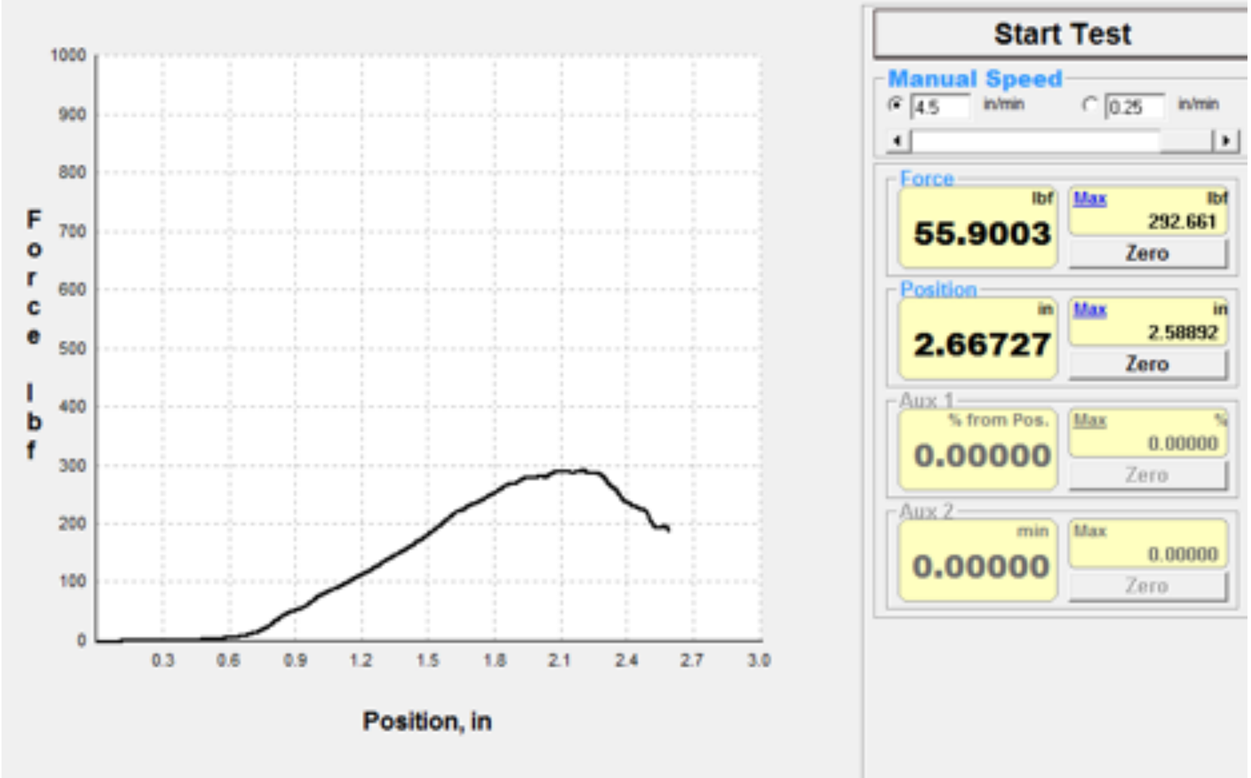
% from Pos. 0.00000

Max % 0.00000

Aux 2

min 0.00000

Max 0.00000



Manual Speed

● 4.5 in/min ○ 0.25 in/min

Force

lbf 55.9003

Max lbf 292.661

Position

in 2.66727

Max in 2.58892

Aux 1

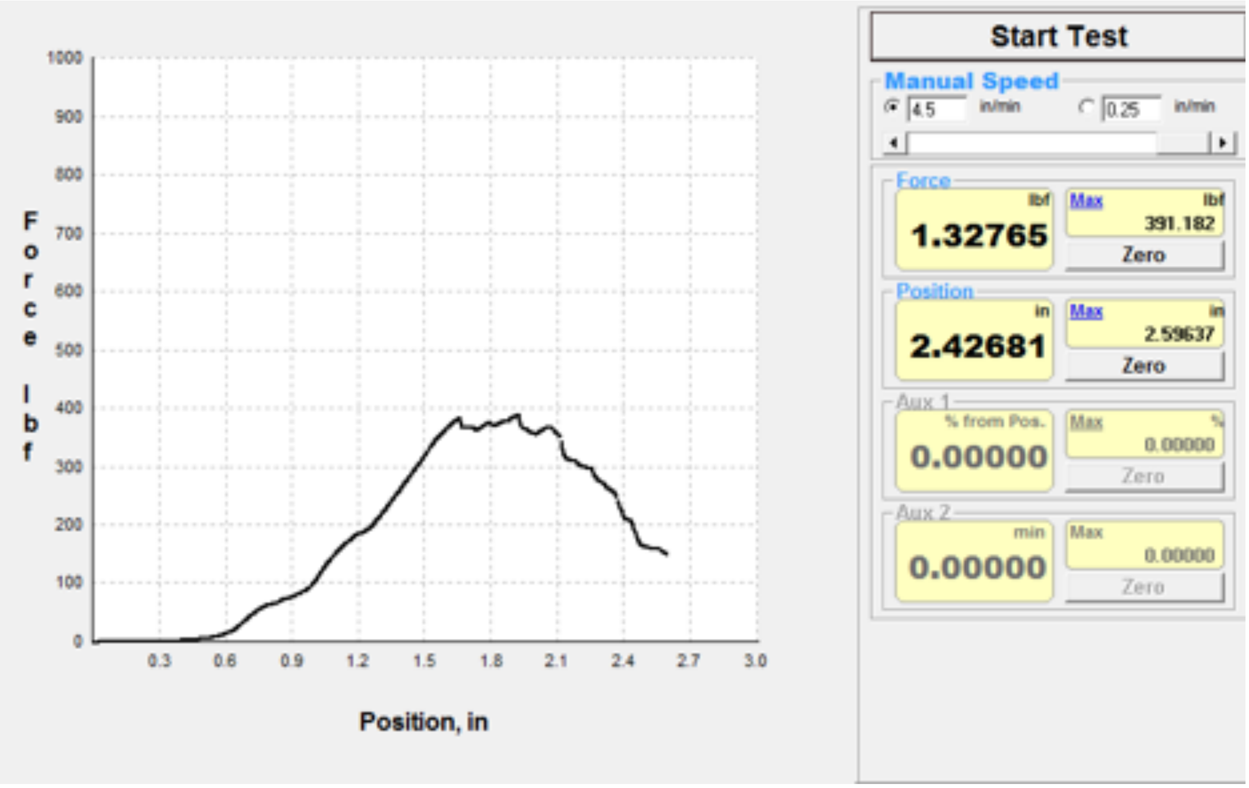
% from Pos. 0.00000

Max % 0.00000

Aux 2

min 0.00000

Max 0.00000



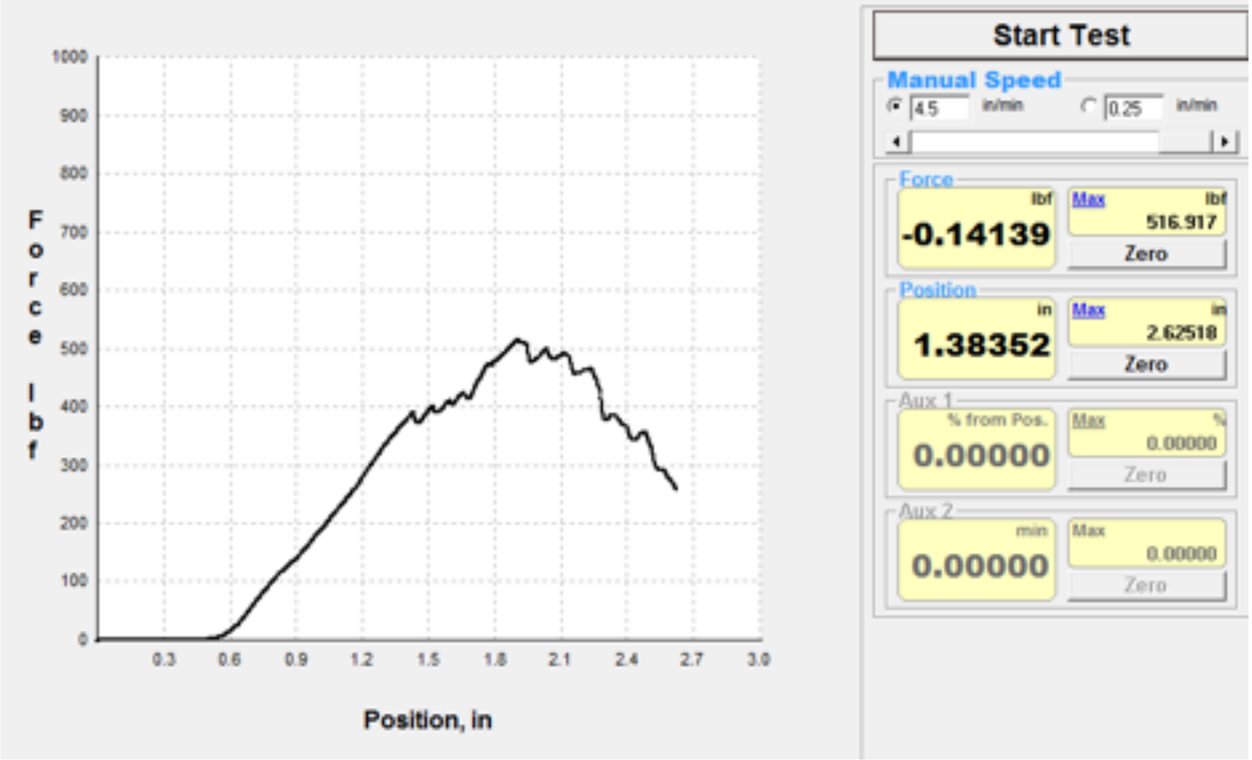
Manual Speed
● 4.5 in/min ○ 0.25 in/min

Force lbf 1.32765
Max lbf 391.182

Position in 2.42681
Max in 2.59637

Aux 1 % from Pos. 0.00000
Max % 0.00000

Aux 2 min 0.00000
Max 0.00000



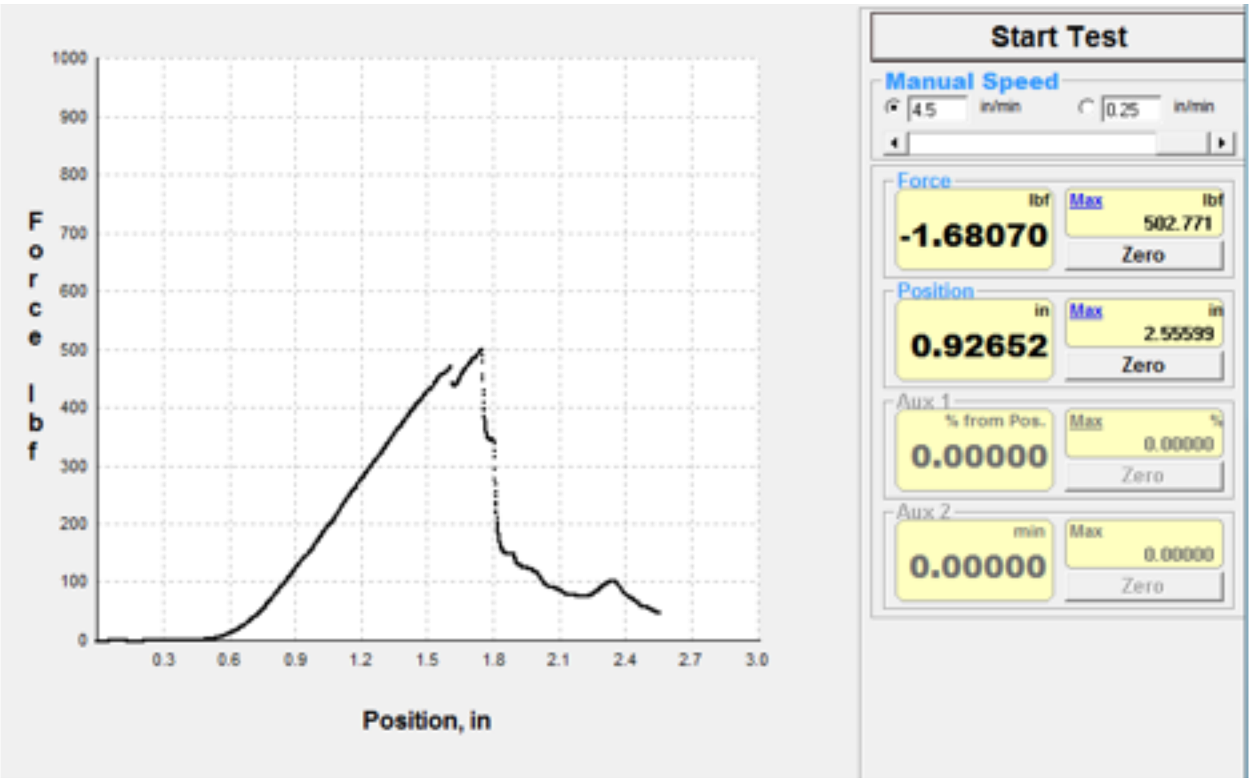
Manual Speed
● 4.5 in/min ○ 0.25 in/min

Force lbf -0.14139
Max lbf 516.917

Position in 1.38352
Max in 2.62518

Aux 1 % from Pos. 0.00000
Max % 0.00000

Aux 2 min 0.00000
Max 0.00000



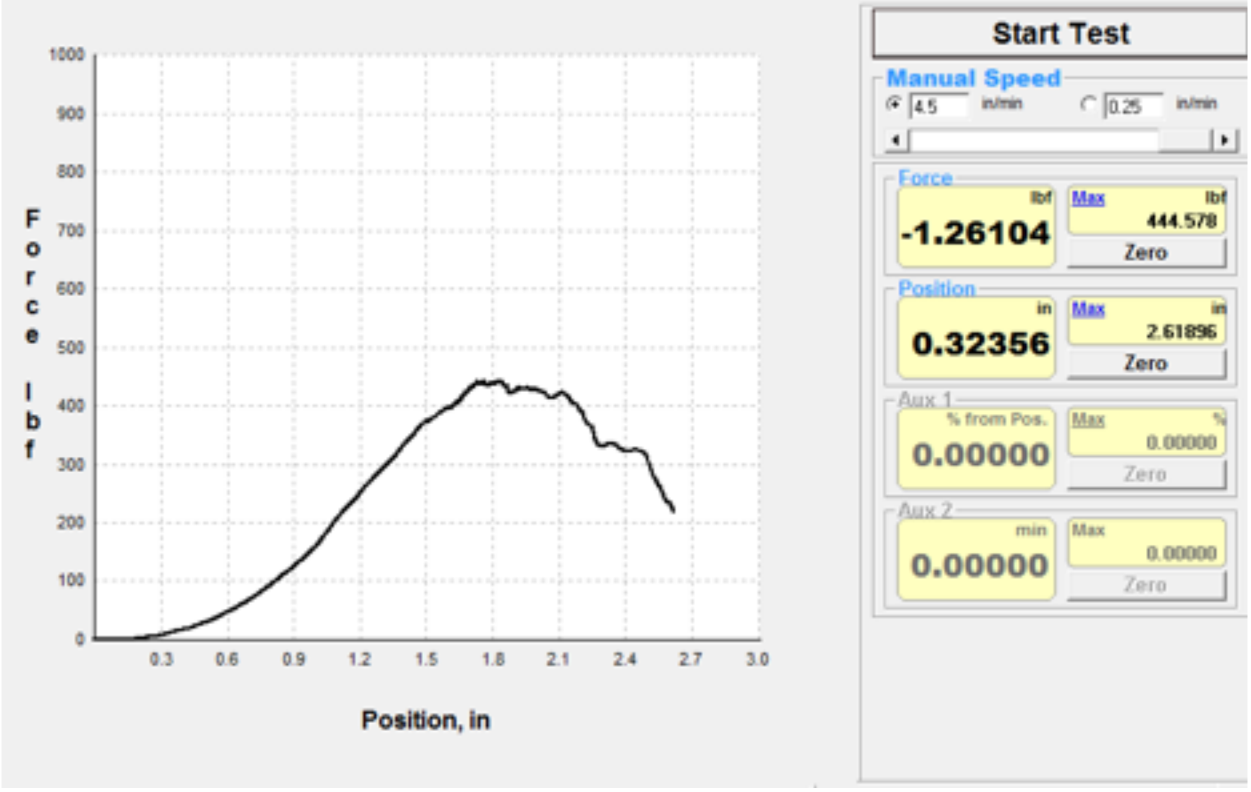
Manual Speed
● 4.5 in/min ○ 0.25 in/min

Force
lbf -1.68070
Max lbf 502.771

Position
in 0.92652
Max in 2.55599

Aux 1
% from Pos. 0.00000
Max % 0.00000

Aux 2
min 0.00000
Max 0.00000



Manual Speed
● 4.5 in/min ○ 0.25 in/min

Force
lbf -1.26104
Max lbf 444.578

Position
in 0.32356
Max in 2.61896

Aux 1
% from Pos. 0.00000
Max % 0.00000

Aux 2
min 0.00000
Max 0.00000

Appendix G - Résumé

DANIEL J. GIBSON

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daniel.dj.gibson@gmail.com

PROFILE

I am currently pursuing a Post Baccalaureate degree in Mechanical Engineering Technology at Central Washington University in Ellensburg, Washington. I am seeking employment in Mechanical / Manufacturing Engineering or a related field.

EDUCATION

Central Washington University, Ellensburg, WA - BS in Mechanical Engineering Technology and Minor in Mathematics, Expected to Graduate June, 2016 (GPA 3.651)

Chapman University, Orange, CA - BM in Music Composition and Minor in German, Class of 2012 (GPA 3.300)

SKILLS & EXPERIENCE

- Internship with AMG - Aero Technologies (June - September 2015, Miami, FL): High Speed Pneumatic Flow Test Bench Design, Tool Design, Tooling Database Maintenance, and Drafting / Modeling
- Designed the cutting system of an electric-powered tree pruner as part of the CWU Engineering Senior Project for H.F. Hauff Co. Inc. (Yakima, WA) and received an Outstanding Presentation award for said project at CWU SOURCE 2016
- Proficient with SolidWorks (Associate Certification), AutoCAD, LabVIEW, Additive Manufacturing, and Computer Aided Manufacturing
- Proficient with Microsoft Office and Apple iWork
- Courses taken in Composites, Ceramics, Metallurgy, Lean Manufacturing, and Quality Control
- Experienced with manual machine tools, CNC machine tools, CNC programming, and welding
- Design and fabrication of a solar air-heating unit for UW's Environmental Innovation Challenge 2014
- Scheduled to take the Fundamentals of Engineering Exam in Summer 2016
- President of CWU Electric Vehicle Club (2014-15), Officer of CWU ASME and SME Clubs (2014-16), President of CWU Fencing Club (2015-16)
- Proficient in German
- Volunteer work with FIRST Lego League and VEX Robotics competitions and Assistance League of the Eastside (Redmond, WA)
- Proficient on various musical instruments; Performed violin in orchestras, operas, musicals, New Music ensembles, and Bluegrass groups

REFERRALS

Frédéric Reaud - Director of Engineering at AMG Aero Technologies (Miami, FL)

Charles Pringle, EIT - Assistant Professor of Mechanical Engineering Technology at Central Washington University

Contact information available upon request