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Composite Cutting Device

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Recycling Carbon Fiber: Cutting Process and Device

By

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Abstract

Title and Author: Composite Cutting Device by Misha Minasyan (Mechanical Engineering Technology)

As the aerospace industry innovates, so does the material that is being used. No longer are airplane manufacturers like Boeing depending on only various metals for making their wings. A transition over the past few years has been made to using composite materials because of there light weight and strength. The issue that composite material brings is that it cannot be recycled without processing. The current 777X made by Boeing has transitioned to used composite to manufacture their airplane wings.

A two student team developed two separate processes that would focus on making the recycling and transport of trimmings simpler. The first process focused on delaminating trimmings using a crushing device. The second process focused on cutting delaminated material. The purpose of delaminating and cutting the material is that it makes for more efficient storing off the scrap trimmings, as well as smaller components that could be chemically processed.

A kinetic energy experiment was conducted and scaled up to a full width and length of a trimming. It was determined that a 1750 RPM motor with 5 HP needed to be reduced to around 600 RPM. A federate of 100 in/minute will be used and will allow for delaminating and cutting with sizes of trimmings ranging from ½ " to 2" pieces dependent of orientation of spacers. Results have not been compiled yet, but will be discussed during the presentation.

Keywords

Composite, Delaminating, Cutting

1: INTRODUCTION

1a: Description:

The issue with Boeings new 777X is that the wings are now being produced using a composite. Making airplane wings come with benefits and negatives. The wings are now lighter than before, but cannot be recycled. Once the composite wing is manufactured, the trimmings are kept and disposed without any form of recycling. An estimate given my John Locklear said that about 660,000 lbs of trimmings is deposed of annually. Due to the high amount of scrap trimmings, a method of reusing or recycling of the carbon fibers will be beneficial to the company as well as the environment. The most effective way of salvaging carbon fibers is through a chemical process that CWU do not have the means of doing. So, to bypass that, a machine will be constructed that will cut scraps into smaller pieces that will allow for easier transportation and processing.

The inspiration behind the design given in this proposal is a paper shredder, or a cardboard partition slicer. With rotating shafts connected to a motor, and blades fastened in desired locations, composite material will be able to be fed into the device after delamination and be cut into easier to handle pieces.

1b: Motivation:

This project was motivated by trying to find a method or device that would allow for salvaging some of the carbon fibers from the trimmings of the wings. By finding another use for the trimmings the team would be benefiting both the company and the environment. Also, getting the experience of developing a process to help in recycling of a new, high use material would be beneficial.

1c: Function Statement:

To cut down delaminated carbon fibers into smaller, easier to process pieces.

1d: Requirements:

- Cut composite material
- Reduce a 1750 RPM motor to a minimum a 600 RPM
- Connect cutter to lab partners delaminating process
- Cutting will have to apply a force of at least 546.7 lb-in
- The device must weigh under 80 lb
- Device must cost less than $2500.00
- Use a single, 5 HP motor
- The overall process (delaminating and cutting) will need to be done in one motion

The device will be required to transmit a torque through a gear system that will allow for mounted blades on shafts to be able to rotate while simultaneously cutting scraps of carbon fibers. Depending on the location of the blades, the size of the cut piece will be able to be manipulated by movement of the blades.

1e: Engineering Merit:

The engineering merit to this project is that a device needs to be constructed that will slice composite material. Due to the overall strength of the material, all aspects of the machine will need to be able to withstand multiple trials of cutting material. The manipulating of gears and torque from a single motor will have to produce the calculated RPM that will allow for cutting of material.

1f: Scope of Effort:

This project will only include operations to will make processing and storing material easier. The original success criteria were going to be based off how many individual carbon fibers were salvaged. But since the devices will not be chemically processing, they will focus on delaminating and cutting instead.

Also, after speaking with John Locklear, an analysis of how this project could be scaled to a full facility was mentioned. Since the scale of this project is small, a potential idea of how to preprocess this material will be developed and a prediction of how this could be scaled up will be calculated. The results generated will be able to be scaled up for a full operation.

1g: Success Criteria:

Success for this project will be based on having a functioning cutting machine by the end on winter quarter or early spring. By functioning it will be able to cut through material that has been delaminated in an earlier process the entirely of the original length.

2. DESIGN & ANALYSIS

Proposed Solution

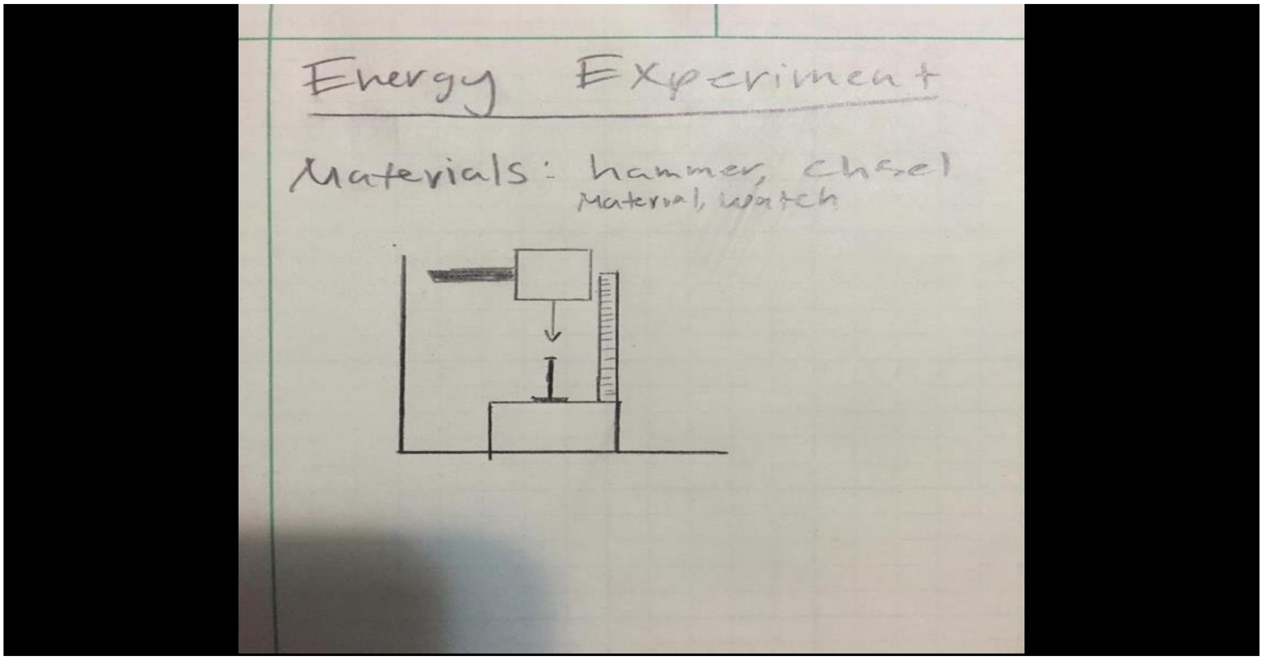
The idea behind the cutting device was inspired by a cardboard partition slitter, or a paper shredder. After a conference call with John from Boeing, it was made evident that an excess of 660,000 lbs of trimmings are accumulated over a year. The cutter was believed to be an efficient way of processing mass amounts of bulk if developed to a full-scale piece of machinery. The idea of feeding a single piece of material into a opening and having sliced pieces on the other end machine would call for easier transporting as well as processing.

Through a motor generating the power, a series of shafts as well as gears will transmit calculated torques that were calculated after an experiment.

Analysis

An experiment was conducted using a hammer, a cut piece of composite and a chisel. By measuring the height at which the hammer was raised, the weight of the hammer and kinetic energy, a starting energy was calculated and scaled for a full-size piece of composite.

Energy Experiment



The image provided was a sketch of how the experiment was conducted. As shown in the image, a hammer was dropped from a certain height which was recorded. A stop watch was timing from initial movement until contact with the chisel. A success to the experiment was based on if the chisel went through the material. The calculation for this experiment can be found in appendix A.1d. By measuring the height at which the hammer was raised, the weight of the hammer and kinetic energy, a starting energy was calculated and scaled for a full-size piece of composite.

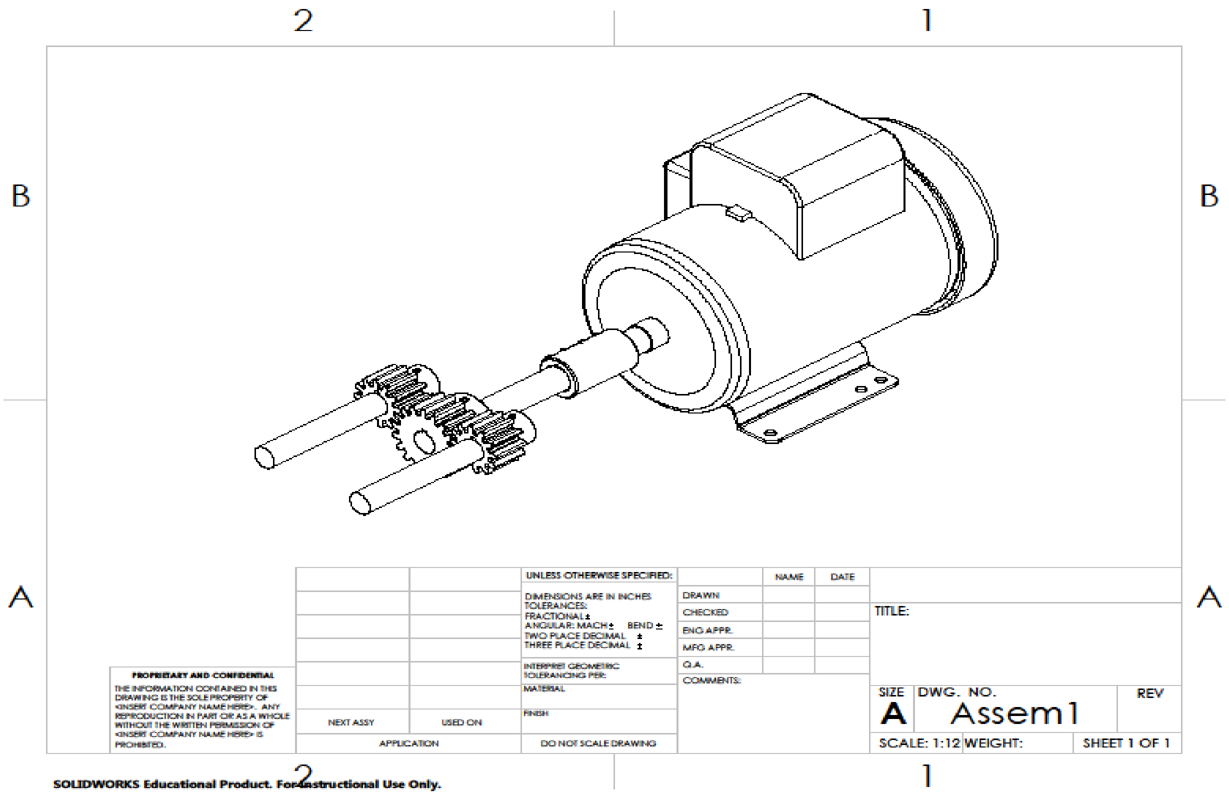
Analysis from Experiment

After calculating an initial energy, another calculation was done to scale the experiment to a full-size piece of material using conservation of energy. This calculation is in appendix A5.

After the scaling of the energy, a required RPM was needed to be calculated. Going back to $KE=1/2mv^2$, the mass was the variable that was altered so that a tangential velocity could be calculated. After the tangential velocity was calculated, a RPM was then calculated. Once having the necessary RPM, minimum diameters were calculated based off the calculated RPM and the RPM provided by the motor that was selected from Mccmaster Carr. The main requirement of this device will be to cut material after is has been delaminated into strips.

The original RPM calculation can be found in appendix A7. The following shaft diameters can also be found in appendix A9.

At CWU, a form of analysis is used called RADD. A requirement, analysis, design and documentation are needed in order to complete a RADD. Since the overall goal of the machine is to cut material, the experiment done was to find the necessary energy needed. From there, shaft diameters and blades were found as design parameters.



The image provided is the general layout of how the machine will be powered originally. Revisions were made that can been seen in appendix B. It is shown that the motor is connected to a shaft that will transmit a torque through the mating gears. With blades mounted on the shaft at desired distances, material will be able to be fed through an opening in the housing which will cut delaminated pieces into thinner, easier to transport and process pieces.

Performance Prediction and Scope

When predicting the success of the device, considering that all components are fastened securely, and the desired torque is met, the cutters should be able to cut through material. A potential issue that could arise the integrity of the cutters. When cutting material for trials in the foundry at CWU, the tungsten carbide blade was sufficient to cut through. But when speaking with John, he said that they use steel cutters and go through a lot of them. The biggest risk then would be finding cutters that would be able to cut through multiple rounds.

Another aspect that will determine success the level of delamination that will occur and the consistency of the delamination. If the fed material is delaminated across all levels, resin will be compromised and should allow for smoother cutting.

Engineering merit of this project will be based on the construction and success of the device. The manipulation of torque based off of a given motor involves calculations and using energy and an experiment to find a RPM that needs to be achieved.

The scope of the testing will be smaller compared to the proposed full warehouse John had us think about. The proof of concept if successful will show that a delaminating and cutting process done in one motion would be able to work.

3. METHODS & CONSTRUCTION

The project conceived this project after taking Plastics and Composites. A Boeing engineer, John Locklear presented us a problem with the recycling of composite material. Using the resources provided by CWU and the MET program, as well as a funding from JCATI the group will develop a bending and cutting process that will be attached together into a single machine. The goal of the combined machine will be when a single piece of material is fed into the bending process, it will move through into the cutting process and come out in strips at the end.

Using Kinetic Energy ($1/2mv^2$), an initial energy was calculated through experimentation. The energy calculation guided the design. Minimum diameters was based off of the energy, blades were selected based of mass, and gears were selected that would apply the needed RPM.

The first parts that were constructed was the housing. Using 5 pieces of 10" x 10" steel, a box was constructed. Initially, 2" was removed from two of the pieces so that a 10" x 8" cube could be instructed. The first operation was to drill and tap the holes that would be used to fasten the housing together with bolts. An issue occurred with trying to get the holes to match onto there mating plate. Using a center punch, a rough estimate was marked and then drilled. But since the steel plates were not perfectly flat, the transferring of the holes was inaccurate and did not provide a perfect fit. To fix this issue, larger holes were drilled and then countersunk so that there was more room for the bolts. A 3/8" drill was used which provided enough clearance. It was evident that certain edges matched. So to keep this assembling consistent, corners and edges were marked and there mating parts also marked so that the same assembly could be achieved.

The second part that was finished was the top plate that will allow for feeding of material. The first operation included using the plasma cutter. Using solidworks to create and stl file, a rectangle was designed. Once in the welding lab, the stl file was transferred onto the computer connected to the plasma cutter. With help from Matt, the plate was positioned so that the rectangle was centered. The plasma cutter cut through the material fine but left a slight dent on one of the edges. After the completion of the plasma cutting, the top plate also had to get ¼" holes drilled and tapped. This time, the holes were drilled on the top plate and holes transferred onto the housing. This proved to be a more efficient way of transferring the location of holes. The housing was now complete.

Once the housing was complete, the next parts to be completed were the shafts. And initial turning operation was done to both sides of the shafts to .998". These shafts were turned to under

1” because the bearings that will house the shafts ware 1 in. Once the shafts were turned to the overall diameters, the next operation was done complete the keyways. Both shafts needed keyways on both sides. Thanks to Matt, the mill was setup and the keys were machined. One issue that occurred was when the speed reduction was switched to sprockets. The sprocket had a keyway, so one of the shafts needed to have a keyway extended. Making the keyway on a second run was a tough operation and was done by the lab technician.

After the shafts were completed, the keys were all machined. The keys that were purchased were ¼” x ¼” and were undersized.

The motor was that purchased has a motor shaft was is 5” off the base. The motor shaft will house the smaller sprocket. The holes that were machined in both front plates were then located 5” off the bottom. The most critical location of the holes needed to be machined 2.5” apart. The 2.5” was calculated based off the gears. The holes could have been a little greater then 2.5 +.005, but could not be less then 2.5” because then the gears would not be able to rotate freely.

The final operation was to press fit the bearings into the machined holes that will house the shafts. Using the press, the bearings were placed over the holes and pressed into place. Another issue occurred after the press fitting because the bearings shrunk and the shafts would no longer fit. It was determined that .002” needed to be removed off all ends of the shafts. Due to that small of a tolerance, the shafts were placed into a manual lathe and sanded instead of machining. The sanding took about one hour and proved to be a effective way of removing minimal material because the shafts fit into the bearings. It was recommended that the shafts have a slight tight fit because the bearings will give a little to the shafts once the motor is connected.

Refer to renderings

In Appendix B, drawing 3 and 4 show diameter calculations. A minimum was calculated but sized up so that fitting with other components would work. The corresponding calculations can be seen in Appendix A 6 and 8.

Device Operation

The device will operate when the AC motor is powered. A delaminated piece of composite material will be fed through a hole in a plate into the rotating cutters. The piece will be fed until it is completely cut the entirety of the given length. Blades should be adjustable to dictate width of cuts.

Benchmark Comparison:

Due to the inspiration behind the design is based of a device like a paper shredder, it is hard to compare. After preliminary testing, it was found that 9000 lbs was the minimum force needed to break the integrity of the resin. So, the proposed device could be compared to a paper shredder but with a x100 power need. There are also cardboard slitters. But all comparisons need to be magnified significantly because unlike paper, this machine purpose will be to cut composite material.

Another piece of equipment that the cutter could be compared to is a wood chipper. A Kowloon diesel wood chipper has a motor that ranges from 60-100 HP. The proposed solution uses a 5HP motor. So the cutter being designed would have 12.5% of the total power of a commercial wood chipper.

Performance Predictions:

If all components are assembled and secure, the device will be able to cut material using only 36% of the total RPM output of the proposed motor.

4. TESTING METHOD

Due to the motor having a variable RPM, a test will have to run in order to find what RPM will provide the best for cutting the composite material into strips. The device will have rotating shafts with cutters mounted onto them. The engine will be fixed and connected to a sprocket system which will transmit power to the device. Due to the material being as hard as it is, experimenting with the power of the motor will need to be done to better predict the RPM vs thickness of the material. Using the calculated minimum RPM that will be the benchmark in which testing will be done.

To test both devices simultaneously, it was proposed that a mount be devised that could hold both operations. A potential issue is the mass of the devices and motors. The motors themselves are near 100 lbs each and the cutting assembly is above 50 lbs. If a plan is developed that would allow for mounting off all components, there is enough funds to spend to achieve this goal.

An issue that can appear when testing is that the delamination process will not produce a consistent delaminated piece of material. So it may be shown that the cutters will more effectively cut a fully delaminated piece of composite versus one that is not delaminated. The cutters will be dependent on the level of delamination.

Test Plan:

The information and equipment that will be needed is a sensor to record the RPM of the shafts. A similar method was used in a thermodynamics lab and that model of testing for RPM will also be used for this device.

The second part of the test will be focused on how efficiently the blades will cut the composite material. The ideal test would include a variable RPM depending on the thickness of the composites that will be cut by the device. A spreadsheet maybe be utilized with variables thicknesses and RPM to predict whether the device will perform by cutting apart the composite material.

Test Documentation and Deliverables

Test data will be collected on an excel spreadsheet so that analysis can be done on variable thicknesses and RPMs. By experimenting the RPM and thickness of material, scaling of a larger, more powerful machine will be done.

BUDGET/SCHEDULE/PROJECT MANAGEMENT

Budget

The budget for this project is $5000.00 due to a grant that was secured from JCATI. A considerable amount of that budget will be spent on the delamination process due to the power that is needed to delaminate. The current proposed device has an estimated cost of $1567.86. The current expenditure is $1673.49. That total is subject to change with the possibility of getting material and labor donated. There is also a risk of raising the price if more intricate parts will need to be machined to tight tolerances.

Prices were determined from McMaster-Carr for appropriate parts. Raw material was estimated.

A parts list with costs is provided in Appendix C with all part numbers and prices. These totals do not include shipping and handling.

Schedule

An estimated schedule is provided in Appendix E in the form of a Gantt Chart as well as an description. The overall schedule is dictated by CWU MET 489 A-C. A proposal is due at the end of fall quarter. The working device will be done sometime within winter and spring quarter. The final project will be due at the end of spring quarter.

The winter break will provide time to work on drawings and completing a more detailed assembly.

The construction of the device was completed March 7, 2018. There are still fasteners and spacers that need to be ordered, but all machining is complete.

Project Management

This project is managed by the designer and the other member of the team. Advice and expertise is given in the form of emails from John, as well verbally in meetings with professors. The

Senior Project series come with a schedule and deadlines. Those dates dictate the pace that certain aspects get done. The winter will be focused on the building of the device while spring will be on testing and presenting the results.

Risk Analysis

One potential risk that the team might face is over spending. Since both operations need separate motors, and high power motor for delamination, a potential to use all funds is likely. Another risk that must be accounted for is if the blades do not last for multiple cycles. When speaking with John, the use of steel cutters was mentioned and that a lot of them were used and tossed because of the composite material.

DISCUSSION

The development of the design has changed a few times over the quarter. At first a device was conceived that would allow for delamination of the material using equipment provided by CWU. But considering that there are two people working on this project, the scope needed to be expanded. That was when the group broke off and focused on delamination and cutting. Once the concrete purpose of the project was addressed, then research and ideas of how to cut the material was developed. The shredder is an efficient way that would only need a single person to operate.

Upon completion of the experiment, a more focused path was set in completing from analysis that would allow for design parameters. The experiment was instrumental in getting some initial values to base the design around. By doing the experiment and using kinetic energy, the changing variable that can be used is the mass of the blade. Finding heavier blades out of a material that can cut through composite still needs to be determined prior to any funds being used on them. But knowing the RPM requirement, the machine should work once constructed.

The ongoing changes have been frequent. The recent development that has the two devices being joined into has called for a few problems that will be addressed during the coming break. A delamination process and cutting process now needs to happen in series, with one initial movement. Focusing on the housing, gear box, motor connections and fastening the entire machine has proven to be a challenge but significant progress has been made. At the current rate once material is ordered and machined, the only potential problem could be the cutters and seeing if they will be able to survive multiple rounds of cutting. And finding a way to secure the entire machine that does not involve a large, heavy piece of steel needs to be analyzed due to the potential rise in cost.

CONCLUSION

Upon completion of the device, a successful project would produce cut material at desired widths due to the blades spacing being adjustable. The project would have met the requirements of getting all power from a single motor, costing under $2,500 and successfully cutting composite material. The major requirement that was recently brought to attention is that both the delamination and cutting must be put together into one device with two separate components. A successful project will count on having a single device, performing delamination and cutting in two separate processes, but with one initial movement and a federate of 100 ft/s. Material should come out in the end delaminated and cut to desired width that will allow for better processing (1in). Due to the spacers that have been added to the assembly, the blades will be able to manipulated. If the device is successful, further research can be done to find out the optimal size of chips. If the optimal size of chips is something that can be achieved on the 4” of keyway, then the blades can be positioned into the desired location for the best results. If the cutter prove to work, then predictions on how many chips can be made within a time period can be predicted.

The project has been successful based off the three listed requirements. But as a group we were not able to complete any testing. The manufacturing of a frame and wiring the motors proved to be a much larger task then originally thought. As a group, we have made the necessary devices and have all the parts needed to conduct tests. If a future group decides to take on the project, they would focus on the frame and wiring of the motors and could conduct tests.

This project taught us a lot about what it takes to design and make a mechanical device. There was a lot of learning on fly but those lessons will stick with us forever and we now have experience in designing mechanical systems. The scope was under estimated but the knowledge gained will be able to last forever in our careers.

ACKNOWLEDGEMENTS

A special acknowledgment to Dr. Johnson for guiding the ideas behind this project. And Dr. Johnson went out of his way and was able to secure a grant that will be used to finance the project. JCATI for supplying the group with funds and an opportunity to share the ideas and results of the project.

Also, a major thank you to professor Pringle for helping with the idea and fine tuning the details. It was through the spreadsheets provided by Professor Pringle and his genuine interest in the project that problems were able to be faced and dealt with. Professor Pringle was always willing to listen and diagnose the many problems that we encountered.

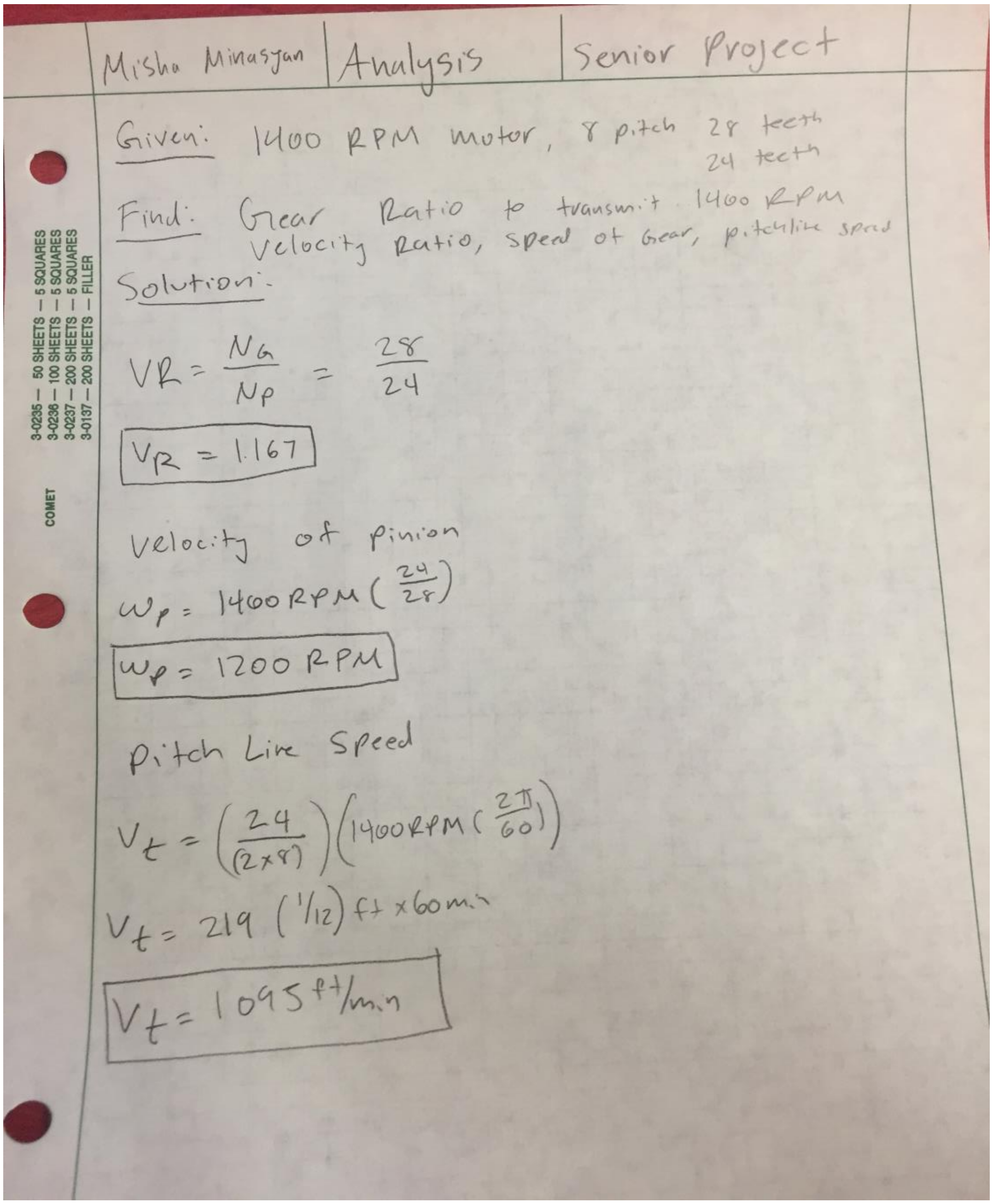
And for John Locklear from Boeing for giving the team the opportunity to work on this project. John supplied the group with valuable information that will be used in the process of developing and building the machine and scaling of the potential operation. It was through a colleague of John that a recommendation was given on the type of blades to use.

Also, to Matt Burvee and Ted Bramble. Matt was able to provide valuable insight on machining and provide lab hours. Matt also was the person in charge of ordering materials and parts and always did them right of way. His advice on machining and helping with complicated machining tasks helped to provide a working device. Ted was able to help achieve the center to center distance that made it possible for the gears to be able to rotate and have contact.

APPENDIX A – Analyses

A.1 Gear Properties

Gear properties that will suit my RPM requirement. Spread sheets have been made due to the number of time this project has been changed to quicker do calculations.



Misha Minasyan | Analysis | Senior Project

Given: 1400 RPM motor, 8 pitch 28 teeth
24 teeth

Find: Gear Ratio to transmit 1400 RPM
Velocity Ratio, speed of Gear, pitchline speed

Solution:

$$VR = \frac{N_G}{N_P} = \frac{28}{24}$$

$$\boxed{VR = 1.167}$$

Velocity of pinion

$$\omega_p = 1400\,RPM\left(\frac{24}{28}\right)$$

$$\boxed{\omega_p = 1200\,RPM}$$

Pitch Line Speed

$$V_t = \left(\frac{24}{(2\times 8)}\right)\left(1400\,RPM\left(\frac{2\pi}{60}\right)\right)$$

$$V_t = 219\left(\tfrac{1}{12}\right) ft \times 60\,min$$

$$\boxed{V_t = 1095\,ft/min}$$

COMET
3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

A.2 Housing Requirements:

Housing requirements to house gear system. Spreadsheet has been made to quicker make changes due to the ongoing changes that have happened.

Misha Minasyan	Analysis	Senior Project

Given: 1400 RPM, 8 pitch 28 teeth
8 pitch 24 teeth

Find: Dimensions in X and y for housing providing .1in of clearance.

Solution:

$$P_d = \left(\frac{8 \text{ teeth}}{\text{in}}\right)\left(\frac{1 \text{ in}}{25.4\text{mm}}\right) = .3149 \text{ teeth/mm}$$

$$a = 1/P_d = 1/.3149 = 3.176 \text{mm}$$

$$D_G = \frac{(28+2)}{.3149} = 95.27\text{mm}$$

$$Y = 95.27\text{mm} + 2(2.54\text{mm}) = \boxed{3.95\text{in} \uparrow}$$

$$X = \frac{24}{.3149} + \frac{28}{.3149} + 2(3.176\text{mm}) + 2(2.54\text{mm})$$

$$\boxed{X = 6.93\text{in} \rightarrow}$$

A.3 Bending Stress Calculation:

Bending stress calculation. Spreadsheet has been made to quicker make these calculations.

Misha Minasyan | Analysis | Senior project

Given: $N_P = 28$ $P_d = 6$ $HP = 1.75 HP$
$N_G = 24$ 1400 RPM $F = 2.25$

Find: Bending Stress in pinion

Solution:

$$S_t = \frac{W_t P_d}{F J} K_o K_s K_m K_B K_v$$

$D_P = N_P/P_d = 28/6 = 4.67$

$$V_t = \frac{(\pi)(4.67)(1400 RPM)}{12} = 1711 \ ft/min$$

$$W_t = \frac{33{,}000(1.75)}{1711} = 33 lb$$

$D_G = 24/6 = 4$

J - Figure 9-15 = .325

$$C = \frac{(28+24)}{(2)(6)} = 4.33 in$$

$n_G = 1400 RPM \left(28/24\right) = 1633.33$ rpm

$VR = (28/24) = 1.167$

K_o - table 9-7 = 1.5 $K_v = 1.13$

$K_s = 1$

$K_m = 1 + .033 + .25 = 1.305$

$K_B = 1$

$$S_{tP} = \frac{(33 lb)(6)}{(2.25)(.325)} (1.5)(1)(1.305)(1)(1.13) = 598 \ lb/in^2$$

A.4 Kinetic Energy Calculation:

An experiment was conducted to find the kinetic energy. Using a hammer and chisel, a kinetic energy to fracture a 5/8" strip of composite material was done.

Analysis

Given: 7 1/2 lb hammer
.2 seconds
$\Delta h = 5.6in$

Find: kinetic energy

Solution:

$ke = 1/2 mv^2$

$$V = \frac{5.6in}{.2s} = \left(28\ in/s\right)\left(\frac{1\ ft}{12\ in}\right) = \underline{2.33\ ft/s}$$

$$ke = (1/2)(7.5\ lbm)\left(\frac{1\ lbf}{32.174\ \frac{lbm \cdot ft}{sec^2}}\right)\left(2.33\ ft/s\right)^2$$

$$ke = .6326\ lbf\text{-}ft\ \left(\frac{12in}{1ft}\right)$$

$$\boxed{ke = 7.593\ lbf\text{-}in}$$

A.5 Scaling the Kinetic Energy

Using the conservation of energy, and the area of the test specimen, a new energy was calculated by using the proportions and calculated energy.

Analysis

Given: 7.593 lb-in $9\,in^2$ Area

$.125\,in^2$ Area

Find: Ke for 3x3in piece

Solution:

$$Ke = (1/2)(7.5\,lbm)\left(\frac{1\,lbf}{32.2\,\frac{lbm\text{-}ft}{s^2}}\right)(2.33\,ft/s)$$

$$Ke = 7.593\ lb\text{-}in$$

$$\frac{7.593\ lb\text{-}in}{.125\,in^2} = \frac{Ke_2}{9\,in^2}$$

$$Ke_2 = \frac{7.593\ lb\text{-}in\,(9\,in^2)}{.125\,in^2}$$

$$\boxed{Ke_2 = 546.7\ lb\text{-}in}$$

A.6 Minimum Diameter

Depending on the required RPM and power, a minimum diameter can be calculated. Using the text book for MET 418, a minimum diameter was calculated, and the shaft was designed with the diameter. The diameter needed to be larger so that it could fit with the other components but the minimum was met.

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

Analysis

Given: 10 HP electric Motor A36
1750 RPM
SF = 3

Find: minimum shaft ϕ

Solution:

$$\text{Torque} = \frac{(63{,}000)(10\,HP)}{1750\,RPM} = 360\ lb\text{-}in$$

Shear Stress In shaft

$$\tau = \frac{(\text{Torque})(r)}{J} = \frac{T\left(d/2\right)}{\left(\frac{\pi}{32}d^4\right)} = \frac{16T}{\pi d^3}$$

$$\tau_{max} = \frac{\tau_y}{n} = \left(\frac{1}{n}\right)\left(\frac{S_y}{2}\right)$$

$S_y = 36000\ psi$ pg 729

$$\frac{16T}{\pi d^3} = \left(\frac{1}{n}\right)\left(\frac{S_y}{2}\right)$$

$$d = \sqrt{\frac{32nT}{\pi S_y}} = \sqrt{\frac{(32)(3)(360\ lb\text{-}in)}{(\pi)(36000\ lb/in^2)}}$$

$$\boxed{d = .5527\,in}$$

A.7 RPM Requirement

Working backwards after an energy was calculated, a tangential velocity was then needed for a piece of composite that has the original thickness. From there, a tangential velocity was calculated and converted in a RPM which will be used as a started point when testing the completed machine.

Analysis

Given: 546.7 lb-in ke, 1 lb blade, Ø=.5527in

Find: V, Required minimum RPM

Solution:

$$546.7 \text{ lb-in} = \frac{1}{2} m v^2$$

$$\sqrt{\frac{(2)(546.7 \text{ lb-in})}{1 \text{ lb}}} =$$

$$V_t = 33.06 \text{ in/s}$$

$$\left(33.06 \text{ in/s}\right)\left(\frac{1 \text{ Rev}}{2\pi r}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = \boxed{571.19 \frac{\text{Rev}}{\text{min}}}$$

For a 1 lb blade, a 571.19 RPM will be required

A.8 Second Minimum Diameter Calculation

Since there an initial RPM and a second RPM transmitted by the gears, a second minimum diameter was needed. Here minimum diameter that the shafts that will have blades attached to them will need to work with the RPM that will be transmitted. The diameter was changed, but was larger then the minimum calculated here.

Analysis

Given: 10 HP electric Motor

571 RPM

SF=3 A-36

Find: minimum shaft Ø

Solution:

$$T = \frac{63000(10\ HP)}{571\ RPM} = 1103.3\ lb\text{-}in$$

Shear Stress in shaft

$$\tau = \frac{T(d/2)}{(\pi/32)(d^4)} = \frac{16T}{\pi d^3}$$

$$\tau_{max} = (1/n)(S_y/2) \qquad S_y = 36000\ psi$$

$$\frac{16T}{\pi d^3} = (1/n)(S_y/2)$$

$$d = \sqrt{\frac{32nT}{\pi S_y}} = \sqrt{\frac{(32)(3)(1103\ lb\text{-}in)}{(\pi)(36000\ psi)}}$$

$$\boxed{d = .967\ in}$$

A.9 Key Calculation for Cutting

Analysis

Given: A36 key 571 lb-in

$N = 3$.

Find: L_{min}

Solution:

$$L_{min} = \frac{(4)(571\ \text{lb-in})}{\left(\frac{36000\text{psi}}{3}\right)(1.25\text{in})(.25\text{in})}$$

$$\boxed{L_{min} = .609\ \text{in}}$$

The Shafts that mate with Gears on the cutters will need a minimum length of .609in to withstand the 571 lb-in Torque

A.10 Key Calculation for Motor

Analysis

Given: A36 steel

Motor RPM = 1750

$N = 3$ $\quad S_y = 36{,}000\,psi$

Find: Torque

L_{min}

Solution:

$$T = \frac{63000\,(10HP)}{1750} = 360\ lb\text{-}in$$

$$L_{min} = \frac{(4)(360\ lb\text{-}in)}{\left(\frac{36000\,psi}{3}\right)(1in)(.25in)}$$

$$L_{min} = .48in$$

The minimum length of the key that will connect the motor to the gear needs to be .48 in. The designed key is equal to the length of the coupling found on Mcmaster-Carr. See drawing B5.

A.11 Diameter for Pins Connecting Housing

Analysis

Given: $T = 571\ \text{lb-in}$

$D = 1\ \text{in} \quad N = 3$

Find:

Ø for pin

τ_d

Solution:

$$\tau_d = \frac{.5\,S_y}{N} \quad \text{Mott}$$

$$\tau_d = \frac{(.5)(36000\ \text{psi})}{3}$$

$$\tau_d = 6000\ \text{lb/in}^2$$

Required Ø

$$d = \sqrt{\frac{4T}{D\pi\tau_d}} \quad \text{Mott 11-19}$$

$$d = \sqrt{\frac{4 \times 571\ \text{lb-in}}{(1\ \text{in})(\pi)(6000\ \text{lb/in}^2)}}$$

$$\boxed{d = .348\ \text{in}}$$

Based off the calculated torque, a minimum diameter of .348 in will be needed to connect the housing. The bolts that will be used are .375 in and are above the minimum given the material.

A.12 Shear Stress in Shaft

Analysis

Given: $\varnothing = 1\,in$

$T = 571\,lb\text{-}in$

$r = .5\,in$

Find: J - polar moment of inertia

τ_{shaft}

Solution:

$$J = \frac{\pi D^4}{32} = \frac{(\pi)(1\,in^4)}{32} = .09817\,in^4$$

$$\tau = \frac{Tr}{J} = \frac{(571\,lb\text{-}in)(.5\,in)}{.09817\,in^4}$$

$$\boxed{\tau = 2908.2\ lb/in^2}$$

The shear in the shaft will have a stress of 2908 psi.

The shaft will experience a shear stress of 2908 psi. The chosen material, A36 will allow the shaft to rotate without failure.

A.13 Chain Spreadsheet Calculation

CHAIN DRIVE DESIGN			
Initial Input Data:	*Example Problem 7-3 - Multiple strands*		
Application:	*Coal Conveyor*		
Drive type:	*Engine-Mechanical drive*		
Driven machine	*Heavily loaded conveyor*		
Power input:	*5*	hp	
Service factor:	*1.5*		Table 7-8
Input speed:	*1750*	rpm	
Desired output speed:	*600*	rpm	
Computed Data:			
Design power:	7.5	hp	
Speed ratio:	2.92		
Design Decisions-Chain Type and Teeth Numbers:			
Number of strands:	*1*		1 2 3 4
Strand factor:	*1.0*		1.0 1.7 2.5 3.3
Required power per strand:	7.50	hp	
Chain number:	*40*		Tables 7-5, 7-6, or 7-7
Chain pitch:	*0.5*	in	
Nunber of teeth-Driver sprocket:	*14*		
Computed no. of teeth-Driven sprocket:	40.83		
Enter: Chosen number of teeth:	*44*		Check availability from vendor
Computed Data:			
Actual output speed:	556.8	rpm	
Pitch diameter-Driver sprocket:	2.247	in	
Pitch diameter-Driven sprocket:	7.009	in	
Center Distance, Chain Length and Angle of Wrap:			
Enter: Nominal center distance:	*30*	pitches	30 to 50 pitches recommended
Computed nominal chain length:	89.8	pitches	
Enter: Specified no. of pitches:	*110*	pitches	Even number recommended
Actual chain length:	55.00	in	
Computed actual center distance:	40.217	pitches	
Actual center distance:	20.108	in	
Angle of wrap-Driver sprocket:	166.4	degrees	Should be greater than 120 degrees
Angle of wrap-Driven sprocket:	193.6	degrees	

The original plan of using a system of gears to reduce the RPM from 1750 to around 600 had to be changed. The reasoning of the change was that finding gears with the number of teeth and pitch diameters proved to be a problem. One way that this could have been fixed was if custom gears were made that would produce a 3:1 reduction. A quote from *rushgears.com* came out to be an excess of $1000.00 which was not possible. Material would have to been ordered and carful machining would have to be done to produce the desired results. To bypass the machining of new gears, a chain and sprocket was used. Using the spreadsheets provided by Professor Pringle, a 2.92 speed reduction was attained, and sprockets ordered from McMaster Carr.

A.14 Gear Spreadsheet Calculation

DESIGN OF SPUR GEARS			*APPLICATION:*	
Initial Input Data:				
Input Power:	$P =$	*7.5*	hp	
Input Speed:	$n_P =$	*600*	rpm	
Diametral Pitch:	$P_d =$	*8*		
Number of Pinion Teeth:	$N_P =$	*20*		
Desired Output Speed:	$n_G =$	*600*	rpm	
Computed number of gear teeth:		20.0		
Enter: Chosen No. of Gear Teeth:	$N_G =$	*20*		
Computed data:				
Actual Output Speed:	$n_G =$	600.0	rpm	
Gear Ratio:	$m_G =$	1.00		
Pitch Diameter - Pinion:	$D_P =$	2.500	in	
Pitch Diameter - Gear:	$D_G =$	2.500	in	
Center Distance:	$C =$	2.500	in	
Pitch Line Speed:	$v_t =$	393	ft/min	
Transmitted Load:	$W_t =$	630	lb	
Secondary Input Data:				
	Min	Nom		Max
Face Width Guidelines (in):	1.000	1.500		2.000
Enter: Face Width:	$F =$	*1.000*	in	
Ratio: Face width/pinion diameter:	$F/D_P =$	0.40		
Recommended range of ratio:	$0.50 < F/D_P < 2.00$			
Enter: Elastic Coefficient:	$C_p =$	*2300*	Table 9-10	
Enter: Quality Number:	$Q_v =$	*6*	Table 9-2	
Enter: Bending Geometry Factors:				
Pinion:	$J_P =$	*0.325*	Fig. 9-15	
Gear:	$J_G =$	*0.410*	Fig. 9-15	
Enter: Pitting Geometry Factor:	$I =$	*0.104*	Fig. 9-21	
	REF:			
	m_G =	1.00		

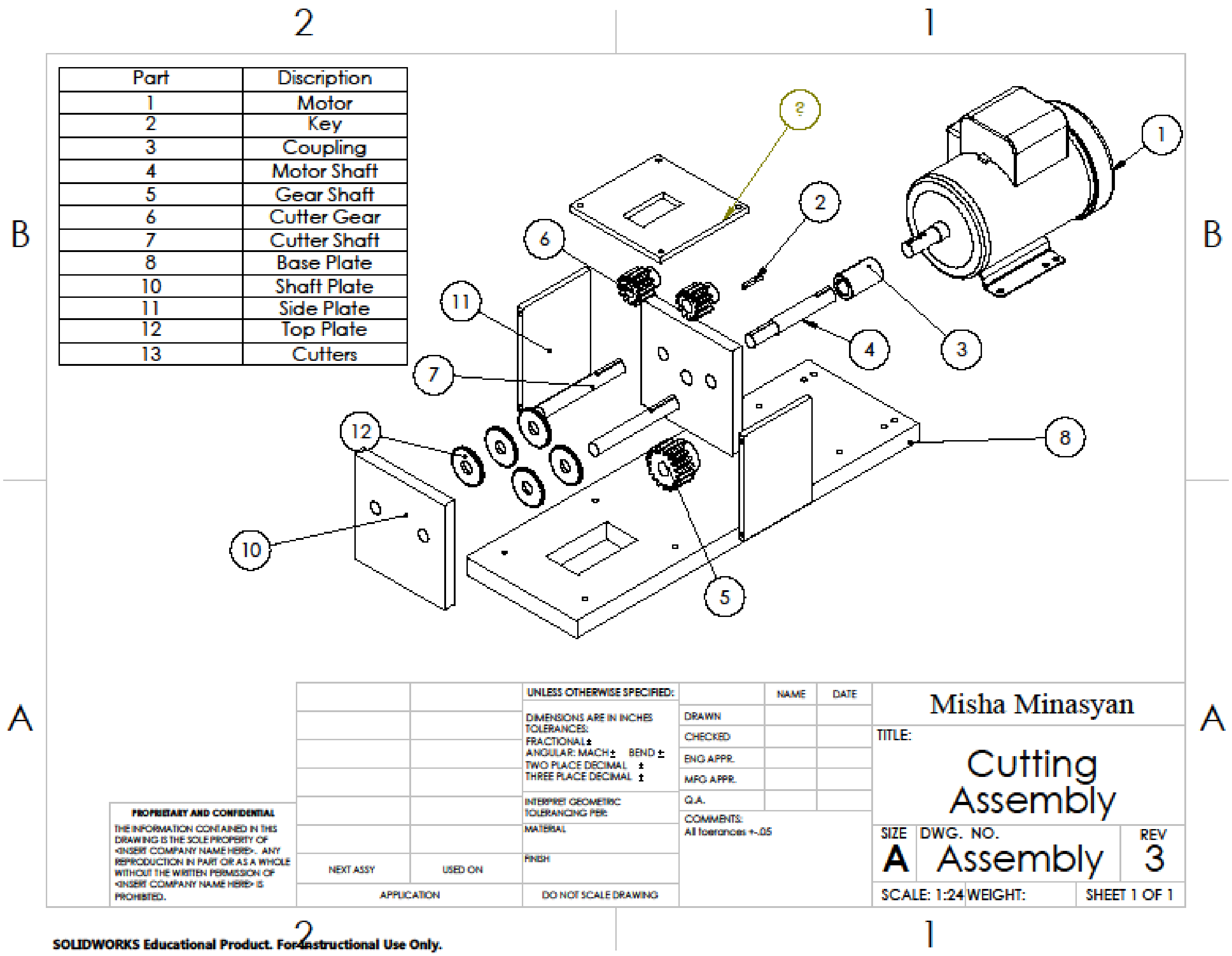
A.14 Gear Spreadsheet Calculation Continued

Factors in Design Analysis:				
Alignment Factor, K_m=1.0+C_{pf}+C_{ma}	If F<1.0	If F>1.0		
Pinion Proportion Factor, C_{pf} =	0.015	0.015	[0.50 < F/D_P < 2.00]	
Enter: C_{pf} =	*0.042*	Figure 9-16		
Type of gearing:	Open	Commer.	Precision	Ex. Prec.
Mesh Alignment Factor, C_{ma} =	0.264	0.143	0.080	0.048
Enter: C_{ma} =	*0.264*	Figure 9-17		
Alignment Factor: K_m =	1.31	[Computed]		
Overload Factor: K_o =	*1.75*	Table 9-6		
Size Factor: K_s =	*1.00*	Table 9-7: Use 1.00 if P_d >= *5*		
Pinion Rim Thickness Factor: K_{BP} =	*1.00*	Fig. 9-18: Use 1.00 if solid blank		
Gear Rim Thickness Factor: K_{BG} =	*1.00*	Fig. 9-18: Use 1.00 if solid blank		
Dynamic Factor: K_v =	1.27	[Computed: See Fig. 9-19]		
Service Factor: *SF* =	*1.00*	Use 1.00 if no unusual conditions		
Hardness Ratio Factor: C_H =	*1.00*	Fig. 9-23 or 9-24; Gear only		
Reliability Factor: K_R =	*1.00*	Table 9-9	Use 1.00 for *R* = .99	
Enter: Design Life:	*3000*	hours	See Table 9-8	
Pinion - Number of load cycles: N_P =	1.1E+08	Guidelines: Y_N, Z_N		
Gear - Number of load cycles: N_G =	1.1E+08	10^7 cycles	>10^7	<10^7
Bending Stress Cycle Factor: Y_{NP} =	*0.96*	1.00	0.98	Fig. 9-20
Bending Stress Cycle Factor: Y_{NG} =	*0.98*	1.00	0.98	Fig. 9-20
Pitting Stress Cycle Factor: Z_{NP} =	*0.92*	1.00	0.95	Fig. 9-22
Pitting Stress Cycle Factor: Z_{NG} =	*0.95*	1.00	0.95	Fig. 9-22
Stress Analysis: Bending				
Pinion: Required s_{at} =	46,793	psi	See Fig. 9-8 or	
Gear: Required s_{at} =	36,335	psi	Table 9-3 or 9-4	
Stress Analysis: Pitting				
Pinion: Required s_{ac} =	209,449	psi	See Fig. 9-9 or	
Gear: Required s_{ac} =	202,835	psi	Table 9-3 or 9-4	
Specify materials, alloy and heat treatment, for most severe requirement.				
One possible material specification:				
Pinion requires HB 320: AISI 4140 OQT 1000; HB 341, 18% Elongation				
Gear requires HB 310: AISI 4140 OQT 1100; HB 311, 20% Elongation				

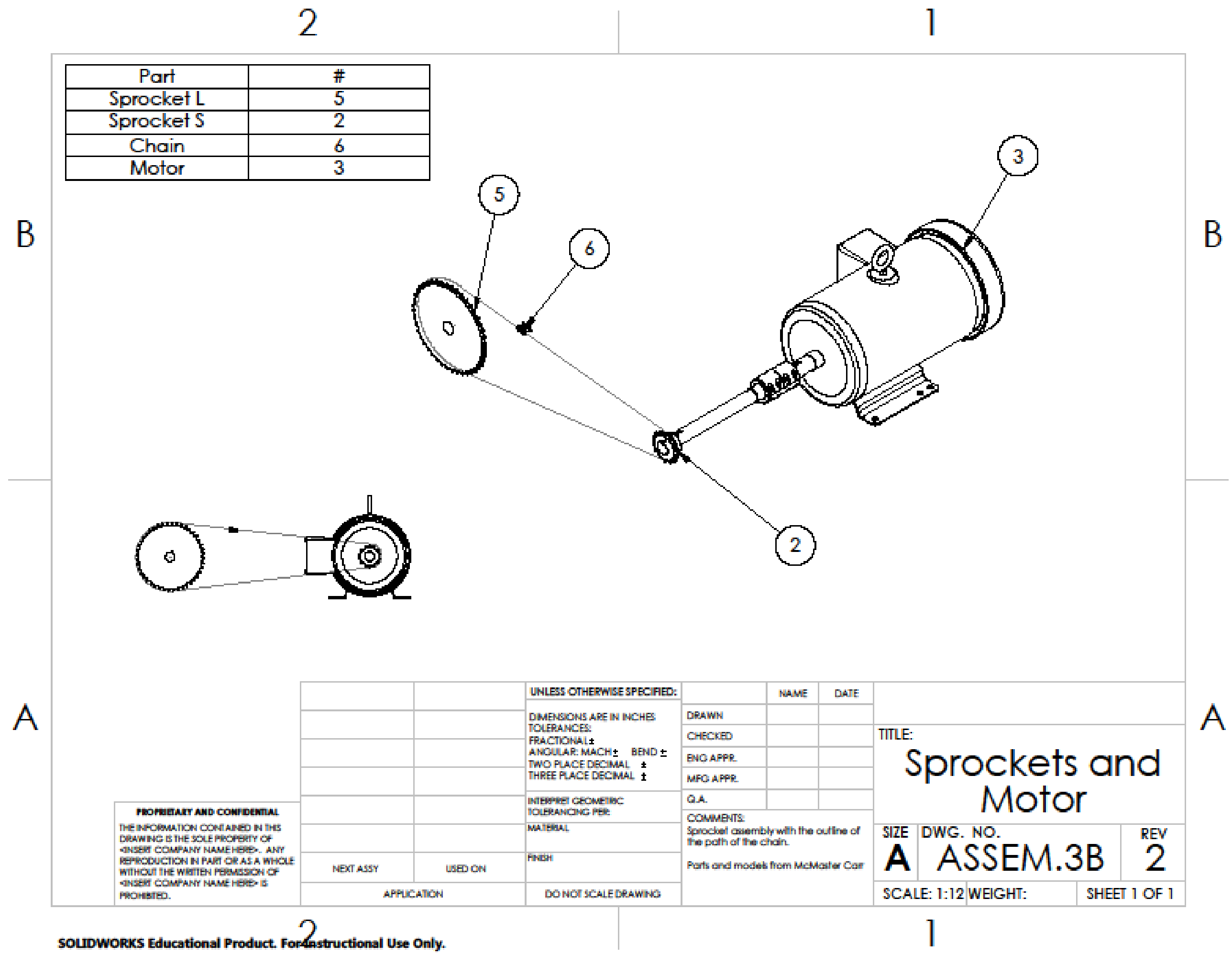
Using the information attained in the previous calculation, multiple iterations were done using this gear calculation spreadsheet provided by Professor Pringle. This spreadsheet provided a convenient way to find the proper gear. But since not all gears were available on McMaster Carr, iterations were done until a set of gears were found that would work but were also readily available for purchase. The final gear had a pitch diameter of 2.5 in and a total of 20 teeth. This proved to be the most critical dimension needed when constructing the device. Since the center to center distance was calculated to be 2.5 in, it was important that it was met.

APPENDIX B – Sketches, Assembly drawings, Sub-assembly drawings, Part drawings

Assembly.1 First Version of Assembly

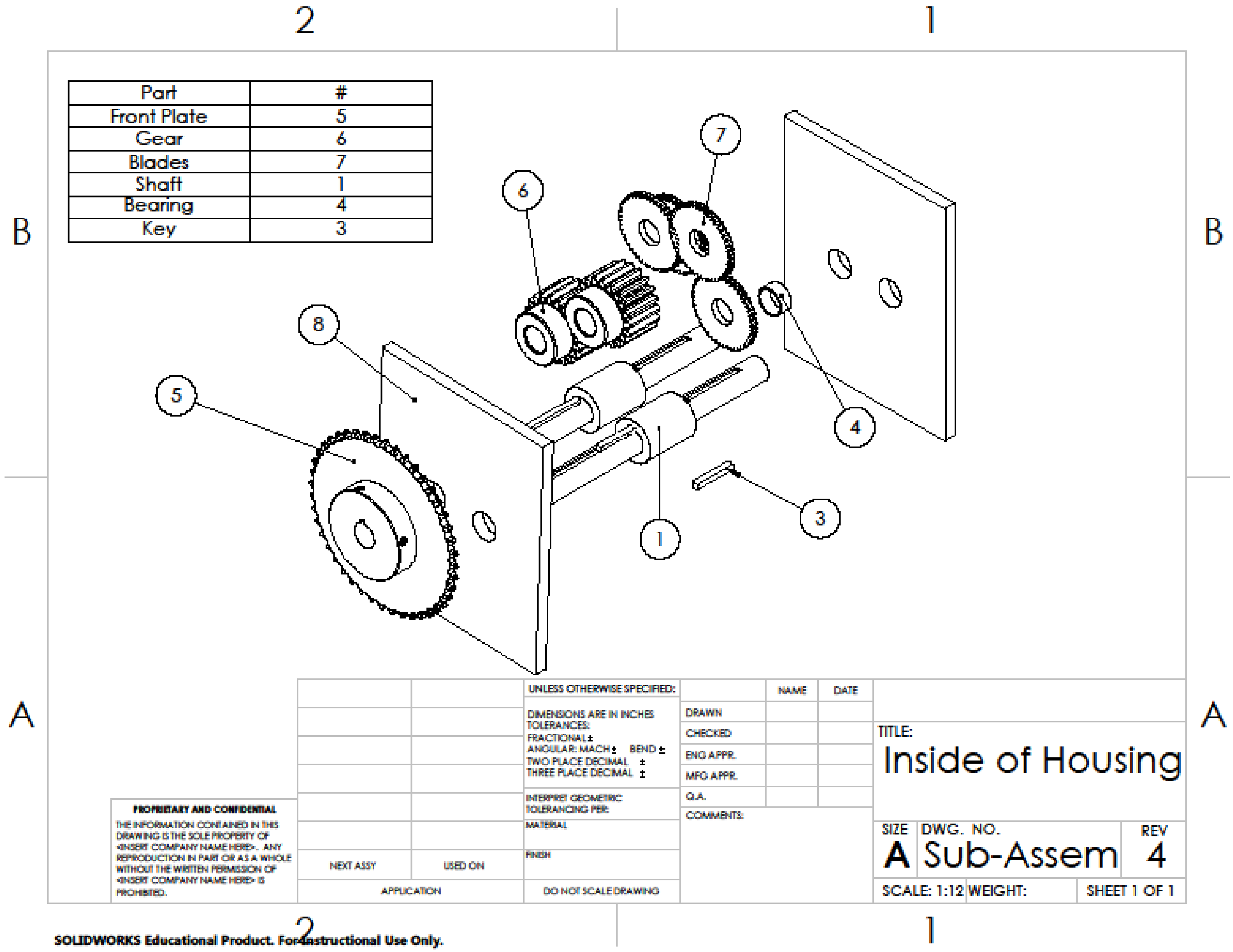


Assembly.2 Final Sprocket Assembly



The assembly drawing represents the motor and sprocket assembly without the housing. The image of the housing with the sprocket and motor assembly was thought to be better apart because of the spacing of the sprockets making it hard to see the entire assembly.

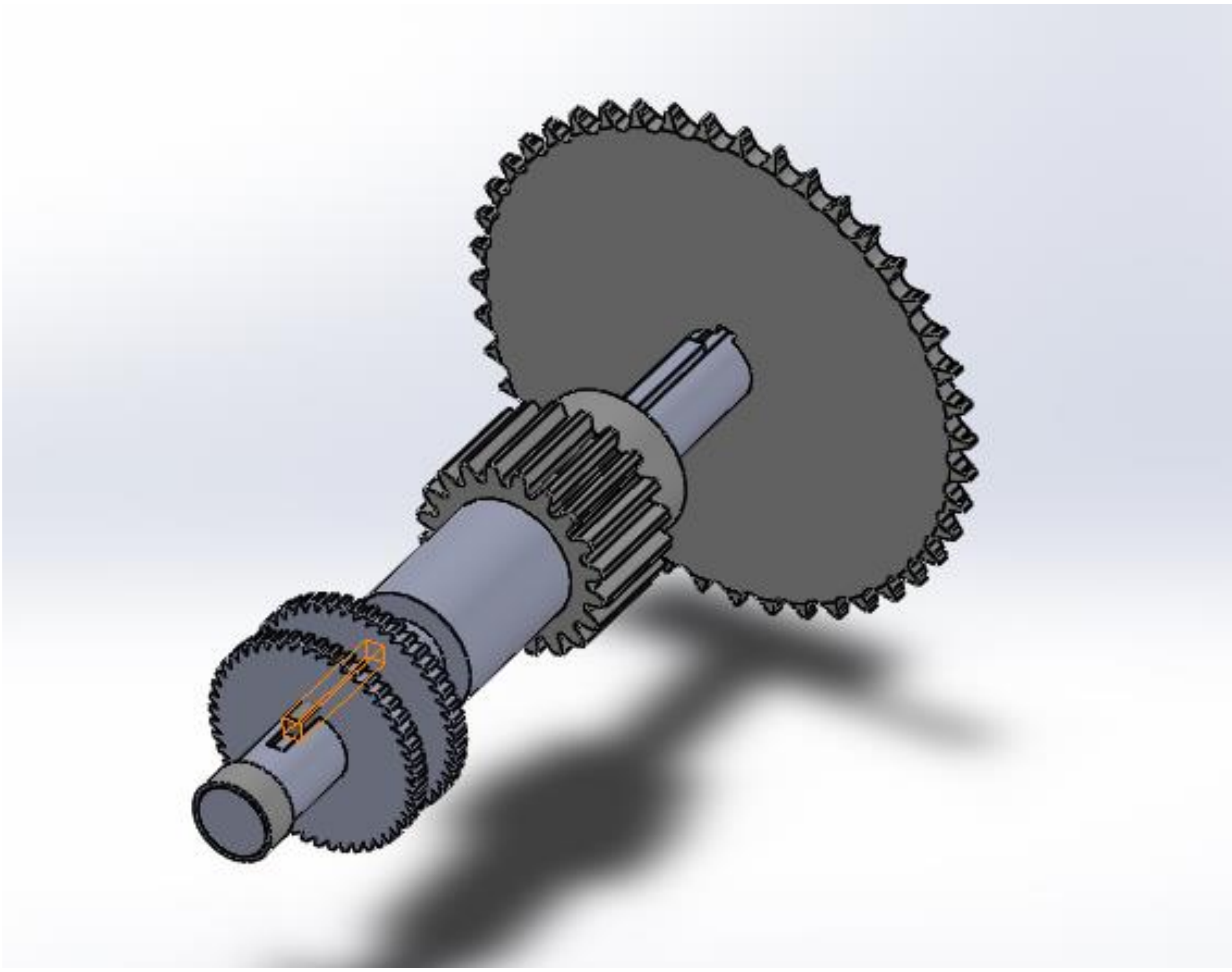
Assembly .3 Inside of Housing



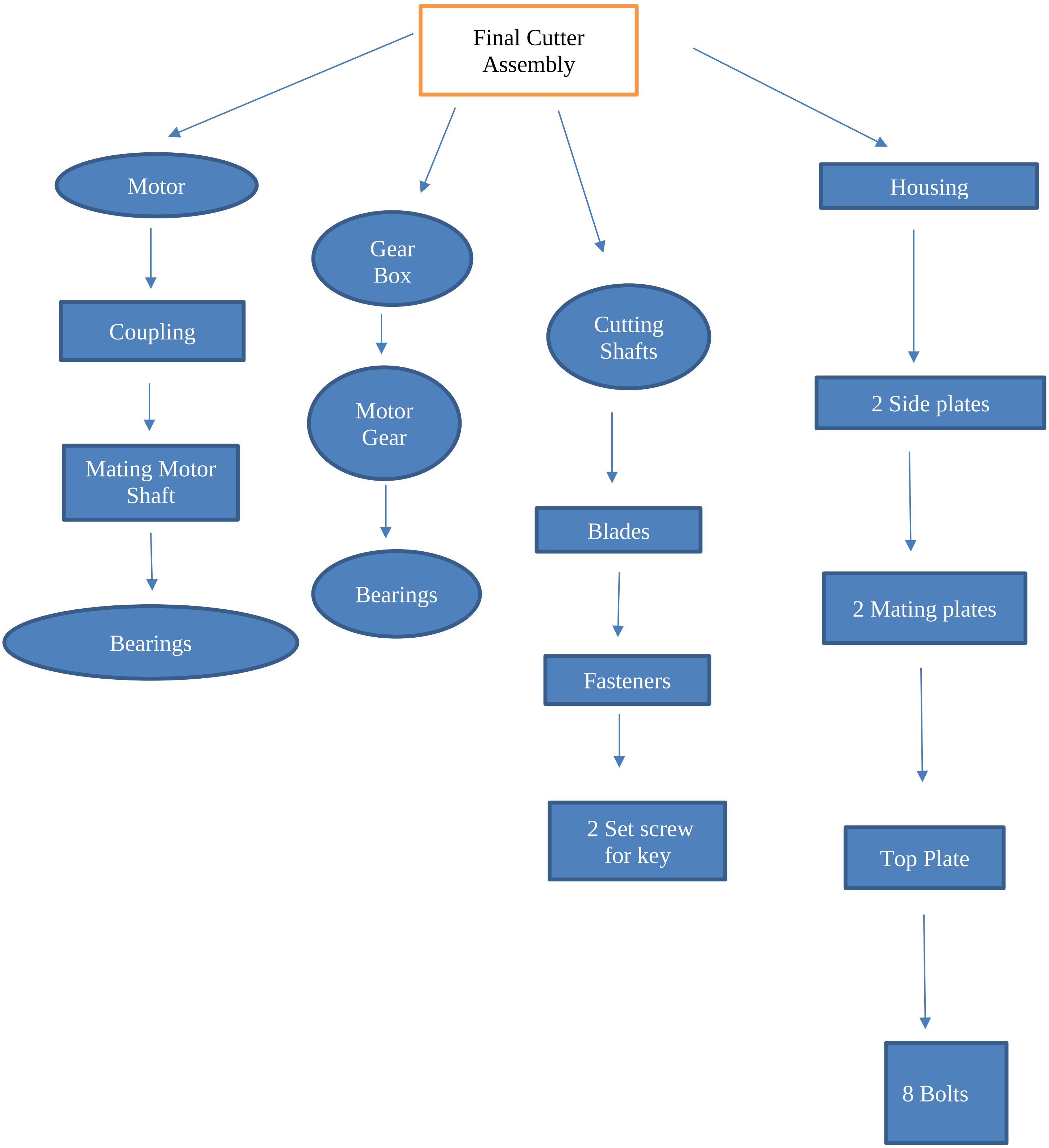
Part	#
Front Plate	5
Gear	6
Blades	7
Shaft	1
Bearing	4
Key	3

This is the assembly of the inside of a constructed assembly. The side plates and top plate were not included. The reason behind this assembly is to show the shafts fully equipped.

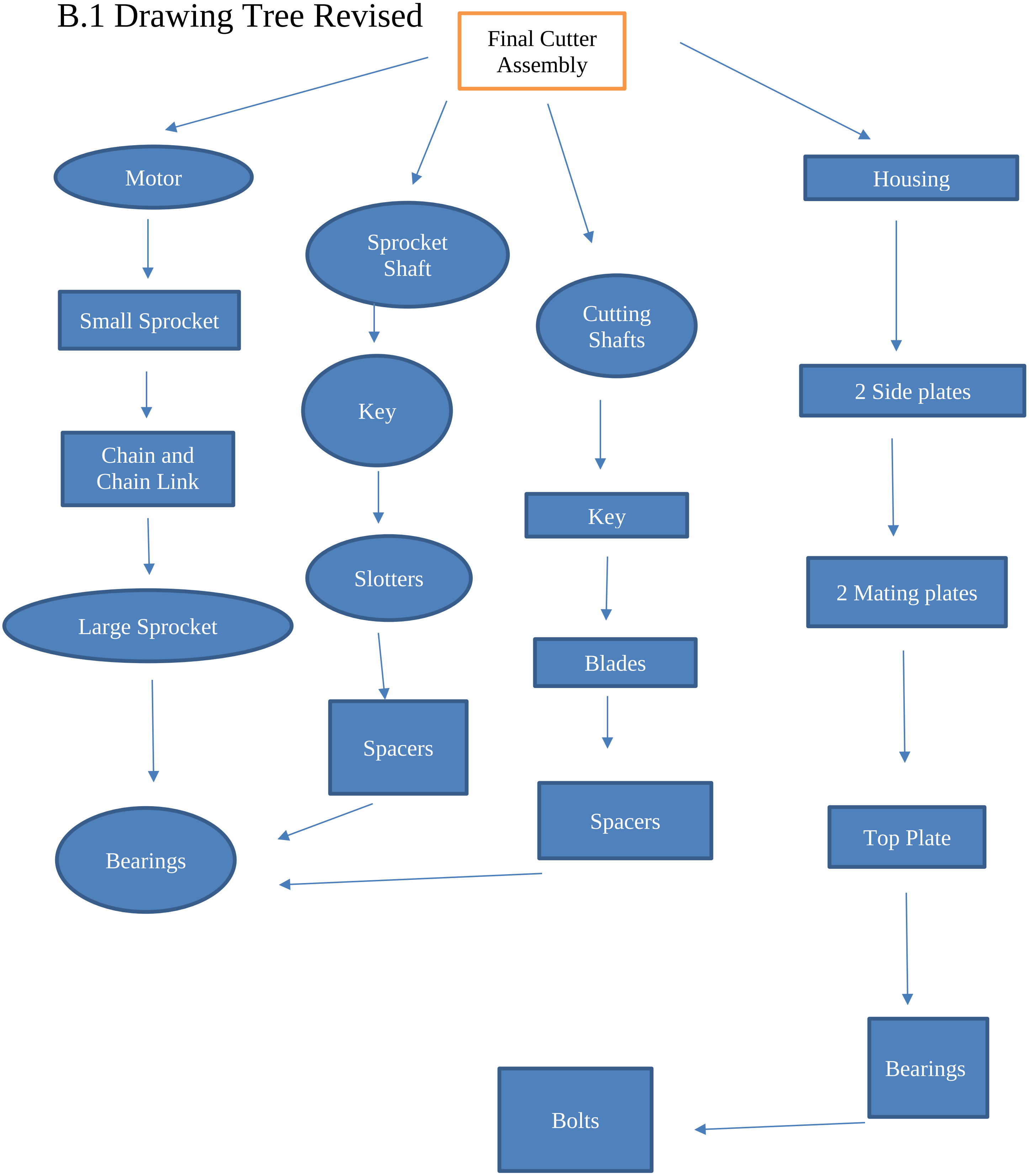
Sprocket Shaft Assembly Model



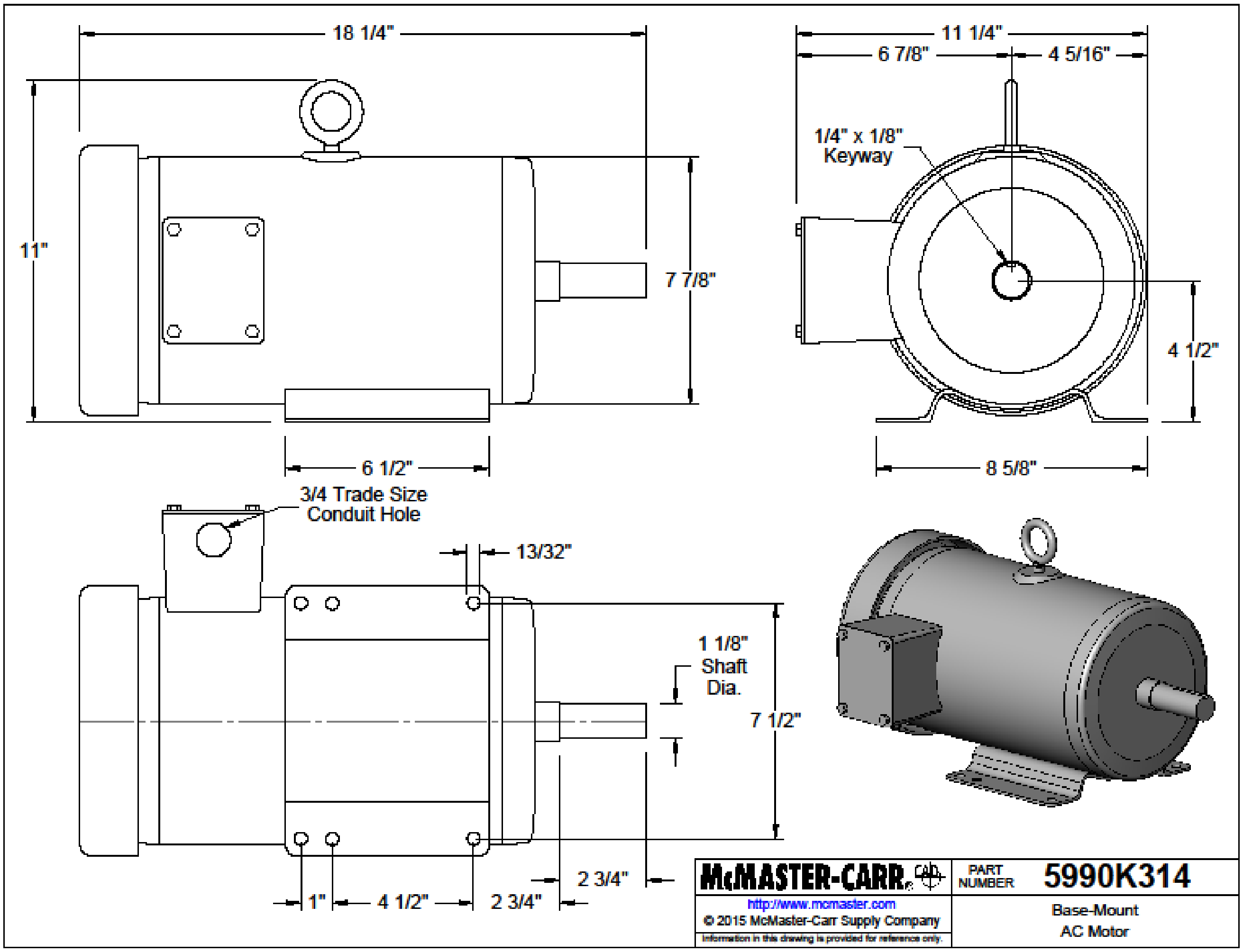
B.1 Drawing Tree- Original



B.1 Drawing Tree Revised

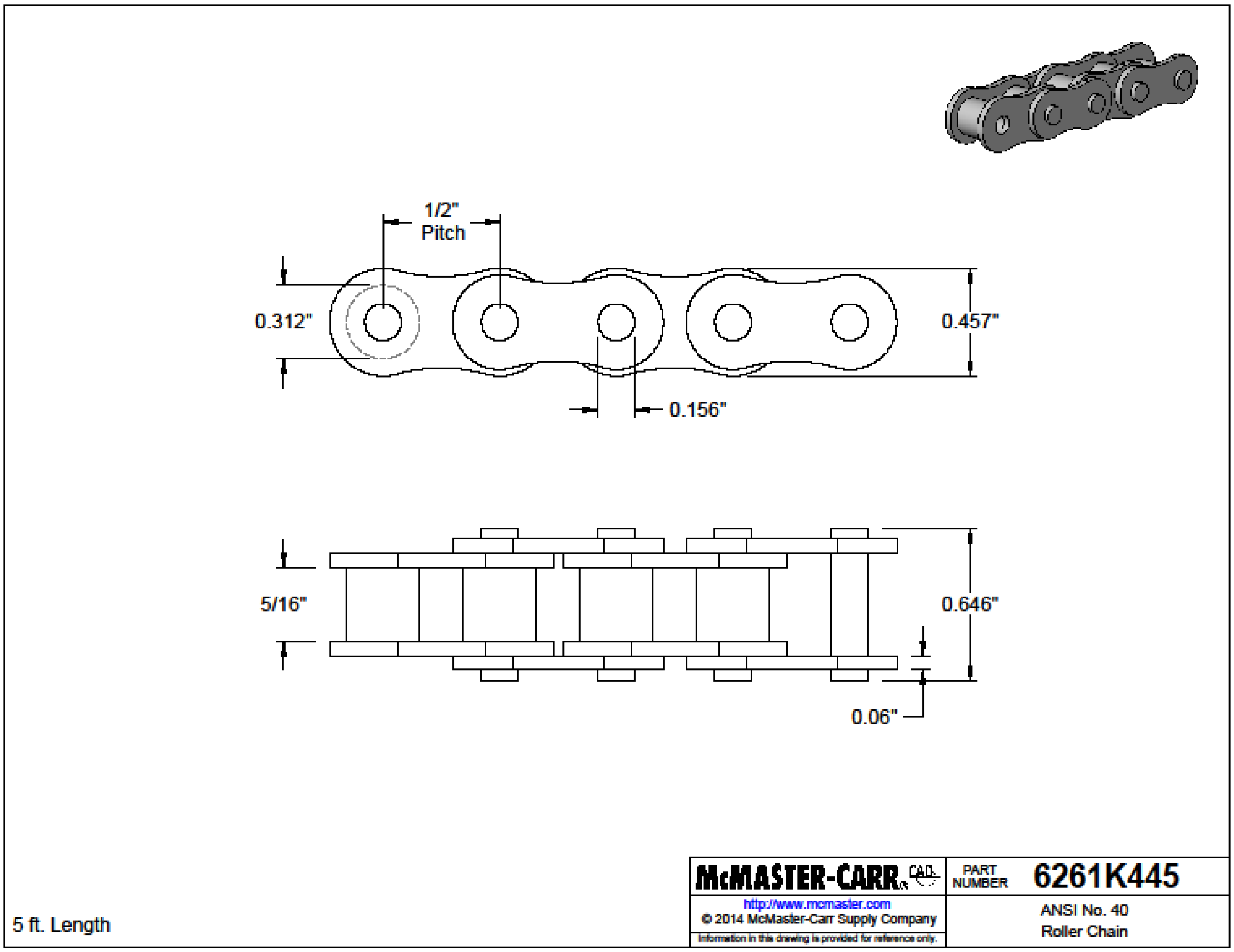


B.2 Electric Motor



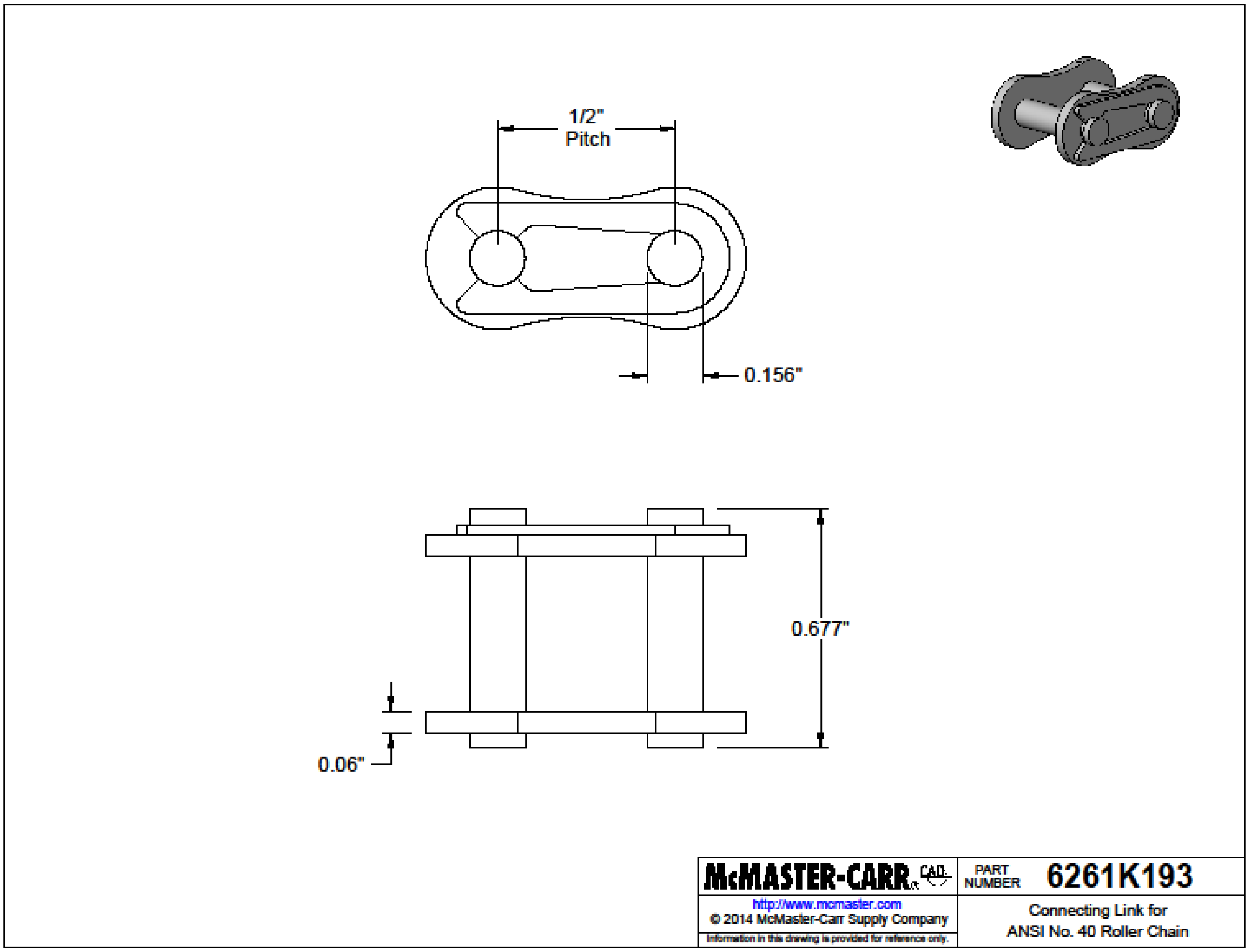
The provided electric motor drawings was provided from McMaster Carr. The base mount AC motor has a maximum RPM of 1750, and a power of 5 HP. There are also holes drilled so that the motor can be mounted to another component that will stop it from moving when in operation. The motor output shaft has a key way, which will be used to house the sprocket.

B.3 Chain



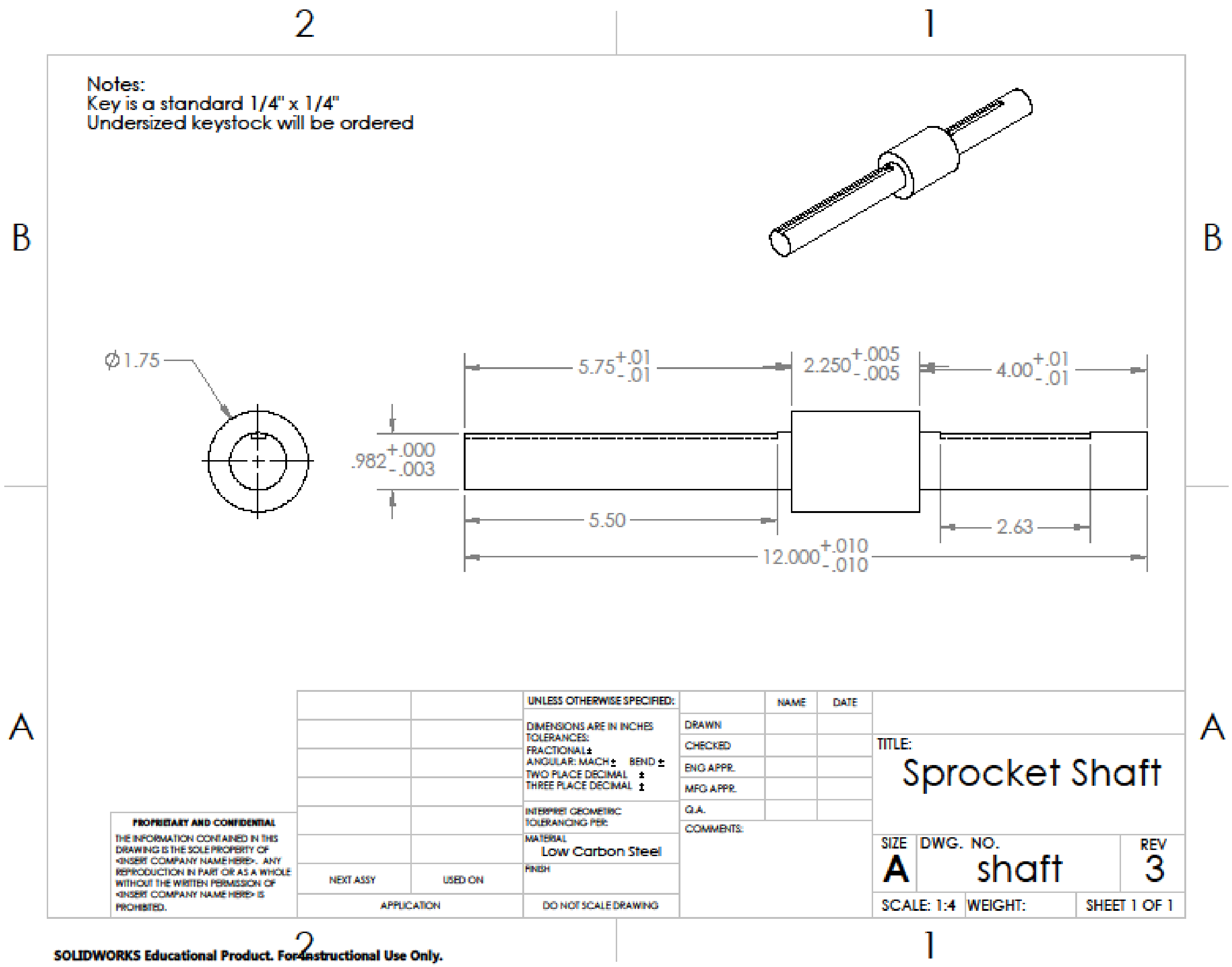
The chain that was used to spec the sprockets was a ANSI 40 chain. The chain has been assembled to the calculated total length of 55 in. 5 ft total length of chain was purchased.

B.3 Connecting link for Chain



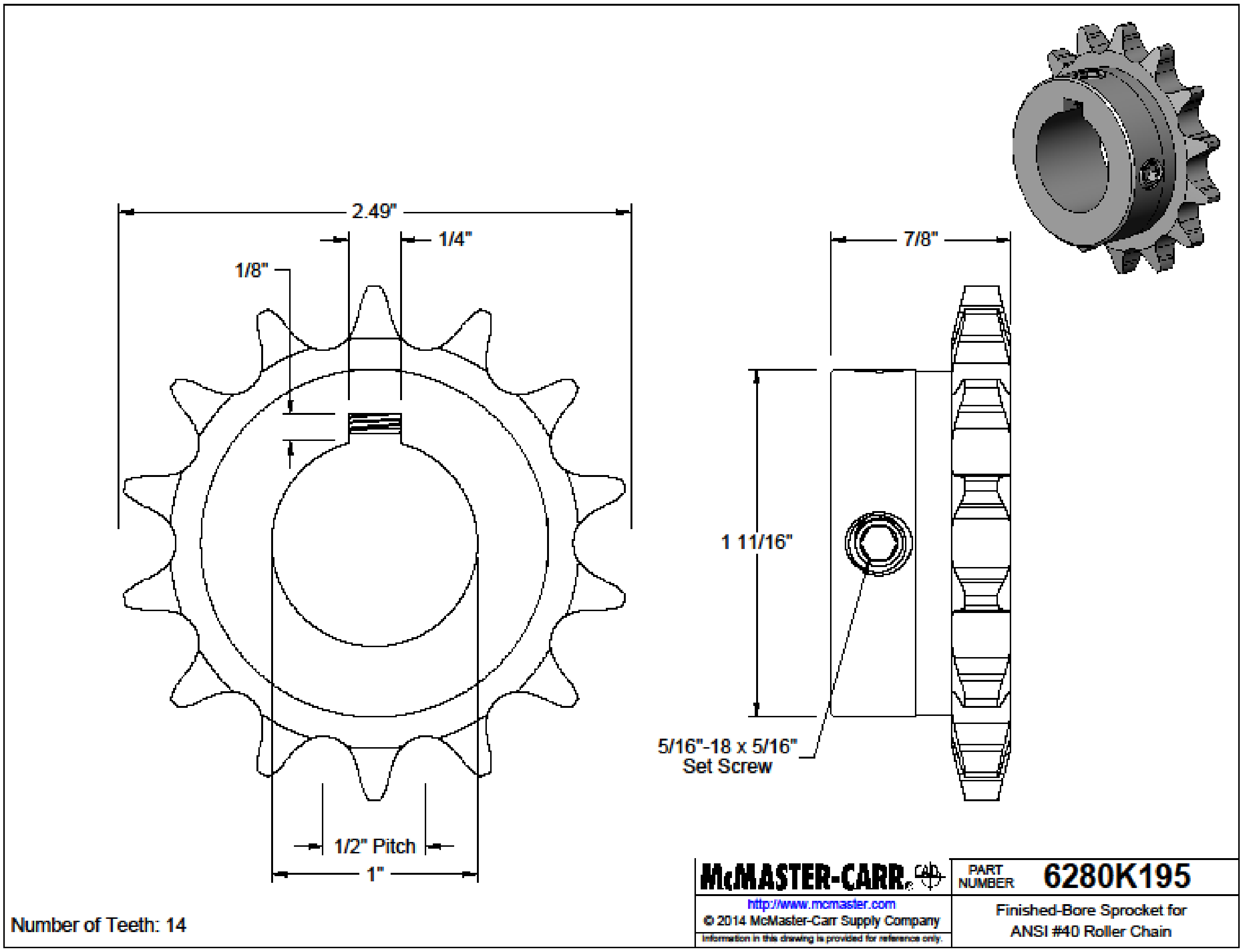
This is the connecting link that is required for the chain to work.

B.4 Shaft for Blades



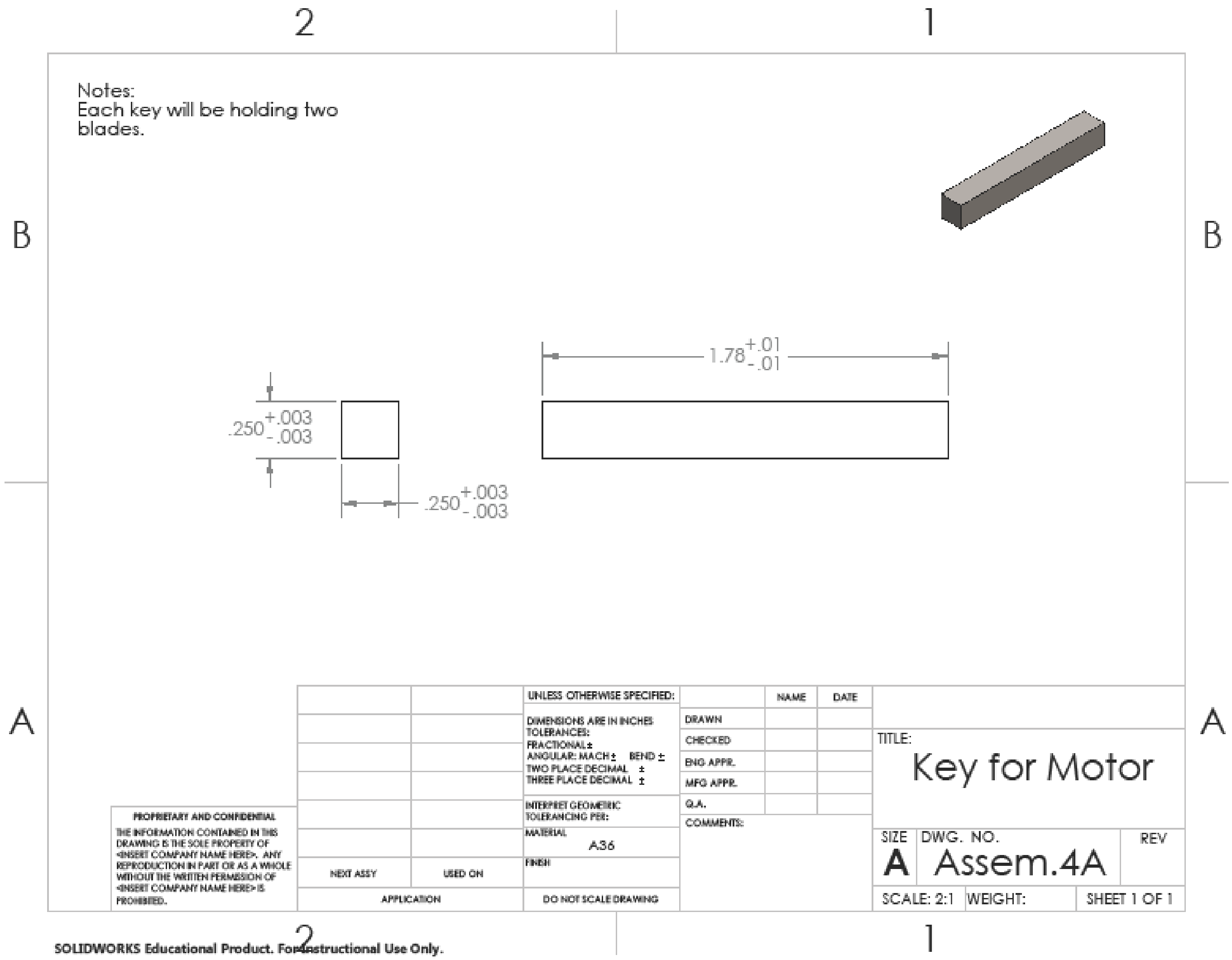
This is the shaft that will be used to house the sprocket, gear as well as the slotters. The two shafts are the same accept for in this one, the keyway was throughout one end so that it could house the sprocket. The other shaft will not have a keyway that is cut throughout the entire shaft.

B.5 Sprocket Small



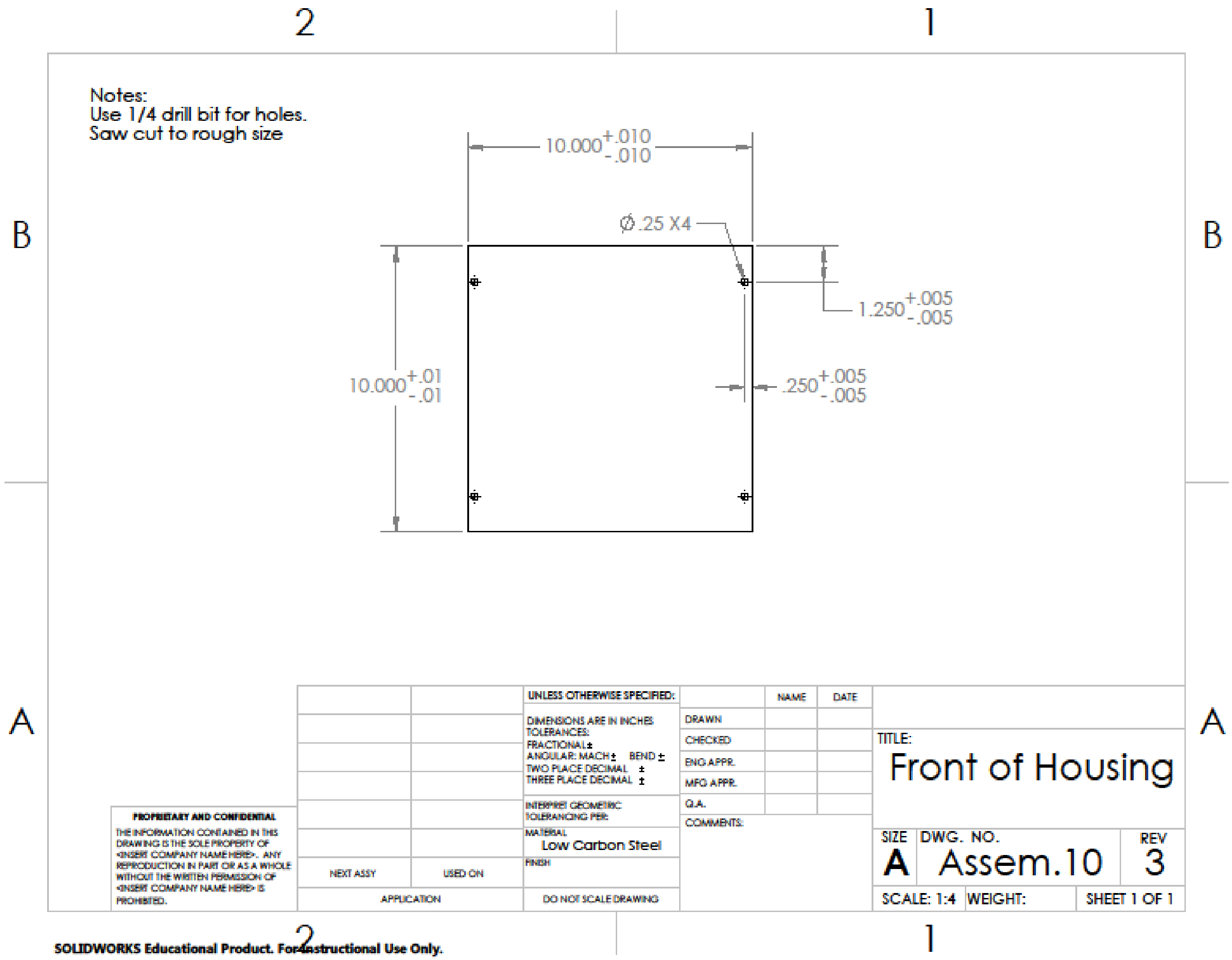
This is the smaller of the sprockets. This sprocket will be directly attached to the motor purchased and fastened through a key.

B.6 Key



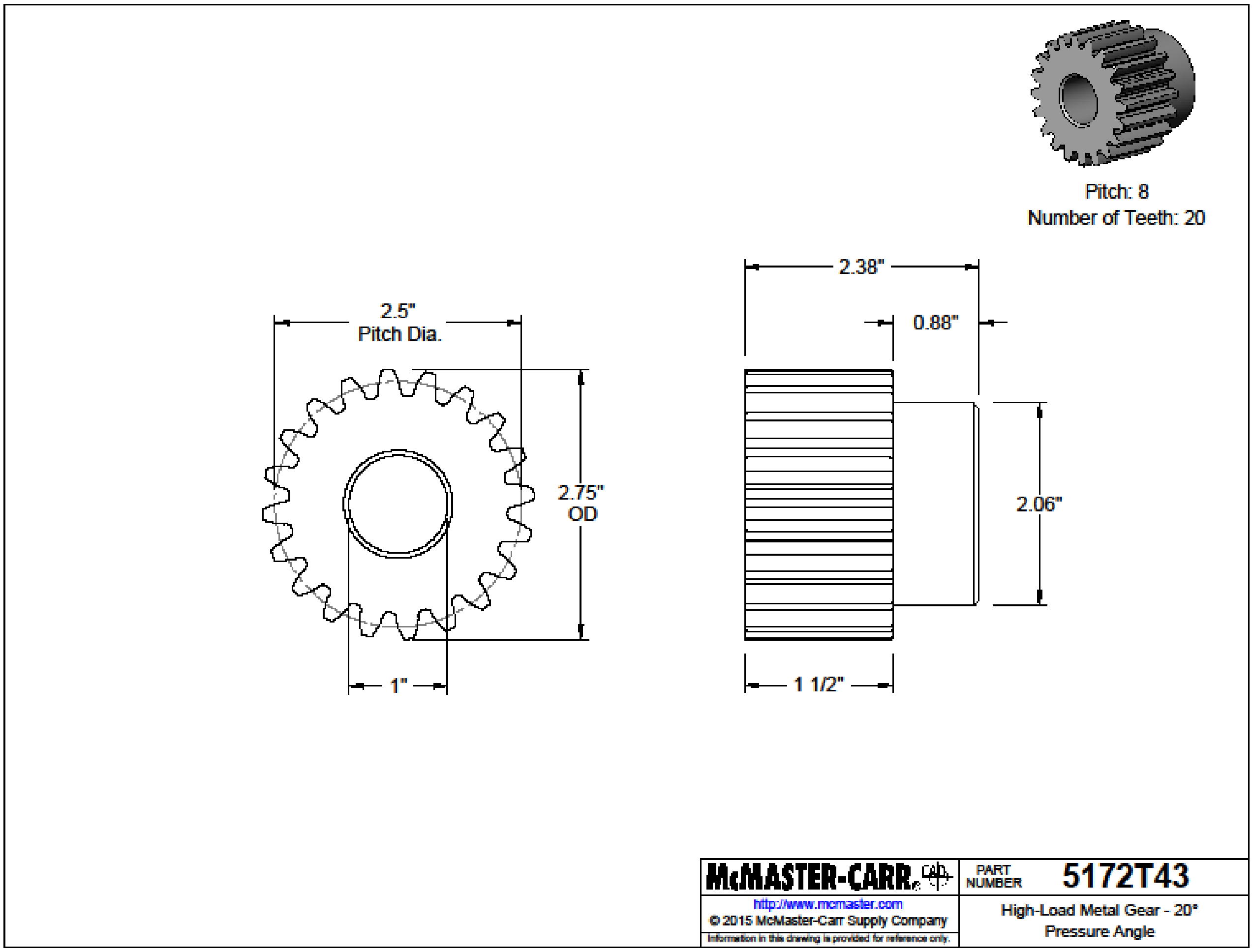
The key provided is based off the key way that is provided in the coupling. This material will be readily available from a previous employer or from scrap from the saw cuts.

B.7 Cover Plate 2



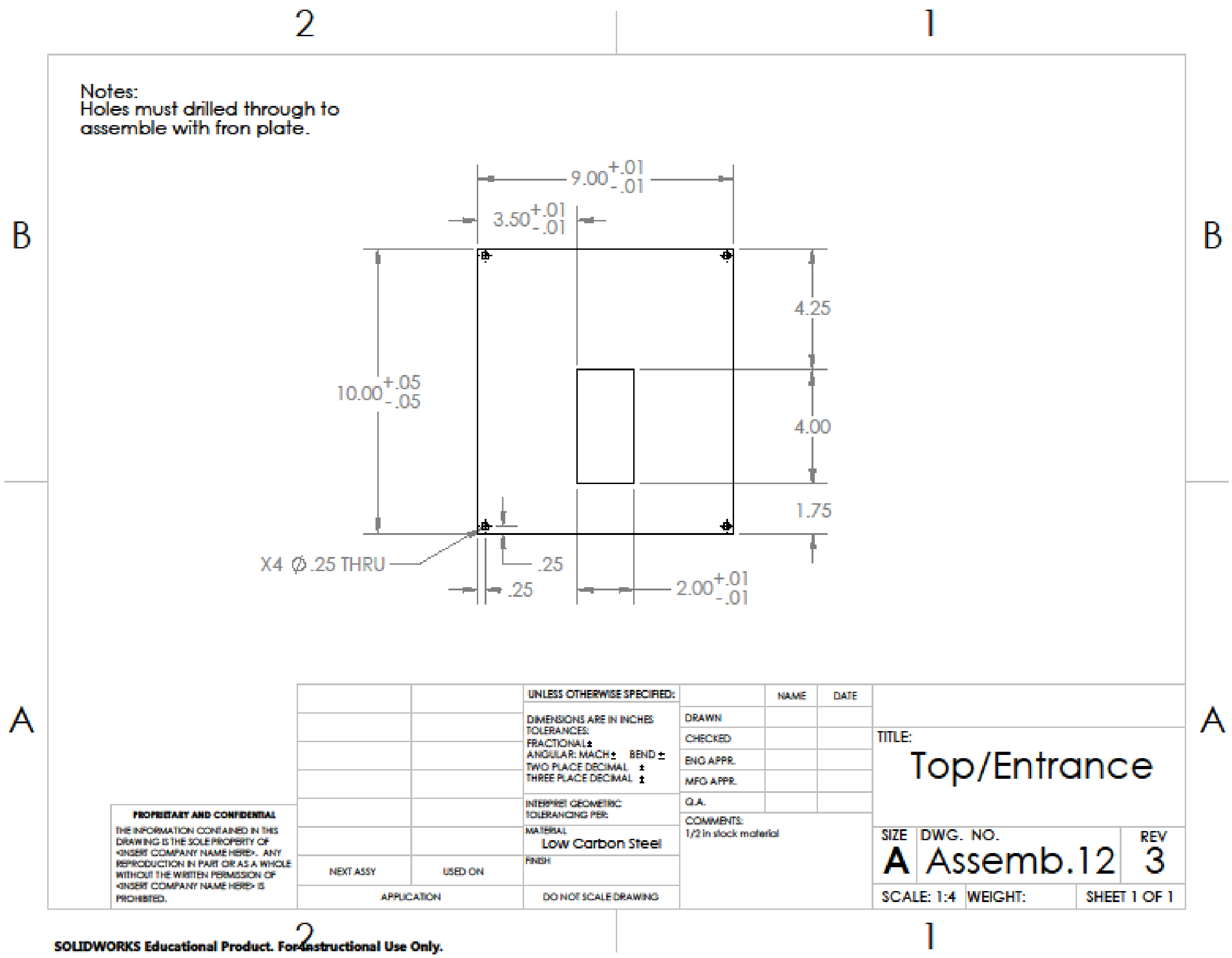
This is the plate that will house the cutting shafts. It will be the last part assembled. There will be 3/8” holes drilled in the bottom of the plate so that it can be fastened. The distance between the holes are based off the position of the shafts and their calculated diameters.

B.8 Gear 1



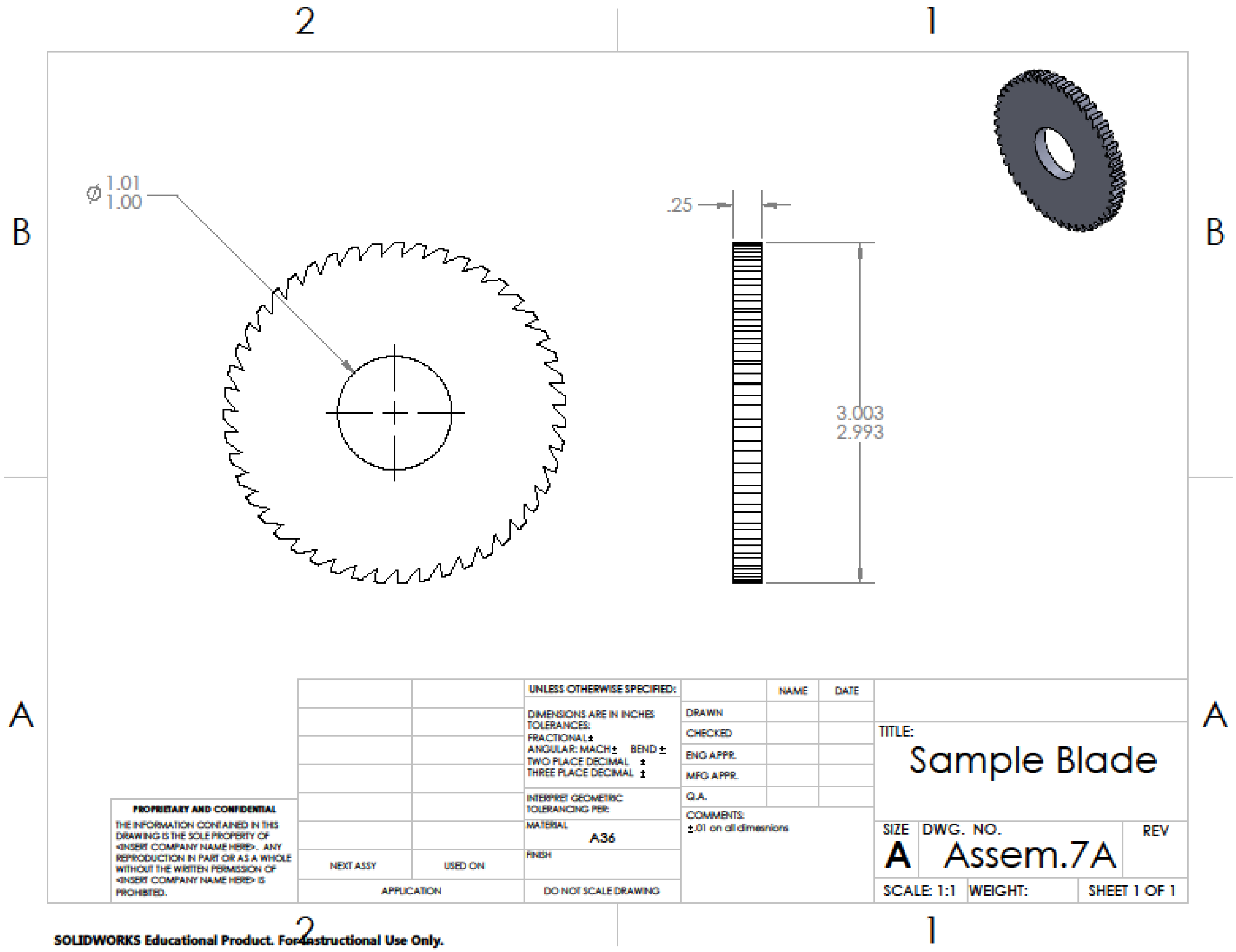
Upon competition of a gear calculation using a spreadsheet provided by Professor Pringle, this gear was found and was available on McMasters Carr. This gear was purchased and assembled onto the device. There are two of these gears total on the assembly.

B.9 Top Plate



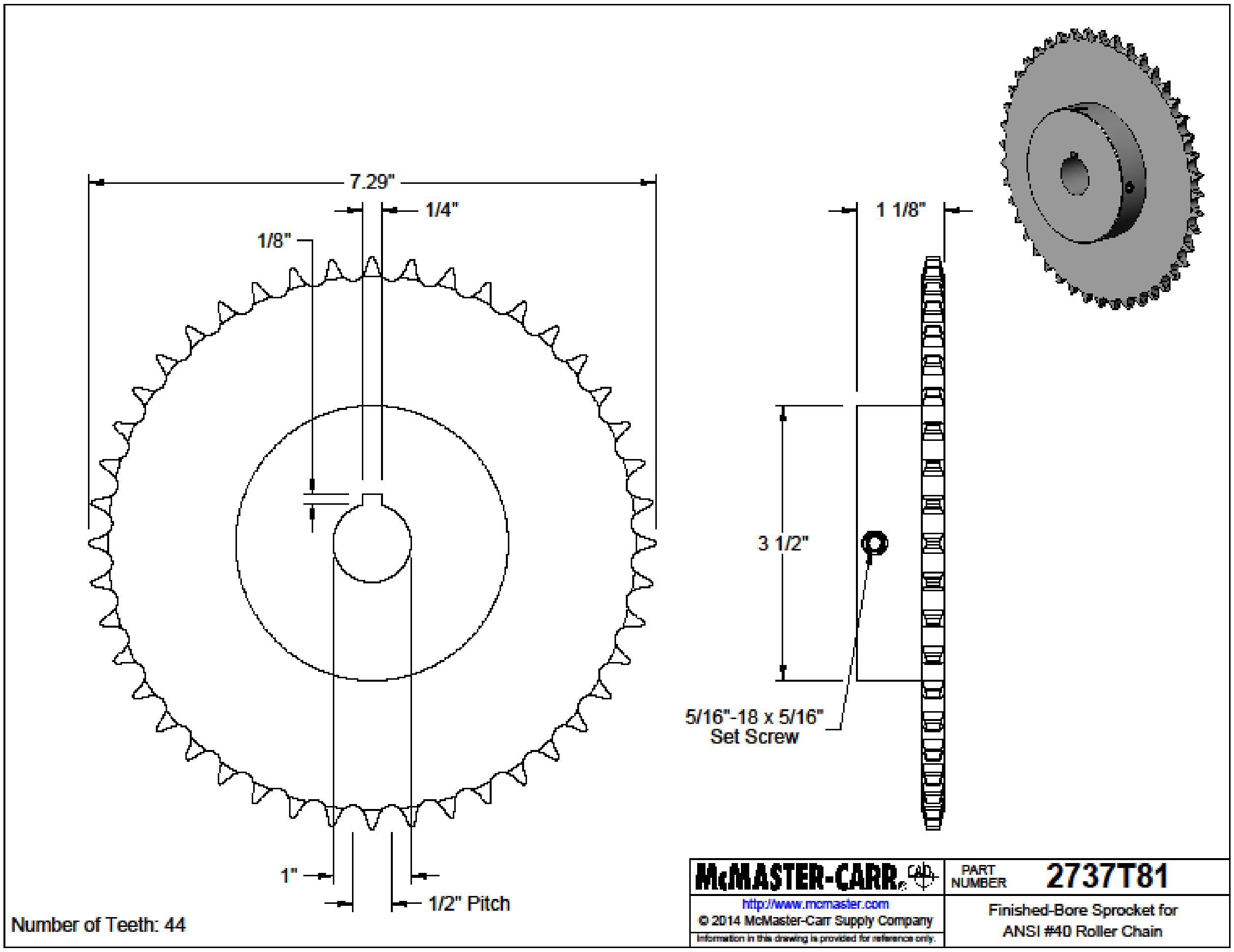
A revision needed to make the hole larger than originally thought. The width of the material once delaminated is still not certain, so the width of the hole is subject to change. The offset of the gap is due to the gears are housed inside of the housing. The critical dimension on this part is the length of the hole so that material will be able to fit. The width may have to altered because it is still not known the exact width the material will be once it has gone through the delamination device.

B.10 Sample Blade



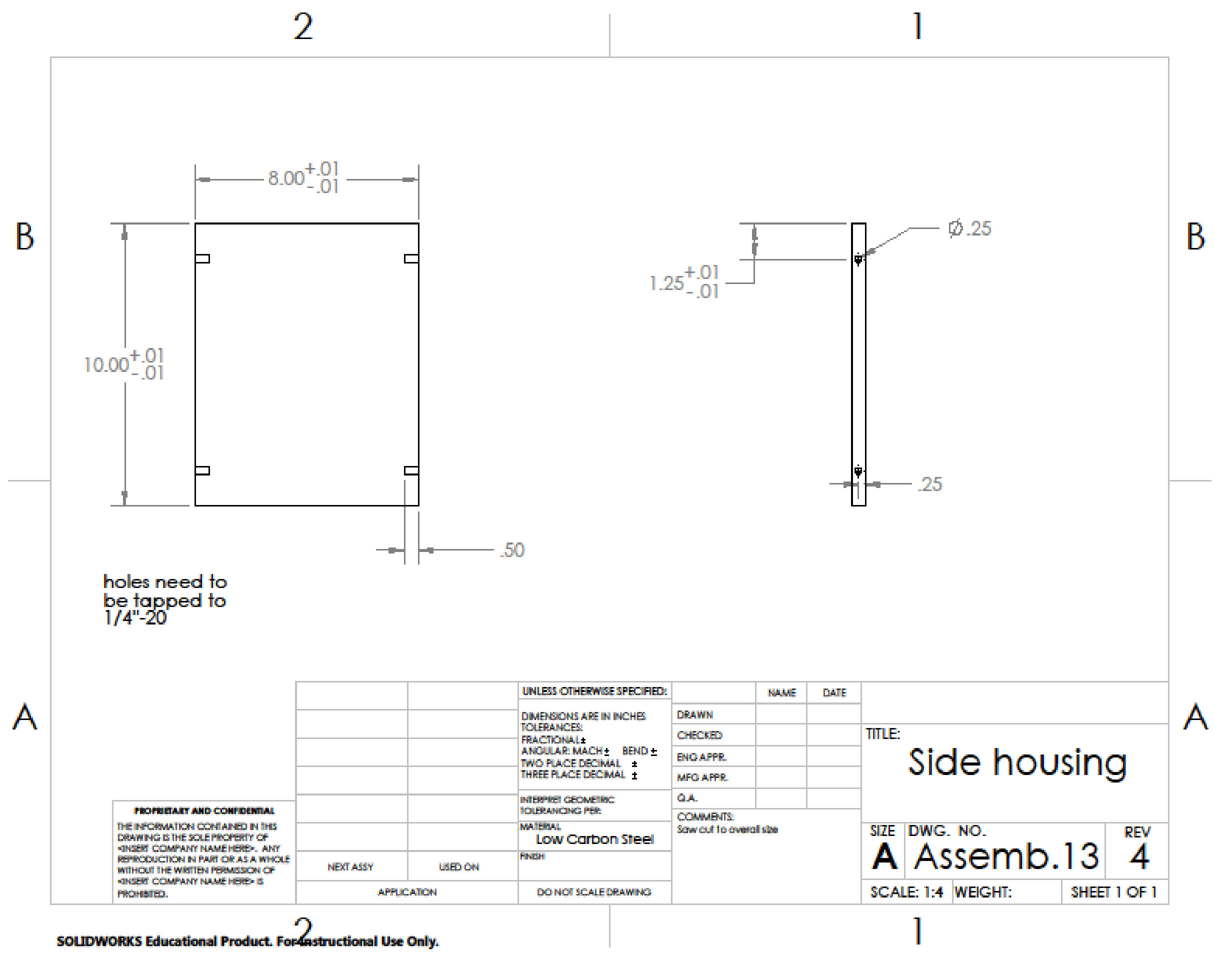
This blade has been used as a place holder. After receiving a recommendation from Boeing, the blade that will be used can be found on this website.
URL: www.mscdirect.com/product/details/73323081

B.11 Sprocket 1

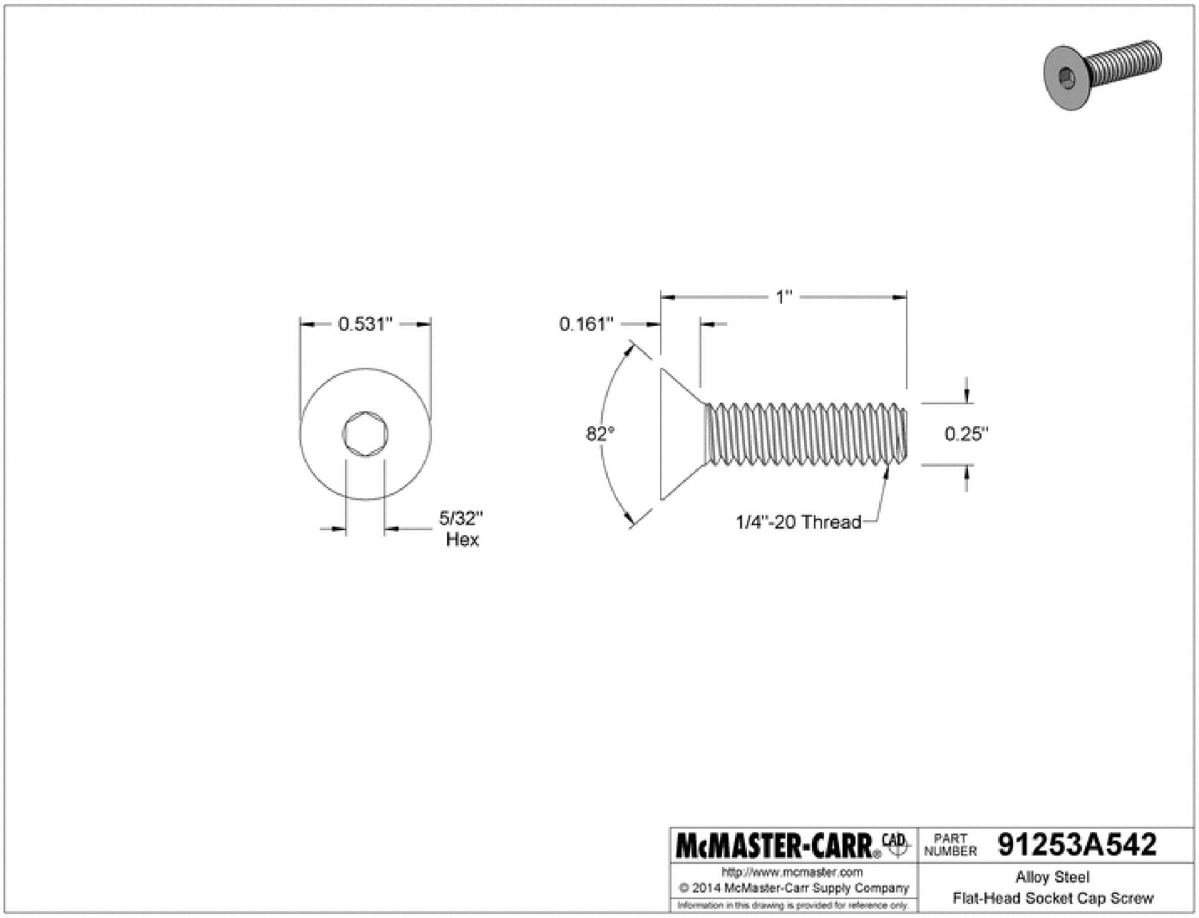


This is the larger sprocket that will be attached to one of the shafts. One of the shafts has a keyway that is continuous due to the fact that the sprocket needs to be connected to it by way of a key.

B.12 Side Plate

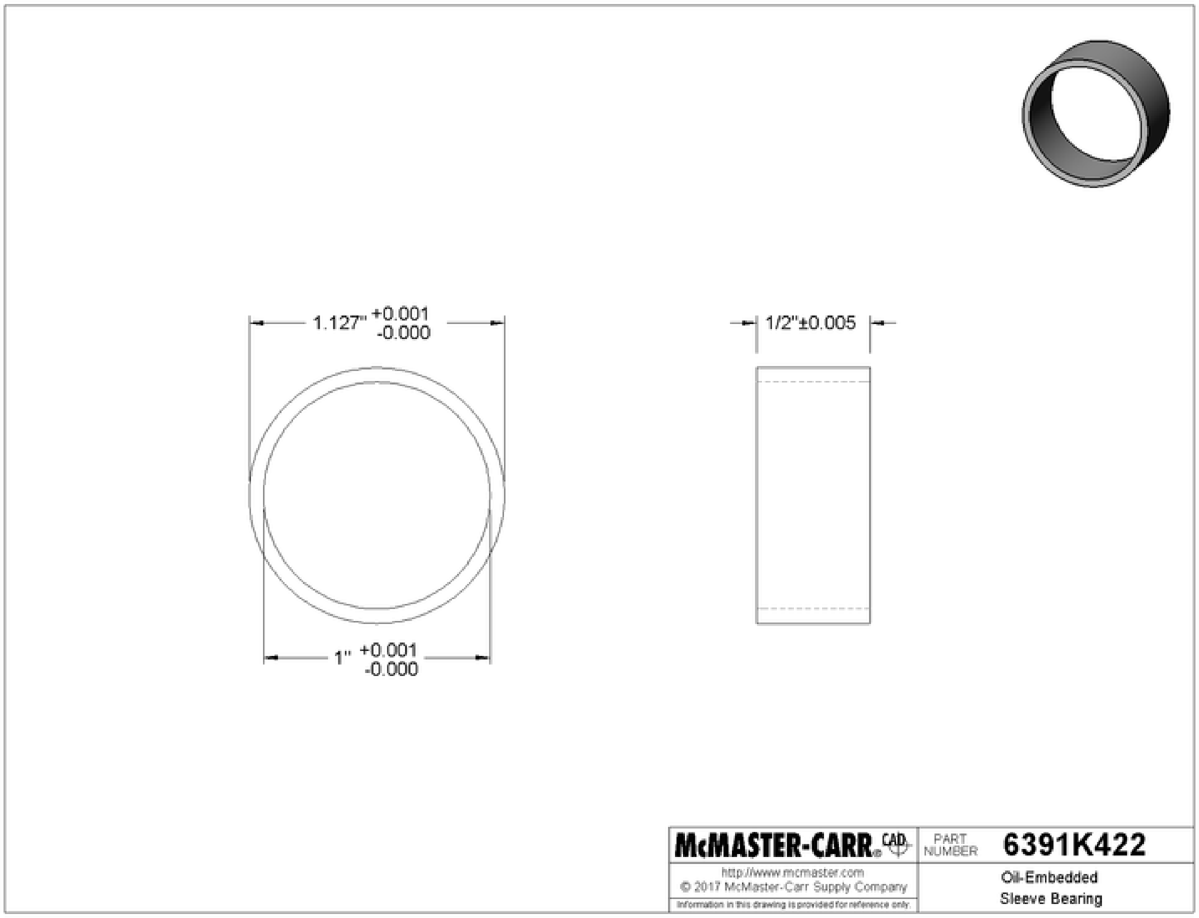


B.13 Bolts



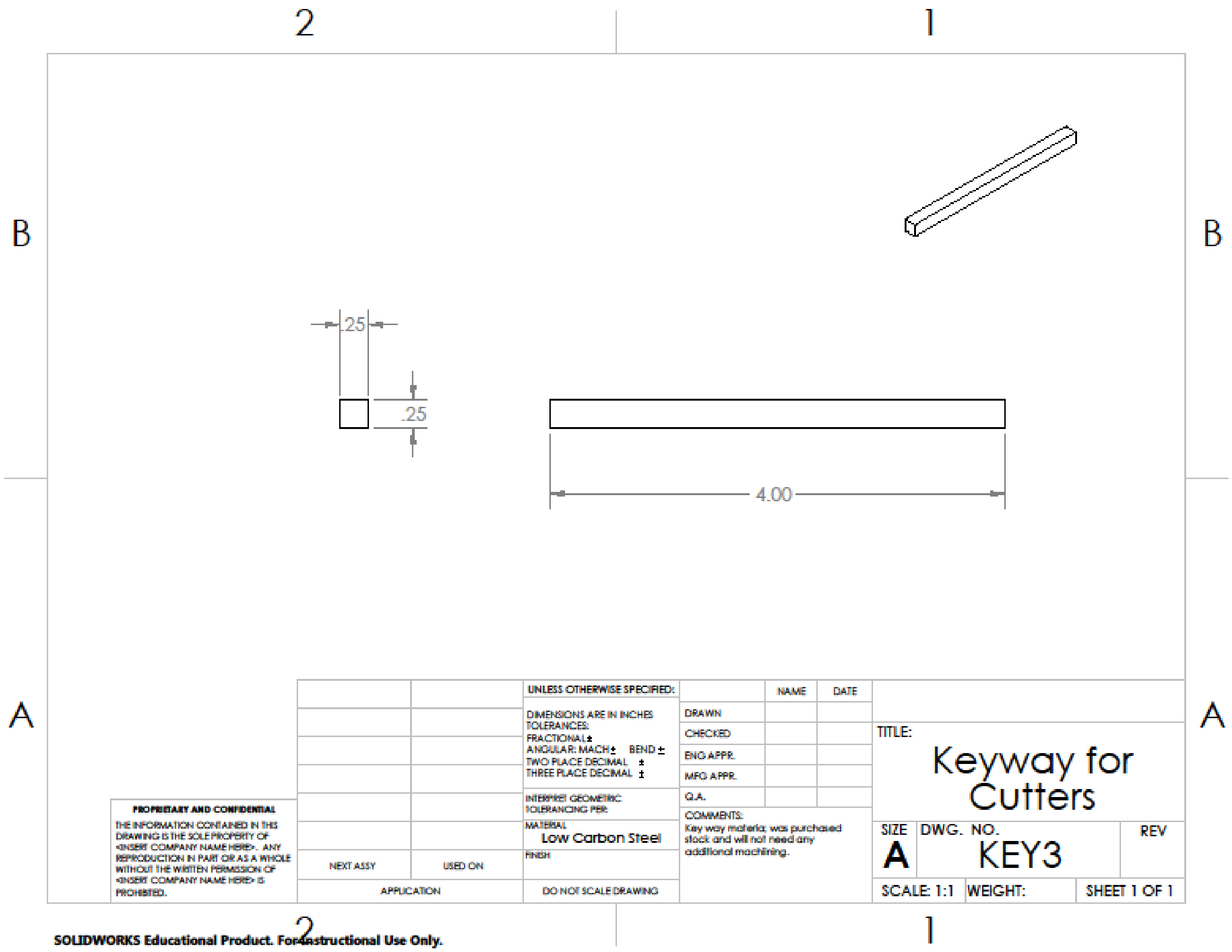
Bolts used to fasten the housing together.

B.14 Bearing



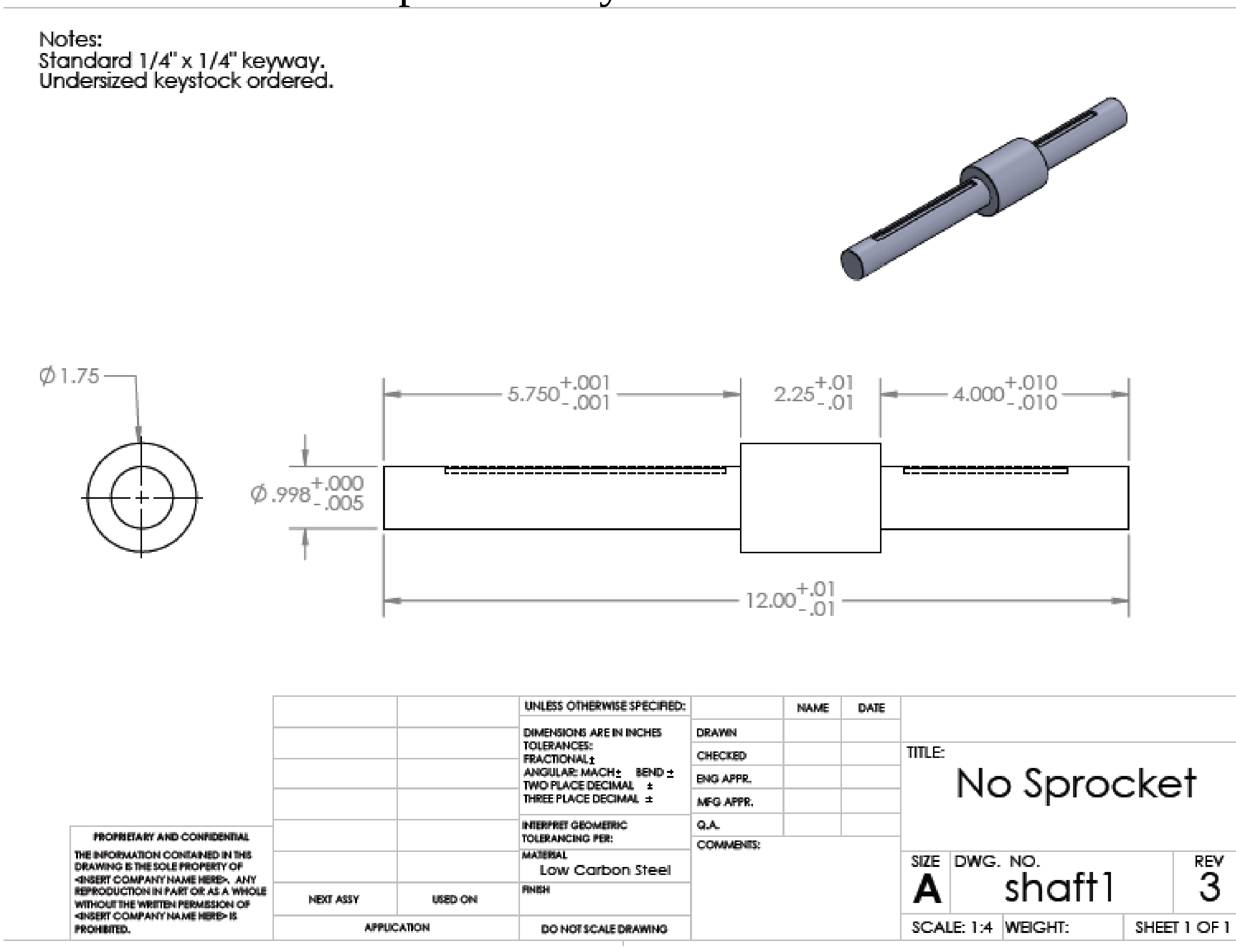
These bearings were purchased and press fit in both the side and front plates of the housing.

B.15 Keyway 2



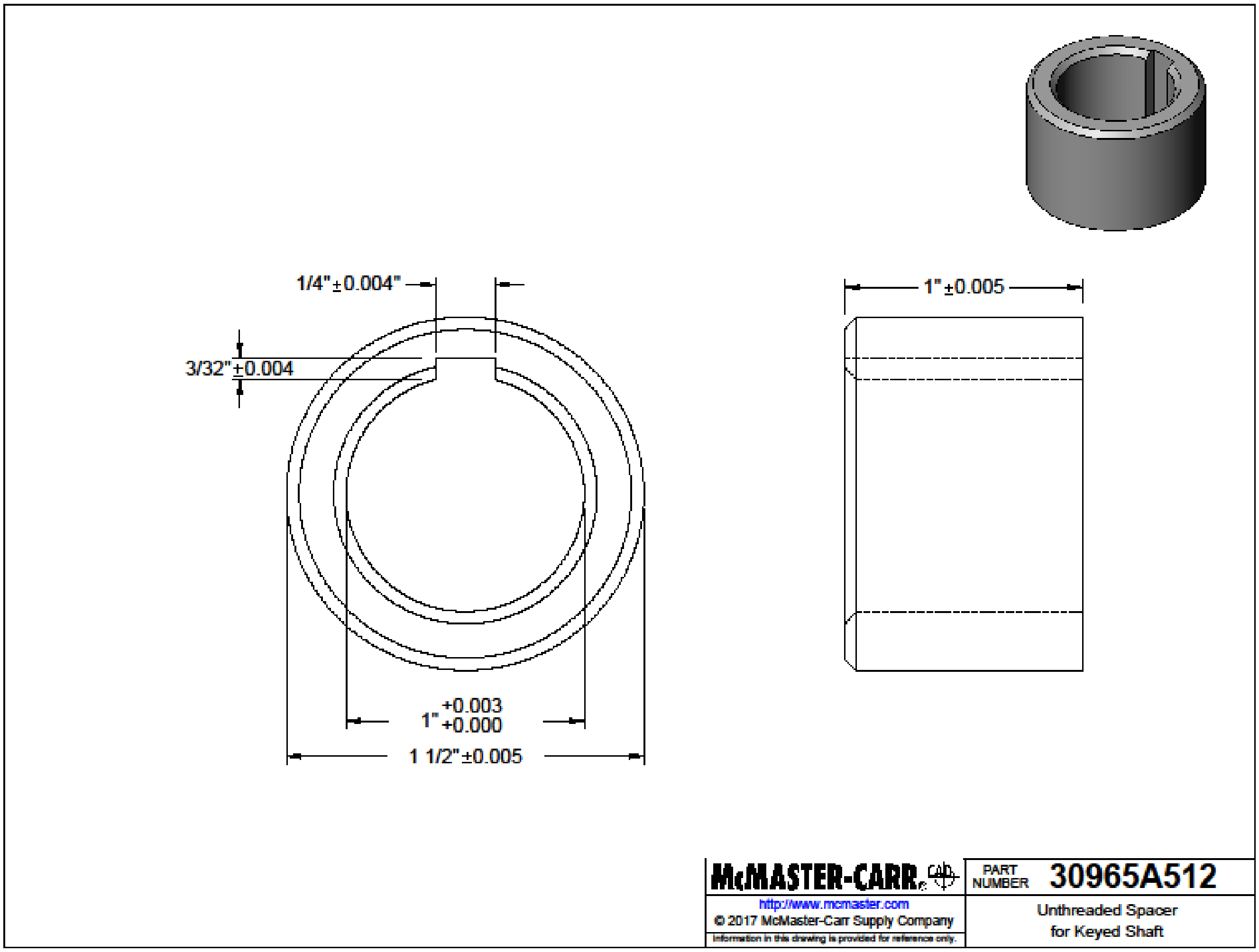
This is the key that will be used on both shafts to house the blades and spacers.

B.16 Shaft without sprocket key



This is the same shaft as the previous shaft but the key way does not extend the entire distance because it will not house the sprocket.

B.17 Spacers



These are the spacers that are used to keep the blades separated.

B.18 Front plate for shafts

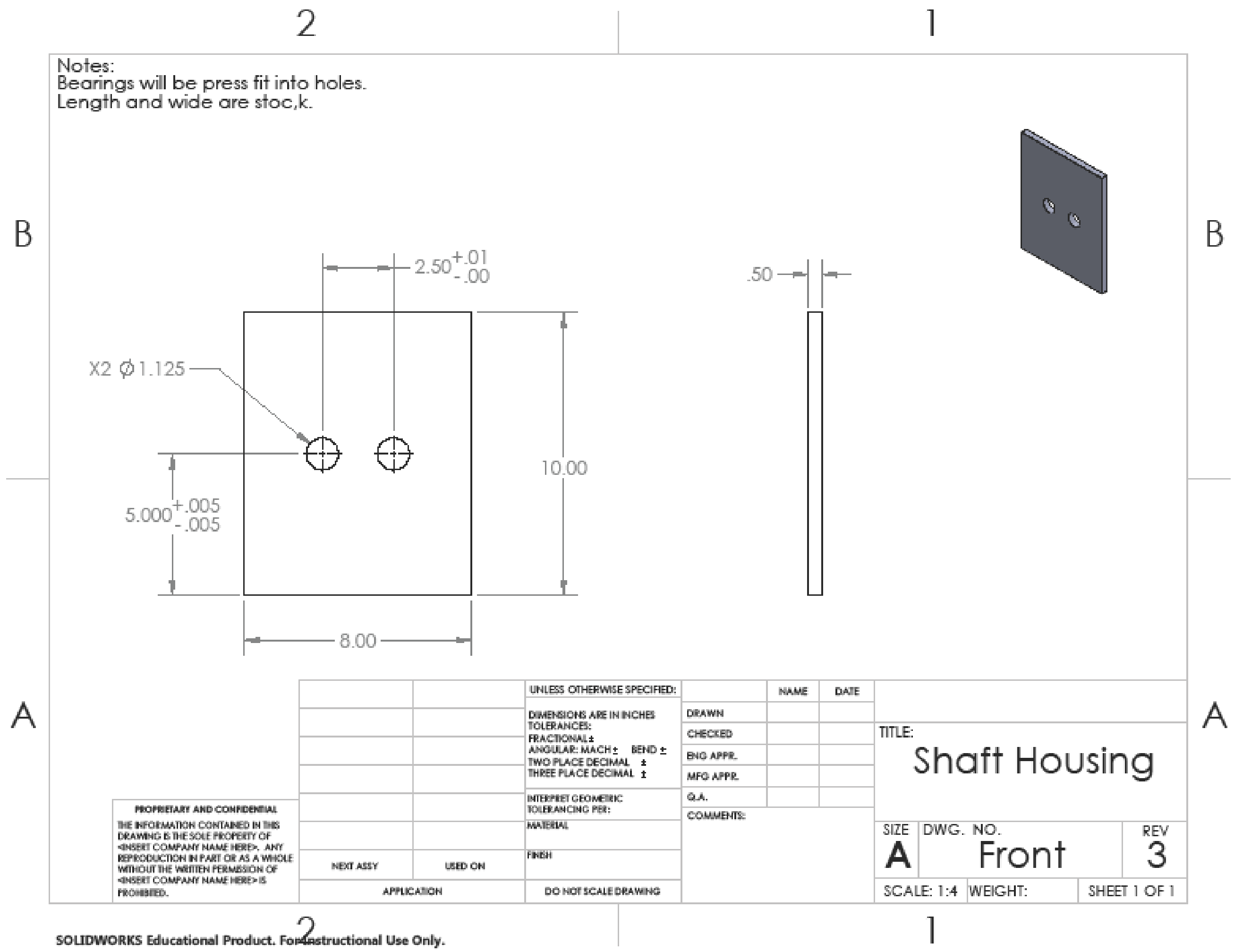


Plate that will house the bearings and the shafts.

APPENDIX C – Parts List and Costs

Part Ident	Part Description	Source	Cost (est)	Quantity
Bearings	1” x ½”	https://www.mcmaster.com/#6391k422/=1b3kdyb	1.74 each	4
Steel for housing	10”x10”x1/2	https://www.mcmaster.com/#6544k36/=1b3kfc3	75.32 each	5
Shafts	1 ¾” x 12”	https://www.mcmaster.com/#8920k72/=1b3kg5s	27.59 each	2
Bolts	¼” – 20 x 1	https://www.mcmaster.com/#91253a542/=1b3khv8	8.42 For 50	1
Slitters	3” x 1/8”	https://www.mscdirect.com/product/details/73323081	$51.52	4
Sprocket L	2737T813	https://www.mcmaster.com/#2737t813/=1bomow9	64.81	1
Sprocket S	6280K685	https://www.mcmaster.com/#6280k685/=1bomq7g	16.81	1
Gears 20 teeth	5172T43	https://www.mcmaster.com/#5172t43/=1bomr1d	69.10	2
Chain - 40	6261K173	https://www.mcmaster.com/#6261k173/=1bomsfo	4.54	5
Connecting Chain	6261K193	https://www.mcmaster.com/#6261k193/=1bomt0v	0.87	3
Shaft 1 ½ x 12	8920K311	https://www.mcmaster.com/#8920k311/=1bomtzv	22.21	1
Motor	5990K314	https://www.mcmaster.com/#5990k314/=1bbaomr	738.32	1
Keyway	98510A136	https://www.mcmaster.com/#98510a136/=1by2aqa	1.55	3

Current total estimated cost is $1673.49. (Total does not include and shipping and handling charges).

APPENDIX D – Budget

The current estimated cost was calculated to be $1673.49. This total does not include any extra fees that were paid due to shipping and handling. Due to the grant being $5,000.00, the two processes split the total with a fund of $2,500.00 to spend on each process. For the cutting process, a majority of the expense was the motor. The motor cost around $732.00 and does not include shipping. Another part of the project that proved to be more expensive then first estimated was the slotters. Thanks to a recommendation from John and one of his employees, a particular blade was found that met all the requirements of width and size. Those cost around $52.00 a piece and a total of four were ordered.

One issue that was resolved was trying to find a economical method for speed reduction. For the cutting process, a 3:1 speed reduction was needed based off previous calculations. The motor that was purchased has a torque of 1750 RPM, 600 RPM was desired. The speed reducers that were found were not 3:1, and a equipment employee said that a 3:1 was not a common speed reducer. To bypass the purchasing of a speed reducer, a sprocket and chain system was used. The sprocket and chain system had a total cost of $107.00 total for the speed reduction that will be used.

Another expense that was resolved last week was finding a way to space the blades 1 in apart. On McMaster Carr, there were 1in spacers that were designed to fit over a ¼" x ¼" key which proved to work. Four of the spacers were purchased but an additional two are needed due to a mistake on the original order.

Currently, the cutting process has about $826.51 left on the budget. The rest of this budget may be spent when testing due to unforeseen problems with mounting.

APPENDIX E – Schedule

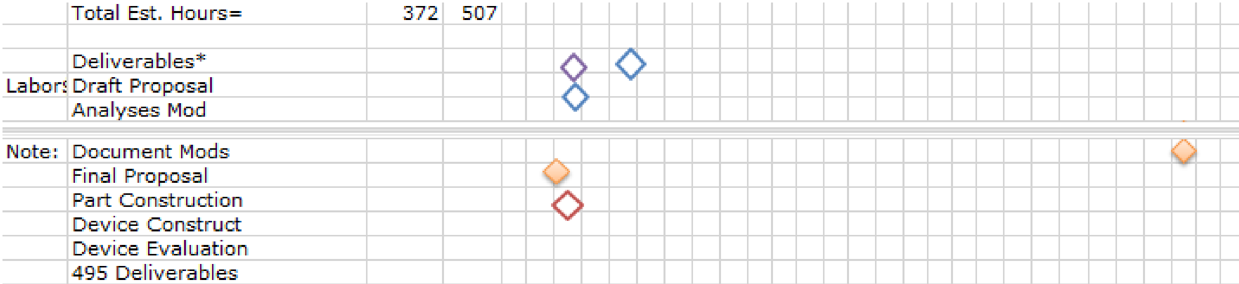
Gantt Chart

Note: June x Presentation
Note: June y-z Spr Finals

PROJECT TITLE:Composite Recycling
Principal Investigator.:____________ Misha Minasyan

TASK: ID	Description	Duration Est. (hrs)	Actua (hrs)	November	Dec	January	February	March	April	May	June
1	Proposal*										
1a	Outline	5	5								
1b	Intro	2	5								
1c	Methods	3	5								
1d	Analysis	25	26								
1e	Discussion	3	5								
1f	Parts and Budget	3	5								
1g	Drawings	30	45								
1h	Revisions	20	33								
1j	Schedule	2	8								
1j	Summary & Appx	10	10								
	subtotal:	103	147								
2	Analyses										
2a	Diameter Calc	1	1.5								
2b	Diameter Spread St	1	1.5								
2c	Energy Experiment	1	1								
2d	Key Way depth	1	1								
2e	Spread Sheet iterations	1	3								
2f	Energy Scale	1	1								
2g	Energy Calc	0.5	1								
2h	Stress Spread Sheet	2	1.5								
2i	Bending Stress	1	1.5								
2j	Torque	5	2								
2k	Gear Ratio	2	2								
2l	Gear Ratio Spread Sheet	4	3								
2m	Structural	1	1								
2n	Material	1	2								
2o	Sprocket Spreadsheet	1	3								
2p	Sprocket	2	5								
2q	Chain Spreadsheet	1	3.5								
2r	Chain	1	2.5								
	subtotal:	27.5	37								
3	Documentation										
3a	Part Rotating Shafts	2	6								
3b	Chain	2	3								
3c	Coupling	1	1								
3d	Key way	1	1								
3e	Cutters	1	2								
3f	Housing	4	6								
3g	Gears	2	3								
3h	Potential motor	1	1								
3i	Proposal Updates	10	14								
3j	Sub assembly	2	3								
3k	Housing assembly	2	3								
3l	Gear assembly	1	1								
3m	Subassembly side	1	2								
3n	Revisions to assembly	15	27								
3o	Gear and Shaft assembly	1	2								
3p	Revisions to drawings	15	20								
3q	Kinematic Check	1	1								
3r	ANSIY14.5 Compl	5	5								
3s	Make Object Files	1	1								
	subtotal:	68	102								

4	Proposal Mods			
4a	Project cutter Schedule	5	5	
4b	Project cutter Inv.	5	8	
4c	Crit Des Review*	1	1	
	subtotal:	11	14	
5	Part Construction			
5a	Meet with techs for plan	3	6	
5b	Order housing	1	1	
5c	Find/Make Inserts	1	1	
5d	Set up Lathe	0.5	0.5	
5e	Machine holes for bearings	1	2	
5f	Machine side of housing	1	3	
5g	Machine front of housing	1	4	
5h	Machine Motor Shaft	1	4	
5i	Machine Shaft	1	4	
5j	Machine Key Way	1	2	
5k	Cut keys	1	1	
5l	Surface Finish	1	1	
5m	Wire Motor	5	5	Not sure who will wire motor or when it will happen
5n	Connect Motor	1	1	
5o	Order coupling	1	1	
5p	Order steel for housing	1	1	
5q	Drill holes on housing	2	3	
5r	Tap holes for housing	1	1	
5s	buy fasteners for blades	1	1	
5t	buy cutters	1	1	
5u	modify cutters	1	1	
5v	Take Part Pictures	1	1	
5w	Update Website	1	5	
5x	Manufacture Plan*	1	1	
	subtotal:	30.5	52	
6	Device Construct			
6a	Shaft and Gear Assem	1	4	
6b	Sprocket Assem	1	4	
6c	Assemble Motor	5	4	
6d	Assemble Chain	1	3	
6e	Assemble Motor Assem	1	1	
6f	Assemble Shaft Assem	1	2	
6g	Assemble Housing	1	1	
6h	Assemble fasteners	1	1	
6i	Take Dev Pictures	1	1	
6j	Update Website	10	7	
	subtotal:	23	28	
7	Device Evaluation			
7a	List Parameters	1	1	
7b	Design Test&Scope	3	3	
7c	Obtain resources	3	3	
7d	Make test sheets	3	3	
7e	Plan analyses	4	4	
7f	Construct Cutting Assem	1	1	
7g	Test Plan*	4	4	
7h	Perform Evaluation	5	5	
7i	Take Testing Pics	1	1	
7j	Update Website	5	5	
	subtotal:	30	30	
8	495 Deliverables			
8a	Get Report Guide	5	5	
8b	Make Rep Outline	5	5	
8c	Write Report	50	55	
8d	Make Slide Outline	5	5	
8e	Create Presentation	5	5	
8f	Make CD Deliv. List	5	5	
8g	Write 495 CD parts	5	6	
8h	Update Website	5	6	
8i	Project CD*	5	5	
	subtotal:	90	97	



Gantt Chart Description

The Gantt chart is a tool that was provided to keep tasks and objectives of this project organized. Prior to the construction of the device, all tasks were placed into the chart including details of each task. All aspects of a part needed to be accounted for. A requirement that included a calculation, the set up of a machine, the running of a machine as well as cleaning. There was a column of the chart that was used to estimate the amount of time it would take to complete a task. The following column was used to account for the actual time spent on a certain task. The total estimated time for the construction of the device was estimated to be 53.5 hours. The actual time spent on completing the device was 80 hours. The actual machining was not the time-consuming portion of the project, rather it was the constant need to revise and change parts and their calculations. For each change of a part, the assembly and the mates used needed to be altered.

The reasoning for certain parts not being done in order was that some parts were needed prior to ordering. For example, the housing was fully completed prior to the ordering of the motor and gears. The holes that were going to be used to house the shafts and bearings did not get machined until two weeks ago. The reasoning behind this was there was uncertainty of which motor would be used, as well the location of the motor shaft was different depending on each motor.

For aspects of the project that have yet to be completed, an estimation is done for both columns. As of now, all aspects of the senior project with regards to fall and winter quarter are complete and current. Prior to testing, there might have to be modifications done to parts of the assembled device and they will be added once completed.

APPENDIX F – Expertise and Resources

John Locklear
Email : john.c.lockleer@boeing.com

Professor Charles Pringle
Professor Craig Johnson
Professor Ted Bramble
Tab Tech Matt Burvee

APPENDIX G – Evaluation sheet (Testing)

Delaminator RPM	Shredder RPM	Blade Spacing	Appearance of Scraps

Above is a sample table that could be used once a test is able to be conducted. Different sprocket sizes may affect if the system works or not.

APPENDIX H – Testing Report

Introduction

Requirements

- Cut composite material with one initial push into the delamination device
- Transfer power from motor to sprocket by way of chain to rotate 600 RPM
- Cut composites into 1 in strips
- Use a federate of 100 in/m

Parameters of Interest

The group is interested if the prototypes developed will be able to delaminate and cut the composite scraps that were provided by Boeing and John Locklear. We were under the impression that we would develop prototypes like we stated in our proposals through research and initial experiments. For delamination, we used a Baleigh press to see how much force was required to delaminate a piece of composite. From there, we used a wedge and a hammer to see how much force was required to split a single layer of composite. With these values, we designed devices to perform the delamination and cutting in two processes by way of electric motors. If successful, we would scale these devices and operations into a full warehouse where processing could happen.

Predicated Performance

Based off the experiments that we ran during the fall, we predicted that our devices would in theory work. Coming from the little experience we had with any machine building or designing, we approached this problem the only way we knew how, which was conducting experiments to get initial values.

Data Acquisition

Data acquisition for this project has proven to be a lot more difficult then we had imagined. We were under the impression that we would make prototypes of the design we produced in fall. We did not know what we needed a frame for all components or that they needed to be connected until the final week of winter quarter. For spring quarter, we have been trying to make up a frame that will be able to house both devise, two motors, a gear reduction and various other components that have been recommended to us. We have no experience in frame design, but luckily were able to find one that we may use. With the existing frame, we are going to add tubing and legs so that it can withstand near 300 lbs of devices and material. We will need a lab technician to weld our tubing onto the existing frame and are not sure if a fixture will also need to be made.

But once a frame is completed, assembled with all the components, motors are wired, connected to grid, and proven to be safe with all the components fastened and secured, then we can run a test. We will power on both motors and get a reading of how fast each devices sprocket are rotating. One of the members will insert a composite strip into the dominator which will push it into the cutting device. Depending on whether strips are being delaminated or cut, we may have to resize our sprockets so that the devices will be operating at a different speed.

The provided spreadsheet shows when and how long tasks took to complete. Everything from numbers 1-7 are complete accept for 7k. 7k is the frame modeling that still needs to be completed prior to testing. It is evident that the predicted time and actual time differ significantly. We used conservative prediction because once manufacturing started, it was evident that all tasks were going to take a lot longer than anticipated. Just getting the housing for the cutter to line up took an extra 4 hours because holes needed to drilled to a higher size and tapped again as an example.

Method/Approach

Resources

JCATI funded our project. Thanks to there funding, we were able to build our proposed devices and buy motors for each device. They pledged $5000.00 for the project.
John Locklear from Boeing provided us initial guidance with the project and proposed the project last year in our Plastics and Composites class. The dialogues we had with him during the first two quarters really helped understand the scope of this project.
Dr. Johnson helped with initial designs and would check in to see progress.
Professor Pringle would take time to help with the many issues we encountered. He mentored us during the design and manufacturing portion.

Matt Burvee allowed us to make our designs into a actual device. Thanks to Matt, a lot of time was saved due to his experience. He would also be hands on when doing an intricate machine process like the keys on my shafts.
Tedman Bramble was also crucial when manufacturing my housing. Thanks to Ted, the gears that are connected to the shaft were able to mate due to the placement of the holes.

Data Capture
Once data is captured, we will include a table or a graph in this section. Whichever form of representation that is best.

Test Procedure Overview
The test procedure which will be shown in detail in the following section is designed so that once both motors are on, an initial push of a single composite piece will be able to travel through both phases.

Operational Limitations
The operational limitation of this test will be the RPM of both devices. If the devices do not perform their operations, it is possible that a different size sprocket would suffice. An issue for this is that the shafts that house the sprockets were machined to hold the sprocket that are currently on and new ones may have to be made.
Another operational limit will be the size of the frame. The stand that we found is already built, so any modifications will have to me made so that they can fit.

Precision and Accuracy Discussion
Our RPM will be precise because the sprockets purchased and chain will provide a RPM once the motor is running at its full 1750 RPM.

Data Storage/Manipulation/Analysis
Data will be stored in tables or on excel. They will also be manipulated in these programs.

Data Presentation
Data will also be presented in excel or word. It will be attached to the appendix of the final report.

Test Procedure

Summary/Overview
The test will consist of feeding a single piece of composite into the delimitator which will push the piece of composite into the cutter. There will be a bin attached to the open end of the cutter which will catch cut material.

Time/Duration
The time of the overall test will be dependent on the rate that the delaminator feeds material through the entire system. At a federate of 100in/m, it will take about 1 minutes to travel through the entire system.

Place

The location is still undetermined due to the amount of power that will be required to run both motors. But the metallurgy lab or foundry lab will probably be where the test is conducted.

Resources Needed

- Lab that can power motors
- Composite materials
- Frame for both devices manufactured and fastened
- Safety glasses
- Emergency stops for motors

Specific Actions to Complete Test

1. Make sure all components and devices are secured. Tighten all bolts with allen wrench so that they are snug and cannot move.
2. Make sure all alignment of devices and motors is correct. Sprockets should be allowed to rotate by hand prior to starting motors. If there are alignment issues and sprockets are not rotating, dissemble and re assemble so that they can rotate.
3. Insert a bin to collect cut material at the end of the shredder. The end of the device is 10” x 8”. A bin larger then that will have to be attached to the end of the cutting device.
4. Separate the blades by using to spacers so that they are ½” apart. They already provided an located on both shafts.
5. Power both motors. They have yet to be wired nor do they have switches or power buttons. Updates will be added once more information is given.
6. Record the RPMs each device is running at. Using a tachometer, record these values in the table provided.
7. Feed composites into the delamination device. The delamination device is the shorter of the two, and will be facing the operator.
8. Observe to see if delamination is happening. If delamination occurs, leave power on so that material can be fed into shredder. Layers will start to break apart.
9. If no delamination occurs, the power off the motors.
10. Change the sprockets and chain of delamination device to produce either a higher or lower RPM.
11. If test is successful, power both motors off.
12. Allow for all moving components to come to a complete stop.
13. Unplug motors.
14. Remove composite material.
15. Remove the bin and observe the physical state of the material that is gathered.

Risk/Safety/Evaluation Readiness/Other

The risk of running these devices is that they can potentially be dangerous if the alignment of motors and sprockets is not correct. Also, there is a potential danger if the devices are not secured. Anyone who is running this test must be aware of moving and rotating parts and stay clear of them. Once powered, the only point of contact should be feeding material into the delamination device. Any manipulation of parts or devices must be done with motors not powered, and all components at a complete stop.
The test is not ready to be conducted. Upon completion of a stand for the delamination device, wired motors, and a frame for both devices, then a test can be run.

APPENDIX I – Testing Data

Due to unforeseen circumstances, we as a group were not able to complete any testing. The group has constructed the devices needed for testing, and a future group could be tasked with finishing a frame and completing the tests.

APPENDIX J – Resume

MIKHAIL K. MINASYAN

2204 N 105th St APT F-105

Seattle, WA, 98133, United States

(206)-853-1625

minasyanm@cwu.edu

PROFESSIONAL EXPERIENCE

WRIGHT MACHINE

Designer/CNC operator: June 2015 – September 2017

- Deliver completed projects.
- Operate lathes, mills, sanders and drills.
- Assist on graphic designs, lead solid works designer.
- Help engineer solutions for various customers.

- Do invoices and keep financials in check.
- Compute and record totals of transactions.

JCPENNEY SEATTLE, WA

Cashier: January 2012 - April 2012

- Receive payment by cash, check, credit cards, vouchers, or automatic debits.
- Issue receipts, refunds, credits, or change due to customers.
- Answer customers' questions, and provide information on procedures or policies.
- Count money in cash drawers at the beginning of shifts to ensure that amounts are correct and that there is adequate change.
- Calculate total payments received during a time period, and reconcile this with total sales.
- Monitor checkout stations to ensure that they have adequate cash available and that they are staffed appropriately.
- Compute and record totals of transactions.

EDUCATION

SHOREWOOD HIGH SCHOOL SHORELINE, WA

- Graduated with 3.5 GPA

CENTRAL WASHINGTON UNIVERSITY , WA

Mechanical Engineering Technology Student, June 2018 expected graduation

- Also took Accounting 201, and Computers for Business 169, PLC experience, Can speak fluent Russian

Additional Skills

- Microsoft Word, Access, Excel and Powerpoint
- Customer Service
- Money Handling and Transactions, Upper level Mathematics
- Recommending Services for Customers

- Social Skills,
- Organization

References

Max Zimmerman- (206) 305-0642

Jorge Landa-(206) 910-1186

APPENDIX K – Website Hyperlink

https://minasyanm.wixsite.com/seniorproject

Videos, manufacturing images, systems images are all included in the website.