Central Washington University

ScholarWorks@CWU

All Undergraduate Projects

Undergraduate Student Projects

Spring 2022

Team H&H RC Baja Drivetrain

William T. Hedlund
Central Washington University, william.hedlund@cwu.edu

Follow this and additional works at: https://digitalcommons.cwu.edu/undergradproj

Part of the Applied Mechanics Commons, and the Manufacturing Commons

Recommended Citation

Hedlund, William T., "Team H&H RC Baja Drivetrain" (2022). *All Undergraduate Projects*. 182.
https://digitalcommons.cwu.edu/undergradproj/182

This Undergraduate Project is brought to you for free and open access by the Undergraduate Student Projects at ScholarWorks@CWU. It has been accepted for inclusion in All Undergraduate Projects by an authorized administrator of ScholarWorks@CWU. For more information, please contact scholarworks@cwu.edu.

Team H&H RC Baja Drivetrain

By

Bill Hedlund
And
Jack Huff - teammate

ABSTRACT

A need for a drivetrain and steering system that could provide locomotion and directional control for the H&H RC Baja racecar was needed. The RC Baja event is a competition hosted by the CWU ASME club in which teams of engineering students compete against each other to test the effectiveness of the respective designs. The car needed to be able to compete in three events: a drag race, solemn course, and a Baja event. This was accomplished by designing and manufacturing several parts of different materials utilizing a range of manufacturing techniques to produce sub-assemblies and that made up the drivetrain systems. The system were constructed using a variety of methods including; matching of parts, 3d printing, and off the shelf parts. The RC car was designed in SolidWorks a parametric modeling software to ensure manufactured parts were easy to assemble the systems were designed using; material analysis, statics, and concepts from mechanical design, across 12 unique engineering analysis to guide the engineering decisions and manufacturing processes and ensure the car would meet all requirements set forth by not drivetrain engineer but also the suspension and chassis Engineer The combination of all analysis, decision matrixes, designing, manufacturing and assembly, resulted in a top speed of 25mph was able to climb inclines up to 30 degrees and weighted less than 4 pounds.

Contents

1. INTRODUCTION

a. Description
The ASME RC Baja event is annual event hosted by Central Washington University's ASME club in which engineering students compete to design, build and test Radio Controlled cars. Students must abide by the rules and regulation set forth by the competition rule book to be eligible to compete in the event. The Cars must compete in three sperate events designed to test the cars acceleration, handling, and off-road capabilities. The project is to design and build a car that will compete in this competition, this report will focus on the drivetrain for the H&H team's car. The drive train will cover power and delivery, steering, and electronics per the competition regulations and mechanical power delivery via gearing and axles.

b. Motivation
The project motivation came from an interest in Baja racing and RC cars. The university has hosted this event in the past and prior attendance of the event sparked an interest in the event. The project presents many challenging aspects for design and competition style that creates excitement and enthusiasm to compete in the competition.

c. Function Statement
The car provides locomotion and direction control.

d. Requirements
Requirements are based on RC Baja regulations and team requirements.

1. Must reach speeds of up to 25mph.
2. Must be able to climb inclines of up to 30^{o}.
3. Total drivetrain weight must not exceed 4 lbs.
4. Must be driven by one electric motor that confirms to current-vintage ROAR bushed or brushless motors.
5. Must use a 7.2v 6 cell battery for power.
6. Rear drive assembly must be able to be swapped in under 10 minutes.
7. Must be operated up to 50ft from driver.
8. Cost must not exceed $500.
9. Withstand minor impacts of under 20 lb-f to the side of the front tires, without catastrophic deformation.

Team member requirements – Jack Huff

1. RC Baja car must be able to be operated at a minimum of 50 ft.
2. The RC Baja car must not exceed 10 lbs.
3. RC Baja chassis must be able to withstand a 1.5 ft drop test if landed upright.
4. Chassis must be able to withstand 150N force applied to the front end.

e. Engineering Merit

The project will apply many different types of engineering analysis including; Technical dynamics, statics, materials, mechanical design, and basic electricity. This analysis will be used to analysis parts like the reduction's gearbox, rear axle, and steering components, to determine designs and suitable dimensions. This analysis will also be performed to ensure the RC car meets the requirements outlines by the principal engineer. These requirements are thought to be acceptable parameters for successful completion of the ASME event and further testing beyond the event. The car's major and minor assemblies will be designed in SolidWorks with proper GD&T being applied to ensure that the drivetrain parts will pair with the chassis and suspension components for ease of assembly.

f. Scope of Effort

The drivetrain portion of the RC Baja car will be carried out by Bill Hedlund. The drive train will consist of;

- Electric motor
- Speed controller
- Steering servo
- Means of controlling steering
- Rear axle assembly
- Power transmission
- Battery
- Wiring and layout
- RC receiver

g. Success Criteria

Success of drivetrain will depend on the completion of the ASME RC Baja competition and testing outlined in report.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

The RC Baja is being designed to compete in the ASME RC Baja competition. The design of the car must allow for power to be transferred to the wheels and provided directional control. The design came from initial brainstorming, the initial idea has since been ruled out in favor of conventional drive shaft and rear differential. Design choices have been made as according to the score received on the decision matrix in order to best guide the project toward meeting all the requirements. The design will consist of a motor mount, Transmission, rear differential, tie rods and tie rod ends.

b. Design Description

The design is conventional it consists of an electric motor mated to as gearbox with an output shaft that connects to a drive shaft. The power transmission will be done via a rear straight axel mounted to the rear swing arm. The tie rod will be controlled by a steering servo with power supplied form the main battery. The power from the motor will be supplied from the battery also through the speed controller.

c. Benchmark

The Traxxas Rustler will serve as the benchmark for the drivetrain portion of this project. Rustler is an off-the-shelf product and considered an entry level RC for competitive racing due to its forgiving nature and lower price point as compared to more race ready Traxxas machines.

d. Performance Predictions

The RC will reach a top speed of 25 mph in both forward and reverse directions and reach this speed within the limits of the course, with minimal wheel spin. The car will also be capable of inclines up to 30 degrees from a resting position.

e. Description of Analysis

The analysis for the drive train consisted of selecting an off the shelf electric motor to serve as the base for all further calculations. To find the torque and rpm need to allow the RC car to perform as designed a motor need to be selected and power out of the motor was needed. In analysis 1 these calculations were performed and will drive the further calculations into gear ratios, tire sizes, and material selection. Further analysis will be completed as more information is collected on the chassis and suspension portion of the project as much of the drivetrain is limited by the designs of the chassis.

f. Scope of Testing and Evaluation

The testing will be evaluated on how well the RC car meets the reequipments set forth in section 1d, with emphasis on top speed, final drivetrain weight, incline test, and assembly swap out times.

g. Analysis

These calculations can be found in appendix A1-12. These are the calculations that are driving the design requirements.

i. Analysis 1

This analysis covers the motor power (W) that can be expected during maximum operation use under ideal conditions with no load applied to the motor. The requirement was to find the find the expected power for use in the top speed, power usage, and gear train calculations. The analysis found this maximum power in watts that can be expected when the motor is moving at full power. This resulted in dwg 20-001, 20-002, and 20-
Appendix A1

ii. Analysis 2

This is the analysis for the maximum RPM and torque of the motor with the given limitation of the motor at ideal expected operational conditions. The requirements were to find the max rpm and torque to meet the top speed and incline requirements. The analysis provided the max rpm and torque, this is used in the gear train design and produced dwg; 20-002,20-004, and later to come drawings.
Appendix A2

iii. Analysis 3

This portion of the analysis covers the gear train values for the rear gearing, transmission gearing. The requirement was to achieve an 8:1 train value per manufacturing of the motor recommendations. Mechanical design was applied to find the three needed ratios. The rear bevel ratio was found to be, 1.66:1 paired with a 5:1 ratio for the reduction gearbox. The overall train value was found to 8.33:1. The resulting documentation is: 20-002, 20-004, 20,007, 20-008, 55-002, 55-003, 55-005, and 55-006.
Appendix A3

iv. Analysis 4

Using the found final gear values analysis was conducted to find the driveshaft diameter with a material of 6061 T6 Aluminum at yield stress and a safety factor of 4. The requirement was to deliver power to achieve the top speed and incline design requirements. This resulted in analysis to solve for the diameter foe the drive shaft, and will result in a final driveshaft drawing.
Appendix A4

v. Analysis 5

With the gear train calculations complete the top speed was re calculated using the final drive and rear tire size of 4 in, the new top speed was found to be 45 mph. The requirement was to reach a speed of 25mph, the analysis proved this will not be an issue. This will be used in the design of the driveshaft as a parameter to design the minimum thickness of the driveshaft keeping in mind the safety factor of the driveshafts.
Appendix A5

vi. Analysis 6

This analysis focuses on the deflection of the rear axle to aid in the design of suitable rear axle for the RC Baja car. The requirement was to survive the torque being supplied from the drive train. The is being conducted to confirm the material and thickness of the rear axle the analysis covers the deflection of the rear axle and produced the drawings for the rear axle and assemblies. 20-011
Appendix A6

vii. Analysis 7

This is the analysis for the tie rods. The requirement is to provide steering and directional control to the steering to the RC car, the analysis was done to first find the length of the tie rods; that length was used in a column bucking equation to find the critical stress that would cause the tie rod to fail. This analysis was all done assuming a 3/32 tie rod after design and common parts sizes a diameter of ¼ was chosen this is not a major concern as the new design is stronger than initially calculated. This resulted in the dwg 20-005.
Appendix A7a&b

viii. Analysis 8

This is the analysis for the Upper Control arms, the requirement is it withstand a drop of 1.5 feet. Part a of the analysis is to finds the length of the upper control arm with the current sketched design. Part of the analysis was a column buckling calculations this is thought to be the most likely failure point. The analysis found that the control arm can support 290lb with a safety factor of 3. This design was chosen as the project would already be ordering $\frac{9}{16}$ diameter 6061 T6 round stock and this would ese production, cut down, on cost and reduce wasted material. The Upper Control Arm dawning is 20-006.
Appendix A8a&b

ix. Analysis 9

The requirement for this analysis was provide locomotion to the RC car, the focus of this analysis was to design the transmission gear reduction, earlier analysis was done to find the transmission gear reduction velocity ratio. The analysis led to the selection of a 12-tooth pinion gear and a 36-tooth driven gear with a gear pitch of 20. Analysis was done to find center distance and meshing factor m_f ratio for the two gears. The ratio was found to be 1.6. This resulted in dwg; 20-007, 20-008, and part 55-002, and 55-003/
Appendix A9

x. Analysis 10

Analysis 10 was done to test the strength of the steering kingpins for the front steering. The requirement was to withstand 20 lb-f side impact without causing the kingpins to exceed yield stress of 40ksi. The analysis was done to confirm king pin size selection was correct, the analysis was done for double shear and found that the kingpin size of 1/8 in. is suitable for the requirements. The resulting documentation is analysis 10. Resulting part 20-012.
Appendix A10

xi. Analysis 11

Analysis 11 was conducted to find the cotter pin size and material. The requirement was to waistband a 20lbf in double shear. Statics analysis was preformed to find the max shear stress, materials analysis was also performed to find the material selection. The pin chosen was a 316 stainless steel pin with a diameter of 3/64. This part is intended to be purchased and resulted in dwg 55-009.
Appendix A11

xii. Analysis 12

This analysis was preformed to produce the driveshaft. Simple geometric analysis was used to find the lengths for the driveshaft dimensions. Statics analysis was used to resolve for the shaft diameter with the corrected input torque values 6.85 ft*lb. The new diameter was selected to be 0.500in. The final length of the driveshaft was determined by using 55-004 u-joints. The resulting part drawing was 20-010 driveline shaft.
Appendix A12

h. Device: Parts, Shapes, and Conformation

The design of the RC Baja drivetrain came from analysis and working closely with the chassis and suspension team to ensure the drivetrain had optimal space for critical components while attempting to maintain the overall form factor decided on from analysis and decision making. The drivetrain is limited by the chassis, extra care has been taken to ensure the proper GD&T met the ASME Y14.5 standard to ensure the assemblies would fit accurately with little to no modification. Parts that require a high degree of tolerance are attempted to held to ±0.005 in and lesser parts within the drivetrain assemblies are held to ±0.01 in; one of major concerns of the drivetrain is ensuring the fastener holes align with the mounting provided by the chassis.

i. Device Assembly

The assembly of the consist of the motor mount sub assembly, the transmission, driveline, and rear axle drive and housing, steering servo, tie rods, and other off the shelf electrical components to provide direction and locomotion controls.

j. Technical Risk Analysis

The technical risk for this project will maximizing the power to weight ratio, the car must reach speeds up to 25mph while maintain structural rigidity during impact testing and competition use but have enough power to climb inclines of 30^{o} and being able to deliver useable power both on and off road. Additional technical risk will be properly wiring and soldering the electrical connections, adjusting motor timing and controlling servos with a remote control.

k. Failure Mode Analysis

One of the most critical section of the RC Baja car will be the rear end assembly. The design of the RC utilizes a singular swing arm which will house the rear drive gears and rear axle carrier. The randomized loading on the axel caused by the swing will present a large amount stress acting on the axel not limited to the just the rotation torque provided form the power transmission system. The power transmission system will also be subject to torque proved from the motor and transmission this may cause fatigue to the drive shafts and drive gears. Additionally, the torque will be transfer by gear and the stress may cause catastrophic failure to the gear teeth all around.

l. Operation Limits and Safety

According to the Justock-3650-G2.1-Sensored motor data the motor should not be running under heavy load conditions and such applications of extended high load may cause the burning. They should never be running at high loads for extended periods of time. The RC Baja car will also undergo stress testing by impact thorough inspection of the electrical components; solder joints, battery condition, Electronic Speed Controller (ESC) connections, and loses or broken wires, these items make cause a short and can potentially cause harm to the operators and the assembly.

3. METHODS & CONSTRUCTION

a. Methods

The parts for this project were designed with the intention to use the CWU equipment; this may include the use of CWU 3D printers, machine shop, and electronics lab. The majority of parts are designed with the use of the 3D printer, all other parts are off the shelf or modified off the shelf parts. The design is intended to minimize any machining work; however, some parts will require machining this will include turning down the diameter for shafts and axle or tapping shaft ends and holes.

The many labs located within the Hogue building and CWU campus will be used for the production and assembly of the RC Baja project. The computer labs have been used for creation of SolidWorks parts, the machine shop has been used in the creation of aluminum manufactured parts, and the Multi modal Education Center has been used for 3d printing of parts.

The electrical portion of the drivetrain assembly will be purchased from off the shelf parts. The parts standard components for RC applications. The intention of the wring is to make a custom wiring harness using donated wire, and connectors to create a system that is modular and can be assembled and tested off platform to ensure all controls are correct and function as intended and comply with the information supplied in the manufactures data sheets.

The design of the project was done by conducting analysis to solve for stress and design according to these values to ensure the parts would withstand operational loadings. Redesign of parts is to be handled by the respective principal engineer. The redesigns may result in a drawing revision number found on the part drawings or may require a new approach to the particular application; if this is the case old part number will be kept but excluded from assembly and report and new part number will be assigned. The new part number will be assigned to help reduce confusion in 6the case of manufactured part vs, part drawing.

i. Process Decisions

Drive Shaft – Following the analysis for driveshaft deflection, the next closet size for round that could be found was 9/16. round 6061 aluminum stock, this stock will need to be cut to a rough length, then turned down 1/16 of an ich on a lathe and final length corrected and prepped for assembly. This work will occur in the Hogue Machine Shop. This design was chosen for the strength, relative low time, and cost. The drive shaft needs to hold the required torque from the motor, the analysis led to the selection of 6061 T6 with a next standard size being 9/16". The machining required is not very complex the engineer feels confident in using the lathe to turn down the diameter. The shaft will be turned and faced to ensure the correct diameter is met and the shaft balanced as to not create fatigue due to vibration and reduce stress placed of the up or down stream gearing. The ends of the driveshaft will need to be tuned down to 3/8 nominal diameter and threads cut to make the threads in the U-joints connected at both ends.

Lower Motor Mount – this part will be produced using a 3D printer because of the complex shape and ease of manufacturing and no strength requirement. These parts will be printed using the printers in Samuelson Hall through the MEC. This Part was chosen to be printed for the ease of manufacturing, low cost, high precision, time, and easy manufacturability. Precession is required for these parts as they must mate with the chassis plate. The printer will help to ensure the holes are in correct locations relative to the true position located from the datum blocks on the drawing.

Material selection – In many cases 6061 T6 aluminum was chosen for its low cost, light weight, ease of manufacturing, and relative strength.

ABS plastic was chosen for the 3d printed parts; however, PLA has since been used for part construction as the access, ease, and cost of printing is more beneficial to the completion of the project. PLA is an acceptable substitute for these parts as strengths are not of great concern nor is heat. a concern Proper measure will be taken to mitigate any new risk caused from switching materials. This may include but is not limited to the application of thermal paste to high heat areas.

The 3D printed parts are to be constructed using 100% infill rate with the use of breakaway supports and rafting bead adhesion when applicable.

b. Construction

i. Description

The RC Baja project will consist of two major portions Suspension and chassis overseen by the suspension and chassis engineer, and the Drivetrain and Steering portion overseen by the Drivetrain engineer. The drivetrain is broken into four further sub-assemblies, Motor mounting, Reduction gearbox, Driveline system -- rear axle system, and Steering system. The parts that make up these assemblies are listed below the assemblies the parts are broken up it the order in which they should be assembled, fasteners are omitted from tree see assembly drawings for details. The drivetrain parts are then broken into two major categories manufactured and purchased parts. The manufactured parts will be broken into two categories external and internal manufactured parts, the external parts will be the 3d printed parts and the internal parts will be the machined parts constructed by the principal engineer.

ii. Drawing Tree, Drawing ID’s

The drawing tree can be found in appendix B. The drawing tree follows a hierarchy order in which the main assembly, is broken into sub-assemblies, and the subassemblies are broken down into parts in the assembly. The sub-assemblies are classified as 10-### sub-assemblies. The parts are broken into two different type’s manufactured parts 20-### and purchased off the shelf parts 55-###. Purchased but adapted parts will fall under the 20-### part as they require machining work.

iii. Parts

The parts being manufactured are in three categories; 3D print, machined, or purchased. The printer parts will be included parts such as 3d printed cases for the reduction gearbox, rear axle housing, motor mounts, and axel carriers. The machined parts will include round shaft that needed to be turned or shortened. This will include connecting pins, tie rods, upper controls arms, axel, rear axle, and kingpins. The purchased parts will include electronic components, u-joints, wheels, and wheel hubs, motor, speed controllers, and batteries.

The machined parts will require the use of the engine lathe to turn parts from round stock to require parts. Additionally, parts like the driveline will require the ends of the parts to threaded for mating with U-joints or tie rod ends if applicable. Parts such as the Upper control arms will require the use of the drill press for drilling the connecting holes for the upper control arms.

iv. Manufacturing Issues

The foreseen manufacturing issues are access to the required machinery. The machining need is limited however this may cause issues as many other students needed access to the same machines. The primary equipment needed are the lathes, drill press, and possibly the milling machine.

The major access issue is 3d printer while the team has a printer with 100% access it is not capable of printing ABS and the machine is new and problems are still being resolved to ensure the reliability of the printer. The CWU printers are expected to be in high demand during the construction phase, access is expected to limit. Additionally, the printers are running only during the business hours of the MEC.

Manufacturability is also an issue in the construction phase, while the principal engineer will be doing the machining, achieving high levels of accuracy in a short period of time will be difficult, extra attention will be used in the manufacturing of these parts but achieving the accuracy specified in the drawings will be a challenge. This problem will be mitigated by applying best practices for machining and referencing the drawings, as well as use of precision measuring equipment in the machine including garnet tables and height gages when scribing the parts.

Manufacturing arose during the machining process; the most common issue is during lathe operations it has proven to be difficult to maintain allowable tolerance for concentricity. This led to the remanufacture of one of the upper control arms as the part was not within tolerance and would have led to issues during the drilling operation. Run out has also been an issue this issue is most present in the rear axle, with the relative long length for the small cross section the rear axle varies in diameter from one end to the other. This error was corrected to be with tolerance but still present.

Other manufacturing issues can be attributed to operator error and mis reading of dimension on drawings and resulting in the scrapping of the first attempt of the driveshaft. The scrapped driveshaft has been used in the construction of another part and reduced machining time on the rear input shaft. The two parts had similar geometries with the rear input shaft benefiting from the mistake.

v. Discussion of Assembly

The device was assembled in section using sub-assemblies, the sub-assemblies consist of the reduction gearbox, the driveline line system, the rear system assembly, steering assembly, and motor mount system, these sub-assemblies are then all mounted to their respective spots on the chassis and connected together to form the device final assembly.

The construction of the sub-assemblies required minor modifications to be made to some parts, primarily drilling and reaming of holes in the 3D printed parts to help with aligning shaft in the cases of the reduction gearbox some holes were perfectly aligned and reaming the hole over 2 thousand was required to allow for enough room for the input and output shafts to be aligned. The assembly process also revealed some issues with fastener clearance and infill issues. During the assembly of the steering system and fastener was added to the steering knuckle with not enough clearance for fastener for the upper control arm the steering knuckle snapped due to overloading of pressure and a manufacturing issue was revealed. The steering knuckle was not printed to 100% infill, and this would have most likely led to part failure during operation of the cars suspension. Other issues found during assembly are holes of two parts not aligning correctly due to what is thought to have been a printing issue

4. TESTING

a. Introduction

The purpose the testing is to evaluate not only how well the RC preformed in the ASME RC Baja event. Trials preformed in this test are deigned to evaluate how well the design requirements have been met. Outside of the solemn, drag, and Baja timed runs, the RC will also be tested on the ability to climb inclines, top speed, and design for manufacturability.

b. Method/Approach

The method for the incline test will be to make three trials at varying inclines and record the pass fail of that particular section. The Top speed test will be done by averaging the highest speed achieved in a straight according to GPS tracking available on smart phones or Go Pro cameras. The rear end assembly test will consist of three to five trials to completely swap the rear axle as one hot swappable sub-assembly.

The incline faced challenges; the principal engineers worked on a resolving the issue the car was facing with the incline testing. The RC is expected to be capable of climbing inclines up to 30 degrees with relative ease. The resulting design revision to come from the testing troubles was a final gearing ratio of 13.3:1 over the initial design ratio of 8.3:1, other modifications include changes to the motor mounting system to increase airflow and help with the cooling issues the team was facing.

The resulting change in gear reduction will have an impact on the top speed of the car. The change will slow down the overall top speed of the car. The design requirement for the drivetrain was for the car to reach 25mph with the new gear ratio the car is expected to reach 27 mph the initial expected top speed was expected to be 45 mph.

c. Test Process

Incline testing will be performed using a staircase and a board of known length to achieve 10^0, 20^0, and $30^{0,}$ each incline will be given three runs and testing will be done by recording the time taken. The primary objective of the incline tests is to test the ability to climb inclines up to 30^0 and know the speed in which it was done.

The Top speed test will be conducted on a long straight flat proton of concrete or hard pack gravel. The testing will be done by making trials and recording the top speed achieved on each run. The speed will be recorded by either GPS smart phone app or the built GPS abilities of the Go Pro camera. The requirement is for the RC to achieve a top speed of 25mph per the design requirement.

The design for manufacturability will be done by timing the removal and reinstallation of the rear axle sub assembly. The point of this test is evaluating the ease of design in a quantitative manner to simulate what repairs under competition conditions would fare. The test can be done by removing the top rear end cover and swapping the rear axle assembly. A replacement rear axle will be needed for the test, or a proper procedure needs to be outlined for using the same axle but accounting for time to swap a new axle assembly.

The team has discussed the testing under the current design of the RC Baja and have decided no further additions or modification to the testing process are needed and testing will proceed as anticipated from fall quarter.

d. Deliverable

The Following tables can be found in the testing data taking sheet, chart 1 is for the incline test, chart 2 is for the top speed test, and chart 3 is for the rear assembly change test. Charts and table will be attacked in the testing handout. Full testing report can be found in appendix G.

The design for manufacturability testing exceeded the predicted results of times under 10 minutes. The testing yielded a 6 minute and 30 second average times for completing the test. An unofficial time of 4 minutes 51 seconds was achieved with practicing the testing procedure. The test faced no major issues parts assembled as intended and provided no hinderance the functionally of the rear axle sub assembly. Test 3 did see the driveshaft come disconnected for the input gear box however, this proved not to a problem during the testing process and the driveshaft coupling was tighten following the testing.

5. BUDGET

a. Parts

The parts for this project will be a combination of designed parts and outsourced or off the shelf parts. The designed parts are intended to be 3-D printed or machined using both CWU equipment and team member own equipment. The parts list will breakdown the parts used for this project and detail further information about outsourced parts and where the parts are being sourced from.

The construction phase has resulted in the creation a few new parts and redesigns of parts. Most redesigns were caught before production. However, mistakes were made during production and two of the manufactured parts had to be redone resulting in scrapped parts and lost labor time. The cost resulting from this are an additional 10 work hours. Additional redesigns include the rear axle carrier which was scrapped and redesigned resulting in additional outsourcing cost and added labor cost for engineering. This was partially mitigated by manufacturing the rear input shaft out of scrapped material. The scrapped part saved on machining time as the diameters were closer to what was needed, and no additional material was needed.

The project encountered a redesign because of testing this account for an addental $60 in total parts and material cost. However, this redesign was scrapped at the decision of the drivetrain engineer no parts were salvageable either due to damage, modified beyond intended use, or the 3D printed part are specially designed for one intended use and can not be used elsewhere.

b. Outsourcing

The 3 d printer parts will be printed by the CWU student use printers where part files will be submitted, and parts will be returned as full compete parts.

Printing of parts occurred tin three locations:

1. Central Washington university Multimodal Education center -- cost based on print hours
2. Central Washington university Hogue Hall Student use MakerBot -- cost based on material
3. Privately owned machines -- price set by individual.

c. Labor

The project is requiring the use of 3-printed parts, the labor cost for parts may verry depending on the machines used, CWU charges a rate of $0.50 per print hour. The labor cost per hour was estimated to be $15 based on prior experiences with this level of work.

The testing portion of the project extended the need for more labor hours as an addental twenty five man hours were needed for either repairs or modifications to the final assembly.

d. Estimated Total Project Cost

$2.008.05 of the project as of writing

e. Funding Source

The funding for this project is supplied by the two principal engineers, who have agreed on a total budget and parts.

6. SCHEDULE

a. Design

The design of the RC Baja car has a hard deadline and must be complete by the end of the 2021 Fall quarter. The design schedule is drive by the competition of the analysis portion as most of the design parts are driven by the completion of the analysis. The intended goal is having the analysis competed by the end of November and all design parts, sub-assemblies, and assemblies completed with correct drawings. Lastly the design of the drivetrain will be linked to the chassis and suspension to ensure the parts will be within tolerance to ease the construction process.

b. Construction

The construction of the RC Baja must be complete by the end of the 2022 winter quarter in order to proceed with the testing phase in the Spring of 2022. The construing phases is expected to cause some slight redesign, this will be completed by the end of winter. The manufacturing quarter has consisted of manufacturing parts within the Hogue Machine shop. The Machined parts are ruining on schedule. The 3d printed parts took longer to produce then expected but most parts were submitted in one order and all parts were received in a timely manner. The pacing of manufacturing is expected to continue to mitigate the risk of falling behind schedule and not meeting the final assembly check off date.

The purchased parts were purchased early in the construction process to lave extra time for shipping should duplicate parts be needed or shipping had delays. Some purchased parts had shipping time estimated at one to one and half months to ship the delay on this part almost cost the functionally of the drivetrain system, fortunately this part arrived a week ahead of the shipping information provided from the vender and parcel service. The team had begun to look into possible solutions should the part not arrive in an attempt to mitigate falling behind schedule.

c. Testing

The testing was conducted in three phases; assembly, top speed, incline. The assembly testing was ahead of schedule went without any issues. The top speed testing was subjected to major setbacks the final assembly suffered major damage in chassis and suspension testing, the schedule allowed for this. However, the testing reviled a major issue in the cars gear train discussed in greater detail in section 4 and later section of the report. The redesign and remanufacture of final drive gear ratio took an addental two weeks to complete and put the project further behind schedule pushing the final test right up against the testing deadline. The testing reports have been worked on despite the setbacks progress continued.

The final testing report was submitted by the deadline with all three test and reports completed to best of ability. The assembly testing report was finished earlier than expected, with the top speed and incline testing falling behind there intended testing dates. The engineers were not pleased with leaving a test for the final week of the testing period however, with the drivetrain redesigns forced the testing to be delayed. To reduce any problems related to the delayed testing the reports were completed in a timely manner to make up for the moved test date.

7. PROJECT MANAGEMENT

Introduction

Many risks are present in the completion of this project, the main risk being; going over budget, going over time and lack of available equipment. The risk of not meeting project deadlines is the principal concern, this is the driving factor that will allow the project to advance from quarter to quarter, and eventually compete in the ASME RC Baja event. Additional attention will be applied to staying under budget if the project goes over budget the project may continue however, the project may not continue if the project does not meet the time deadline. The project has many factors and mentors in place to help ensure the project is completed successfully.

a. Human Resources

The Drivetrain and steering principal engineer Bill Hedlund will be responsible for overseeing the design, manufacturing, and testing of the drivetrain and steering components and assemblies. Additional human resources will be the many mentors of the project and project teammate chassis and suspension principal engineer Jack Huff.

b. Physical Resources

The largest portion of the physical resources was the CWU and personal 3D printers, final production parts will be constructed using the CWU 3D printers for their ability to print in ABS plastic and greater precision of printed parts. Parts used for mockup will be printed using personal machines and done so in PLA for ease of use.

The Hogue machine shop will be used for manufacturing metallic parts with the use of lathes, drill press, and milling machines. The Hogue electricity lab will be used for the soldering of the leads into the motor, and practice of soldering.

A standard tap and die set are required for the completion of the project, as well as other common hand tools, wrenches, screwdrivers, measuring equipment, etc.

The major risk for Physical resources is losing access to the resources, breaking or damaging equipment.

c. Soft Resources

The primary soft resources used in the completion of the project were the Microsoft Office suite and SolidWorks, Backups of SolidWorks files were made to an external drive and internal drive of the computer; backups of any of the Microsoft products was done to the same computer and cloud through OneDrive and Office 365.

d. Financial Resources

The financial support of the project was provided by the team members out of pocket. The risk of going over budget is being minimized by accounting for all scrap metal and mockup of parts done in more cost-efficient material. The largest risk for budget overrun will be shipping. If the project goes over budget it may continue at the continued expense of the team members.

8. DISCUSSION

a. Design

The design portion of project was completed by the end of fall quarter. The project began with a simple sketch of what the respective engineers thought would be the best solution to enter the ASME event. The initial drivetrain design had the motor located with the rear swing arm and driven by belt. However, this design was scrapped in favor of a more conventual yet through to be more practical design. The uses a reduction gearbox, a rear live axel, and independent front steering.

The reduction gear and rear live axel were at first based on purchasable rear mitier gear set, and power and top speed were driven by these preselected gears. The rear gearing set was replaced when new bevel gears were selected that allowed for a more desirable train value. The train value the engineer was striving for was a ration greater 8:1, the final drive ratio used in the RC came out to be 8.33:1 this is favorable as it puts less stress on the motor, replacement gears are more available and diametrical pitch is easier to work with. A major risk with the drivetrain was overloading the motor, this risk was mitigated by abiding by the manufacture's recommendations of a ratio no lower than 8:1 much care was taken to select gears that would following these parameters.

The steering portion of the drivetrain and steering was designed to be as simplistic as possible, to help with ease of use and reliability. The steering portion included the design of the upper control arms, tie rods, steering knuckle, sub axels, kingpins, and pins and fasteners. The directional control will be provided by a steering servo that will rotate and manipulate the tie rods turning the wheels. The front steering is set to work with the independent front suspension agreed upon by both engineers, for its simplistic yet proven design based on team experiences. Much is present in damaging the front-end parts this was accounted for in the analysis by applying a safety factor of at least three all front-end parts and fasteners to ensure impacts will allowed for the contend operation of the RC.

The design of the electronic portion of the RC Baja car had to fit the rules set by the ASME RC Baja rule book. A 2s lipo battery was selected to power the ROAR approved RC motor. The remaining wiring, and wire retainment will be completed during the construction portion of the RC project.

b. Construction

The construction process has been the bulk of the time sinks. The principal engineers have taken full advantage of machine shop open hours. The two Control-Arm, Uppers have been completed. Along with the driveshaft and rear input shaft. The tie rods were switched from a round stock to 8-32 threaded rod to ease in the manufacturing process. Time and time again it were proving to be very difficult to cut threads on the end of machined shafts of these small diameters and it would be more cost and time effective to switch to threaded rod.

These parts were given high priority in the early phases of machining to ensure ample time could be afforded if any problems arose in the manufacturing process. All machined part has been completed and are ready for final assembly.

The 3D printable parts have been completed including, but not limited too; The Upper and lower Rear axle cases, The Knuckle-Steering, Forward and Aft Cases-Reduction, rear axle hubs, and motor mount. The 3d printed parts caused some manufacturing issue with holes not aligning in cases that required high precision. This was present on the aft reduction gearbox case to where the output hole had to be drilled 0.005 in over the already reamer hole to account for enough free space for the shafts to spin without binding. The upper rear axle case was also reprinted as the print was warped during printing; this is difficult item to spot as it can only be replicated when fasteners are installed in the entire sub assembly.

The electronic parts were assembled without any major troubles, the soldering was done by the principal engineer with assistance from mentors. The electronic speed controller was converted to a dean's style plug to interface with the batteries purchased. The electronics were assembled at about the halfway point in the assembly process to test for any possible errors. The original transmitter and receiver received was discovered to be defective and has since been replaced. All other electronics work as anticipated.

The assembly process took three weeks as parts required slight modifications to allow for assembly this accounted for operations like drilling out support materials reaming holes, and clarence trimming some fits. All other sub-assemblies mounted to the chassis without requiring further work. The front steering system took longer to assemble as the nature of the design required high amounts of attention to ensure all parts aligned and function as intended.

C. Testing

The assembly testing was conduction with ease and nor major issues arose. The average time was found to significantly lower than the design requirement had specified for.

The incline testing had proven to be a challenge, upon initial testing it was revealed that the output gear on the reduction gear box was slipping. Two separate attempts were made to resolves this issue. The slipping issue was resolved but reviled a new set of problems to overcome. The motor began to overheat a t very alarming rate. The initial thought was that the motor mount was restricting airflow to the motor. The team cut the motor mount in half and significantly improved airflow, but this was not the solution. A fan and cooling duct have been developed to move more air over the motor to help with cooling. The most significant change was selecting and implementing a new final drive ratio to help reduce the load on the motor the ratio the car was designed to was 8.3:1 the new final drive ratio is 13.3:1, this ratio will increase the torque to the wheels and reduce the amperage the motor pulls to overcome the static state of the car.
No procedural changes have been made to the test as a result of this design revision.

The top speeding testing is unchanged the calculated top speed was found to be 45 mph; however, this will be different given the new final drive ratio, the design change should not affect the 25-mph design requirement set by the engineers. The car only achieved a top speed of

7.2 mph, this speed was achieved using a GPS speed tractor on a smart phone that was attached to the car and the car made three top speed runs. However, the stability of the car played a major factor in the top of the car. The testing now needed a wide-open venue to achieve top speeds, following the difficulties other teams had with accidents during the testing process.

The Incline testing will be switched to focus on the angles the car is capable of climbing rather than the ease of the 30^{o} incline. The engineers were not confident in the cars ability to reach that level of climb.

9. CONCLUSION

The design of the RC Baja car is conational deign that of a rear-wheel-drive rear solid axel with an independent front dual A arm front suspension. The power is delivered form a brushless DC motor that connects to the reduction gear box paired with rear final drive bevel gear that drives the rear axle. The steering controlled by a single servo that pushes and pulls the tie rods to provide directional control to the front wheels.

The analysis for the design uses many key components form core engineering classes including; basic electricity, statics, strengths of materials, technical dynamics, and mechanical design. The analysis was preformed using the RADD method in which each analysis included a design parameter, analysis, design, and documentation; the RADD analysis was then used in the creation of the many parts used in the final assembly.

The design conforms to the function statement and requirements, in which the drivetrain provides locomotion and directional control, drivetrain components meet the weight requirements, is under parts budget, exceeds speed requirements, and conforms to ASME RC Baja rules and regulations.

The RC was designed to be easily constructed all 3d printed parts are ready to begin manufacturing in the winter quarter, parts list has been fully assembled and parts are ready to be ordered in within the coming weeks, the selection of needed has begun to be compiled and arrangements have been made to begin prototyping over the holiday break, and calculations have run though, and errors have been corrected.

The third phase of the project, the testing phase was conducted with test being carried out, design revision and repairs being made as needed. The assembly test design for manufacturing was the strongest portion of the testing phases. The top speed and incline testing was not at the level that the engineers hoped for but, these issues are known and work will continue outside of the project to chase the continuous drive for improvement.

10. ACKNOWLEDGEMENTS

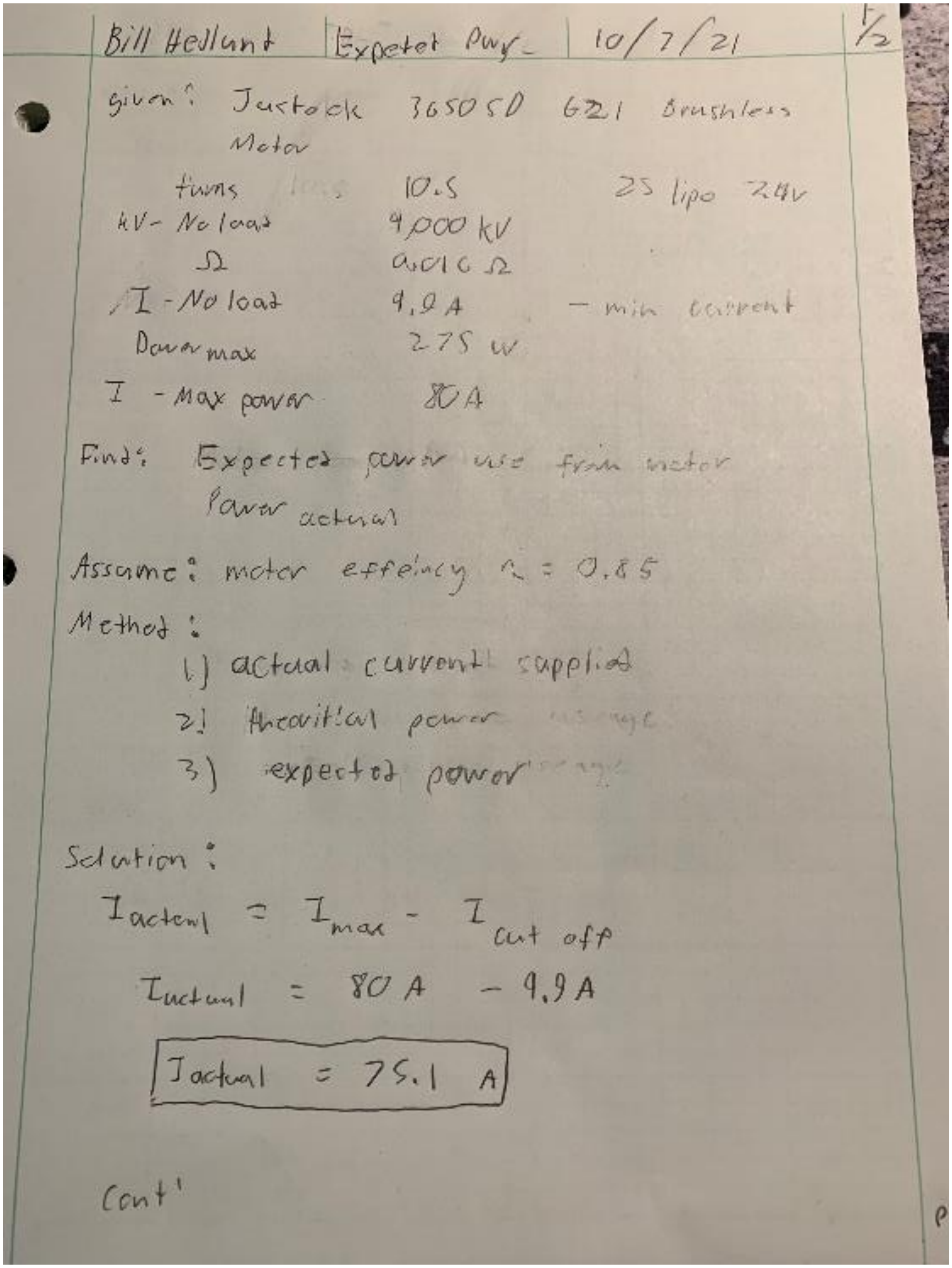
This project engineer would like to the thank his mentors, Dr. Choi, Professor, Pringle, Professor Fuhrman, Chris Berkshire, lab Technician Austin, classmates Ryan LaFrombois, Matthew Hart, and Mathew Morgan, project partner Jack Huff, and other outside mentors; Ethan Salkic, Parks Freilinger, Nathan Simmons and many others. The engineers would also like to thank CWU for its use of facilities, including the Hogue machine shop, and CAD labs, and for providing the access to SolidWorks 2021 and Microsoft office products for this project.

REFERENCES

(Rober L. Mott, 2018)

APPENDIX A - Analysis

Appendix A-1 – expected useable motor power



Bill Hedlund | Expected Pwr | 10/7/21 | 1/2

given: Justock 3650SD G2.1 Brushless Motor

turns 10.5 2S lipo 24V

kV - No load 4,000 kV

Ω 0.016 Ω

I - No load 4.9 A — min current

Power max 275 W

I - Max power 80 A

Find: Expected power use from motor

Power actual

Assume: motor effeincy η = 0.85

Method:

1) actual current supplied

2) theoritical power

3) expected power

Solution:

$I_{actual} = I_{max} - I_{cut\ off}$

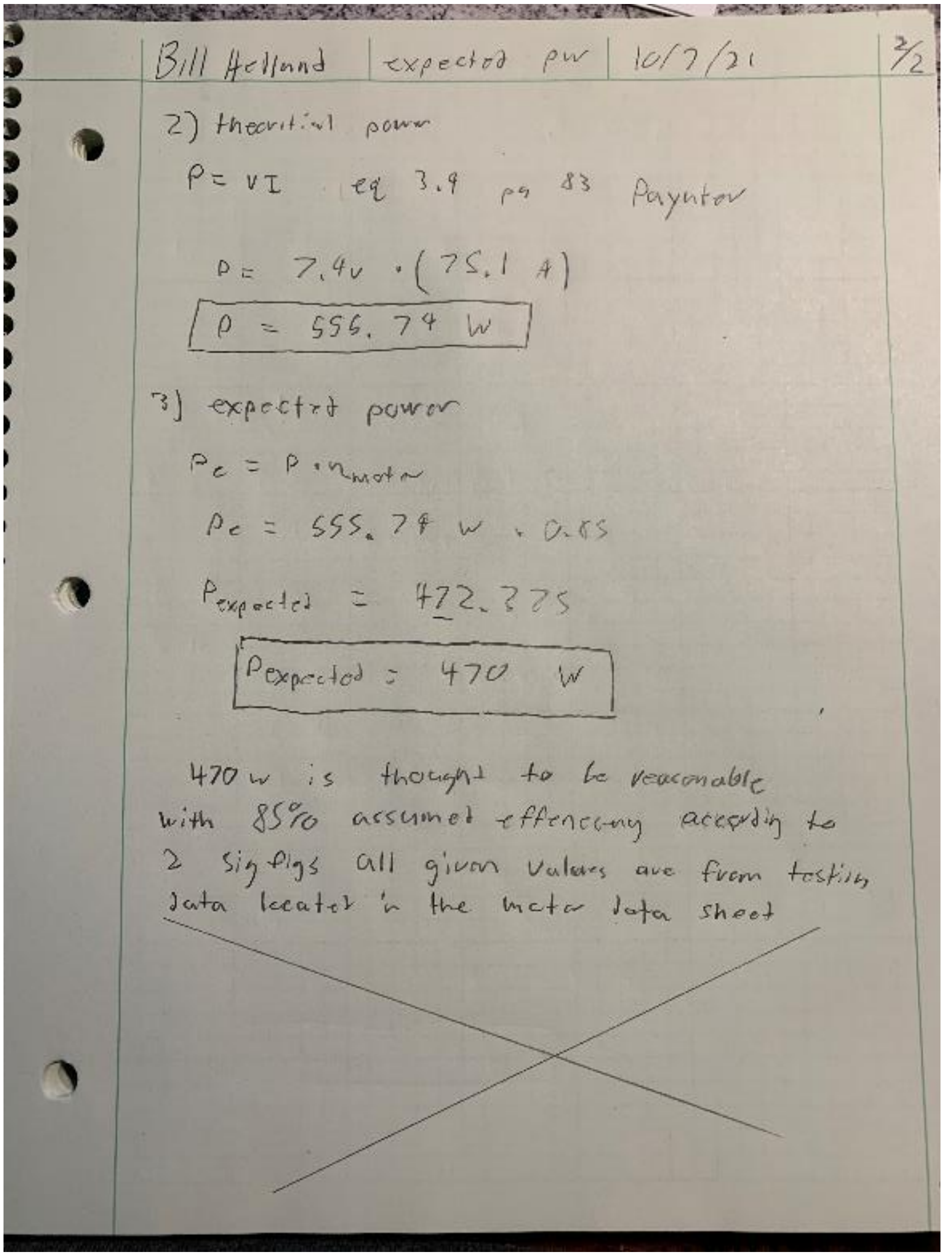
$I_{actual} = 80\ A - 4.9\ A$

$I_{actual} = 75.1\ A$

Cont'

Figure 1 provided power calculations

Appendix A-1 – expected useable motor power cont.



Bill Helland | expected pw | 10/7/21 | 2/2

2) theoritical power

$P = VI$ eq 3.9 pg 83 Paynter

$P = 7.4v \cdot (75.1\ A)$

$P = 556.74\ W$

3) expected power

$P_e = P \cdot \eta_{motor}$

$P_e = 555.74\ w \cdot 0.85$

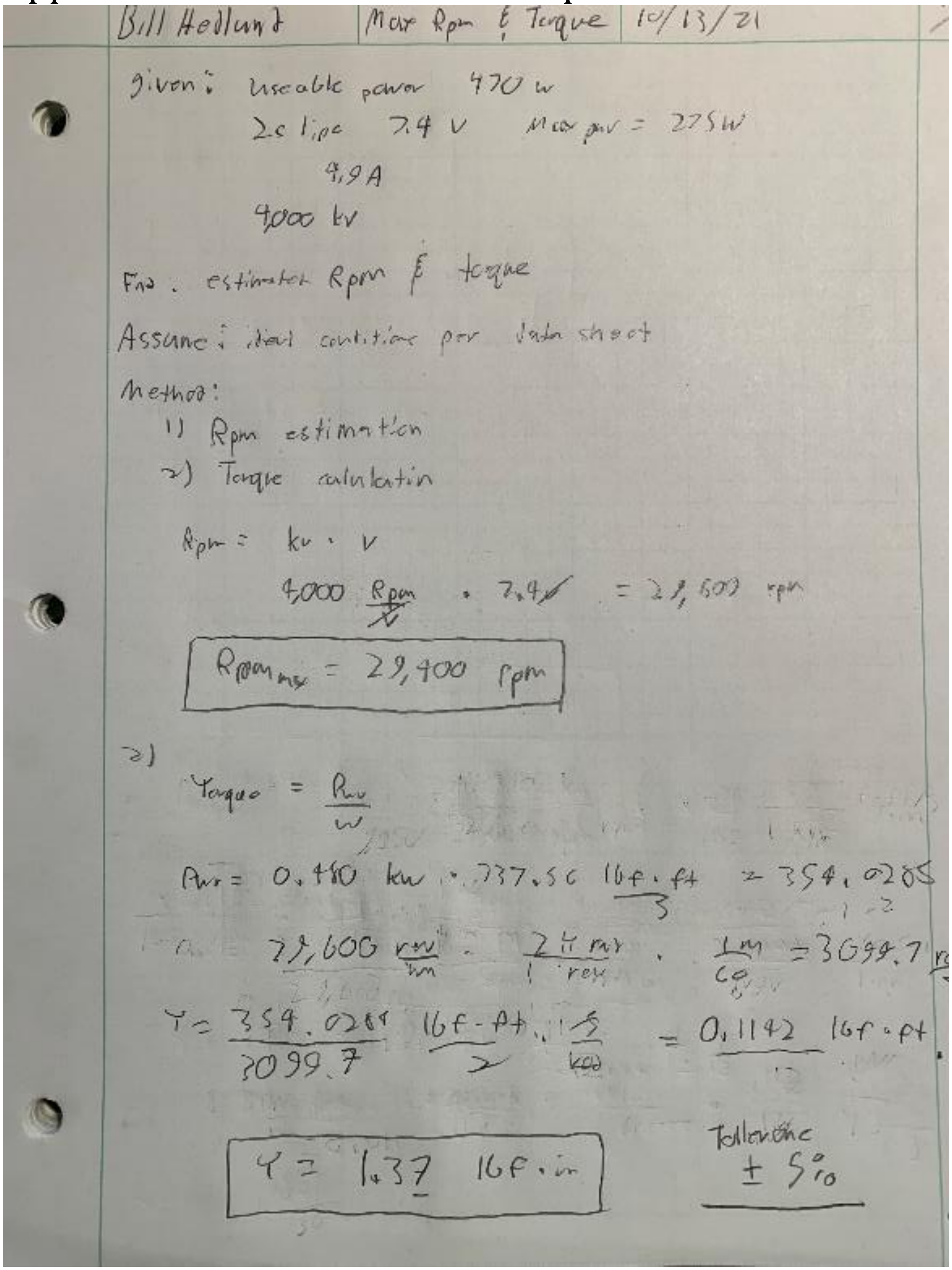
$P_{expected} = 472.375$

$P_{expected} = 470\ W$

470 w is thought to be reasonable with 85% assumed effenceny according to 2 sig figs all given values are from testing data located in the motor data sheet

Figure 1 provided power calculations

Appendix A-2 – Max RPM and torque calculations


Bill Hedlund | Max Rpm & Torque | 10/13/21

given: useable power 470 w
2s lipo 7.4 V   Max pwr = 275W
9.9A
4000 kv

Find: estimated Rpm & torque

Assume: ideal conditions per data sheet

Method:
1) Rpm estimation
2) Torque calculation

Rpm = kv · v
4,000 Rpm/V · 7.4 V = 2?,600 rpm

Rpm$_{max}$ = 29,400 rpm

2)
Torque = Pwr / ω

Pwr = 0.480 kw · 737.56 lbf·ft/s = 354.0288

ω = 2?,600 rev/min · 2π rad/1 rev · 1 min/60 s = 3099.7 rad/s

τ = 354.0288/3099.7 lbf·ft/s · s/... = 0.1142 lbf·ft

τ = 1.37 lbf·in

Tolerance ± 5%

Figure 2 MAX Rpm and Torque calculations

Appendix A-3 – Gear train ratios calculations

Bill Hedlund | Gear train calculations | 11/19/21

given: design ratio 8:1

reducer $N_P = 12$

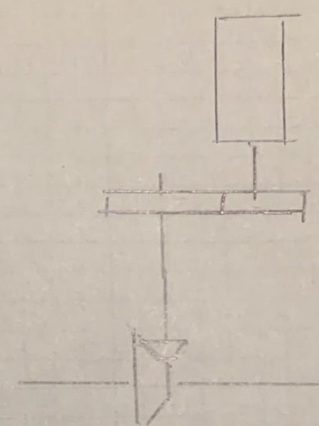
$N_G = 60$

$P_d = 24$

Bevels $N_P = 18$

$N_G = 30$

$P_d = 12$



Find:

1) RV_1 – reducer
2) RV_2 – bevel
3) T_V

Assume: ideal gear configurations

Method: see find:

Solution:

1) $R_{V_1} = \frac{N_G}{N_P} \Rightarrow \frac{60}{12} = 5:1$

2) $RV_2 = \frac{N_G}{N_P} \Rightarrow \frac{30}{18} = \frac{5}{3} = 1.6\bar{6}:1$

3) $TV_1 = RV_1 \cdot RV_2$ or $\frac{N_{GS} \cdot N_{GL}}{N_{PS} \cdot N_{Gb}}$

$T_V = \frac{60 \cdot 30}{12 \cdot 18} = \frac{1,800}{216} = \frac{25}{3}$

$$\boxed{T_V = 8\tfrac{1}{3} : 1}$$

$\frac{8\frac{1}{3} - 8}{8} \cdot 100$

$\% = 4.167 < 5$

okay

Figure 3 analysis 3 part 1 gear train

Appendix A-4 – Driveshaft diameter calculations

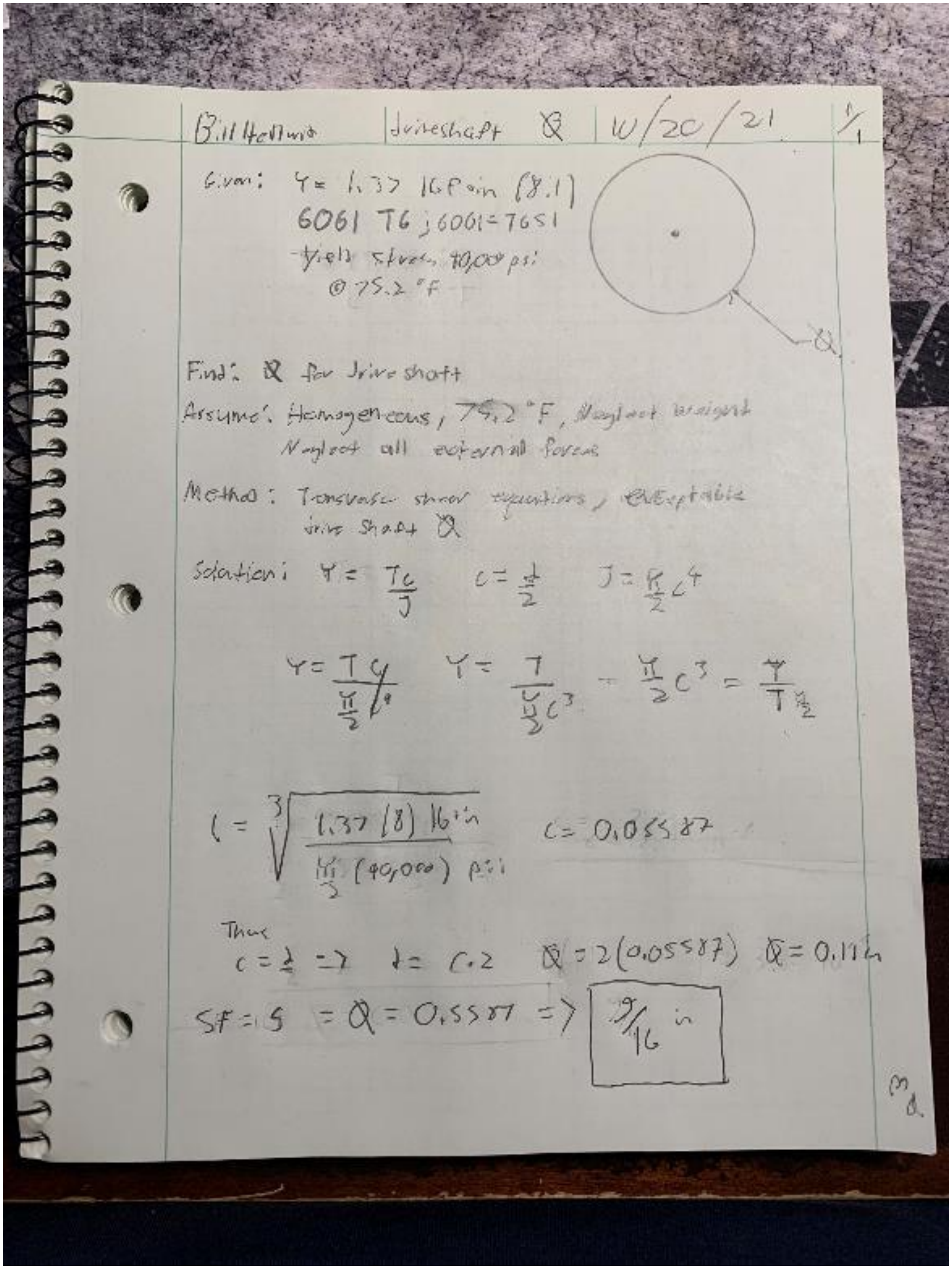
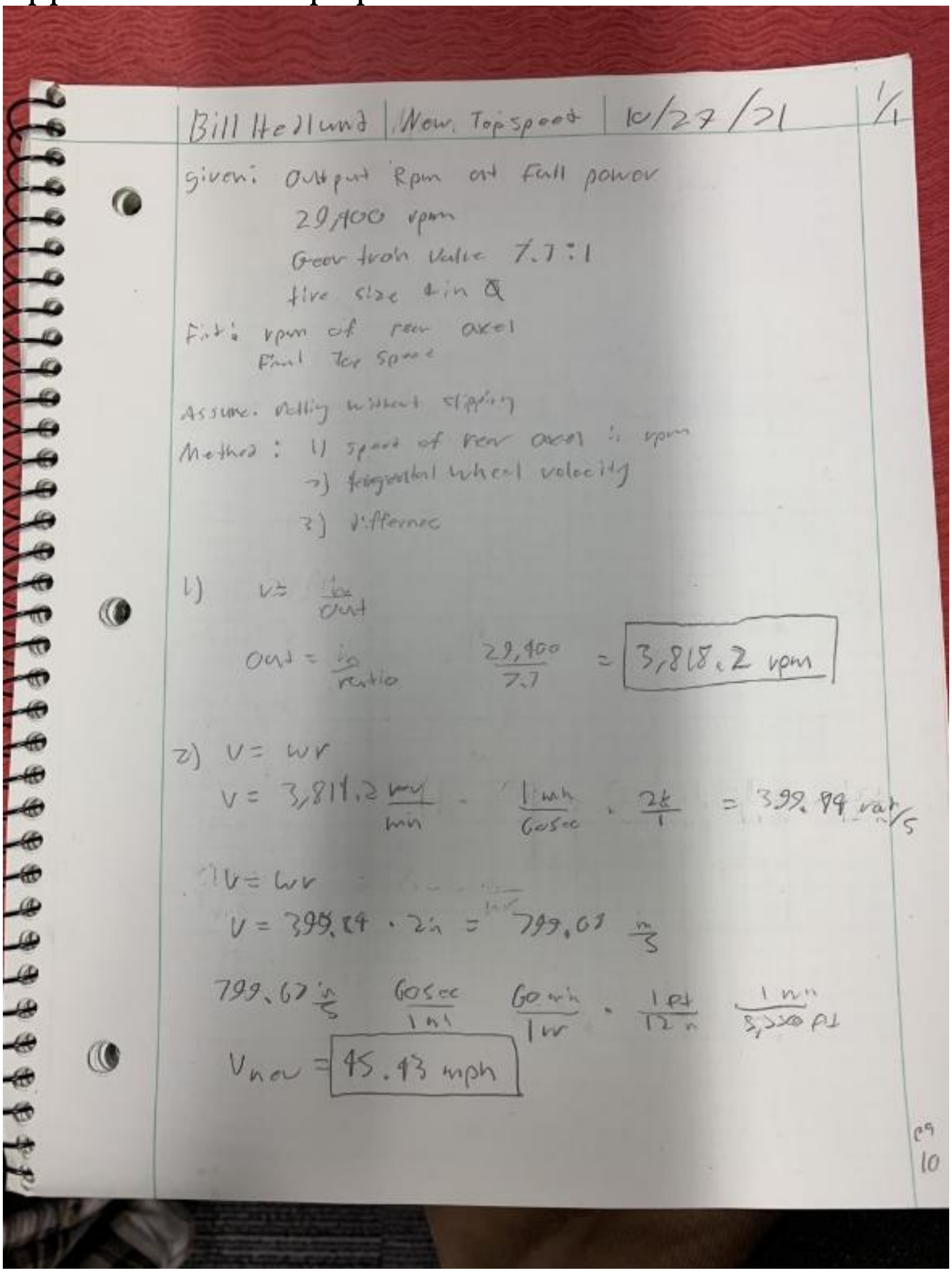


Figure 4 Analysis 4 driveshaft diameter calculations

Appendix A-5 – Top speed calculations



Bill Hedlund | New Top speed | 10/27/21 | 1/1

given: Output Rpm at Full power
29,400 rpm
Gear train Value 7.7 : 1
tire size 4 in Ø

Find: rpm of rear axel
Find Top Speed

Assume: rolling without slipping

Method: 1) speed of rear axel in rpm
2) tangential wheel velocity
3) difference

1) $v = \frac{in}{out}$

$out = \frac{in}{ratio}$ $\quad \frac{29,400}{7.7} = \boxed{3,818.2 \text{ rpm}}$

2) $V = \omega r$

$V = 3,818.2 \frac{rev}{min} \cdot \frac{1 min}{60 sec} \cdot \frac{2\pi}{1} = 399.84 \; rad/s$

$V = \omega r$

$V = 399.84 \cdot 2 in = 799.67 \frac{in}{s}$

$799.67 \frac{in}{s} \cdot \frac{60 sec}{1 min} \cdot \frac{60 min}{1 hr} \cdot \frac{1 ft}{12 in} \cdot \frac{1 mi}{5,280 ft}$

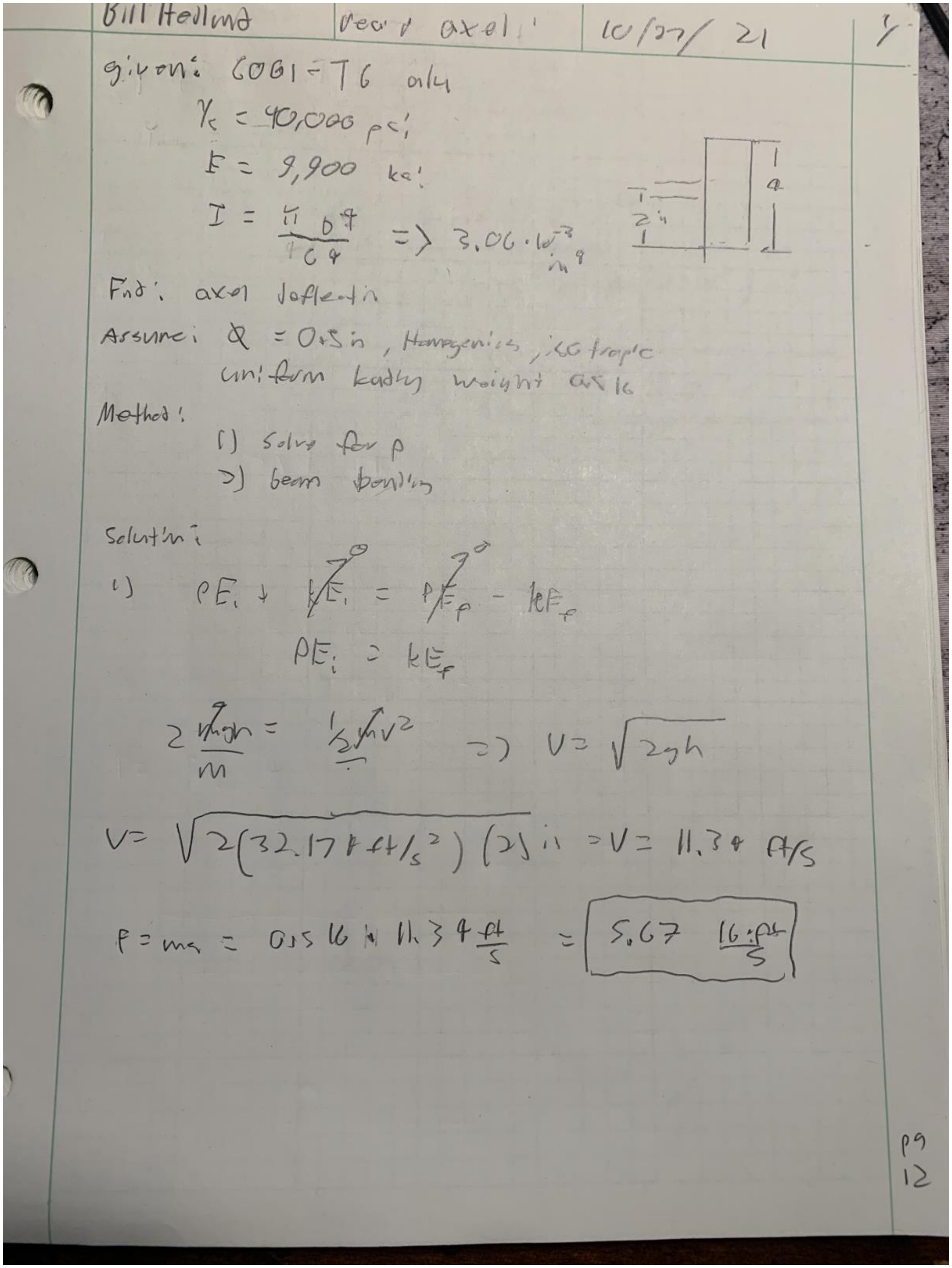
$V_{new} = \boxed{45.43 \text{ mph}}$

pg 10

Figure 5 Top Speed Calculation

Appendix A-6 – Driveshaft deflection calculations

+



Bill Hedlund | Rear axel | 10/27/21 | 1/1

given: 6061-T6 alu

$Y_s = 40{,}000$ psi

$E = 9{,}900$ ksi

$I = \frac{\pi D^4}{64} \Rightarrow 3.06 \cdot 10^{-3}$ in^4

Find: axel deflection

Assume: $\delta = 0.5$ in, Homogenious, isotropic, uniform body weight axle

Method:

1) Solve for P
2) beam bending

Solution:

1) $PE_i + KE_i = PE_f - KE_f$

$PE_i = KE_f$

$mgh = \frac{1}{2} m v^2 \Rightarrow v = \sqrt{2gh}$

$v = \sqrt{2(32.174\ ft/s^2)(2)\ in} \Rightarrow v = 11.34$ ft/s

$F = ma = 0.5\ lb \cdot 11.34\ \frac{ft}{s} = 5.67\ \frac{lb \cdot ft}{s}$

pg 12

Figure 6 Driveshaft deflection calculations

Appendix A-6 – Driveshaft deflection calculations cont’

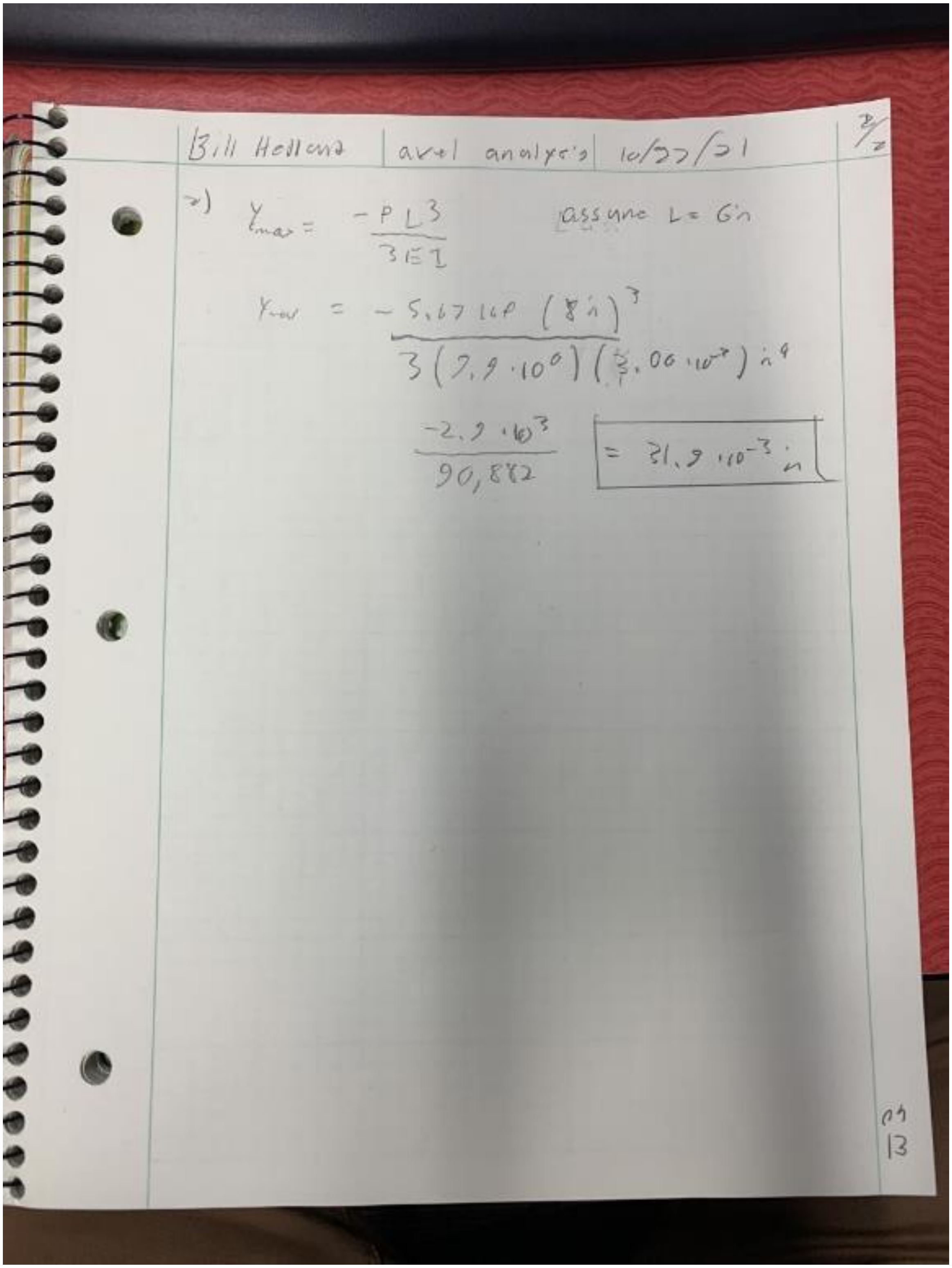
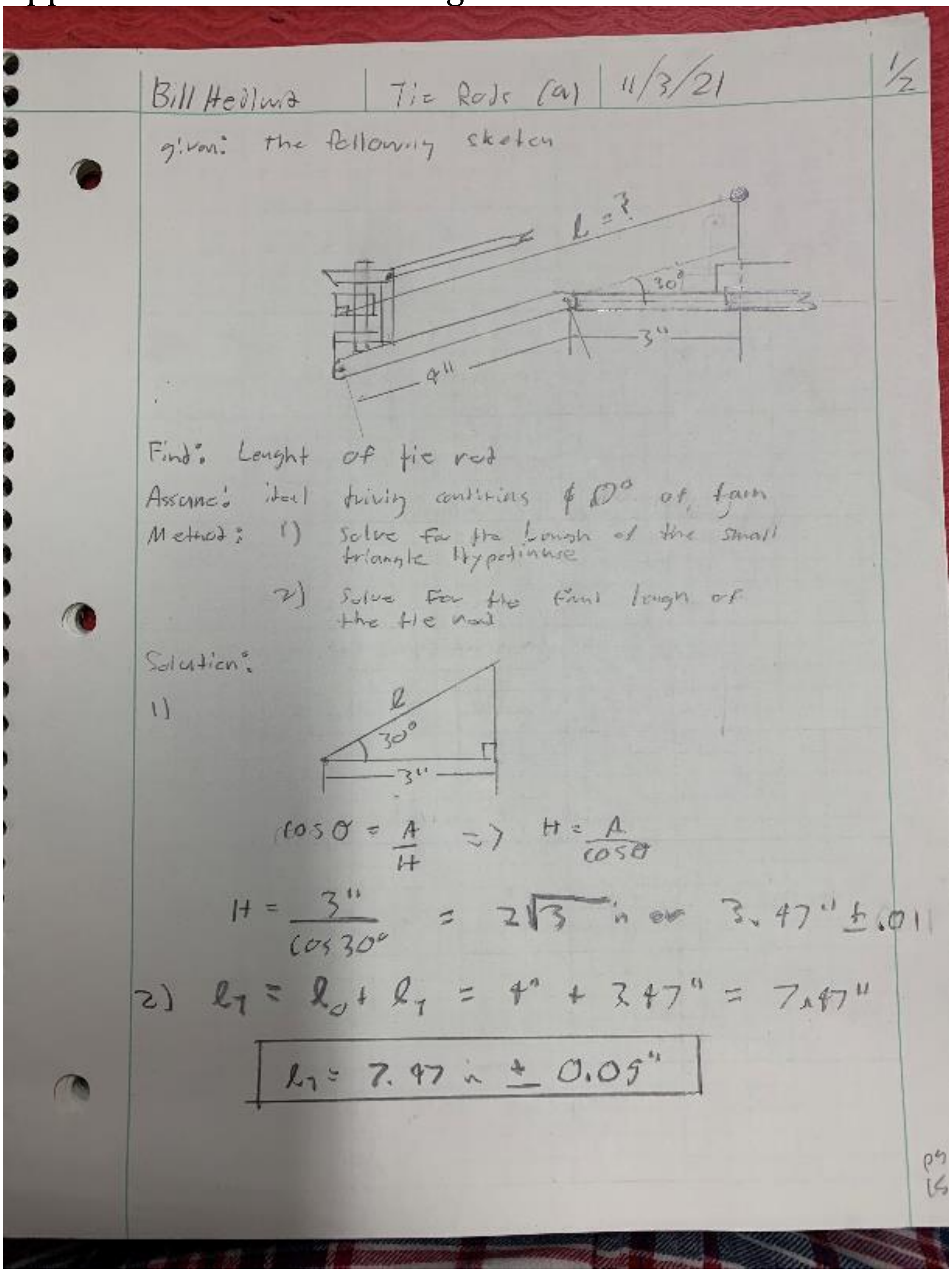


Figure 7 Driveshaft deflection cont'

Appendix A-7a – Tie rod length calculation



Bill Hedlund | Tie Rods (a) | 11/3/21 | 1/2

given: the following sketch

Find: Lenght of tie rod

Assume: ideal driving conditions & 0° of turn

Method: 1) Solve for the length of the small triangle Hypotinuse

2) Solve for the final length of the tie rod

Solution:

1)

$\cos\theta = \frac{A}{H} \Rightarrow H = \frac{A}{\cos\theta}$

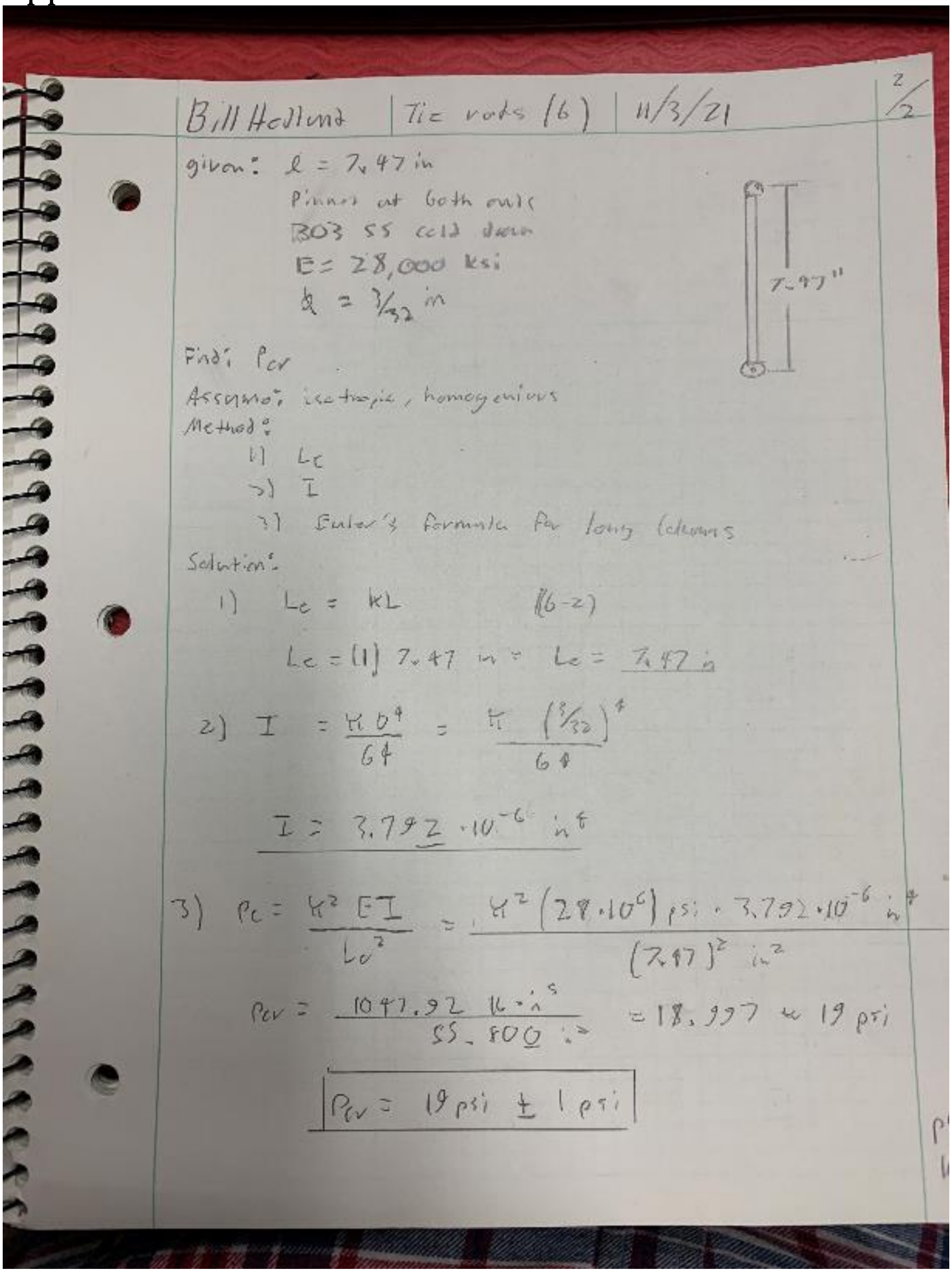
$H = \frac{3''}{\cos 30^\circ} = 2\sqrt{3}$ in or $3.47'' \pm .01$

2) $l_T = l_o + l_1 = 4'' + 3.47'' = 7.47''$

$l_T = 7.47$ in $\pm 0.05''$

Figure 8 Analysis 7a tie rod length

Appendix A-7b – Tie rod stress calculations



Bill Holland | Tie rods (6) | 11/3/21 2/2

given: $l = 7.47$ in
Pinned at both ends
303 SS cold drawn
$E = 28{,}000$ ksi
$d = 3/32$ in

7.47"

Find: P_{cr}

Assume: isotropic, homogenious

Method:
1) L_e
2) I
3) Euler's formula for long columns

Solution:

1) $L_e = kL$ (6-2)

$L_e = (1)\ 7.47$ in $\therefore L_e = 7.47$ in

2) $I = \frac{\pi D^4}{64} = \frac{\pi (3/32)^4}{64}$

$I = 3.792 \cdot 10^{-6}$ in^4

3) $P_c = \frac{\pi^2 E I}{L_e^2} = \frac{\pi^2 (28 \cdot 10^6)\ \text{psi} \cdot 3.792 \cdot 10^{-6}\ \text{in}^4}{(7.47)^2\ \text{in}^2}$

$P_{cr} = \frac{1047.92\ \text{lb} \cdot \text{in}^5}{55.800\ \text{in}^2} = 18.997 \approx 19$ psi

$P_{cr} = 19$ psi ± 1 psi

Figure 9 Tie Rod strength analysis

Appendix A-8a – Upper Control arm Length

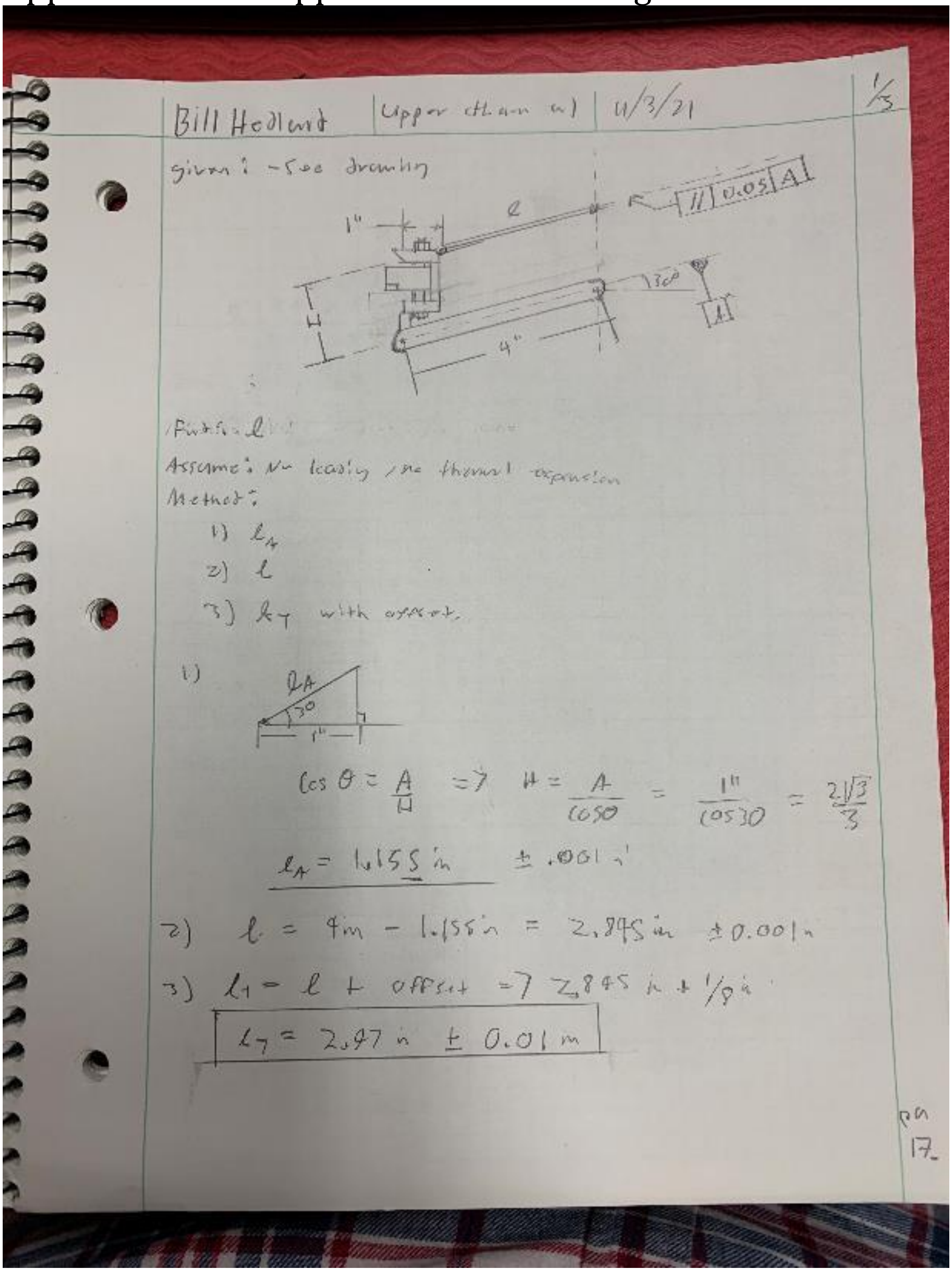
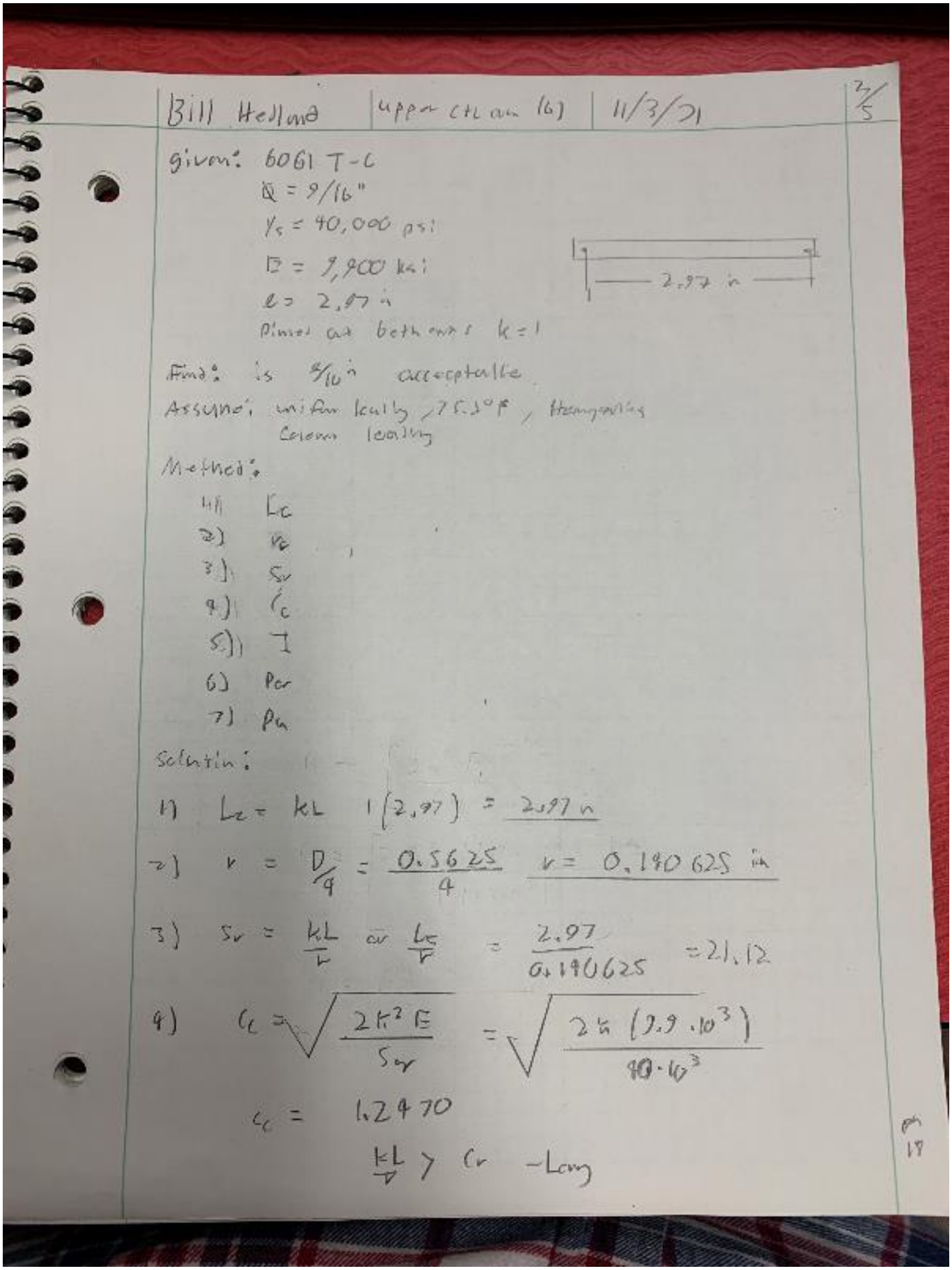


Figure 10 Analysis 8 Upper control arm length

Appendix A-8b – Upper Control arm strength analysis


Bill Hellmo | upper ctl arm (6) | 11/3/21 | 3/5

given: 6061 T-6
$D = 9/16"$
$Y_s = 40{,}000$ psi
$E = 9{,}900$ ksi
$l = 2.97$ in
Pinned at both ends $k = 1$

2.97 in

Find: is 9/16 in acceptable

Assume: uniform loading, 75.3°F, homogeneous column loading

Method:
1) L_e
2) r
3) S_r
4) C_c
5) I
6) P_{cr}
7) P_a

Solution:

1) $L_e = kL \quad 1(2.97) = 2.97$ in

2) $r = \frac{D}{4} = \frac{0.5625}{4} \quad r = 0.140625$ in

3) $S_r = \frac{kL}{r}$ or $\frac{L_e}{r} = \frac{2.97}{0.140625} = 21.12$

4) $C_c = \sqrt{\frac{2\pi^2 E}{S_y}} = \sqrt{\frac{2\pi^2 (9.9 \cdot 10^3)}{40 \cdot 10^3}}$

$C_c = 1.2470$

$\frac{kL}{r} > C_c$ – Long

pg 17

Figure 11 Analysis 8b part 1 upper control arm strength calculations

Appendix A-8b – Upper Control arm strength analysis cont'

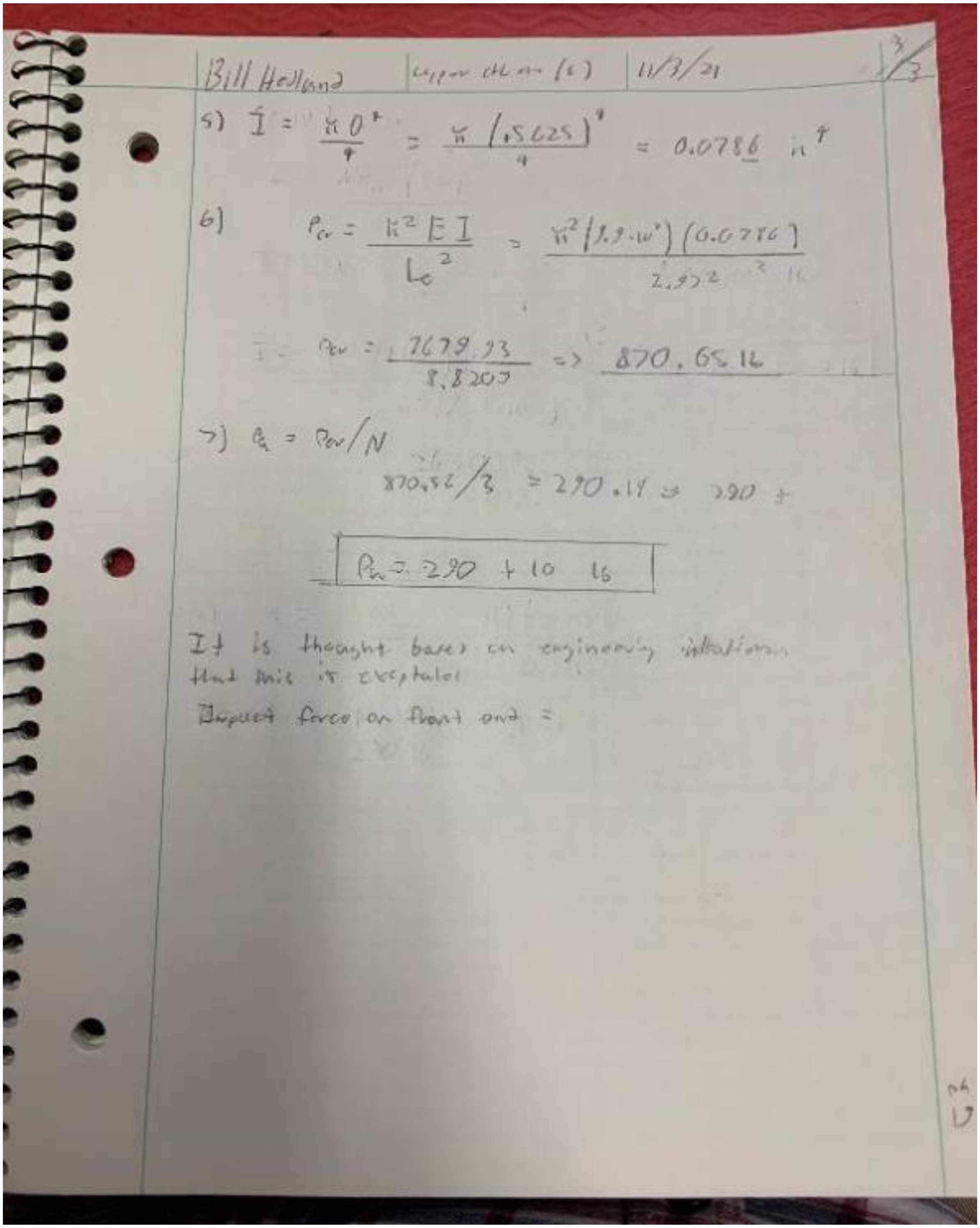
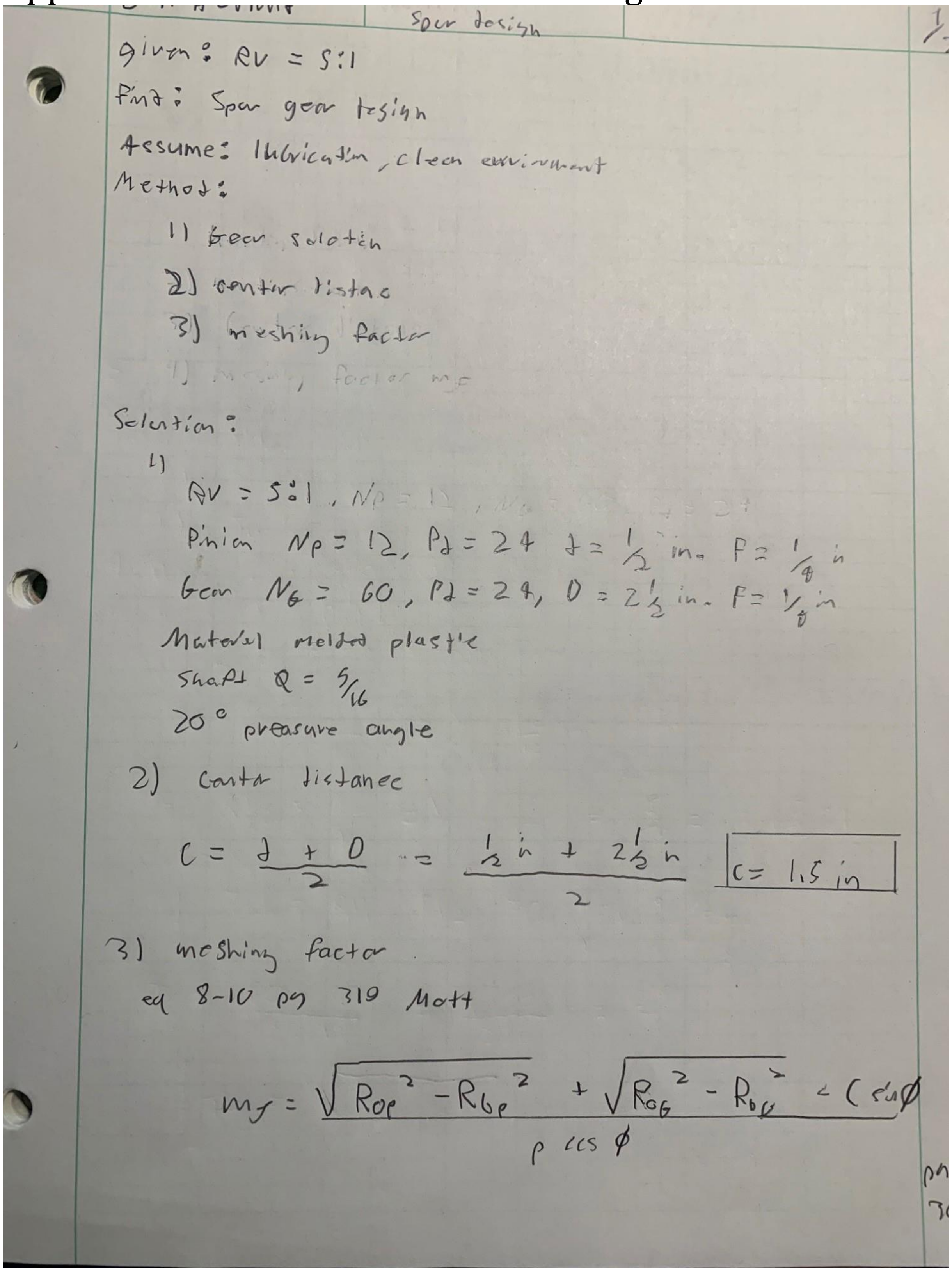


Figure 12 Analysis 8b part 2 strength calculations

Appendix A-9 – Gear selection and design for transmission



Spur design

given: RV = 5:1

Find: Spur gear design

Assume: lubrication, clean environment

Method:

1) Gear selection
2) center distance
3) meshing factor

Selection:

1)

RV = 5:1

Pinion $N_P = 12$, $P_d = 24$, $d = \frac{1}{2}$ in, $F = \frac{1}{8}$ in

Gear $N_G = 60$, $P_d = 24$, $D = 2\frac{1}{2}$ in, $F = \frac{1}{8}$ in

Material molded plastic

Shaft $\varnothing = \frac{5}{16}$

20° pressure angle

2) Center distance

$$C = \frac{d + D}{2} = \frac{\frac{1}{2}\text{ in} + 2\frac{1}{2}\text{ in}}{2} \qquad \boxed{C = 1.5 \text{ in}}$$

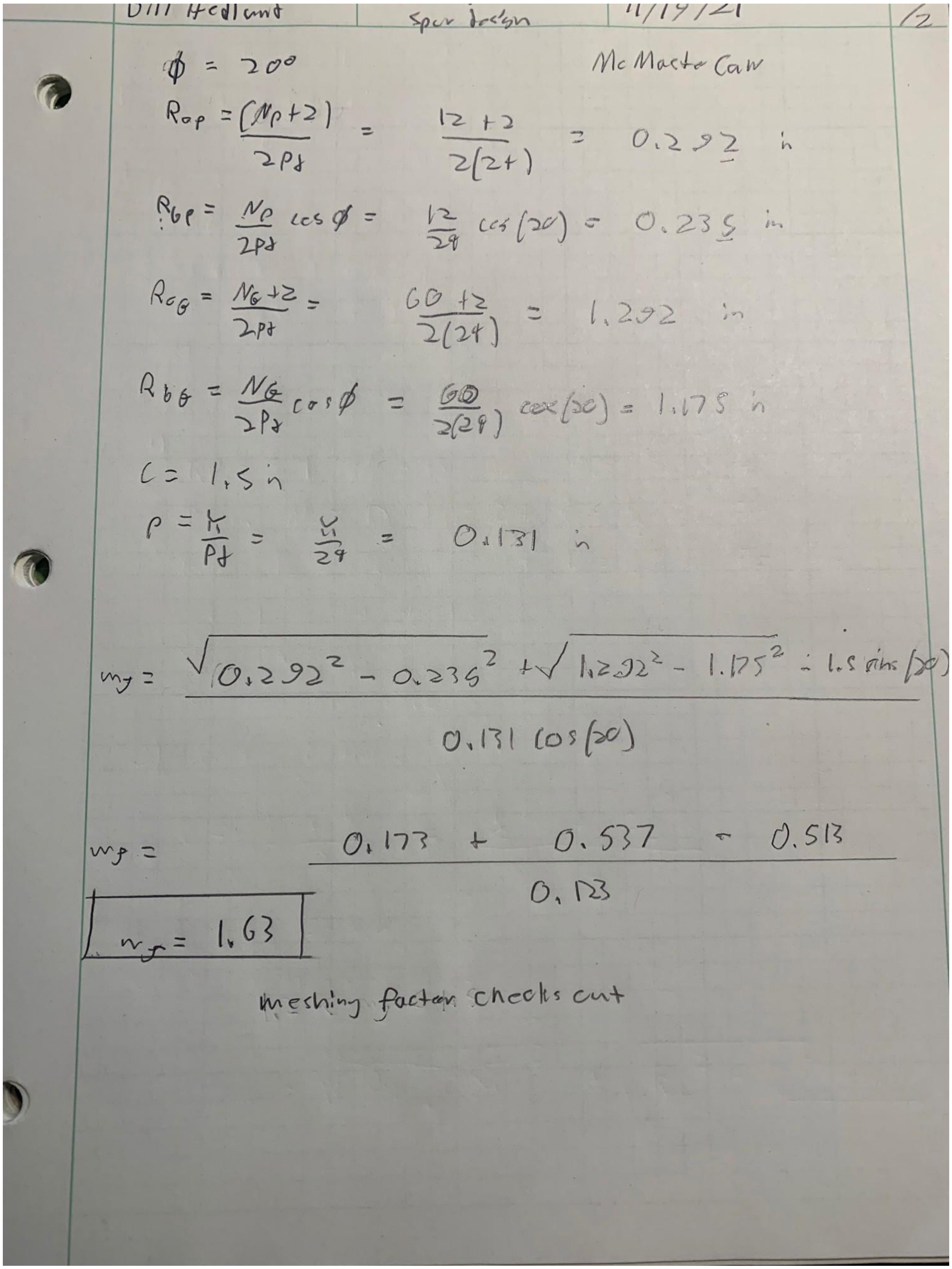
3) meshing factor

eq 8-10 pg 319 Mott

$$m_f = \frac{\sqrt{R_{oP}^2 - R_{bP}^2} + \sqrt{R_{oG}^2 - R_{bG}^2} - C\sin\phi}{p\cos\phi}$$

Figure 13 transmission gear design

Appendix A-9 – Gear selection and design for transmission cont'


Dill Hedlund | Spur design | 11/19/21 | 2

$\phi = 20°$ McMaster Carr

$R_{op} = \frac{(N_p + 2)}{2P_d} = \frac{12+2}{2(24)} = 0.292$ in

$R_{bp} = \frac{N_p}{2P_d}\cos\phi = \frac{12}{24}\cos(20) = 0.235$ in

$R_{oG} = \frac{N_G + 2}{2P_d} = \frac{60+2}{2(24)} = 1.292$ in

$R_{bG} = \frac{N_G}{2P_d}\cos\phi = \frac{60}{2(24)}\cos(20) = 1.175$ in

$C = 1.5$ in

$p = \frac{\pi}{P_d} = \frac{\pi}{24} = 0.131$ in

$$m_f = \frac{\sqrt{0.292^2 - 0.235^2} + \sqrt{1.292^2 - 1.175^2} - 1.5\sin(20)}{0.131\cos(20)}$$

$$m_f = \frac{0.173 + 0.537 - 0.513}{0.123}$$

$m_f = 1.63$

meshing factor checks out

Figure 14 Transmission gear design cont'

Appendix A-10 – King pin dimensions

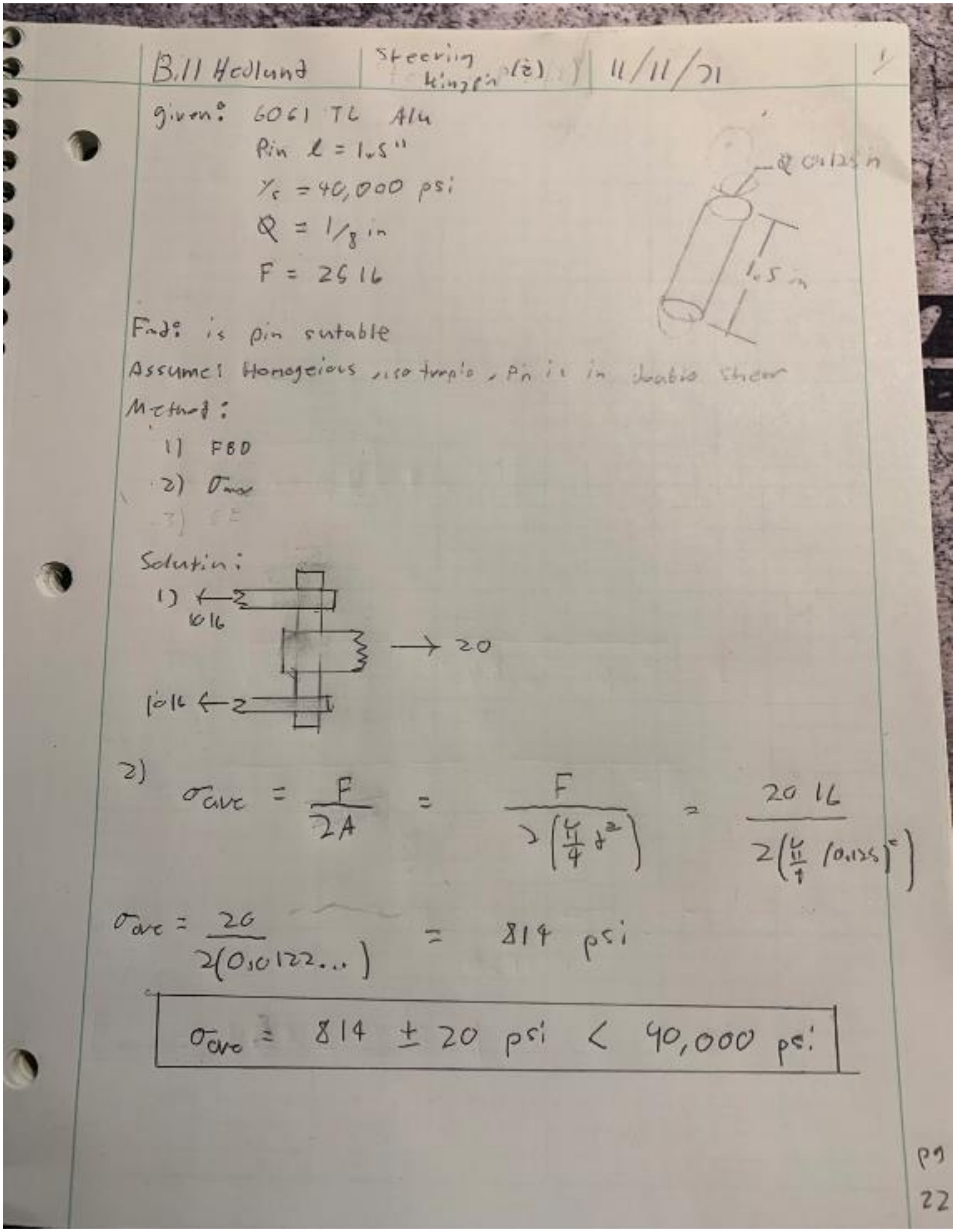


Figure 15 diameter and length conformation for king pin

Appendix A-11 – Cotter pin selection, king pin

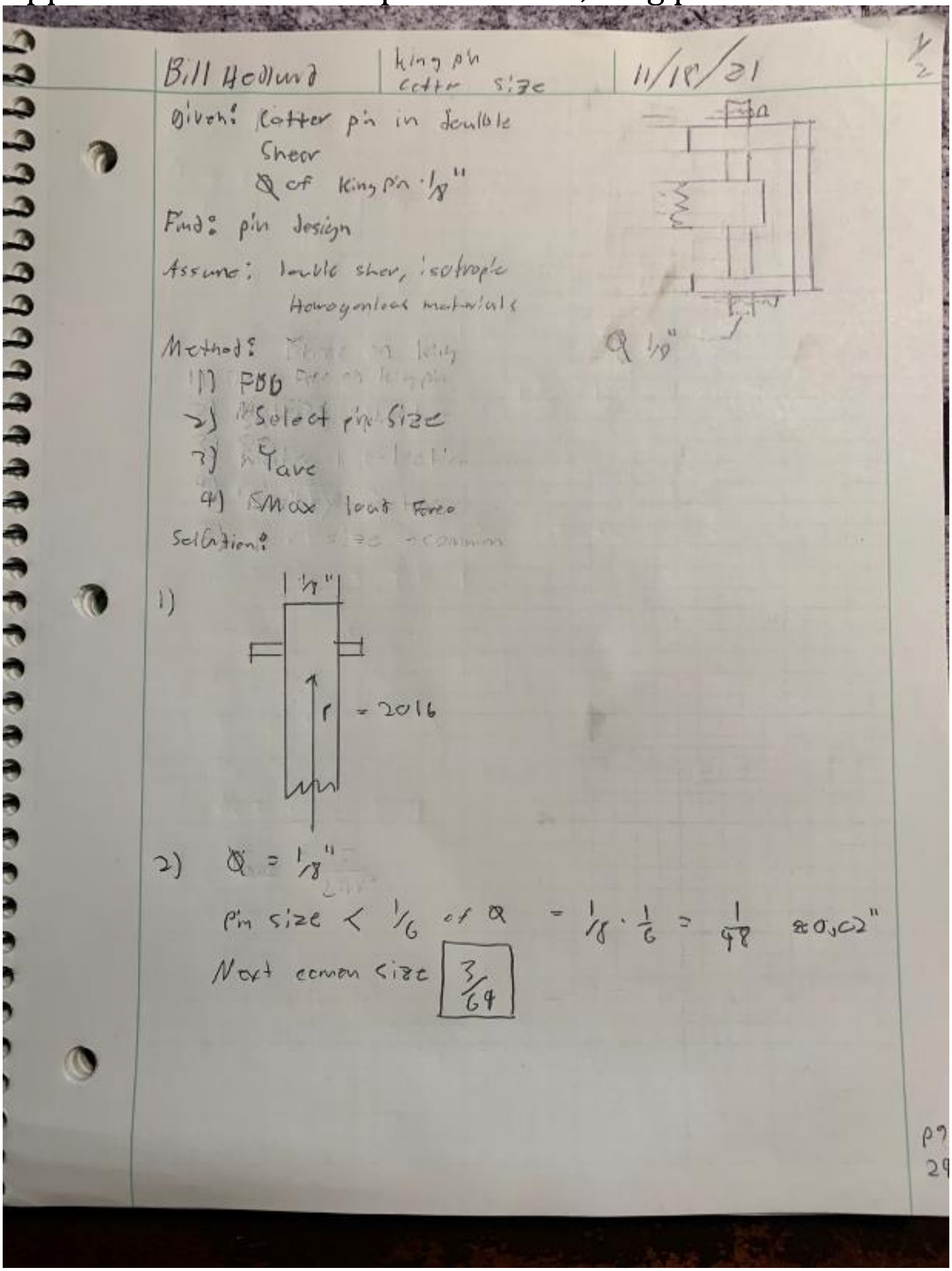
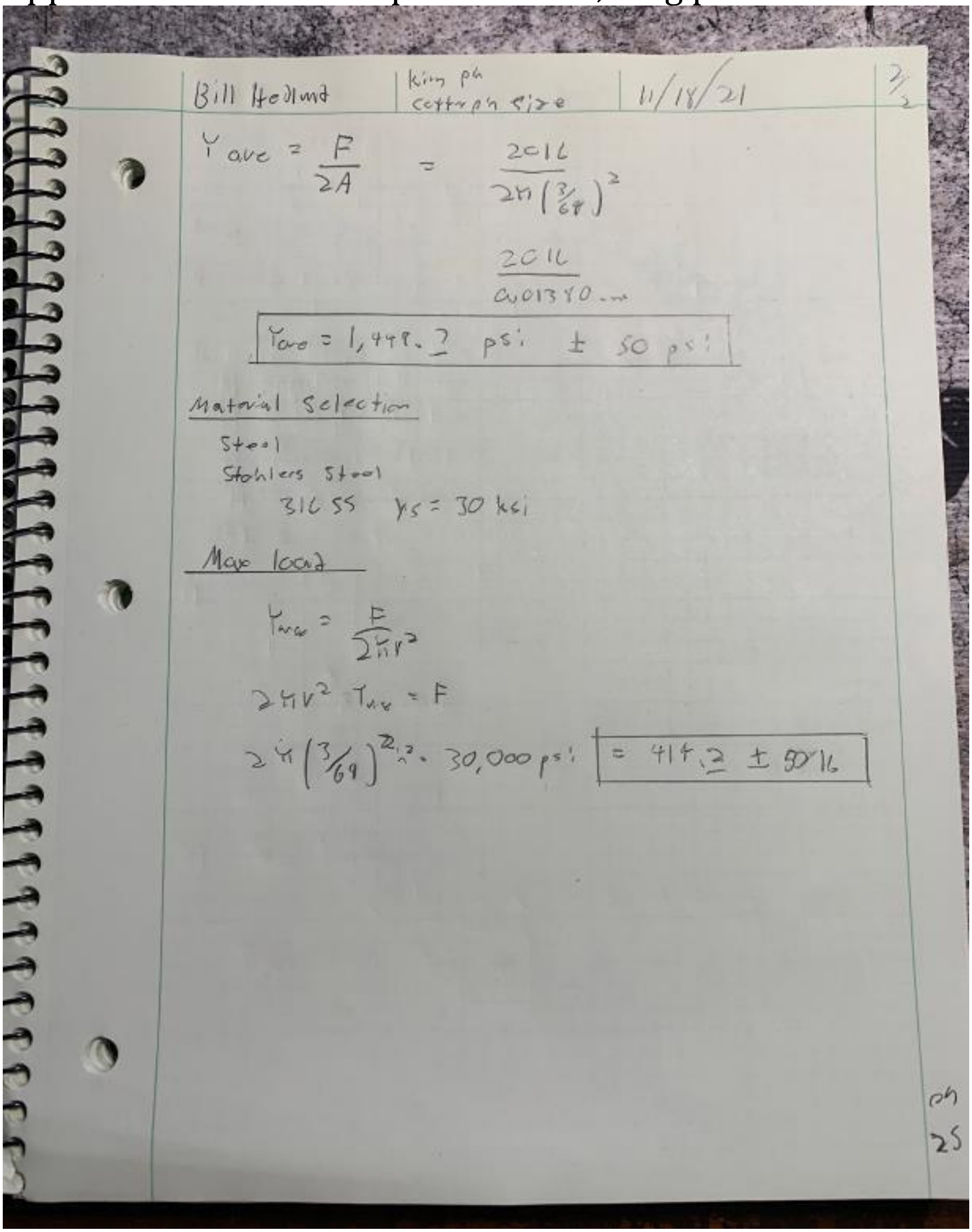


Figure 16 Cotter Pin selection

Appendix A-11 – Cotter pin selection, king pin Cont’


Bill Hedlund | King pin cotter pin size | 11/18/21 | 2/2

$\tau_{ave} = \frac{F}{2A} = \frac{2016}{2\pi(3/64)^2}$

$= \frac{2016}{0.01380...}$

$\tau_{ave} = 1,448.2$ psi $\pm$ 50 psi

Material Selection

Steel
Stahlers Steel
316 SS $\tau_s = 30$ ksi

Max load

$\tau_{ave} = \frac{F}{2\pi r^2}$

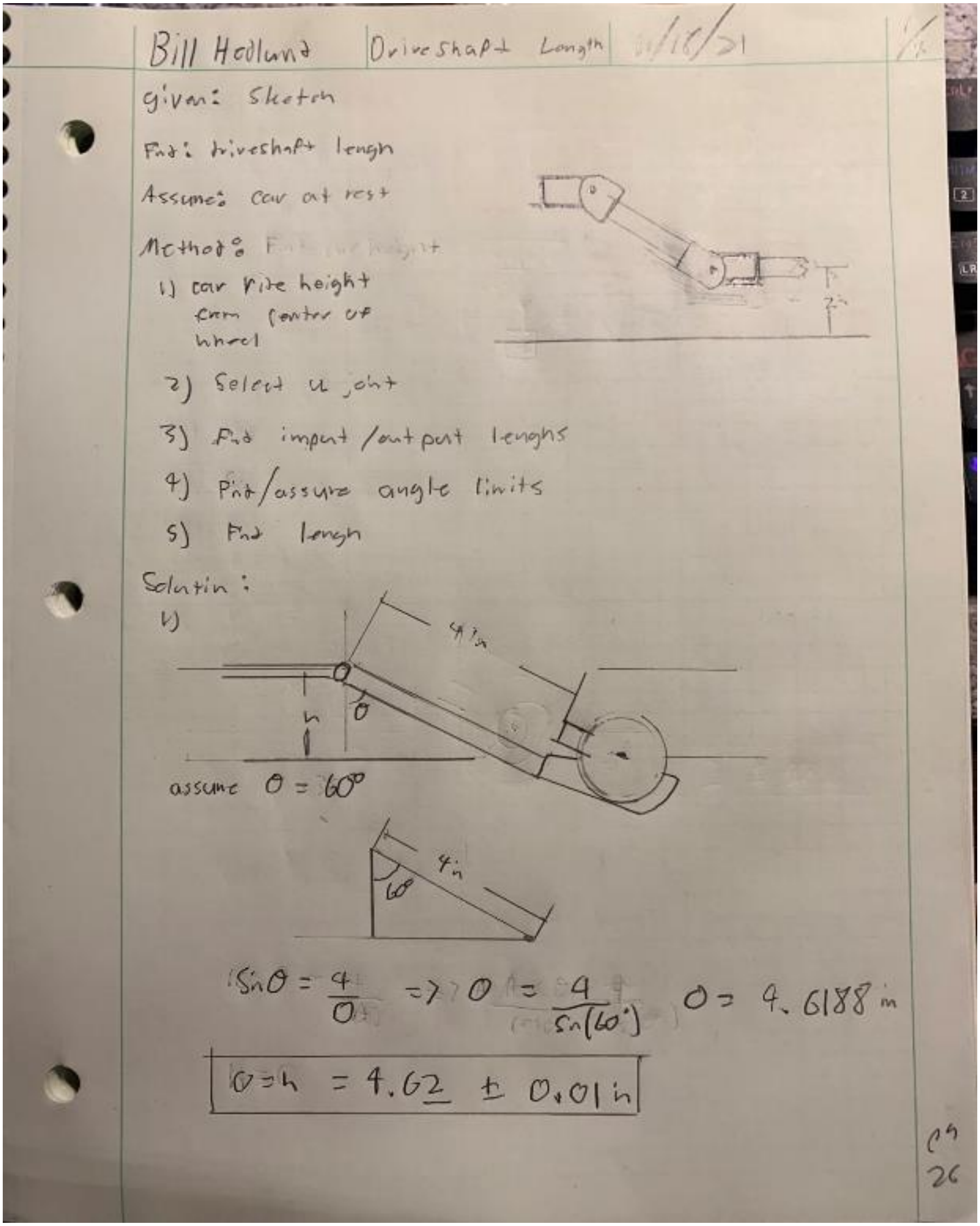
$2\pi r^2 \tau_{ave} = F$

$2\pi(3/64)^2 \cdot 30,000$ psi $= 414.2 \pm 50\%$

pn 25

Figure 17 Cotter pin selection

Appendix A-12 – Driveshaft design



Bill Hedlund | Driveshaft Length | 11/18/21

given: Sketch

Find: driveshaft length

Assume: car at rest

Method:

1) car ride height from center of wheel
2) Select u joint
3) Find input/output lengths
4) Find/assure angle limits
5) Find length

Solution:

1)

assume $\theta = 60°$

$\sin\theta = \frac{4}{O} \Rightarrow O = \frac{4}{\sin(60°)}$ $O = 4.6188$ in

$O = h = 4.62 \pm 0.01$ in

Figure 18 driveshaft design

Appendix A-12 – Driveshaft design Cont’

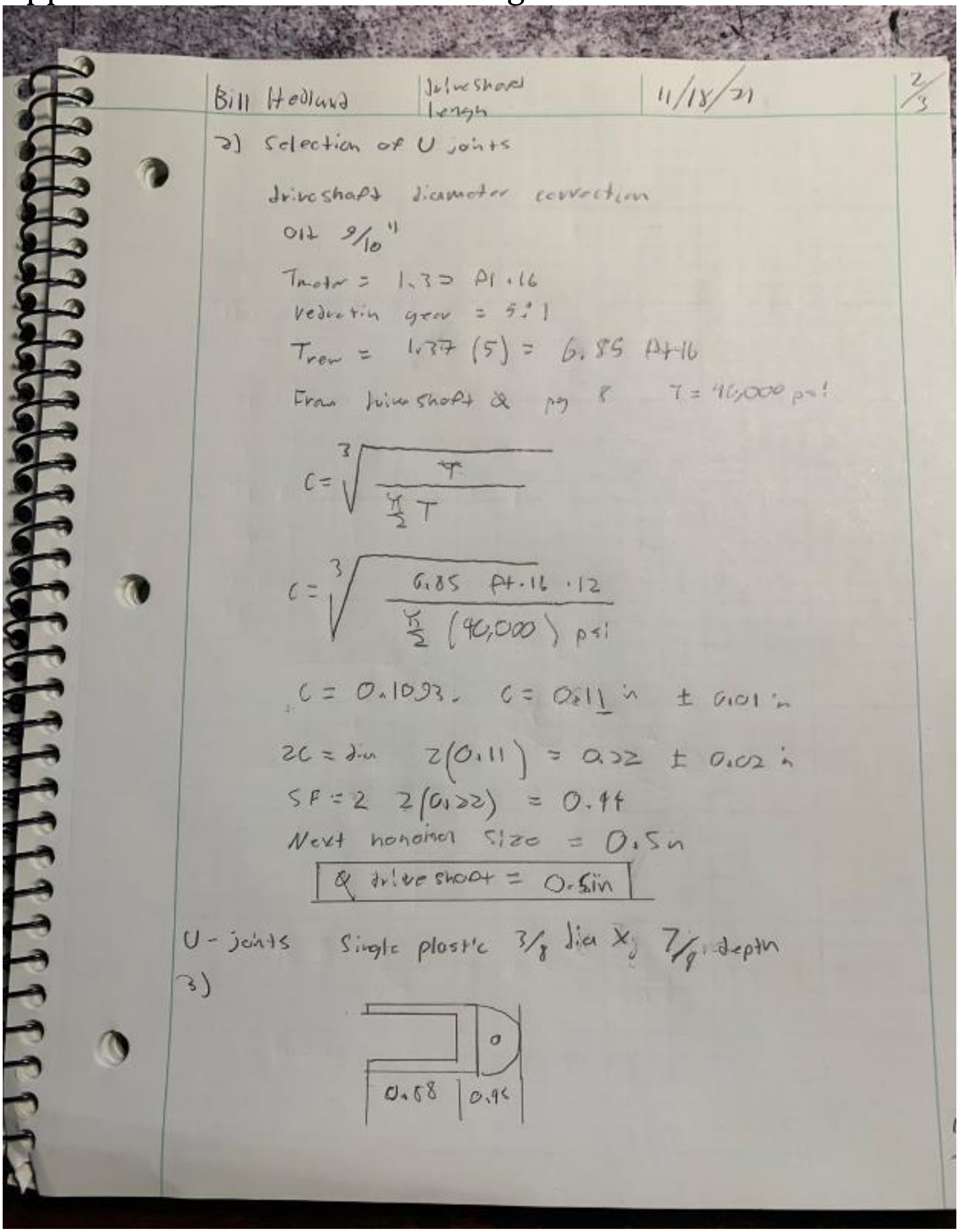


Figure 19 Driveshaft design cont'

Appendix A-12 – Driveshaft design Cont’

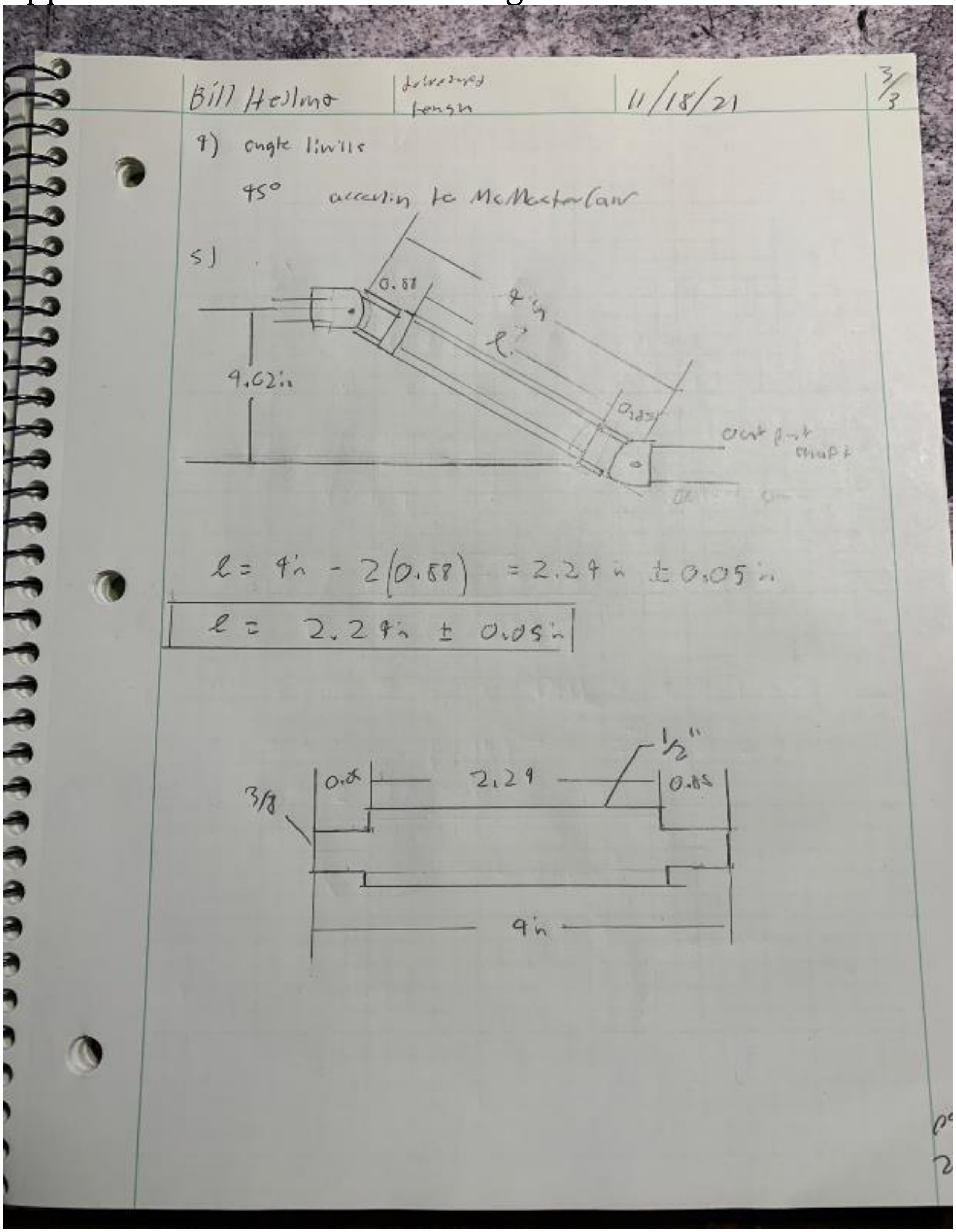
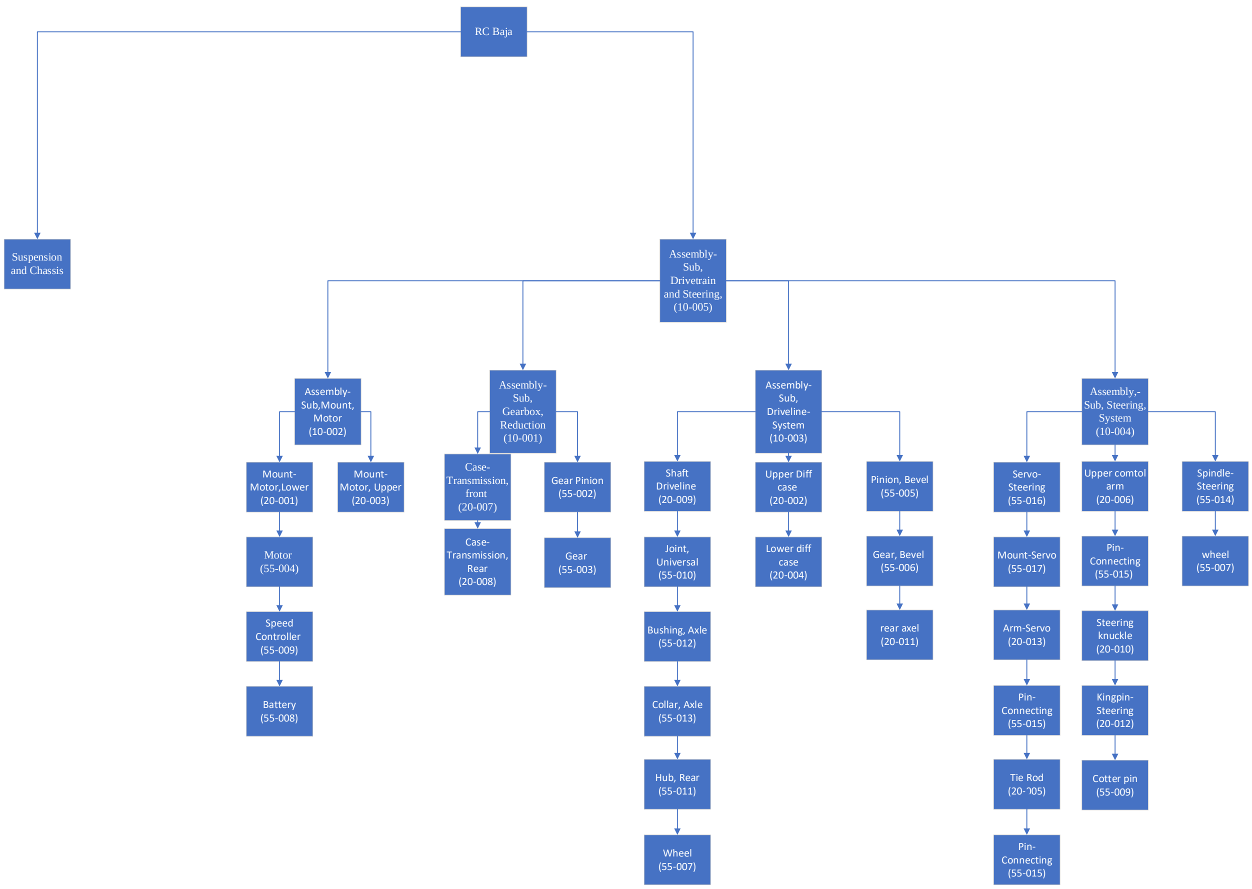


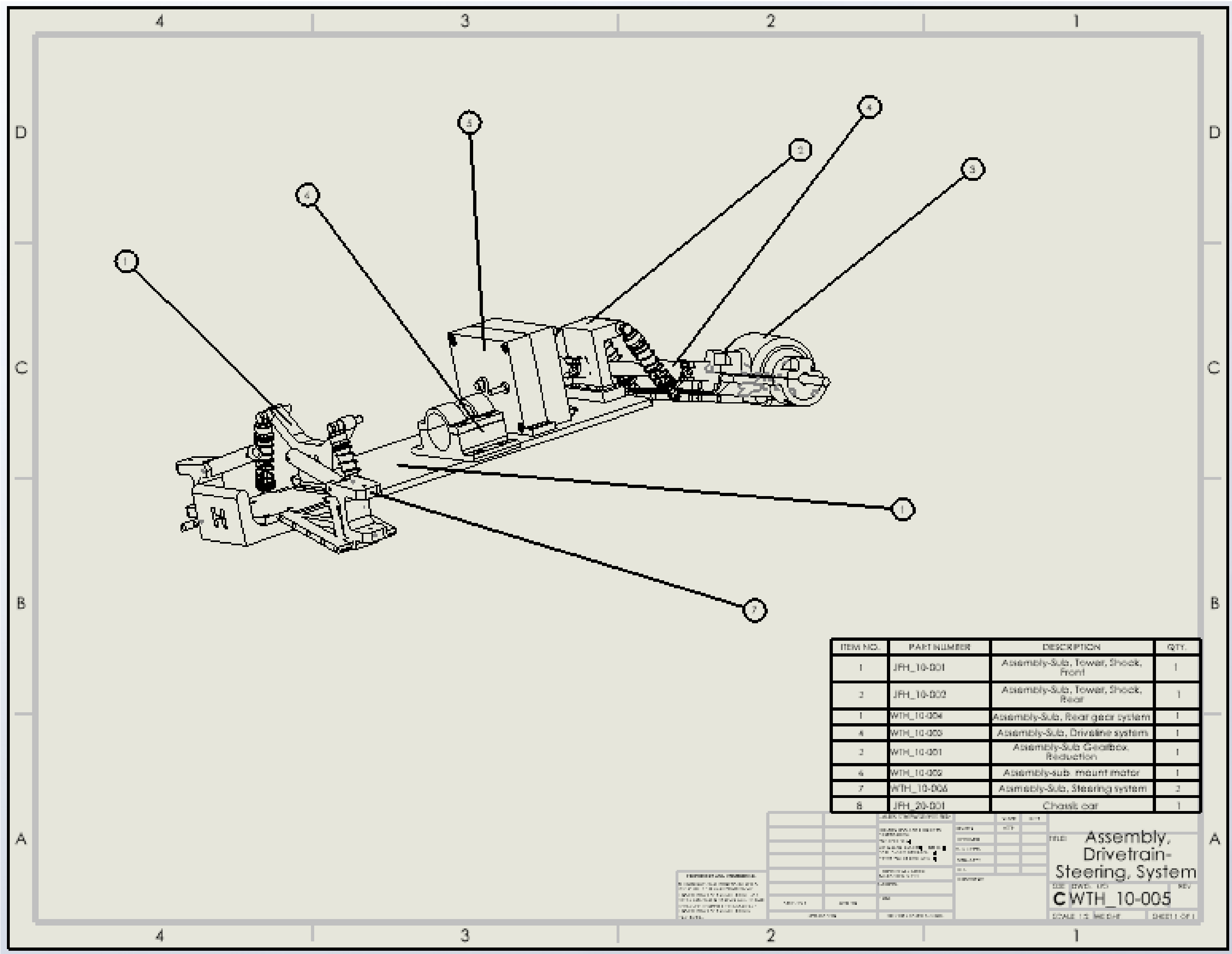
Figure 20 Driveshaft design cont'

APPENDIX B - Drawings

Appendix B – Drawing Tree



Appendix B – WTH_10-005 Drivetrain system



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	JFH_10-001	Assembly-Sub, Tower, Shock, Front	1
2	JFH_10-002	Assembly-Sub, Tower, Shock, Rear	1
3	WTH_10-004	Assembly-Sub, Rear gear sytem	1
4	WTH_10-003	Assembly-Sub, Driveline system	1
5	WTH_10-001	Assembly-Sub Gearbox, Reduction	1
6	WTH_10-002	Assembly-sub mount motor	1
7	WTH_10-006	Assembly-Sub, Steering system	2
8	JFH_20-001	Chassis car	1

Figure 21 Drivetrain and steering systems complete assembly

Appendix B – WTH_55-001 Assembly-Sub, Gearbox, reduction

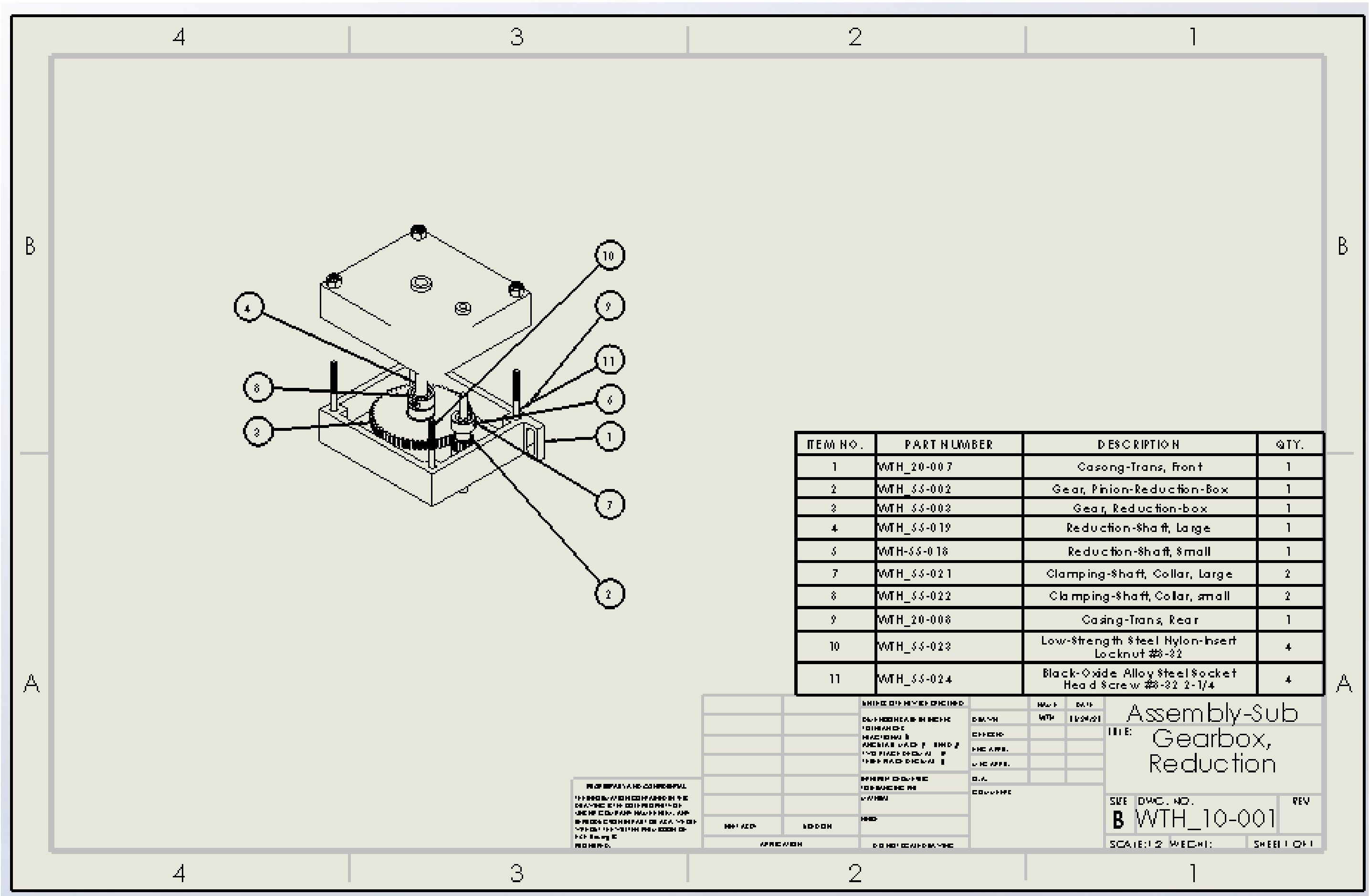


Figure 22 Reduction gearbox assembly

Appendix B – WTH_20-001 Mount-Motor, Lower

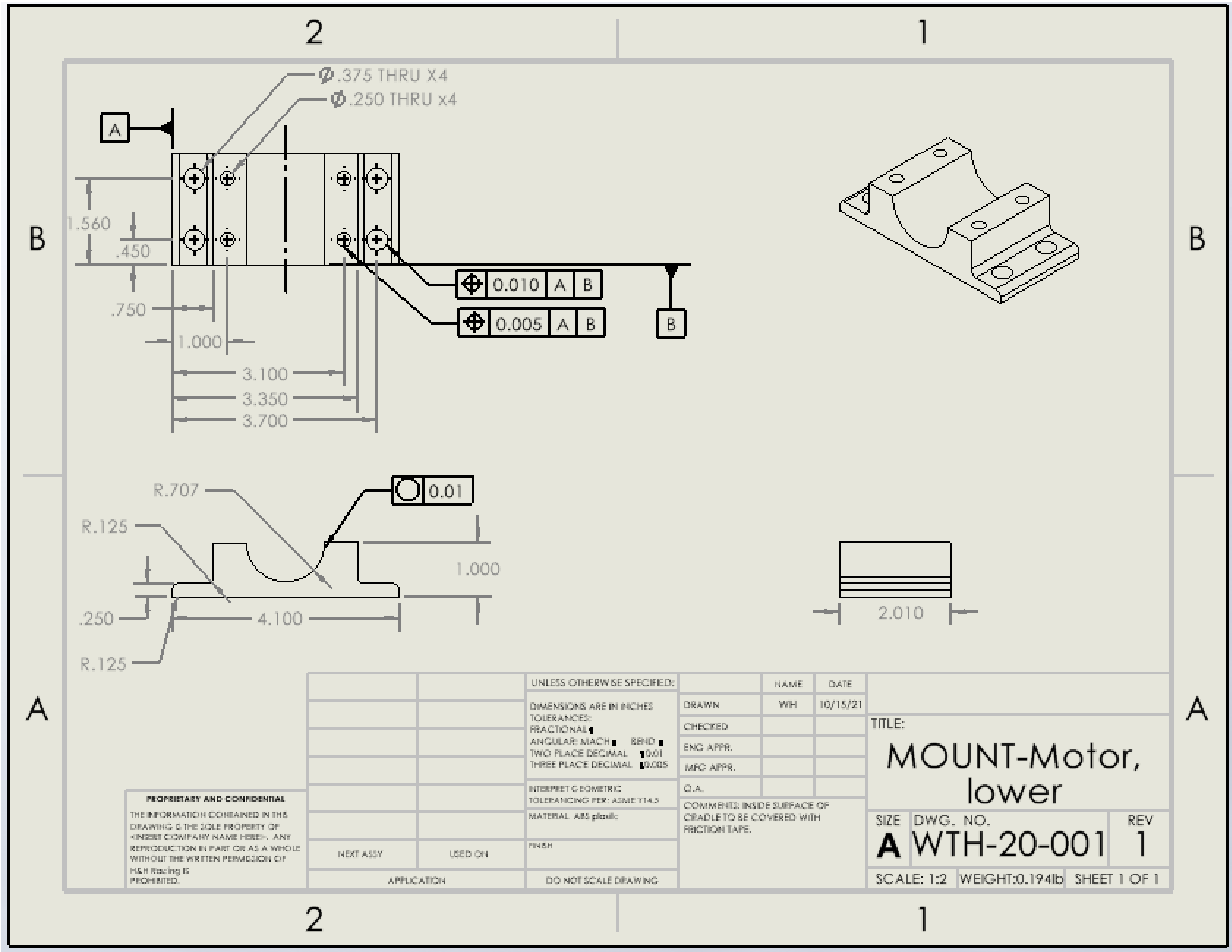


Figure 23 Lower motor mount drawing WTH20-001

Appendix B – WTH_20-002 Housing-Lower, Rear

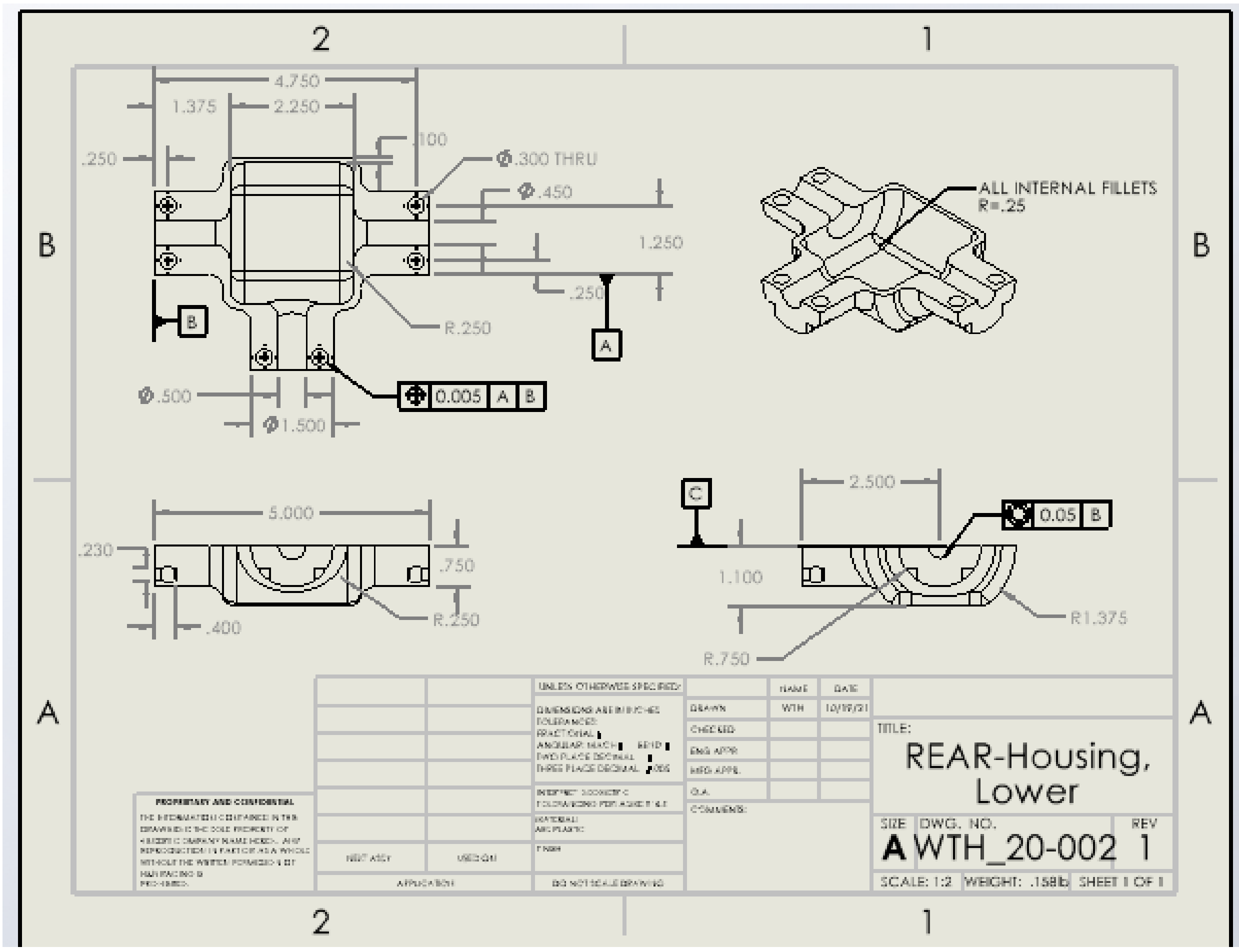


Figure 24 Lower rear gear housing

Appendix B – WTH_20-003 Mount-Motor, Upper

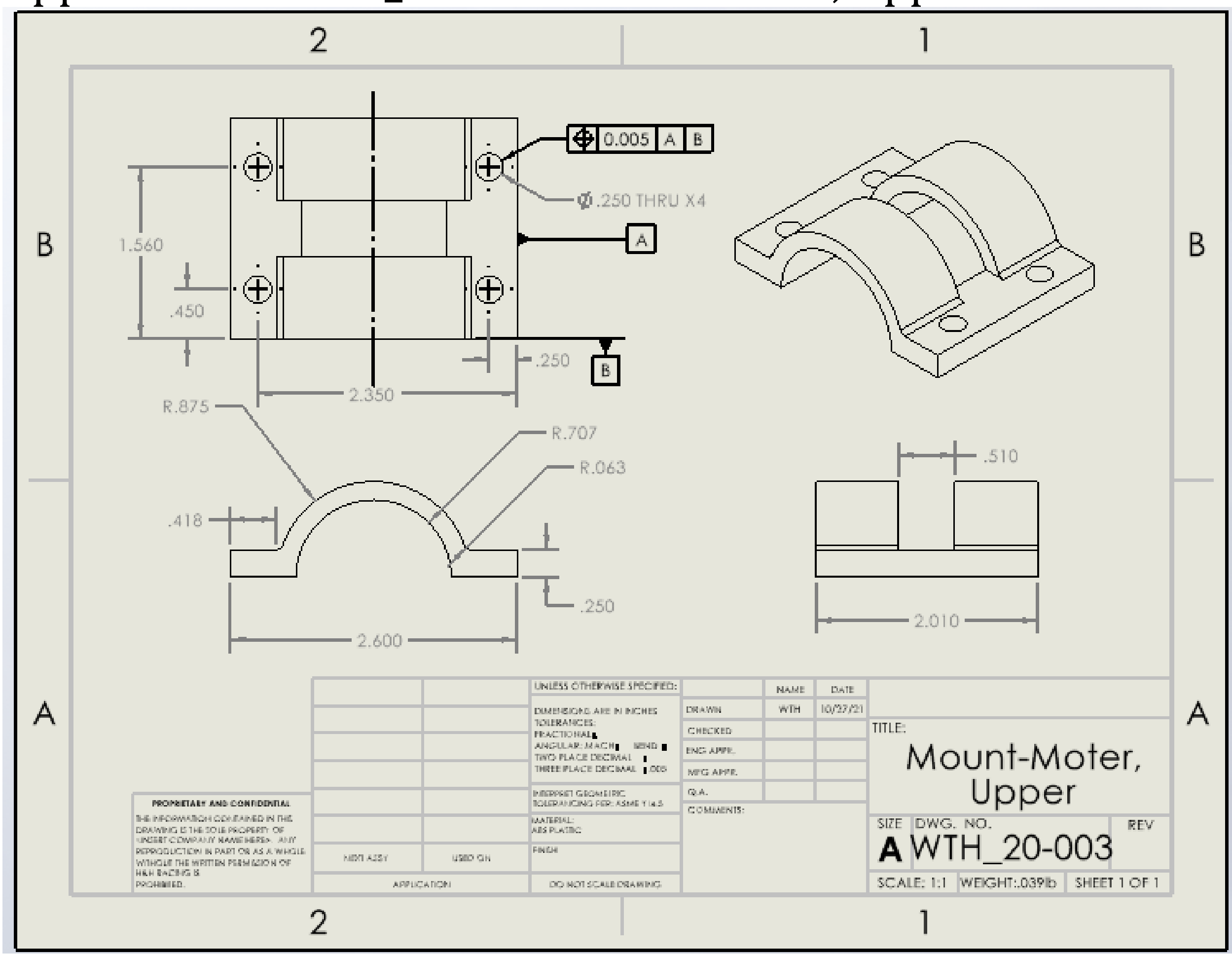


Figure 25 Upper motor mount half

Appendix B – WTH_20-004 Housing-Upper, Rear

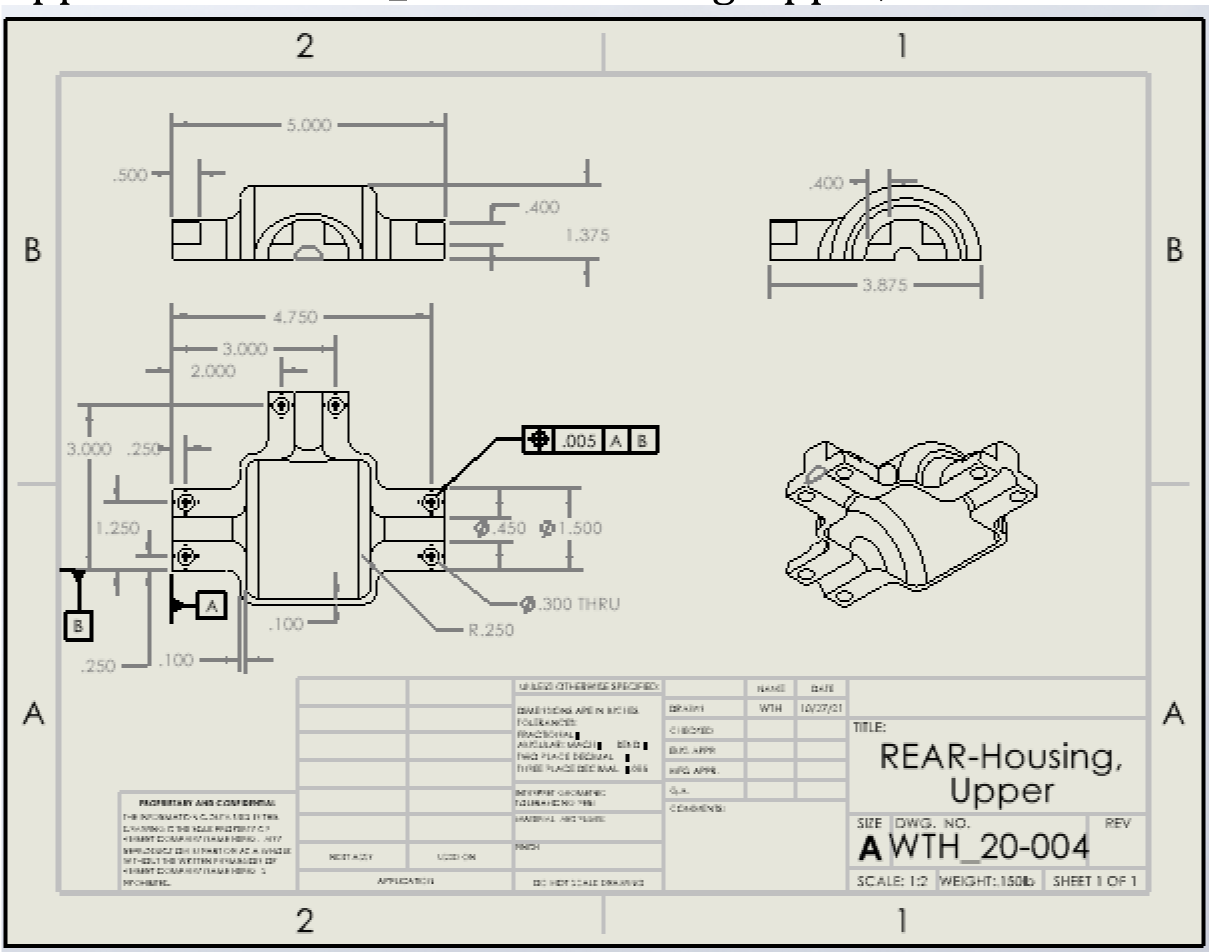


Figure 26 upper rear gear case

Appendix B – WTH_20-005 Tie Rod, Front

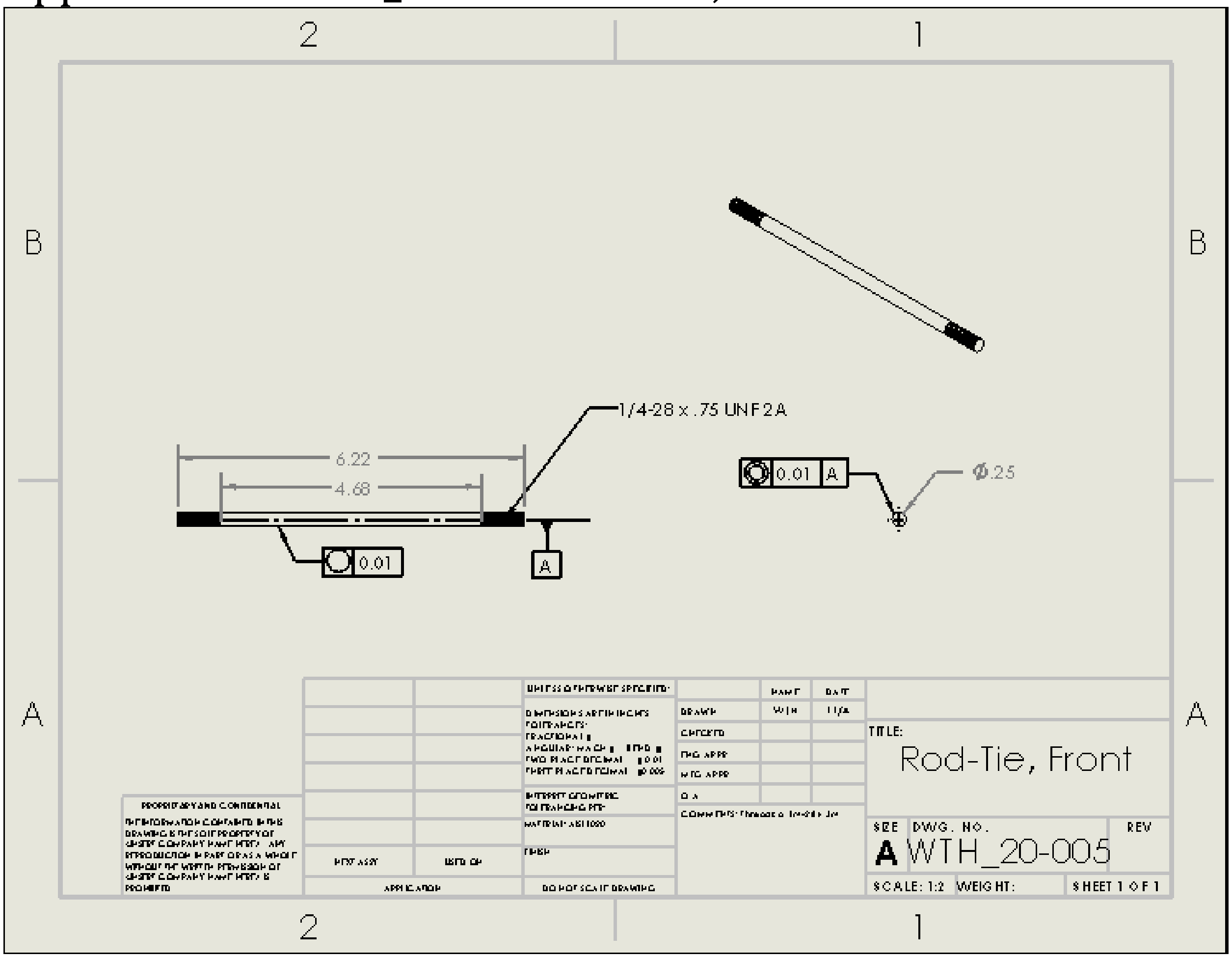


Figure 27 WTH_20-005 Front tie rods

Appendix B – WTH_20-006 Arm-Control, Upper

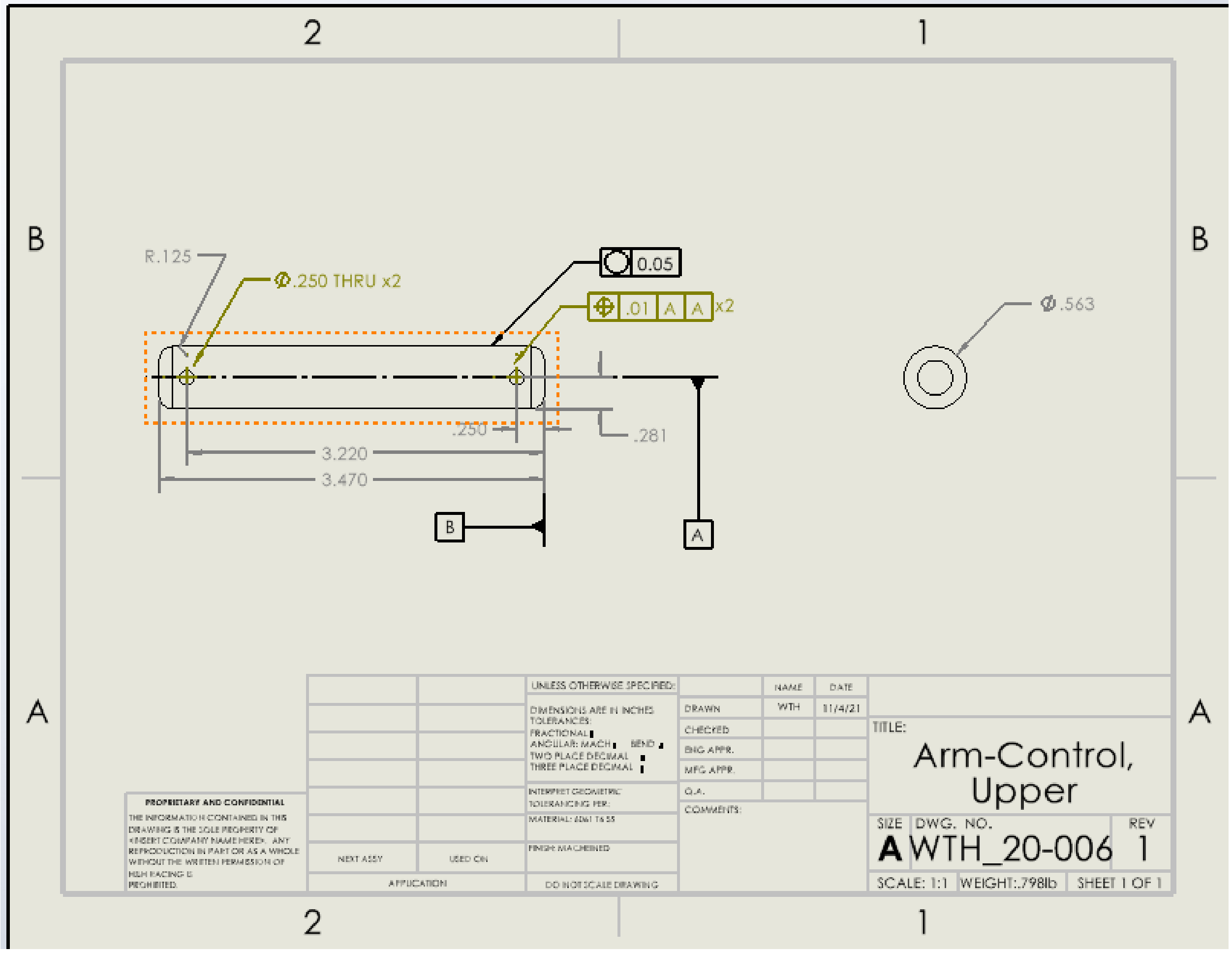


Figure 28 WTH_20-006 Upper control arm

Appendix B – WTH_20-007 Casing-Transmission, Front

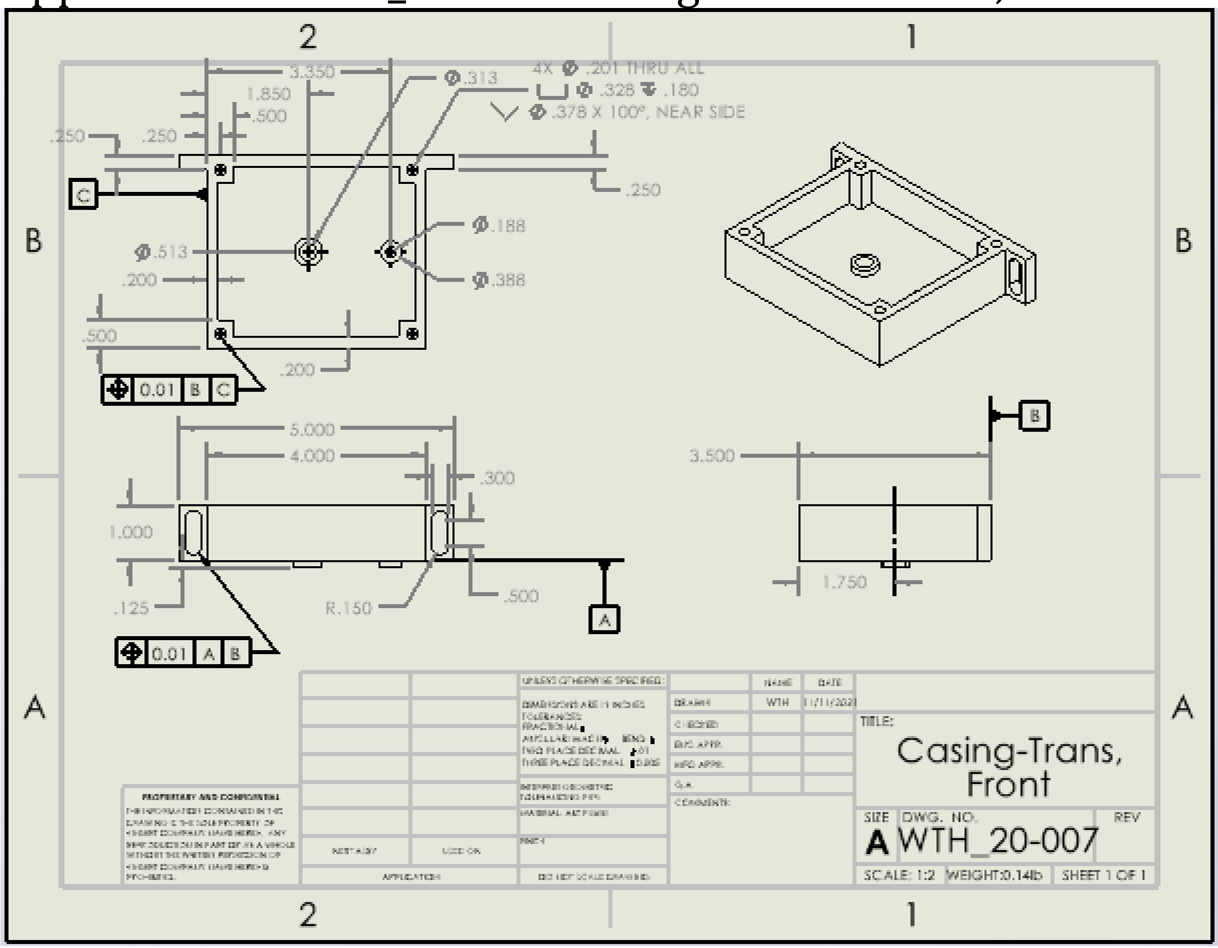


Figure 29 WTH_20-007 Front Transmission Casing

Appendix B – WTH_20-008 Casing-Transmission, Rear

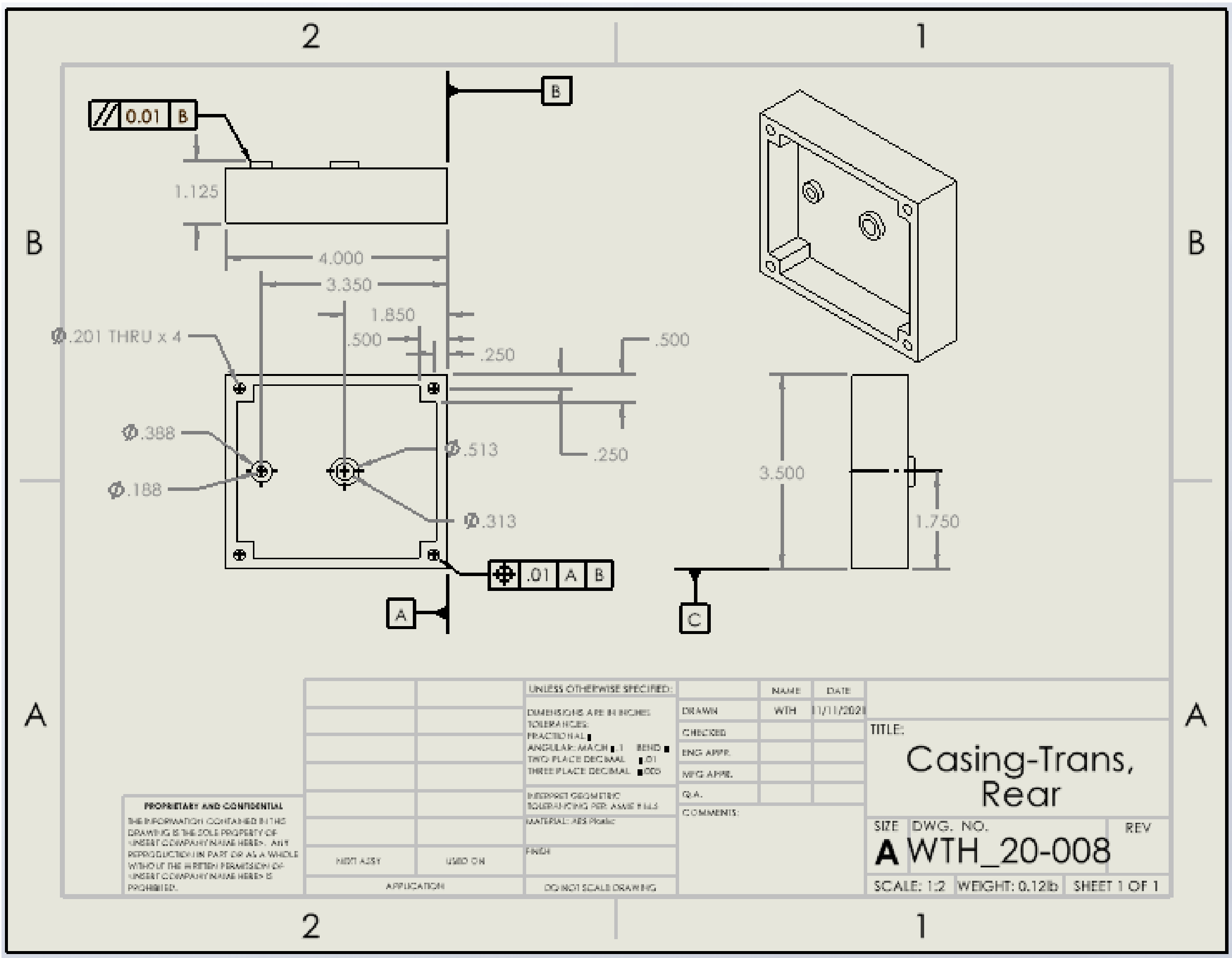


Figure 30 WTH_20-008 Rear Transmission Casing

Appendix B – WTH_20-009 Shaft, Driveline

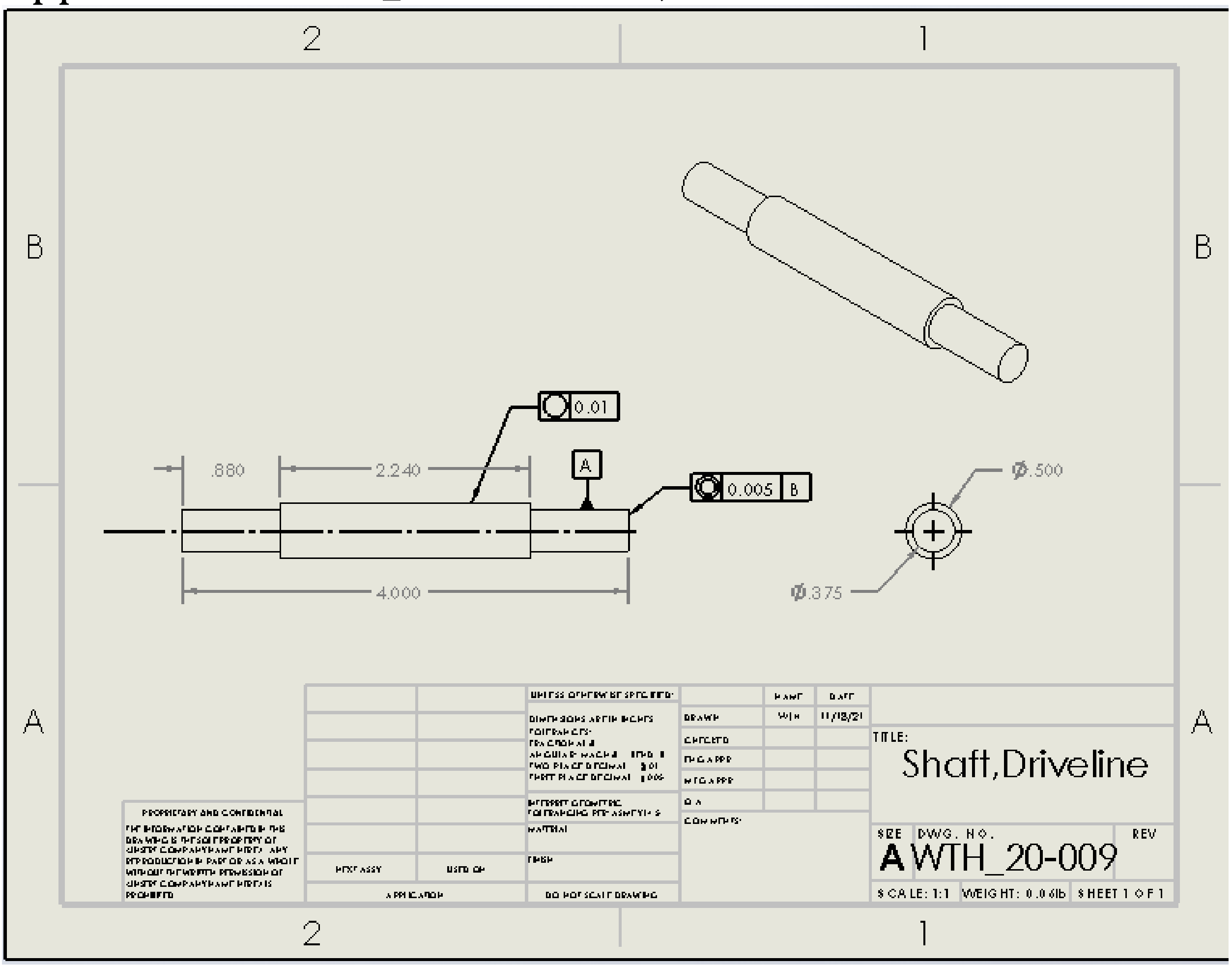


Figure 31 Driveshaft

Appendix B – WTH_20-010 Knuckle-Steering, Front

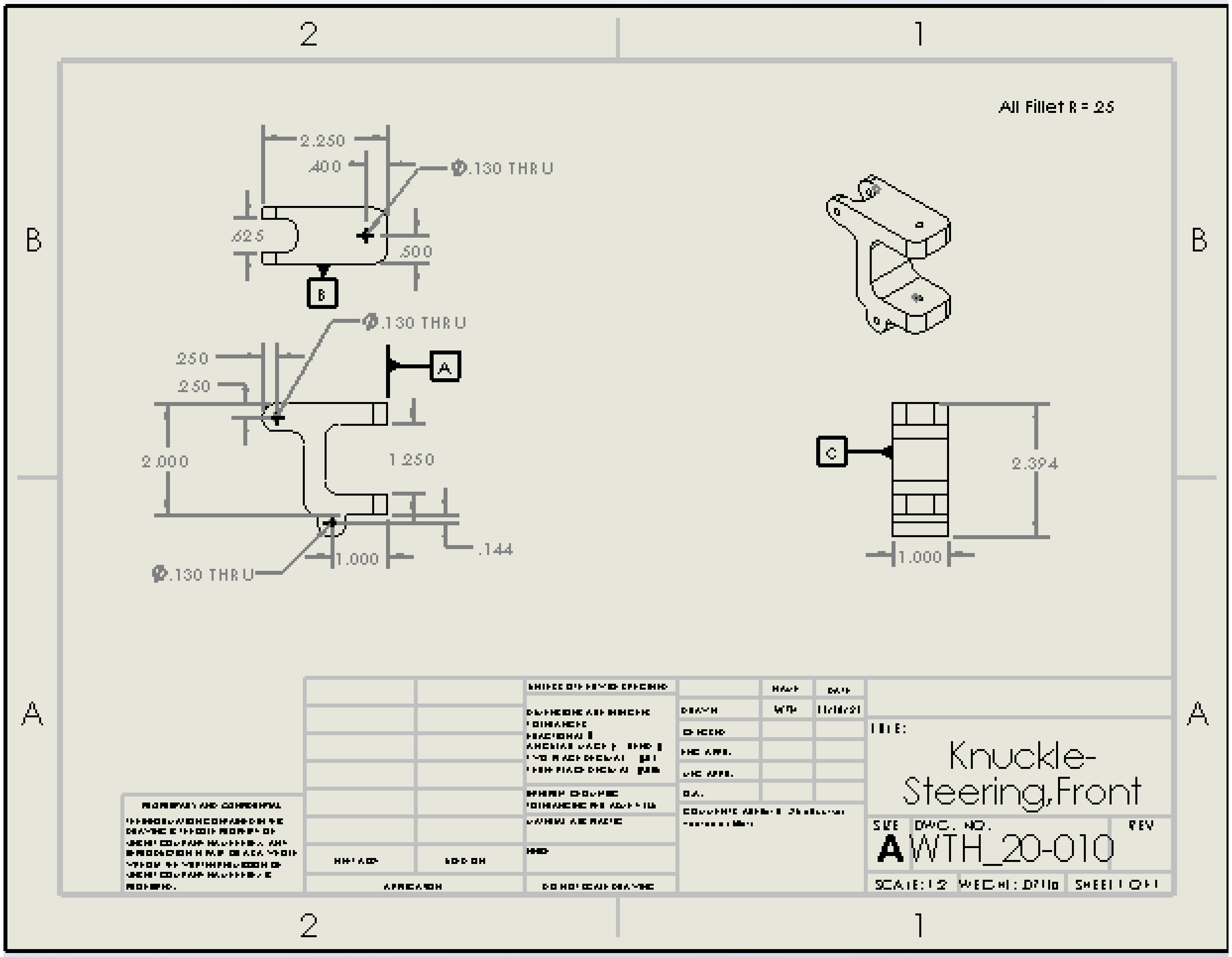


Figure 32 Front Steering Knuckle

Appendix B – WTH_55-002 Gear, Pinion-Reduction-Box

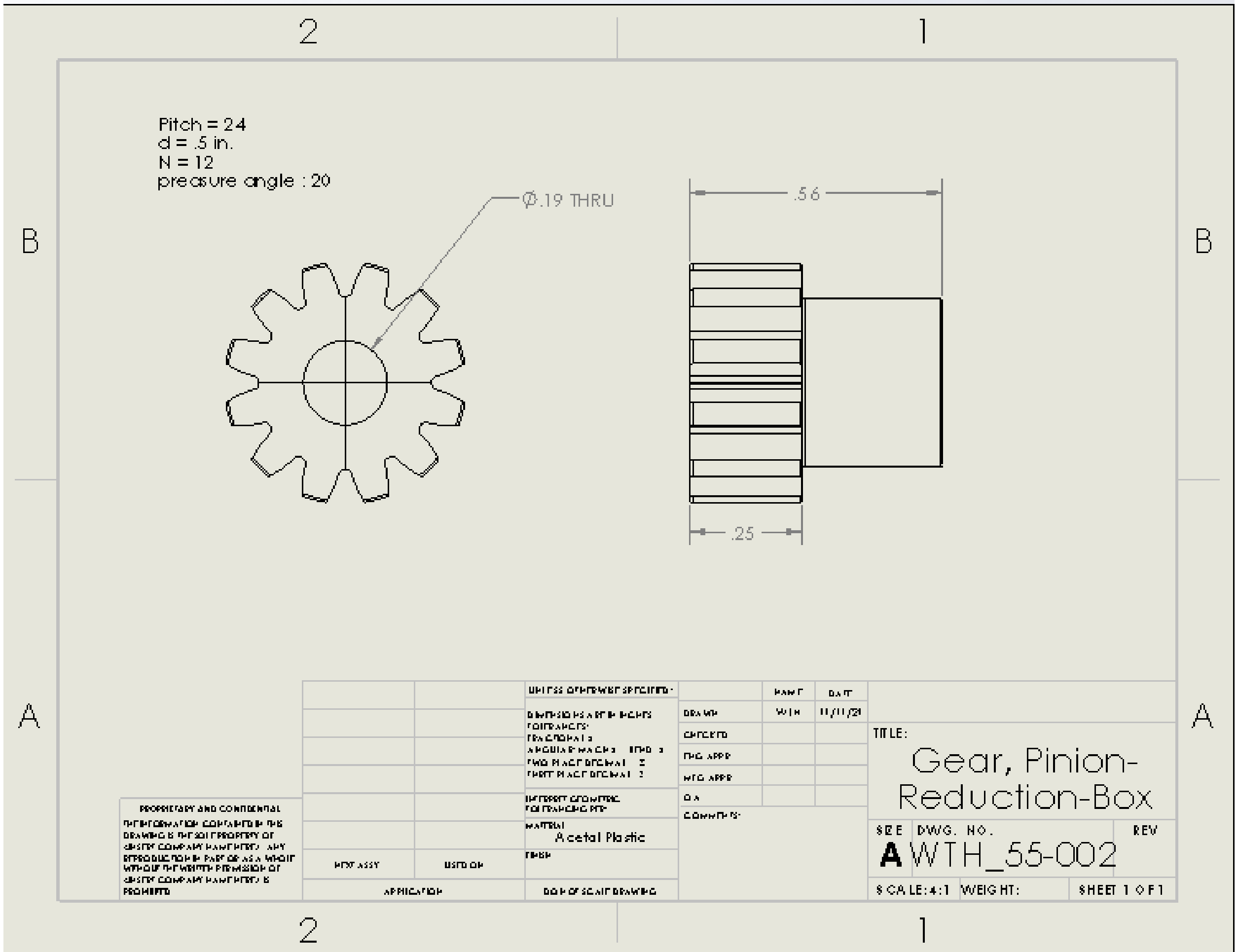


Figure 33 Gearbox pinion

Appendix B – WTH_55-003 Gear, Reduction-Gearbox

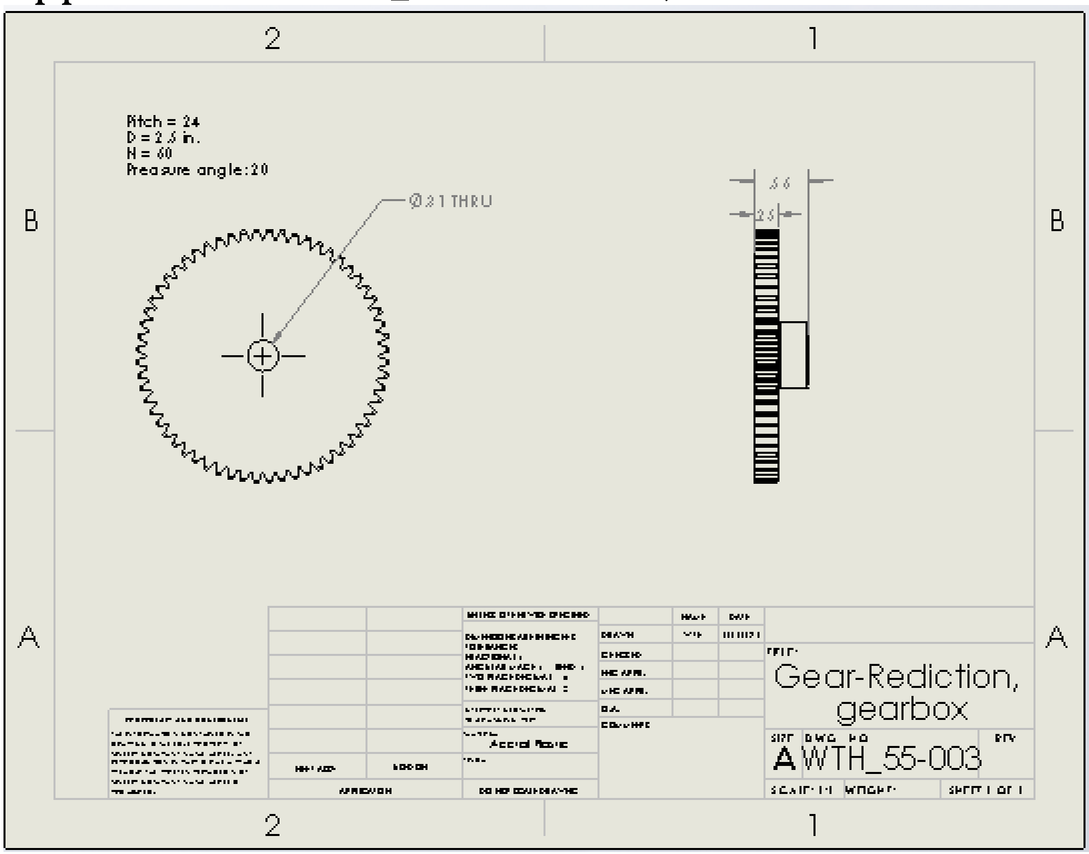


Figure 34 gearbox driven gear

Appendix B – WTH_55-018 Shaft-Reduction, Driven

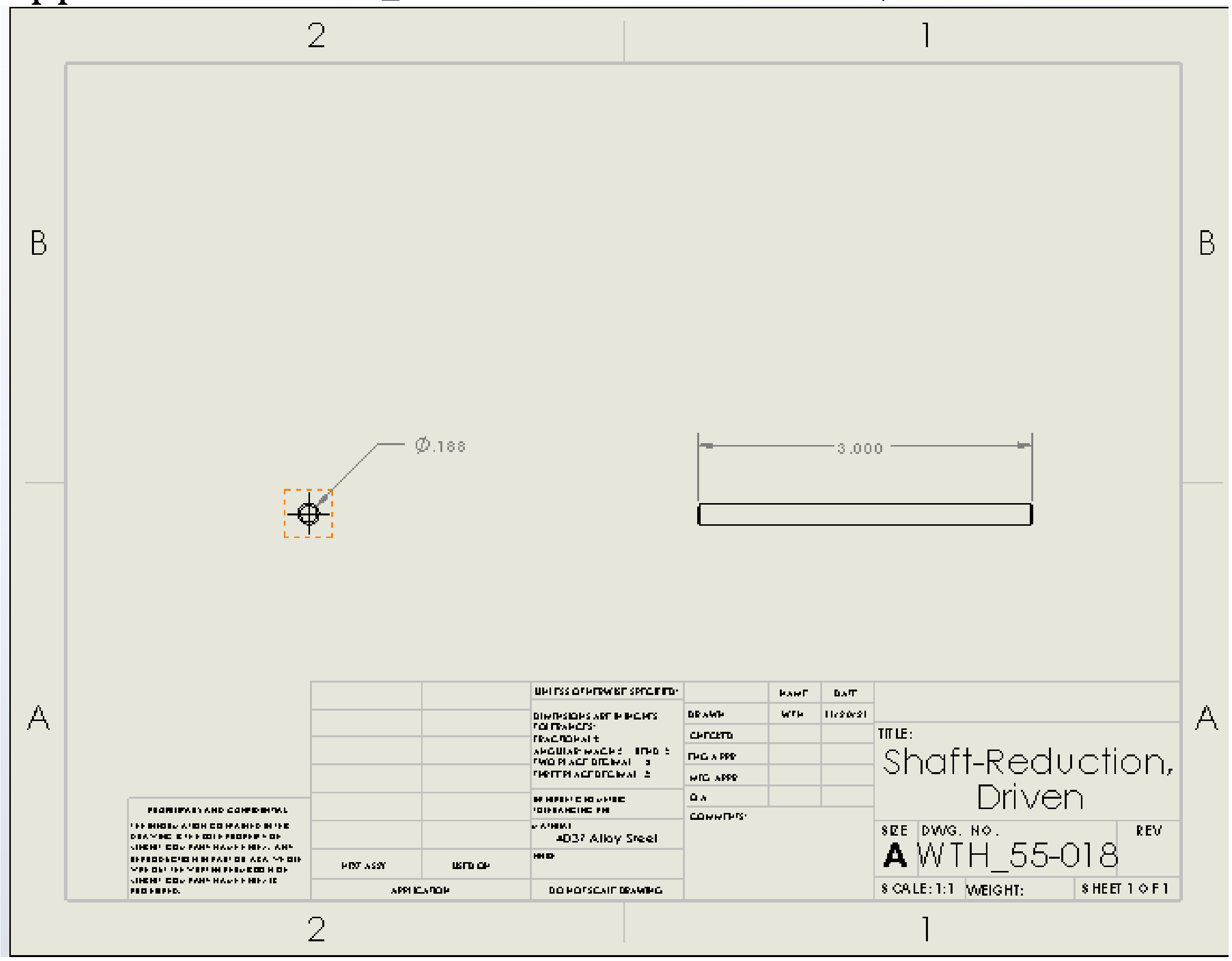


Figure 35 Gearbox driven shaft

Appendix B – WTH_55-019 Shaft-Reduction, Pinion

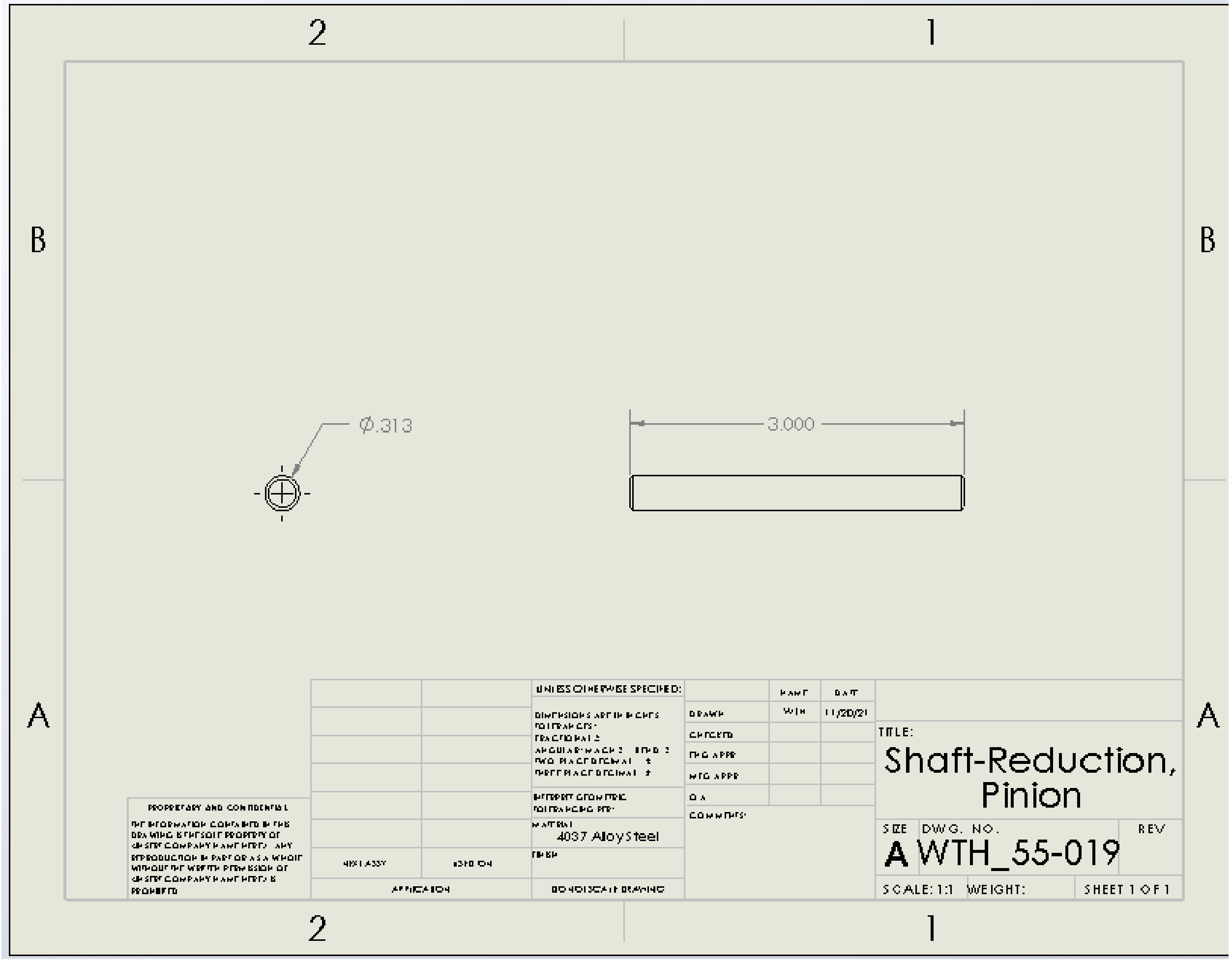


Figure 36 Gearbox pinion shaft

Appendix B – JFH_20-001 Chassis, Car

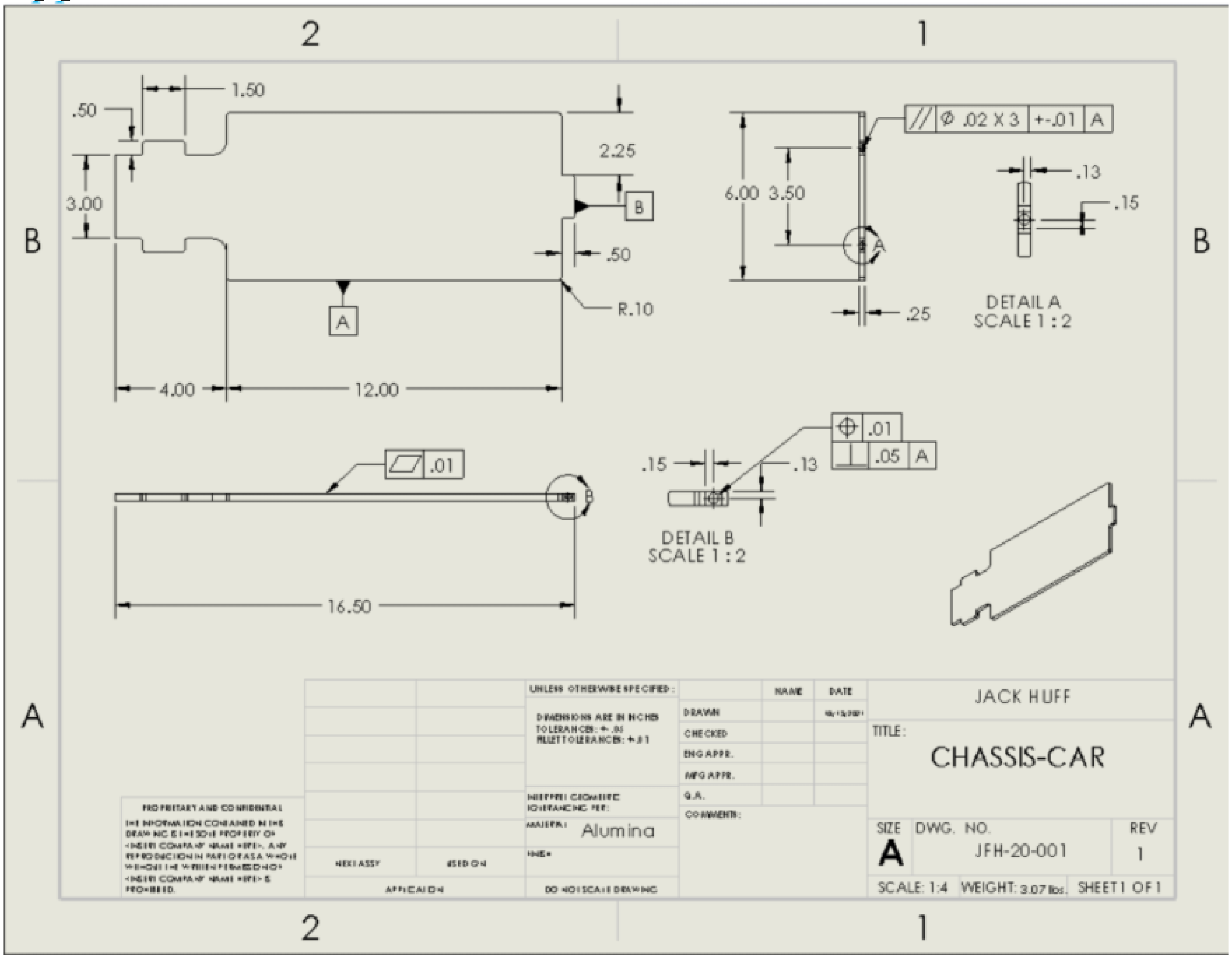


Figure 37 Chassis drawing

Appendix B – JFH_20-002 Arm-Swing, Front

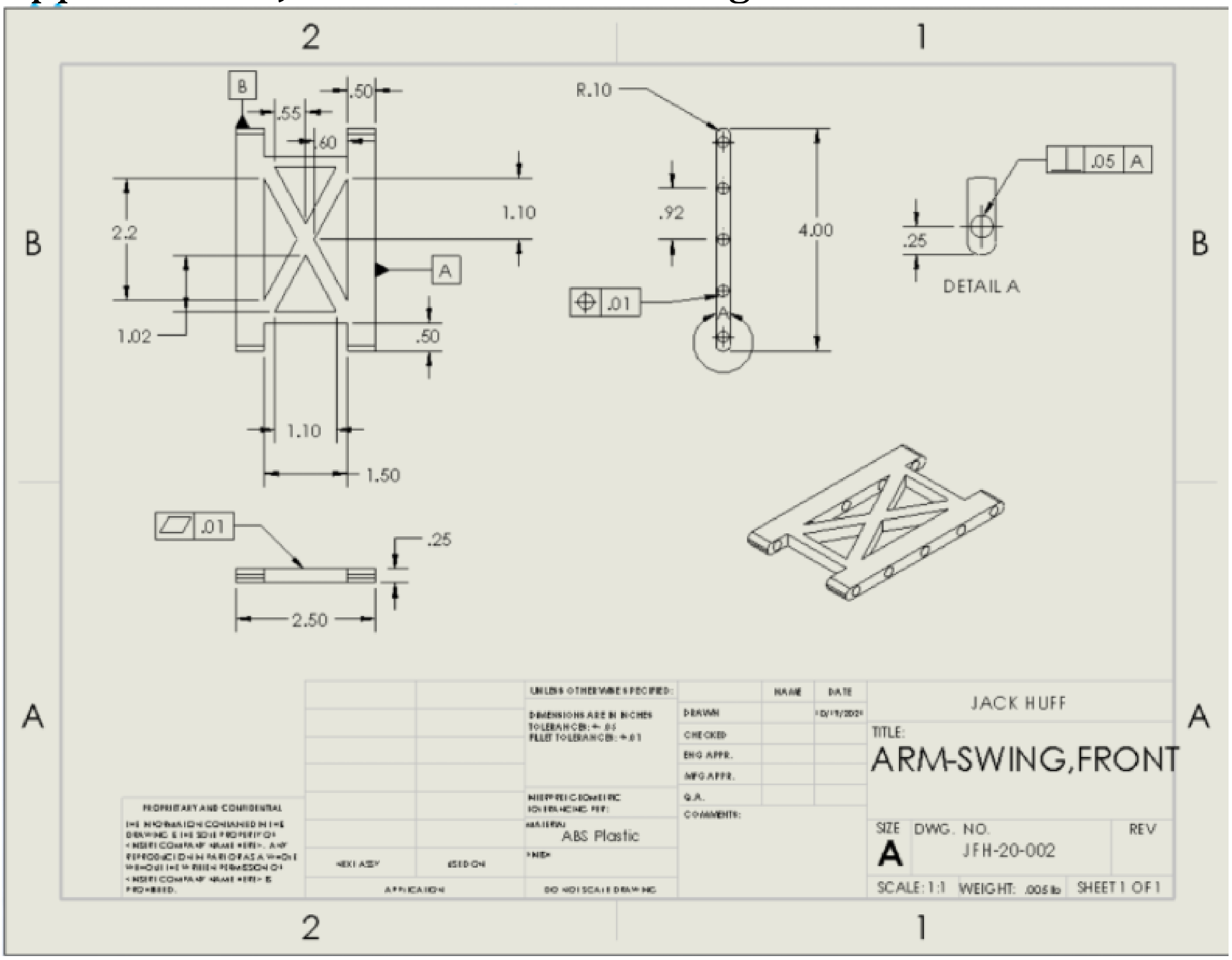


Figure 38 Front lower swing arms

Appendix B – JFH_20-003 Tower-Shock, Front

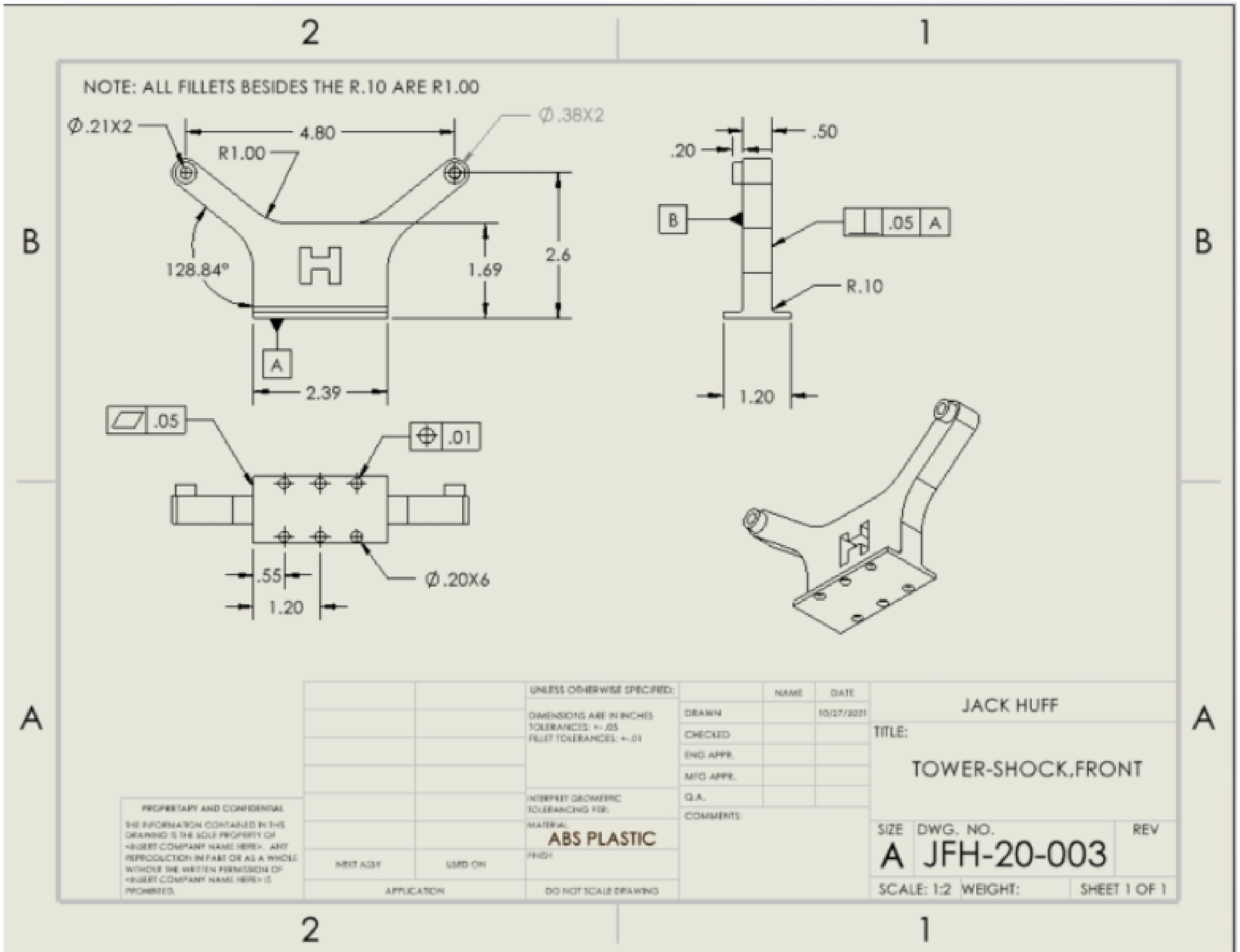


Figure 39 Front Shock tower

Appendix B – JFH_20-004 Tower-Shock, Rear

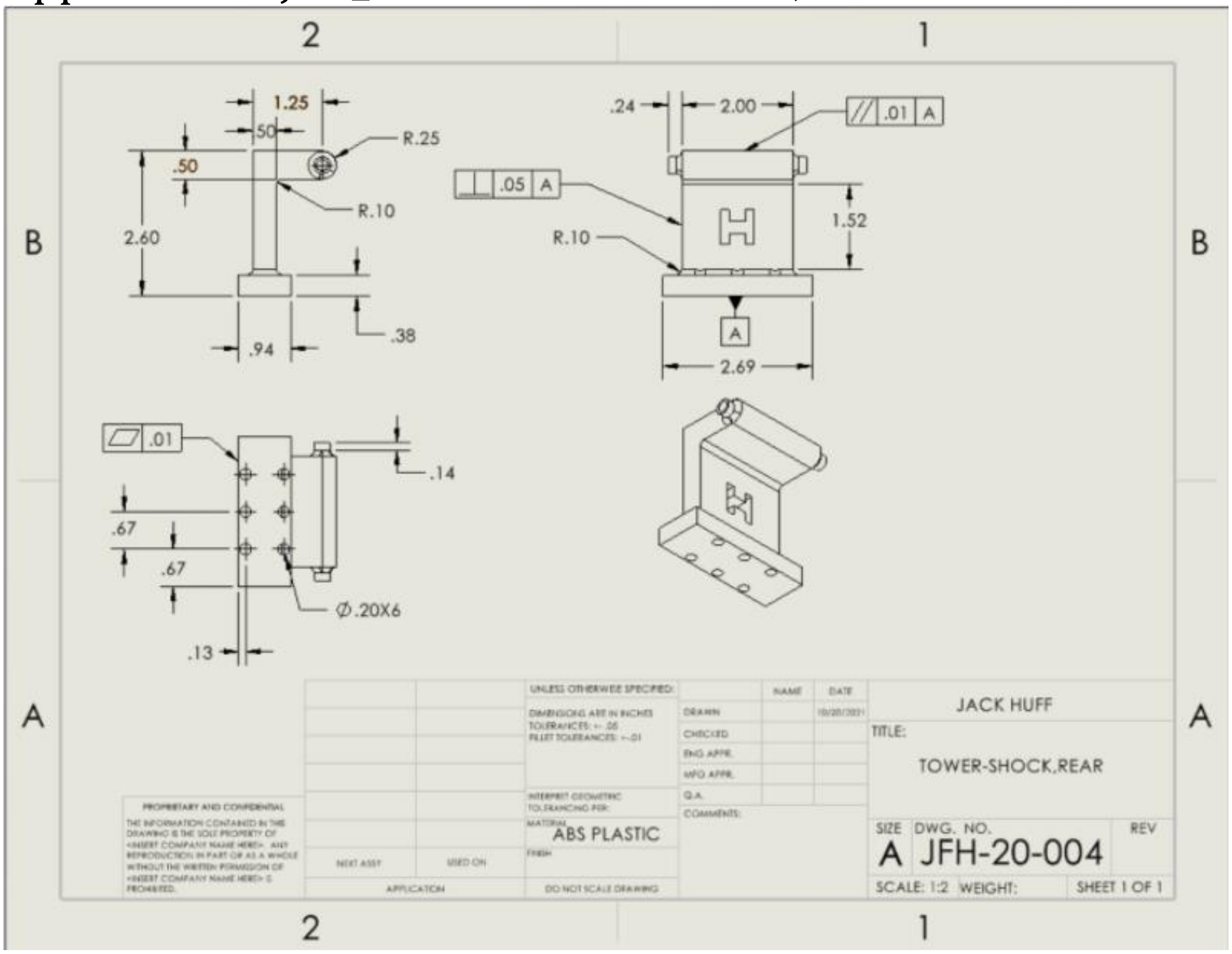


Figure 40 Rear Shock Tower

Appendix B – JFH_20-005 Support-Bumper, Front

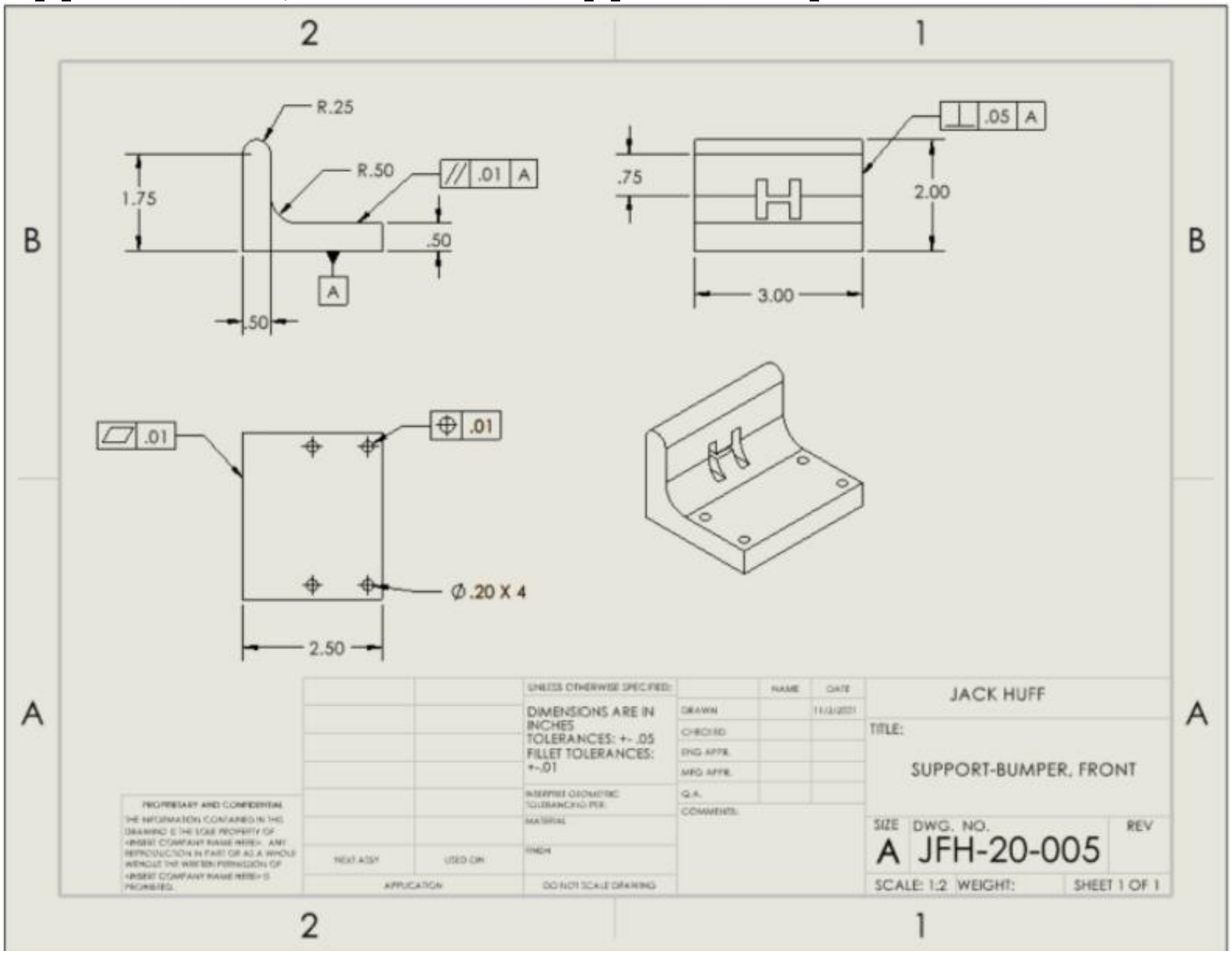


Figure 41 Front Bumper

Appendix B – JFH_55-001 Strut-Suspension, Front

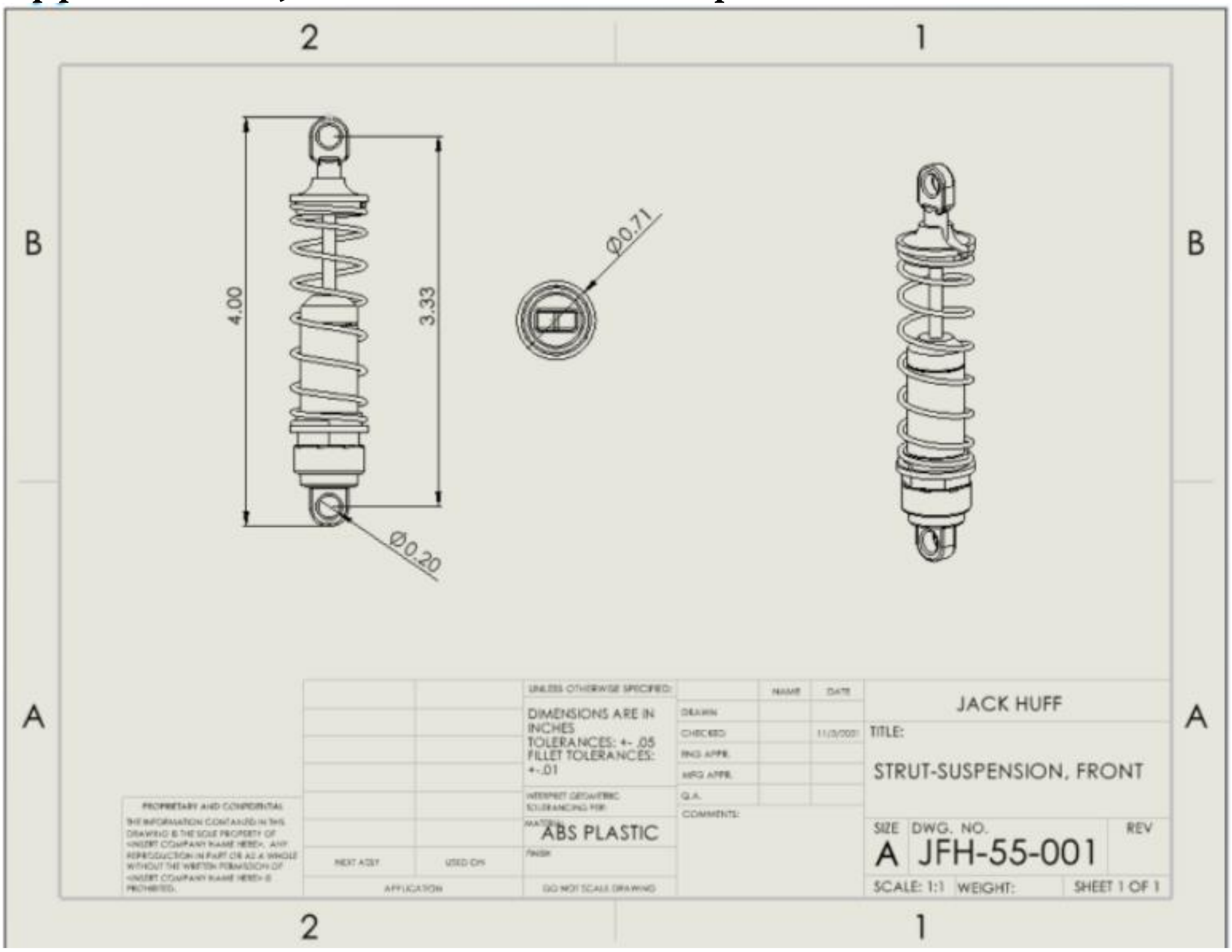


Figure 42 Front suspension strut

Appendix B – JFH_55-002 Suspension-Pin, Front

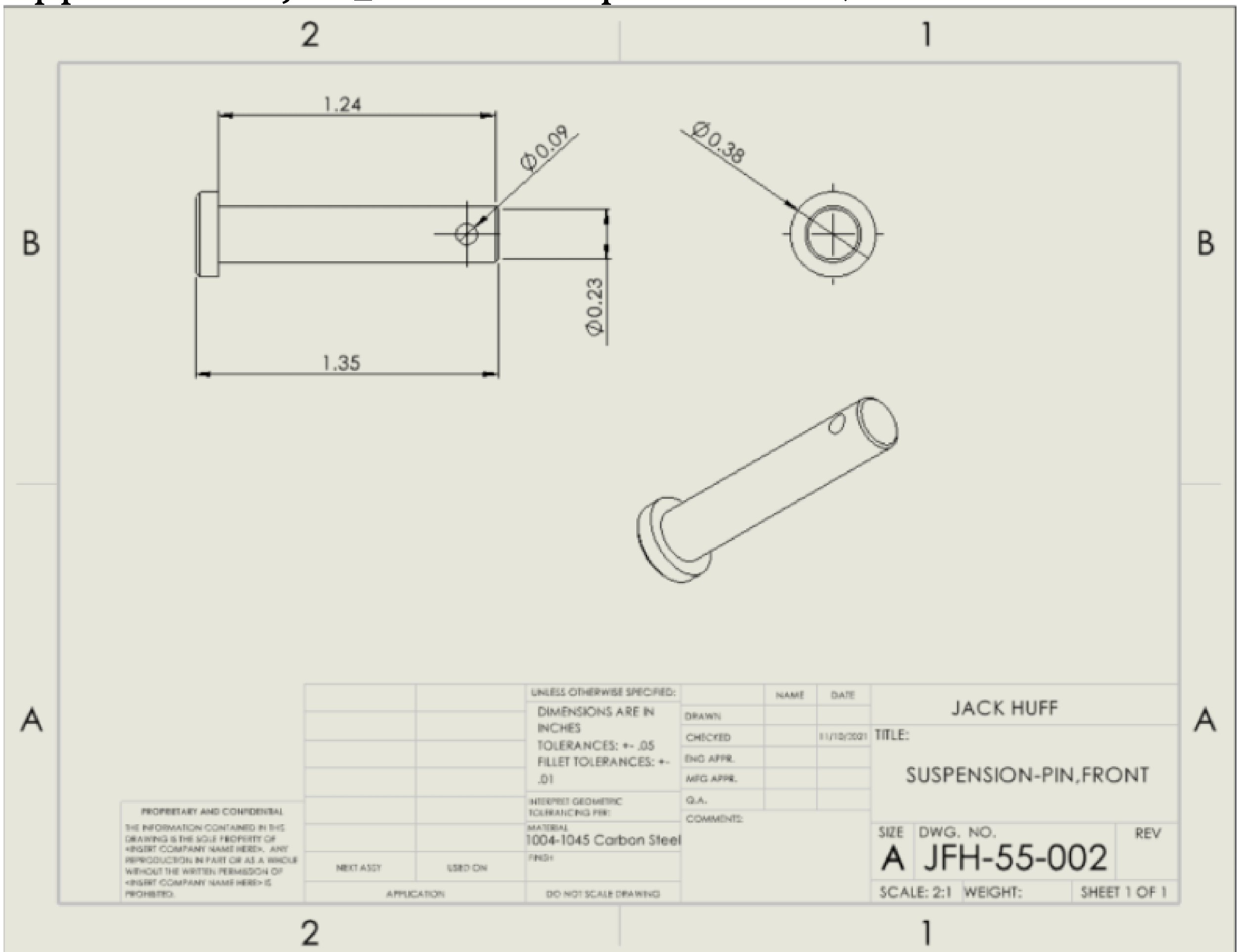


Figure 43 Front suspension pins

Appendix B – JFH_55-003 Suspension-Pin, Rear

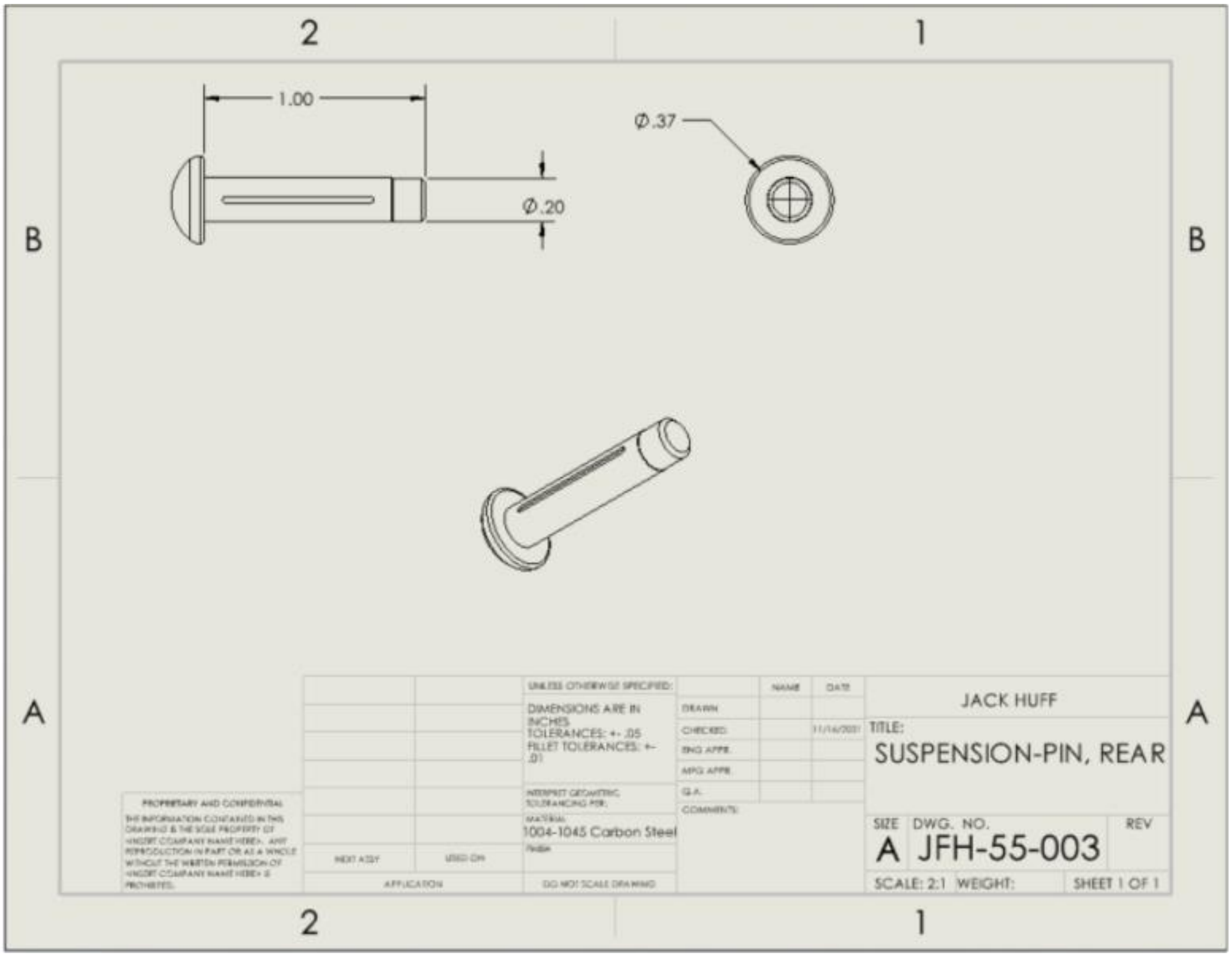


Figure 44 Rear suspension pins

APPENDIX C – Parts List and Costs

Table C1. Parts List

Part number	Qty.	Part Description	Source	Unit Cost	Actual cost
WTH_20-001	1	Mount-Motor, Lower	School Print	$6.00	$6.00
WTH_20-002	1	Housing-Rear, Lower	School Print	$2.00	$2.00
WTH_20-003	1	Moount-Motor, upper	School Print	$5.00	$5.00
WTH_20-004	1	Housing-Rear, Upper	School Print	$3.00	$3.00
WTH_20-005	2	Rod-Tie, Front	mfg	$15.00	$30.00
WTH_20-006	2	Arm-Control, Upper	mfg	$15.00	$30.00
WTH_20-007	1	Casing-Transmission, Front	School Print	$2.00	$2.00
WTH_20-008	1	Casing-Transmission, Rear	School Print	$2.00	$2.00
WTH_20-009	1	Shaft, Driveline	mfg	$15.00	$15.00
WTH_20-010	2	Knuckle-Steering, Front	School Print	$3.00	$6.00
WTH_20-015	1	Carrier, Axle,Rear	School Print	$5.00	$5.00
WTH_55-002	2	Gear, Pinion-Reduction-Box	Mcmaster Carr	$3.00	$6.00
WTH_55-003	1	Gear, Reduction-Gearbox	McMaster Carr	$9.57	$9.57
WTH_55-004	1	Motor-speed controller	HobbyWing	$110.95	$110.95
WTH_55-005	1	Bevel- Pinion	Mcmaster Carr	$8.87	$8.87
WTH_55-006	1	Bevel- driven	Mcmaster Carr	$10.24	$10.24
WTH_55-010	2	U-joints	Mcmaster Carr	$38.50	$77.00
WTH_55-018	1	Shaft-Reduction, Driven	Mcmaster Carr	$12.99	$12.99
WTH_55-019	1	Shaft-Reduction, Pinion	Mcmaster Carr	$12.27	$12.27
WTH_55-021	2	3/16 dia transmissionm shaft	Mcmaster Carr	$3.34	$6.68
WTH_55_022	2	5/16 dia transmission shaft	Mcmaster Carr	$2.74	$5.48
Total	28				$366.05

Table 2 Parts list total

Part number	Qty.	Part Description	Source	Unit Cost	Actual cost
JFH_20-001	1	CHASSIS-CAR	mfg	$20.00	$0.00
JFH_20-002	2	ARM-SWING,FRONT	School Pri	$4.00	$3.00
JFH_20-003	1	TOWER-SHOCK,FRONT	School Pri	$4.00	$3.00
JFH_20-004	1	TOWER-SHOCK,REAR	School pri	$4.00	$3.00
JFH-20-005	1	BUMPER-SUPPORT,FRONT	School Pri	$5.00	$3.00
JFH-55-001	1	SUSPENSION-STRUT,FRONT	amazon	$50.00	$40.00
JFH-55-002	0	SUSPENSION-PIN,FRONT	Mcmaster	$5.00	$0.00
JFH-55-003	0	SUSPENSION-PIN,REAR	Mcmaster	$5.00	$0.00
WTH_20-001	1	Mount-Motor, Lower	School Pri	$6.00	$6.00
WTH_20-002	1	Housing-Rear, Lower	School Pri	$2.00	$2.00
WTH_20-003	1	Moount-Motor, upper	School Pri	$5.00	$5.00
WTH_20-004	1	Housing-Rear, Upper	School Pri	$3.00	$3.00
WTH_20-005	2	Rod-Tie, Front	mfg	$15.00	$30.00
WTH_20-006	2	Arm-Control, Upper	mfg	$15.00	$30.00
WTH_20-007	1	Casing-Transmission, Front	School Pri	$2.00	$2.00
WTH_20-008	1	Casing-Transmission, Rear	School Pri	$2.00	$2.00
WTH_20-009	1	Shaft, Driveline	mfg	$15.00	$15.00
WTH_20-010	2	Knuckle-Steering, Front	School Pri	$3.00	$6.00
WTH_20-015	1	Carrier, Axle,Rear	School Pri	$5.00	$5.00
WTH_55-002	2	Gear, Pinion-Reduction-Box	Mcmaster	$3.00	$6.00
WTH_55-003	1	Gear, Reduction-Gearbox	McMaster	$9.57	$9.57
WTH_55-004	1	Motor-speed controller	HobbyWir	$110.95	$110.95
WTH_55-005	1	Bevel- Pinion	Mcmaster	$8.87	$8.87
WTH_55-006	1	Bevel- driven	Mcmaster	$10.24	$10.24
WTH_55-010	2	U-joints	Mcmaster	$38.50	$77.00
WTH_55-018	1	Shaft-Reduction, Driven	Mcmaster	$12.99	$12.99
WTH_55-019	1	Shaft-Reduction, Pinion	Mcmaster	$12.27	$12.27
WTH_55-021	2	3/16 dia transmissionm shaft	Mcmaster	$3.34	$6.68
WTH_55_022	2	5/16 dia transmission shaft	Mcmaster	$2.74	$5.48
Total	35				$418.05

APPENDIX D – Budget

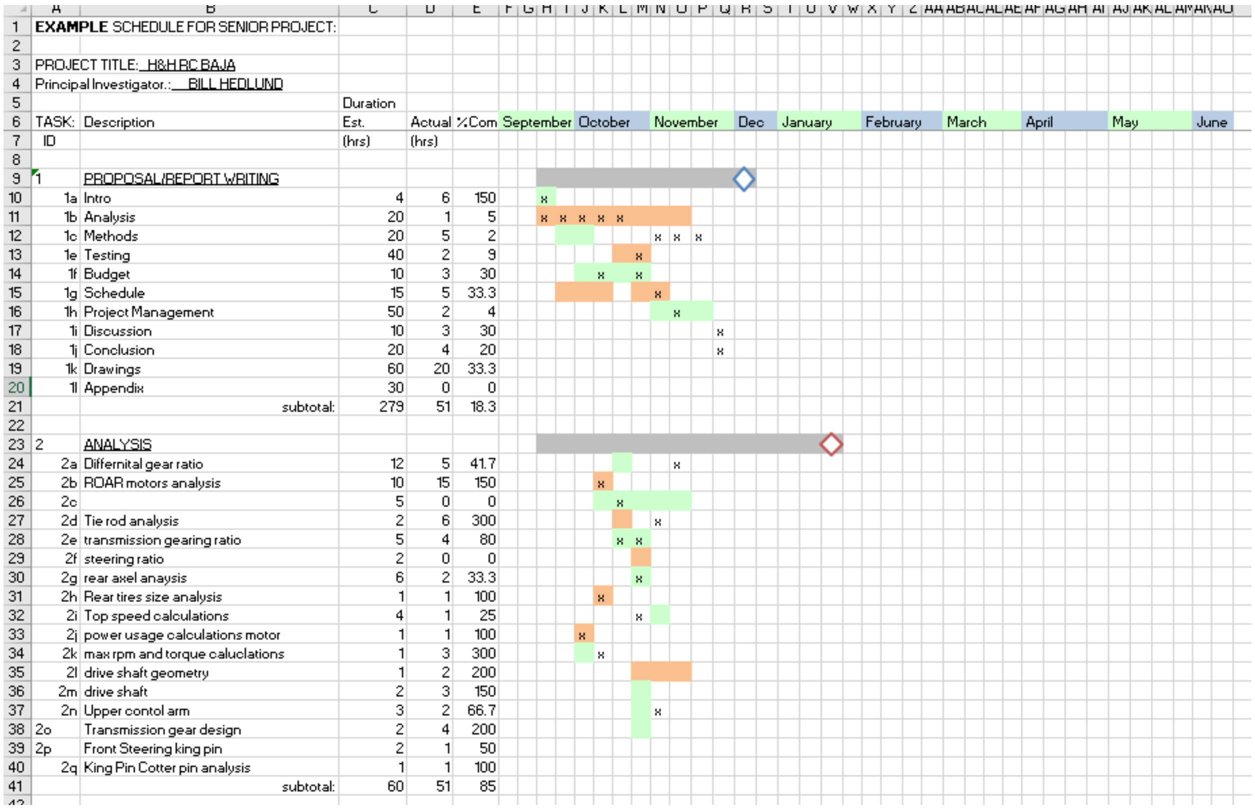
Table D1. Project Budget.

Item	Qty	Description	Cost
Total Parts	35	All parts needed	$418.05
Manufactured Parts	19	Parts that were 3D printed or made out of school	$90.00
Labor cost	1	Manual labor by project members	$1,500.00
		Total Cost	$2,008.05

Figure 45 project budget

APPENDIX E – Schedule

Figure E1. Project Gantt Chart.



EXAMPLE SCHEDULE FOR SENIOR PROJECT:

PROJECT TITLE: H&H RC BAJA

Principal Investigator.: BILL HEDLUND

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Com
1	PROPOSAL/REPORT WRITING			
1a	Intro	4	6	150
1b	Analysis	20	1	5
1c	Methods	20	5	2
1e	Testing	40	2	9
1f	Budget	10	3	30
1g	Schedule	15	5	33.3
1h	Project Management	50	2	4
1i	Discussion	10	3	30
1j	Conclusion	20	4	20
1k	Drawings	60	20	33.3
1l	Appendix	30	0	0
	subtotal:	279	51	18.3
2	ANALYSIS			
2a	Differnital gear ratio	12	5	41.7
2b	ROAR motors analysis	10	15	150
2c		5	0	0
2d	Tie rod analysis	2	6	300
2e	transmission gearing ratio	5	4	80
2f	steering ratio	2	0	0
2g	rear axel anaysis	6	2	33.3
2h	Rear tires size analysis	1	1	100
2i	Top speed calculations	4	1	25
2j	power usage calculations motor	1	1	100
2k	max rpm and torque caluclations	1	3	300
2l	drive shaft geometry	1	2	200
2m	drive shaft	2	3	150
2n	Upper contol arm	3	2	66.7
2o	Transmission gear design	2	4	200
2p	Front Steering king pin	2	1	50
2q	King Pin Cotter pin analysis	1	1	100
	subtotal:	60	51	85

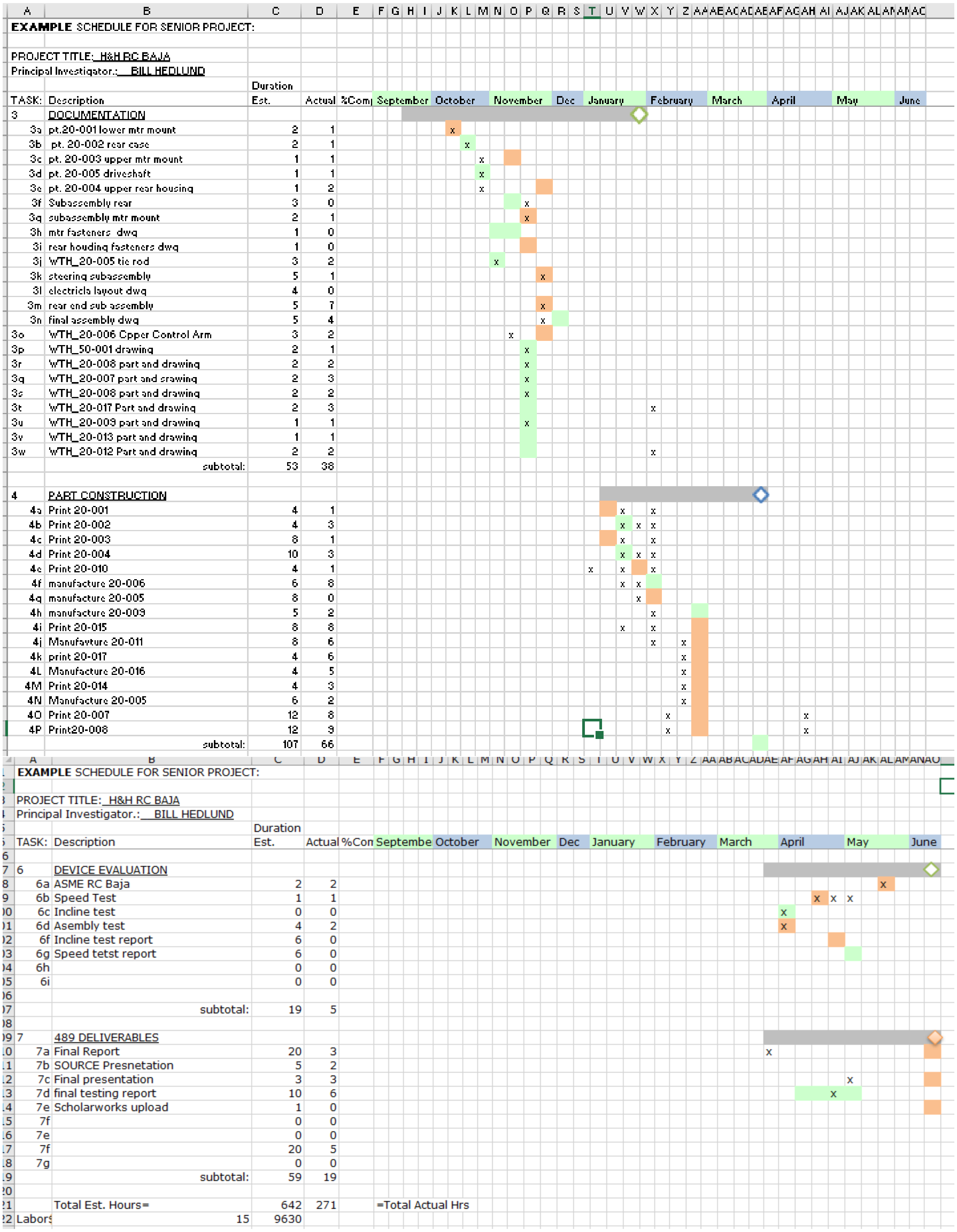


Figure 46 Gantt Chart of project

APPENDIX F – Expertise and Resources

Table F.1 Decision matrix

Criterion	Weight	est Possibl	Design #		Design #		Design #		
	1 to 3	3	1	Score x Wt	2	Score x Wt	2	Score x Wt	
Cost	2	6	1	2	1	2	1	2	
Weight	2	6	2	4	3	6	2	4	
precision	3	9	3	9	1	3	1	3	
ase of use	1	3	1	1	3	3	2	2	
time	3	9	2	6	1	3	1	3	
cturability	2	6							
Total	13	39		22		17		14	
NORMALIZE THE DAT		2.56		56.41		43.59		35.90	Percent
								45.30	Average
								10.36	Std Dev.

Figure 47 Base Decision matrix

Table F.2 Decision matrix – driveshaft manufacturing

Criterion	Weight	est Possibl	mecheine shop		Out sourced		Design #		
	1 to 3	3	1	Score x Wt	2	Score x Wt	2	Score x Wt	
Cost	3	9	3	9	1	3	0	0	
Weight	3	9	0	0	0	0	0	0	
precision	3	9	1	3	3	9	0	0	
ase of use	3	9	1	3	3	9	0	0	
time	3	9	2	6	2	6	0	0	
cturability	3	9	2	6	3	9	0	0	
Total	18	54		27		36		0	
NORMALIZE THE DAT		1.85		50.00		66.67		0.00	Percent
								38.89	Average
								34.69	Std Dev.

Figure 48 Driveshaft manufacturing

Table F.3 Decision matrix – lower motor housing

Criterion	Weight	est Possibl	3D print		Mill		out Source		
	1 to 3	3	1	Score x Wt	2	Score x Wt	2	Score x Wt	
Cost	3	9	3	9	1	3	1	3	
Weight	3	9	3	9	1	3	1	3	
precision	3	9	3	9	2	6	3	9	
ase of use	3	9	3	9	1	3	2	6	
time	3	9	2	6	1	3	3	9	
cturability	3	9	3	9	1	3	2	6	
Total	18	54		51		21		36	
NORMALIZE THE DAT		1.85		94.44		38.89		66.67	Percent
								66.67	Average
								27.78	Std Dev.

Figure 49 lower motor mount decision matrix

Table F.4 Decision matrix – material selection matrix

Criterion	Weight	est Possibl	6061 T6		AISI 1020		ABS Plastic		
	1 to 3	3	1	Score x Wt	2	Score x Wt	2	Score x Wt	
Cost	3	9	1	3	1	3	3	9	
Weight	3	9	2	6	1	3	3	9	
achinability	3	9	3	9	1	3	1	3	
Strengh	3	9	3	9	3	9	1	3	
Total	12	36		27		18		24	
NORMALIZE THE DAT		2.78		75.00		50.00		66.67	Percent
								63.89	Average
								12.73	Std Dev.

Figure 50 upper control arm material selection

APPENDIX G – Testing Report

Appendix G1 Test 01 Assembly test.

Introduction

The purpose of the assembly test is evaluating the design for ease of manufacturability. The test is meet the 10-minute disassembly and reassembly of the rear axle system to simulate repairs under race conditions in which a rear axle assembly can be fully swapped as a single component. The test will be conducted by removing all the fasteners and cases needed to allow for a rear axle swap and the reassembly of the system to fully functional in under 10 minutes. This test will be conducted to evaluate design requirement 6 "Rear drive assembly must be able to be swapped in under 10 minutes." (pg. 6) data will be collected using a stopwatch to record times. This test will fall under Gantt chart item 6d and will be conducted in the first week of April.

Method/Approach

The testing was conducted by using the Hogue Hall Machine shop and the hand tools inside the shop. The cost of the testing would only account for labor cost for the tester and the test helper. The data for the test was captured two ways first with a stop watch and recoded on the data sheet and secondly the test was recoded using a video camera. The data was collected in a table where the average time will be computed as serve as the level of success of the test.

Test Procedure

Summary: The following procedure documents the steps taken to perform the assembly test. The assembly test was conducted to by the H&H racing RC Baja team drivetrain engineer in coloration with the suspension and chassis engineer. The test was evaluating the time needed to perform a rear axle assembly swap. The following procedure outline how the testing was conducted.

Time: The test was conducted Wednesday April 6, 2022, from 12:00pm to 2:00pm. 15 minutes were required for set up and 10 minute was required to return all tools to shadow boards.

Place: The test was conducted in the Hogue Hall room 108 Machine shop at Central Washington University Ellensburg campus.

Required equipment:

- Stopwatch (cell phone stop watched used for testing due to access and ease or use)
- Number 3 regular screwdriver (flat head)
- 3/8 box wrench
- SAE ¼ hex head wrench
- Work bench

- Shop stool
- Data collection sheet
- Mechanical pencil
- Safety glasses (required per MET machine policy)
- Second team member for operation of stopwatch.
- Full RC car assembly.

Risk: The test could not have been conducted without the use of the prescribed hand tools and the assistance of second member to operate the stopwatch. Safety glasses were required for testing per venue. Other risk may have included unintended damage to the rear axle system parts due to mishandling of tools.

Procedure: the test was conducted according to the following procedure.

1. Collect equipment:
    a. Screwdriver
    b. Box and hex wrench
    c. Stopwatch
    d. Data collection sheets
    e. Writing pencil
2. Place the car on the work bench, ensure ample room for repositioning of the RC as needed.
3. Begin with hands placed on the work bench.
4. When signal is given timer starts the stopwatch.
5. Pick up the aft end of the RC car.
6. Using the flat head screwdriver and the 3/8th Allen wrench begin by removing 4 aft screws. Screws 1,2,3, and 4 in figure 51.
    a. The screwdriver will be placed under the rear end. With the wrench placed on the up facing nuts use the screwdriver to remove the bolts.
7. Remove the two Allen head screws (Black).
    a. The nuts for these crews are located in a tighter position and may require the RC to be repositioned.
8. Remove the rear axle.
    a. Move the rear axle carrier to allow the input gear to move forward and unmate the gear pair. Rear axle will be free by this time.
    b. Pick the rear axle up out of the carrier.
9. Set the Axle on the workbench and remove hands.
10. Reinstall the rear axle.

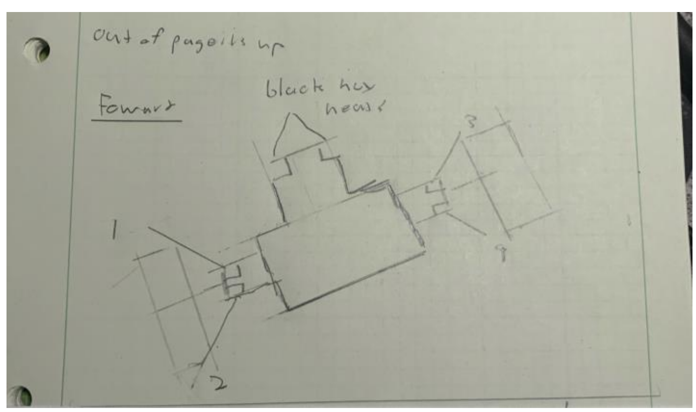


Figure 51 bolt pattern

a. Ensure that the gears are in mesh and shaft collars line up with the cut out in the plastic housings.
11. With the heads of the 4 aft bolts facing the work bench insert one at the corner.
    a. Reinstall the upper case.
    b. Insert the nut onto the one bolt and begin to tighten.
    c. Repeat step b for the reaming three bolts.
12. Install the two forward bolts with heads facing up.
13. Ensure the rear axle is properly installed by turning the wheels by hand and ensure the drive shaft spins.
14. Give signal that test is complete and stop stopwatch.
15. Recording the time on the data sheet.
16. Repeat steps 3-15 for the two remaining trials.

Figure 52 fastener alignment

Deliverables

Appendix G1.1 – Procedure Checklist

Ensure the following:

- Screwdriver is properly sized
- Allen Wrenches are properly sized
- Box wrench is the proper size.
- Work area is free and clear.
- Car is already in good working order.
- Camera is ready to go
- Timer is ready and understands the stopping and starting conditions.

Appendix G1.2 – Data Forms

Table 3 Assembly test black data sheet.

Assmebly time test		
trial number	Time (m)	Notes
1		
2		
3		
ave	#DIV/0!	
Tester name		
Test date		

Appendix G1.3 – Raw Data

Table 4 assembly test raw data

Assmebly time test		
Trial number	Time (m)	Notes
1	7.22	spacer seating issue
2	6.28	----
3	5.40	driveshaft falling out
Tester name	Bill Hedlund	
Test date	4,4,22	

Appendix G1.4 – Evaluation Sheet

Table 5 Assembly test calculated data.

Assmebly time test		
Trial number	Time (m)	Notes
1	7.22	spacer seating issue
2	6.28	----
3	5.40	driveshaft falling out
ave	6.30	"=AVERAGE(B3:B5)"
Tester name	Bill Hedlund	
Test date	4,4,22	

Equations used for evaluation of data are the built-in average function within excel averaging the three trial runs.

Appendix G1.5 – Schedule (Testing)

Table 6 Schedule for testing

EXAMPLE SCHEDULE FOR SENIOR PROJECT:

PROJECT TITLE:_H&H RC BAJA

Principal Investigator.:__BILL HEDLUND

TASK:	Description	Duration Est.	Actual	%Com	September	October	November	Dec	January	February	March	April	May	June
6	DEVICE EVALUATION													
6a	ASME RC Baja	2	2										x	
6b	Speed Test	1	1									x x		
6c	Incline test	0	0									x		
6d	Asembly test	4	2									x		
6e	Assembly test report	10	2											
6f	Incline test report	6	0											
6g	Speed tetst report	6	0											
6h		0	0											
6i		0	0											
	subtotal:	29	7											

The schedule for the testing process was worked into the overall schedule of the project and accounts for a major portion of the scheduled time for the Spring Quarter.

Appendix G2 Test 02 Top Speed Test

Introduction

The purpose of the top speed test is evaluating the effeteness of the drivetrain. The test is a simple three trial test in which the RC is ran at full power in a straight line and a GPS tracking app records the high speed achieved by the car. The test will be conducted by pavement to allow for the best traction possible. The test will compare to the design requirement for top speed of 25mph they will be collected in a data and the average of the top speeds taken to reduce and unforeseen interferences.

Method/Approach

The testing was conducted by using the Hogue Hall apron and a GPS speed tracking app, with a smart phone, and one driver. The testing results collected using the top speed data provided by the app; the data was later captured and recorded in the data collection sheet. The test occurred by making three straight top speed runs from west side of the apron the east end of the apron. The speedometer ap was confirmed to be within +/-2 mph by comparing the speed reached in a road going vehicle to the speedometer in the vehicle. The data will be collected in a table.

Test Procedure

Summary: The following procedure documents the steps taken to perform the top speed test. The test was conducted to by the H&H racing RC Baja team drivetrain engineer in coloration with the suspension and chassis engineer. The test was evaluating the ability of the final assembly to achieve the top speed set forth in the main reports design requirements. The following procedure outline how the testing was conducted.

Time: The test was conducted Thursday April 28, 2022, from 8:00am – 10:00am. 15 minutes were required for set up and 10 minute was required to return all testing equipment to the desired locations.

Place: The test was conducted in the Hogue Hall FLUKE Lab apron at Central Washington University Ellensburg campus.

Required equipment:
- Data collection sheet
- Mechanical pencil
- Safety glasses (required per MET machine policy)
- Full RC car assembly.
- GPS speed app (Speedometer simple)
- Spare battery
- Remote controller
- Smart phone

Risk: The test could not have been conducted without the use of the described testing equipment. Safety glasses were required for testing per venue. Other risk may have included unintended damage to the full assembly following complication other principal engineers faced when conducting similar testing.

Procedure: the test was conducted according to the following procedure:

1. Collect the required equipment;
   - Data collection sheet
   - Mechanical pencil
   - Safety glasses (required per MET machine policy)
   - Full RC car assembly.
   - GPS speed app (speedometer simple)
   - Spare battery
   - Remote controller
2. Switch the RC cars speed controller on.
   a. The switch is located on forward side of the speed controller.
3. Switch on the Remote controller.
   a. Switch can be found on the front panel of the remote.
4. Place the smart phone on the car in safe location:
   a. Zip ties may be used for this.
   b. Phone can also be wedge in between the front bumper and front shock tower.
5. Ensure the car is operational by:
   a. Turning the wheels to ensure car has directional control.
   b. Slowly adding throttle to ensure car has forward movement.
6. Open the Speedometer Simple app
   a. Ensure the run data is clear by pressing the refresh button.
7. Place the car at the west end of the apron facing east.
   a. Westend – staircase
   b. Eastend – ramp
   c. See figure 53

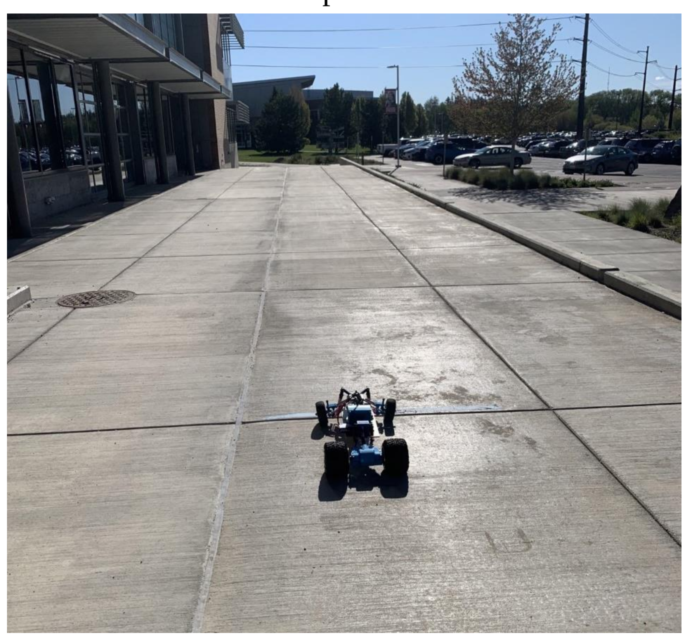


Figure 53 testing venue

8. Begin by slowly adding power to the car using the remote.
   a. As power is added watch to ensure the car will not crash.
   b. Continue to add power until 100% throttle is reached.
9. Once max power is reached, decelerate the car.
10. Take a screen shot of the speedometer app.
11. Record data in the empty data sheet.

12. Switch battery as needed to ensure car has ample charge.
13. Repeat steps 5-12 for at least three trials.

Deliverables

Appendix G2.1 – Procedure Checklist

Ensure the following:

- Data collection sheet is on hand.
- Mechanical pencil is on hand.
- Safety glasses are on.
- Full RC car assembly is operational.
- GPS speed app (Speedometer simple) app is working.
- Car battery is charged.
- Spare battery is charged.
- Remote controller has batteries and is operational.
- Smart phone has enough charge to conduct testing.

Appendix G2.2 – Data Forms

Table 7 top speed test blank data sheet

Top Speed test		
trial number	Speed (mph)	Notes
1		
2		
3		
ave		
Tester name		
Test date		

Appendix G2.3 – Raw Data

Table 8 top speed test collected data

Top Speed test		
trial number	Speed (mph)	Notes
1	4.40	Front wheel isses
2	4.80	Clicking
3	6.60	
ave		
Tester name	Bill Hedlund	
Test date	4,28,22	

The above is the collected data for the top speed testing.

Appendix G2.4 – Evaluation Sheet

Table 9 top speed test evaluated data

Top Speed test		
trial number	Speed (mph)	Notes
1	4.40	Front wheel isses
2	4.80	Clicking
3	6.60	
ave	5.27	"=AVERAGE(B3:B5)"
Tester name	Bill Hedlund	
Test date	4,28,22	

Equations used for evaluation of data are the built-in average function within excel averaging the three trial runs.

Appendix G2.5 – Schedule (Testing)

Table 10 Schedule

EXAMPLE SCHEDULE FOR SENIOR PROJECT:

PROJECT TITLE:_H&H RC BAJA

Principal Investigator.:__BILL HEDLUND

TASK:	Description	Duration Est.	Actual	%Com	September	October	November	Dec	January	February	March	April	May	June
6	DEVICE EVALUATION													
6a	ASME RC Baja	2	2										x	
6b	Speed Test	1	1									x x	x	
6c	Incline test	0	0									x		
6d	Asembly test	4	2									x		
6e	Assembly test report	10	2											
6f	Incline test report	6	0											
6g	Speed tetst report	6	0											
6h		0	0											
6i		0	0											
	subtotal:	29	7											

For further information regarding the scheduling of testing please see section 6 in above engineering report.

Appendix G3 Test 03 Incline testing

Introduction

The purpose of the incline testing was to evaluate the effectiveness of the drivetrain under loading conditions. The initial test was designed to compare with inclines used in the RC Baja competition. The testing was conducted using a staircase and a wooden board to create the ramp. The data for the test will be collected as time taken to summit incline with respect to the angle of incline.

Method/Approach

The test was conducted using the eastern staircase in the Hogue Hall FLUKE Lab. The incline for the test was set up using a scrap piece of wood from the wood's lab. The slab was laid on the stairs and the built-in level app on apple iPhone was used to determine the angle of the ramp. The angles used were 10, 20, and 30 degrees. A stopwatch was used to record the time taken to summit the ramp at respective speeds and recorded.

Test Procedure

Summary: The following procedure documents the steps taken to perform the incline test. The test was conducted to by the H&H racing RC Baja team drivetrain engineer in coloration with the suspension and chassis engineer. The test was evaluating the design of the final gear train and how well the car could summit inclines. The following procedure outline how the testing was conducted.

Time: The test was conducted Thursday May 12, 2022, from 8:00am – 9:00am. 15 minutes were required for set up and 10 minute was required to return all testing equipment to the desired locations.

Place: The test was conducted in the Hogue Hall FLUKE Lab at Central Washington University Ellensburg campus.

Required equipment:

- Data collection sheet
- Mechanical pencil
- Safety glasses (required per MET machine policy)
- Full RC car assembly.
- Measure app (installed with default iOS)
- Spare battery
- Remote controller
- Smart phone
- Board or another rigid surface to act as a ramp.
- Volunteer to operate stopwatch

Risk: The test could not have been conducted without the use of the described testing equipment. Safety glasses were required for testing per venue. Other risk may have included unintended damage to the full assembly following complication other principal engineers faced when conducting similar testing.

Procedure: the test was conducted according to the following procedure:

1. Collect the required equipment:
    - Data collection sheet
    - Mechanical pencil
    - Safety glasses (required per MET machine policy)
    - Full RC car assembly.
    - Spare battery
    - Remote controller
    - Board (ramp)
    - Volunteer timer operator
2. Switch the RC cars speed controller on.
    a. The switch is located on forward side of the speed controller.
3. Switch on the Remote controller.
    a. Switch can be found on the front panel of the remote.
4. Place the ramp on the stairs and verify 10 degrees.
    a. Ramp can be within +/- 0.5 degrees
5. Place the car at the end of the ramp. See figure 54.
6. Give signal to timer
    a. Operator will start stopwatch.
    b. Car operator will begin to climb the ramp very power as needed ensure wheels roll without slipping.
7. Stop stopwatch at end location see figure 54 for reference.
    a. In the case of this testing the third stair was the stop location on the 30-degree trial.
8. Record time on data collection sheet for respective trial and incline degree.
9. Repeat trials for three timed runs at angle.
10. Repute test at angles of 20 and 30 degrees.
11. Verify the angle of the ramp after each change ensure angle is within tolerance.

Figure 54 ramp set up.

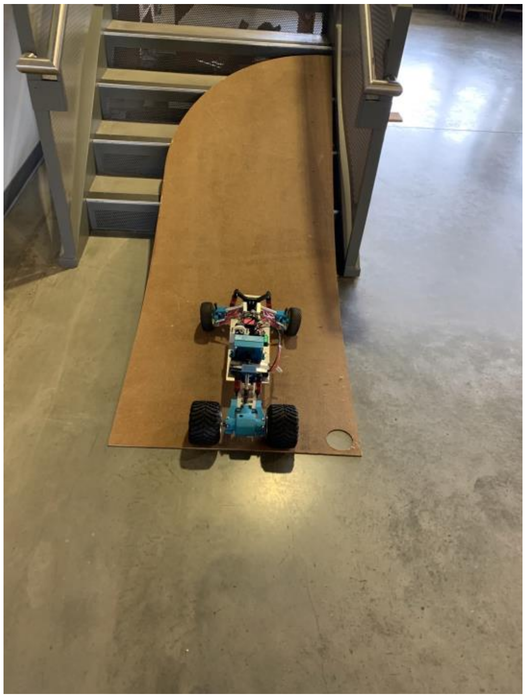


Figure 55 auxiliary view

Deliverables

Appendix G3.1 – Procedure Checklist

Ensure the following:

- Data collection sheet is on hand.
- Mechanical pencil is on hand.
- Safety glasses are on.
- Full RC car assembly is operational.
- Car battery is charged.
- Spare battery is charged.
- Remote controller has batteries and is operational.
- Smart phone has enough charge to conduct testing.

Appendix G3.2 – Data Forms

Table 11 blank data table

	A	B	C	D	E
1	incline testing	10 degree	20 degree	30 degree	
2	trial number	Time (m)	Time (m)	Time (m)	Notes
3	1				
4	2				
5	3				
6	ave	#DIV/0!	#DIV/0!	#DIV/0!	

Appendix G3.3 – Raw Data

Table 12 raw data for incline test

incline testing	10 degree	20 degree	30 degree
trial number	Time (m)	Time (m)	Time (m)
1	0.97	1.14	1.32
2	1.02	1.21	1.30
3	1.05	1.19	1.27
ave			

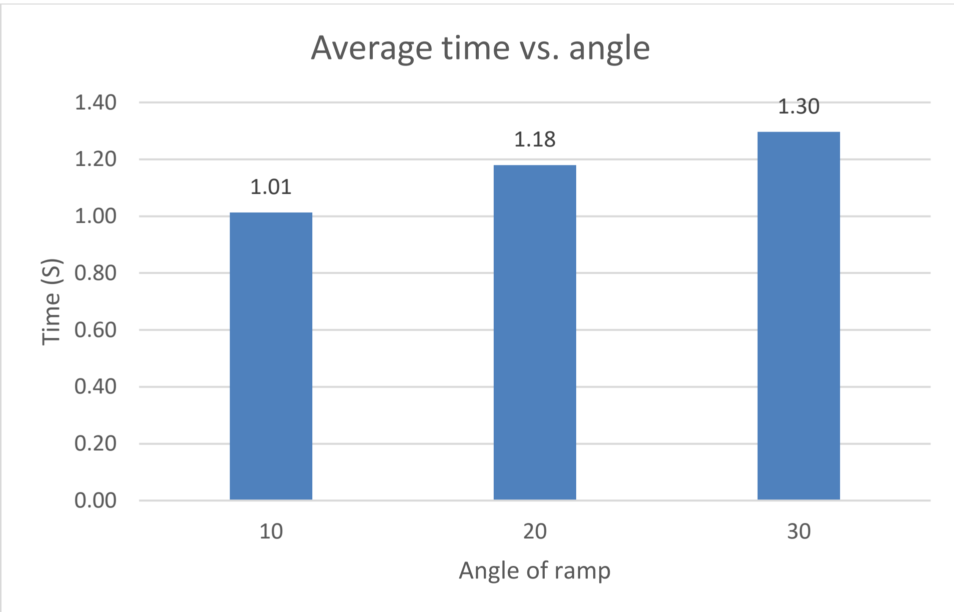
Appendix G3.4 – Evaluation Sheet

Table 13 evaluated data

incline testing	10 degree	20 degree	30 degree	
trial number	Time (m)	Time (m)	Time (m)	Notes
1	0.97	1.14	1.32	
2	1.02	1.21	1.30	
3	1.05	1.19	1.27	
ave	1.01	1.18	1.30	"=AVERAGE(D3:D5):

Equations used for evaluation of data are the built in average function within excel averaging the three trial runs.

Table 14 Tabulated data



The data for this test was collected in a chart and analyzed in a graph to help show the change in relation to time as they correspond to the difference in angles.

Appendix G3.5 – Schedule (Testing)

EXAMPLE SCHEDULE FOR SENIOR PROJECT:

PROJECT TITLE:_H&H RC BAJA

Principal Investigator.:__BILL HEDLUND

TASK:	Description	Duration Est.	Actual	%Com	September	October	November	Dec	January	February	March	April	May	June
6	DEVICE EVALUATION													
6a	ASME RC Baja	2	2									x		
6b	Speed Test	1	1									x x	x	
6c	Incline test	2	1										x	
6d	Asembly test	4	2									x		
6f	Incline test report	6	2										x	
6g	Speed tetst report	6	2										x	
6h	assembly testing report	3	2									x		
6i	final testing report	1	1										x	
	subtotal:	25	13											

The incline testing was behind schedule due to a multitude of reasons further discussed in section 6 of the testing report.

APPENDIX H – Resume

Bill Hedlund

Kent, WA 98032
Phone: (206) 499-3322
E-Mail: bill.hedlund99@gmail.com

OBJECTIVE

Mechanical Engineering Technologist seeking to become a part of your well-respected team, to apply my knowledge and experience to further the companies' objectives and goals.

SKILLS & ABILITIES

- Proficient in Microsoft Word, Power Point, and Excel
- Certified in SolidWorks, Proficient in AutoCAD 2019, and National Instruments LabView 2019

EDUCATION

Bachelor of Science in Mechanical Engineering Technology Expected graduation June 2022
Minor: **Robotics and Automation**
Central Washington University, Ellensburg, WA
Cumulative GPA: 3.39

EXPERIENCE

Engineering Intern | North Star Casteel Products inc. | Seattle, WA June-Sep. 2021

- Wrote SOP's and other training materials for various positions within the companies casting process.
- Worked with industrial engineers to streamline the No-Bake molding process.
- Designed a conceptual layout for the new foundry building, by applying the principles of lean manufacturing.

Forming Intern | Exotic Metals Forming Company | Kent, WA June-Aug. 2019

- Learned the process of bulge forming, hydro forming, and superplastic forming
- Obtained hands on experience with all above mentioned processes
- Designed and produced a shop aid to assist with organization in the hydro forming process

Fabrication Intern | The Boeing Company | Auburn, WA July 2017-Aug. 2017

- Worked alongside engineers and machinists to gather practical knowledge in the engineering process
- Trained on various shop equipment and gained experience with End Lathes, Pneumatic tools, seal, and composite hand layup

President | CWU American Society of Mechanical Engineers | Ellensburg, WA Sept. 2020-Present

- Represent the ASME club to the student senate
- Collaborate with 15-20 fellow club member to plan and host weekly meetings and activities

COMMUNITY PROGRAMS

Eagle Scout | Scouts BSA | Burien, WA

2007-2014

- Led the troop for two year
- Attended various leadership development programs