Spring 2018

YZ250 LHRB

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YZ250 Left Hand Rear Brake

Making a Dual Caliper Bracket for the Rear Axle

By

Ethan Di Loreto

Table of Contents:

b. Proposed schedule
c. Project Management
   i. Human Resources
   ii. Physical Resources
   iii. Soft Resources
   iv. Financial Resources

6. Discussion
   a. Design Evolution / Performance Creep
   b. Project Risk analysis
   c. Successful
   d. Project Documentation
   e. Next phase
7. Conclusion
   a. Restate your design title and its complete design readiness.
   b. Restate your important analyses and how this contributes to success.
   c. Restate your design predicted performance vs actual performance, with respect to your requirements. Use bullets if appropriate.
8. Acknowledgements
9. References
10. Appendix A – Analyses
11. Appendix B – Drawings
12. Appendix C – Parts List
13. Appendix D – Budget
14. Appendix E – Schedule
15. Appendix F - Expertise and Resources
16. Appendix G –Testing Data
17. Appendix H – Evaluation Sheet
18. Appendix I – Testing Report
19. Appendix J – Resume/Vita

INTRODUCTION

Description:

When the foot brake is inaccessible, there is no other way of operating the rear brake. While it has been suggested that you can link hydraulic systems to have two master cylinders, this creates a weak and inefficient system. It was determined that the best way to achieve the goal of having a left hand rear brake is with a secondary caliper. Wherein the problem lays, there is no way to just lay another caliper on the rotor and hope for the best.

A Left Hand Rear Brake (LHRB) means that a motorcycle can not only have the rear brake operated by the foot pedal that comes standard on all bikes, but it can be actuated by a lever located on the handlebar as well. The purpose of this engineering project is to design a bracket that can hold two brake calipers while not hindering stock handling. It should also add braking usability and power.

The device is to be made of mild steel for the first models, this will allow for ease of prototyping, fitment testing, and finalized design testing. The bracket needs to be functional, holding two brake calipers, be crash resistant and resistant to the elements.

The testing methods will be both in the field and in the lab. It will be bench tested for weight and deflection requirements. Then it will be tested in real world situations to see how well it will hold up in maximum conditions.

The predicted results of the steel version of the bracket is to be: 1) The device should not weigh more than 150% of the original bracket for a single brake caliper. 2) No arm of the bracket should deflect more than ten-thousands of an inch under the maximum braking force. 3) The brake lever should be able to complete a full lock of up the rear brakes with a 10lb force pull on the hand lever. After testing sequences are completed an aluminum version is the end goal of the project.

Motivation:

The motivation for this project is mostly a personal preference that applies to the riding style of the author, having a secondary way of applying the rear brake will prove to be very useful in riding situations. As well kits like this are rare, there has never been a production one made for a yz250, and lastly this project should make an affordable version. The complete kits that do exist, are usually around the 500 dollar mark.

Function Statement:

A device is needed that will successfully hold a secondary brake caliper on the rear axle of a 2002 YZ250.

Requirements:

- The project should cost no more than $400 total.
- The steel version should be no more than 150% more than the weight of the original bracket. (Ex. If OEM is 5oz, the project should be no more than 12.5oz)

- Project will be started in steel, for availability and prototype cost purposes. The end goal is to make it out of aluminum. If time allows. This should be no more than 10% the weight of the original bracket.
- It should deflect no more than 0.010" during max braking force. (TBD)
- It should successfully hold two brake calipers, with no problems (deflection listed in #4, break, not fit right or otherwise function improperly).
- The brake set up should provide an easy one finger brake pull. (The brakes should lock up with only about 10lbs of pull on the outside of the lever.)
- If there is time for more design and fabrication: Two different set ups are to be devised, one using the standard rotor, and one using the oversized rotor. The requirement for this is that it should be quick and easy to swap over. No more than 15 minutes total.
- Should be easy to build, time effective. Once process is fine-tuned, 0.5 parts per hour or less should be standard.

Success Criteria:

Project will be successful if the bracket meets or exceeds requirements as well as functions properly.

Scope:

This project will entail an entire auxiliary brake system on a motorcycle, the focus will be mainly on the bracket that holds the calipers.

Benchmark:

Hoheydesigns.com has a dual caliper bracket for a street bike. A model specific bracket for 2003-2010 CBR600RR. It is made of machined aluminum and costs $200, no other specifications are listed on this product.

Project Success:

Success depends on whether or not the bracket will hold two calipers, not break under maximum braking force, and the reliability should be repeatable.

DESIGN & ANALYSIS

The big picture conception of the design was rather easy, once it was decided that two calipers were needed on the rear rotor, all that was needed was a bracket that would hold two calipers. Which brings us to why this is an engineering project. Anybody could slap some metal together with some holes and some bolts to hold it together right? Well quite likely, but this project's goal is to design a bracket that is a light as possible, using engineering techniques to design a bracket that utilizes the least amount of material with the maximum strength. A rough sketch will be shown here of the general idea. This design will be modified and adjusted throughout the quarter to optimize the design. As well as different materials are to be tested as well as different rotor sizes for more or less braking force.

All of this design concept work has been proved and can be viewed in appendix A where the analysis green sheets are located. See Fig. 13 and Fig. 14 for an example of finding the thickness and width requirements of a bracket and the deflection of the bracket at that dimension, respectively. Calculations were also made to prove the worthiness of a larger brake rotor. Showing a noticeable increase in stopping torque at the rear wheel. Along with that it needed to be proven that the stock bolt patterns could handle the added forces. The green sheets proved that you could have a minimally small design while using A36s steel. It was also found that that design would need to be enlarged for aluminum to still have an acceptable safety factor. It appears that going from a half inch wide bracket (steel) to a three quarter inch wide (aluminum) will be good enough. That is using half inch material. However, if that is found through testing to be inadequate using five sixteenths material will raise the safety factor even more as discussed further in the green sheets themselves.

Analysis sheets contain written notes and observations with in them. For example: A quarter inch plate design gives you a safety factor of almost 1.5, which seems low for the given environment, but the weight savings may be worth it. Lab and field testing will determine whether or not a larger safety factor is required. (Fig. 9, Analysis 5, Appendix A)

As of winter quarter with the first round of field testing complete, (see testing section for more information on the testing) a second iteration of the design has been formed based on knowledge learned from the testing. As more explicitly described in the testing section, it appears that the device was subject to overload via side loading. In possible combination with radial load about the axis of the axle. Regardless of the true cause, a need for a stronger design was clear. The overall width of each of the arms was increased from a half an inch to five – eighths of an inch for a better moment of inertia in both directions of possible loading. This also made the design appear cleaner, as the bolt through holes now do not fill up the majority of the space at the end of the arm. Increasing strength at the end of the arms as well. Larger radius fillet were implemented as well to shorten the overall length of the arms providing more resistance to torque as the brakes are applied. Along with this the design was also improved in design by rotating both calipers closer to the swingarm. Keeping this same theme in mind the design was compacted by rotating the caliper closest to the rear of the bike farther forward. *(See figure 3a and 4a).*

So what is the downside of this V2 design? More likely than not we have gone over the original weight requirement. The weight of the additional material will be heavier than the previous version. Once the weight testing starts it will be known for certain though. Now even though material has been added the aforementioned design changes relating to moving the calipers closer together and closer to the swingarm has actually decreased the amount of space that needs to be filled to strengthen the design. As seen in *figure 3a and 4a* the two center arms have essentially been merged and now form one thicker arm. To recap, the strength has been improved and weight has been gained, but minimized as much as possible.

Fig 1 Concept

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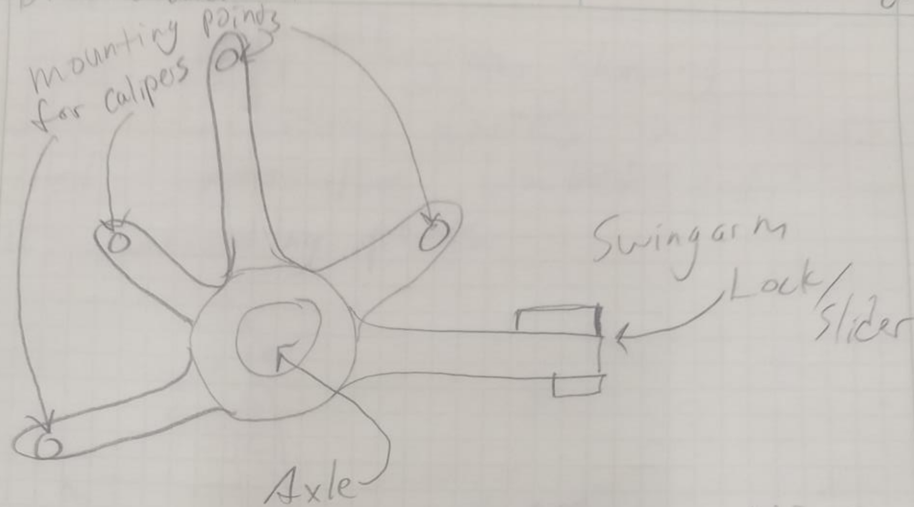
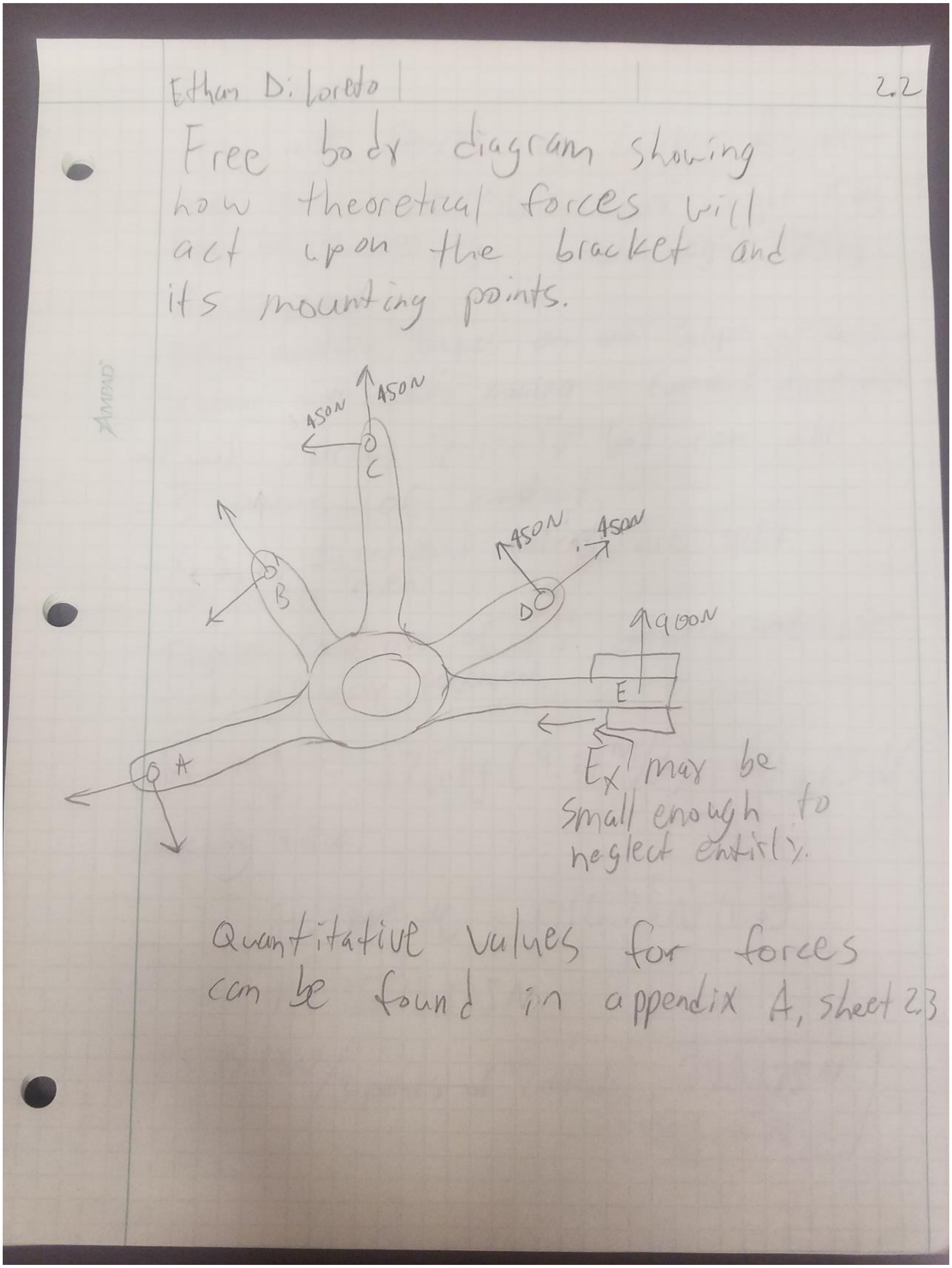


Dual Caliper bracket Sketch V3.0

This version is to be comprised of 5 seperate parts that are easy to manufacture. They will then be welded together to form the bracket. This is done to keep cost low, as well as build efficency. without compromising strength or any of the other requirements.


Ethan Di Loredo 2.2

Free body diagram showing how theoretical forces will act upon the bracket and its mounting points.

E_x may be small enough to neglect entirely.

Quantitative values for forces can be found in appendix A, sheet 2.3

Fig 2 Forces Labeled

Performance Predictions:
This device will allow for an easy brake pull to fully lock the brakes (10 lb pull), it will be designed to be as light as possible (less than or equal to 50% (10% aluminum) of the weight of the original bracket) and it will deflect no more than .10 inches. It will be quick to build once process is designed.

METHODS & CONSTRUCTION

The author has tried to make various version of a dual caliper brake, like a mechanical cable that hooked into the existing system. While that worked, it did not work well, it took considerable effort to pull the lever. While the system could have been greatly improved, the only real way to make it work excellent would be to make it full hydraulic. The author thought of also tapping into the existing master cylinder with a secondary brake line. While this has been documented to work, again it was pretty much a unanimous decision that it sucked compared to a separate system. A weak system is no good, much of the fluid flows from one master cylinder into the other. Leaving the best choice of having two separate calipers. The idea is simple, make a bracket that holds two calipers on the rear axle with a brake line that runs up to the handlebars with a master cylinder/lever for actuation. Costs will be kept down as much as possible as this project will be funded by the author. Most parts can be bought. Everything else can be built. After using a decision matrix it has been reluctantly decided to go with aluminum and steel, while a composite would be far neater of a project, it is somewhat out of the scope of this project.

Device Construction:
The main piece that will be built will be made out of plate steel or aluminum (different models) to specified dimensions. After all the parts of the bracket have been formed, the bracket can be installed on the motorcycle. Then the calipers (bought) can be attached to the bracket, the stainless steel brake line(s) (bought) hooked up after that, and finally the master cylinder/lever (bought) hooked up. Of course the brakes have to be bled once that is complete.

After completely building a few of the devices it can be noted that welding is probably the most time intensive part of the build process. It was originally thought that this would be fairly simple. Yet proven to not be the case. The other parts of the project are about as they appear to be. The axle spacer can be cut with the band saw to have multiple pieces after the lathe work has been done. Only leaving the milling of the keyway which is very quick. The axle block is also very smooth piece to make. It is still unfortunate that the project was built in solid works 2017, and thereby cutting off access to CNC programs. It was not an issue however as the part was still time effective to build by hand. Even clearing the hole of extra material was quicker and easier than first thought.

As for the welding of the project, as mentioned earlier it was slightly more difficult than expected. It was designed so that all welds would take place on the back side of the part. The first step is to put the main bracket over the axle spacer, check for flushness and weld the backside. The next step is to slide the swing arm lock bracket portion onto the axle slider as well. It is at this point it was discovered that when sliding the piece on it comes into contact with the welds too soon. Leading to two options, either make the weld smaller or remove material after the weld has been laid. Since it is only welded on one side make the weld weaker is not a good option. This means slight removal of material so that the bracket will slide on farther. Which albeit not difficult takes time. This is the only real hiccup encountered though. The axle block then slips into its place and can be welded as planned. That is the last step of welding. Check over the welds and clean them up if necessary and then install.

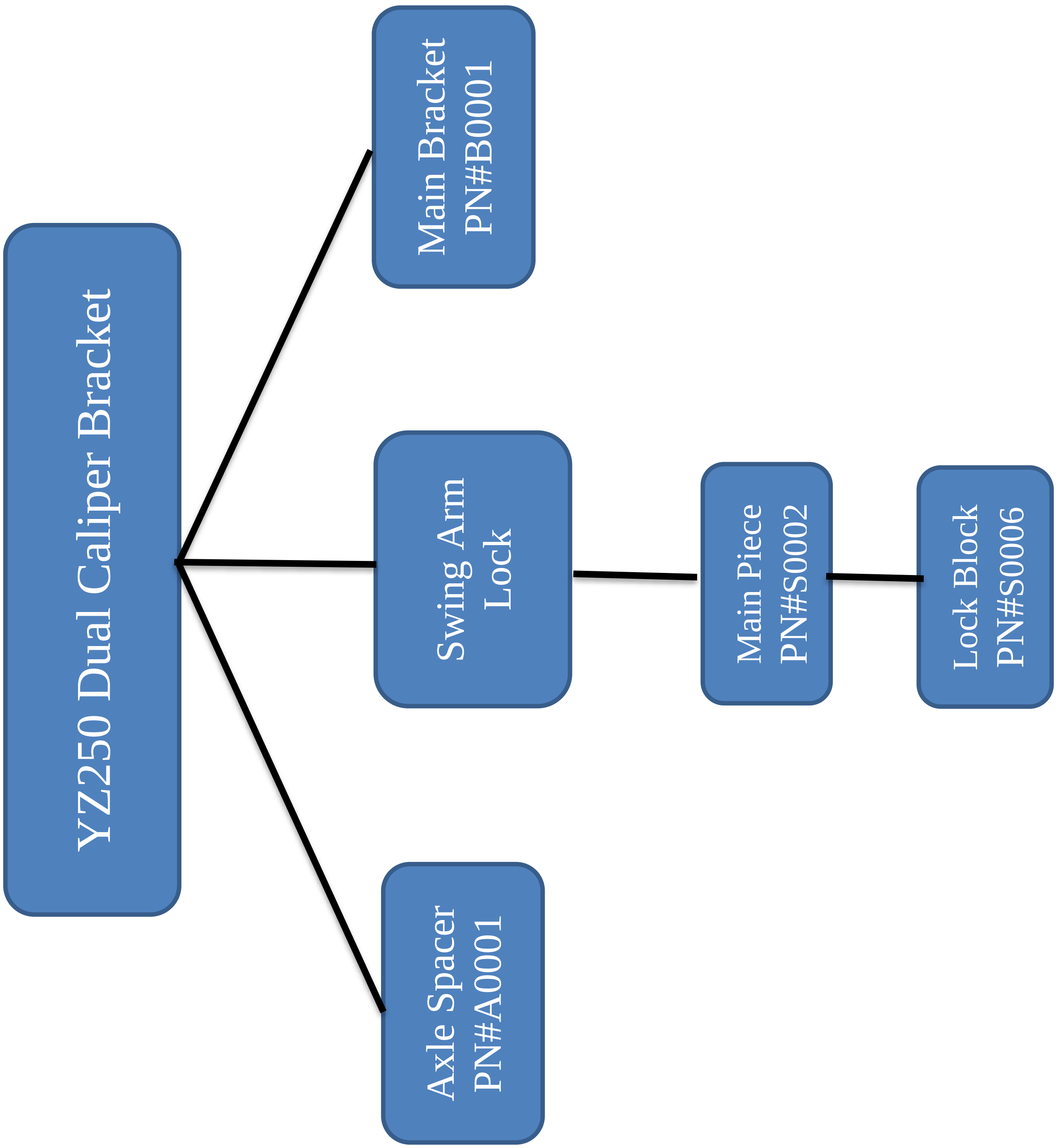
Device Construction, referenced with drawings:
See Appendix B for specific drawings. All parts of the bracket parts need to be welded together. Once that is complete, the

Device Operation:

The operation of this device is very simple, it is to hold two calipers while adhering to the rest of the design requirements. The system operation is simple as well. It needs to be able to be able to lock the rear wheel up using either of the brake calipers at any given time.

Benchmark Comparison:

The device will be within 20% of the weight of the benchmark. The device will produce the same or more braking torque than the benchmark under a standard pull of 10 lbs on the lever.


YZ250 Dual Caliper Bracket
Main Bracket
PN#B0001
Swing Arm
Lock
Axle Spacer
PN#A0001
Main Piece
PN#S0002
Lock Block
PN#S0006

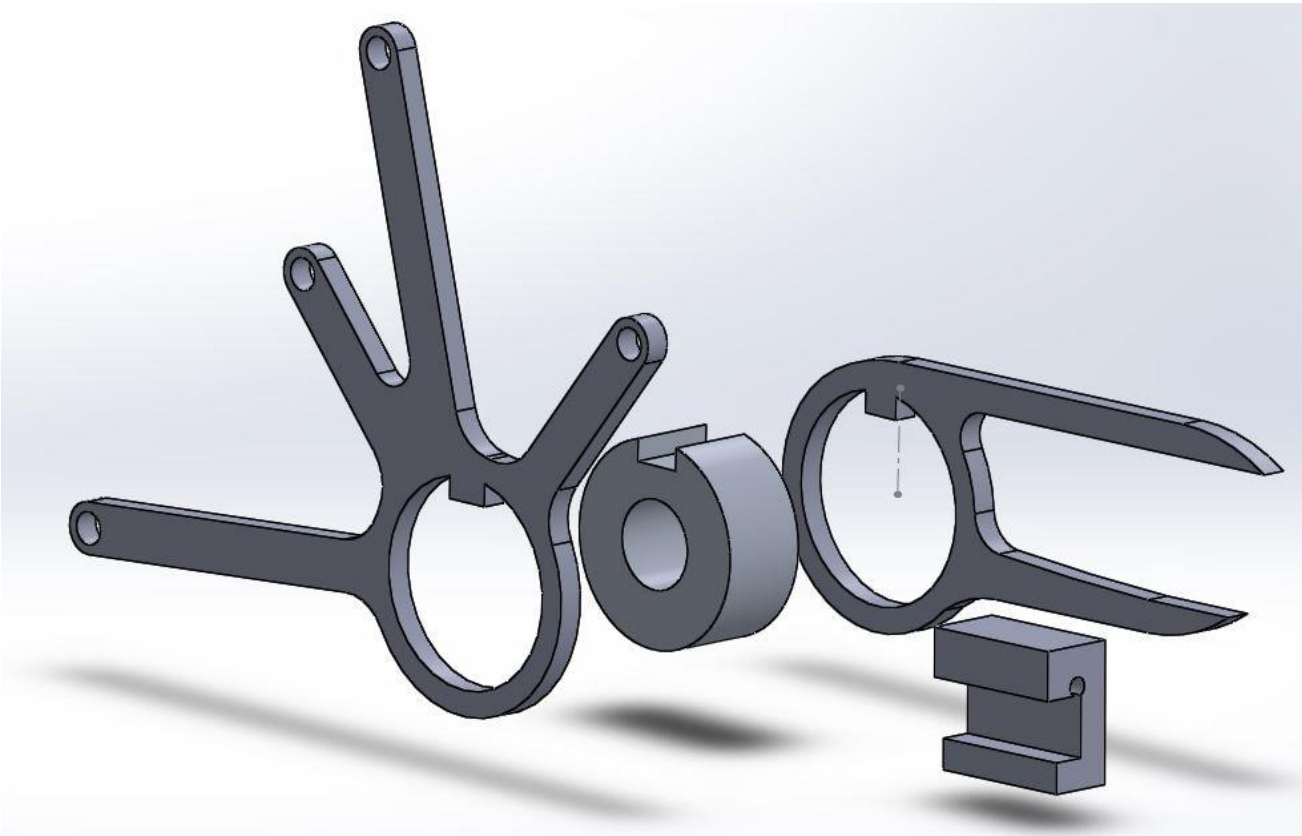


Fig 3 Exploded View. (V1)

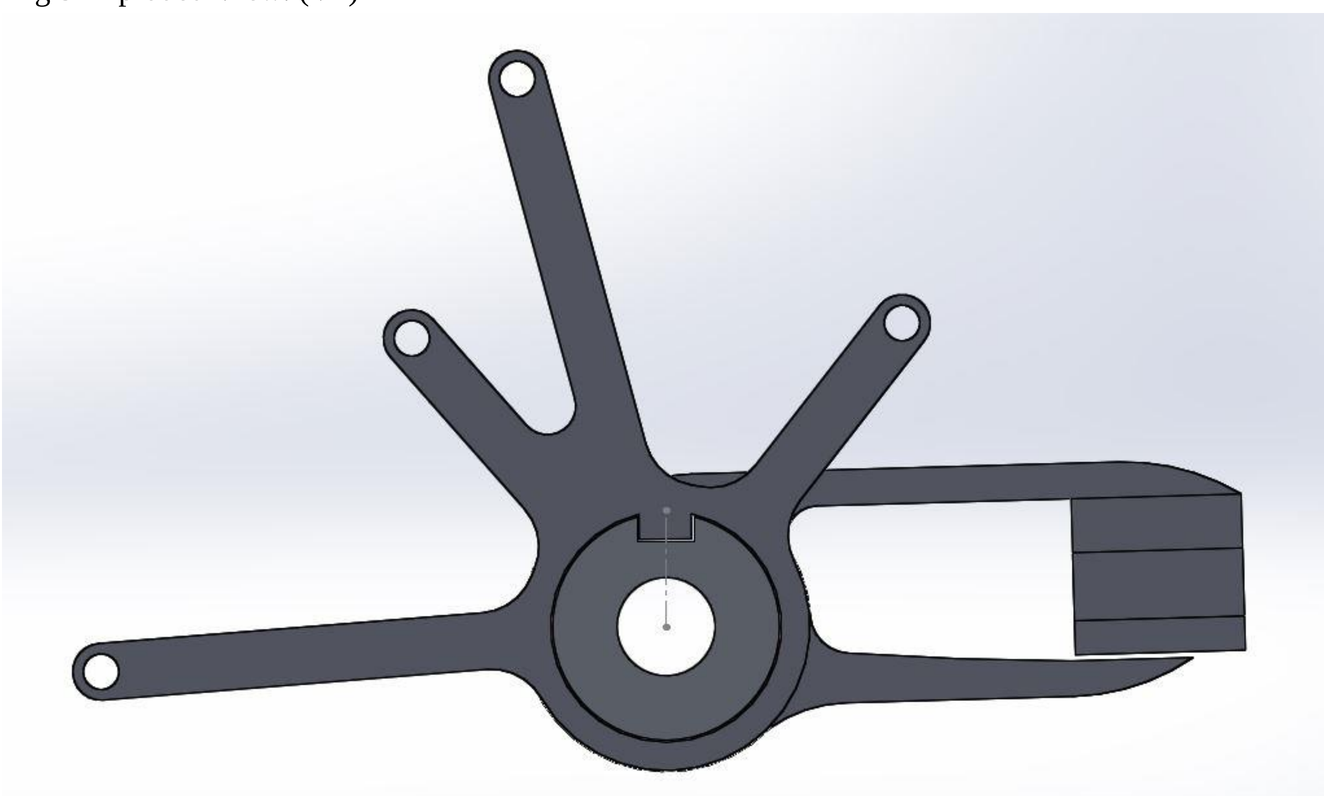


Fig 4 Completed Assembly View. (V1)

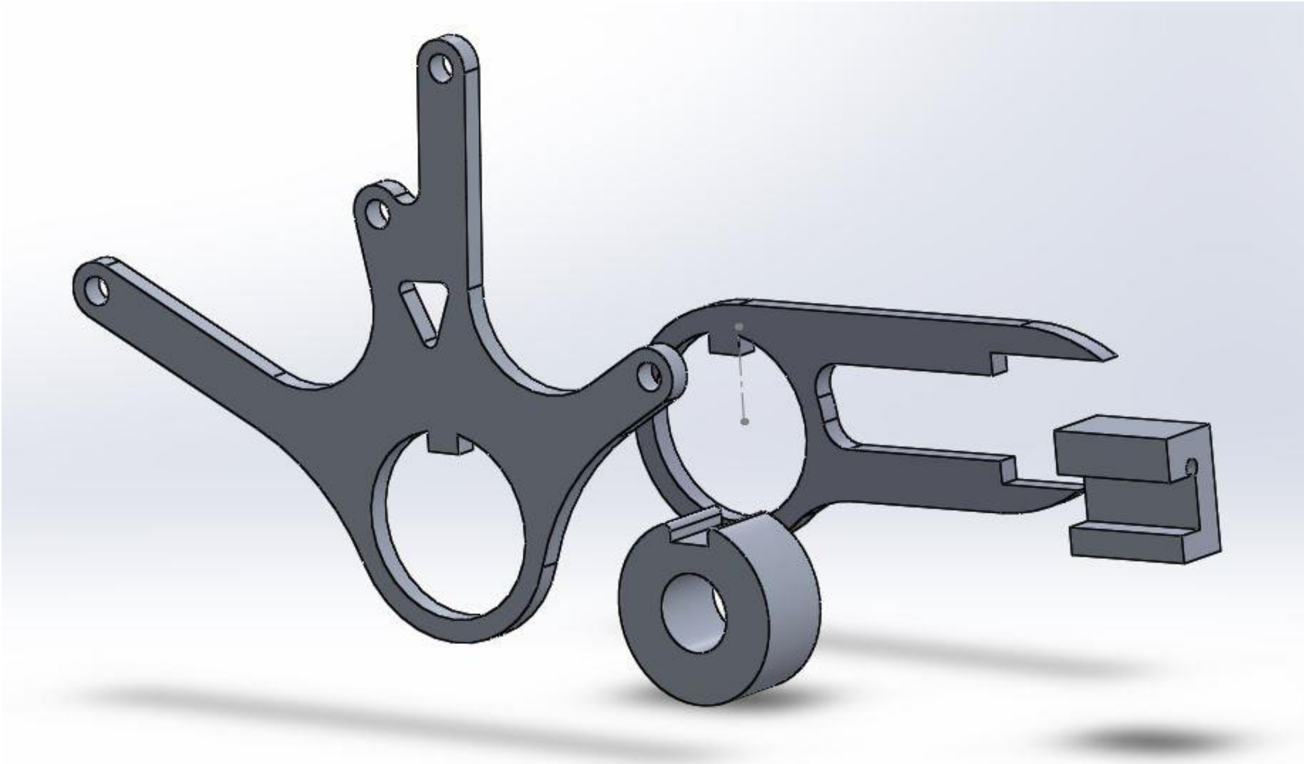


Fig 3a Exploded View. (V2)

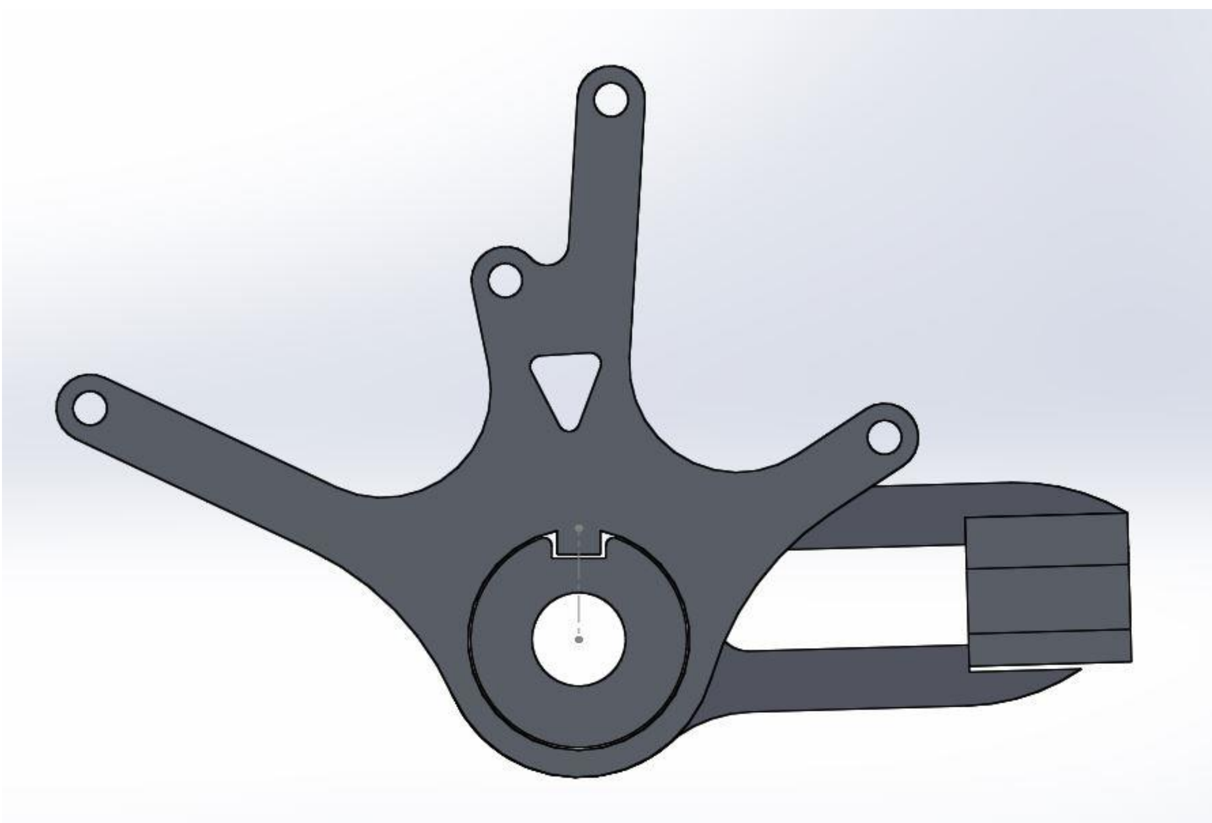


Fig 4a Complete Assembly View. (V2)

TESTING METHOD

Test for weight requirements:

Weigh OEM parts, weigh designed parts, compare.

Test for deflection:

Design jig to hold device. Hang weights from bolt holes in approximate direction of braking force. Add weight until desired and measure the deflection in intervals.

Testing for brake force created by lever pull:

Measure how much many fingers (of the designer/author) are needed to produce approximately 10 pounds of force. Then take bike to test site, use phone GPS to get up to 20mph, 30mph etc… and see if the rear tire will completely lock up until a full stop is complete. Using only the correct predetermined force from fingers always on the end of the lever. (Leverage changes depending on location of lever pull.)

BUDGET/SCHEDULE/PROJECT MANAGEMENT

Cost and Budget:

The total cost of this project is estimated to be $222.44. The majority of the cost will be buying additional parts (not project material). The Majority of fabrication/design will be on a plasma table. The author will be fully funding this project.

The largest (as in the most expensive) items were the calipers, the master cylinder and the brake line. All other fittings, hardware and even supply metal were of little expense in comparison. The brake calipers were bought used of EBay, as OEM equipment bought new is extremely expensive. The brake line was one of the highest priced items due to it's longer than normal length. A 75" Stainless Steel line was need to be properly routed from the handlebars to the rear wheel.

In the future it would be beneficial to purchase a stainless steel brake line to replace the OEM one going to the foot brake. This will improve upon the stock brake line for a few reasons. It will be tougher and more abrasion resistant, a new banjo can be purchased to route the brake line down the caliper so it does not stick out as far (to avoid being hit by rocks etc…) and lastly SS brake lines do not have the tendency to bulging under braking. This bulging is most noticed in situations where the brakes are operating at high temperatures. When bulging occurs the brake line expands and the valuable force that could be going to the caliper is wasted.

All parts have been bought. All parts arrived on time, or have yet to arrive, but are on track to arrive on time. No incorrect parts were shipped so far. Some parts/metal supply were either cheaper than expected (coupons, other discounts) or were in the case of the steel from Hansen Metalworks, it was donated at no charge.

Anything that needed to be ordered was ordered. Some parts for the aluminum version are currently in transit. Once those are obtained, the building of the aluminum version can commence. There should be little to no slow down.

There are only a few consumables is this system, the brake pads will be the most common item to be replaced. They are about 30 dollars for a pair of pads from the local motorcycle dealer.

Through standard use they will become thin past the point of safe operation and will need to be replaced. Brake fluid is the only other consumable. Its life span greatly depends on how hard the brakes are used. The only real reason it needs to be replaced (if it was installed properly in the first place) is if it gets too hot.

Schedule:

Tasks:

Complete Intro
Design and Analysis
Methods and Construction
Testing Methods
Discussion and Conclusion
Appendix
-Milestone 1
Obtain Materials (2" Round Bar, 3/4" Flat Bar (Alum and Steel)
Axle Spacer lathe set up
Axle Spacer Lathe Cuts (Drill, Bore)
Axle Spacer mill set up
Axle Spacer mill cuts
Build swing arm lock block
Hole location
Drilling
Mill Setup
Mill Operations
Hole clearing
Cut out main bracket piece (Outsource, 1 week)
Cut out swing arm lock main piece (Outsource, 1 week)
Press Parts together
Install for test fit
MIG/TIG welder setup
Weld Layout setup
Weld bracket cutouts together
Complete install for testing (brake lines, master cylinder etc…)
Clean up (Total)
Project Build (Milestone 2)-Milestone 2
Test Weight Requirements
Obtain Scale
Build test Jig
Test Deflection Requirements
Set up for brake force testing
Test Braking force/lever pull
Complete Testing (Including write up) (MS3)-Milestone 3

Milestones:

Milestone 1: Complete project proposal by end of fall quarter.
Milestone 2: Complete project build process by end of winter quarter.
Milestone 3: Complete project testing by end of spring quarter.
Total project time estimated to be hours.

Schedule Discussion:

The main goal of this project is to prove the author is proficient in engineering. To do this a project needs to be properly proposed, designed, built and tested. In this project it was decided to add extra steps that can be taken to take the project over the top. Those extra steps are however entirely dependent on how much time and money remains from doing what is absolutely necessary to the project. The schedule was designed with those points in mind. To complete the schedule is to complete one single part. This means it is fully welded and ready for install. For the actual hours of the schedule it was chosen to use only the first build for the hour's calculation. The time decreased immensely for the second iteration. And in theory it would continue to decrease before reaching at flat spot in time. Also building multiple parts at the same time will decrease build time. Making the designated 0.5 parts per hour completely feasible. For the purposes of this assignment it made the most sense to show how long it took to build the first one. As for specifics, it turns out that the first one took an entire 2 hours less than expected. 10.7 hours was expected, 8.7 hours was the actual. Which sounds like a long time still, but as expected nothing goes as smoothly as planned the first time and all sort of things come up that need to be dealt with.

Next topic is start and finish times. Project was ahead of schedule the entire time. Weeks 1 through 4 of winter quarter was all that was needed to get the first version done. Weeks 4 through 6 the aluminum version was started. However, once the first test of the steel version was complete the second one was started with new design complete. The aluminum project was having difficulty with the plasma cutter as well. This was partially expected. Which is exactly why the author deemed the steel version the necessary part for completing. Just in case anything came up in something that the author was not as familiar with. The last weeks of the quarter were spent working on the report and fine tuning the project. *(See Gantt chart in Appendix E for reference).*

Project Management:

Risk:

All risk associates with safety. Proper safety equipment and measures must always be taken when: Using equipment for building the project and when using project after complete.

The author will provide all designs calculations and parts of this project. Resume is found in Appendix J.

DISCUSSION

Already issues have been met along the process. The original idea was to buy one more rear caliper and make a new bracket that could hold two rear calipers. The bracket would be extremely difficult to make for the rear OEM rear calipers without casting due to their intricate design. They have an external brake clip embedded into the bracket casting. Making a casting for a low production process does not make very much sense. The next idea was to use street bike calipers in the rear. The brake pads were self-contained. Letting me have a sensible design for my bracket. It was originally planned that the bracket would be made out of machined aluminum. The main problem with this design was that the street bike calipers had a large over hang in the back and interfered with the wheel spokes. This issue was being worked around, however over thanksgiving brake a new idea formed and it was decided to do one final major change in direction for the project. ***(Pg. 10 Pic 1 and Pic 2)***

People in the past have done the machined aluminum brackets. To make this one better than the benchmark this bracket will be even lighter and most importantly cost effective. Having simply parts and a quick production process will make the option affordable. Using the front calipers off the yz250 on the rear is another advantage. This will not only make the entire kit more cost effective, but a dual piston caliper will give better braking force as well as better braking feel at the hand lever.

Lastly the project will be made out of steel in original form. ***(Fig 7 appendix A)*** Sort of a prototype method as it were. Steel plate is cheaper and easier to weld than its aluminum counterparts. Once the dimensions and process is perfected it can be converted over to aluminum. ***(Fig 10 appendix A)*** (While making proper bracket size adjustment based on material. Calculations found in appendix A for these differences.)

If there is still time left in the schedule a convertible method should be in the works as well. Having a larger rotor gives you even more brake power and brake feel at the lever. ***(Fig 5 appendix A)*** But adds considerable weight. The best option then: having both. An adapter bracket that raises the calipers up to account for the larger rotor will be made. The swap should be quick, and will give the rider the best set up no matter the conditions.

In the future it would be great to continue with making this a composite bracket. Even with a larger rotor, a composite bracket will have such a low weight that it would be well worth the effort. It is just out of the scope for this project timeline. Having created the bracket out of aluminum will make it easy in the future to go the composite route though. It will be able to make a cast of the original part and make composite molds off that.

CONCLUSION

Fall Conclusion:

After much consideration it is believed that the current design requirements will provide the best product for its intended use. It will successfully solve the solution. The design should in theory from the numbers and calculations generated meet all the requirements given. As mentioned in the discussion section, the most recent iteration of the project, along with meeting all the requirements, will exceed in other areas. In theory it should be cost effective, quick, strong, light and versatile. A virtual best of both worlds.

Winter Conclusion:

As winter comes to a close, two version of the project have been made and one round of testing has been completed on the first version. The first test brought much needed improvements to light. It was also an opportunity to clean up and improve the overall look and design of the bracket. See the testing and design sections for more in depth discussions on the project. Now the project is tucked in closer, has more protection for trail damage caused by rocks and trees etc… Two of the arms have been combined to reduce needed material for strength to go along with the overall increased cross sectional area of the arms and bracket. In final conclusion for winter the last iteration of the project will be the strongest and most compact version yet and is likely to succeed and excel in testing. With the one drawback being that is likely to fail the weight test due to added material.

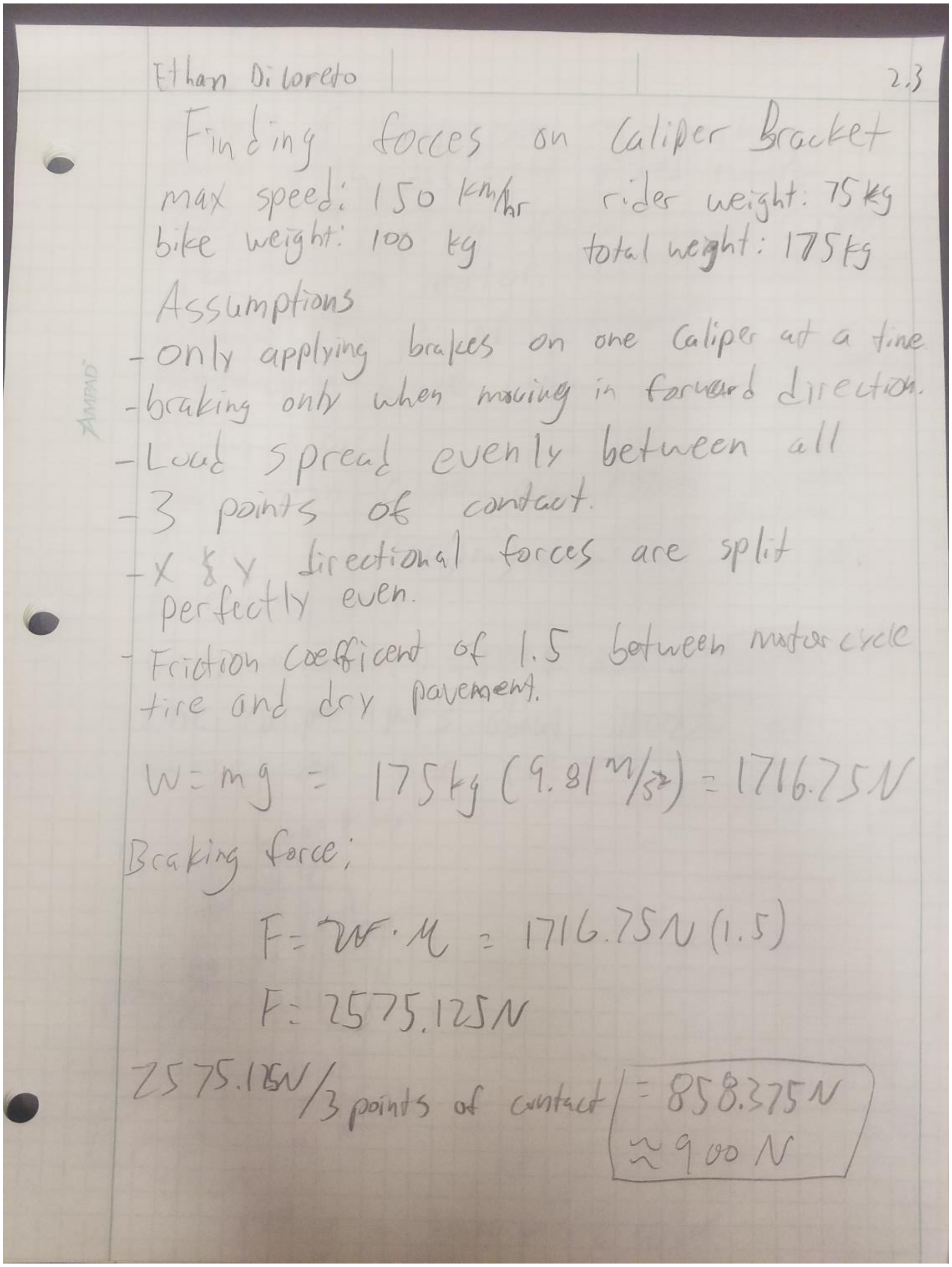
Spring Conclusion:

With the proposal, the building, and the testing complete a final conclusion to the project can be formed. While as usual nothing goes perfectly according to plan this project went considerably well. The end result was a product that worked great and with the exception of the weight, passed all requirements set at the beginning of the year. Only one version failed in testing, and with a valuable lesson learned the project was strengthen and succeeded. In the future a water jet should be used to cut aluminum pieces out to complete the aluminum version. Depending on whether or not the weight is satisfactory or not, the next step would be a composite bracket to reduce weight further. All in all project was a success.

ACKNOWLEDGEMENTS

Professor Ted Bramble for his input on the build portion of the project.
Tyler Hansen for his use of plasma table, help cutting materials, donation of some project material and input from real world experience as a power sports mechanic of over 10 years.
Matt Burvee for help setting up welding equipment and machine shop equipment, and input on designs.
Nolan Stockman for helping in welding/machining labs and for filming welding for video requirements in senior project.

APPENDIX A – Analyses



Ethan DiLoreto 2/3

Finding forces on Caliper Bracket

max speed: 150 km/hr rider weight: 75 kg
bike weight: 100 kg total weight: 175 kg

Assumptions
- only applying brakes on one caliper at a time
- braking only when moving in forward direction.
- Load spread evenly between all
- 3 points of contact.
- X & Y directional forces are split perfectly even.
- Friction coefficent of 1.5 between motorcycle tire and dry pavement.

$W = mg = 175kg(9.81 m/s^2) = 1716.75N$

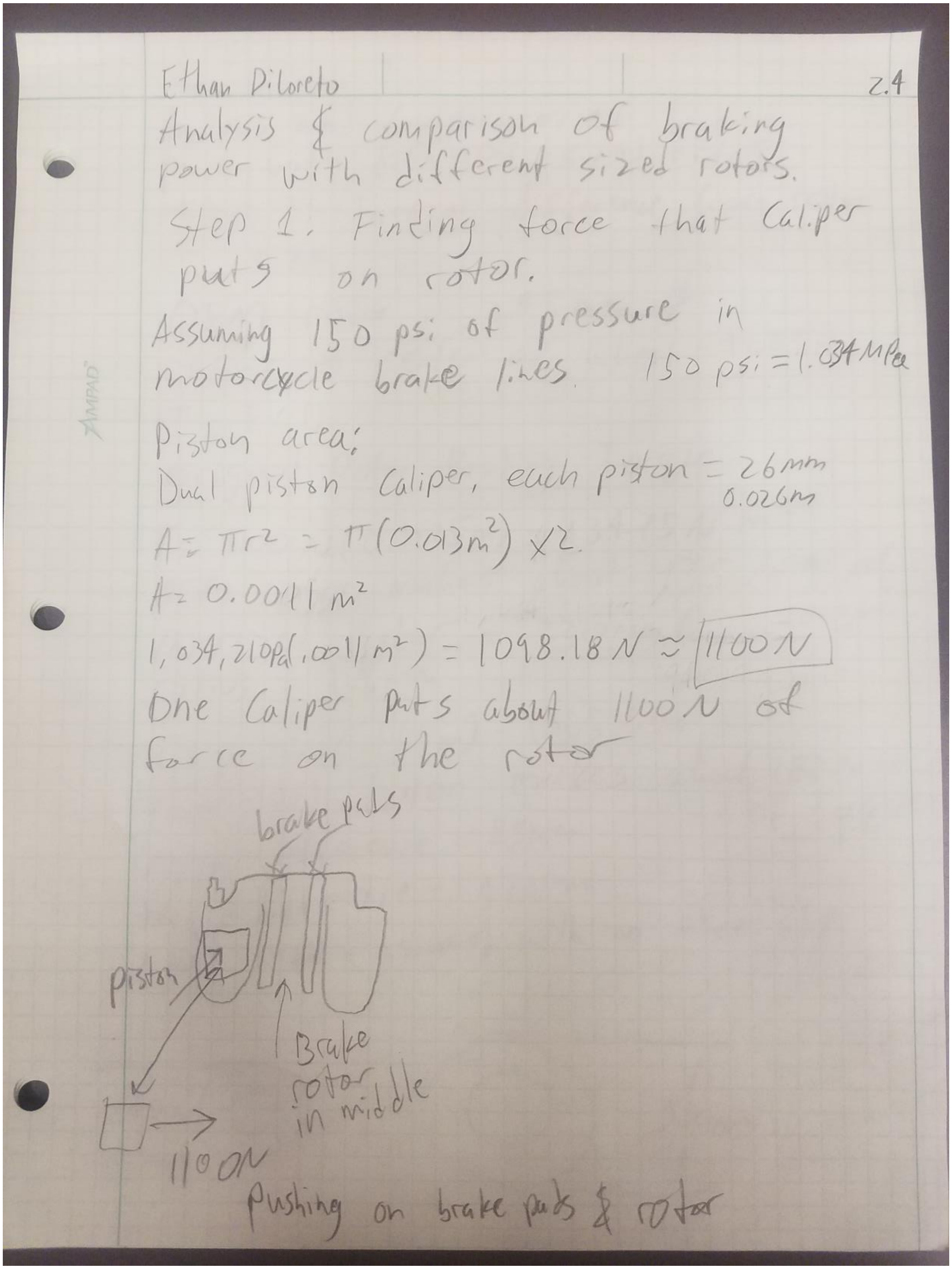
Braking force;

$F = W \cdot \mu = 1716.75N(1.5)$

$F = 2575.125N$

$2575.125N / 3$ points of contact $= 858.375N \approx 900N$

Fig 5 Analysis 1


Ethan Diloreto 2.4

Analysis & comparison of braking power with different sized rotors.

Step 1: Finding force that Caliper puts on rotor.

Assuming 150 psi of pressure in motorcycle brake lines. 150 psi = 1.034 MPa

Piston area:

Dual piston Caliper, each piston = 26mm
0.026m

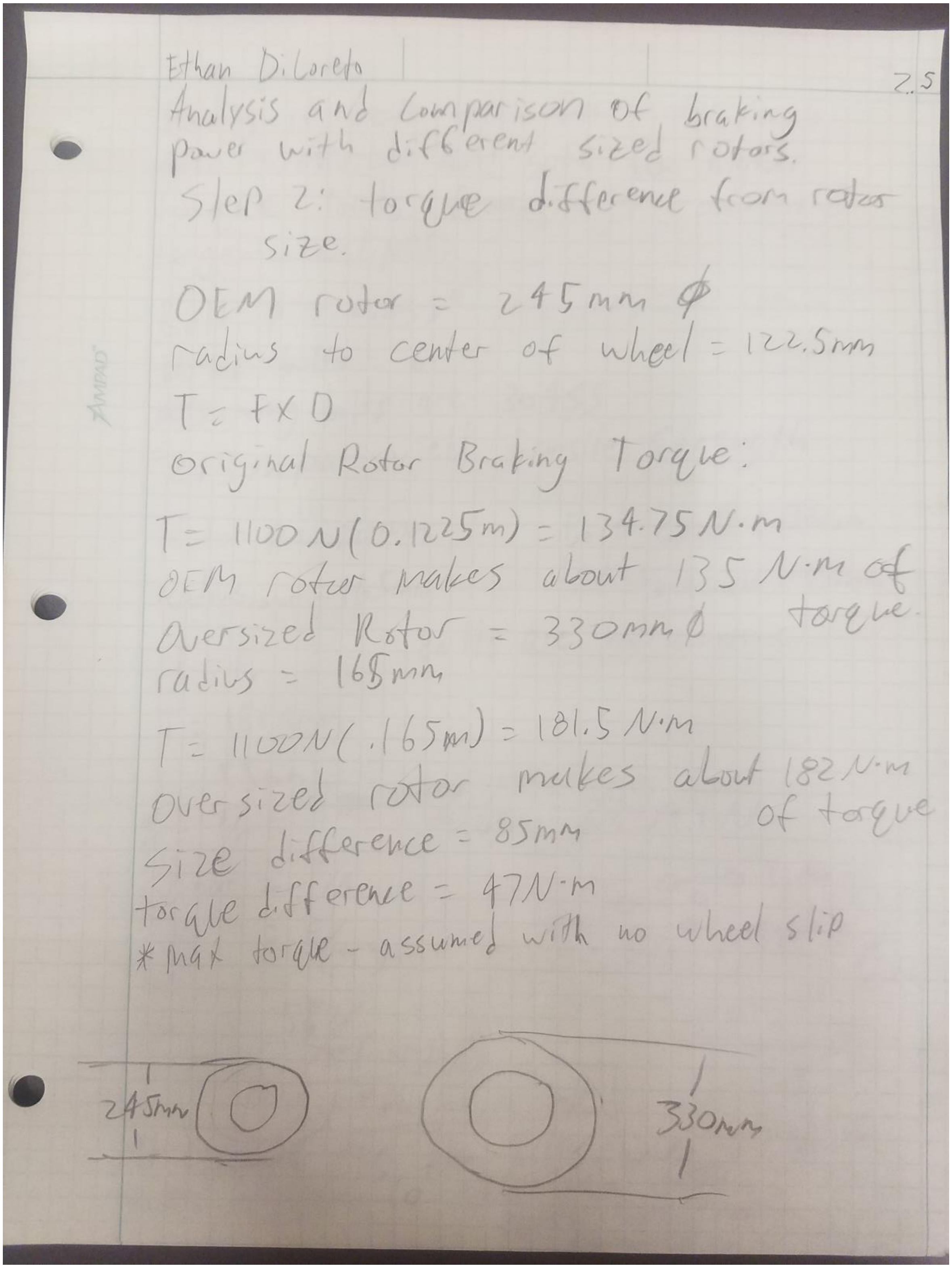
$A = \pi r^2 = \pi(0.013m^2) \times 2$.

$A = 0.0011\ m^2$

$1{,}034{,}210Pa(.0011\ m^2) = 1098.18\ N \approx$ 1100 N

One Caliper puts about 1100 N of force on the rotor

Fig 6 Analysis 2



Ethan DiLoreto

2.5

Analysis and Comparison of braking power with different sized rotors.

Step 2: torque difference from rotor size.

OEM rotor = 245mm ϕ

radius to center of wheel = 122.5mm

T = F × D

Original Rotor Braking Torque:

T = 1100 N (0.1225 m) = 134.75 N·m

OEM rotor makes about 135 N·m of torque.

Oversized Rotor = 330mm ϕ

radius = 165mm

T = 1100N (.165m) = 181.5 N·m

oversized rotor makes about 182 N·m of torque

size difference = 85mm

torque difference = 47N·m

* max torque - assumed with no wheel slip

Fig 7 Analysis 3

Ethan DiLoreto 2.6

Finding if OEM bolts for rotor/hub are sufficient and safe for higher torque loads from larger rotor and larger caliper.

Bolt $\phi = 0.235''$ $r = .1175'' \approx 2.985mm$

\# of bolts = 6

assuming bolts are 304SS

215 mpa yield tensile strength

Rotor $\phi = 330mm$

$Radius_{rotor} = 165mm$

Bolt circle = 110mm

$radius_{Bolt\ circle} = 55mm$

Bolts are hub centric

$T = F_r$

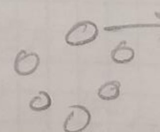
$T = 182\ N\cdot m$

$r = 55mm$

$F = T/r = 182\ N\text{-}m / 0.055m = 3309.1N$

Shear $= F/A$

$= F/(\pi r^2)$



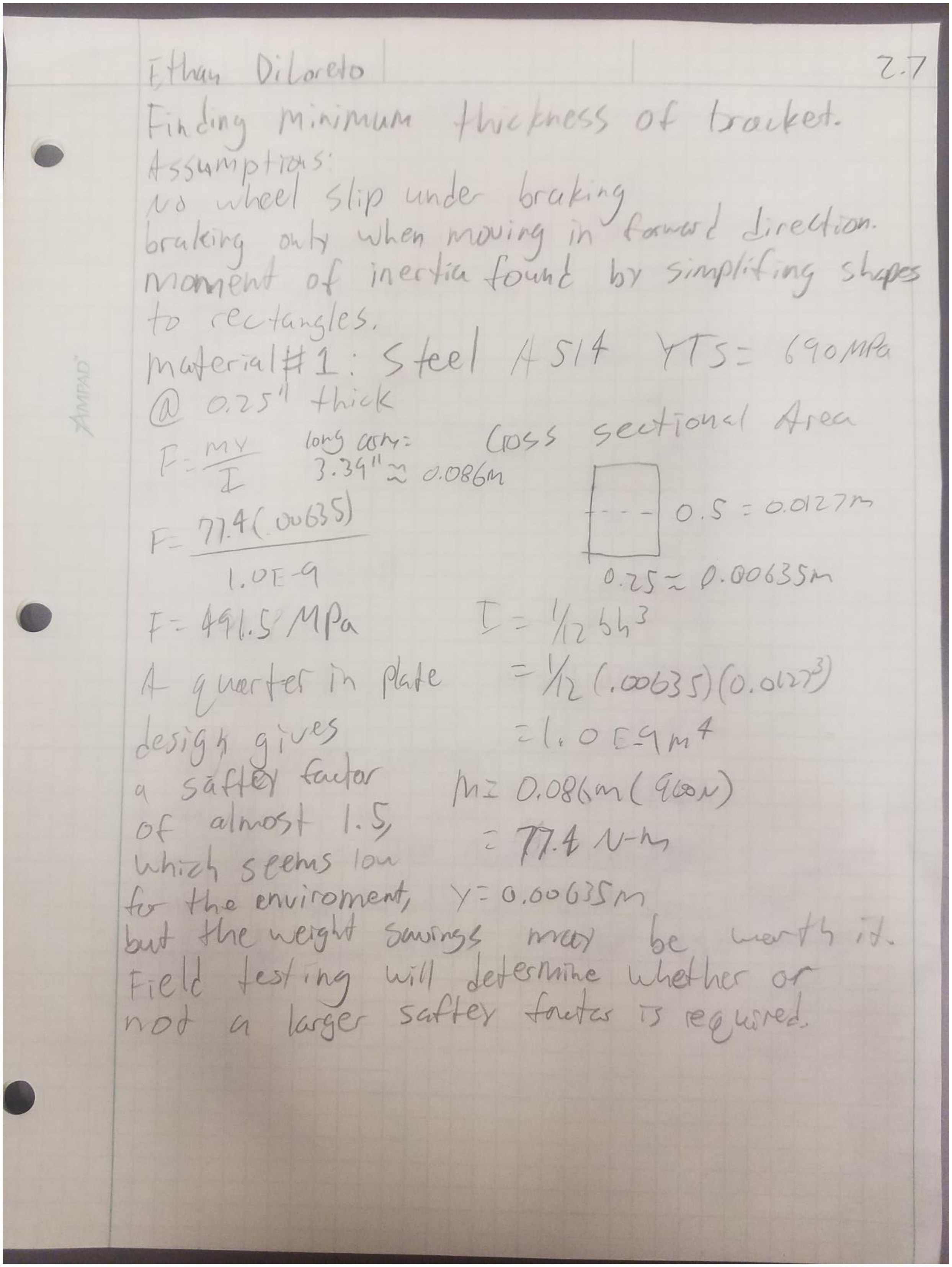
$= 552 / \pi(.00298^2)$

$= 19.8\ MPa$ on a bolt

At 215 mpa YTS, the bolts have a safety factor of over 10 before they yield.

Bolts are safe.

Fig 8 Analysis 4



Ethan DiLoreto 2.7

Finding minimum thickness of bracket.
Assumptions:
No wheel slip under braking
braking only when moving in forward direction.
moment of inertia found by simplifing shapes to rectangles.

material #1: Steel A 514 YTS = 690 MPa
@ 0.25" thick

$F = \frac{MY}{I}$ long comp: 3.39" ≈ 0.086m

Cross sectional Area
0.5 = 0.0127m
0.25 ≈ 0.00635m

$F = \frac{77.4(.00635)}{1.0E-9}$

F = 491.5 MPa

$I = \frac{1}{12}bh^3$
$= \frac{1}{12}(.00635)(0.0127^3)$
$= 1.0E{-9}\ m^4$

M = 0.086m (900N)
= 77.4 N-m
Y = 0.00635m

A quarter in plate design gives a saftey factor of almost 1.5, which seems low for the enviroment, but the weight savings may be worth it. Field testing will determine whether or not a larger saftey factor is required.

Fig 9 Analysis 5

Ethan DiIorcio 2.8

Minimum bracket dimensions.

Assumptions:

Same as 2.7 in appendix A.

Changes must be made for aluminum

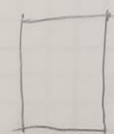
I will still use 1/4" plate but a larger width.

6063-T6 Aluminum

YTS = 241 MPa

longarm: 0.086m

Cross section



$F = \frac{My}{I}$

$I = \frac{1}{12}(.00635)(.01905^3)$

$= 4.0E-9$

$F = \frac{77.4(.009525)}{4E-9}$

$M = 0.086m(900N)$

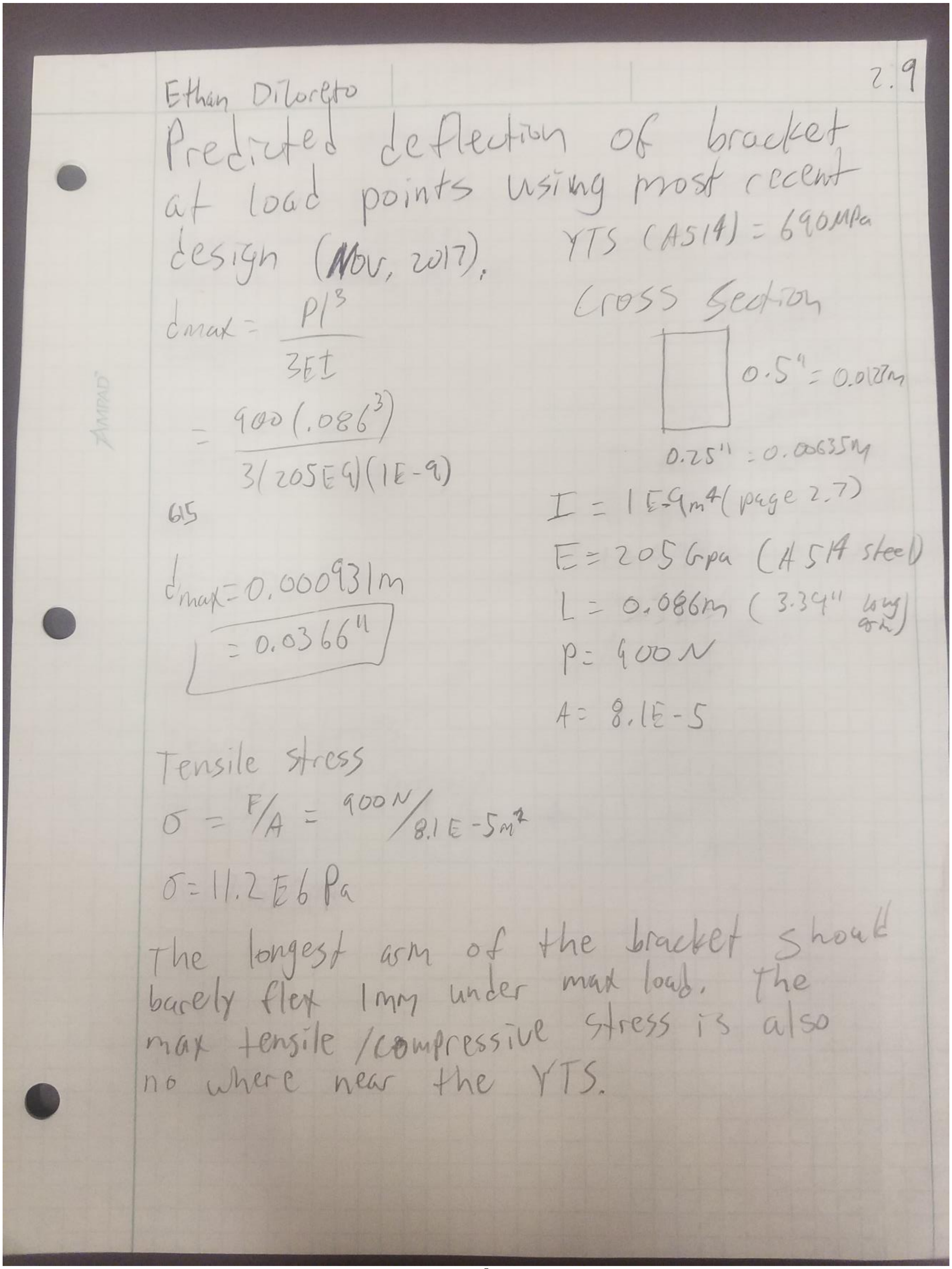
$= 77.4\ N\text{-}m$

$F = 184.3\ MPa$

$y = 0.009525m$

A larger cross section area gave us about the same safter factor compared to steel. Almost 1.5. Which is still low but could be worthwhile for the weight savings.

Fig 10 Analysis 6



Ethan DiLoreto 2.9

Predicted deflection of bracket at load points using most recent design (Nov, 2017).

YTS (A514) = 690MPa

Cross Section

0.5" = 0.0127m

0.25" = 0.00635m

$d_{max} = \frac{Pl^3}{3EI}$

$= \frac{900(.086^3)}{3(205E9)(1E-9)}$

615

$d_{max} = 0.000931m$

$= 0.0366"$

$I = 1E\text{-}9m^4$ (page 2.7)

$E = 205$ Gpa (A514 steel)

$L = 0.086m$ (3.39" long arm)

$P = 900N$

$A = 8.1E\text{-}5$

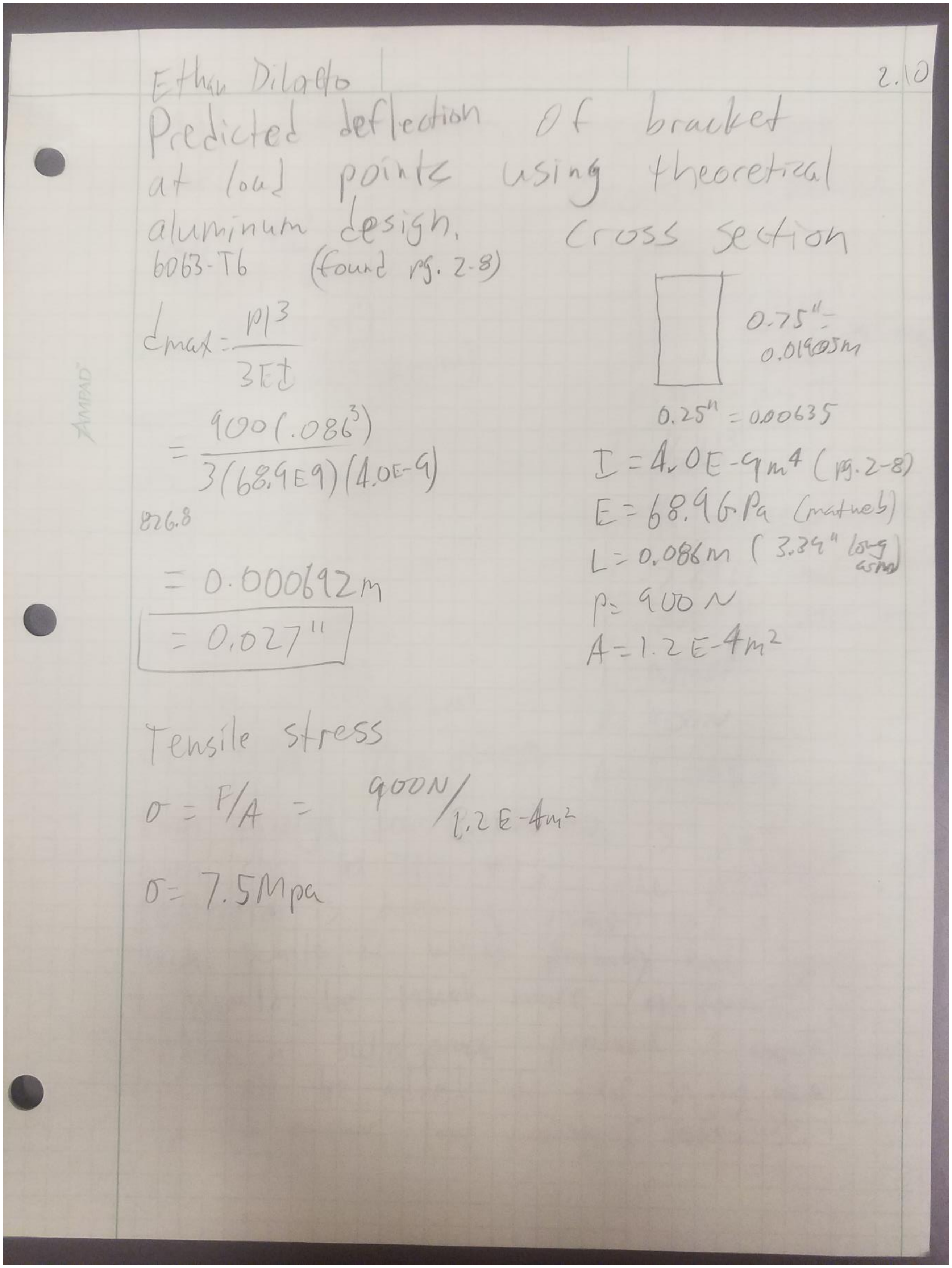
Tensile stress

$\sigma = F/A = 900N / 8.1E\text{-}5m^2$

$\sigma = 11.2E6$ Pa

The longest arm of the bracket should barely flex 1mm under max load. The max tensile/compressive stress is also no where near the YTS.

Fig 11 Analysis 7



Ethan DiLoreto 2.10

Predicted deflection of bracket at load points using theoretical aluminum design.

6063-T6 (found pg. 2-8)

$$d_{max} = \frac{Pl^3}{3EI}$$

$$= \frac{900(.086^3)}{3(68.9E9)(4.0E-9)}$$

826.8

$= 0.000692m$

$= 0.027''$

Cross section

0.75" = 0.01905m

0.25" = 0.00635

$I = 4.0E-9 m^4$ (pg. 2-8)

$E = 68.9 GPa$ (matweb)

$L = 0.086 m$ (3.39" long asm)

$P = 900 N$

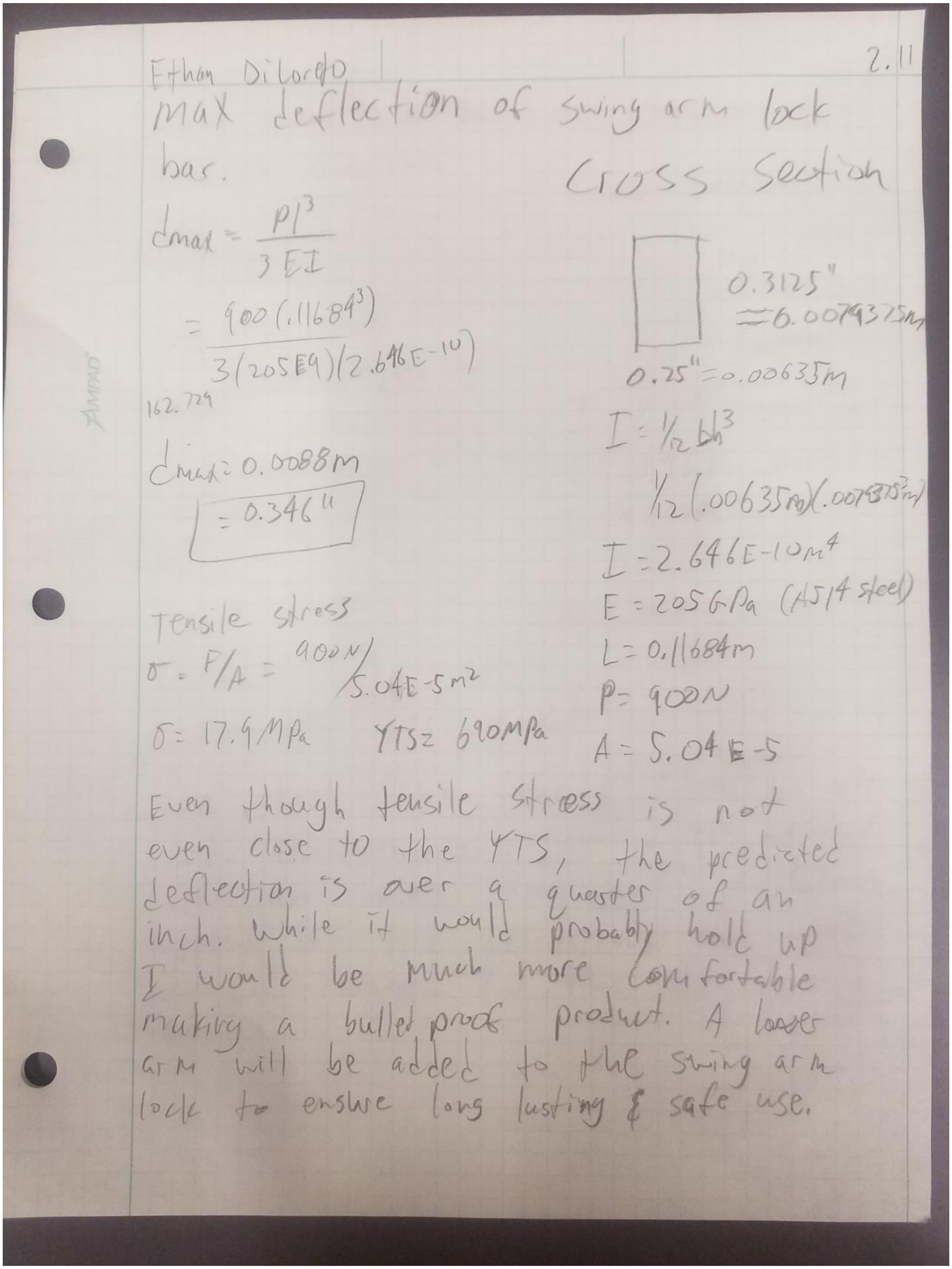
$A = 1.2E-4 m^2$

Tensile stress

$\sigma = F/A = 900N / 1.2E-4 m^2$

$\sigma = 7.5 Mpa$

Fig 12 Analysis 8



Ethan DiLordo 2.11

max deflection of swing arm lock bar.

$d_{max} = \frac{Pl^3}{3EI}$

$= \frac{900(.11684^3)}{3(205E9)(2.646E-10)}$

162.729

$d_{max} = 0.0088m$

$= 0.346''$

Cross Section

0.3125" ≅ 0.0079375m

0.25" = 0.00635m

$I = 1/12\, bh^3$

$1/12(.00635m)(.0079375^3 m)$

$I = 2.646E-10 m^4$

E = 205 GPa (A514 steel)

L = 0.11684m

P = 900N

A = 5.04 E-5

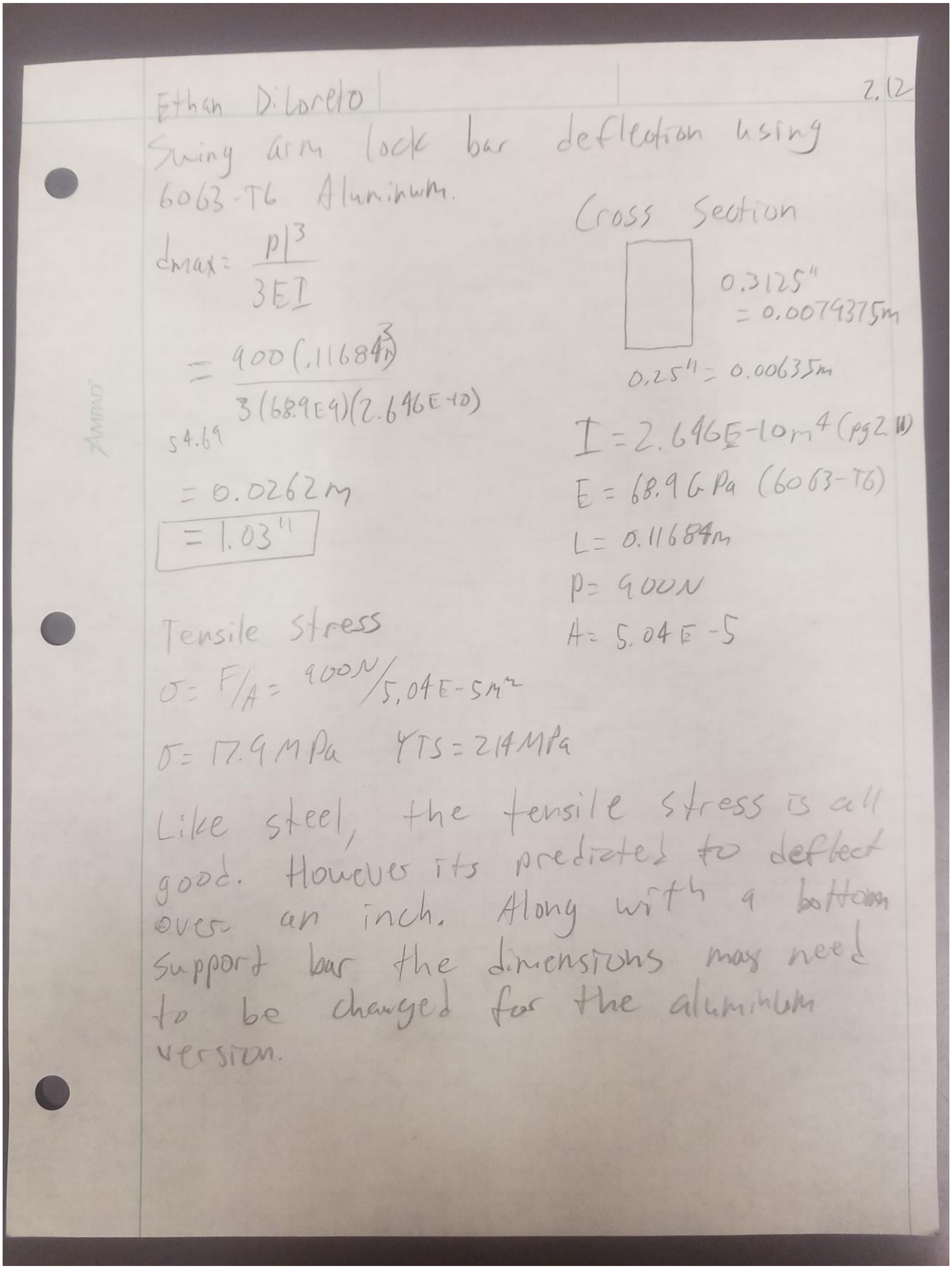
Tensile stress

$\sigma = F/A = 900N / 5.04E-5 m^2$

σ = 17.9 MPa YTS = 690 MPa

Even though tensile stress is not even close to the YTS, the predicted deflection is over a quarter of an inch. While it would probably hold up I would be much more comfortable making a bullet proof product. A longer arm will be added to the swing arm lock to ensure long lasting & safe use.

Fig 13 Analysis 9


Ethan DiLoreto 2.12

Swing arm lock bar deflection using 6063-T6 Aluminum.

Cross Section

0.3125" = 0.0079375m

0.25" = 0.00635m

$d_{max} = \frac{PL^3}{3EI}$

$= \frac{900(.11684)^3}{3(68.9E9)(2.646E-10)}$

54.69

$= 0.0262m$

$= 1.03''$

$I = 2.646E{-10}\,m^4$ (pg 2.11)

$E = 68.9\,GPa$ (6063-T6)

$L = 0.11684m$

$P = 900N$

$A = 5.04E{-5}$

Tensile Stress

$\sigma = F/A = 900N / 5.04E{-5}\,m^2$

$\sigma = 17.9\,MPa \quad YTS = 214\,MPa$

Like steel, the tensile stress is all good. However its predicted to deflect over an inch. Along with a bottom support bar the dimensions may need to be changed for the aluminum version.

Fig 14 Analysis 10

Ethan DiLoreto 2.C

Aluminum minimum bracket dimensions.

If a saftey factor larger than 1.5 is desired and a larger width is not desired then the bracket must be made out of thicker material. We will test 5/16 6063-T6 aluminum.

Assumptions:

same as found in appendix A, pg. 2.7

YTS = 241 MPa

cross section

longest arm = 0.086m

0.75" = 0.01905m

0.3125" = 0.00794m

$$F = \frac{MY}{I}$$

$$F = \frac{77.4(0.009525)}{5E-9}$$

$$I = 1/12(.00794)(.01905^3)$$

$$5.0E-9\,m^4$$

$F = 147.4\,mPa$

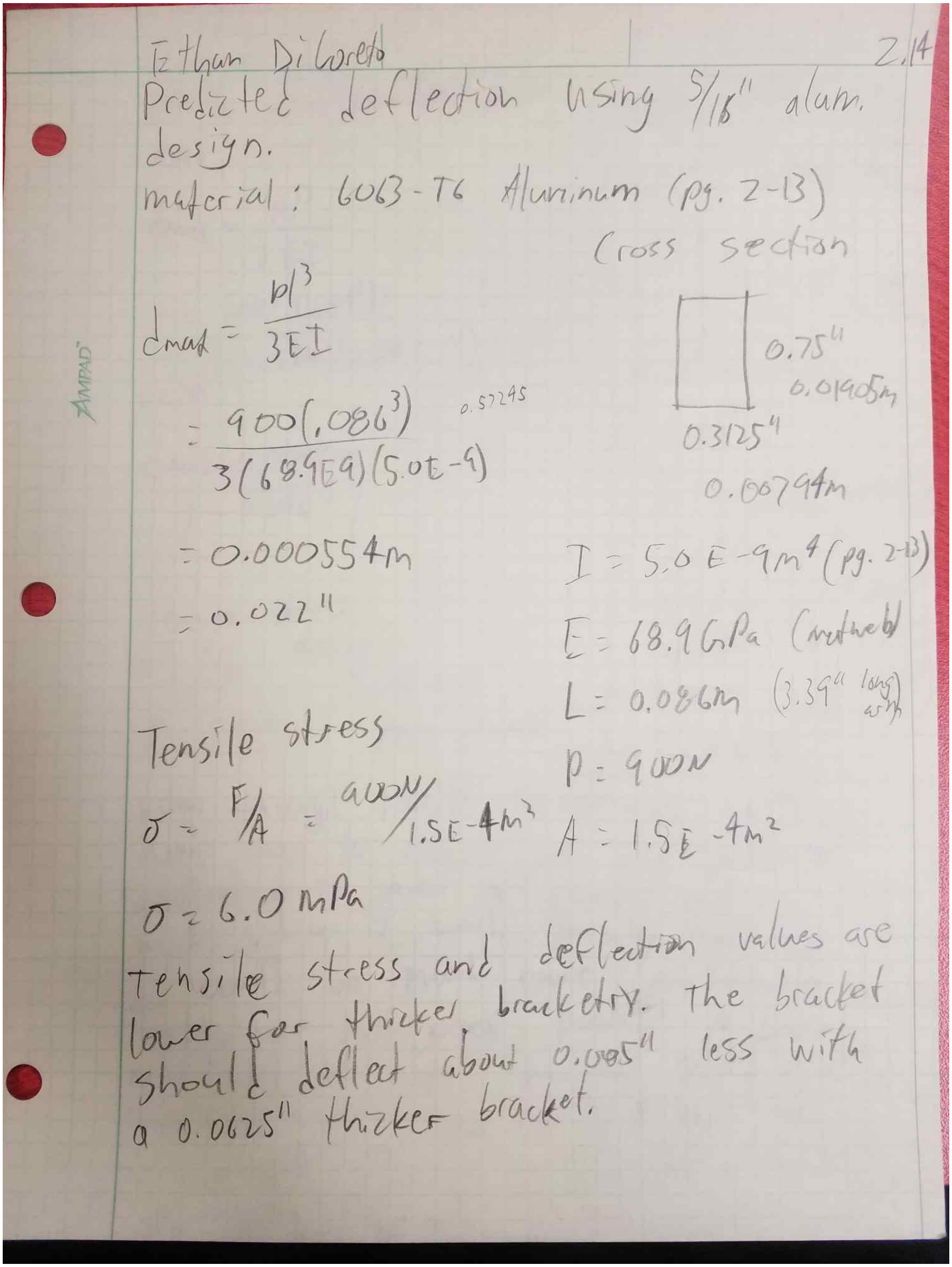
$M = 0.086m(900N)$

$= 77.4\ N\text{-}m$

$Y = 0.009525m$

Increasing mat'l width from 0.25" to 0.3125" reslly on increases the saffer factor from 1.5 to 1.6, depending on weight and cut quality on thicker material this may not be worth it.

Fig 15 Analysis 11


Ethan DiLoreto 2.14

Predicted deflection using 5/16" alum. design.

material: 6063-T6 Aluminum (pg. 2-13)

Cross section

0.75"
0.01905m
0.3125"
0.00794m

$d_{max} = \frac{Pl^3}{3EI}$

$= \frac{900(.086^3)}{3(68.9E9)(5.0E-9)}$ 0.57245

$= 0.000554m$

$= 0.022"$

$I = 5.0E-9 m^4$ (pg. 2-13)

$E = 68.9 GPa$ (matweb)

$L = 0.086m$ (3.39" long with)

$P = 900N$

$A = 1.5E-4 m^2$

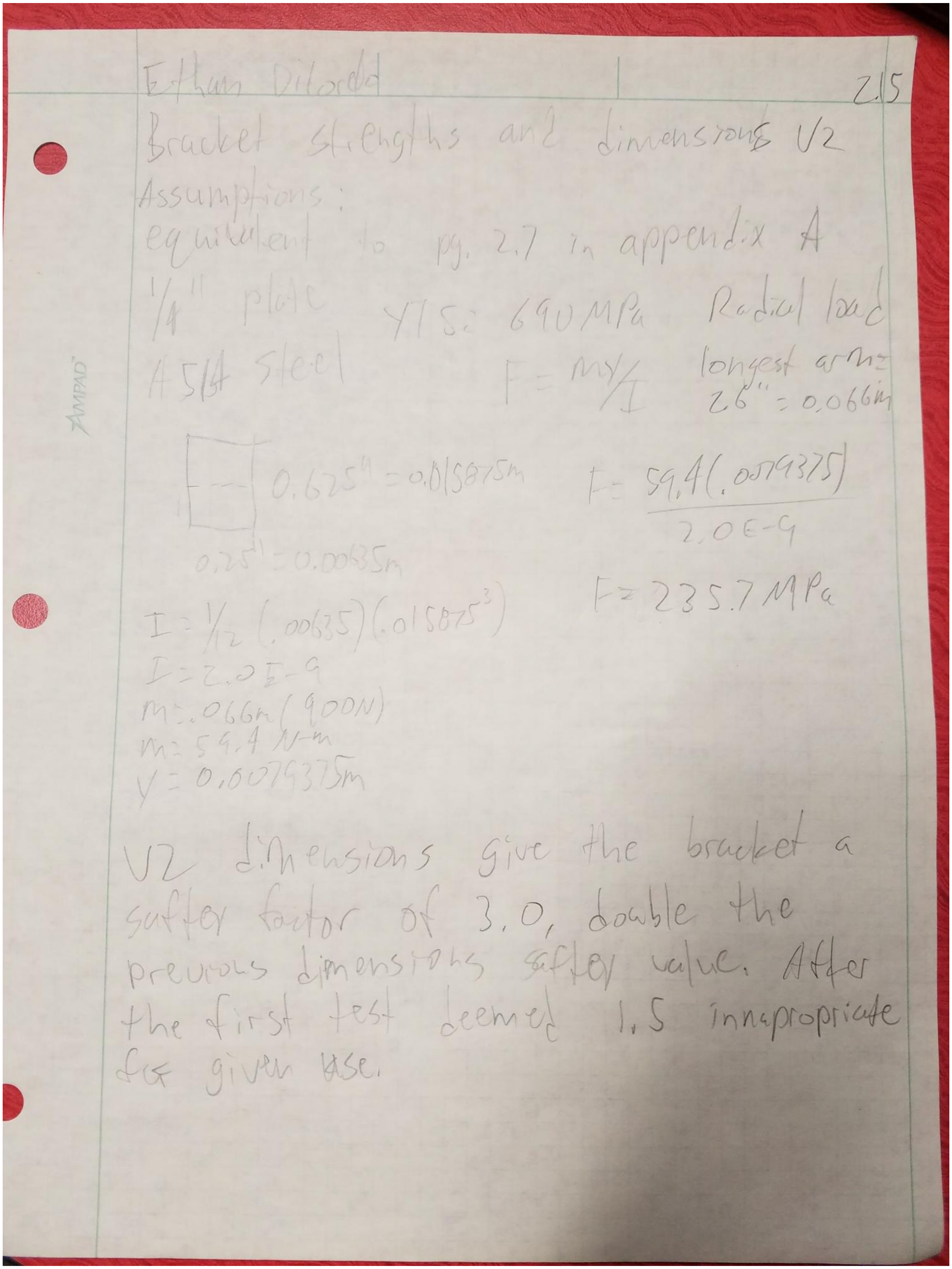
Tensile stress

$\sigma = F/A = 900N / 1.5E-4 m^2$

$\sigma = 6.0$ MPa

Tensile stress and deflection values are lower for thicker bracketry. The bracket should deflect about 0.005" less with a 0.0625" thicker bracket.

Fig 15 Analysis 12


Ethan Dilorde 2.15

Bracket strengths and dimensions V2

Assumptions:

equivalent to pg. 2.7 in appendix A

1/4" plate YTS: 690 MPa Radial load

A 514 Steel $F = My/I$ longest arm = 2.6" = 0.066m

0.625" = 0.015875m

0.25" = 0.00635m

$F = \frac{59.4(.0079375)}{2.0E-9}$

$F = 235.7$ MPa

$I = 1/12(.00635)(.015875^3)$

$I = 2.0E-9$

$M = .066m(900N)$

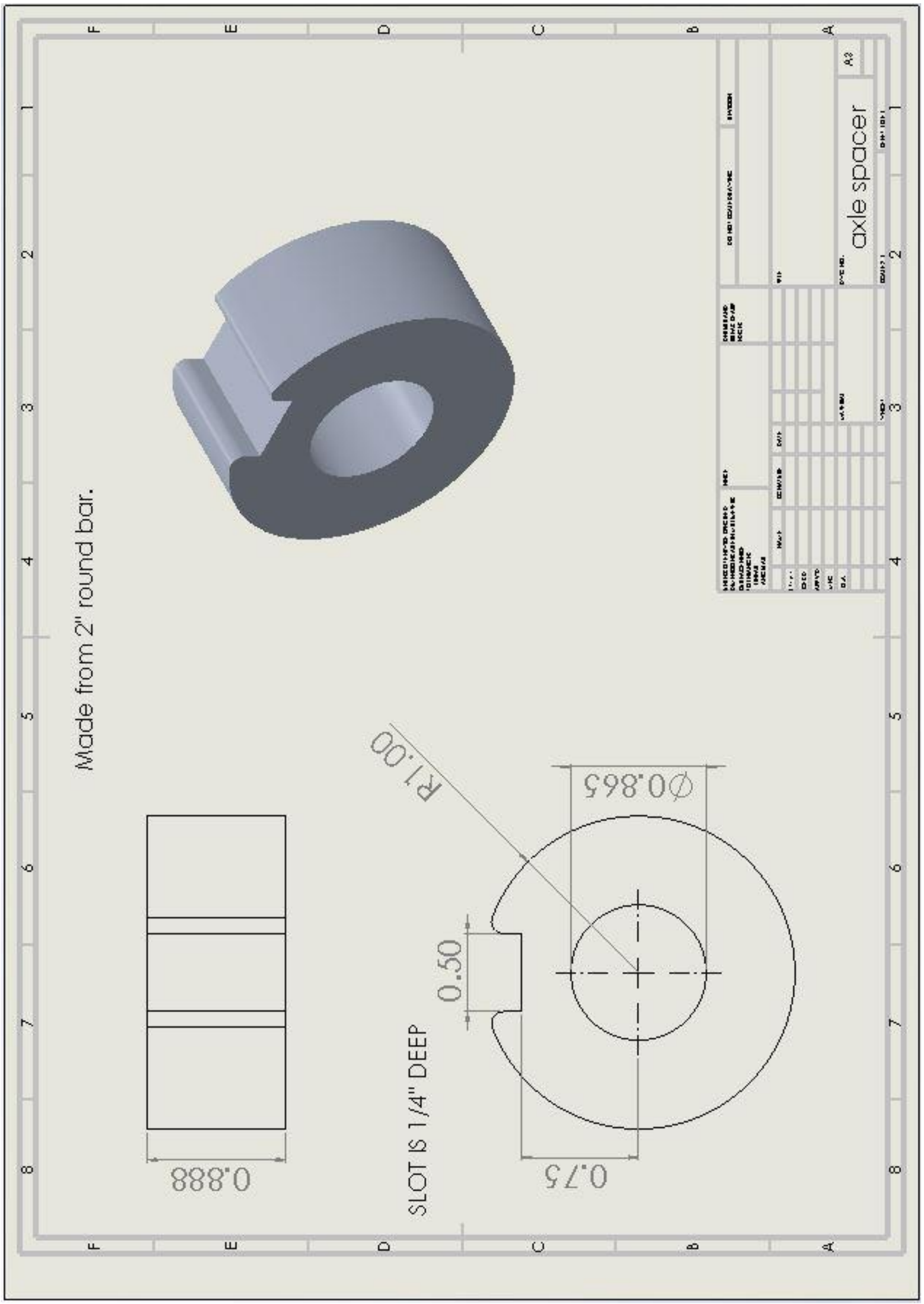
$M = 59.4$ N-m

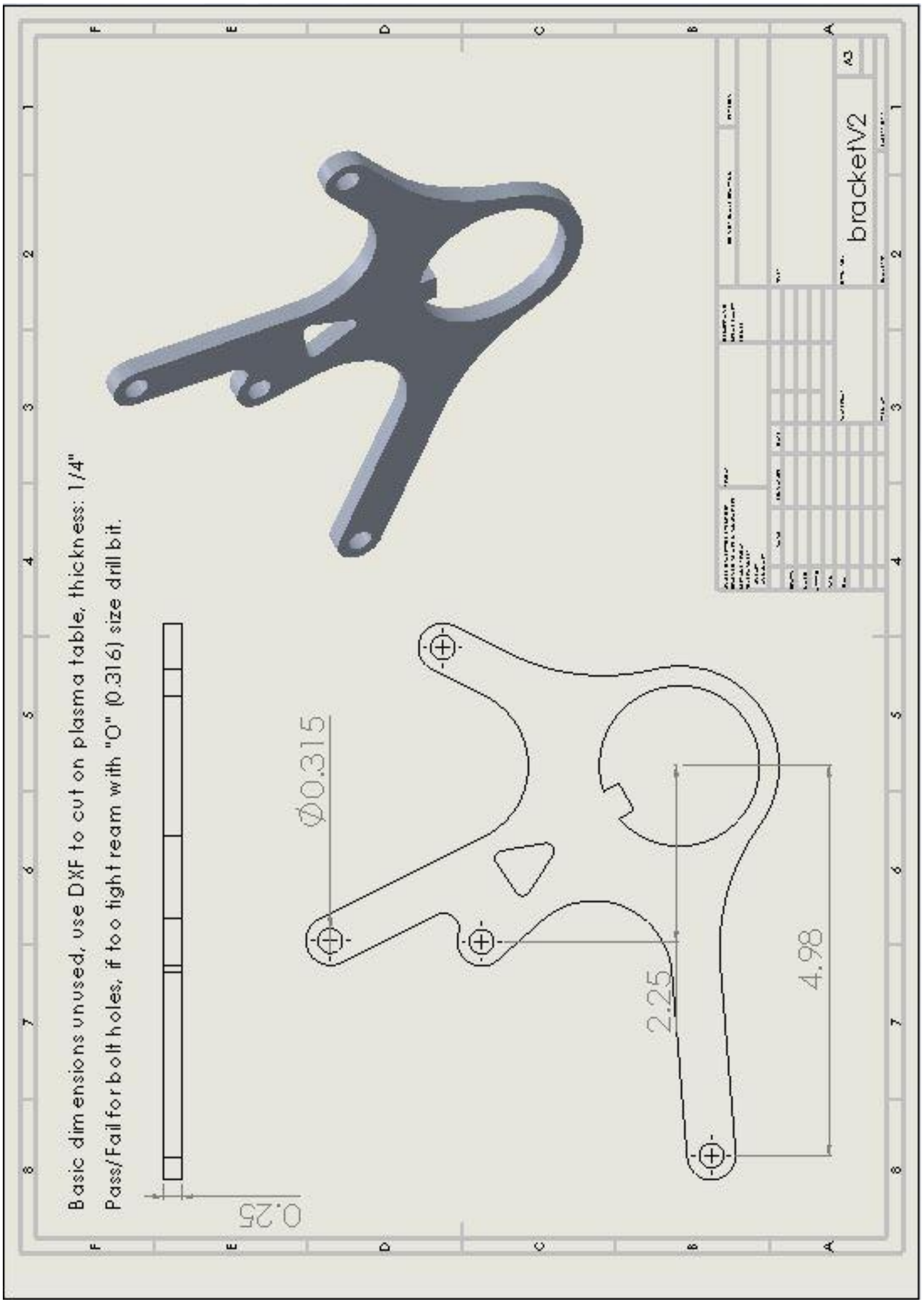
$y = 0.0079375m$

V2 dimensions give the bracket a saftey factor of 3.0, double the previous dimensions saftey value. After the first test deemed 1.5 innapropriate for given use.

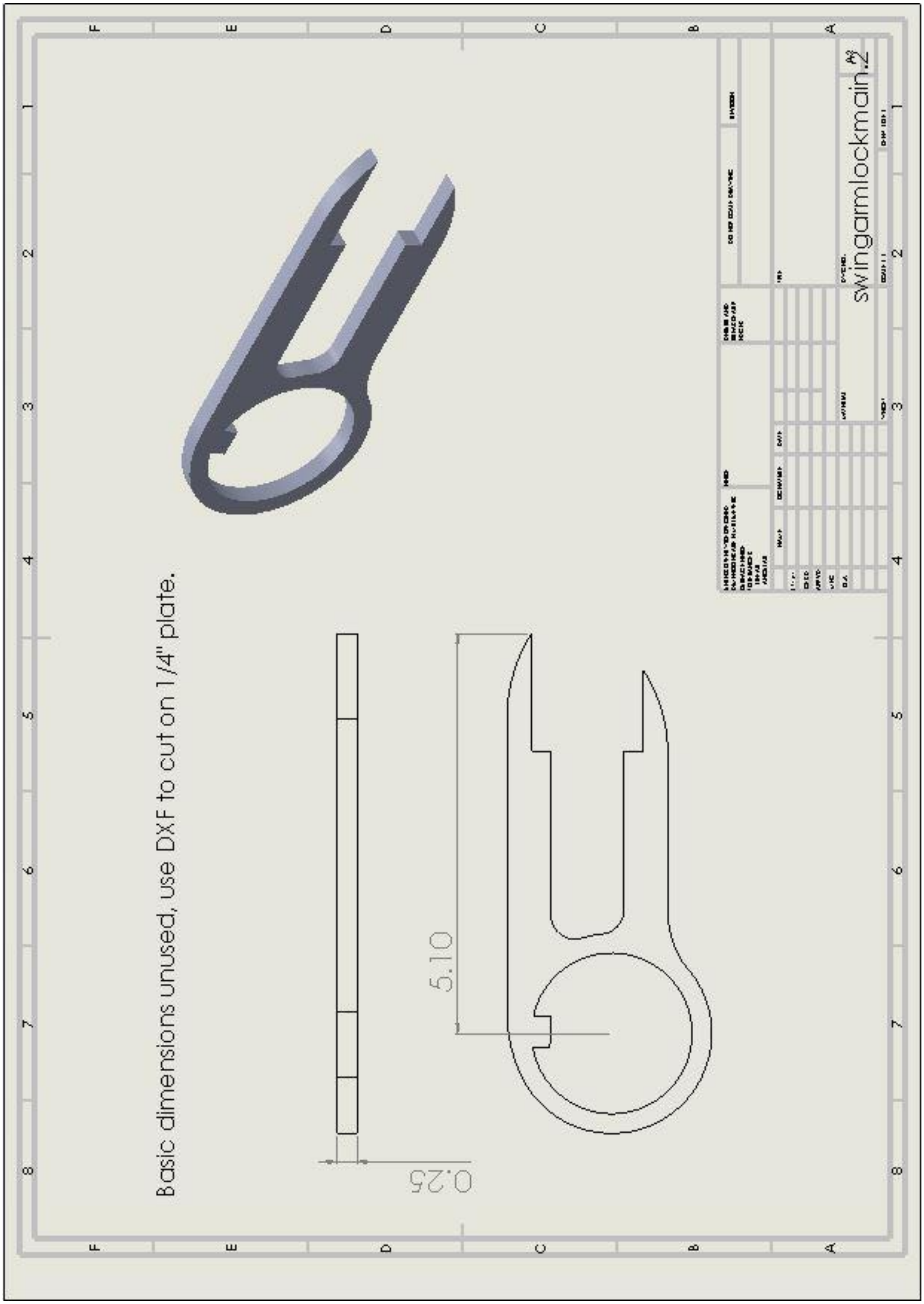
Figure 16 Analysis 13

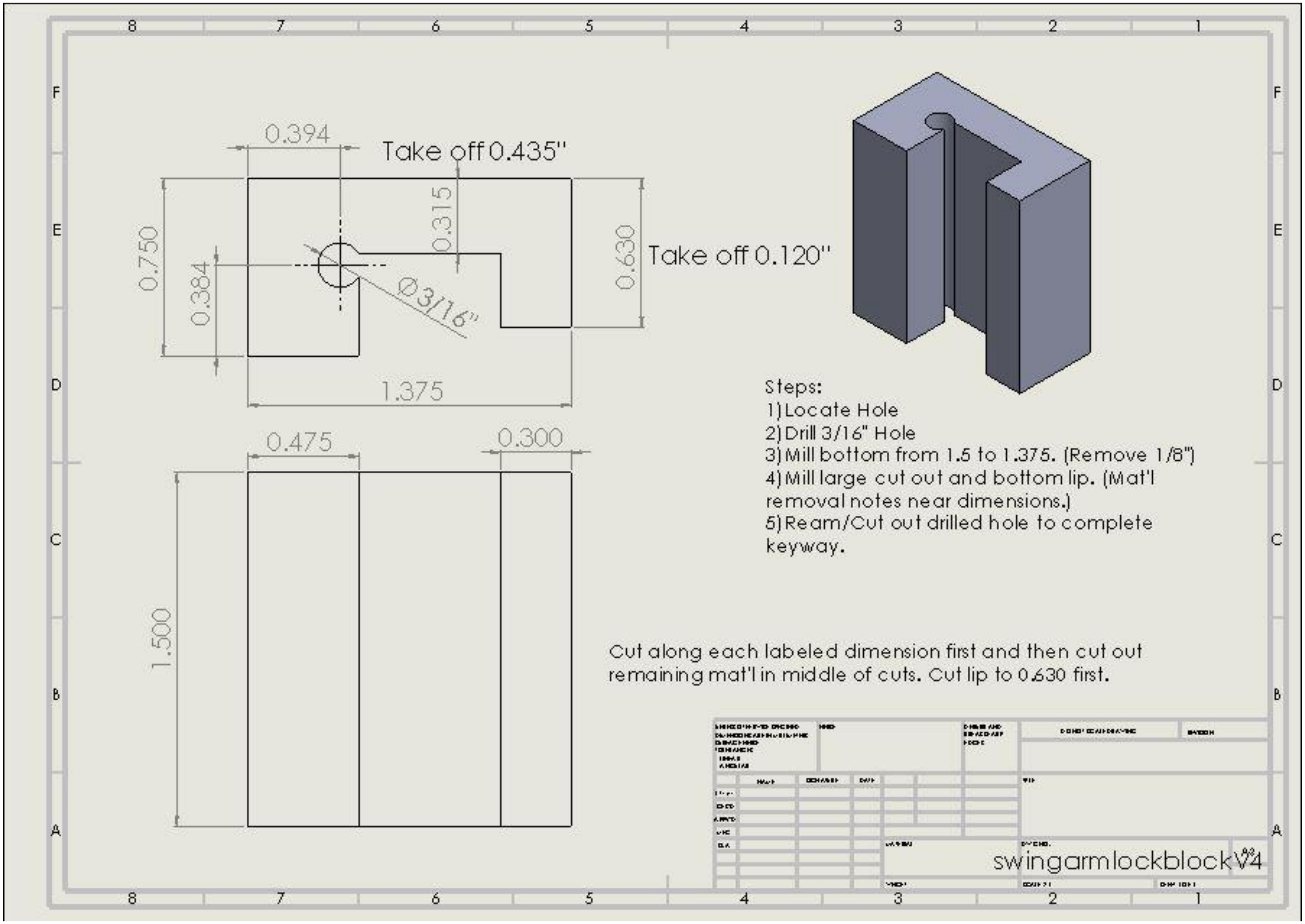
APPENDIX B – Sketches, Assembly drawings, Sub-assembly drawings, Part drawings



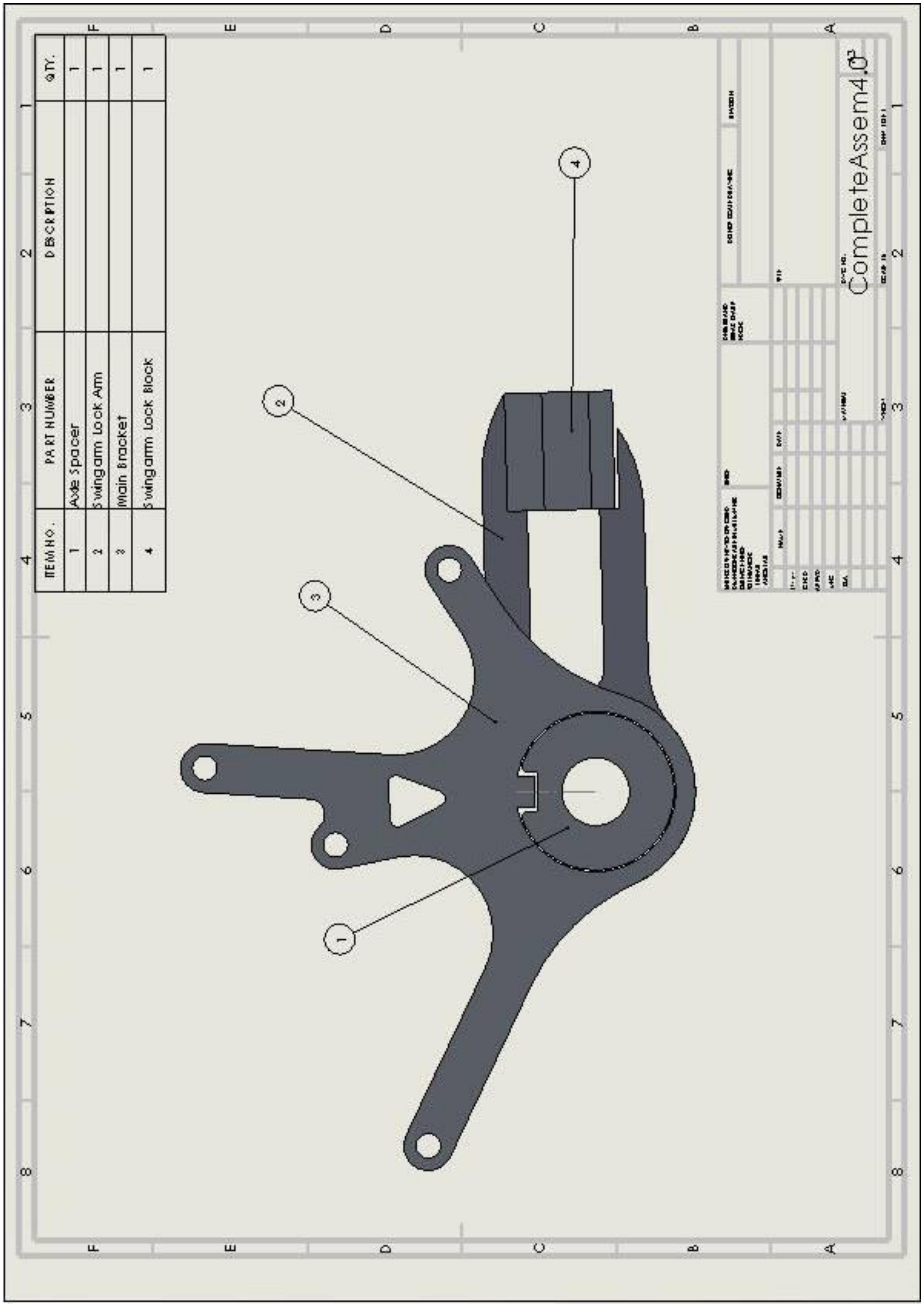


Basic dimensions unused, use DXF to cut on plasma table, thickness: 1/4"
Pass/Fail for bolt holes, if too tight ream with "O" (0.316) size drill bit.
Ø0.315
2.25
4.98
0.25
bracketV2
A3


Basic dimensions unused, use DXF to cut on 1/4" plate.
5.10
0.25
swingarmlockmain.2


0.394
Take off 0.435"
0.315
0.630
Take off 0.120"
0.750
0.384
Ø3/16"
1.375
0.475
0.300
1.500
Steps:
1) Locate Hole
2) Drill 3/16" Hole
3) Mill bottom from 1.5 to 1.375. (Remove 1/8")
4) Mill large cut out and bottom lip. (Mat'l removal notes near dimensions.)
5) Ream/Cut out drilled hole to complete keyway.
Cut along each labeled dimension first and then cut out remaining mat'l in middle of cuts. Cut lip to 0.630 first.
swingarmlockblockV4

Assembly Drawing



APPENDIX C – Parts List and Costs

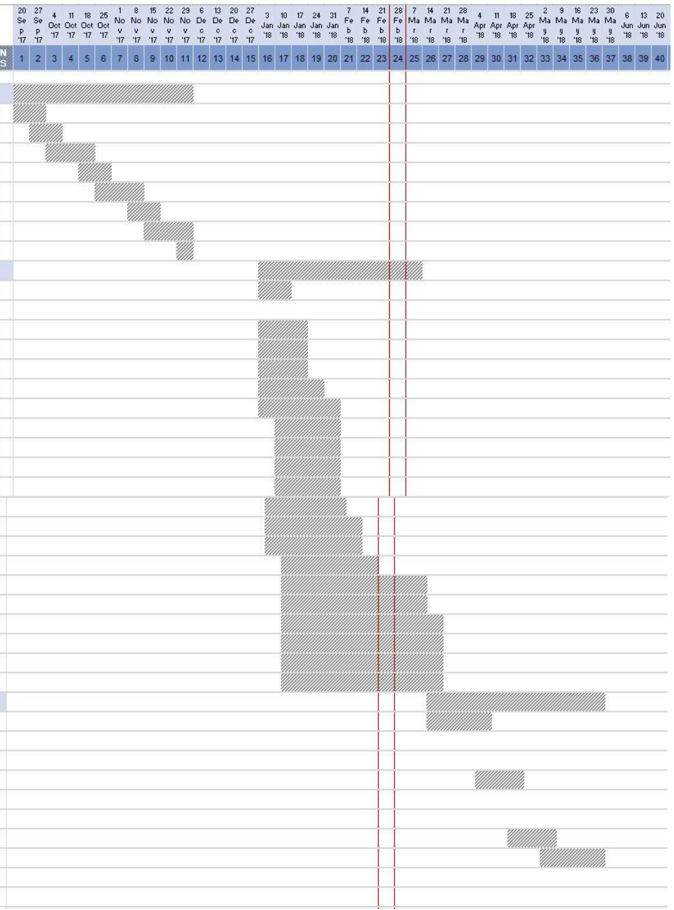
Part Ident	Part Description	Source	Cost (Est.)	Cost (Act.)	Disposition
Steel	Plate 0.25 inch 8”x8”	Hansen Metalworks	$10	$0.00	Bought/Salvage
Steel	Round Bar 2”x12”	Various	$10	$0.00	Bought/Salvage
Steel	Flat Bar .75”x1.5”	Various	$11.73	$0.00	Bought/Salvage
Aluminum	Plate 0.25 inch 8”x8”	Online Metals	$10.20	$9.53	Bought/Salvage
Aluminum	Round Bar 2”x12”	Various	$30.86	$0.00	Bought/Salvage
Aluminum	Flat Bar .75”x1.5”	Online Metals	$7.23	$6.15	Bought/Salvage
Calipers (2)	Front 2002 Yz250	Ebay (used)	Varies $25-$40	$60.00	Bought
Master Cylinder/Lever	Actuator for Hydraulic system	Ebay	$65.00	$65.00	Bought
Brake Line	Goodrich 75”	Paulson’s Motorsports	$49.54	$49.54	Bought
Banjo Fitting (1)	90 degree	Paulson’s Motorsports	$14.62	$14.62	Bought
Banjo Fitting (1)	10 degree	Paulson’s Motorsports	$11.15	$11.15	Bought
Caliper Bolts (4)	20mm Socket Head	Kundson’s Lumber	$4.11	$4.11	Bought
		Cost Total: (Est.)	~$222.44		
		Cost Total: (Act.)		$220.10	

APPENDIX D – Budget

The Parts list and cost should be the total of all the monetary value spent. Most labor will be completed by the author. Tyler Hansen, of Hansen Metalworks may cut out the plate metal on his plasma table. For two reasons, one his plasma table is capable of making deeper cuts than the one at CWU. Two, it will be cheaper to just pay for the material and cutouts through him. Instead of buying entire sheets of metal. All equipment needed should be available at CWU for the author to use, expect the plasma table portion.

APPENDIX E - Schedule

WBS	TASK DESCRIPTION	Hours Est.	Hours Act.	PROGRESS	PLAN START	PLAN END	PLAN DAYS
	Fall Quarter - Proposal				9/20/17	12/1/17	73
1	Complete Intro	1.2	2.2	100%	9/20/17	9/30/17	11
2	Design & Analysis	8.4	15.4	99%	9/30/17	10/10/17	11
3	Methods & Construction	15.1	12.8	100%	10/10/17	10/20/17	11
4	Testing Methods	4.6	3.1	100%	10/20/17	10/30/17	11
5	Budget & Schedule	2.2	5.1	100%	10/30/17	11/9/17	11
6	Discussion & Conclusion	2.7	3.2	100%	11/9/17	11/19/17	11
7	Appendix	12.8	5.6	82%	11/19/17	11/29/17	11
	Project Proposal (Milestone)	47.0	47.4	97%	12/1/17	12/1/17	1
	Winter Quarter - Build				1/3/18	3/9/18	66
1	Obtain Materials (2" Round Bar, 3/4" Flat)	1.2	0.5	100%	1/3/18	1/10/18	7
2	Axle Spacer lathe set up	0.4	0.4	100%	1/4/18	1/18/18	14
3	Axle Spacer Lathe Cuts (Drill, Bore)	0.4	0.4	100%	1/5/18	1/19/18	14
4	Axle Spacer mill set up	0.2	0.3	100%	1/6/18	1/20/18	14
5	Axle Spacer mill cuts	0.4	0.2	100%	1/7/18	1/21/18	14
6	Build swing arm lock block			100%	1/8/18	1/30/18	22
7	Hole location	0.5	0.2	100%	1/9/18	1/31/18	22
8	Drilling	0.2	0.1	100%	1/10/18	2/1/18	22
9	Mill Setup	0.1	0.2	100%	1/11/18	2/2/18	22
10	Mill Operations	1.5	1.3	100%	1/12/18	2/3/18	22
11	Hole clearing	0.3	0.1	100%	1/13/18	2/4/18	22
12	Cut out main bracket piece (Outsource, 1 week)			100%	1/14/18	2/13/18	30
13	Cut out swing arm lock main piece (Outsource, 1 week)			100%	1/15/18	2/14/18	30
14	Press Parts together	0.1	0.1	100%	1/16/18	2/20/18	35
15	Install for test fit	0.1	0.1	100%	1/17/18	2/22/18	36
16	MIG/TIG welder setup	0.1	0.1	100%	1/18/18	3/19/18	60
17	Weld Layout setup	0.3	0.1	100%	1/19/18	3/20/18	60
18	Weld bracket cutouts together	1.3	1.5	100%	1/20/18	3/21/18	60
19	Complete install for testing (brake lines, master cylinder etc...)	2.3	2.0	100%	1/21/18	3/22/18	60
20	Clean up (Total)	1.3	1.1	100%	1/22/18	3/23/18	60
21	Project Build (Milestone 2)	10.7	8.7	100%	1/23/18	3/24/18	60
	Spring Quarter - Testing				3/27/18	6/1/18	67
1	Test Weight Reqs	2.4		0%	3/27/18	4/11/18	15
2	Obtain Scale	0.3		0%			
3	Build test Jig	10.3		0%			
4	Test Deflection Reqs	2.3		0%	4/12/18	4/27/18	15
5	Set up for brake force testing	10.6		0%			
6	Field Testing	30.4		10%			
7	Test Braking force/lever pull	6.8		0%	4/28/18	5/13/18	15
8	Complete Testing (Including write up) (MS3)	11.2		1%	5/14/18	6/1/18	18
		44					
	Total Time	101					



APPENDIX F – Testing

Introduction:

There will be two stages of testing and 4 sections of testing to be completed. Stage one, section one is field testing. Section 2 of stage 1 is testing the force needed to lock up the rear wheel. This will be done in the field as well. There is little point in bench testing this device if it cannot hold up to real world situations. Risk to the operator is minimal when testing this device as well. In a controlled environment chances of a mishap are extremely small.

Stage two includes all bench testing. Section one is the most basic, the weight needs to be tested to see if the weights meet the design requirements made in fall. Section 2 is testing if the device meets the deflection standard set.

The predictions for all tests are as follows:

Stage one, section one (ST1, SE1): The device will hold 2 brake calipers and not break or deform.

Stage one, section two (ST1, SE2): 10lbs of pull on the lever, at 25 mph and 2/10ths of a second to lock the tire up.

Stage two, section one (ST2, SE1): The steel version should be no more than 150% more than the weight of the original bracket. (Ex. If OEM is 5oz, the project should be no more than 12.5oz)

Stage two, section two (ST2, SE2): It should deflect no more than 0.010" during max braking force. (TBD)

Data acquisition for ST1, SE1 will be observational only. For ST1, SE2 data will be gathered from video footage showing lever and tire operation. (See procedures for more specific details.) ST2, SE1 will be recorded by pictures showing which item is being weighed and the weight. ST2, SE2 will be documented on paper and with pictures. (See procedures for more).

Schedule:

The schedule is to be completed as per the Gantt chart found in Appendix E.

Method/Approach:

Resources needed:

ST1, SE1:

- Working motorcycle to attach bracket to.
- Fuel.
- Truck for transport.

ST1, SE2:

- Working motorcycle to attach bracket to.
- Fuel.
- Truck for transport.
- Paper, pens etc…
- GPS device that shows real time speed.
- Camera and/or timing equipment.

- Linear scale.
- Bump stop for lever.

ST2, SE1:

- OEM device
- Project device
- Scale

ST2, SE2:

- Hydraulic press
- Dial Indicator
- Jig for holding device
- Project device

Precision and Accuracy:

ST1, SE1:
Observational only.
ST1, SE2:
Lb force measurement: +/- 1lb. MPH: +/- 3 mph. Time: +/- 0.005 seconds
ST2, SE1:
Weight: +/- 0.001 grams
ST2, SE2:
Deflection: +/- 0.0005 inches

All testing except ST1, SE2 is relatively precise and accurate. The simple tests will involve little to no error. However, the lever force testing, while a necessary test to determine performance is still considered to be a difficult test to pull off error free. The first part is that the test is being done on dirt. For a number of reasons (legality, bike wear, site availability, etc…). To add on to that the lever perch is not perfectly rigid so if the lever is pulled a little bit harder, more than the desired force may be transmitted and lastly there is no access to a perfect method for precisely and accurately reading the times gathered from the video. The frame rate set to 60fps, double what is standard and the maximum the computer program will read to increase the accuracy as much as possible.

Data storage/manipulation/analysis:

All data will be stored electronically. As discussed previously data recording procedure will be outlined in procedure. Analysis and presentation will also be discussed later.

Test Procedure:

ST1, SE1

- Prep motorcycle.
- Safety check.
- Safety gear.
- Ride motorcycle.

ST1, SE2

Summary:

This test will be to determine the amount of force required to fully actuate the brake calipers. In this scenario that is being defined as a complete lock up of the rear wheel, while going a speed of 25 mph.

Time:

The majority of the time needed will be for preparation and travel. See the procedure and resource sections for more. A good assumption would be around 4-6 hours total.

Place: TBD, based on weather conditions.

Resources needed:

- Working motorcycle to attach bracket to.
- Fuel.
- Truck for transport.
- Paper, pens etc…
- GPS device that shows real time speed.
- Camera and/or timing equipment.
- Scale.
- Bump stop for lever.

Preparation steps:

- Measure desired force (10lbs, 15lbs) in line with the pull direction on the outermost edge of the lever using a fish scale or something similar.
- Repeat this three times and take average distance of the three.
- Put a stop in between the bar and the lever at this point, to prohibit more than 10lbs of force being put on the lever. (stop may be held with tape or zipties)

Procedure steps:

- Acquire all necessary items.
- Travel to testing locations.
- Find flat dirt/gravel** road appropriate for testing.
- Set up speedometer device. (Tape or ziptie phone to bar pad)
- Get up to a consistent 25mph, and pull lever in firmly against the pre-built stop.
- Have an assistant (or video) confirm if the rear wheel locks up completely, and the time it took for full lock up. (For best results mount a video recording device somewhere close to rear wheel to get time down to fractions of a second, if possible.) (See figure 19 for example).
- Repeat at least 10 times.
- As bonus material, increase speed in 5mph increments and record time to lock rear wheel up.

Safety:

- Wear all appropriate safety gear.
- Check safety of test site, make sure no traffic accidents can occur.
- Give motorcycle safety check before riding.

Discussion:

There are many opportunities for error in this test procedure. Different road surfaces will give different readings. Different operators may yield different results. However the setup detailed above will hopefully reduce these possible errors as much as possible. This test should give a good idea of the brake performance that this set up gives. In the future a good test to perform would be to route the stock rear brake caliper into the hand lever and test how well it works. Then compare the two for a clear representation of power.

**Realistic condition are infinitely variable in real world situations. To keep some consistence dry dirt is desired. While dry pavement would give the most accurate results, it will not only be increasingly difficult to find a legal paved road to test on, but will increase wear on motorcycle components unnecessarily.

ST2, SE1

- Acquire scale
- Weigh OEM bracket
- Record weight with pictures and on paper if desired
- Weigh project bracket
- Record weight with pictures and on paper if desired

ST2, SE2

- Acquire bracket
- Acquire test jig
- Acquire dial indicator
- Acquire safety equipment
- Install test jig
- Set up in hydraulic press
- Set press to desired pressure on desired arm of bracket
- Record deflection (pictures here too)
- Repeat 3 to 5 times, recording each and take the average of the trials.

All safety equipment needed for all tests:

- Wear all appropriate safety gear when appropriate.
- Check safety of test sites, make sure no traffic accidents can occur.
- Give motorcycle safety check before riding.
- Give testing equipment safety check.
- Wear safety glasses whenever appropriate.

APPENDIX G – Testing Data

Testing Results and Analysis:

ST1, SE1

Stage 1, Section 1, Test 1, February 10, 2018

The good:

The first field test went extremely well. Better than hoped for. Braking power was phenomenal. Lever feel was on point. The first test was over the course of eight hours or so. For over half of that time there were no issues of any kind. The terrain that this device was being tested on can best be described as gnarly. It took many hits from rocks of all sizes and was subjected to sudden and violent braking almost nonstop.

The issues:

Again nearly 5 or so hours into testing the foot pedal felt a little spongy and the braking response was different. Upon inspection the device had been bent. It may not have been from fatigue of just the brake torque on it though. It bent about 30 degrees forward (in a radial motion about the axle of the vehicle). *(See Figure 17 and 18 below).* As well as bending approximately 3 to 5 degrees inward (towards the rotor). The best hypothesis delivered is that a combination of being hit on a rock (side load) and repeated and violent radial loads being applied eventually fatigued the material enough to cause it to bend.

Conclusion:

Important knowledge was gained from this first test, see the design and analysis section for more specific details on what changes were made and why.

Figure 17, Post Test 1

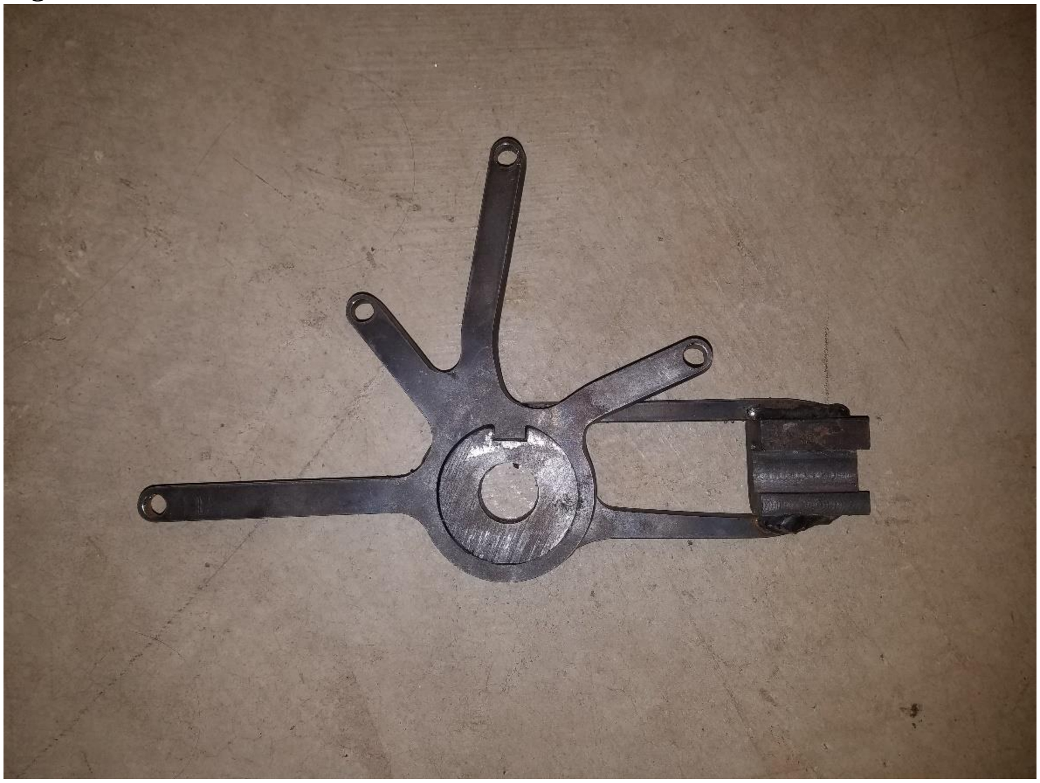


Figure 18, Post Test 1

APPENDIX H – Data Evaluation

Stage 1, Section 1, Test 2, April 27, 2018

The good:

Excellent performance on braking, no brake fade, exponentially stronger than stock. Proved to be quite useful on tricky side hills, starting the bike while on a hill, long, steep and difficult downhill sections, and lastly for loading and unloading from the truck.

The bad:

None! Worked consistently the entire day with no issues, no warping, bending breaking or falling off of any sort.

Conclusion:

Test ST1, SE2 complete.

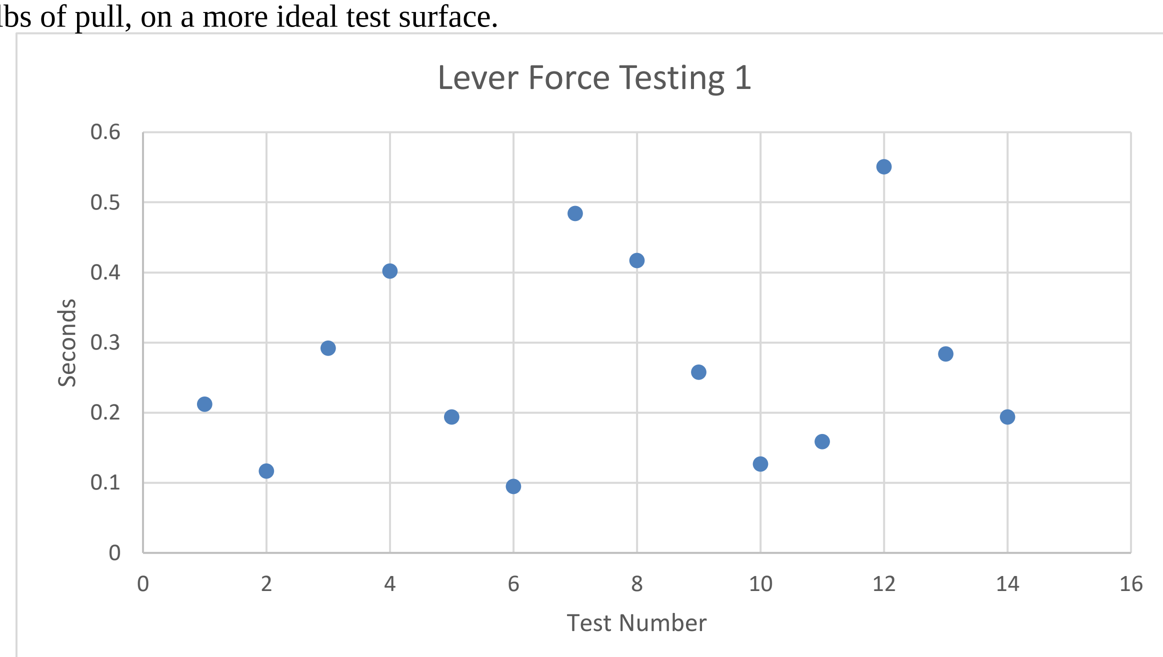
ST1, SE2

Stage 1, Section 2, Test 1, April 13, 2018

The data is all over the map. There is zero consistency and patterns discernable. So why would this be? The main reason is most likely weather and timing. There was not much of a choice but to go out this particular weekend (to have testing complete for TDR1). Which meant that it has been raining for week, on dirt. This made conditions extremely undesirable. The mud was very slick. I expected a fair amount of inconsistency due to the nature of the test regardless. (See testing discussion for more this tests potential issues). But it was largely above average in these conditions.

What can be done about these issues? Wait until the dirt is dry and try again.

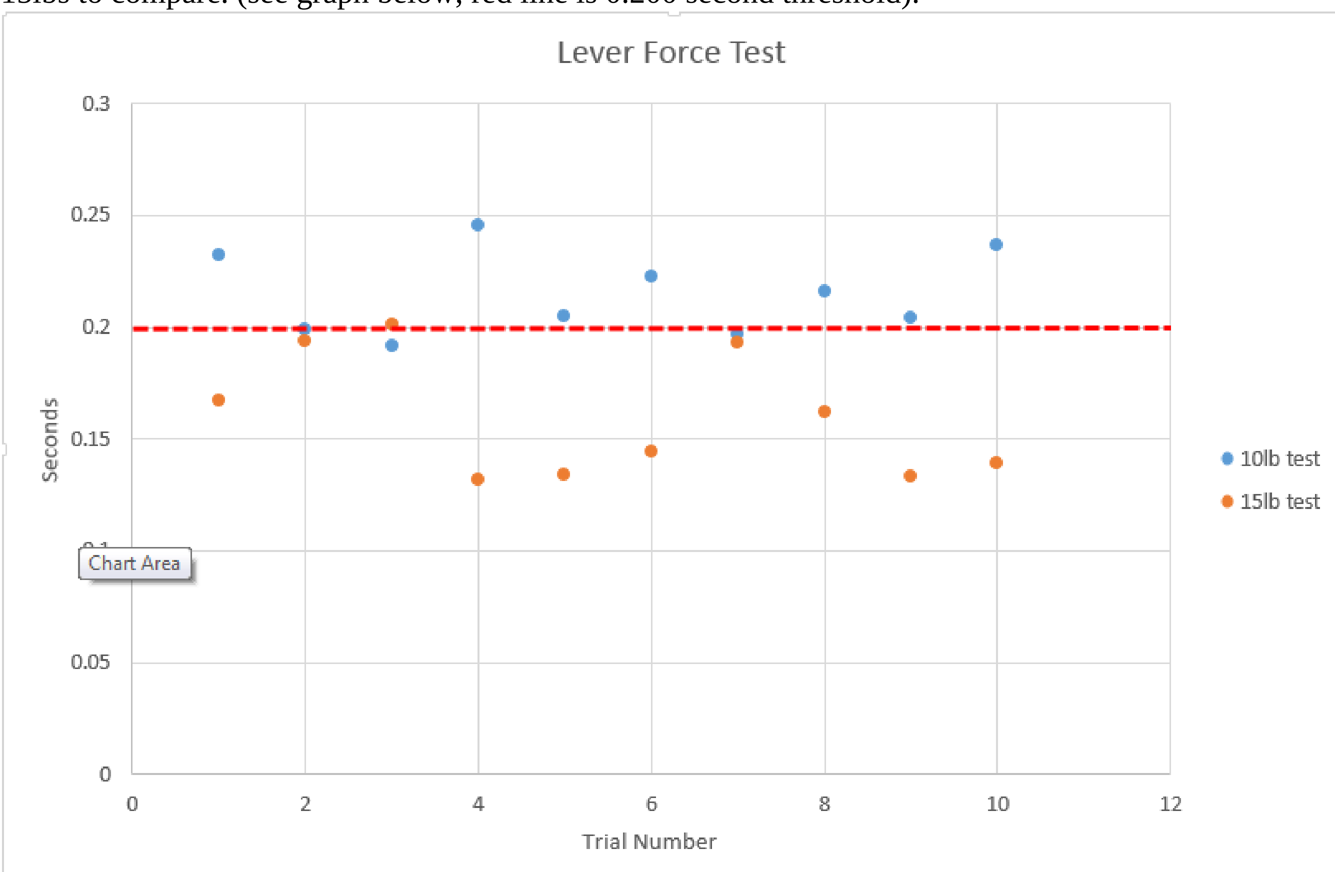
Did it pass the test? It is hard to be sure given the circumstances, but it would appear to be no. Looking at the data, as scattered as it is nearly 60% of the points are above 0.200 seconds. And upon reflection, 10lbs of lever pull is actually very light. This test should be done again at 15lbs of pull, on a more ideal test surface.



Results (seconds):
0.484
0.212
0.117
0.194
0.127
0.194
0.095
0.292
0.417
0.258
0.402
0.159
0.551
0.284

Stage 1, Section 2, Test 2, April 27, 2018

The data had an expected consistency this time around. The sun came through and dried the dirt up at the test site. This time 10 rounds were done at 10lbs and 10 rounds were done at 15lbs to compare. (see graph below, red line is 0.200 second threshold).



APPENDIX I – Testing report

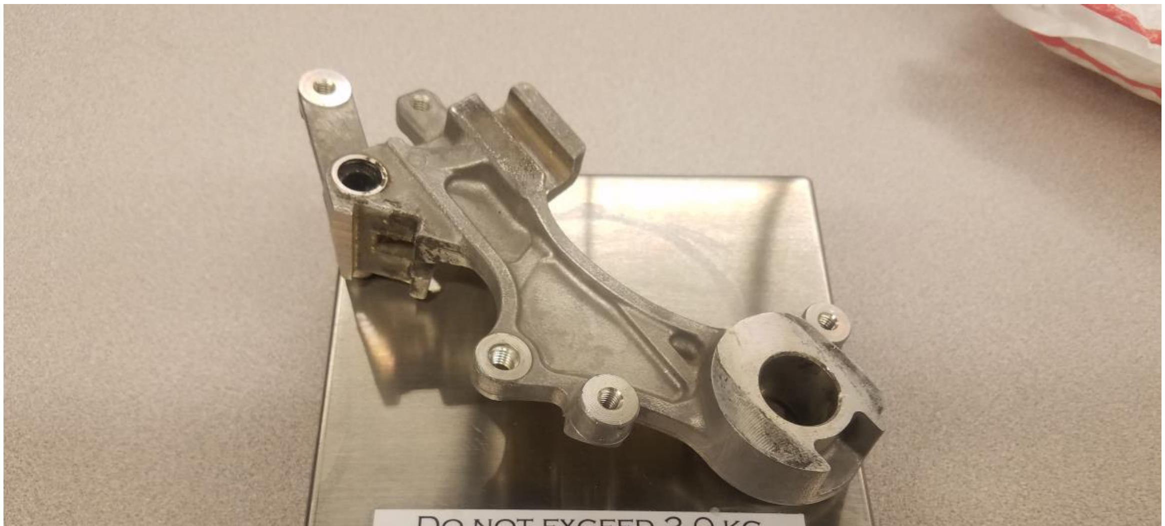
As seen, appropriate conditions made this test worlds better. The 10lb test actually yielded to be nearly appropriate. Still 70% were above the 0.2 seconds threshold but 100% were under a 1/4th of a second. Moving onto the 15lb test, 90% of the points passed with only one stray coming in at 0.201, and at one-one-thousandths of a second away from the threshold it is hard to say it does not count either. Testing complete for ST1, SE2.

Results (seconds):
10lb test
.232
.199
.192
.246
.205
.223
.197
.216
.204
.237

15lb test
.167
.194
.201
.132
.134
.144
.193
.162
.133
.139

ST2, SE1
Weight Test Results:
OEM Aluminum: 272.5g
V1 Steel: 891.6g
V2 steel: 979.9g
272.5g*(150%) = 408.75g max weight allowable to pass.
Both V1 and V2 failed weight test by a large factor. Since V1 was replaced by the stronger V2 only V2 will actually be taken into consideration. V2 was overweight spec by over 500 grams, almost three times the weight of the OEM bracket.

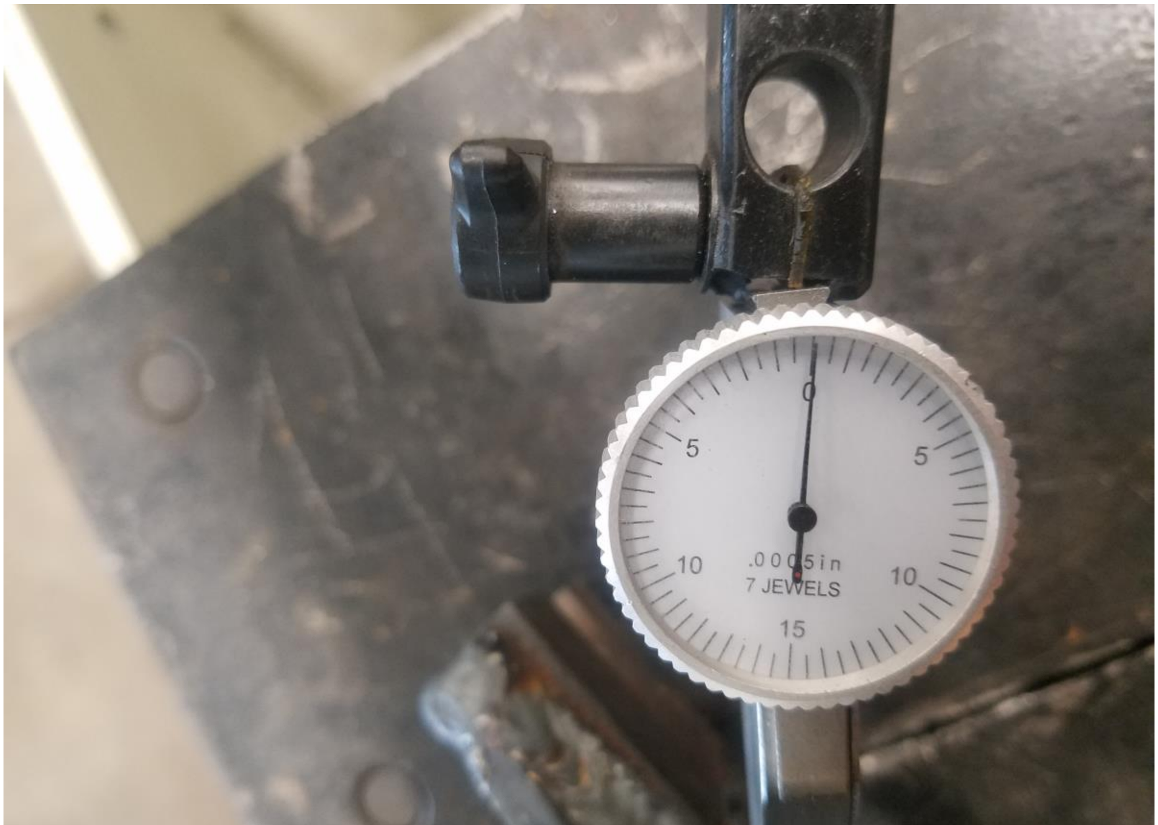
Conclusion:
Weight test failed. There is not much to be done for this. A more reasonable weight expectation should have been put in place in the first place for the steel requirements. There is still a chance that the aluminum version could someday pass its weight requirement. There is no real way to take weight away from the steel version. Due to the destructive nature of the environment that this device is used in it needs to be a strong as possible.




Do not exceed 2.0 kg
Or scale may be damaged
AWS
ON/OFF
Hold
Mode
Tare
Max: 2000g d: 0.1g


OFF
Hold
g
979.9
Max: 2000g d: 0.1g

ST2, SE2
Deflection test results.
Trial 1: 0.008”
Trial 2: 0.007”
Trail 3: 0.0085”
Average: 0.0078”
Deflection testing was a solid pass. With a requirement of 0.010” Every single trial yielded results under that mark. This shows that the math proved to be correct for the arm deflection.
Conclusion:
Test passed, design completes requirements.


.0005in
7 JEWELS

.0005in
7 JEWELS

APPENDIX J – Resume

Qualification Summary:
A highly motivated, yet easy to get along with person with a high level of interpersonal skills. Mechanical Engineering student at Central Washington University.

Core Competencies:

- Written and verbal communication skills
- Proficient with changing technology
- Problem solving
- Ability to follow directions
- Ability to work well alone or in groups
- Ability to learn and adapt quickly

Education History:

- Woodrow Wilson High School, Tacoma, WA. Graduated with honors in 2015.
- Tacoma Community College, Tacoma, WA. Graduated with Associate of art degree in 2015.
- Central Washington University, Ellensburg, WA. Mechanical engineering student on the dean's list. 2015 - present

Professional Experience:
Port of Tacoma
Maintenance Facility
Tacoma, WA
Maintenance Engineer Intern
2017 – Present

- Designing and implementing a serial number and tracking system for the rigging gear of the entire Port of Tacoma has been my main project. The East Blair pier has been somewhat of a test site for the program. All of the equipment has been cataloged in a spreadsheet, designed specifically for tracking the equipment and the inspections of that equipment. All of this has made it so the gear can be properly inspected and documented per regulation requirements for the life of the gear.
- Creating and engineering the organization of maintenance records, inspection records, work orders and new parts, as well new and used equipment.
- Completing side projects, such as going out and finding all the switch gear and equipment listed in the system and making sure it is actually there and correctly labeled and
- Obtaining quotes for items like crane festoon systems to replace worn parts.

Paulson’s Motorsports
Motorcycle Dealership
Lacey, WA
Mechanic/Special Assignments
2016 - Present

- Uncrating, inspecting, and assembling new power sports products.
- Preparing customer products with proper oil, gas, tire pressure and overall check.
- Installing customer add on parts for power sports vehicles.
- Interacting with customers in the shop and on the show room floor.
- Delivery and pick up of vehicles.
- Repairing Customers vehicles.
- Fork-Lift Operator
- Fork-Lift Maintenance Mechanic
- Any other jobs as required, (Ex: building maintenance)

Bull Built Differentials
Differential Repair Shop
Bonney Lake, WA
Assistant Mechanic
June, 2015 - Present

- Tearing down, inspecting, and cleaning customer’s axles for reassembly by master technician.
- Completing axle swaps when shop was under heavy load.
- Repairing shop interior and exterior on an as needed basis.
- Organizing and reorganizing the shop layout for maximum efficiency.

Our Savior Lutheran Church
Garage Ministry
Puyallup, WA
Volunteer Mechanic
September, 2011- June, 2015

- Learning how to proficiently tear down, clean, inspect, repair or replace and properly reinstall parts and equipment.
- Performing tests to find the customers described problem with vehicle.
- Teaching new incoming volunteers with knowledge gained from experience.

Landscape/Manual Laborer Business
General Labor
Various Locations
Self Employed
April, 2010 - Present

- Mowing, weed whacking, edging, weeding gardens, trimming and general lawn maintenance
- Hauling heavy loads of dirt, gravel, and other products for garden/lawn applications
- Removing junk
- Moving
- Painting
- Setting up and organizing shops
- Taking inventory of parts

YouTube Channel
Instructional Vehicle Repair Videos
Internet
Videographer/Editor
March, 2013 - Present

- Filming videos for maintenance and repair education
- Editing and uploading videos
- Replying to further questions from viewers in the comments section

APPENDIX K - Project Visuals

Figure 19, project (V1) fully built and installed

Figure 20, Steel cut outs of V2

Figure 20, Lever set up.
Upper lever (silver/black) is for the clutch
Lower lever (black/red) is for rear brake

Figure 21, fully built V2, waiting to be installed.

Figure 22, milling process for building swing arm lock block.