

Summer 2017

Directional Rope Capture Device

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DIRECTIONAL ROPE CAPTURE DEVICE

Seaver Philipp

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Directional Rope Capture Device By Seaver Philipp (Engineering Technologies, Safety, and Construction)

The current market for rope capture devices shows a trend of using toothed devices as the method of creating a rope capture system. These systems are effective for a variety of applications but in any scenario in which a high load is encountered there is a large amount of damage done by the teeth to the rope. The objective of this project was to create a rope capture device that did not utilize teeth in order to create a safer loading condition on the rope. The method used for this project was application of equiangular spirals, this is the same method used for climbing cams. A profile was built using a section of a mathematical curve and was imported into a CAD/CAM program in order to be manufactured. Initial calculations showed that a small cam could replace the toothed plates used in commercial devices in order to remove the elements which could damage the sheath of the rope. The results of the project showed a successful application of the mathematical principles in creating a device that would slide up the rope cleanly in one direction but immediately catch in the opposite direction. This proof of concept device demonstrates the working concepts of a camming unit as a replacement of a toothed device.

Keywords: Equiangular Spiral, Rope Capture, Sheath, Cam

Introduction

Motivation:

This project was motivated by a need for a device that could be used in roped climbing applications where a climber is either ascending a rope or climbing alongside a fixed rope and does not wish to damage the rope in case of a fall. The reason this product differs from a traditional ascender is that it was conceived to fulfill a dual purpose of being an ascender as well as being a top rope solo device. This is a scenario where a climber is more likely to fall on the device and if the climber were to be using a toothed ascender. In this scenario, they would most likely cause significant damage to their rope.

Function Statements:

To hold onto the rope when being pulled down

To slide up the rope when being pulled up

To hold the weight of the climber while attached to the rope

Design requirements:

The device must conform to the following requirements

- Must support a load of 3500 lb_f
- Must not break any rope threads after 100 catch/release cycles
- Must be pulled up the rope with less than 5 lb_f
- Must attach to a standard size carabiner
- Profile must be smaller than 5inx5inx3in
- Must cost less than \$500 in materials
- Must not slide down the rope more than 5 inches when fully weighted
- Device must hold a load of 3500 lb without yielding.
-

Success Criteria:

Must catch a mass of 200 lb_f which has fallen from 5 feet above the device.

Scope of Effort:

The scope of this effort will be designing and constructing the rope capture device while utilizing a purchased carabiner, harness and rope.

Success of the project:

depends on the device being able to fulfill the role of a standard ascender without the use of a toothed camming device which causes damage to the rope under heavy loading conditions. The success of the project will not depend on the ergonomics of the device in the role of a standard ascender because the device was also conceived to fulfill the role of a top rope solo ascension device. This would differentiate the design from a traditional ascender by eliminating exterior device controls, which could be activated by bumping into the user or rock face during operation while also minimizing the profile of the device.

Design and Analysis

Approach:

The initial idea that was conceived was for a device that works in a similar manor to current designs with the removal of the teeth. The additional forces which must be accounted for by the removal of the teeth were to be taken up by the redesign of the camming unit. This design was to take place in a similar manor to spring loaded camming devices which are a popular form of climbing protection.

Design Description:

The Design of the unit will initially be square with a hole for the carabiner to attach to; there will be a back plate for the rope to be pressed into and a pulley like device in the middle, which will cam into the rope.

Benchmark:

Several rope capture devices were considered as a benchmark, the one that was chosen for comparison was the Petzl Micro Traxion, see Figure 1. This device was chosen for comparison due to its popularity as a multiuse directional rope progress capture device.



Figure 1: Petzl Micro Traxion

Performance Predictions:

The predictions that were made based off calculations were that a camming angle of 20 degrees should be sufficient in generating holding power in order for the rope to be directionally caught. The device should face a maximum shear force of 52 KSI under worst-case loadings given that frictional resistance as the only force holding the rope in place. The maximum loading the shear pin can take using SAE 304 is 31 KSI. Given the fact that climbing rope is not rigid, the rope will deform under the loading area of the cam and then will provide additional mechanical stopping power due to deformation. However if the device grabs the rope using only frictional forces the maximum weight it could support is 2370 lbs.

Description of Analysis:

The analysis conducted began with the forces required to hold up a 200 lb. mass with a factor of safety of 10 and was then followed through the device in order to find the minimum forces which all parts must be able to sustain. This led to the camming angle that was calculated based on equations that were derived from a much more basic scenario than what will be experienced by the device. These same equations are also used for spring loaded camming devices so the values produced considering a factor of safety on the input coefficient of friction should be acceptable. See appendix A for exact derivations.

Scope of testing and Evaluation:

The scope of testing and evaluation will involve taking the device into a controlled environment where a rope will be ascended using a prusik knot along with the device while the climber is being backed up on another rope or by a third ascending method. The rope will then be inspected after a number of ascents for any visual damage to the rope threads. After this the device will be loaded into the tensile testing machine in order to find the maximum loading at which the device catastrophically fails.

Analysis:

The analysis for the device is described here; each calculation has been given its own description as follows.

1. The first calculations made were a starting point for force the device would be under, the basic loading is taken to be a 200 lb. mass. Here the loading is simply given a factor of safety to account for potential dynamic loadings which are prone to happen to climbing gear. The loadings used for calculations were chosen using standard ratings for climbing gear.

2. The second calculations were a look back at the initial calculations to see how large of an acceleration the body would be under given a five-foot vertical fall from above the device. This showed an acceptable rate of max deceleration given this scenario.
3. Here the physical forces of stopping the rope with friction alone are calculated and steel is used as a material for parts which will be under heavy physical loadings such as the cam and back plate.
4. Calculation 4 mathematically describes the shape of the cam, which must use friction to engage with the rope and cam directionally. Polar coordinates are used due to the nature of the equations.
5. This calculation further describes the exact shape of the engaging half of the cam, which must be of an exact profile based on the equation found for the general profile in A4. This equation will be directly imported or modified to another coordinate system and then imported to solid-works in order to build this part.
6. The forces that are to be placed on the cam to stop the rope will be transferred onto a connecting pin, which is attached to the back plate. The shear force that will be placed on the connecting pin is calculated here.
7. Calculation seven deals with the additional forces of a spring holding the cam in an initial position on the rope. This will cause a frictional force when moving the device up the rope, which will be an additional force to the gravitational force on the device when finding the maximum force to raise the device on a rope.
8. Calculation 8 looks at the spring force and the minimum force it can apply to the cam for the maximum raising force to remain under 5 lb.
9. Calculation nine deals with the forces that the attaching carabiner will put on the back plate under maximum loading conditions.
10. Calculation 10 finds the maximum forces on the pin in order to select a material that can withstand the forces generated under maximum loading given the worst-case scenario for device loading.
11. These calculations go over a material selection and look at the maximum loading before failure given the material selected.
12. Continuation of calculation 11.

Design Issues:

There were several design issues which were encountered, such a primary method of construction used for similar devices being steel which has been worked into unique shapes which act as a single piece for the entire housing for the device. The calculations for such shapes as well as the manufacture would prove challenging so a much more basic design was used in the design calculations which involved more straightforward forces. The second issue in calculations is a lack of publication on the coefficient of static friction for nylon on steel, so for calculations a kinetic coefficient of friction was used.

Calculated Parameters:

Maximum device loading: 2370 under frictional loading only

Polar equation in mm for cam profile: $8.863e^{(\pi \cdot 0.2)}$

Best Practices:

While there is no standard for a factor of safety in climbing gear design and manufacture there are standard loadings used to rate devices at their failure loadings, these typically range from 15-22 KN. For this device a rating of 3500 lb. of force was chosen which equates to 15.6 KN. The camming angle was modified to account for some loss of friction due to wet condition or rope treatments. The back plate thickness was a standard thickness of a similar device and of a similar material that will be used. The hole for the carabiner was also of a similar diameter of a device which falls under this category. The factor of safety for climbing devices is built into a standard for the amount of force such devices should fail under, for pieces of climbing protection this loading can be as low as 2 KN while for carabiners it can be as high as 65 KN depending on the material and usage. For belay devices there is no true standard but the devices are approximately rated to 15 KN.

Device: Parts, Shapes and Conformations:

The device was conceptualized with a minimal approach to design so there are only five parts. In order to maintain a small profile there is no grab handle like a traditional ascender. For a full list of parts see Appendix C.

Device Assembly, Attachments:

The device assembly will be straightforward except for closing the connections on the pins. These will be riveted in order to make the connections more permanent.

Tolerances, Kinematics, Ergonomics, ect. :

The tolerances of the overall body dimensions only need to maintain slight alignment with the cover plate and back plate. The dimensions for the stop plate and the cam pin hole will be machined within 20 thousands of an inch and the cam will have to be machined to within 10 thousands of its polar curve.

The device will primarily be hands free so there will be minimal ergonomic concerns.

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

This device will be for personal use during rope ascension, it is best practice to use two devices during such activities so that the failure will not directly result in death or injury. Even though there is a large factor of safety placed on this device it should not be used alone, the real world operating conditions have the potential to involve factors such as wet or icy ropes, ropes with inconsistent diameters, highly corrosive environments and rough terrain which could cause impact damage to the device which has not been accounted for here. The operation limits of this device are between 40-120 degrees Fahrenheit, in outdoor activities not involving corrosive environments such those than can be found in underground caves.

Methods and Construction

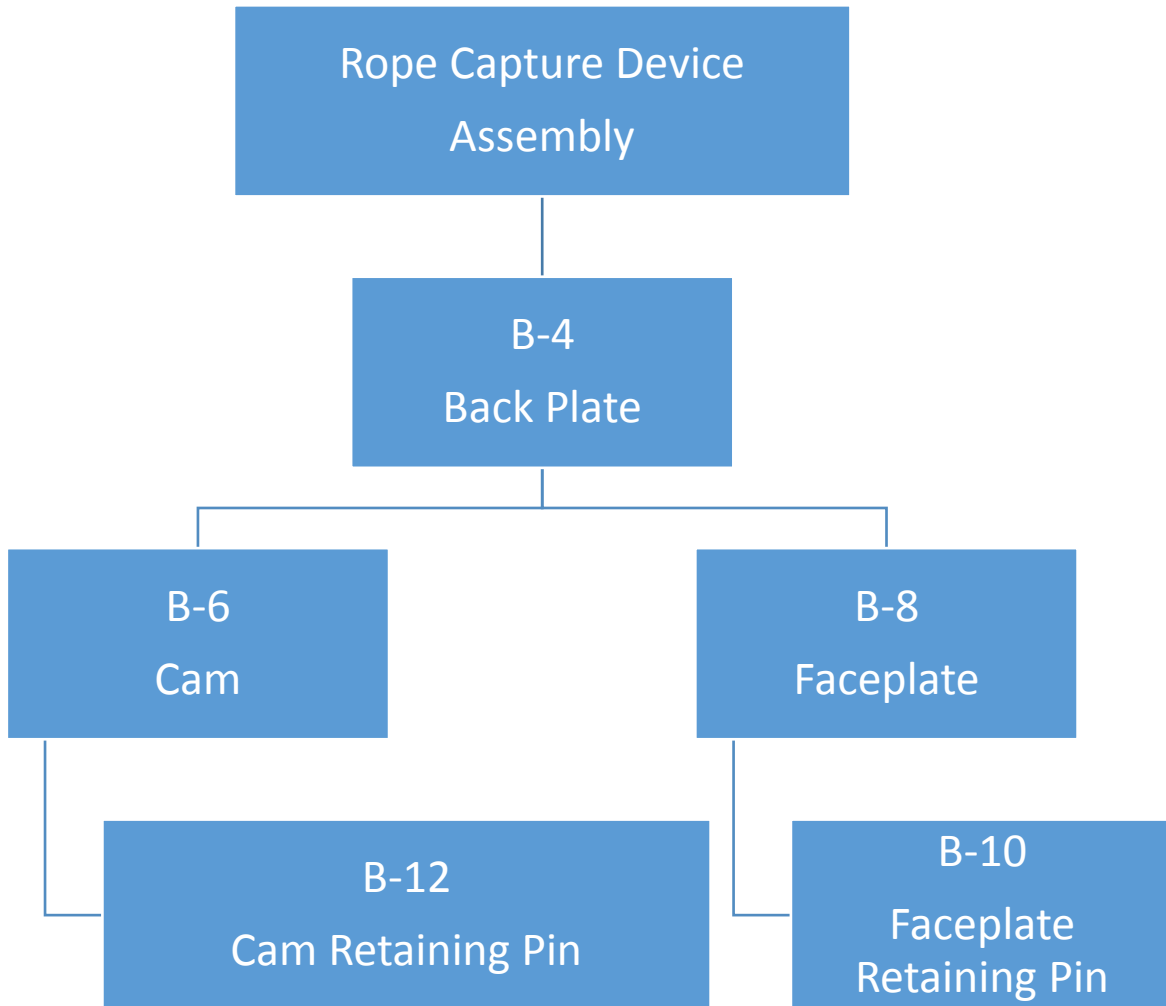
Construction

Description

This device was designed and built using construction methods taught at central Washington University, the device will also be built using the resources at CWU. The initial design considerations can be seen in appendix B1-3. The initial design also used a spring in order to give initial engagement of the cam of the rope; the final design uses the back plate geometry in order to cause the ropes path to always interact with the cam eliminating the need for a spring and its complex mounting. The device was assembled using 2 hammer riveted pins in order to hold all device parts together.

Drawing Tree, Drawing ID's

The drawing tree below shows the drawing numbers and names of each part as it relates to the assembly. The device is comprised of a single assembly with a minimal number of parts in order to simplify construction and reduce the number of failure modes.



Parts List and Labels

- B4: Back plate
- B5: Back plate rendering
- B6: Cam
- B7: Cam rendering
- B8: Faceplate
- B9: Faceplate rendering
- B10: Faceplate retaining pin
- B11: Faceplate retaining pin rendering
- B12: Cam retaining pin
- B13: Cam retaining pin rendering

Manufacturing Issues:

The manufacture of the device will take part at Central Washington University with nearly all activities taking place in the machine shop. This will be restricted to the capabilities of the central machining lab and so if the manufacture of the Back-plate is too complex for the tools available it will have to be built at another location.

The primary issue during construction at central is the precision of the CNC mills, which will be used in the machining of the back-plate and the cam. The cam must be mathematically precise in order for the operation of the device to be successful and the back-plate requires a shaft to be either milled or turned into part of it in order to reduce the total number of parts.

After manufacturing the device the issues encountered included eliminating several fillets on the back plate in order to reduce the complexity of manufacture, increasing the thickness of the back plate backing material in order to grip in in a vice from the bottom in order to machine the part more easily.

Discussion of assembly, sub-assemblies, parts, drawings

The assembly is built off of the back plate with the installation of the cam being the first step, once slotted into its pin, the cam retaining pin is put in place, then the device is flipped over and the cam retaining pin is riveted in place. The next step is placing the faceplate over the back plate and installing the faceplate retaining pin, once in place the faceplate retaining pin is also riveted to hold the device together.

Testing Methods

Introduction:

Testing a climbing product should be done in a manner that will simulate the actual working conditions and use of the device as well as the unexpected shock loading which can occur during climbing.

Method/Approach:

The approach that will be used to test the device will be ascending the rope and holding static positions on the rope with a 200 lb. load to test the holding power of the cam. This first test will determine if the mathematically determined geometry of the cam will work in a given scenario. If the device passes the initial testing then there will be a shock loading applied to the device, a 200 lb. mass will be dropped from 5 feet above the cord while attached to the device with a second piece of rope. This will test the devices ability to handle shock loadings.

Test Procedure:

1. Fix a rope to a high structure in a position where the rope is vertical and hanging freely of any nearby obstacles
2. Ascend the rope several times using the constructed device as a primary device and two standard rope ascension methods as backup systems
3. Fully weight the device while taking tension off any other devices

Deliverables:

The results of the testing show that the designed device caused less abrasive damage while weighting the device on the rope over multiple loadings. The second test revealed the force to pull the designed device up the rope was much higher than the benchmark devices. See appendix G-I.

Budget/Schedule/Project Management

Proposed Budget

Part Suppliers, Substantive Costs and Sequence or Buying Issues:

The materials for this project will be acquired through MetalsDepot.com with OnlineMetals.com as a backup supplier. There are no issues with buying metal stock in sequence due to the small amount of material needed to produce a single unit.

Determine Labor or Outsourcing Rates and Estimate Costs:

The labor costs for this project are considered to be the following, 25\$/h for the principle engineer and 40\$/h for any engineer who is brought on in assistance with the complex manufacture of parts.

Labor:

The Labor for this project will primarily be the principle engineer, the only labor predicted for the completion of two of the parts will be any additional help required in order to manufacture complex structures such as the cam.

Estimate Total Project Cost:

The estimated total project cost will be \$4400 in labor for the principle engineer, an estimated \$200 in labor for the manufacture of the Cam and Back-plate and an estimated \$95 in materials. This brings the project to a total cost of \$4695.

Funding Source:

This project will be funded by the principle engineer.

Proposed Schedule

Specify deliverables, milestones:

The Deliverables will be the project proposal report which will be initially completed by December 5th, 2016 and the device will be constructed by March 10th, 2017. Testing and presentation will be completed by June 1.

Estimate total project time:

The total project time will be 173 Hours.

Gantt Chart:

See appendix E.

Project Management

Human Resources:

The human resources for this project include the principle engineer, CWU engineering staff and Matt Burvee.

Physical Resources:

The resources utilized for the manufacturing part of this project are the machines accessible in Hogue Hall's Machine Lab. Such machines include, CNC end mill, CNC lathe and the drill press.

Soft Resources

The soft resources for this project include Solid-works for creating drawings of the parts as well as Excel for the generation of the Gantt chart.

Financial Resources

The budget for this project came from the principle engineer of the project.

Discussion

Design Evolution/ Performance Creep

The potential evolution of this design would involve generating smaller dimensions around non-critical components in order to reduce weight and size. There is also an optimization to be done around the placement of the cam on the back plate. This optimization would involve selecting an ideal range of ropes for the device to be used with and creating the geometry such that the rope will still interact with the cam with minimal force required to slide the device up the rope.

Project Risk Analysis

The risk of the project lies in the manufacture of the device, generating the dimensions required on the back plate and cam will be the most difficult and will require knowledge of machining that the primary engineer does not possess. While the parts are machineable, the process of machining these parts from stock would most likely not be ideal for manufacture.

Successful

The success of the device depends on its ability to actually ascend ropes. There was also success in the project in that the principle engineer gained knowledge of the design process of a device from the conceptual stage to the design and analysis to production stage.

Project Documentation

All documentation for the project is contained in this report, with all auxiliary documents in the appendix.

Next Phase

The next phase of this project is the manufacture of the device followed by testing.

Conclusion

The device designed in this document is not ready for commercial use, it has been designed as a prototype only and would require significant testing and redesign for mass manufacture in order to be commercially released. This device however has the following capabilities.

- The ability to bite the rope without use of teeth, which would damage the rope in shock loadings.
- The ability to hold 2300 lb. under maximum loading.

Acknowledgements

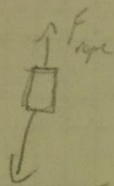
References

Appendix A – Analysis

Seaver Philipp | Send report | 10/12/2016 | 1/2

Given: a 200 lb climber is ascending a rope
 Find: minimum load the device must withstand in water

Solution:



$200 \text{ lb}_c = F_{\text{climber}}$

Force of water = 200 lb drag contact
 acceleration / static Use Factor of safety of
 10 due to nature of equipment / dynamic
 loadings

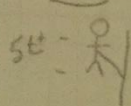
$$200 \text{ lb}_c \cdot 10 = 2000 \text{ lb}$$

Due to the dynamic loading potential and nature
 of the equipment failure resulting in the potential
 for loss of life 2000 lb of force should not
 be considered a maximum loading condition
 unless in the case of using a dynamic rope
 to mitigate impact forces

for calculations an industry standard will be used for the
 minimum failure load of the device, this loading will
 be 3500 lb

Scenario: climber falling from 5 ft above device

Find: impact forces on device

SE: 

Solution: Velocity of climber on impact =

F.S.M.A $(V_2)^2 = (V_1)^2 + 2(a_c)(s - s_0)$

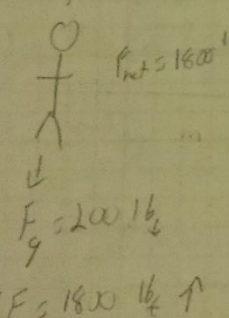
$$V_2 = \sqrt{(0)^2 + 2(32.2 \text{ ft/s}^2)(10 \text{ ft} - 0 \text{ ft})}$$

$$V_2 = 25.377 \text{ ft/s}$$

maximum acceleration such that 22000 lb_f is applied to climber

F.S.M.A $\frac{1800 \text{ lb}_f \cdot \frac{32.2 \text{ lb}_m \text{ ft/s}^2}{\text{lb}_f}}{200 \text{ lb}_m} = a$

$\uparrow 200 \text{ lb}_f$



$F_{net} = 1800 \text{ lb}_f \uparrow$

$F_g = 200 \text{ lb}_f \downarrow$

$\Sigma F = 1800 \text{ lb}_f \uparrow$

max acceleration = 289.9 ft/s^2

time to decelerate =

$$V_2 = a_c \cdot t$$

$$t = \frac{V_2}{a_c} = \frac{25.377 \text{ ft/s}}{289.9 \text{ ft/s}^2}$$

$$t = 0.0875 \text{ seconds}$$

Given a standard dynamic rope, dynamic elongation is 30-40% the impact could easily be spread over a longer period of time than 0.0875 seconds allowing a more reasonable deceleration which will not injure the climber due to a high acceleration.

Same Philipp	Genes project	10/12/2016	1/1
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Given: a friction based device must hold onto a rope with a loading of 3500 lb

First force required to hold rope

Solution: rope strength material: nylon
 cam material: steel
 coefficient of friction for steel on nylon = $\mu_k \approx 0.3$
 see [diracdelta.co.uk](http://www.diracdelta.co.uk)

rope $F_{ropc} = 3500 \text{ lb}$
 sliding $F_{cam} = F_{block}$
 $F_{ropc} = (F_{cam} + F_{block}) \mu_k$
 $3500 \text{ lb} = 2 F_{cam} \cdot 0.3$
 $5833 \text{ lb} = F_{cam}$

$F_{device} = 3500 \text{ lb}$

$F_{cam} = 5833 \text{ lb}$

$F_{block} = 5833 \text{ lb}$

$F_{ropc} = 3500 \text{ lb}$

$F_{block} = 5833 \text{ lb}$

$F_{cam} = 5833 \text{ lb}$

A 3: Required forces on rope to hold climber

Sever Philipp

Genr. report

10/12/2016

Given! a cam must engage with frictional forces to hold the rope in one direction

Find! camming angle of cam

Solution:



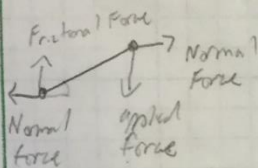
$$F_{\text{normal force left}} = F_{\text{normal force right}}$$

$$F_{\text{applied}} = -F_{\text{friction}}$$

$$F_{\text{friction}} R \cos(\beta) = F_{\text{normal}} R \sin(\beta)$$

$$F_{\text{normal}} \tan \beta = F_{\text{applied}}$$

$$\text{coefficient of friction} \geq \tan \beta$$

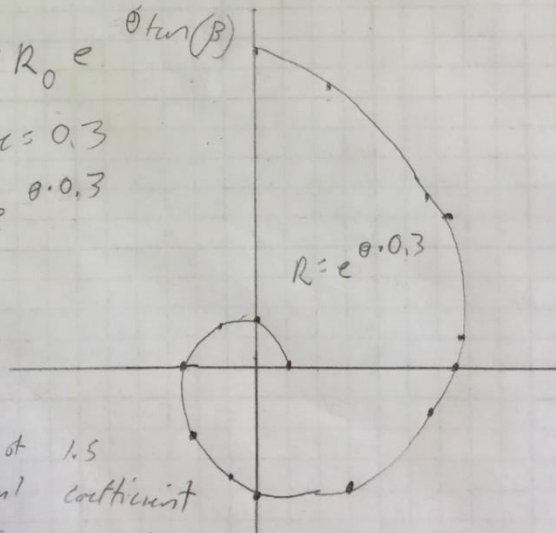


$$\frac{dR}{R d\theta} = \tan(\beta)$$

$$R = R_0 e^{\theta \tan(\beta)}$$

$$\text{for } \mu = 0.3$$

$$R = e^{\theta \cdot 0.3}$$



Compared to similar camming products on Subaru satels of 1.5 is used for the frictional coefficient so that the equation used for the cam will be $R = e^{\theta \cdot 0.2}$

Serial	Name	Date	Page
	Shreyas Philip	10/18/2016	d/h

Given: rope diameter from 11 to 8.5 mm,
 camming angle of $\alpha = 20^\circ$

Find: size of cam required for this range of ropes

Solution

assume ropes can be compressed to $\frac{1}{2} \phi$ maximum
 cam must fill range of 12 mm (for insulation to 4.25 mm)

12 mm range $= (12 - 4.25) \text{ mm} = 7.75 \text{ mm}$

Ideally cam range is accomplished in $\frac{1}{2}$ revolution of cam
 so $x e^{\pi \cdot 0.2} = x e^{(0) \cdot 0.2} = 7.75 \text{ mm}$

$$x e^{\pi \cdot 0.2} - x = 7.75 \text{ mm}$$

$$e^{\pi \cdot 0.2} - 1 = \frac{7.75 \text{ mm}}{x}$$

$$x = \frac{7.75 \text{ mm}}{e^{\pi \cdot 0.2} - 1}$$

$$x = 8.863 \text{ mm}$$

Back half of cam will continue on an slope back into geometry

cam width $= 8.863 \text{ mm} + 16.613 \text{ mm}$
 $= 25.476 \text{ mm}$

Seard Phillip | Senior project | 10/10/2016 | 1/1

Given: a cam holds the rope against a steel plate under a 5833 lb loading

Find: force of cam on retaining pin

Solution: The cam is attached to a pin connected to the backing plate. The pin will be acted on in single shear within force of 5833 lb.

3800 lb 5833 lb

Pin Backing plate

Cam

$\Sigma F = 5833 \text{ lb}$

$\Sigma F = 5833 \text{ lb}$

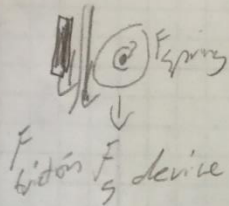
A 6: Cam Pin Shear Forces

Seaver Philipp | Senior project | 10/12/2016 | 1/1

Given: a spring holds the cam in place against the rope to initially engage frictional forces

Find: force of spring in lbf so that the force to lift the device is less than 5 lbf

Solution: Coefficient of friction



Estimated weight of device = 3 lbf

Coefficient of friction steel-nylon = 0.3

max pull up force = 5 lbf

$$F_{\text{max}} = F_{\text{weight}} + 2[F_{\text{cam}} \cdot \mu_k]$$

$$5 \text{ lbf} = 3 \text{ lbf} + 2[F_{\text{cam}} \cdot 0.3]$$

$$F_{\text{cam max}} = 3.33 \text{ lbf}$$

Seamus Phillip	beam project	10/19/2016	1/1
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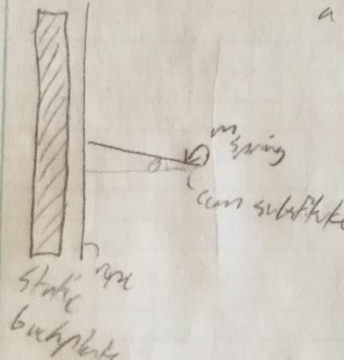
given: a camming angle of 11.31° find maximum spring force on rope so the force to lift a 3 lb device on a rope find 1 spring force

Solution: to come in contact with rope, that has a ϕ of 8.5 mm cam will be $8.863 + (12 - 8.5) = 12.363 \text{ mm}$

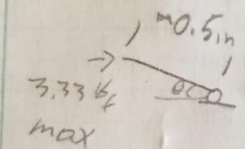
$12.363 \text{ mm} \cdot \frac{1 \text{ inch}}{25.4 \text{ mm}} = 0.487 \text{ in}$

torque = $FR \sin \theta$

torque = $3.33 \frac{1}{2} \cdot 0.5 \text{ in} \cdot \sin(20) = 0.569 \text{ lb in}$



rope
 static bushplate
 cam shaftplate
 spring



$3.33 \frac{1}{2}$
 0.5 in
 20°
 max
 from pairs
 evaluation

Seamus Philipp	Senior Project	10/10/2016	7/2
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Given: a device loaded with 3500 lb is attached to a carabiner

Find: shear forces that will act on loaded side of device under full load

Solution:

force will cause double shear on plate $F_{shear} = \frac{3500 \text{ lb}}{2} = 1750 \text{ lb}$

The backplate will be made of a steel material with a thickness of 0.625 in, with a minimum width of 0.125 in, the hole diameter will be 0.575 to 0.6 in.

Shear stress $= \frac{3V}{2A} = \frac{3(1750 \text{ lb})}{2(0.125 \text{ in} \times 0.625 \text{ in})} = 33 \text{ ksi}$

The material for this hole must have a yield strength higher than 33 ksi in shear

A 9: Carabiner Shear Forces

Seaver Philipp Senior project 10/27/2016 ✓

Given: a cam pin with $\phi = 0.4$ inches with a
0.125 inch hole in the middle 5833, 162 loading

Find: max shear force

Solution: $r = \frac{V}{A} = \text{single shear}$

$$A = \frac{\pi}{4} (0.4 \text{ in})^2 - \frac{\pi}{4} (0.125 \text{ in})^2 = 0.113 \text{ in}^2$$



max shear force before yield: $\tau_{max} = \frac{V}{A}$

$$\tau_{max} = \frac{58.33 \text{ lb}}{0.113 \text{ in}^2} = 51619 \text{ PSI}$$

yield strength must be greater than
52 kSI

Good Ph. 1/9/1	Senior project	11/7/2016	1/2
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Material selection

given: minimum yield for pin = 52 ksi, minimum yield for
 crank bolt = 33 ksi, resistance to corrosion, good machinability,
 FSL material suitable for design

Solution:

based on the parameters above the material selected
 will be A/E 304, a stainless steel which
 is machinable with moderate strength

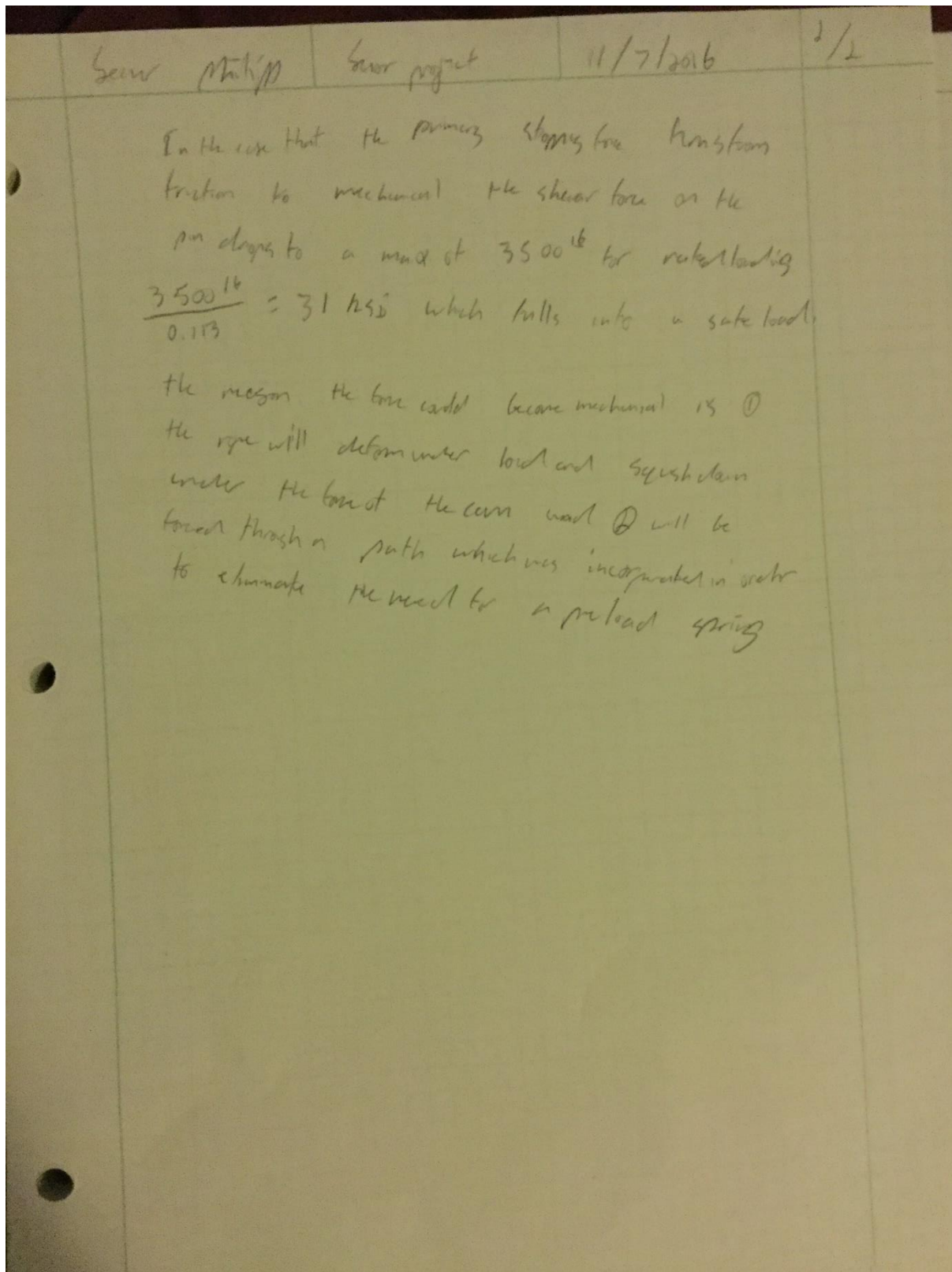
Yield strength: 35 ksi

yield is above crank bolt ~~design~~ design strength
 but lower than pin hole strength

the max loading for the pin now depends to

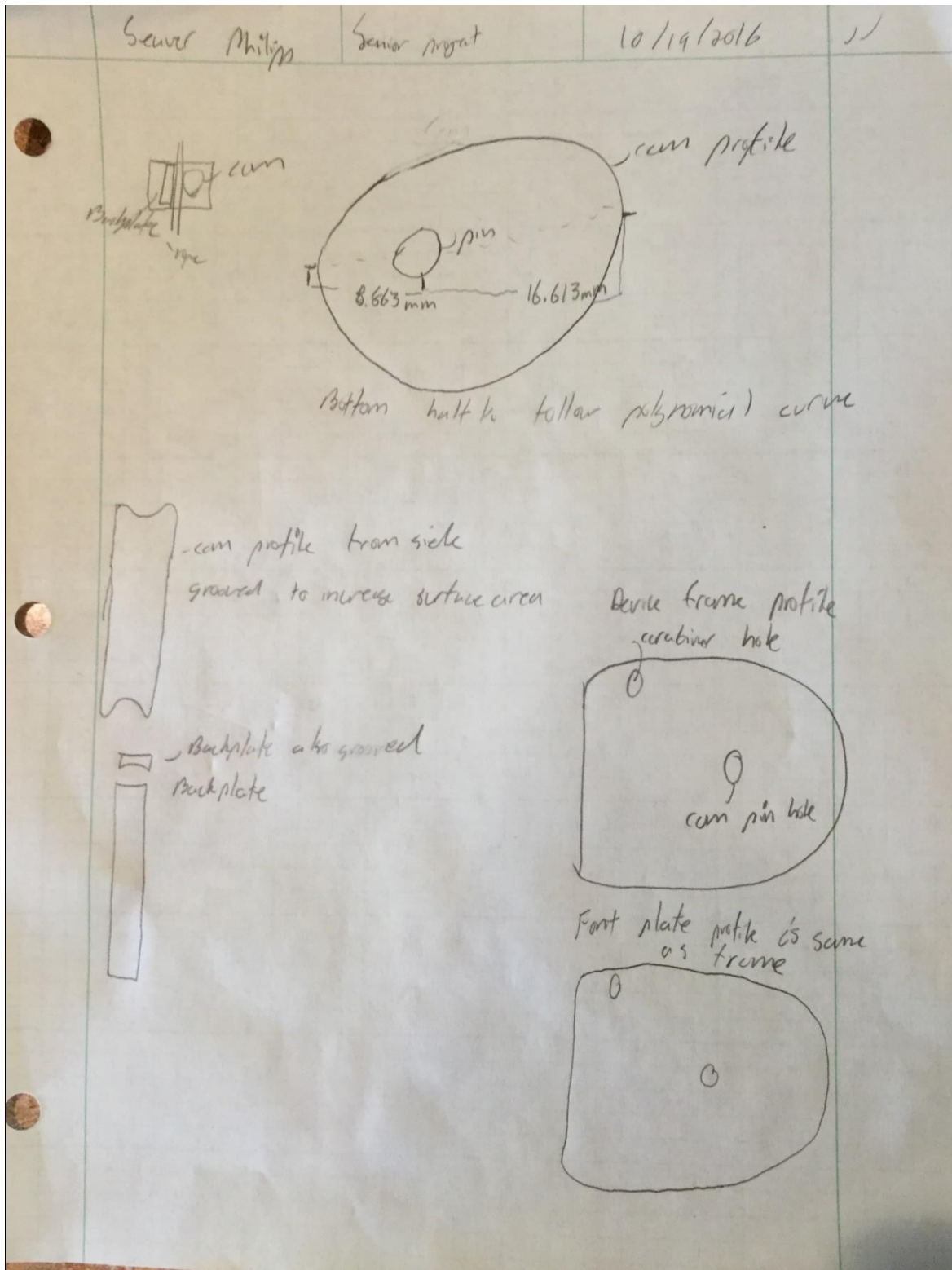
$$35 \text{ ksi} \times \frac{F}{0.113 \text{ in}^2} \quad F \leq 3955 \text{ lbf}$$

which translates
 to a direct loading of 2373 lbf under a worst
 case friction only loading, this is about 68% of
 the design requirement, the actual failure load will likely
 be higher due to a mechanical stoppage caused due to
 the deformation of the climbing rope.

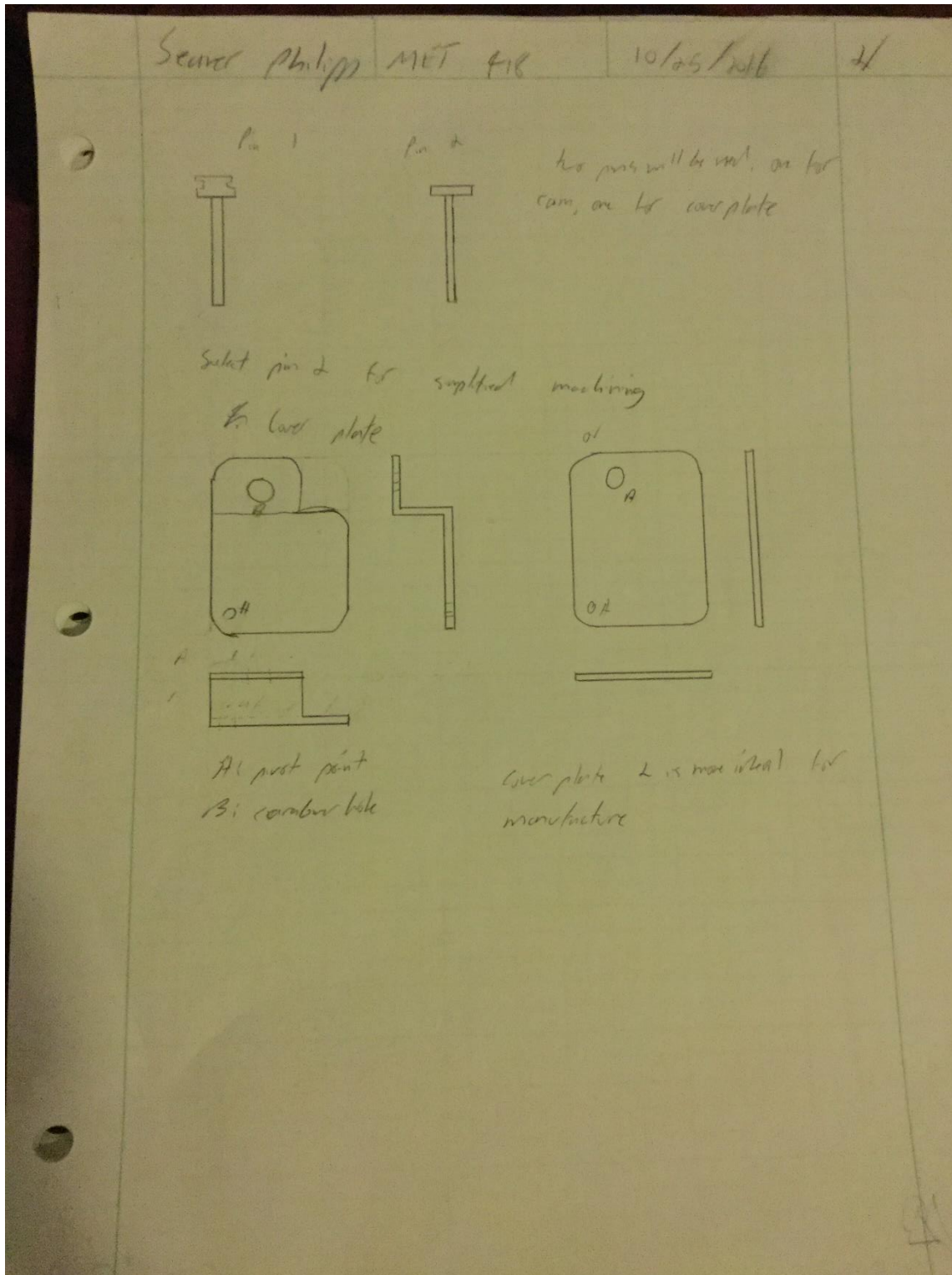


A 12: Cam Pin Material Selection 3

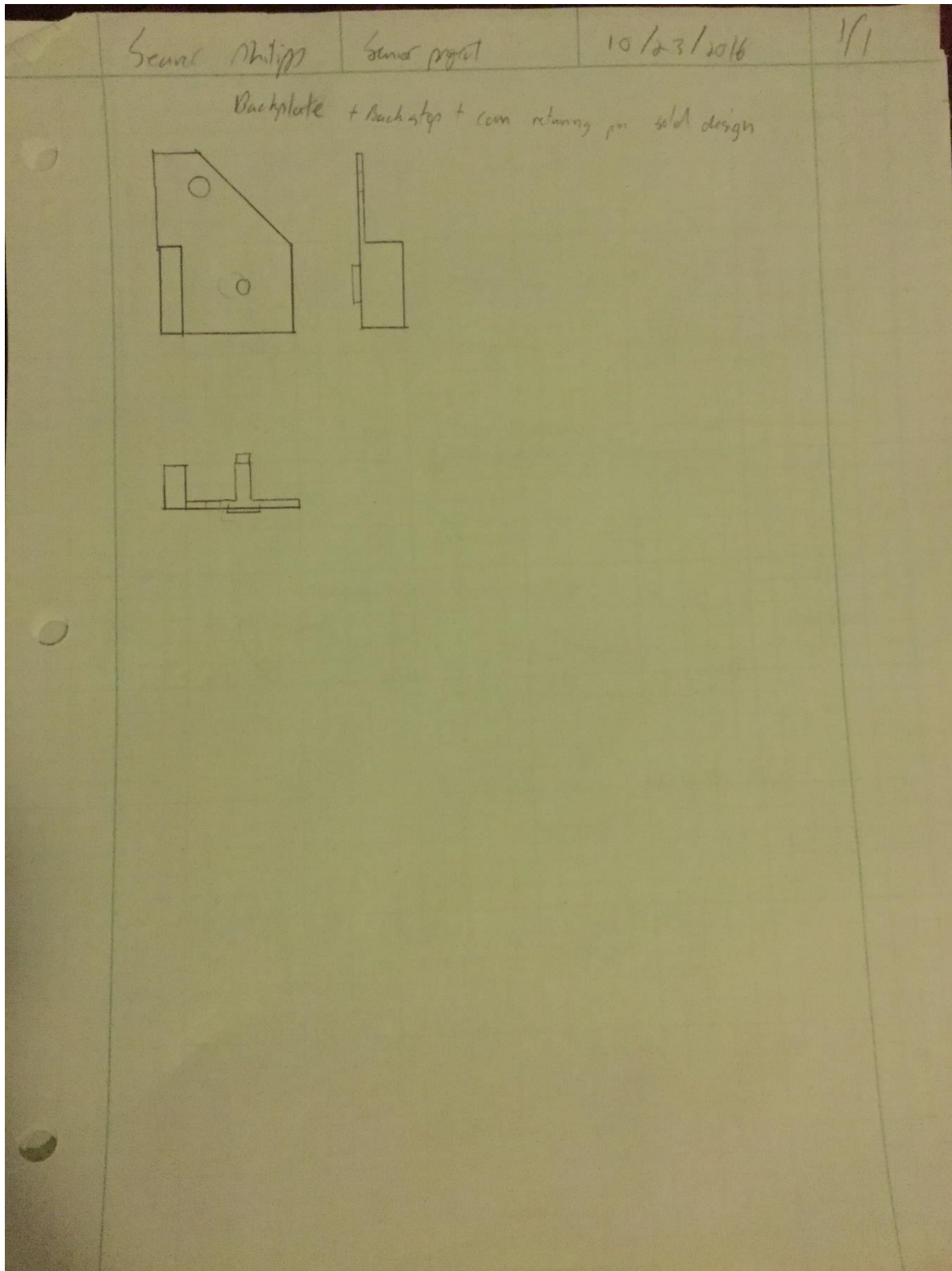
Appendix B – Drawings



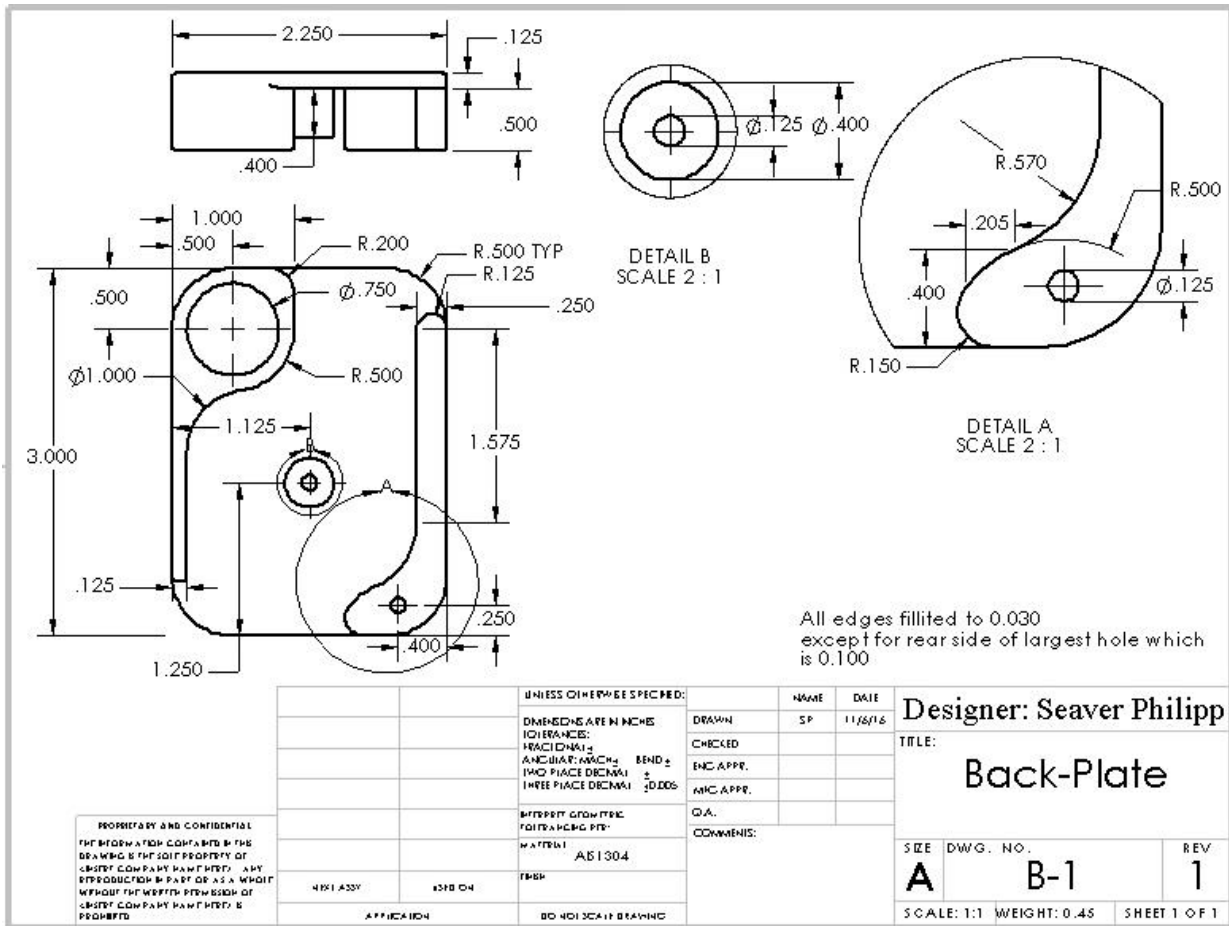
B1: Concept Drawings



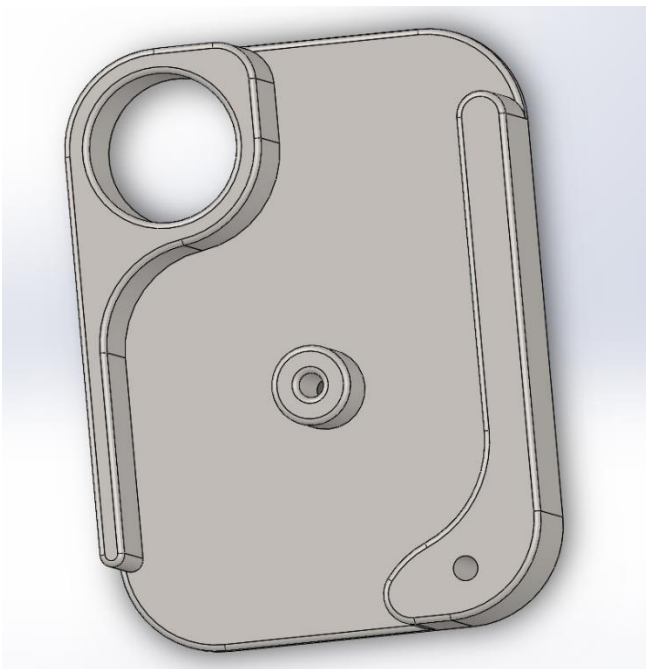
B 2: Concept Drawings 2



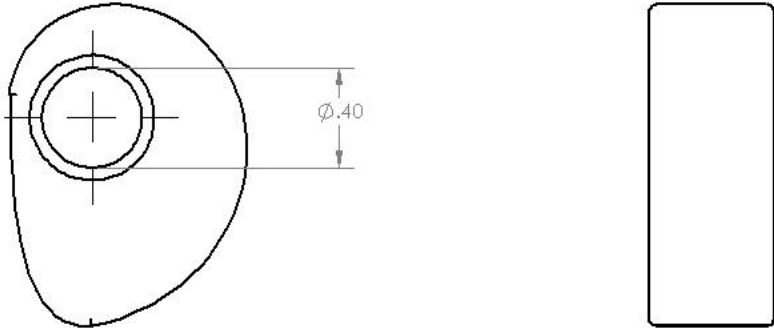
B 3: Concept Drawings 3



B 4: Cam Back-Plate Drawing



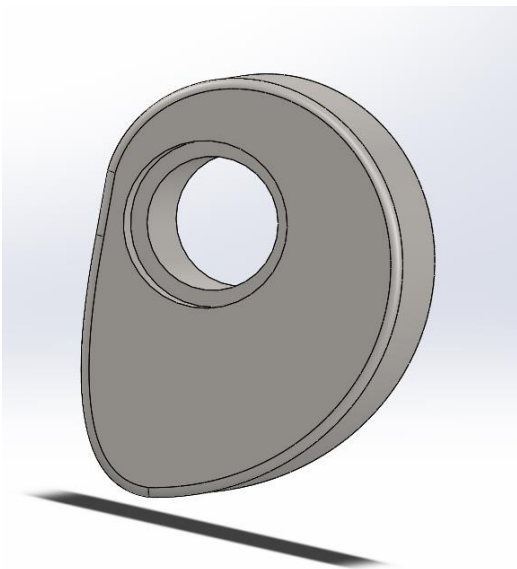
B 5: Cam Backplate Rendering



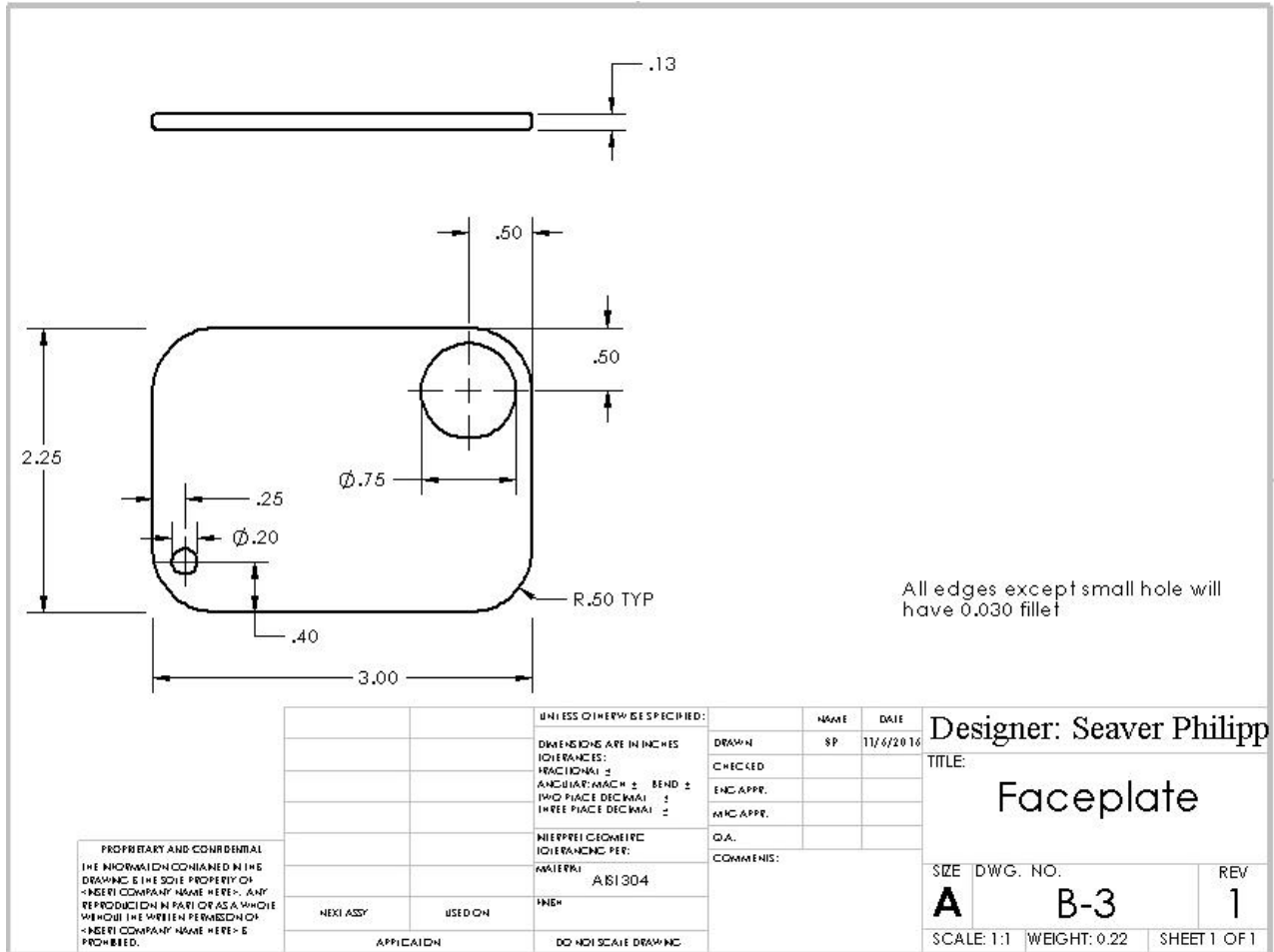
See Solidworks files for Part Dimensions

PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.			UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		NAME DATE	Designer: Seaver Philipp TITLE: <h2 style="text-align: center;">Cam Profile</h2> SIZE DWG. NO. REV A B-2
	NEXT ASSY USED ON	APPLICATION	MATERIAL AISI304	FINISH	DRAWN SP 11/9/2016 CHECKED ENG APPR. MFG APPR. Q.A. COMMENTS:	
			DO NOT SCALE DRAWING		SCALE: 2:1 WEIGHT: 0.12 SHEET 1 OF 1	

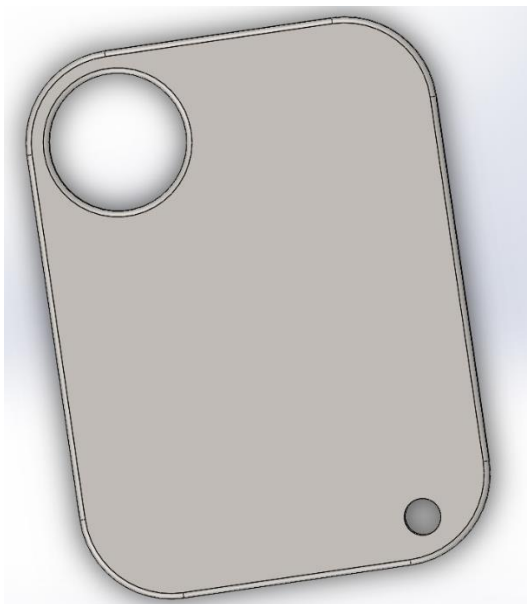
B 6: Cam Drawing



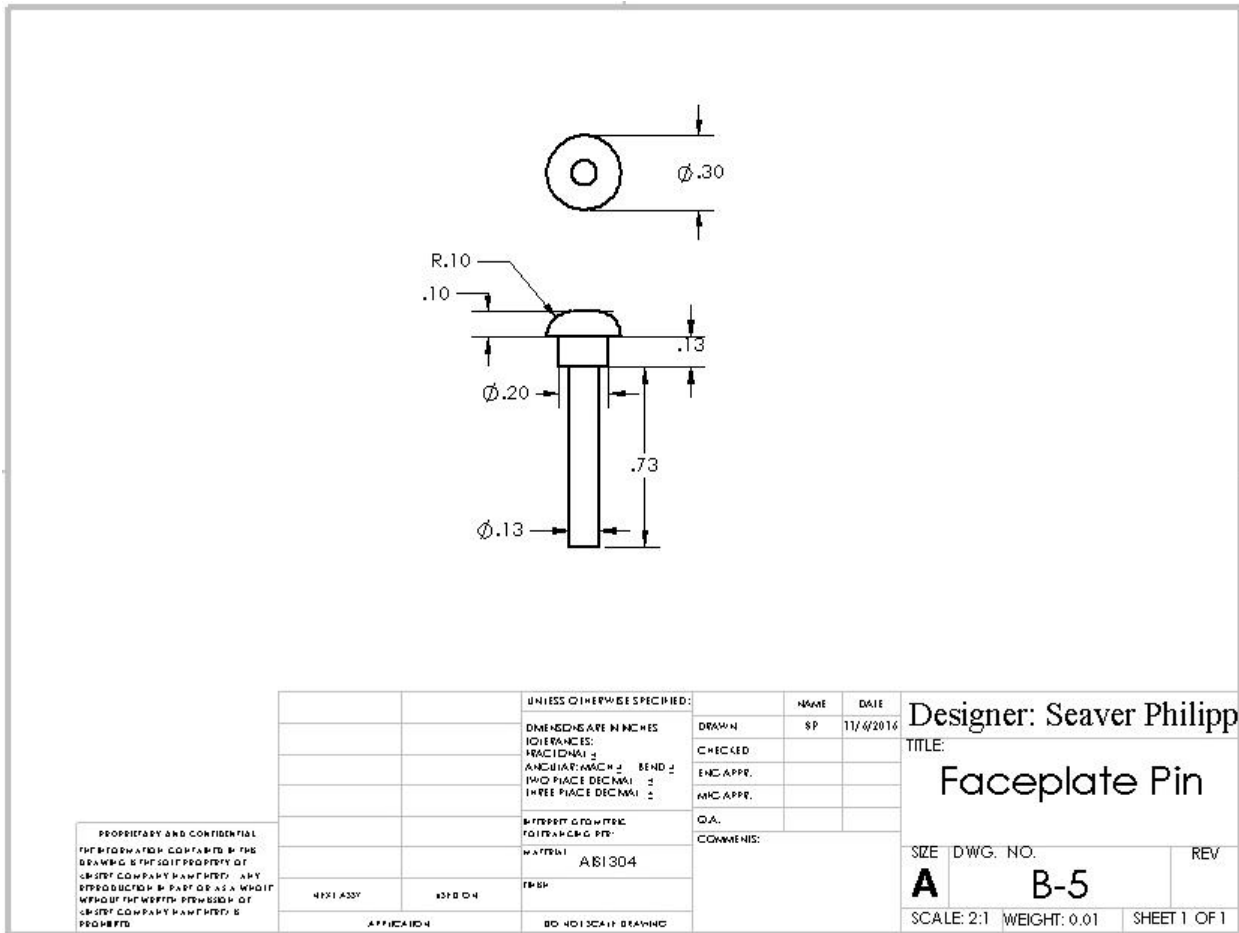
B 7: Cam Rendering



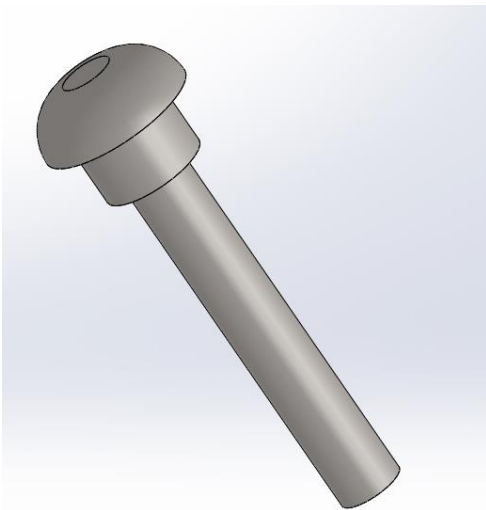
B 8: Faceplate Drawing



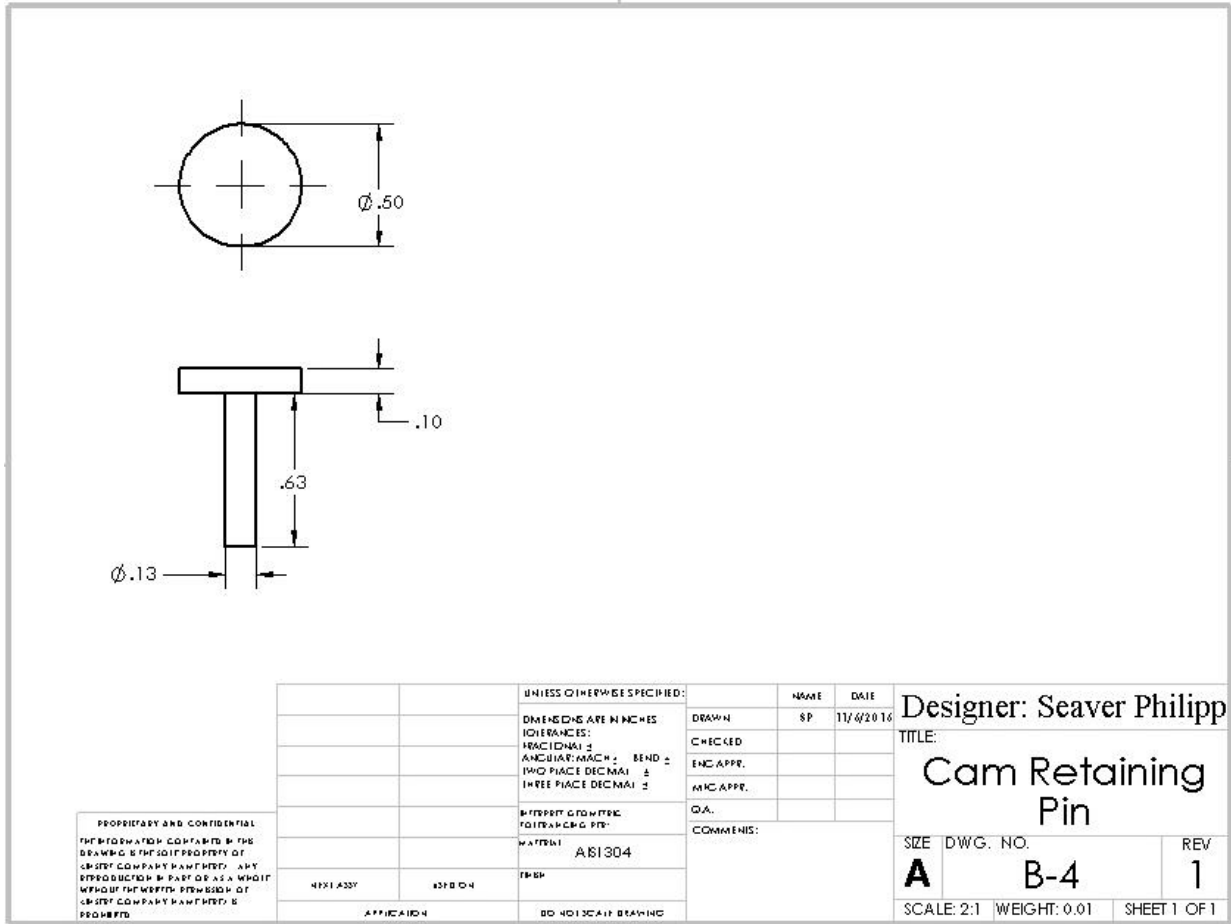
B 9: Faceplate Rendering



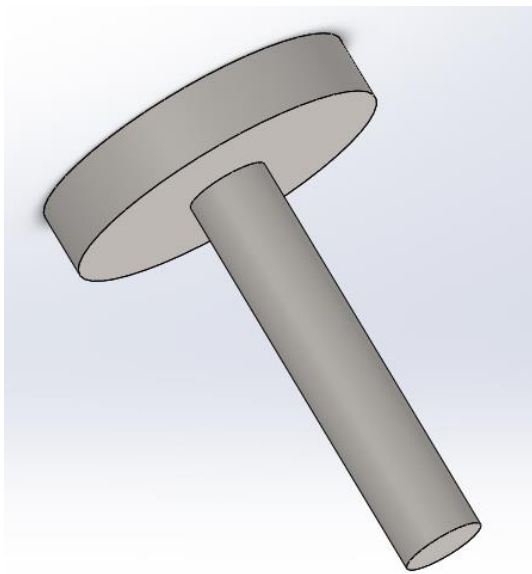
B 10: Faceplate Pin Drawing



B 11: Faceplate Pin Rendering



B 12: Cam Pin Drawing



B 13: Cam Pin Rendering

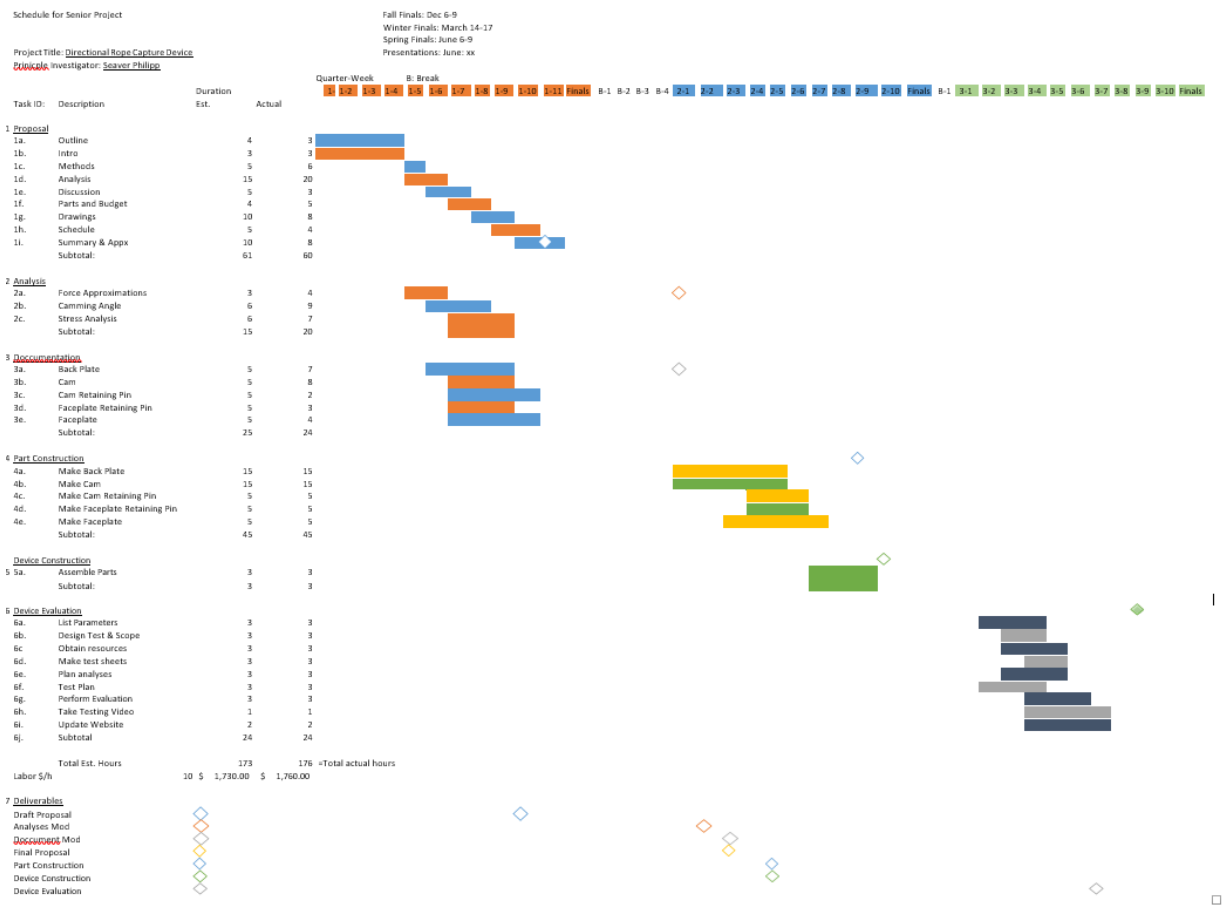
Appendix C – Parts List

Part	Drawing #	Stock	Cost	Source
Back-Plate	B-4	4"x1"x5"	\$35	Metals Depot
Cam	B-6	4"x1"x5"	\$25	Metals Depot
Cam retaining pin	B-12	1"x4" round	\$10	Metals Depot
Faceplate	B-8	4"x1"x5"	\$12	Metals Depot
Faceplate retaining pin	B-10	1"x4" round	\$10	Metals Depot

Appendix D – Budget

Part/Product/labor	Quantity	Source	Cost	Total Spent
Principle Engineer Labor	176 hours	-	25 \$/h	\$4400
Additional Engineering labor	5 hours	-	40 \$/h	\$200
Steel Stock Flat	1	Metals Depot	\$40/foot	\$40
Steel Stock Round	1	Metals Depot	15\$/foot	\$15

Appendix E – Schedule

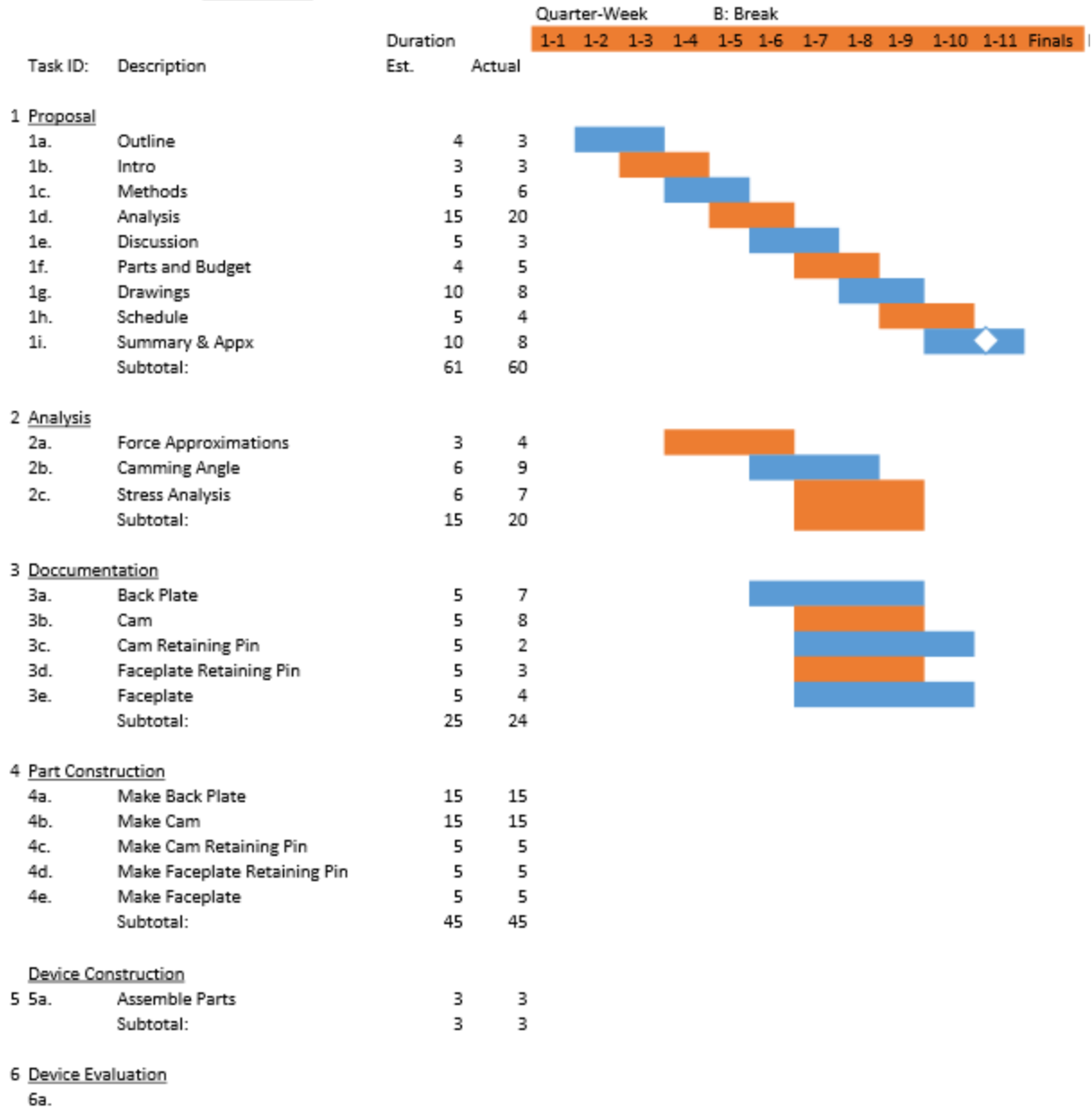


E 1: Gantt Chart Overview

Schedule for Senior Project

Fall Finals: Dec 6-9
 Winter Finals: March 14-17
 Spring Finals: June 6-9
 Presentations: June: xx

Project Title: Directional Rope Capture Device
 Principle Investigator: Seaver Philipp



E 2: Gantt Chart for First Quarter

Appendix F – Expertise and Resources

Appendix G – Testing Data

Testing Results for Test 1

Device	Predicted Damage Count	Measure Damage Count
Petzl Micro Traxion	25	23
Senior Project	12	10

Rope 1 was used with Engineered Device

Rope 2 was used with Petzl Micro Traxion











Testing Results for Test 2

Seard Philipp | Senior Project test 2 | 9/26/2017 | 1/1

measurements taken in lbs.

Device	Device Weight	pull test 1	pull test 2	pull test 3	pull test 4
Abel micro traction	0.20	0.75	0.70	0.70	0.75
Limbs lock roll n lock	0.20	0.80	0.85	0.85	0.90
Senior Project	0.85	6.55	6.15	6.35	6.55

predicted value 6 lb

Averages

Micro Trax : 0.725

roll n lock : 0.85

Senior Project : 6.40

Device	Device Weight	Test 1	Test 2	Test 3	Test 4	Average
Micro Trax	0.2	0.75	0.70	0.70	0.75	0.725
Roll n Lock	0.2	0.80	0.85	0.85	0.90	0.85
Senior Proj	0.85	6.55	6.15	6.35	6.55	6.40

Measurements taken in lbs.

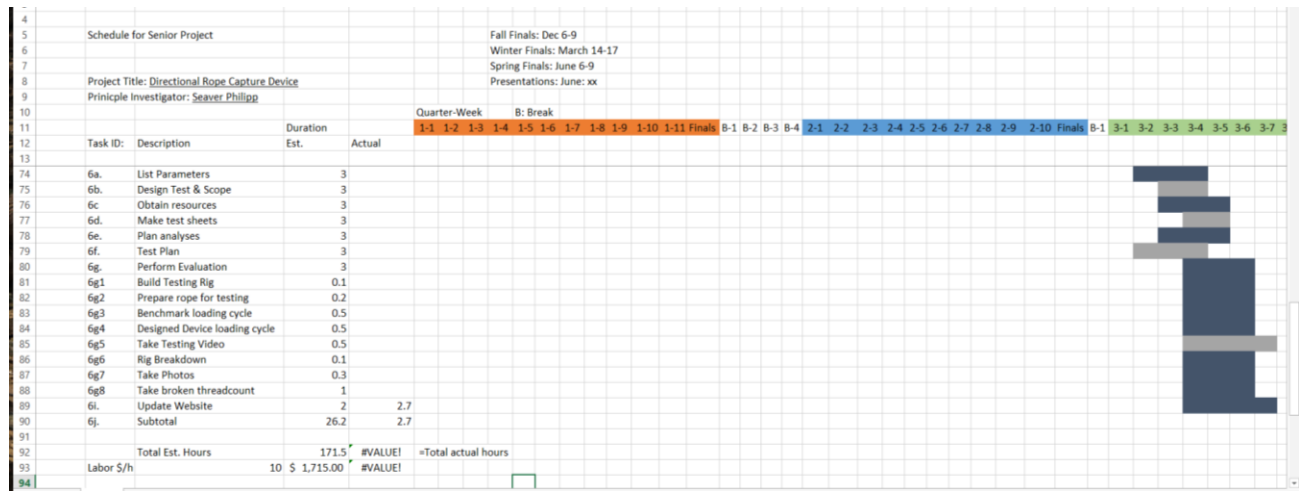
Predicted Pull Weights

Micro Traxion: 1 lb.

Roll n Lock: 1 lb.

Senior Project: 6 lbs.

Gantt Chart



Procedure Checklist

Test 1

- Build Testing Rig
- Mark Rope
- Test Benchmark Device
- Test Designed Device
- Take Video of Testing
- Take Photos of Rope
- Deconstruct Testing Rig
- Upload Photos and Video
- Take Broken Thread count and record

Test 2

- Gather Device, Benchmark Devices, Rope and Hanging Scale
- Measure force to pull devices up rope
- Record

Appendix H – Evaluation Sheet

Testing Results for Test 1

Device	Predicted Damage Count	Measure Damage Count
Petzl Micro Traxion	25	23
Senior Project	12	10

Testing Results for Test 2

Device	Device Weight	Test 1	Test 2	Test 3	Test 4	Average
Micro Trax	0.2	0.75	0.70	0.70	0.75	0.725
Roll n Lock	0.2	0.80	0.85	0.85	0.90	0.85
Senior Proj	0.85	6.55	6.15	6.35	6.55	6.40

Measurements taken in lbs.

Predicted Pull Weights

Micro Traxion: 1 lb.

Roll n Lock: 1 lb.

Senior Project: 6 lbs.

Appendix I –Testing Report

Rope Capture Device Abrasion Testing Design Guide

Introduction

The primary function of the device is to reduce the amount of sheath damage in comparison to a traditional ascender design utilizing teeth. So in this test, the designed ascender as well as a benchmark will be tested in order to compare their abrasive damage to the rope over a standard loading cycle for ascension. This test will require two ascenders, a rope, somewhere to hang the rope that will hold 500 lbs. and a high definition camera. The parameter of interest will be the amount of fiber damage seen on the rope sheath. The predicted performance for this test is that the designed device will cause less damage to the sheath of the rope. Data acquisition will be by camera in order to take clear pictures and

then evaluated by sight. The testing is to be taken place over the third and fourth weeks of the quarter (see gantt chart). The secondary testing includes measuring the amount of force required to pull the device up the rope under a typical climbing scenario.

Method / Approach

The resources required for the testing include

- The ascender that is to be tested
- A benchmark ascender that is in like new condition
- A climbing rope that is in like new condition
- Any additional hardware that would be required for the chosen rigging site
- High definition camera
- 180 lb. mass
- Carabiner
- Sling
- Hanging Scale

The test will involve weighting both devices on a small section of rope multiple times with the weight of an average climber and then inspecting the rope for abrasion damage. The limits of this testing will be the weight applied; the abrasive damage caused by the toothed design will increase dramatically under high loads which will not be tested here. The precision and accuracy of this test will depend on the number of times the rope is weight and how small of an area of rope the loads are kept to. The data for this test will be stored digitally and analyzed by attempting to count the number of broken fibers in the pictures the data will be presented in two photos highlighting any damage to the ropes sheath. The second test will involve pulling the devices up the rope with a hanging scale.

Test Procedure

Test 1

To test the ascenders a small section of rope will be loaded repeatedly using the ascenders in order to compare abrasion damage. There is no time or location requirement for the test. The resources required are listed above in the method / approach section.

Test 2

To test the force to pull the device up the rope the devices will be loaded on the rope with a section of rope hanging below and a hanging scale will be used to pull the devices up the rope. A reading will be taken once the scale stabilizes at a certain weight.

Testing Procedure (test 1)

1. Find a suitable place that can hold 500 lbs. to hang a climbing rope such that at least 5 feet are hanging freely and the rope is capable of supporting 500 lbs.
2. Tape off 2, 5 +/- .25 inch sections of rope and label them section 1 and 2. The ends of the rope provide the easiest sections to measure. Use an easily removable tape (not duct tape) and use as much as you want as long as it stays in place and the 5 inch section is not taped over.
3. Mark the tape on one side of the rope so that the abrasive part of each ascender can be loaded on the same side of the rope every time.
4. First attach the benchmark device onto one of the rope sections so that the abrasive side will always act on the marked side of the rope, and using a rope or cord attached to the ascender load the device with 180 lb. for 3 seconds.
5. After unloading the device slide it to a spot in the same 5 inch section of rope and repeat the loading.
6. Repeat steps 3 and 4 until the first device has been loaded on the rope 50 times. After each loading the device should be slid up the rope to a new location and once at the end of the 5 inch section it should then be removed and replaced at the bottom of the 5 inch section.
7. Repeat step 3-5 for the second device in the second taped off section of rope
8. Now disassemble the testing rig
9. Place the climbing rope against a clear background (piece of paper) and use the digital camera to take pictures of the damaged side of the rope
10. After uploading the images review the sheath images and count the number of broken fibers on each section of rope

This test will involve minimal risk due to the low to ground testing.

Deliverables

The values produced by test 1 will be a count of the number of broken fibers produced by each device with a calculated percent reduction in the number of fibers by the more successful device. Success criteria for this test would be a broken fiber count less than 25. The values produced by test 2 will be the force required to pull the device up the rope.

Appendix J – Resume

Seaver Philipp

812 W Bender Rd Ellensburg, WA 98926 | 509-607-1782 | Philipps@cwu.edu

Objective

- To further my mechanical knowledge and understanding working with experienced engineers in order to obtain a more complete education.

Education

| 2013-PRESENT | CENTRAL WASHINGTON UNIVERSITY

- Intended Major: Mechanical Engineering Technology
- Related coursework completed: Technical Writing, Computer Aided Design and Drafting, Machining, Computer Basics, General Chemistry
- Cumulative GPA: 3.85
- Current Standing: Junior

| 2011 | ELLENSBURG HIGH SCHOOL

Graduated

Skills & Abilities

ELECTRONIC

- Writing Reports, Proposals, Memos and Emails
- Using the full Microsoft suite software including access and excel

MECHANICAL

- Performing basic mechanical diagnostics, carrying out repairs as well as parts fabrication for motorcycles, automobiles and tractors

Experience

FARM LABOR AND GENERAL REPAIRS

- Working informally for family members performing mechanical repairs, home repairs and landscaping such as reroofing, drywall and painting