

Automatic Safety Brake for a Snowboard

Major Qualifying Project Report

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ABSTRACT

Runaway snowboards pose a very hazardous threat to skiers, snowboarders, and all other patrons of ski resorts. Currently, the only safety mechanism to prevent runaway snowboards is the safety leash. However, the safety leash is unreliable because it does not automatically activate and requires the rider to manually strap it around their ankle, and is also not fully functional because it is not activated unless the rider is on the board. The goal of this project was to design, prototype, and test an automatic safety snowboard brake which activates and deactivates automatically, and remains functional when the board is not in use. The project team researched existing patents and designs for both ski and snowboard brakes, analytically designed a spring loaded piston – cylinder brake mechanism and a four bar driving mechanism, performed finite element stress analysis on the critical components, selected the material, created a rapid prototype, and tested the functionality of the brake under a variety of realistic conditions. These methods yielded a successful, fully functional automatic snowboard safety brake.

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TABLE OF CONTENTS

List of Figures	7
List of Tables	10
Executive Summary	11
1.0 INTRODUCTION	13
2.0 LITERATURE REVIEW	15
2.1 <i>Target Population</i>	15
2.2 <i>Injuries Caused by Runaway Snowboards</i>	15
2.3 <i>Existing Designs & Patents</i>	17
2.3.1 <i>The Traditional Ski Brake</i>	17
2.3.2 <i>Snowboard Brakes</i>	18
3.0 TASK SPECIFICATIONS, DESIGN CONCEPTS, ANALYTICAL DESIGN DESCRIPTION OF COMPONENTS, SUBASSEMBLIES & FINAL ASSEMBLY	25
3.1 <i>Task Specifications</i>	25
3.2 <i>Design Concepts</i>	26
3.3 <i>Analytical Design Descriptions of Components & Subassemblies</i>	27
3.3.1 <i>Brake Mechanism Subassembly</i>	27
3.3.2 <i>Brake Piston</i>	28
3.3.3 <i>Brake Cylinder</i>	29
3.3.4 <i>Brake Attachments</i>	30
3.3.5 <i>Brake Nest</i>	32
3.3.6 <i>Guiding Pin</i>	33
3.3.7 <i>Compression Spring Selection</i>	33
3.3.8 <i>Four Bar Driving Mechanism Subassembly</i>	35
3.3.9 <i>Four Bar Driving Mechanism Kinematic Design & Analysis</i>	36
3.3.10 <i>Ground Link</i>	40
3.3.11 <i>Input Link</i>	41
3.3.12 <i>Coupler Link</i>	42
3.3.13 <i>Follower Link</i>	42
3.3.14 <i>Track Cap</i>	43

3.3.15 Bolt Pattern Inserts	44
3.3.16 Base Plate	46
3.3.17 Riser	47
3.3.18 Purchased Components.....	48
3.3.19 Full Assembly.....	49
3.4 Materials Selection & Stress Analysis of Critical Components.....	49
3.4.1 Material Selection.....	50
3.4.2 Finite Element Stress Analysis (FEA) of Critical Components.....	61
4.0 RESULTS	67
4.1 Test Procedure	67
4.2 Results and Analysis	69
4.3 Customer Reviews	75
5.0 CONCLUSION.....	81
5.1 Customer Reviews	81
5.2 Entrepreneurship of Product	82
5.2.1 Market	82
5.2.2 Production.....	84
5.2.3 Market Saturation	85
5.2.4 Risk.....	86
Bibliography	90

List of Figures

Figure 2.1: (Szafranski, 1989).....	17
Figure 2.2: Patent brake design (Kelly, 2004)	19
Figure 2.3: Snowboard brake binding configuration (Kelly, 2004).....	20
Figure 2.4: Manually operated brake (Ozburn, 1994).....	22
Figure 2.5: Braking device in open and closed position. (Freemon, 2001)	23
Figure 2.6 (FSU Skateboards, 2003).....	24
Figure 3.1: Final Design Concept	26
Figure 3.2: Brake Mechanism Subassembly (Deactivated)	27
Figure 3.3: Brake Mechanism Subassembly (Activated).....	27
Figure 3.4: Brake Piston	28
Figure 3.5: Brake Cylinder	29
Figure 3.6: Standard Brake Attachment (Two Inch Version Shown).....	30
Figure 3.7: Powder Brake Attachment (Two Inch Version Shown).....	31
Figure 3.8: Brake Nest Bottom	32
Figure 3.9: Brake Nest Top.....	32
Figure 3.10: Four Bar Driving Mechanism Subassembly (Deactivated).....	35
Figure 3.11: Four Bar Driving Mechanism Subassembly (Activated).....	35
Figure 3.12: Four Bar Driving Mechanism.....	36
Figure 3.13: Mechanism Configuration 1	37
Figure 3.14: Mechanism Configuration 2	37
Figure 3.15: Mechanism Configuration 3	38
Figure 3.16: Mechanism Configuration 4	38
Figure 3.17: Mechanism Configuration 5	38
Figure 3.18: Ground Link	40
Figure 3.19: Input Link	41

Figure 3.20: Coupler Link.....	42
Figure 3.21: Follower Link.....	43
Figure 3.22: Track Cap	43
Figure 3.23: Snowboard Bolt Patterns (Savant, 2011).....	44
Figure 3.24: Burton 3D Three Hole Bolt Pattern Dimensions (Alpine Carving, 2011).....	45
Figure 3.25: 4x4 Four Hole Bolt Pattern Insert	46
Figure 3.26: Burton 3D Three Hole Bolt Pattern Insert.....	46
Figure 3.27: Base Plate	46
Figure 3.28: Riser.....	47
Figure 3.29: Full Assembly.....	49
Figure 3.30: Important Considerations for Materials Selection (Leardon Solutions, 2009).....	50
Figure 3.31: Young’s modulus v. Density (All materials) (CES Edupack, 2009).....	52
Figure 3.32: Young’s modulus v Density (Polymers) (CES Edupack, 2009).....	53
Figure 3.33: Polymers v Young’s Modulus (10^6 psi) (CES Edupack, 2009)	54
Figure 3.34: Polymers v Density (lb/ft ³) (CES Edupack, 2009)	55
Figure 3.35: Polymers v Hardness (HV) (CES Edupack, 2009).....	56
Figure 3.36: Polymers v Price (USD/lb) (CES Edupack, 2009).....	57
Figure 3.37: Polymers v Yield Strength (ksi) (CES Edupack, 2009)	58
Figure 3.38: Polymers v Tensile Strength (ksi) (CES Edupack, 2009).....	59
Figure 3.39: First Extreme Loading Condition.....	62
Figure 3.40: von Mises Stress Analysis of First Extreme Loading Condition.....	63
Figure 3.41: Displacement Analysis of First Extreme Loading Condition.....	63
Figure 3.42: Second Extreme Loading Condition.....	64
Figure 3.43: von Mises Stress Analysis of Second Extreme Loading Condition	65
Figure 3.44: Displacement Analysis of Second Extreme Loading Condition	65
Figure 4.1: Starting Position of Snowboard for the Static Perpendicular Test	67

Figure 4.2: The result from a parallel static test on a 10 degree slope on groomed snow.	68
Figure 4.3: This shows the results of a parallel dynamic.	69
Figure 4.4: Graphical analysis of average distance to stop in inches.....	74
Figure 4.5: Graphical analysis of time to stop in seconds.....	75
Figure 4.6: Mike Halloran visually inspecting our brake.	76
Figure 4.7: Mike Halloran testing the function of the driving mechanism.....	76
Figure 4.8: Mike Aiesi examining the brake end effector designed for deep powder conditions.....	77
Figure 4.9: Mike Martin, the snowboard rental manager, trying the brake system.	78
Figure 4.10: Nick McAllister testing the function of the driving mechanism to retract the brake.	78
Figure 4.11: Heidi Dow Besse evaluating our brake system.	79
Figure 4.12: This picture shows the low profile rental board in the foreground with the safety board equipped with traditional high-back bindings in the background.	80
Figure 5.1: Market Saturation (Palizza, 2010).....	85
Figure 5.2: Mount Wachusett Rental Liability Release Agreement (Wachusett Mountain, 2011)	88

List of Tables

Table 3.1: Spring Specifications (Highlighted Spring Chosen for Final Design).....	34
Table 3.2: Cumulative Data for Mechanism Design Configurations.....	39
Table 3.3: Design Matrix for Mechanism Design Configurations.....	39
Table 3.4: Summary of Purchased Components.....	48
Table 3.5: Material Properties (Top three materials) (CES Edupack, 2009).....	59
Table 3.6: Material Selection Decision Matrix.....	60
Table 4.1: Distances and Times on a 10 degree slope.....	70
Table 4.2: Distances and Times on a 20 degree slope.....	70
Table 4.3: Distances and Times on a 30 degree slope.....	70
Table 4.4: Average Distance, Time, and Velocity on a 10 degree slope.....	71
Table 4.5: Average Distance, Time, and Velocity on a 20 degree slope.....	71
Table 4.6: Average Distance, Time, Velocity on a 30 degree slope.....	72
Table 4.7: Average Distance, Time, and Velocity dependent on slope for groomed conditions.....	72
Table 4.8: Average Distance, Time, and Velocity dependent on slope for loose granular conditions.....	73
Table 4.9: Average Distance, Time, and Velocity dependent on slope for ice conditions.....	73

Executive Summary

All across the country thousands of people flock to ski resorts during the winter months to take part in the many activities available. Through their participation there are inherent risks that are often overlooked and could lead to severe injury. One of these risks is runaway snowboards. In a perfect world snowboards are tethered to riders through the use of a leash that is strapped around their leg. The problem occurs when the rider exits their bindings for one reason or another and removes the leash. Now their unattended board can be knocked into motion accidentally by another patron of the mountain and has the potential to become a projectile heading down the mountain with sufficient momentum to cause injury or property damage. The design for a solution was needed since snow skis already have a built in brake that works extremely well for its size to bring a ski with momentum to a short stop.

The design had to be compact enough to not interfere with normal operation of the board and couldn't add too much additional weight. A solution was drawn up utilizing a step plate that fits inside the binding and when the rider steps down onto it, a cable is drawn. This cable is attached to a shaft in a cylinder. The shaft has a 90 degree cut into that as it's drawn into the cylinder a pin fits into the cut and rotates the shaft. On the end of the shaft is the brake attachment that makes contact with the snow to provide the braking force. When the foot is removed from step plate a spring in the cylinder behind the shaft forces the shaft out. As the shaft is pushed out the fixed pin rotates the shaft and brake attachment from a horizontal storage position to a vertical active position.

The design was manufactured and worked as intended to immediately activate once the foot was removed from the binding and bring the board to a quick and safe stop. Our brake was

tested on a local mountain and results were recorded. The brake outperformed expectations and was welcomed by ski patrol and rental managers as a much needed improvement and possible purchase prospect to equip on their fleet of rental boards.

1.0 INTRODUCTION

In today's world of downhill skiing and snowboarding, runaway equipment is often responsible for damage to other riders' equipment and for causing injury to unsuspecting riders. Currently, the most widely used method of runaway snowboard prevention is the use of an ankle safety leash, which is simply a strap connecting the rider's ankle to the snowboard. In many states, snowboarders are required by law to use ankle safety leashes on their snowboards at mountain ski resorts. Even though it is usually required by law that snowboarders use safety leashes, it is often the first piece of equipment to be neglected or ignored. As a result of riders' neglect to wear their safety leashes, their snowboard sometimes runs away when they detach from them and cause injury to unsuspecting mountain goers. Even after a rider has detached from his snowboard, the potential danger of a runaway snowboard still exists if he does not responsibly store it in a secure position. If not stored securely, the snowboard could fall over and runaway if it lies on even the slightest slope. It is clear that a fully optimized alternative device to prevent runaway snowboards is a necessary piece of safety equipment that will greatly benefit the snowboarding and ski communities.

The goals of this Major Qualifying Project were to analytically design and analyze, prototype, and test an automatic snowboard safety brake. The safety brake must automatically activate once the rider releases their boot from their forward binding and deactivate when the rider steps back into the forward binding. Since the safety brake would be most marketable as an aftermarket attachment, it must also be universally compatible with all current snowboard bindings. In order to accomplish the goals of this project, we researched existing patents and designs for snowboard and ski brakes, developed task specifications for the new design, created a

design concept, analytically designed and analyzed the necessary components, created a prototype of the final design, and tested the prototype under a variety of real world conditions.

2.0 LITERATURE REVIEW

2.1 Target Population

The target population for the snowboard braking system is snowboard riders who want to increase the safe operation of their equipment. Currently, it is a challenge and unrealistic to get experienced riders to use the current means of preventing their snowboards from sliding down the mountain, such as snowboard safety leashes. We are going to take our efforts at advertising our product to beginner riders and rental equipment distributors. Our product will be sold separately from snowboard bindings and will be an aftermarket attachment. Ideally ski resort rental centers will be the biggest target for our project, making them a mandatory safety attachment for all boarders renting boards. Riders renting boards at ski resorts are most often inexperienced and this attachment will allow for the safety of themselves and other riders on the mountain of all experience levels.

Due to different variations in snowboard binding bolt patterns, our brake will have to fit multiple brands of board bindings. Along with paying attention to the binding bolt patterns, the braking device will need to be adjustable for all different board sizes, usable by all age groups, and functional with both goofy and regular binding stances. By keeping all of these factors in consideration while creating the braking device, the brake will be able to be used by almost the entire snowboard population creating a larger market for the product.

2.2 Injuries Caused by Runaway Snowboards

Most injuries involving snowboards are typically from riders falling from either inexperience or attempting to perform tricks. The most common snowboard injuries are those to the wrists, knees, ankles and head. Often a strained or torn anterior cruciate ligament (ACL) is a

result of knee injuries because the rider's feet are strapped in place and do not have the ability to move and twist in the direction that the board moves (Quinn, 2007). These are the most commonly seen snowboarding related injuries, but injuries from runaway snowboards are a cause which is very often overlooked. These unmanned snowboards can be a danger to unsuspecting riders and can damage their equipment.

Human injury has been a common result from snowboards sliding down the mountainside unattended. It has been ruled in the Court of Appeal by the State of California that riders are responsible for using safety devices to prevent snowboards from running loose down the mountain. If a rider fails to use this device and it causes some injury, then the rider is fully responsible for the damage caused by their board. This was the case at the Heavenly Valley Ski Resort in Lake Tahoe, California on January 29, 1994. 11 year old Jennifer Campbell found the ski trail that she was on was too challenging for her to finish riding down, so she took off her skis and began to walk down the mountain until she was a point where she felt comfortable riding again. Once past the challenging part of the trail, she sat down on the mountainside and began to put her skis back on (Campbell v. Derylo, 1999), (Snowboarding-Transworld, 2000). While putting her skis on a runaway snowboard came sliding down the mountain and hit an unsuspecting Jennifer in the lower back. The reason for this runaway board crashing into young Jennifer was due to the snowboarder's lack of responsibility to wear his ankle safety leash. As stated by the National Ski Responsibility Code: "always use devices to prevent runaway equipment" (National Ski Patrol, 2011). The snowboard rider was clearly in violation of this part of the code.

2.3 Existing Designs & Patents

2.3.1 The Traditional Ski Brake

The idea for the snow brake was originally designed and intended for use on snow skis. Over the years the design has been close to perfected, working seamlessly with the binding to bring the ski to a quick stop whenever the boot is released. The first styles of these brakes were crude and bulky. Quickly, they were optimized to become what they are known to be today. Some of the first patents were issued in the 1960's with the most notable revision in 1988 by the Solomon Ski Company. This patent marked the evolution of the ski brake. The new design was now trim and compact. The skier didn't notice the brake on the binding until it was deployed. The effect was huge; soon mountains required a binding brake on all skis. Pictured below are the drawings from the patent in 1988 (Szafranski, 1989)

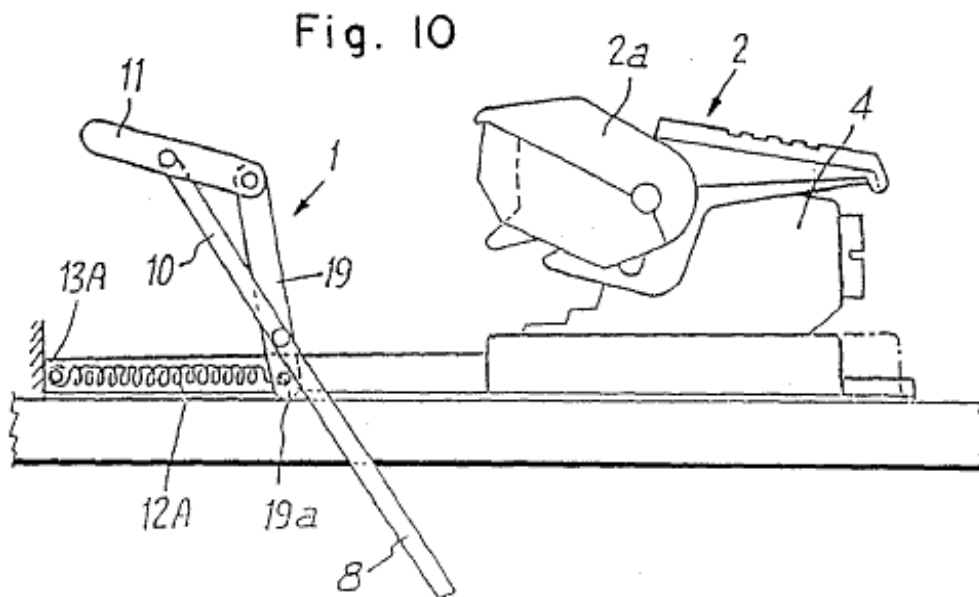


Figure 2.1: (Szafranski, 1989)

This new design became so popular that the snow ski binding brake is now standard equipment on all new bindings. Every skier going down a mountain will have a brake on each ski. They work effortlessly to bring runaway skis to a quick and effective stop in a reasonable distance from the skier. There are no runaway skis that afflict serious damage or injury. This modification has changed the face of skiing forever.

2.3.2 Snowboard Brakes

The issue of runaway boards has been one that has not been completely ignored by snowboard enthusiasts. Through our research we were able to identify several patent designs which were designed to achieve the same or similar goals as we were hoping to accomplish. These patent designs showed potential of working as well as some that would not meet our design specifications. To get a better idea of our braking system we looked at the following three patent designs.

Patent 1: United States patent application number: 10/570,959

Publication number: US 2007/0075524 A1

Filing date: September 8, 2004

Publication date: April 5, 2007

(Kelly, 2004)

The first patent that we evaluated was one that had a very simple design concept. The braking device would be attached to the snowboard and would be activated by the snow boarder removing his boot from the binding, which in turn would remove a pin from the brake and activate it into the open position. This spring-loaded device would swing 270 degrees and make contact with the snow causing the brake teeth to slow the board down.

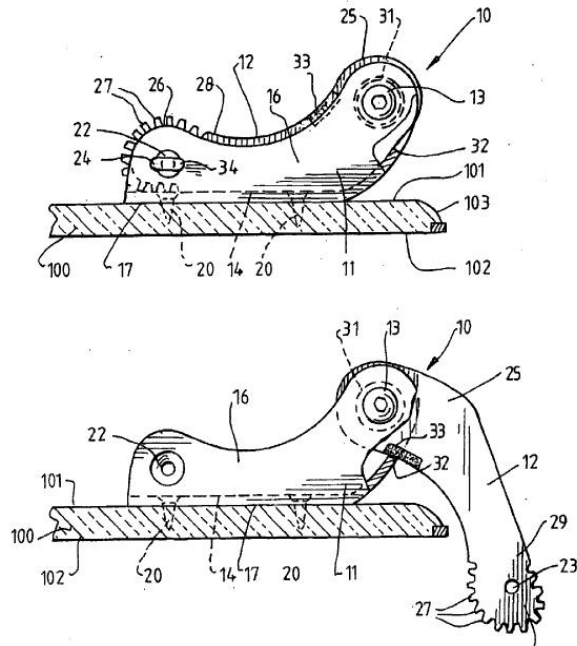


Figure 2.2: Patent brake design (Kelly, 2004)

This design for the braking device is very similar to the idea we were hoping to pursue. The design has a dimensionally small object which when triggered in this case, when a pin off of the binding is pulled, causes the arm to swing forward into the snow. In figure 2 you can see the brake device attached to the bindings.

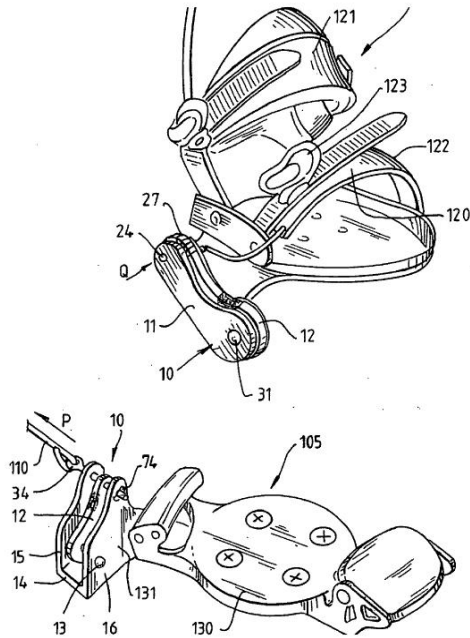


Figure 2.3: Snowboard brake binding configuration (Kelly, 2004)

The design of the actual braking mechanism looks to show much potential because it is able to be effective but at the same time stay out of the rider's way when not in use. This device gave us some good ideas to look at while we are designing our device. It will be crucial to have the braking system be recessed from the edge of the board. This allows the rider to be able to make sharp cuts and not worry about hitting the braking device on the ground while in the closed position. With good attributes there are always some that aren't always desirable. This patent has a pin that needs to be pulled in order to activate the device. This is not much of a problem but the rider may have to remove their gloves to release and replace the pin. The amount of extra work required to reset the brake when strapping in the board could be the determining factor of someone not using this device. If this design were capable a way in which it could be retracted automatically then it has the potential to be used much more. During our research of existing brakes on the market, we were able to come across a design that closely followed the design

presented in this patent. This market design will be discussed in the section titled “Existing Designs on the Market”.

Patent 2: United States patent number: 5,356,168
Publication number: US 2007/0075524 A1
Filing date: December 10, 1992
Issue date: October 18, 1994
(Ozburn, 1994)

The second patent that we researched was one that wasn't exactly what we were looking to create, but the actual device intrigued our group. This design is one that is entirely manual; it requires the rider to physically pull a lever every time they step out of their binding. The design of the braking device was good, but the fact that it is manually operated was the determining factor that caused our group to not look further into this. As the case is today, riders are responsible for using a leash when they snowboard but a majority of them neglect to use this safety device. Having a braking system that is manually operated may also yield similar results to riders who neglect safety leashes. Figure 4 shows the manually operated brake.

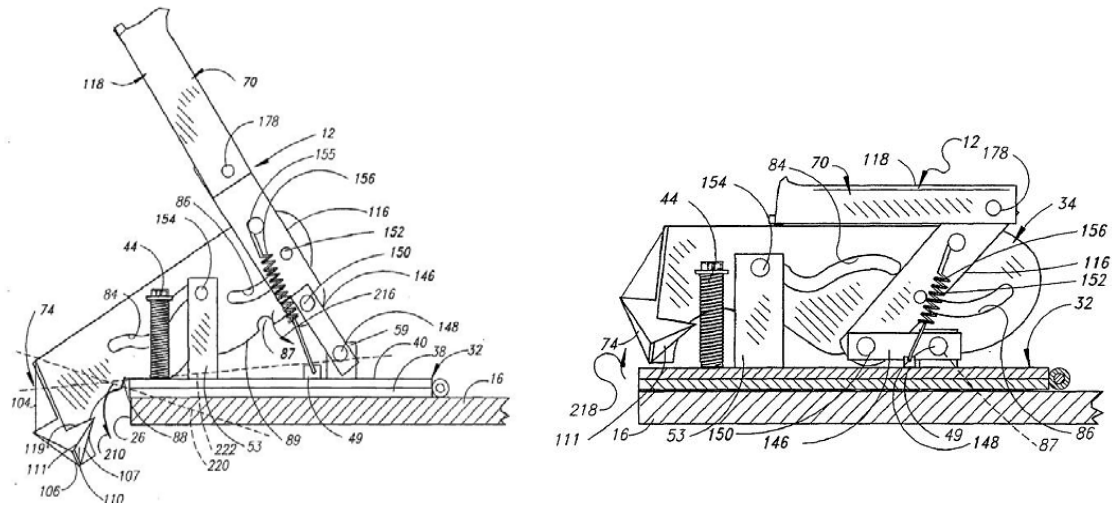


Figure 2.4: Manually operated brake (Ozburn, 1994)

If this braking system were able to incorporate a release mechanism into the binding of the snowboard, then it would come much closer to the task specifications that we had created for our final design. Another aspect we considered a flaw in this design is that the braking device is somewhat bulky on the top of the board. As well as being bulky, it seems to be very close to over-hanging off the edge of the board. It almost seems as if the brake has the possibility to be in the way of the rider if they were taking sharp turns or performing tricks. Ultimately this design was forfeited as a possible design to base our brake off of.

Patent 3: United States patent application number: 9/815,191

Publication number: US 2002/0175497 A1

Filing date: March 20, 2001

Issue date: November 28, 2002

(Freemon, 2001)

The next patent that we looked at while researching was one that can simply be described as working like a mousetrap. It consists of a simple rod and spring that rotates outward over the

board when the rider's boot comes out of the binding. When the rider has their boot in the binding it is applying pressure onto the rod to hold it in place. Once the rider releases their boot from the bindings, the spring of the rod rotates it forward so that it swings out over the edge of the board acting as a brake. This braking device differs from the other two patents that we looked at because this design automatically releases the break once the rider steps out of the boot binding. This was one of the key features that we were looking to accomplish with the design of our braking system. This, and the other designs, lacks the ability for the brake to automatically retract when the rider steps back into his binding.

With this braking system not being able to retract automatically it creates more work for the rider. The rider will not be able to successfully ride the board without fully retracting the rod until it is brought back underneath the boot and the boot is placed back in the binding. If this design could be connected to a way of mechanically retracting the snow brake when stepping into the binding, it could prove to be a more valuable design than it currently is. Figure 5 below shows the third patent in its open and closed positions.

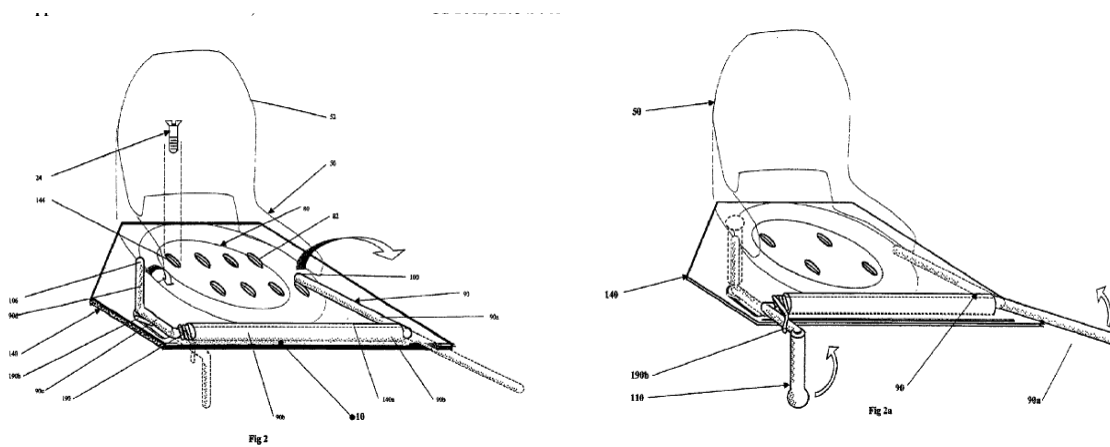


Figure 2.5: Braking device in open and closed position. (Freemon, 2001)

FSU Snowboard Brake

The FSU Snowboard Brake was developed to eliminate runaway snowboards. It was designed and tested in Australia where it received a warm welcome from the Australian Ski Patrol Association. They noted that for many years they had seen “daily incidents where snowboards are dropped, accidentally knocked or blown from racks or from where parked, to runaway downhill often accelerating to speeds in excess of 100kph and passing through busy ski slopes” (FSU Skateboards, 2003).

The FSU Skateboard Company came up with a solution to the runaway board problem; however it’s not ideal for our specifications. The whole mechanism relies on the rider wearing a leash that activates the device.

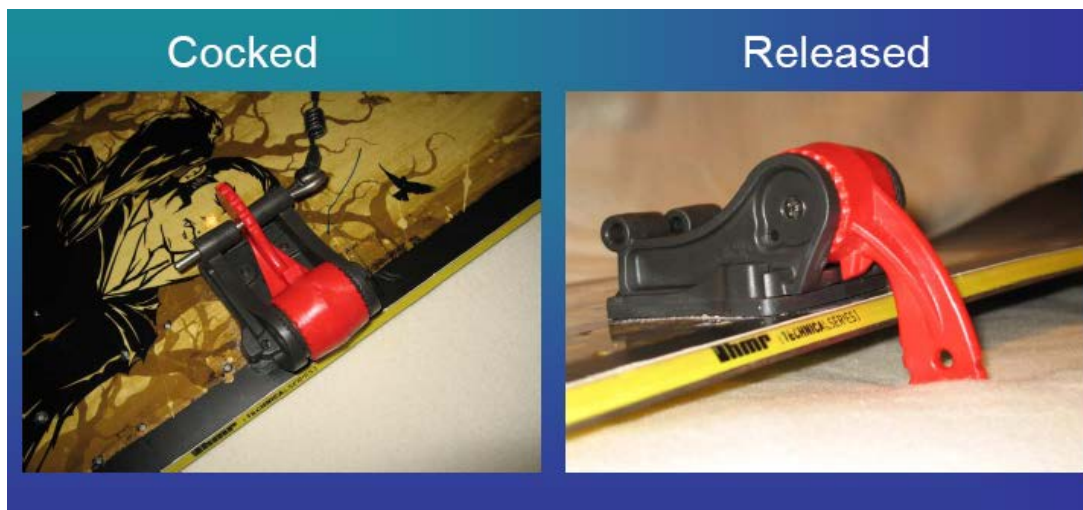


Figure 2.6 (FSU Skateboards, 2003)

As you can see in Figure 2.6 above, a leash that is supposed to be attached to the rider’s leg activates the safety brake. However, if the rider has removed the leash to walk around and the board is dropped, it will still runaway. This contradicts the basic idea behind our project which is an alternative to having a leash attached to ones snowboard. We already know that people are not attaching the regular leashes to their boots already so we do not see any change in this behavior.

3.0 TASK SPECIFICATIONS, DESIGN CONCEPTS, ANALYTICAL DESIGN DESCRIPTION OF COMPONENTS, SUBASSEMBLIES & FINAL ASSEMBLY

3.1 Task Specifications

Task specifications define what functions the system must be capable of doing. The task specifications are as follows:

1. The mechanism must prevent a snowboard from any further linear motion down slope after it has become static and not subjected to an externally applied force.
2. The mechanism must stop a snowboard in motion quickly and in a short distance.
3. The mechanism must be functional with the snowboard both parallel and perpendicular to the slope.
4. The mechanism must automatically activate when the rider detaches from the forward snowboard binding.
5. The mechanism must retract completely clear of the edge for riding and carving when the rider is properly secured in the binding.
6. The mechanism must be able to rotate along with the forward binding to the desired angle of the rider.
7. The mechanism must be able to be locked in the retracted position for storage and transportation.
8. The mechanism must be functional for most existing binding configurations.
9. The mechanism must be operational for all standard riding conditions and temperatures.
10. The mechanism must not fail mechanically from the forces inflicted on it.
11. The mechanism must not interfere with normal operations of the snowboard and be aesthetically acceptable to most riders.

If all of the task specifications are fulfilled by the final design of the automatic snowboard brake, it can be considered a fully functional design.

3.2 Design Concepts

Existing snowboard safety brake patents and designs mimic the design concept and functionality of the conventional ski brake used today. Each safety brake featured a mechanism mounted to the top of the snowboard which rotated downward about an axis parallel to the edge of the board. However, only one of the existing safety brakes activated automatically when the rider detached from the board and it required that a safety leash be worn by the rider.

Our team first considered adding a spring loaded mechanized means of automatically deploying and retracting the brake to the existing snowboard safety brakes design patents, which are similar to the traditional ski brake design. After some more careful consideration, our team decided that modifying the existing safety brake design patents would result in a considerably bulky product which could be prone to failure due to all of the exposed linkages which would be involved. Our safety brake design concept involved a spring loaded piston – cylinder mechanism driven by a four bar driving mechanism, shown in Figure 3.1.

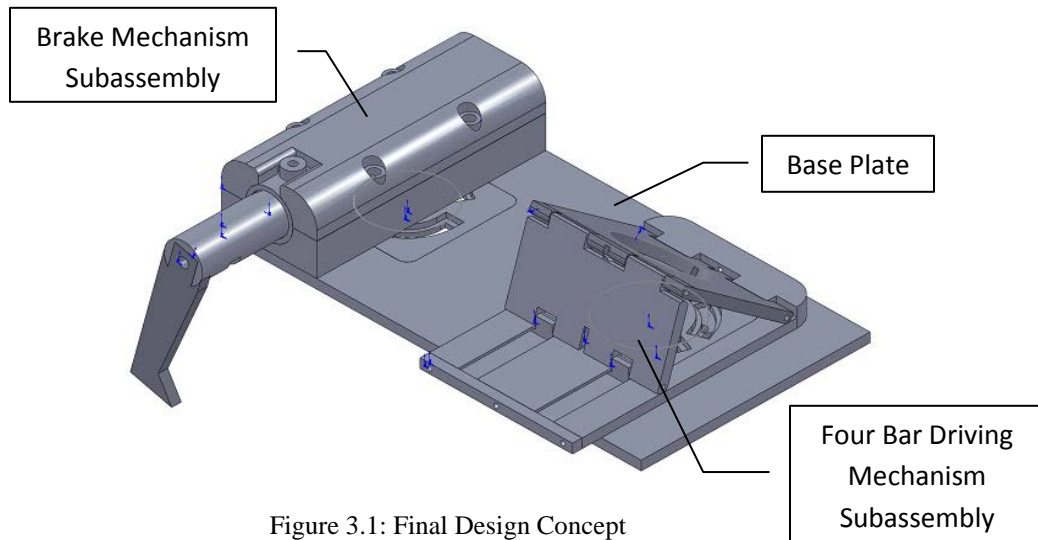


Figure 3.1: Final Design Concept

The design concept included a piston with a rectangular keyway feature which was housed inside of a spring loaded cylinder. A rounded pin threaded through the cylinder was seated inside the keyway of the piston. The pin and piston keyway create both linear motion normal to the edge of the snowboard and rotational motion about an axis normal to the edge of the snowboard as the piston is driven by the spring and the four bar mechanism, whose coupler point is attached to the internal end of the piston by a steel cable. On the exposed end of the piston is a brake attachment which is designed to rotate downward about an axis normal to the edge of the board and dig into the snow.

3.3 Analytical Design Descriptions of Components & Subassemblies

Appendix A contains dimensioned orthographic drawings of all subassemblies and components.

3.3.1 Brake Mechanism Subassembly

The brake mechanism subassembly for the snowboard safety brake is shown in Figure 3.2 and Figure 3.3 below.

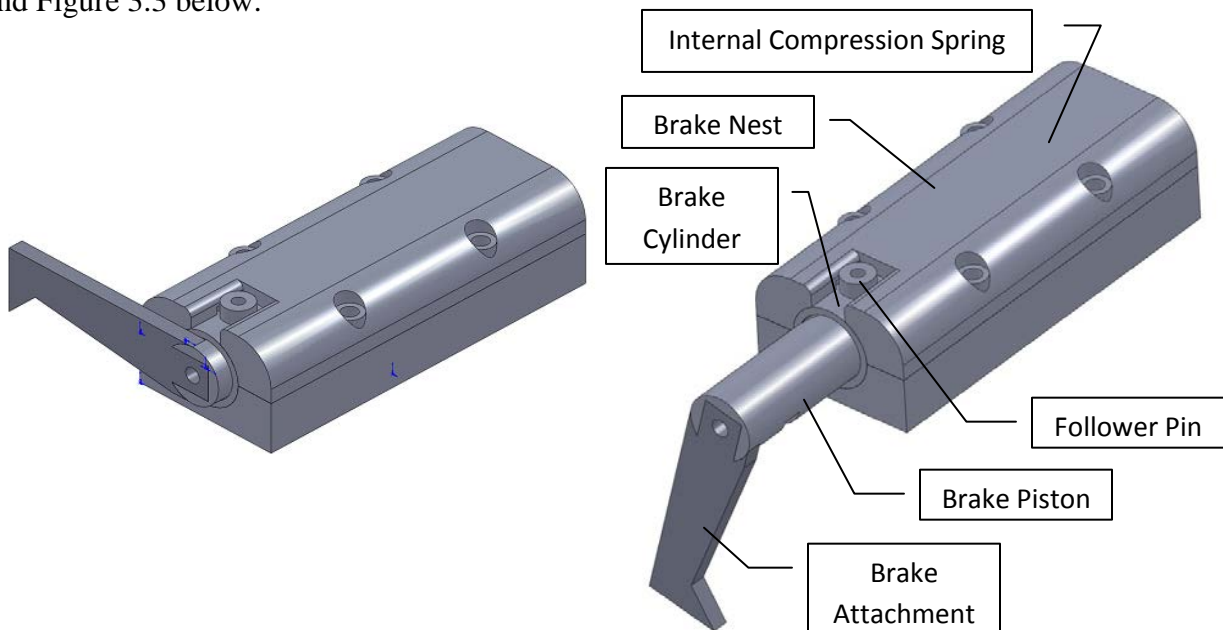


Figure 3.2: Brake Mechanism Subassembly (Deactivated)

Figure 3.3: Brake Mechanism Subassembly (Activated)

The brake mechanism subassembly is comprised of the brake cylinder, brake piston, brake attachment, brake nest, an internal closed and ground compression spring, and the follower pin. This subassembly is mounted to the base plate which is mounted to the top surface of the snowboard. While in the deactivated or compressed position, the long edge of brake attachment is parallel with the edge of the snowboard clear of the plane of the bottom surface of the snowboard, as shown in Figure 3.2. Once the piston is released and subjected to the force from the compression spring, it travels 1 inch in a linear motion with zero rotation to facilitate extension beyond the snowboard edge. The piston continues its travel for another 1 inch in a linear motion while rotating 75° to fully engage the brake.

3.3.2 Brake Piston

The brake piston for the brake mechanism subassembly of the snowboard safety brake is shown in Figure 3.4.

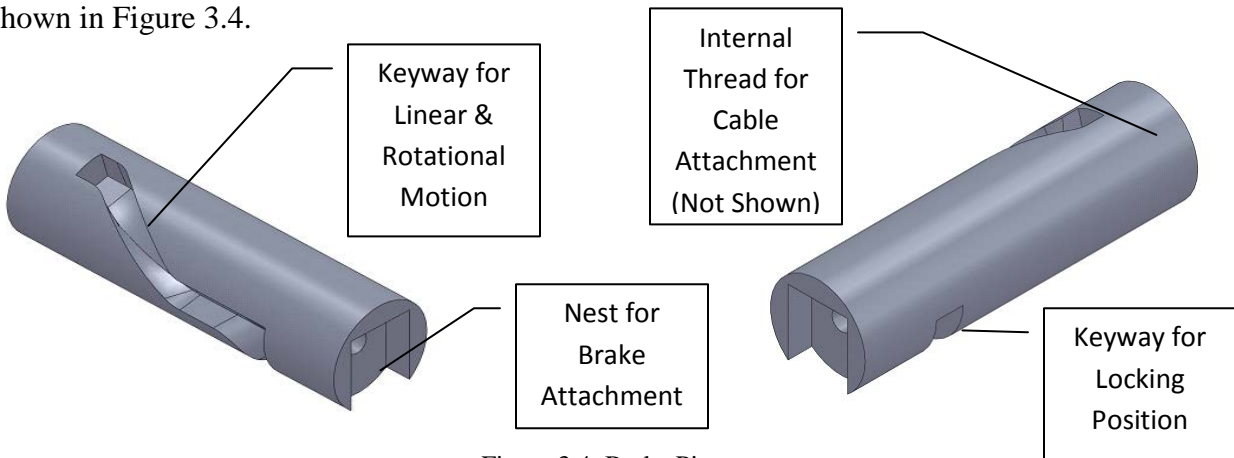


Figure 3.4: Brake Piston

The brake piston is a one inch diameter, 3 ½ inch long piston which housed inside of the brake cylinder. It features a grooved keyway that is 9/32 inches wide by 9/32 inches deep. The keyway has two inches of total linear length, and rotates 75 degrees about the axis of the piston. The rounded tip of the ¼ inch pin that is threaded through the cylinder seats inside of the keyway. The grooved keyway is designed so that the long edge of the brake attachment will be

parallel with the top surface of the snowboard in the deactivated position. When the linear force of the compressed spring is applied to the rear face of the piston to move it to the activated position, the grooved keyway provides a one inch linear motion to move the brake off of the edge of the snowboard followed by a combination of another one inch of linear motion with 75 degrees of rotational motion so that the brake will dig into the snow below the plane of the bottom surface of the snowboard. From the pin location in the deactivated position, the keyway rotates 180° about the axis of the piston. This allows the user to remove the pin from the functional portion of the keyway by rotating the piston, which locks the piston into place so it will remain in the deactivated position for storage or transport.

On the front face of the brake piston, there is a cut out and ¼-20 threaded hole for nesting and mounting the brake attachments to. On the rear face of the piston, there is a 6-40 threaded hole for attaching the cable from the four bar driving mechanism.

3.3.3 Brake Cylinder

The brake cylinder for the brake mechanism subassembly of the snowboard safety brake is shown in Figure 3.5.

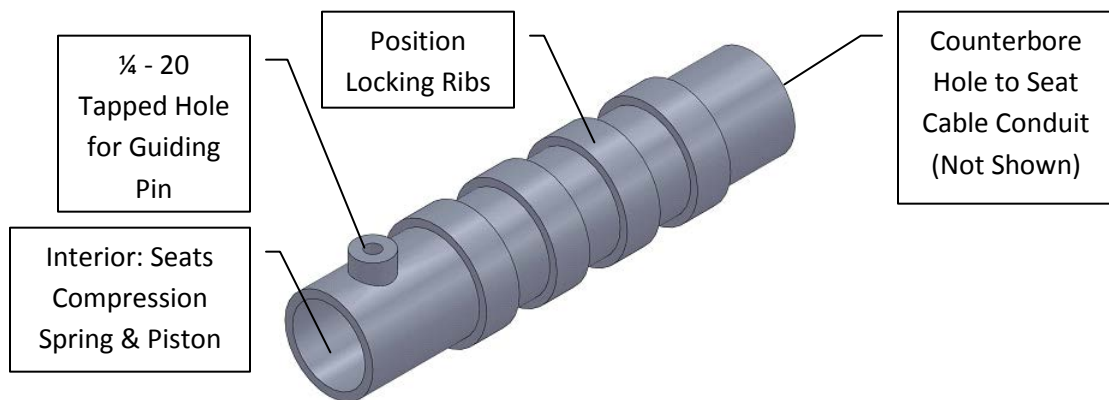


Figure 3.5: Brake Cylinder

The exterior of the brake cylinder has a 1 ¼ inch diameter and is six inches in length. The interior of the brake cylinder has a 1 1/32 inch diameter and is 5 ¾ inches deep. The brake piston and compression spring is housed inside of the cylinder, and secured as an item by the rounded guiding pin which threads into the ¼-20 tapped hole. The cylinder is housed in inside of the brake nest. The 1.45 inch diameter position locking ribs are designed to allow the position of the brake on the snowboard to be moved in either direction in increments of half an inch to accustom all board widths. On the back of the cylinder, there is a counterbored through hole designed to seat the cable conduit and to allow the cable to passes through to connect to the brake piston.

3.3.4 Brake Attachments

A total of four brake attachments, in two sizes and two designs, were designed and fabricated for the brake mechanism subassembly of the snowboard safety brake. The brake attachments are fixed to the outer end of the piston and dig into the snow when the brake is deployed to the activated position. The two brake attachment designs are the standard brake attachment and the powder brake attachment, both are designed for different snow conditions. The standard brake attachment design is shown in Figure 3.6.

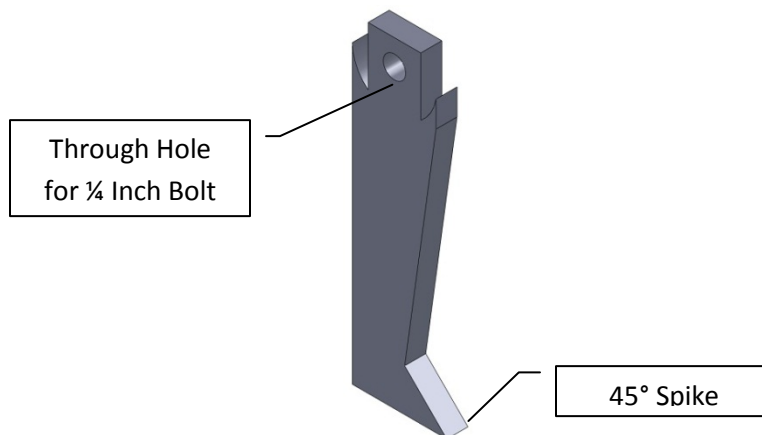


Figure 3.6: Standard Brake Attachment (Two Inch Version Shown)

Since the standard brake attachment enters the snow in a rotational motion of 75 degrees as it is deployed, a spike was designed on the end of the attachment to allow it to dig deeper into the snow. The spike is designed to prevent the snowboard from coming out of a static condition while at rest, and to cause the board to slow down and turn off of the trail if it is sliding down the slope. The spike is a 45 degree point and is ½ inch in length. The standard brake attachment is designed in two different sizes, one which lifts the edge of the snowboard two inches off of the ground at the point of contact and one which is designed to lift the edge of the snowboard three inches off of the ground at the point of contact. To lift the entire edge of the snowboard off the ground, multiple brakes would be required. Each standard brake has a width of 1 inch at its widest point and a thickness of ¼ inch.

The powder brake attachment design is shown in Figure 3.7.

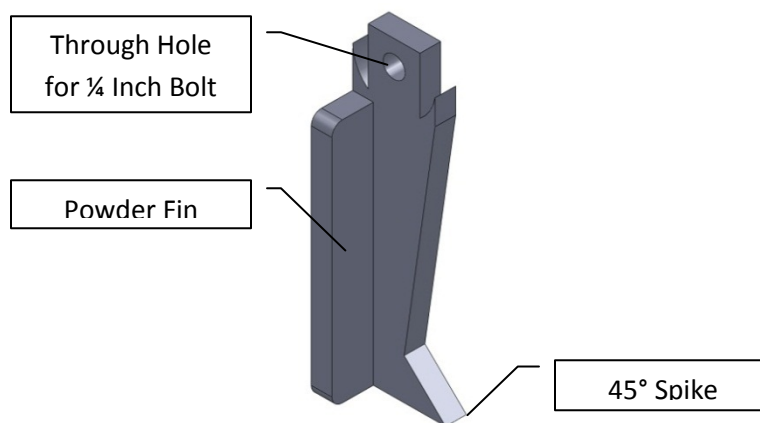


Figure 3.7: Powder Brake Attachment (Two Inch Version Shown)

The powder brake attachment is the exact same design as the standard brake attachment, with the addition of a power fin. The powder fin is an extrusion on the outer face of the brake designed to create more drag as it moves through powder snow conditions. If the powder is too thin and too deep, the standard brake attachment would not be able to lift the edge of the board

and cause it to rotate and turn of the trail. The powder fin has a width of ½ inch and a thickness of ¼ inch, and is also designed in both two inch and three inch versions.

3.3.5 Brake Nest

The brake nest for the brake mechanism subassembly of the snowboard safety brake is shown in Figure 3.8 and Figure 3.9.

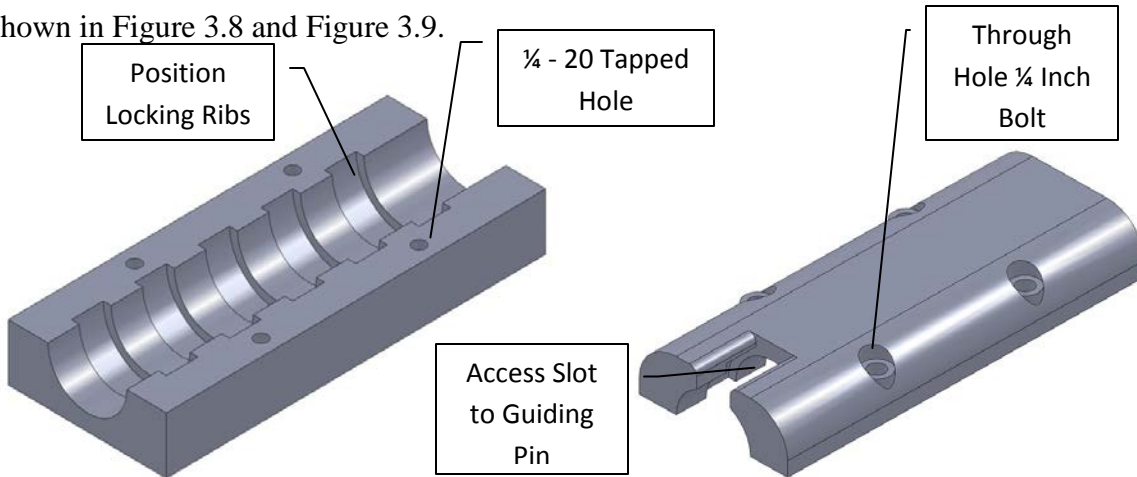


Figure 3.8: Brake Nest Bottom

Figure 3.9: Brake Nest Top

The brake nest houses the 1 ¼ inch nominal diameter brake cylinder and keeps it in a defined position when the brake mechanism subassembly has a force applied to it, so that it does not slip within the nest and move away from the edge of the snowboard. To do so, the nest is designed with 1 ½ inch diameter position locking ribs to provide a snug fit between itself and the cylinder. These ribs allow the position of the brake cylinder, piston, and attachment relative to the edge of the snowboard to be adjustable in increments of ½ inch, so that brake is compatible with both narrow and wide snowboards. On the brake nest top, an access slot is designed to allow the rider to access the set screw guiding pin without disassembling the nest. The nest is secured together by four ¼ -20 bolts, and is secured to the base plate by five ¼ - 20 bolts. The outer dimensions of the assembled brake nest are 2 ½ inches in width, 6 inches in length, and 1 ¾ inches in thickness.

3.3.6 Guiding Pin

The guiding pin, which threads into the brake cylinder and sits in the grooved keyway of the brake piston, is simply a ¼-20 set screw with the threads turned off the portion that sits in the grooved keyway and the tip rounded.

3.3.7 Compression Spring Selection

In selecting the compression spring to drive the brake mechanism subassembly from the deactivated position to the activated position some design parameters were first compiled to ensure proper functionality, listed below.

- The spring must provide enough force to power the brake attachment into the snow.
- The spring must provide some force on the brake piston when it is in the activated position to prevent it from easily compressing back into the brake cylinder.
- The spring must be easily compressible by the four bar driving mechanism.
- The spring must operate in the range of 4 ½ inches to 2 ½ inches in length.
- The spring must have a minimum compressible length less than 2 ½ inches.
- The spring must have a maximum deflection greater than two inches.
- The outer diameter of the spring must be as close to one inch as possible as to prevent the spring from buckling as it is compressed.
- The ends of the spring must be closed and ground to ensure even distribution of its force on the piston.

The force of a compression spring is defined in Equation 1.

$$F = k \cdot x \quad \text{Equation (1)}$$

F = Force (lb)

k = Spring Rate or k Factor (lb/in)

x = Compressive Displacement from Free Length (in)

After reviewing Century Spring Corporation’s entire inventory of springs, three springs were selected and purchased each with a different spring rate (small, medium, large), a free length as close to 4 ½ inches as possible, a minimum length less than or equal to 2 ½ inches, and an outer diameter as close to one inch as possible. Three different springs with three different spring rates were purchased so that the correct spring could be chosen experimentally rather than analytically, since it was difficult to gage how much force is required to push the brake attachment into the snow and how much force makes the four bar mechanism tough to operate. The specifications of the three springs are shown in Table 3.1.

Spring 1 (Provider: Century Spring Corp)							
P/N	Outer Diameter	Inner Diameter	Material	Free Length	Max Deflection	Min Length	Spring Rate
S-270	1.00"	0.82"	SS	5.13"	2.90"	2.23"	7.8
	Max Force	Activated Length	Activated Deflection	Activated Force	Deactivated Length	Deactivated Deflection	Deactivated Force
	22 lbs	4.5"	0.63"	4.914 lb	2.5"	2.63"	20.514 lb
Spring 2 (Provider: Century Spring Corp)							
P/N	Outer Diameter	Inner Diameter	Material	Free Length	Max Deflection	Min Length	Spring Rate
4365	1.00"	0.84"	Spring Steel	4.75"	2.90"	1.85"	6
	Max Force	Activated Length	Activated Deflection	Activated Force	Deactivated Length	Deactivated Deflection	Deactivated Force
	18	4.5"	0.25"	1.5 lb	2.5"	2.25"	13.5 lb
Spring 3: High Rate Spring (Provider: Century Spring Corp)							
P/N	Outer Diameter	Inner Diameter	Material	Free Length	Max Deflection	Min Length	Spring Rate
2826	0.875"	0.675"	Music Wire	4.5"	2.5"	2"	17
	Max Force	Activated Length	Activated Deflection	Activated Force	Deactivated Length	Deactivated Deflection	Deactivated Force
	43	4"	0.5"	8.5 lb	2"	2.5"	43 lb
* For high rate spring, cylinder shortened by 0.5"							

Table 3.1: Spring Specifications (Highlighted Spring Chosen for Final Design)

After testing each spring experimentally spring number two was determined to be the best spring, having a spring rate 6 lb/in, requiring 13 ½ pounds of force to compress, and applying 1 ½ pounds of force on the brake piston in the activated position.

3.3.8 Four Bar Driving Mechanism Subassembly

The four bar driving mechanism subassembly for the snowboard safety brake is shown in Figure 3.10 and Figure 3.11.

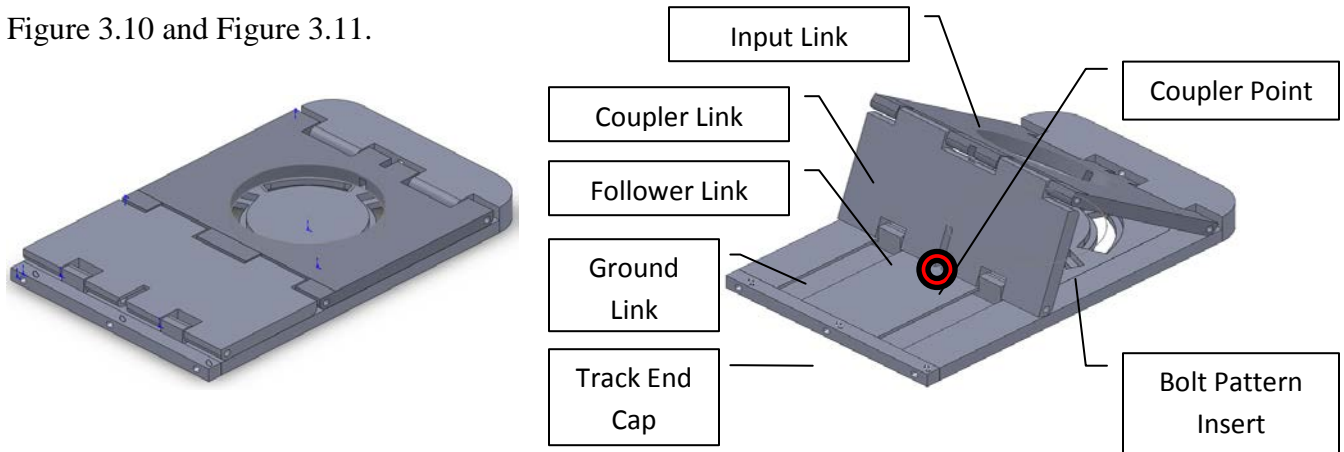


Figure 3.10: Four Bar Driving Mechanism Subassembly (Deactivated)

Figure 3.11: Four Bar Driving Mechanism Subassembly (Activated)

The four bar driving mechanism subassembly is comprised of the ground link, input link, coupler link, follower link, track end cap, and the bolt pattern insert. This subassembly is mounted inside of the front or forward binding because that is the foot which most riders often leave attached when pushing themselves across a flat plane. The four bar driving mechanism is designed to retract the brake piston and the brake attachment from the activated position to the deactivated position as the rider steps into the forward binding by use of a steel cable connecting its coupler point, denoted by the red circle in Figure 3.9, to the rear of the previously mentioned brake piston. As the mechanism is compressed to the deactivated position, shown in Figure 3.8, the coupler point is displaced two inches linearly. Consequently, the brake piston is displaced two inches linearly to the deactivated position. When the rider removes his foot from the forward binding, the spring loaded brake mechanism returns to the activated position causing the driving mechanism to return to its activated or decompressed state shown in Figure 3.9. While in the activated position, the spring loaded brake mechanism will provide the tension on the cable

required for the mechanism to stay in the secure in the activated or decompressed position. In the deactivated or compressed position, the mechanism lays completely flat, having a thickness of $\frac{1}{2}$ inch. The full subassembly is $6 \frac{5}{8}$ inches in length and four inches wide, and is universal to both the four bolt snowboard bolt pattern and the Burton three bolt snowboard bolt pattern.

3.3.9 Four Bar Driving Mechanism Kinematic Design & Analysis

This section explains the kinematic design and analysis used to develop the fully functional four bar driving mechanism, shown in Figure 3.12 below. This mechanism is a non – Grashof four bar crank – slider mechanism, meaning that it translates a rotational input into a linear output. Since the mechanism is a four bar linkage, it is composed of an input link “X”, a coupler link “Y”, a slider output link “Z”, and a ground link.

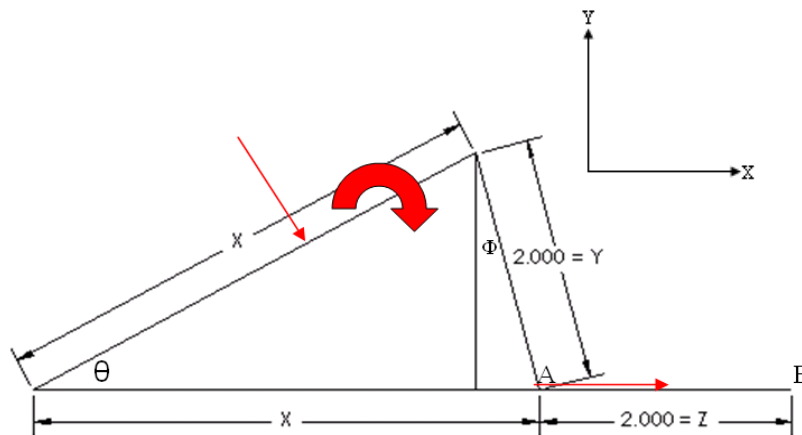


Figure 3.12: Four Bar Driving Mechanism

Again, the mechanism will be installed on the base of a snowboard binding so that it can be operated by a rider attaching and detaching their foot to the binding. A steel cable which is connected to the back of the brake piston is attached to the mechanism at the coupler point “A”. When a rider steps into the binding, his foot will rotate the input link (X). This will translate the

coupler point “A” linearly along the slider output link (Z) to point “B”, pulling the cable two inches in the positive X direction and deactivating the brake.

Several geometric configurations of the mechanism are shown in Figure 3.13, Figure 3.14, Figure 3.15, Figure 3.16, and Figure 3.17. The length of the coupler link (Y) and the slider output link (Z) are fixed at two inches, since that is the desired distance of the translation. The variable geometries of the mechanism are the length of the input link (X) and the angles θ , and Φ . The purpose of examining these configurations is to decide which configuration best satisfies the following design criteria: the shortest input link (X), the smallest angle θ , and the largest angle Φ .

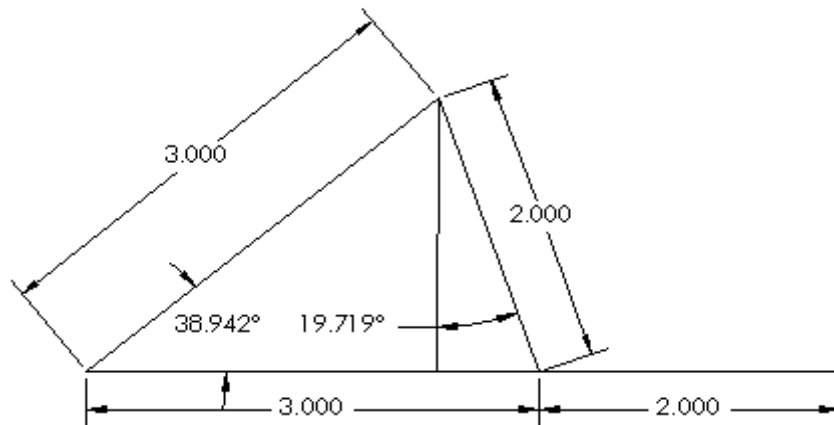


Figure 3.13: Mechanism Configuration 1

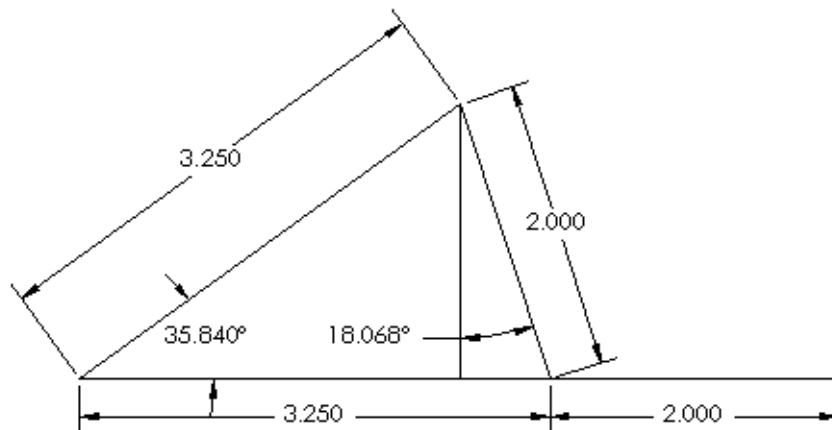


Figure 3.14: Mechanism Configuration 2

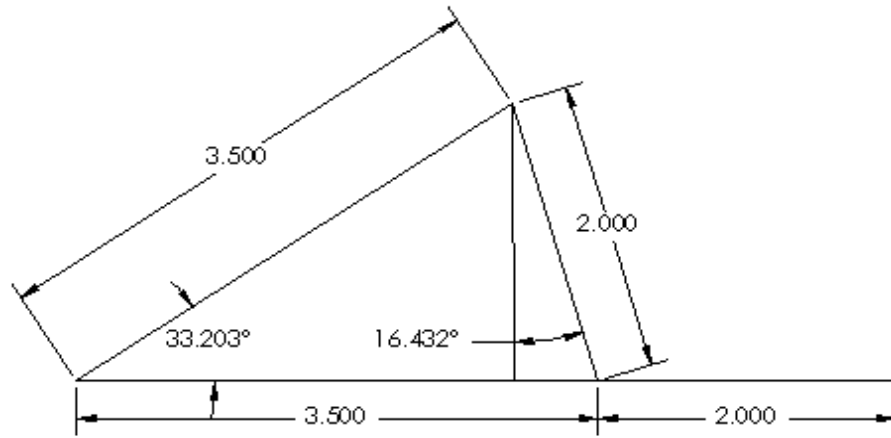


Figure 3.15: Mechanism Configuration 3

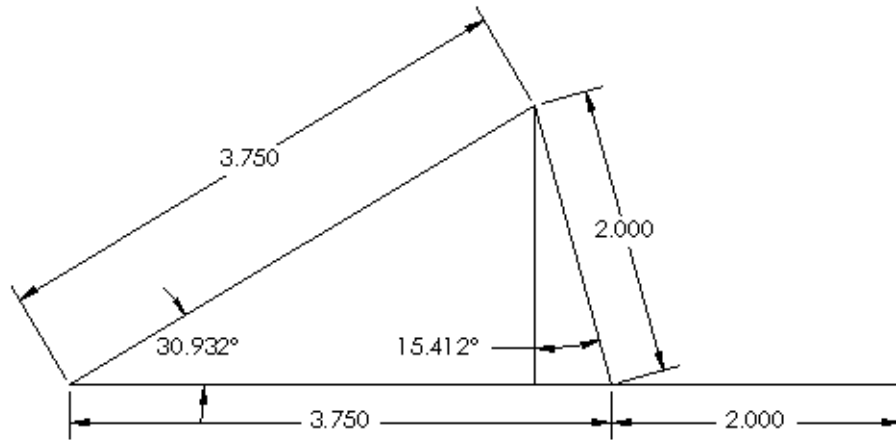


Figure 3.16: Mechanism Configuration 4

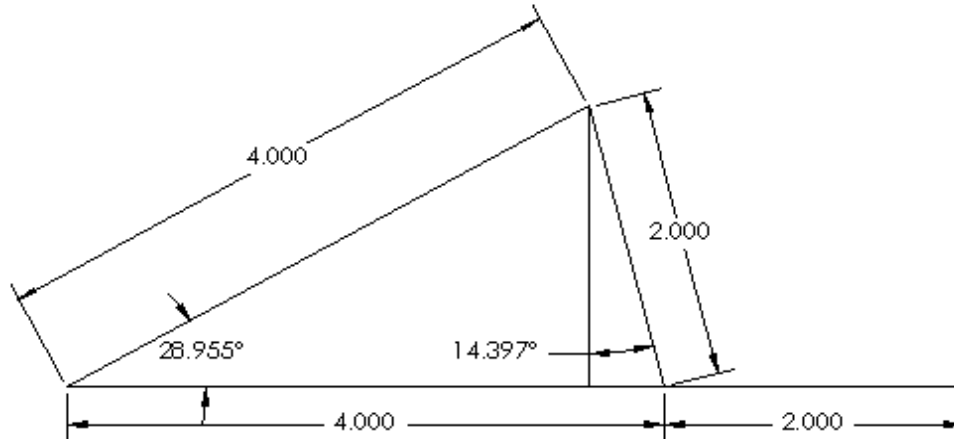


Figure 3.17: Mechanism Configuration 5

CUMULATIVE DATA:

Configuration	X	Y	Z	Θ	Φ
1	3	2	2	38.942	19.719
2	3.25	2	2	35.840	18.068
3	3.5	2	2	33.203	16.432
4	3.75	2	2	30.923	15.714
5	4	2	2	28.955	14.397

**All angles taken from activated position in degrees.*

Table 3.2: Cumulative Data for Mechanism Design Configurations

DESIGN MATRIX:

A design matrix was created to choose which configuration satisfied the previously stated design criteria. Each variable for each configuration was ranked from five (best) to one (worst). The configuration which received the most points was considered the best overall configuration. By this methodology, the first configuration proved to best satisfy the design criteria and should be investigated further.

Configuration	X	θ	Φ	Total
1	5	1	5	11
2	4	2	4	10
3	3	3	3	9
4	2	4	2	8
5	1	5	1	7

Table 3.3: Design Matrix for Mechanism Design Configurations

SELECTION:

Due to area constraints created by the interchangeable bolt pattern inserts which fit into the ground link between the input link and the follower link on the mechanism, we could not use configuration one. Configuration two did provide enough space for the bolt pattern inserts and was thus chosen as the final design.

3.3.10 Ground Link

The ground link for the four bar driving mechanism subassembly of the snowboard safety brake is shown in Figure 3.18.

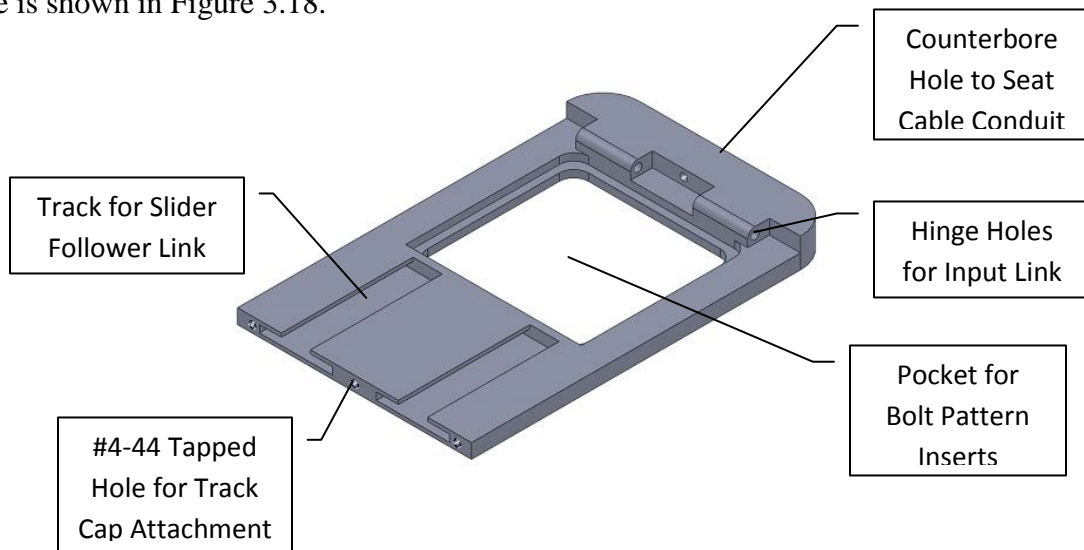


Figure 3.18: Ground Link

The ground link contains the desired bolt pattern insert, and is connected to the input link and the follower link. The ground link is essentially the anchor for the entire four bar driving mechanism. The pocket or cut-out in the middle of the link is designed to seat the bolt pattern insert of choice, either the standard four bolt pattern or the Burton three bolt pattern. The input link is hinged by a 1/8 inch stainless steel dowel pin through the holes on the rear of the ground link as shown in Figure 3.18. The slider follower links are designed to seat inside the ground link's follower link tracks, which have height of 1/8 inch, a width of 1 1/4 inches, and a length of

2 3/8 inches to allow the coupler point exactly two inches of displacement when the mechanism is operated. The track cap is designed to connect to end follower link tracks by three #4-40 screws the piece to keep the follower links contained within the tracks. On the back of the ground link, there is a counterbored through hole designed to seat the cable conduit and allow the cable to pass through to connect to the coupler point on the coupler link. The ground link is 6 3/8 inches in length, four inches width, and has a thickness of 1/4 inch on the forward end that the input and coupler links are compressed onto, and a thickness of 1/2 inch at the rear.

3.3.11 Input Link

The input link for the four bar driving mechanism subassembly of the snowboard safety brake is shown in Figure 3.19.

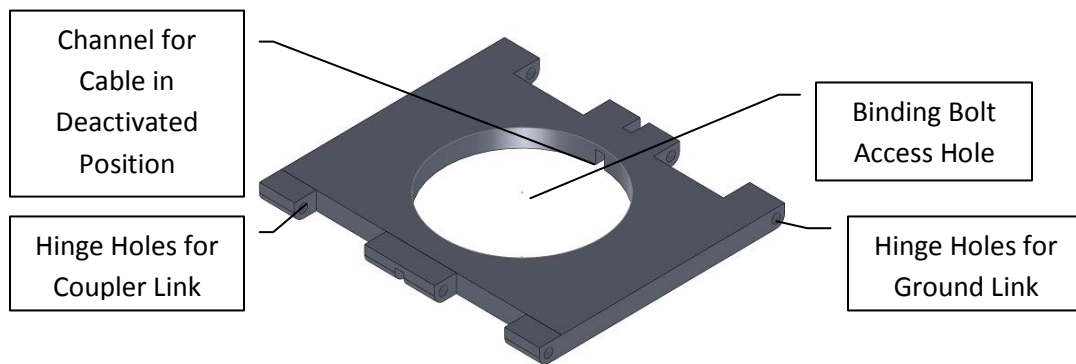


Figure 3.19: Input Link

The input link is the link of the four bar driving mechanism which has the force of the riders boot applied directly to it. It is hinged to the ground link by 1/8 diameter stainless steel dowel pin at one end and to the coupler link at the other, as shown in Figure 3.19. It is designed with a channel cut on the underside to allow a space for the cable to be seated when the link is fully compressed. It also features a 2.23 inch diameter access hole through the middle of the

link so that binding bolts can be accessed without disassembling the entire linkage. The input link is four inches in width, 3 ½ inches in length, and ¼ inch thick.

3.3.12 Coupler Link

The coupler link for the four bar driving mechanism subassembly of the snowboard safety brake is shown in Figure 3.20.

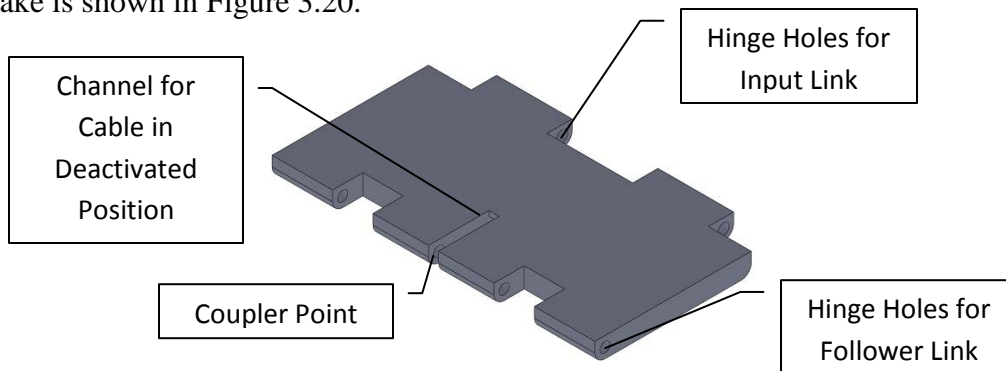


Figure 3.20: Coupler Link

The coupler link is hinged to the input link by 1/8 inch stainless steel dowel pin at one end and to the follower link at the other. At the coupler point, shown in Figure 3.20, the steel cable is attached to the 1/8 inch dowel pin hinge by an eye fitting so that it is free to rotate around the hinge to compensate for the rotation of the link as the mechanism is operated. The coupler link is designed so that the coupler point will travel exactly two inches linearly when the mechanism is compressed so that the brake piston is fully retracted. Like the input link, the coupler link features a channel cut on the underside to allow a space for the cable to be seated when the link is fully compressed. The input link is four inches in width, 2 ¼ inches in length, and ¼ inch thick.

3.3.13 Follower Link

The follower link for the four bar driving mechanism subassembly of the snowboard safety brake is shown in Figure 3.21.

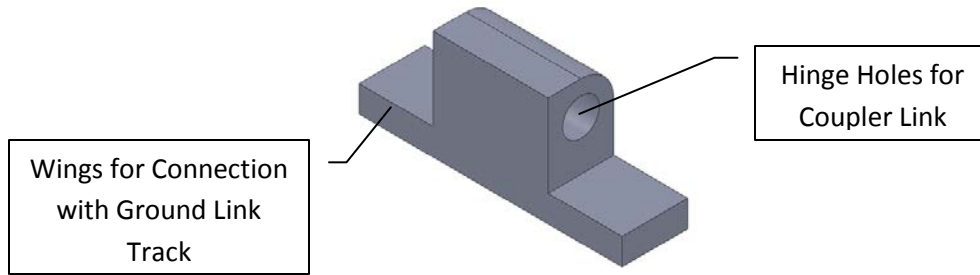


Figure 3.21: Follower Link

The follower links are hinged to the coupler link by a 1/8 inch stainless steel dowel pin at one end and secured inside the ground link track by their two wings, shown in Figure 3.21, to the other end. The hinge holes on the follower links have tolerances to allow them to rotate freely, so that when the mechanism is operated they perform a one dimensional linear motion within the track. The bottom of the link which is seated in the pathway in the ground link is 0.1 inches in thickness, one inch in width, and 1/4 inch in length. The tab for hinging to the coupler link is .3125 inches in height, .44 inches in width, and 1/4 inch in length.

3.3.14 Track Cap

The track cap for the four bar driving mechanism subassembly of the snowboard safety brake is shown in Figure 3.22.

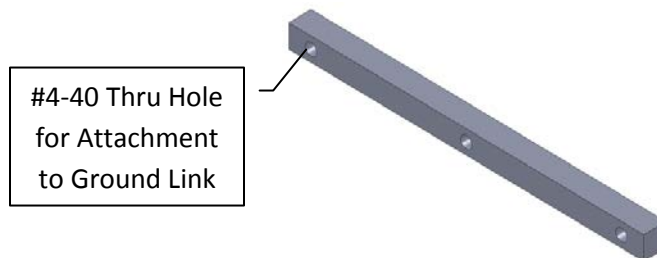


Figure 3.22: Track Cap

The track cap is bolted to the front of the ground link by three #4-40 bolts. It is designed to close off the follower link tracks to keep the follower links contained and the track clear of snow and other debris. The track cap is removable so that the follower links can be easily changed if one needs to be replaced. The cap has a $\frac{1}{4}$ inch in thickness, $\frac{1}{4}$ inch in length, and four inches in width.

3.3.15 Bolt Pattern Inserts

In today's snowboard market, there are mainly two bolt pattern designs commonly found on consumers' snowboards. These are the traditional 4x4 four bolt pattern and the Burton 3D three hole bolt pattern, shown in Figure 3.23.

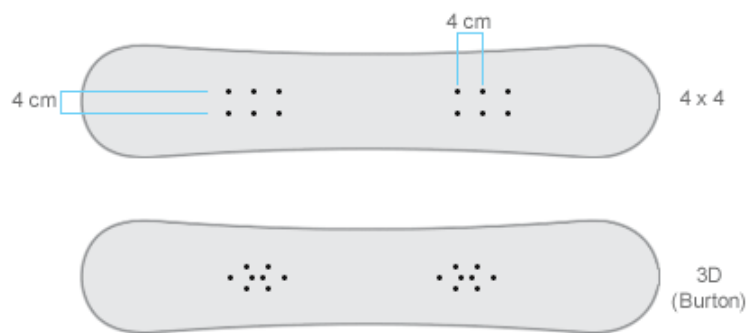


Figure 3.23: Snowboard Bolt Patterns (Savant, 2011)

The 4x4 four bolt pattern is a square pattern of four approximately $\frac{1}{4}$ inch diameter holes. Each hole is separated by a distance of four centimeters from its two adjacent holes. The dimensions of the Burton 3D three hole bolt pattern are shown in detail in Figure 3.24.

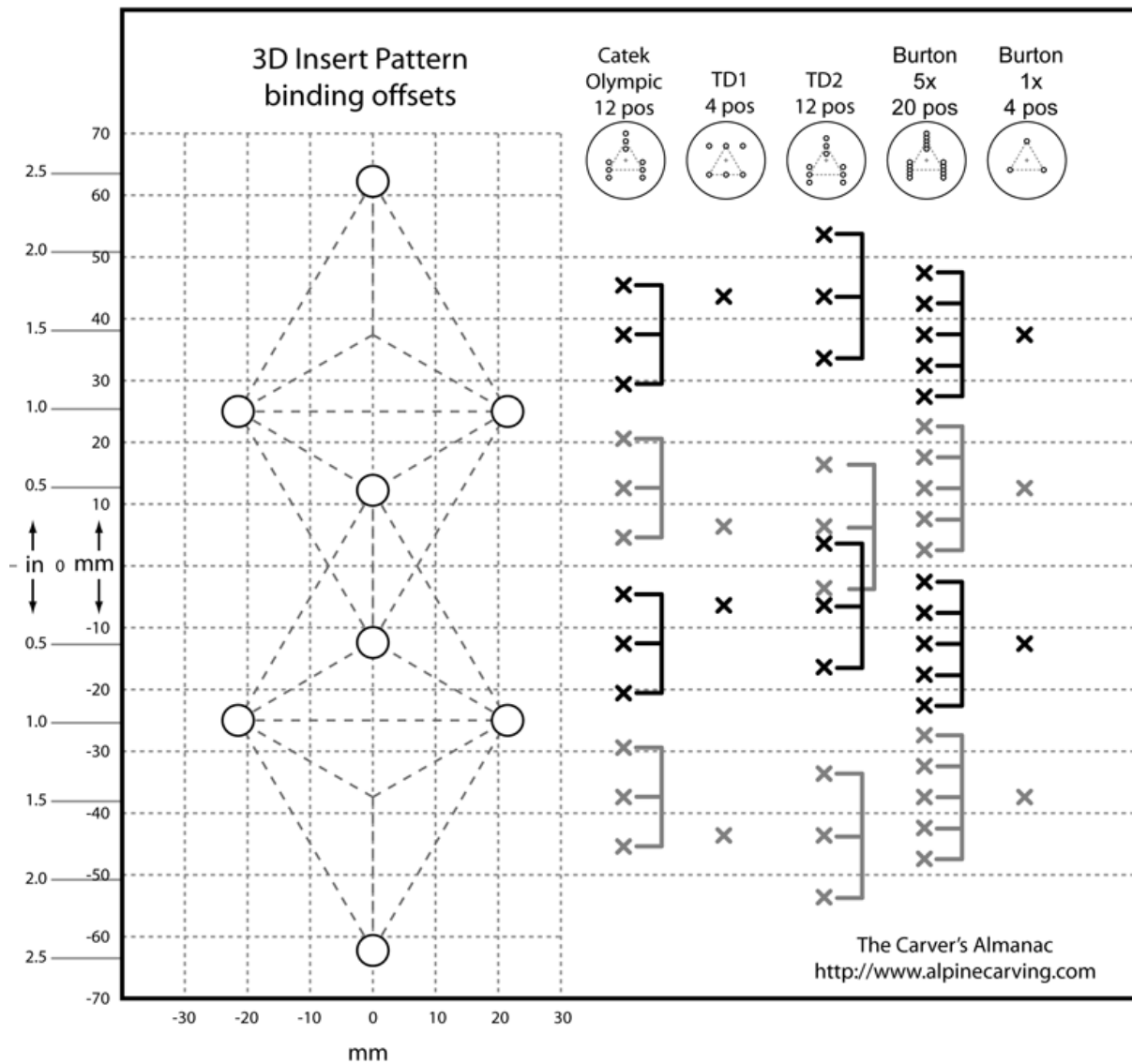


Figure 3.24: Burton 3D Three Hole Bolt Pattern Dimensions (Alpine Carving, 2011)

Since the 4x4 four bolt pattern and the Burton 3D three hole bolt pattern are considerably different dimensionally, interchangeable inserts were needed to make the automatic snowboard safety brake universal to all strap in bindings. The brake pattern inserts for the four bar driving mechanism subassembly of the snowboard safety brake are shown in Figure 3.25 and Figure 3.26.

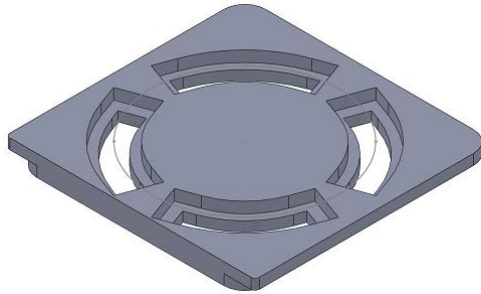


Figure 3.25: 4x4 Four Hole Bolt Pattern Insert

Flanged Edge

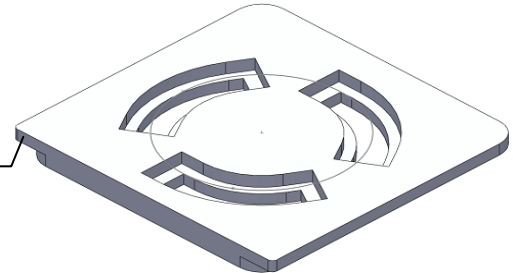


Figure 3.26: Burton 3D Three Hole Bolt Pattern Insert

The bolt pattern inserts are designed to nest inside of the pocket on the ground link and base plate by use of the three flanged edges. Only three edges are flanged so that the user can make no mistake in the orientation of the insert. The patterns are slotted about a circumference and counter-sunk for $\frac{1}{4}$ inch button head screws so that the four bar driving mechanism is able to rotate along with the binding to the rider's preferred angle. The bolt pattern inserts are capable of 25 degrees of rotation both CW and CCW. The inserts are $\frac{1}{4}$ inch in thickness in the center, $\frac{1}{8}$ inch in thickness at the flanges, $2\frac{3}{4}$ inches in length, and $2\frac{3}{4}$ inches in width.

3.3.16 Base Plate

The base plate for the snowboard safety brake is shown in Figure 3.27.

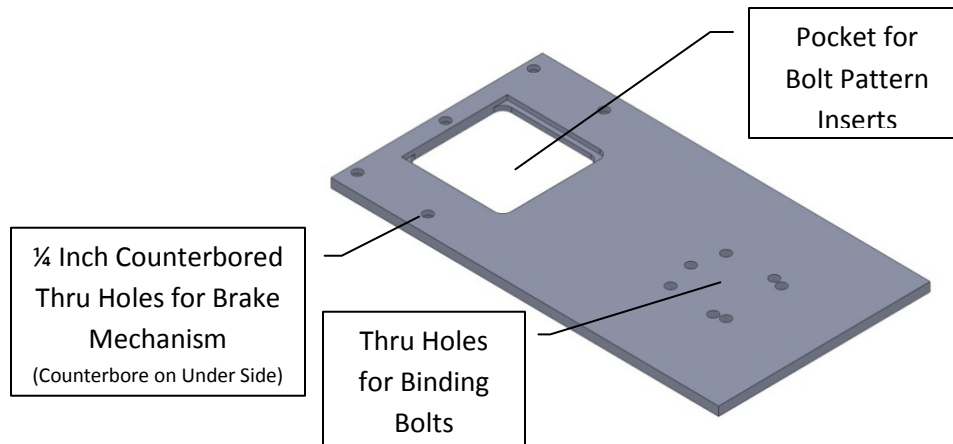


Figure 3.27: Base Plate

The base plate secures the brake mechanism subassembly, the four bar driving mechanism subassembly, and both the 4x4 four bolt pattern insert and the Burton 3D three bolt

pattern insert. The base plate itself is secured in between the bottom of the forward binding and the top surface of the snowboard by the binding bolts. Therefore, the forward binding bolts secure both the binding and the entire automatic snowboard safety brake. The base plate is designed with holes for both bolt patterns so that it is universal between all strap in bindings. Bolt pattern inserts are not necessary for the base plate because it must not rotate with the binding in order to remain square on the snowboard. The pocket or cut-out on the left hand side of the base plate is designed to seat the bolt pattern insert not in use for storage. The extra bolt pattern insert is secured underneath the brake mechanism which is bolted down onto the base plate. The base plate is six inches in width, 11 inches in length, and $\frac{1}{4}$ inch in thickness.

3.3.17 Riser

The riser for the snowboard safety brake is shown in Figure 3.28.

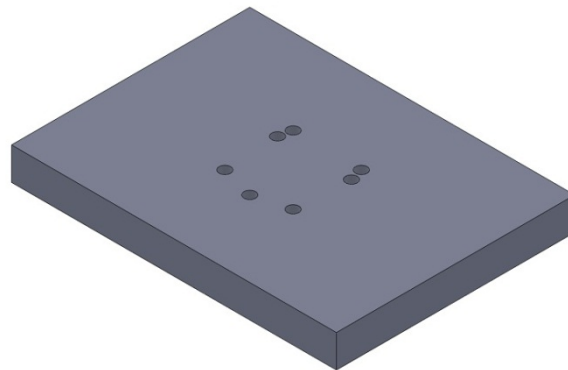


Figure 3.28: Riser

The riser is secured under the rear binding which the four bar driving mechanism is not fixed inside of. It is designed to eliminate the offset in the height of the rider's feet created by the added thickness of the baseplate and four bar driving mechanism so that the rider's feet are level when strapped into the bindings. The riser is designed with holes for both the 4x4 four bolt pattern and the Burton 3D three bolt pattern so that it is universal between all strap in bindings.

Bolt pattern inserts are not necessary for the riser because the rear foot is typically kept at zero degrees. The riser is seven inches in width, 5 ½ inches in length, and ¾ inch in thickness.

3.3.18 Purchased Components

A summary of the purchased components is shown in Table 3.4.

Component	Function	Supplier	Specs	Part Number	Cost
Steel Cable	Motion Translation	Flanders Cables	1/16" Diameter, 1x19 Strand	610-03106	\$0.72 / ft
Cable Conduit	Cable Protection	Flanders Cables	OD: .019" ID: .090"	610-03302	\$2.23 / ft
Threaded Cable End	Cable Attachment	McMaster Carr	#6-40 Thread	3870T21	\$5.53 / Ea.
Cable Eye Fitting	Cable Attachment	McMaster Carr	N/A	3872T11	\$6.09 / Ea.
1/8" Dowell Pin	Linkage Construction	McMaster Carr	Stainless Steel	95609A010	\$12.54 / ft
¼" Set Screw Guiding Pin	Brake Function	Home Depot	Turned & Rounded on End	N/A	N/A

Table 3.4: Summary of Purchased Components

3.3.19 Full Assembly

The full assembly of the snowboard safety brake is shown in Figure 3.29.

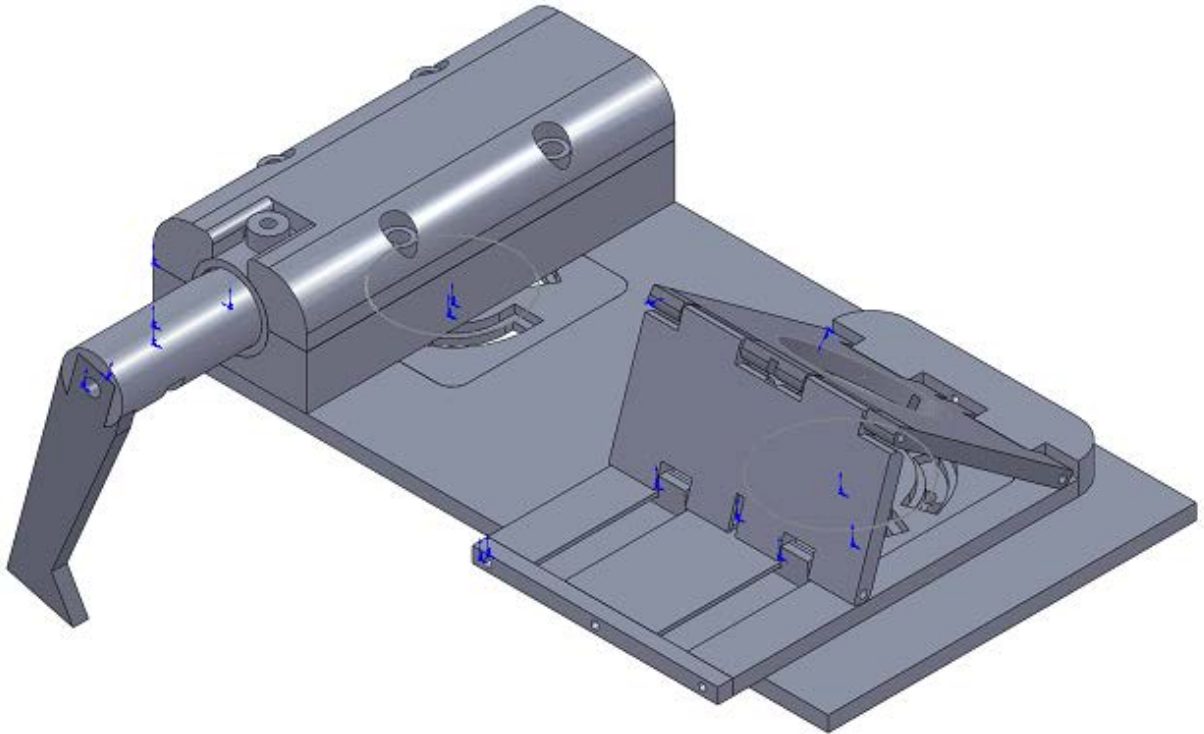


Figure 3.29: Full Assembly

****Note**** See Appendix A for dimensioned orthographic drawings of all subassemblies and components.

3.4 Materials Selection & Stress Analysis of Critical Components

In order to increase the manufacturability of all of the components of the automatic snowboard safety brake in terms of both volume and quality, our team decided that every component should be injection molded from a strong, dense polymer with a low friction coefficient to maximize the smoothness of the mechanisms. A material was chosen using the CES EduPack materials software to compare several properties of several potential materials.

In order to ensure the chosen material was satisfactory, finite element stress analysis was performed on the components of the safety brake under extreme loading using the chosen material properties.

3.4.1 Material Selection

In order to select a material to fabricate our final part from our team used program CES Edupack, computer software which contains a materials selection database and processes for forming these materials. This database contains descriptions and quantitative properties of many materials. In order to select the best material for the automatic snowboard safety brake, our team first developed an Ashby Method for what criteria we were looking for in a material (Ashby, 2011). When beginning to choose the material that would be used in our final design, we used Figure 3.30 as a guide. This figure shows the four most important characteristics when choosing a material. These four factors are function, material, shape and process. These four aspects of material selection allow you to choose a material that will meet all of the functions in order for the material to be the appropriate choice for your design and application. (Ashby, 2011)

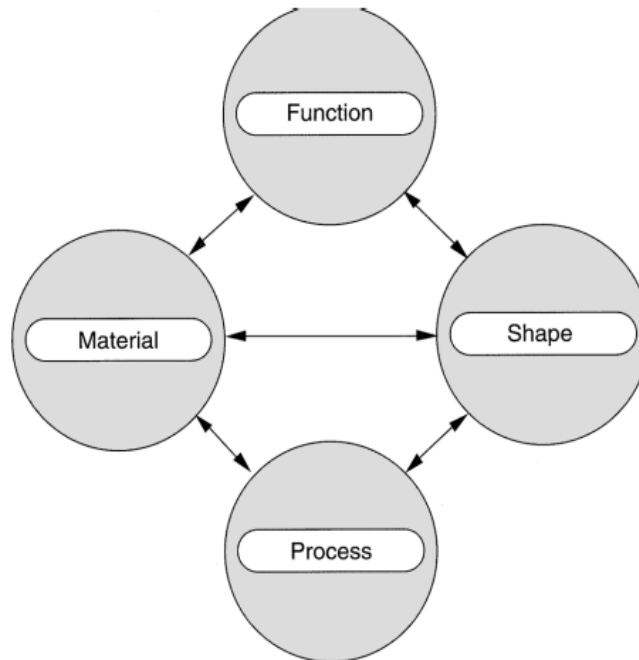


Figure 3.30: Important Considerations for Materials Selection (Leardon Solutions, 2009)

When choosing the material, we evaluated several different material properties for our materials. These material properties were young's modulus, density, hardness, cost, yield

strength and tensile strength. These properties were chosen in order to evaluate the performance of the material as well as the cost and weight which will be a important characteristics to look at when looking at the impact it will have on the function of the snowboard and the amount of money to bring this product to market. These properties were used to compare and evaluate all of the materials against one another in each of these categories, where the superior materials will be the front runners in most of these categories.

With CES Edupack having a large database of materials we first evaluated all of the materials on a graph of young's modulus v. density. This graph showed materials from all categories of ceramics and glasses, hybrids: composites -foams - natural materials, metals and alloys, and finally polymers and elastomers. When further investigating these materials and some of their properties, we were able to narrow down our materials search. We were able to disregard ceramics and glass and hybrids: composites -foams - natural materials because these materials would be too brittle and weak to support the loads on our foot plate and our braking device. We next eliminated metals and alloys because although these materials properties performed well; the price, weight, and machineability were not satisfying enough to pursue. This left polymers and elastomers and polymers. We quickly eliminated elastomers due to their poor material properties in regards to our needs and we began to focus our search on polymers, which is the category that our prototype was created from.

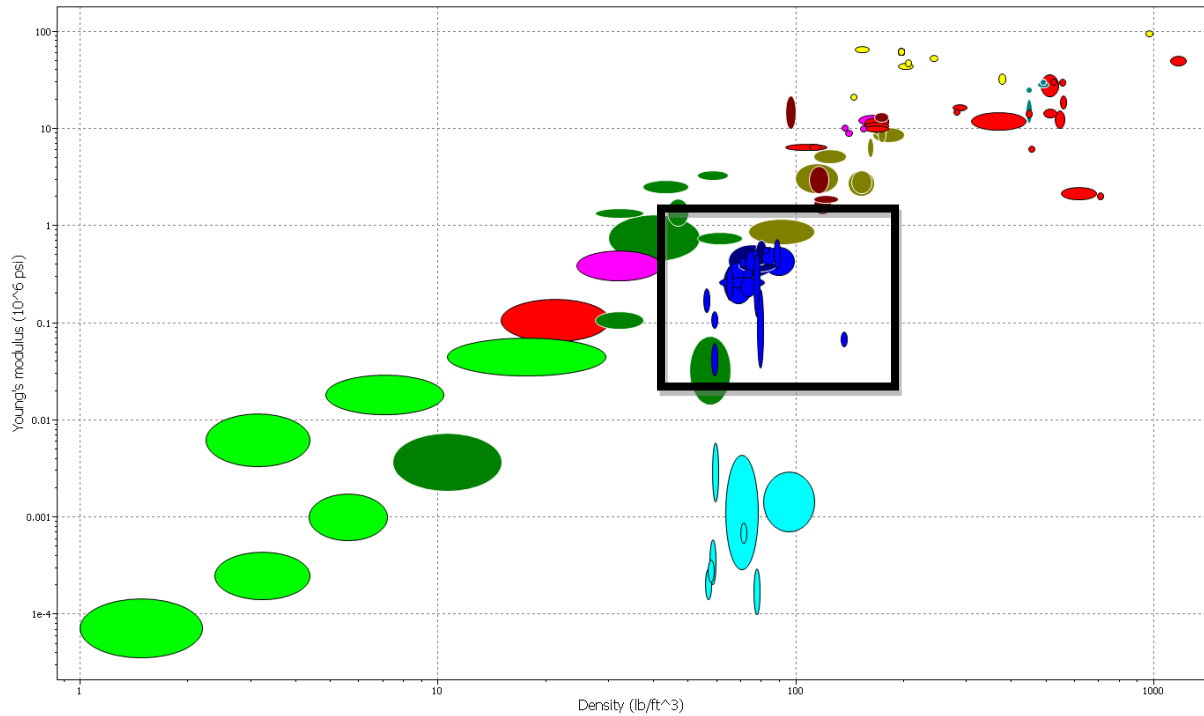


Figure 3.31: Young's modulus v. Density (All materials) (CES Edupack, 2009)

In Figure 3.31 we were hoping to obtain both the lowest density and the highest young's modulus. After eliminating several material categories we were able to narrow our search down to polymers which can be seen in the dark blue colors and outlined in Figure 3.31. The following graph shows our material selection of the polymers with the all other material categories eliminated from our material search.

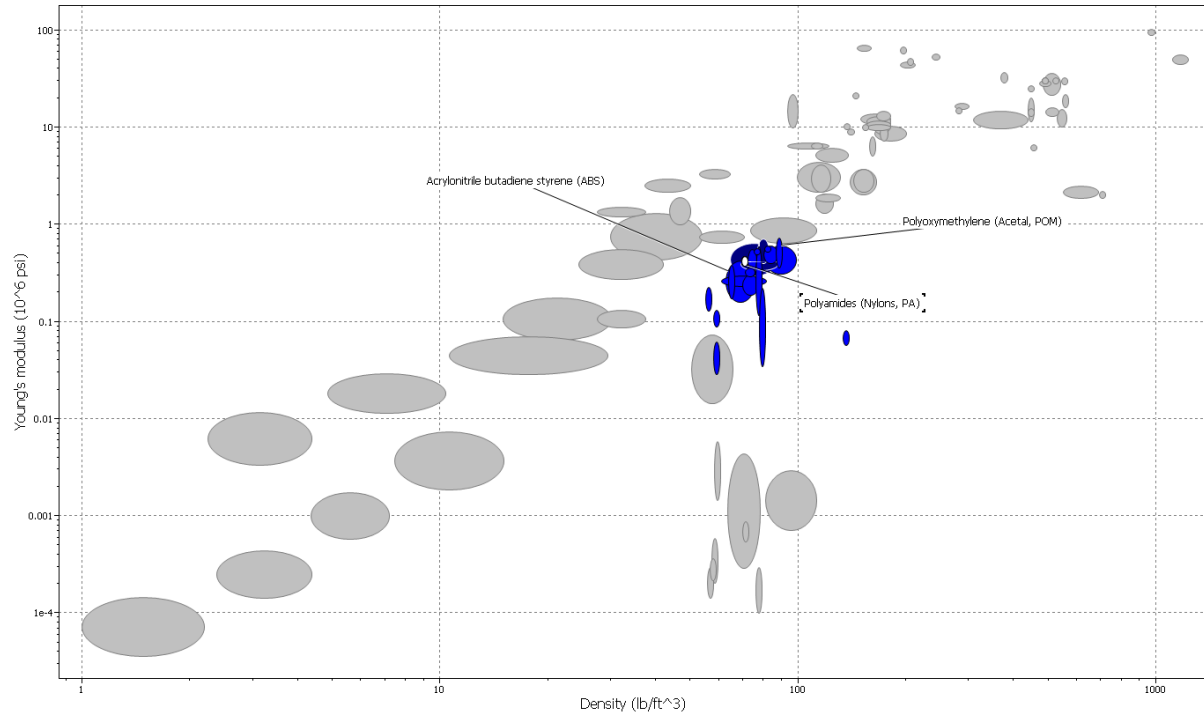


Figure 3.32: Young's modulus v Density (Polymers) (CES Edupack, 2009)

With our material search being narrowed down to one category of materials we began to plot our polymers against the material properties which we identified above. With each category several materials were highlighted as leading candidates by their performance and other material properties. Figure 3.33 shows the polymers being evaluated on their young's modulus properties.

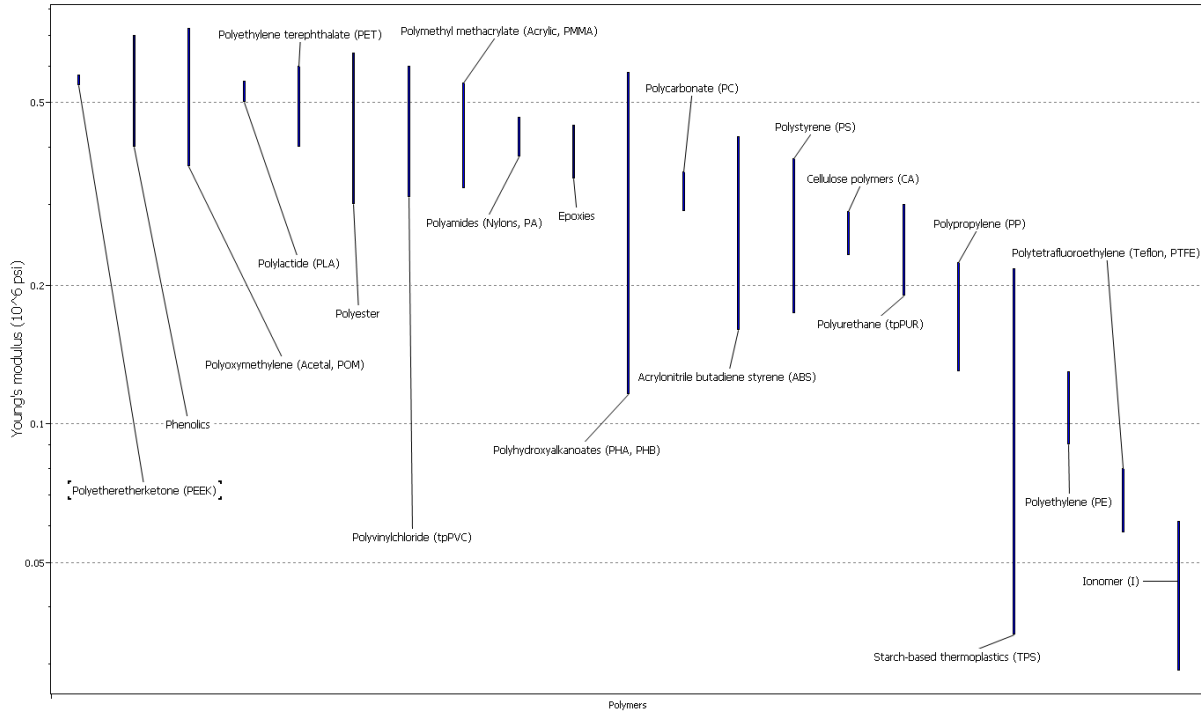


Figure 3.33: Polymers v Young's Modulus (10⁶ psi) (CES Edupack, 2009)

When evaluating young's modulus we were searching for products which showed the highest values of this category. Young's modulus describes the change that a material goes through in either compression or tension in one direction (Britannica Encyclopedia, 2011). This is an important characteristic in our case as there will be tension on our driving mechanism when the rider is strapped their boot bindings and standing on it as well as when the brake is deployed and making contact with the ground. At a quick glance Polyoxymethylene (Acetal, POM) or commonly known as Delrin had the highest young's modulus value as well as a range in the top majority of all of the polymers. In Figure 3.34, you can see the comparison of the parts in regards to density.

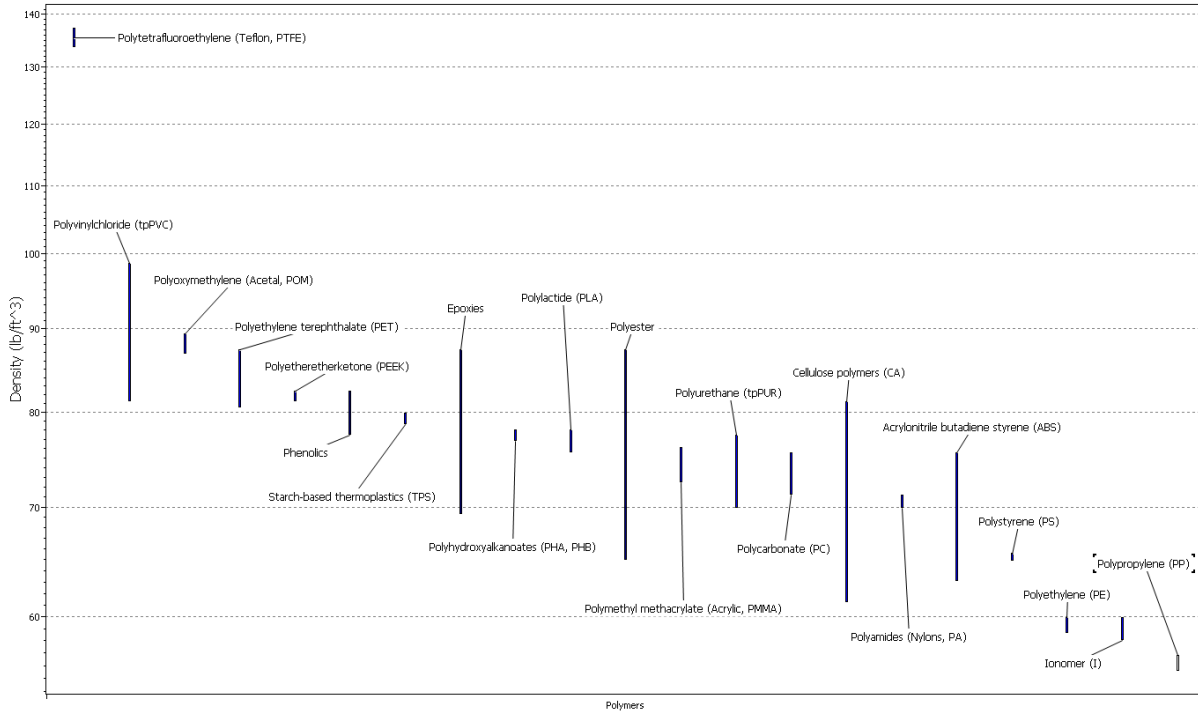


Figure 3.34: Polymers v Density (lb/ft³) (CES Edupack, 2009)

With the range in density of the products being very similar in an average range of 55-90 (lb/ft³) excluding one value we would be able to choose any value between these ranges. Here the density of the product is not really a huge factor because all of these polymers have very similar density values. Any material here would accommodate our needs in regards to density. Next, Figure 3.35 will show the relationship between the materials and their hardness.

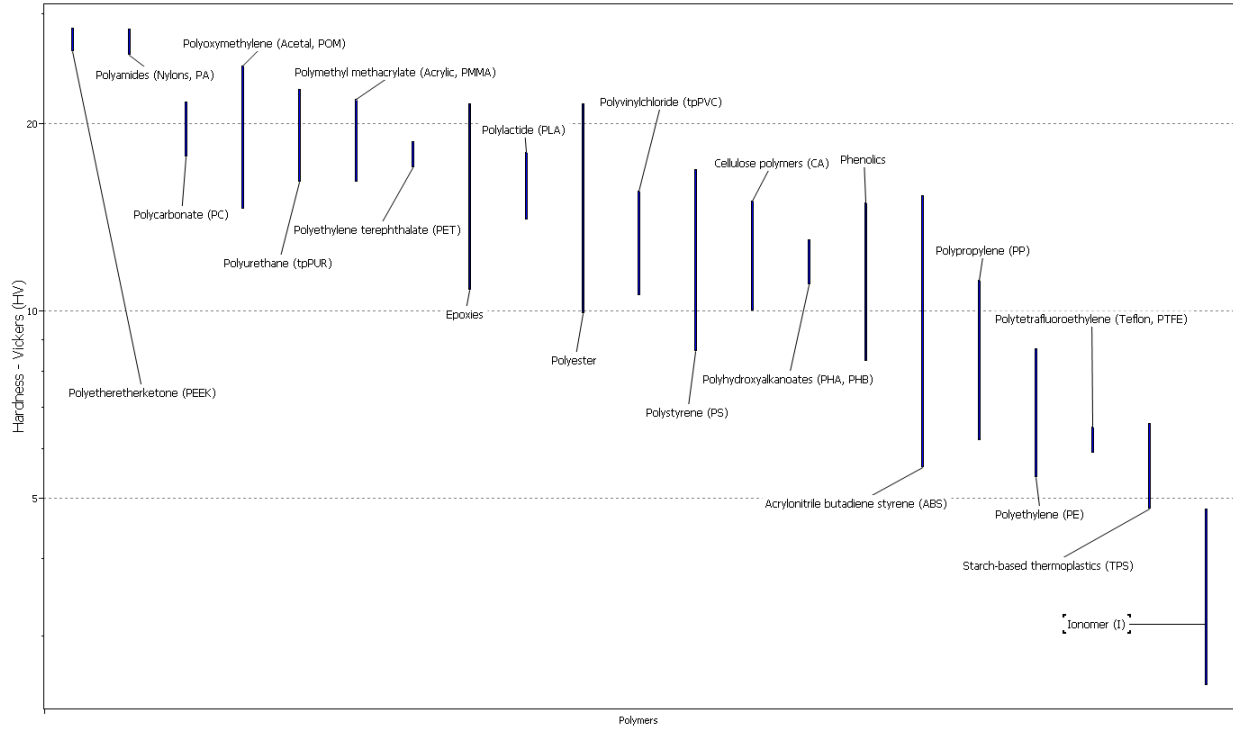


Figure 3.35: Polymers v Hardness (HV) (CES Edupack, 2009)

Looking at leading materials for hardness, Delrin once again has one of the highest values as well as Nylon. The hardness of these materials is measured by the Vickers hardness scale which is used to measure all types of metals and materials. It is important for our material to possess this property in order to ensure that the parts will be strong enough to resist the forces they will encounter while performing their functions. Polyetheretherketone (PEEK) continues to have some of the highest values, but the price per pound of this product which is 46.8 – 53.9 USD/lb makes this product too expensive for our application. Next we looked at the price of these materials in Figure 3.36.

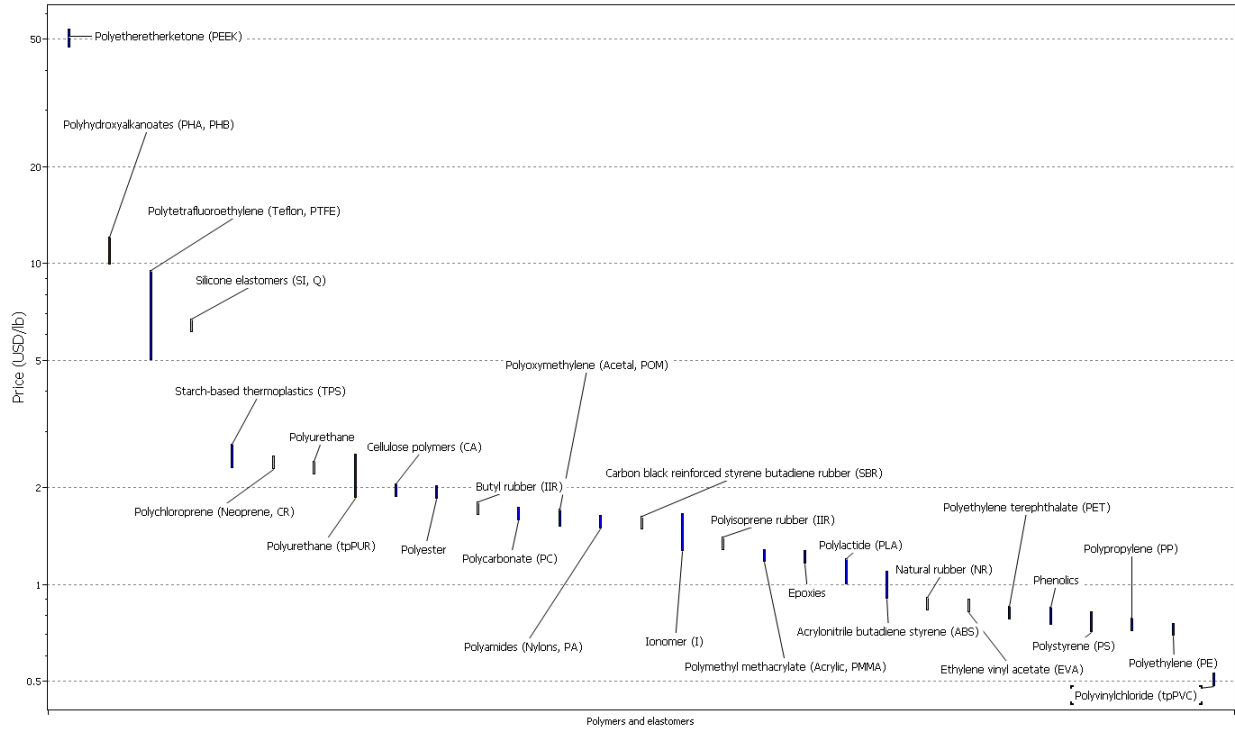


Figure 3.36: Polymers v Price (USD/lb) (CES Edupack, 2009)

Even if materials perform well in other material properties, the cost of the material can be a very big deciding factor. When looking into the price chart we chose to only consider materials that were under the 2 USD/lb range in order to ensure the price of the chosen material is one which will not be too expensive. By setting the limit of our product to 2 USD/lb we were able to consider 19 out of the 28 materials being evaluated. Next, Figure 3.37 shows the evaluation of the yield strength of the polymers.

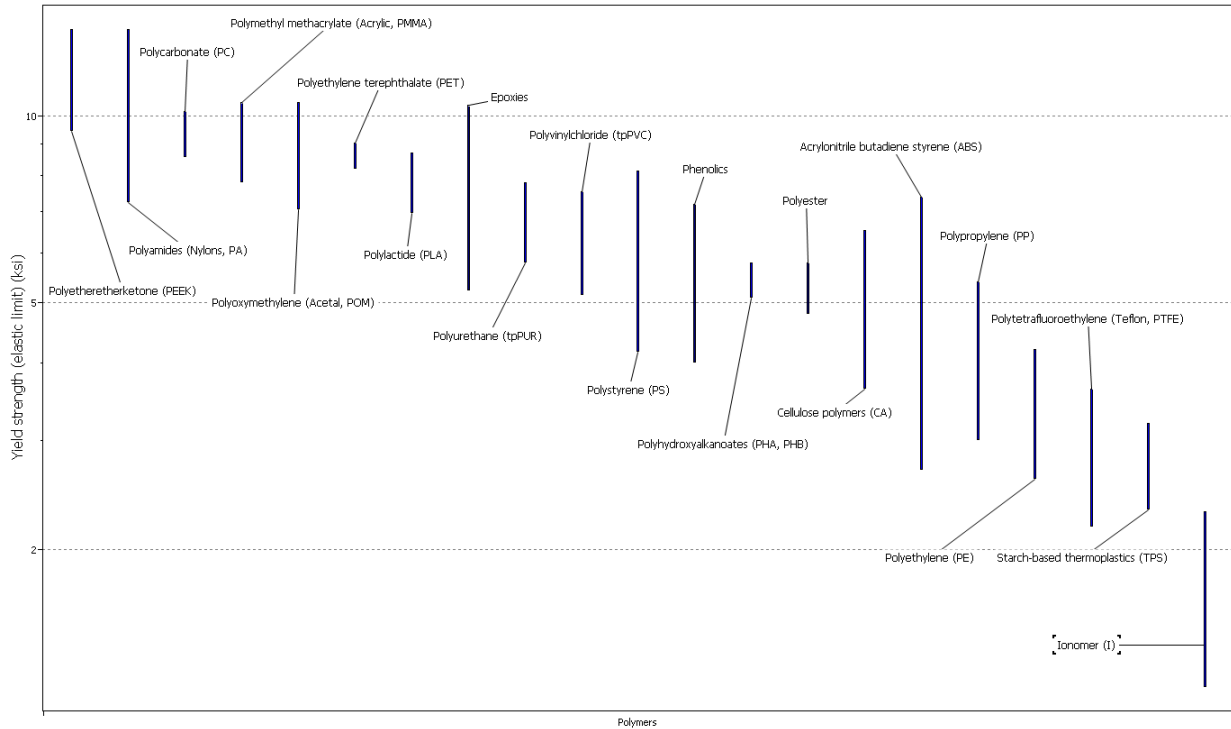


Figure 3.37: Polymers v Yield Strength (ksi) (CES Edupack, 2009)

Yield strength can be defined as a materials ability to resist permanent deformation (Britannica Encyclopedia, 2011). As seen as leading candidates in other categories, both Delrin and Nylon have some of the highest values for yield strength. This is an important value to have because with the many forces being put on the braking device when it is in the extended position, it is key for the material to not permanently deform since it will be uses time and time again. Finally Figure 3.38 shows the tensile stress of the different polymers.

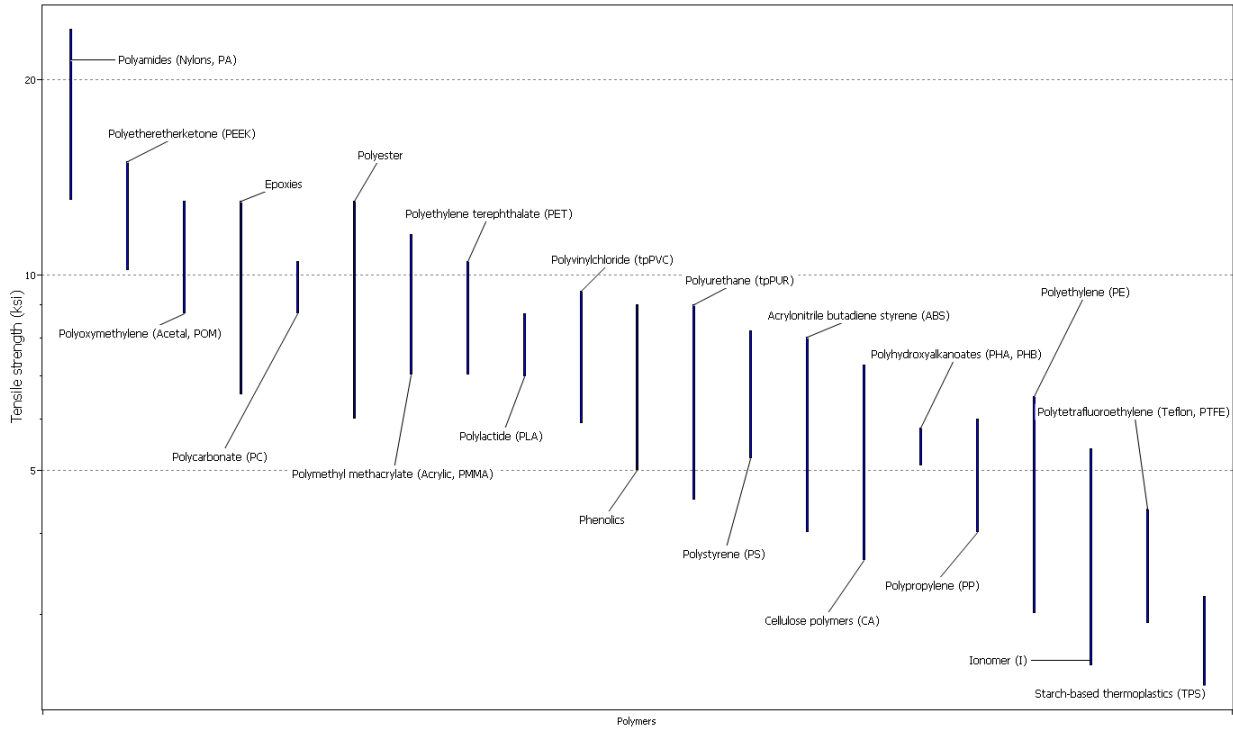


Figure 3.38: Polymers v Tensile Strength (ksi) (CES Edupack, 2009)

The last category which we looked at was the tensile strength versus the polymers. Once again the top two candidates were Delrin and Nylon. Both of these materials were either in or above the 10 ksi range as were 6 other materials in the polymer category.

Through our analysis we decided to narrow the field down to the three top performing materials. These materials were Nylon, Delrin, and ABS. With this decision we took the material property values of each these materials and compared them to one another. These values can be seen below in Table 3.5.

	Acrylonitrile butadiene styrene (ABS)	Polyoxymethylene (Acetal, POM)	Polyamides (Nylones, PA)
Density (lb/ft ³)	69.9 - 71.2	86.8 - 89.3	69.9 - 72.2
Price (USD/lb)	1.49 - 1.64	1.51 - 1.72	1.49 - 1.64
Youngs Modulus (10 ⁶ psi)	0.38 - 0.464	0.363 - 0.725	0.38 - 0.464
Hardness - Vickers (HV)	5.6 - 15.3	14.6 - 24.8	25.8 - 28.4
Yield Strength (psi) - MAX	7.4	10.5	13.7
Tensile Strength (psi) - MAX	8.01	13	23.9
Melting Point (°F)	420-428	320 - 363	410 - 428

Table 3.5: Material Properties (Top three materials) (CES Edupack, 2009)

Along with the material properties of young's modulus, density, hardness, cost, yield strength and tensile strength, we also included the melting points of the materials. The reason for evaluating the melting point temperature is because all three materials are easily moldable. Having a moldable material is crucial because our manufacturing process to mass produce our brake would be injection molding which requires the material to be melted down to a liquid and forced into our molds. This process would allow for the least amount of wasted product because the extra scraps could just be melted down and used again in the application of another part.

In order to choose the best material from our three top choices, we created a decision matrix which ranks the materials on a scale of 1-3, with three being the best material for that category and one being the worst. At the end of the comparison the material with the highest score will be the material that we choose. The decision matrix can be seen below in Table 3.6.

	Acrylonitrile butadiene styrene (ABS)	Polyoxymethylene (Acetal, POM)	Polyamides (Nylones, PA)
Density (lb/ft ³)	3	1	2
Price (USD/lb)	Cost can be neglected because the largest difference is .08 USD/lb		
Youngs Modulus (10 ⁶ psi)	1	3	1
Hardness - Vickers (HV)	1	2	3
Yield Strength (psi) - MAX	1	2	3
Tensile Strength (psi) - MAX	1	2	3
Melting Point (°F)	1	3	1
Total	8	13	13

Table 3.6: Material Selection Decision Matrix

After evaluating all of the materials against the material properties of young's modulus, density, hardness, cost, yield strength and tensile strength both Polyoxymethylene (Acetal, POM) or Delrin and Polyamides (Nylons, PA) were the two materials which had the best material property values. From our research, both of these materials are better in some areas and worse compared to one another. When getting the material for our prototype base plate we had the opportunity to choose either Delrin or Nylon. Both of these materials competed and performed the best against all of the other materials which we researched. After speaking to the experts at

Plastics Unlimited of Worcester they recommended Delrin as the better material for the application which we are trying to use it for.

3.4.2 Finite Element Stress Analysis (FEA) of Critical Components

The brake piston and brake attachment assembly were analyzed using finite element stress analysis. These components are subject to the most extreme loading conditions due to their cantilever behavior. The four bar driving mechanism is not subject to extreme loading conditions because it is designed to displace under loading and does not resist. Since all of the components of the automatic snowboard safety brake are to be constructed from Delrin, the stress analysis was performed only on the brake piston and brake attachment assembly. If the most extreme loading conditions are satisfied, the normal loading conditions will also be satisfied.

The loading conditions that were considered are both a six foot free fall impact with the snowboards entire mass loaded on the brake attachment. The force of this impact was calculated as follows:

$$m_{\text{snowboard}} = 15 \text{ lb} = 6.8 \text{ kg}$$

Assume free fall of 6 feet before impact. 6ft = 1.829m

$$PE = KE$$

$$mgh = \frac{1}{2} mv^2 \rightarrow v = \sqrt{2gh}$$

$$v = \sqrt{2(9.81)(1.829)} = 35.88 \text{ m/s} = \Delta V$$

$$I = m_{\text{snowboard}} \Delta V = 244 \text{ N*s (Impulse)}$$

Assume time of collision is 0.7 s.

$$I = F(\Delta t)$$

$$244 \text{ N*s} = F (.7\text{s})$$

$$F = 348 \text{ N} \approx 350 \text{ N}$$

The first extreme loading condition simulates the snowboard falling straight down on the brake attachment with its entire momentum, as depicted in Figure 3.39.

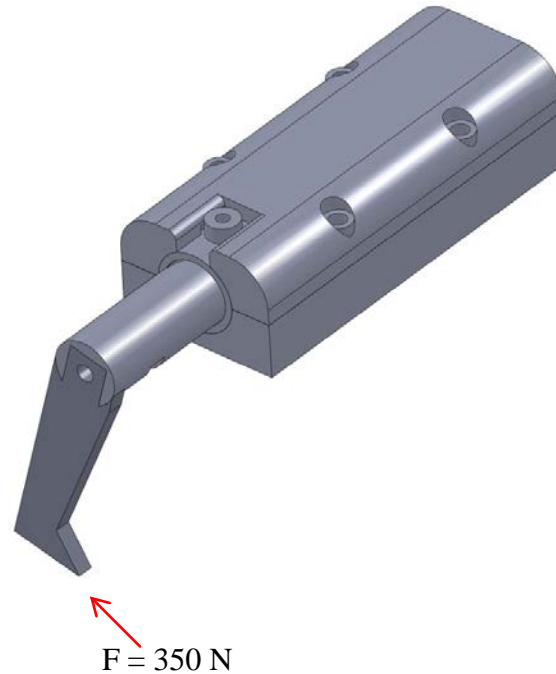


Figure 3.39: First Extreme Loading Condition

Since the brake attachment is only rotated 75 degrees from horizontal, it will impact the ground at its point and the force of 350 N will be applied normal to it as shown in Figure 3.39. Using the Simulation Tool in SolidWorks 2010, the finite element stress analysis was performed with proper constraints, loading conditions, and material properties applied to the assembly to determine the maximum von Mises stress and displacement endured by it. See Appendix B for CES EduPack 2010 material properties of Delrin. The von Mises stress and displacement models of the assembly under the first extreme loading condition are shown in Figure 3.40 and Figure 3.41.

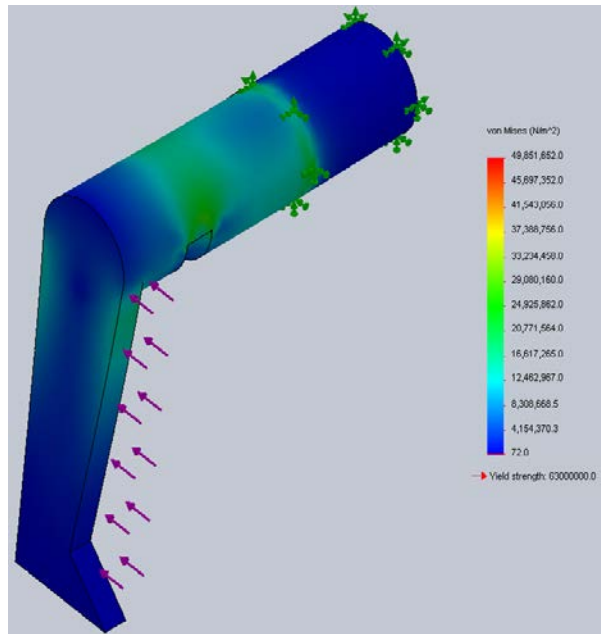


Figure 3.40: von Mises Stress Analysis of First Extreme Loading Condition

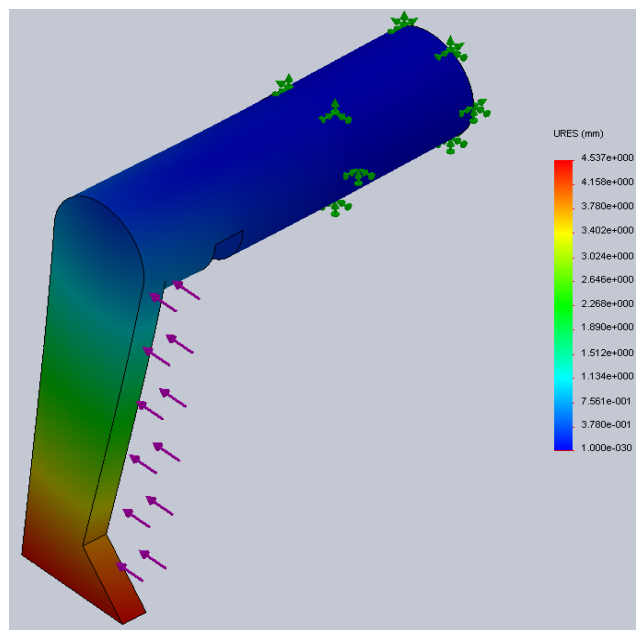


Figure 3.41: Displacement Analysis of First Extreme Loading Condition

The maximum von Mises stress endured by the assembly was 49.9 MPa, about 10 MPa lower than the yield strength of Delrin. The maximum displacement of the assembly was only

4.54 mm. Since the maximum von Mises stress is less than the yield strength of Delrin, the material satisfies the first extreme loading condition.

The second extreme loading condition simulates the board falling along a trajectory which causes the entire momentum of the snowboard to be applied to the brake attachment perpendicular to the spike, as depicted in Figure 3.42.

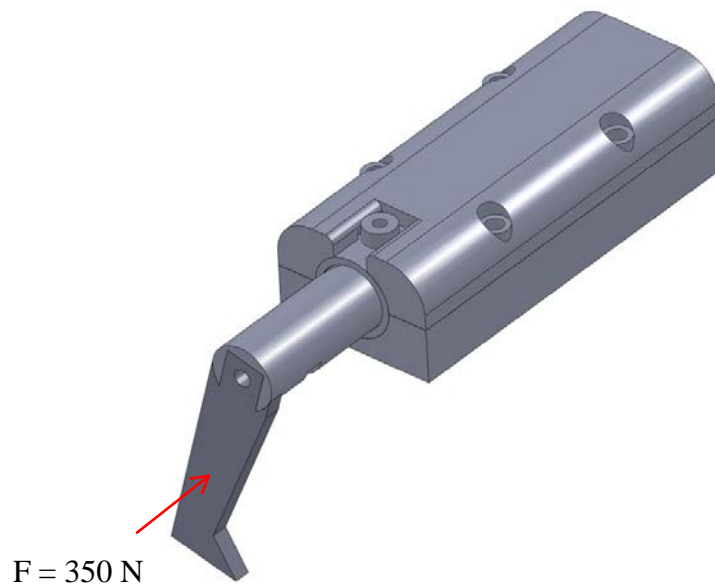


Figure 3.42: Second Extreme Loading Condition

Using the Simulation Tool in SolidWorks 2010, the finite element stress analysis was performed with proper constraints, loading conditions, and material properties applied to the assembly to determine the maximum von Mises stress and displacement endured by it. The von Mises stress and displacement models of the assembly under the first extreme loading condition are shown in Figure 3.43 and Figure 3.44 below.

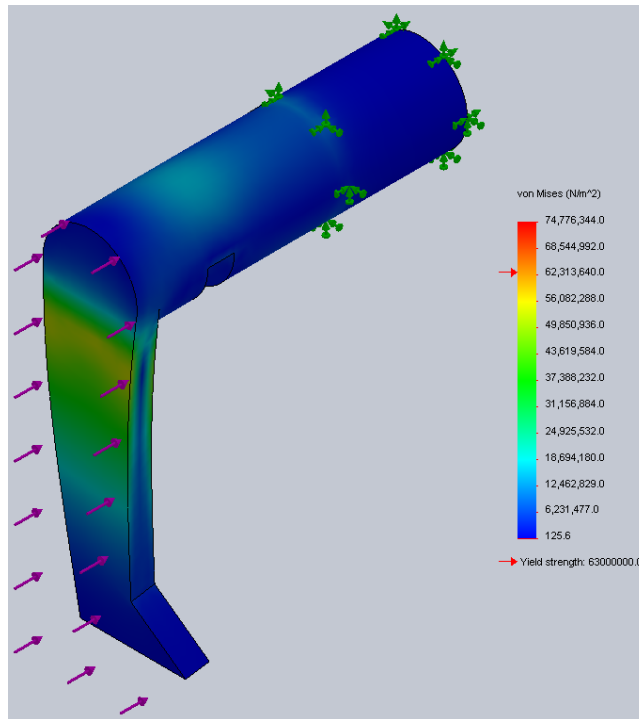


Figure 3.43: von Mises Stress Analysis of Second Extreme Loading Condition

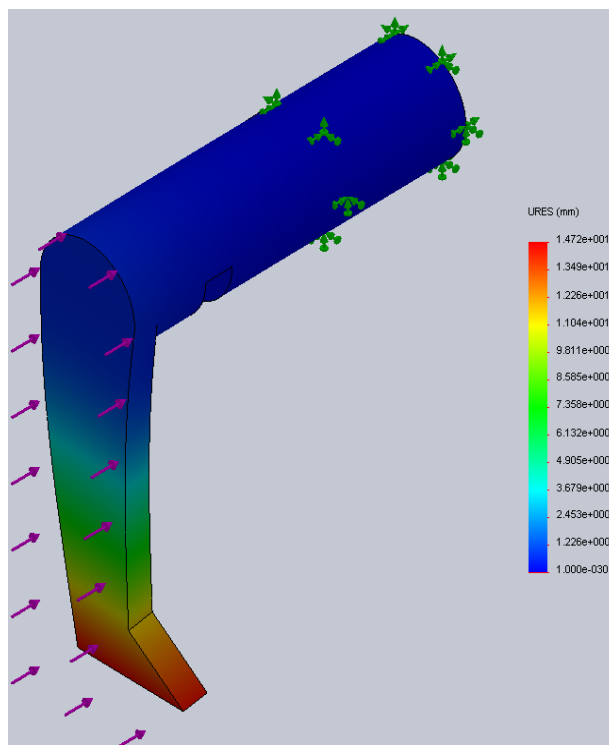


Figure 3.44: Displacement Analysis of Second Extreme Loading Condition

The maximum von Mises stress endured by the assembly was 74.8 MPa, about 2 MPa higher than the yield strength of Delrin and about 15 MPa less than the tensile strength of Delrin. The maximum displacement of the assembly was 14.72 mm. The maximum von Mises stress is slightly larger than the yield strength but significantly less than the yield strength of Delrin, and the displacement is about 1 ½ cm. Therefore, these loading conditions may cause some significant bending of the brake attachment, but no failure.

Since the stress analysis of the components subject to extreme loading conditions showed no failure, Delrin is confirmed as the chosen material.

4.0 RESULTS

4.1 Test Procedure

The safety brake was put through a number of tests to make sure that it was functional in all conditions. It was tested on slopes of three different slopes of 10 degrees, 20 degrees, and 30 degrees. Along with varying slopes, the brake was tested with three different slope conditions of groomed trails, loose granular trails, and iced trails. These tests provide results for every practical condition that someone can be in if a riders snowboard takes off downhill.

For the perpendicular static test, the board was positioned perpendicular with the hill with the toe side edge angled approximately at 45 degrees. This would simulate a rider sitting on the hillside adjusting their boots in the bindings. The board was then dropped simulating the effect of someone losing the grip on their snowboard and the results were recorded.



Figure 4.1: Starting Position of Snowboard for the Static Perpendicular Test

The next test performed was the parallel static test. The board was placed facing down hill and the front was lifted up two feet. The board was then dropped and the distance it traveled

and the time it took to stop were recorded. This test was designed to copy the characteristics of a rider dropping their board facing downhill.



Figure 4.2: The result from a parallel static test on a 10 degree slope on groomed snow.

The final test performed was the parallel dynamic test. This test was performed by giving the board an initial velocity down the hill by placing the front of the board on the hill and pushing it forward before it was released. This test was designed to simulate a binding failure at a cruising speed.



Figure 4.3: This shows the results of a parallel dynamic.

Each of these test were performed 3 times each so that the results would have average values to graph. With the information plotted on the graphs one would be able to estimate the distance traveled and amount of time to start depending the slope of the hill they are riding on. This also allows for outliers to be ruled out so that the data collected can be confirmed as accurate.

4.2 Results and Analysis

The first step in the analysis of the results was to calculate the average values for distance traveled, time to stop, and average velocity. These values show the brakes capability to stop a runaway snowboard on any hill slope and starting position. Below is a table of the actual datasheet with the individual trial times and distances on it.

Slope Angle:	10 Degrees	Trial 1		Trial 2		Trial 3	
Snow Condition	Starting Condition	Distance	Time	Distance	Time	Distance	Time
Groomed	Perpendicular (Static)	0	0	0	0	0	0
	Parallel (Static)	1.5	0.42	1	0.34	1.5	0.47
	Parallel (Dynamic)	27	3	22	2	41	2
Loose Granular	Perpendicular (Static)	0	0	0	0	0	0
	Parallel (Static)	6	2.14	2.5	0.86	5.5	1.96
	Parallel (Dynamic)	134	8.94	85	7.34	165	9.67
Ice	Perpendicular (Static)	1	0.28	1	0.24	1.5	0.42
	Parallel (Static)	2	0.72	2.5	0.64	3	0.97
	Parallel (Dynamic)	21	3.25	32	3.57	14	2.67

Table 4.1: Distances and Times on a 10 degree slope

Slope Angle:	20 Degrees	Trial 1		Trial 2		Trial 3	
Snow Condition	Starting Condition	Distance	Time	Distance	Time	Distance	Time
Groomed	Perpendicular (Static)	0.5	0.32	1	0.42	0.5	0.38
	Parallel (Static)	3	1.23	4	1.32	3	1.12
	Parallel (Dynamic)	55	4.62	24	2.24	44	4.32
Loose Granular	Perpendicular (Static)	1	0.44	0.5	0.31	0.5	0.27
	Parallel (Static)	8	2.21	10	2.42	6	1.87
	Parallel (Dynamic)	140	9.17	164	9.89	172	10.21
Ice	Perpendicular (Static)	2	0.72	2.5	0.89	3	0.98
	Parallel (Static)	3	1.18	7	1.34	5	1.16
	Parallel (Dynamic)	22	3.74	28	3.45	34	3.76

Table 4.2: Distances and Times on a 20 degree slope

Slope Angle:	30 Degrees	Trial 1		Trial 2		Trial 3	
Snow Condition	Starting Condition	Distance	Time	Distance	Time	Distance	Time
Groomed	Perpendicular (Static)	5	2.78	1	0.14	1.5	0.36
	Parallel (Static)	4	2.14	8	2.74	5	1.76
	Parallel (Dynamic)	77	5.2	86	6.32	94	6.74
Loose Granular	Perpendicular (Static)	2.5	0.38	3	0.51	4	0.69
	Parallel (Static)	22	4.74	12	2.76	14	2.31
	Parallel (Dynamic)	177	14.76	167	11.53	179	12.23
Ice	Perpendicular (Static)	7	1.9	4.5	1.4	3	1.8
	Parallel (Static)	16	4.76	14	4.25	8	3.48
	Parallel (Dynamic)	47	6.7	56	6.92	67	7.89

Table 4.3: Distances and Times on a 30 degree slope

With this data collected, it was further analyzed into new tables showing the average distance traveled, average time to stop, and average velocity of the snowboard. These values were calculated for each condition on each slope. Below are the tables of these calculated values.

Slope Angle:	10 Degrees	Average Distance (inches)	Average Time (Seconds)	Average Velocity (inches/second)
Snow Condition	Starting Condition			
Groomed	Perpendicular (Static)	0.00	0.00	0.00
	Parallel (Static)	1.33	0.41	3.25
	Parallel (Dynamic)	30.00	2.33	12.86
Loose Granular	Perpendicular (Static)	0.00	0.00	0.00
	Parallel (Static)	4.67	1.65	2.82
	Parallel (Dynamic)	128.00	8.65	14.80
Ice	Perpendicular (Static)	1.17	0.31	3.72
	Parallel (Static)	2.50	0.78	3.22
	Parallel (Dynamic)	22.33	3.16	7.06

Table 4.4: Average Distance, Time, and Velocity on a 10 degree slope

Slope Angle:	20 Degrees	Average Distance (inches)	Average Time (Seconds)	Average Velocity (inches/second)
Snow Condition	Starting Condition			
Groomed	Perpendicular (Static)	0.67	0.37	1.79
	Parallel (Static)	3.33	1.22	2.72
	Parallel (Dynamic)	41.00	3.73	11.00
Loose Granular	Perpendicular (Static)	0.67	0.34	1.96
	Parallel (Static)	8.00	2.17	3.69
	Parallel (Dynamic)	158.67	9.76	16.26
Ice	Perpendicular (Static)	2.50	0.86	2.90
	Parallel (Static)	5.00	1.23	4.08
	Parallel (Dynamic)	28.00	3.65	7.67

Table 4.5: Average Distance, Time, and Velocity on a 20 degree slope

Slope Angle:	30 Degrees	Average Distance	Average Time	Average Velocity
Snow Condition	Starting Condition	(inches)	(Seconds)	(inches/second)
Groomed	Perpendicular (Static)	2.50	1.09	2.29
	Parallel (Static)	5.67	2.21	2.56
	Parallel (Dynamic)	85.67	6.09	14.07
Loose Granular	Perpendicular (Static)	3.17	0.53	6.01
	Parallel (Static)	16.00	3.27	4.89
	Parallel (Dynamic)	174.33	12.84	13.58
Ice	Perpendicular (Static)	4.83	1.70	2.84
	Parallel (Static)	12.67	4.16	3.04
	Parallel (Dynamic)	56.67	7.17	7.90

Table 4.6: Average Distance, Time, Velocity on a 30 degree slope

Further analysis of data was then performed to show the trend of the brake performance in the different conditions depending on the slope of the hill that the snowboard is released on. The first step was to arrange the data into a more manageable table so that it could be easily read. The data was put into three different tables depending on the snow condition. This not only shows the trend that the data follows but also points out which conditions are the ideal conditions for the safety brake to perform in. Below are the rearranged tables.

	Slope	Average Distance	Average Time	Average Velocity
Groomed Perpendicular	10 Degrees	0.00	0.00	0.00
	20 Degrees	0.67	0.37	1.79
	30 Degrees	2.50	1.09	2.29
Groomed Parallel	10 Degrees	1.33	0.41	3.25
	20 Degrees	3.33	1.22	2.72
	30 Degrees	5.67	2.21	2.56
Groomed Dynamic	10 Degrees	30.00	2.33	12.86
	20 Degrees	41.00	3.73	11.00
	30 Degrees	85.67	6.09	14.07

Table 4.7: Average Distance, Time, and Velocity dependent on slope for groomed conditions

	Slope	Average Distance	Average Time	Average Velocity
Loose Granular Perpendicular	10 Degrees	0.00	0.00	0.00
	20 Degrees	0.67	0.34	1.96
	30 Degrees	3.17	0.53	6.01
Loose Granular Parallel	10 Degrees	4.67	1.65	2.82
	20 Degrees	8.00	2.17	3.69
	30 Degrees	16.00	3.27	4.89
Loose Granular Dynamic	10 Degrees	128.00	8.65	14.80
	20 Degrees	158.67	9.76	16.26
	30 Degrees	174.33	12.84	13.58

Table 4.8: Average Distance, Time, and Velocity dependent on slope for loose granular conditions

	Slope	Average Distance	Average Time	Average Velocity
Ice Perpendicular	10 Degrees	1.17	0.31	3.72
	20 Degrees	2.50	0.86	2.90
	30 Degrees	4.83	1.70	2.84
Ice Parallel	10 Degrees	2.50	0.78	3.22
	20 Degrees	5.00	1.23	4.08
	30 Degrees	12.67	4.16	3.04
Ice Dynamic	10 Degrees	22.33	3.16	7.06
	20 Degrees	28.00	3.65	7.67
	30 Degrees	56.67	7.17	7.90

Table 4.9: Average Distance, Time, and Velocity dependent on slope for ice conditions

This data shows that the snowboard is capable of stopping in an adequate distance and a short amount of time. Not only does the safety brake stop the board from moving it also keeps the average velocity of the board to a significantly low velocity. This means that even if the board travels far enough or long enough to make contact with another rider that the damages caused would be minimal due to the low velocity that the board would be traveling at.

This data also shows which conditions are the ideal for the best functionality of the brake. The brake performed the best on a groomed trail and the worst on a loose granular trail. The worst condition that was tested was on a hill with a slope of 30 degrees and a loose snow

condition. Even with the worst possible conditions the safety brake arrested the snowboard is within fifteen feet. The average time that it took the board to stop was within thirteen seconds.

The previous data was added into graphs so that the average time to stop and the average distance to stop can be estimated depending on the slope of the hill that the snowboard was dropped on.

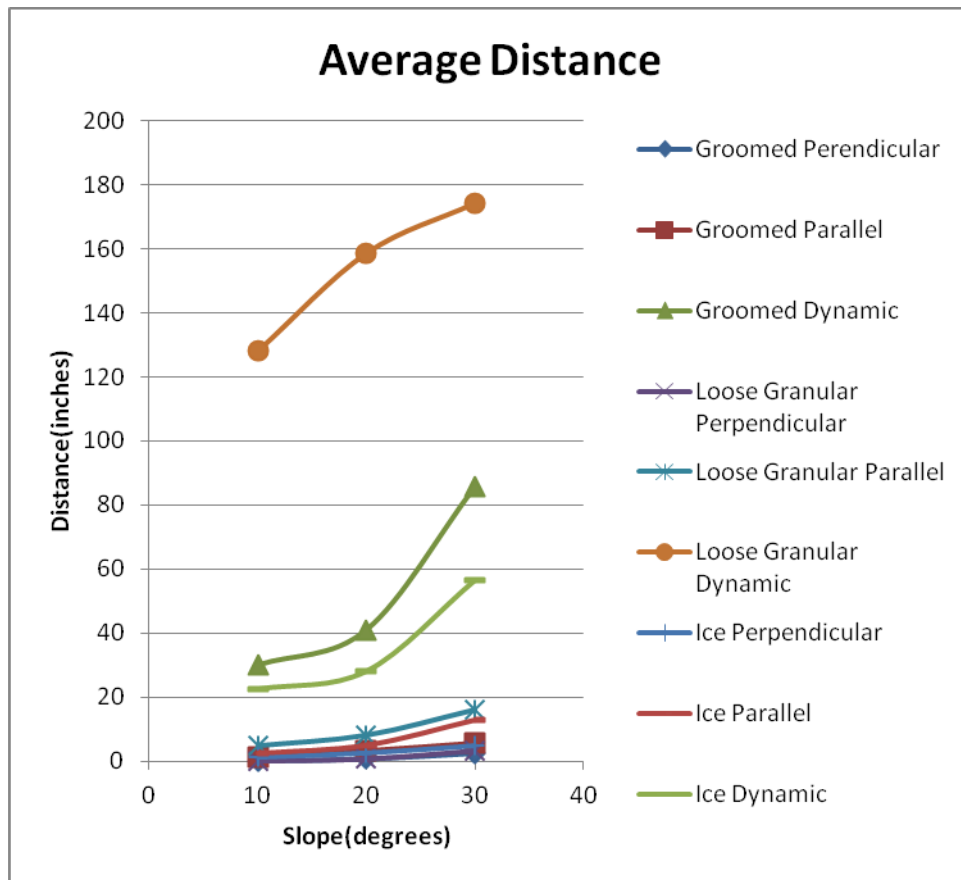


Figure 4.4: Graphical analysis of average distance to stop in inches

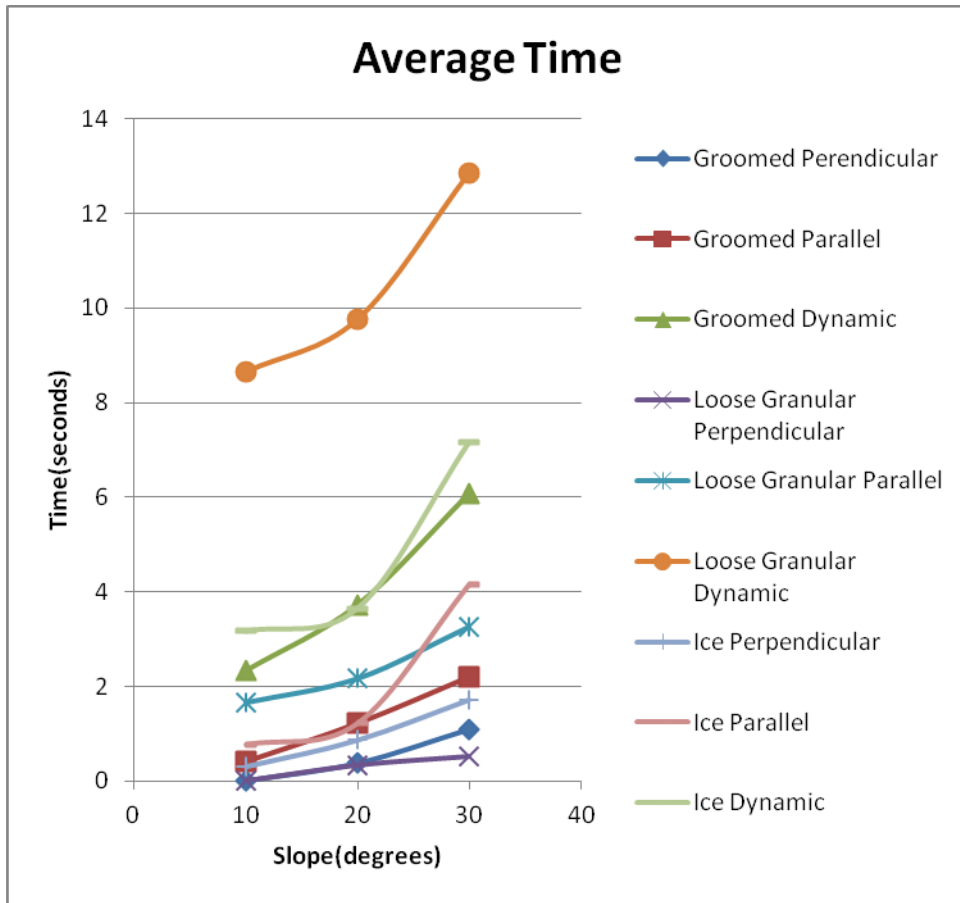


Figure 4.5: Graphical analysis of time to stop in seconds

4.3 Customer Reviews

Once the safety brake was assembled it was ready to be tested on an actual ski slope. The brake was taken to the Wachusett Ski Resort and brought to the ski patrol building to interview some of the ski patrolmen on duty. Mike Halloran is the director of the ski patrol. He examined the safety brake fully installed onto the snowboard. He was impressed with its operation and said runaway boards usually involve novice riders. Here you can see Mike checking out the prototype.



Figure 4.6: Mike Halloran visually inspecting our brake.



Figure 4.7: Mike Halloran testing the function of the driving mechanism

Mike suggested to bring the safety brake to the rental building where Mike Aiesi, the ski rental manager, got a firsthand look at the brake. He thought the safety brake was a great idea. He mentioned how the mountain doesn't attach leashes on rental boards anymore because they come back missing. Renters would not use them and they usually get taken or ripped off of the binding. He liked the fact that the footplate doesn't require any extra action from the rider. Mike was also impressed by the simplicity of the driving mechanism.



Figure 4.8: Mike Aiesi examining the brake end effector designed for deep powder conditions.

The next employees to inspect the safety brake were Mike Martin, who is the snowboard rental manager, and Nick McAllister, a snowboard rental employee. They were both impressed with the design and they are both snowboarders themselves. They mentioned that it seemed bulky and were concerned about the added weight. Nick had a thought that the brake would be helpful when standing up and trying to strap in to keep the board from sliding. He was quoted calling the design “fantastic”.



Figure 4.9: Mike Martin, the snowboard rental manager, trying the brake system.



Figure 4.10: Nick McAllister testing the function of the driving mechanism to retract the brake.

The last employee to inspect the safety brake was Heidi Dow Besse, the head of the rental department. She was extremely impressed and very eager to see the functionality of the safety brake and the mechanics of the system. She expressed great interest in the brake because none of their rental boards have leashes attached to them and they often get away from beginner riders. She thought not only would it be good for the rental market, but also for beginners and parents concerned about safety. Her only concern was the overall height of the brake system. All of their rental boards use a binding with a very low profile allowing boards to be stacked closely on top of one another. The current brake would transfer flawlessly to their rental boards, however it would interfere with their racking system.



Figure 4.11: Heidi Dow Besse evaluating our brake system.



Figure 4.12: This picture shows the low profile rental board in the foreground with the safety board equipped with traditional high-back bindings in the background.

5.0 CONCLUSION

5.1 Customer Reviews

The project results show that the safety brake was capable of stopping the snowboard if it had become detached from the owner. Not only did the brake stop the board but it did so in a timely manner while keeping the velocity of the snowboard at a minimal. The results reflect the effectiveness and practicality of installing safety brakes on snowboards.

Even though the safety brake had sparked some interest from a local rental shop it still brought up the point that the design is slightly too large. With more time on this project, the safety brake would get a new look with smaller parts and a more streamlined design. After seeing the stress analysis of the brake end it became clear the piston inside of the braking mechanism did not have to be as thick as it was. This is where most of the bulk of the brake nest originates from. Every other aspect of the brake nest would become smaller and low profile with the reduction in the diameter of the piston. This was a concern towards the end of the design phase of the project and it resurfaced again once the prototype was shown to potential consumers.

Another flaw in the presentation of the project is a full section of results. The results for the brake look promising and effective but there is no control to compare to. One would assume that the average velocity of runaway snowboard would be more than what the results of the safety brake show but there is no hard evidence to back that up. The project had a very small window of opportunity for the testing phase and the time for a control experiment was not able to fit.

5.2 Entrepreneurship of Product

There are many factors involved in the process of bringing a new product to market. First off, the product which you have designed and built could have very well been thought up by another inventor and may already have a patent design. Even further than that, a product very similar to yours could already be in the market. To avoid this scenario, a patent for the design must be submitted to prevent others from stealing your idea. This is known as patent infringement, when others try to profit off of your design. When creating this product you will need to be on both the offensive and the defensive when it comes to patents.

If you currently hold the patent for the design then you would be on the offensive towards anyone who was marketing a design very similar to yours. If someone else holds the patent then you would be on the defensive because they would be making sure that your design was not similar to theirs. To avoid situations like these, you must execute a thorough patent search prior to further pursuing your idea. This will allow you to see if your product is infringing on any patents already filed.

5.2.1 Market

Just because you have come up with a brilliant idea that creates a solution to a pre-existing problem does not necessarily mean that the product should be marketed. When considering bringing a product to market there are many factors which must first be evaluated before further continuing in the process. The three big questions to ask are:

- 1) How big is the market for this product?
- 2) How much will people pay for the product?
- 3) How many should be built?

These three questions, with number one being the most important to ask, will make it easy to see if this product is something that will be profitable or if it will be a failure in the market. Next, there are two factors to consider. First, will you the inventor be bringing this product to market yourself or would it be a better idea to sell your patent to a pre-existing company for them to manufacture your idea. Either possibility will be profitable (Leardon Solutions, 2009).

In the case of our snowboard braking mechanism, it would be very valuable to talk to leaders in snowboarding manufacturing market, such as Burton, Ride or K2 to gain an idea of the type of market for a product as ours. A conversation could take place where the idea would be presented and feedback on the success of the product in the market could be given. In order to ensure the safety of your product, it would be important to have both parties sign a non-disclosure agreement to protect the design concept from being stolen from the companies evaluating it (Schaufeld, 2011)

When looking at the marketing of a product, it is wise to begin to look at both a marketing plan and a business plan for the product. This will vary if the product is to be manufactured by the inventors or the rights sold to a private organization for them to manufacture. When choosing a market plan for the product you must also look for future needs and future advancements to the design. You may also want to look at things that might go wrong with your product and keep that in mind when designing the final product. If you plan for such instances then in the future, you will be able to add those attachments or fix those small pieces to your part instead of having to completely redesign your product. You should always plan your market strategy for the future when designing the product. By planning for your original design to be compatible for the future you can increase the value of the investment. This means that in

several years a whole new design will not be needed to meet the markets needs, but instead you can add slight modifications to the product because you designed it to receive these modifications in the past (Schaufeld, 2011).

5.2.2 Production

The production of the product is one aspect which will take the most time planning and manufacturing. There are many different factors that must be considered when producing something on a large scale opposed to producing single items at a time. You must consider what material the product will be made of, the type of process it will undergo to be formed and a facility and equipment to perform these processes. This is because the production of a design often carries large upfront costs which will take some time to pay back before making a profit. These procedures need to be well developed before any investment is placed in the production of the idea (Leardon Solutions, 2009).

We also needed to select the material our product would be made of. This process can be seen in the above section of material selection where we chose to use delrin as the material for our product. Once our material is selected, a method for processing the material needs to be determined. In the case of our snowboard brakes, we looked into existing methods used in forming and shaping high end plastics. When selecting our final method, we looked at not only fast processes but lean manufacturing to prevent waste and increase profit. The process we chose was injection molding. This would allow for our material to be ordered in pellets, melted down, injected into the mold, and then formed into the desired part. In order to complete this process molds must first be created to give the melted material its shape. Through market research some of the most common materials used for the molds or dies are hardened steel or aluminum. Both

of these materials can be machined from CNC machines and will be capable of creating tens of thousands of products in their lifetime.

5.2.3 Market Saturation

Market saturation can be defined as “When the amount of product provided in a market has been maximized in the current state of the marketplace. At the point of saturation, further growth can only be achieved through product improvements, market share gains or a rise in overall consumer demand” (Investopedia, 2011 This means that at some point the product will meet its maximum selling point and other competing products will begin to address problems which the original device does not. This is a result of the advancements in the market and can easily be seen in figure 5.1: below.

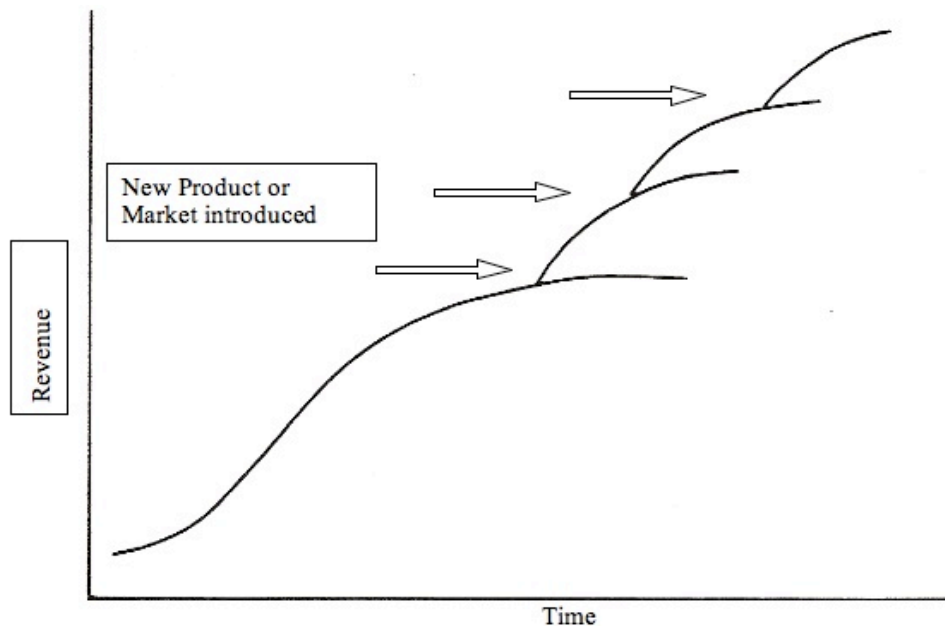


Figure 5.1: Market Saturation (Palizza, 2010)

This figure shows the market saturation of a product. What the chart does not show is the initial revenue loss from equipment and materials that will occur in order to start up the

manufacturing process. These are known as start up costs. Over a short period of time the product will begin to raise revenue. Once the product reaches a certain point it will begin to plateau, meaning that it will no longer be increasing profits. As the chart shows, in the early stages of the first product, you should begin to plan ahead for the future and start designing renovations for the product which will meet the futures needs as well as new applications and new markets for the product. This means that when the original design begins to plateau profit wise, the newly designed product will meet the newer market needs and take over the market from the old design. This marketing concept can work over a long period of time. It requires that you always look ahead of the current product and design for future innovations (Schaufeld, 2011).

By looking to the future for the market, you will be able to develop new products from the existing concept. This original design can be a “platform design” (Schaufeld, 2011) for future work. In our case this snowboard braking mechanism with minor alterations can be opened up to bigger markets such as snow sleds and snow mobiles. Because the product already has the ground work laid or a platform built, it makes the product that much easier to move to different markets. By studying the market saturation of other products, you can begin to develop a time line when you product will reach its maximum revenue level.

5.2.4 Risk

When creating a new product there is always risk involved in the markets which you put your product into. This can include the risk of competing against other products in the market as well as the risk of the product failing to perform in the field. In our case one of the biggest risks we envisioned was damage to other riders or skiers if the brake failed to perform properly.

If a rider is injured when your product fails to perform properly, then the manufacturer is at fault and a lawsuit against the manufacturer could be possible (Schaufeld, 2011). Knowing this, we investigated how snow resorts are so successful in protecting themselves and reducing the responsibility of liability on their part. We decided to look at what preventive measures they take to mitigate their liability of injury to riders. When looking at what the market of this product would be, we decided it would be most appealing to beginner snowboarders and would be popular in the rental business of Ski Mountains. Once our market was selected we looked at the precautions which the rental shops took to prevent liability. In the case of Mount Wachusett and most mountain resorts they have their rental riders sign a rental agreement and release of liability before the use of their equipment. The reverse side of the rental agreement from Mount Wachusett can be seen below in Figure 5.2:

RENTAL & LIABILITY RELEASE AGREEMENT

PLEASE READ CAREFULLY BEFORE SIGNING

1. I accept for use as is the equipment listed on this form, and accept full responsibility for the care of the equipment while it is in my possession.
2. I will be responsible for the replacement at full retail value of any equipment rented under this form, but not returned to the shop.
3. I have received instruction on the use of my equipment and fully understand its use and function.
4. I have made no misrepresentations to Wachusett Mountain Associates concerning my height, weight, age or skier type.
5. I verify that the visual indicator setting recorded on this form agree with the numbers appearing in the visual indicator windows of the equipment listed on this form.
6. I agree to hold harmless and indemnify Wachusett Mountain Associates and its owners, agents and employees, as well as the equipment manufacturers and distributors for any loss or damage, including any that results from claims for personal injury, death or property damage related to the use of this equipment.
7. I understand that there are inherent and other risks involved in the sport of snow skiing or Boarding, for which this equipment is to be used, that injuries are a common and ordinary occurrence to the sport, and I freely and voluntarily assume those risks.
8. I understand that a ski-binding-boot system will not release at all times or under all circumstances where release may prevent injury or death, nor is it possible to predict every situation in which it will release, and it is, therefore, no guarantee of my safety. In snowboarding, cross-country skiing and snow blade use, the binding system will not ordinarily release as a result of forces generated during ordinary operation.
9. I hereby release from any legal liability Wachusett Mountain Associates and its owners, agents and employees, as well as the manufacturers and distributors of this equipment from any and all liability for damage and injury or death to myself or to any person or property resulting from the selection, installation, maintenance, adjustment or use of this equipment and for any claim based upon negligence, breach of warranty, contract or other legal theory, accepting myself the full responsibility for any all such damage, injury or death which may result.
10. This agreement is governed by the applicable law of this state or province. If any part of this agreement is determined to be unenforceable all other parts shall be given full force and affect.
11. To RELEASE FROM LIABILITY AND HOLD HARMLESS Wachusett Mountain Associates and any other participating sponsors, their officers, agents, employees, directors, shareholders, affiliated entities, subsidiaries, all insurers, and all sponsors for any and all loss, damage, injury or expense that Participant may suffer, or that participants next of kin may suffer, as a result of Participant's practicing for and/or participation in the scheduled event, due to any cause whatsoever, including but not limited to negligence on the part of Wachusett Mountain Associates and any other participating sponsors, their officers, agents, employees, directors, shareholders, affiliated entities, subsidiaries, all insurers, any entity or person hired to perform any function.

Figure 5.2: Mount Wachusett Rental Liability Release Agreement (Wachusett Mountain, 2011)

Looking at sections 6 through 9 of the rental agreement highlighted in the red box above, it is clearly stated that the rider waives all of the liability from “Mount Wachusett Mountain Associates, its owners, agents and employees as well as the equipment manufacturers and distributors are not legally responsible or liable for and injury from the equipment”. By having the rider sign this agreement all personnel mentioned before are not responsible in any way. By pursuing the market of mountain resort rental equipment, our product would not only be targeted to new riders as we had planned, but it would not hold the manufactures and distributes liable if failure of the device occurred. This is an important factor to consider because a legal lawsuit would be extremely detrimental to the profit margin of a new company. However this risk can be simply avoided with a liability release waiver such as the one above.

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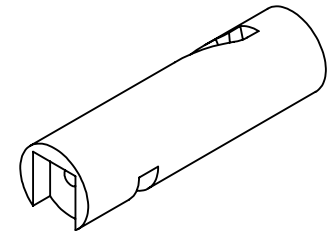
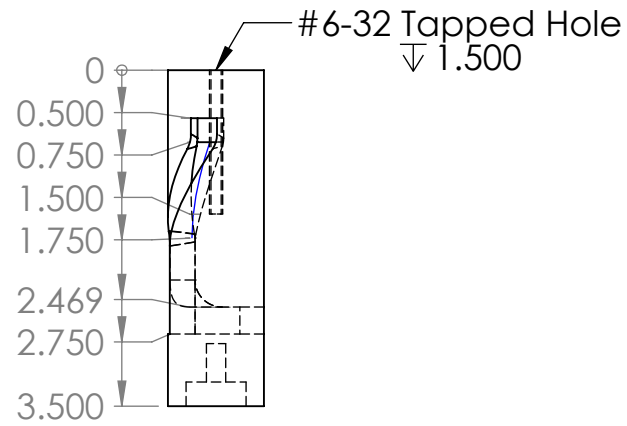
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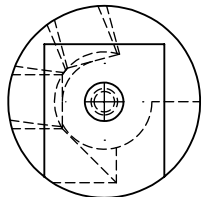
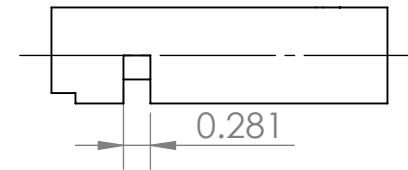
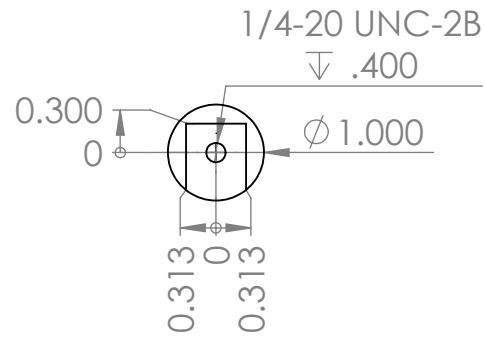
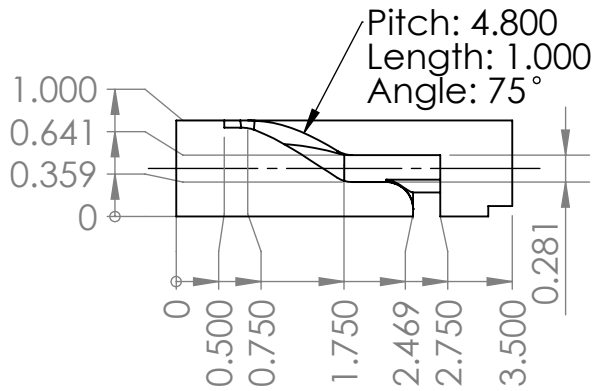
Appendix A – Orthographic Drawings

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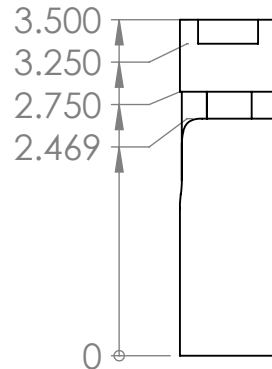
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DETAILED FRONT VIEW



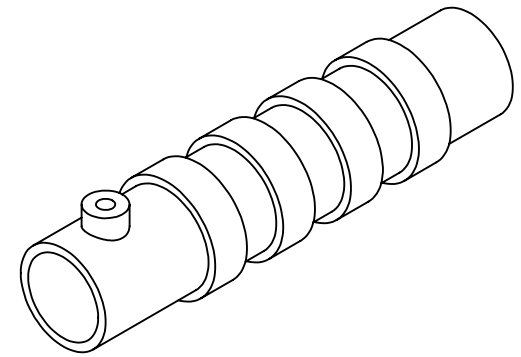
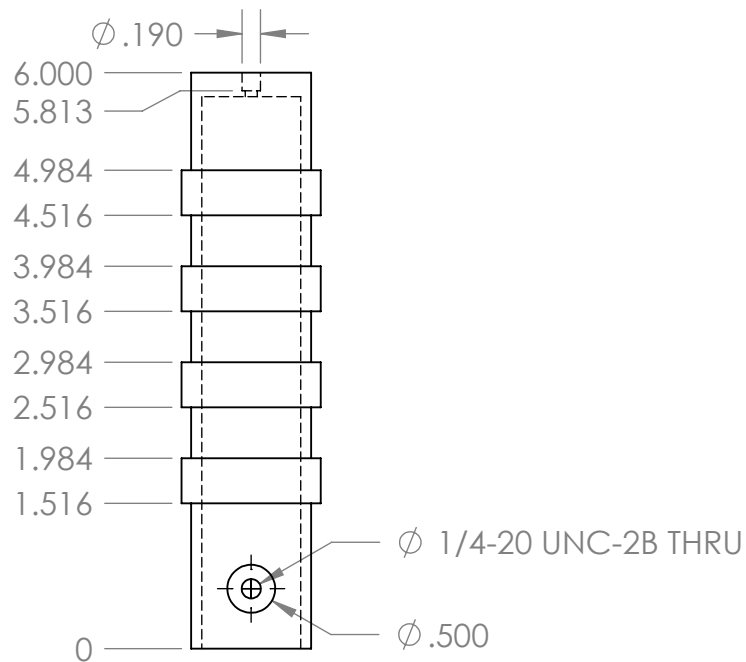
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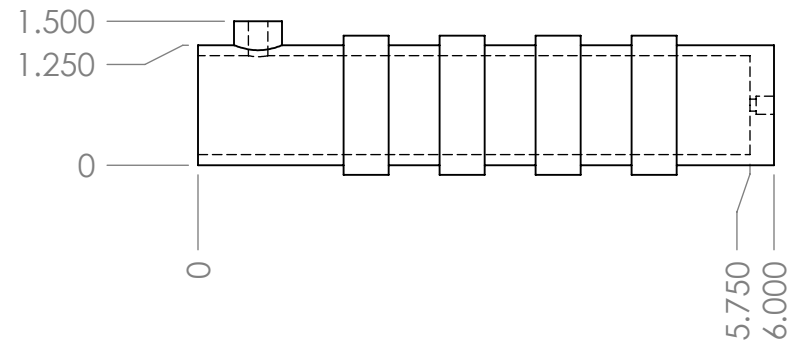
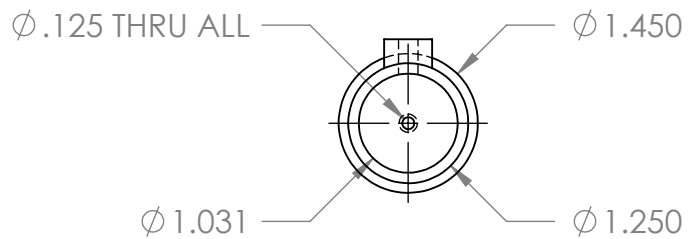
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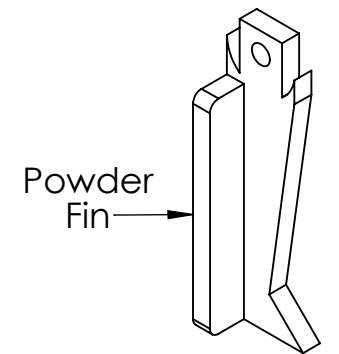
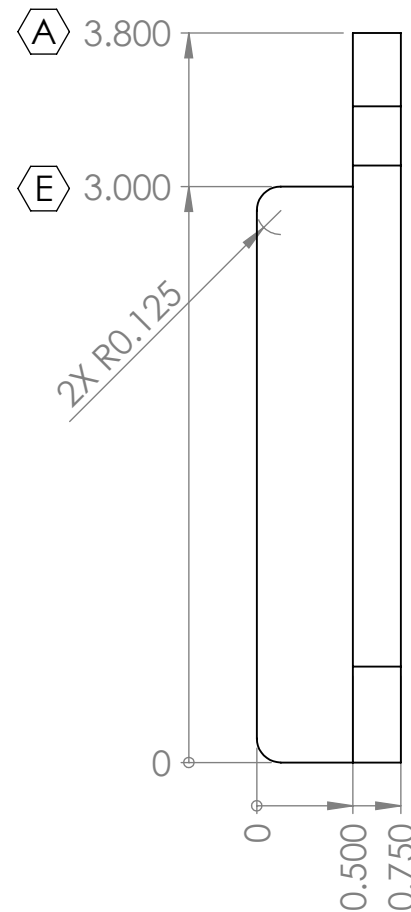
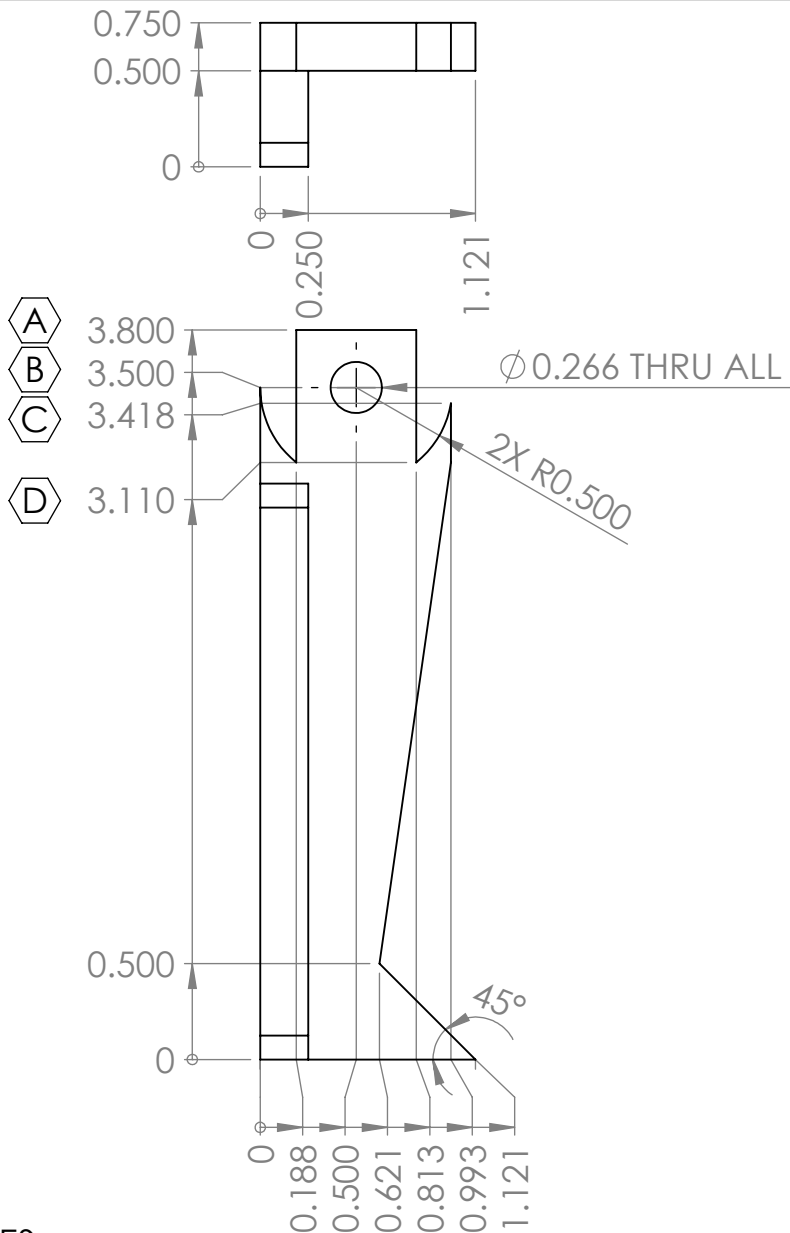
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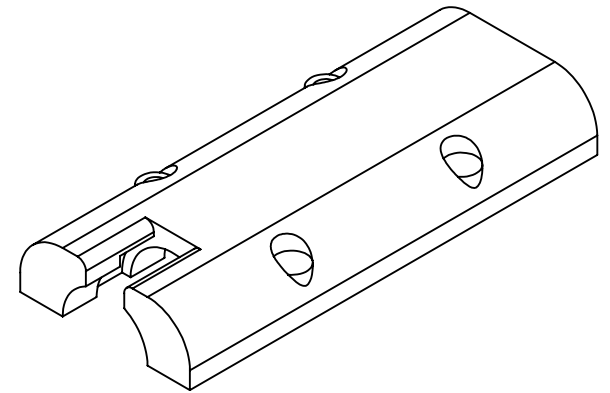
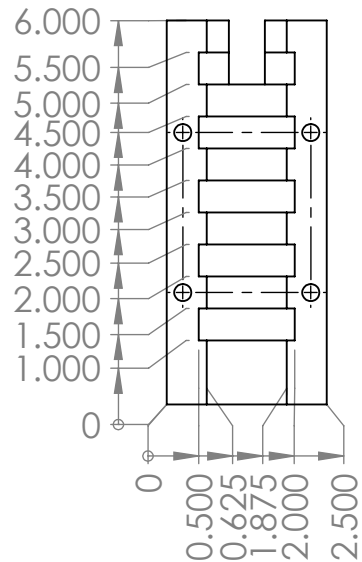
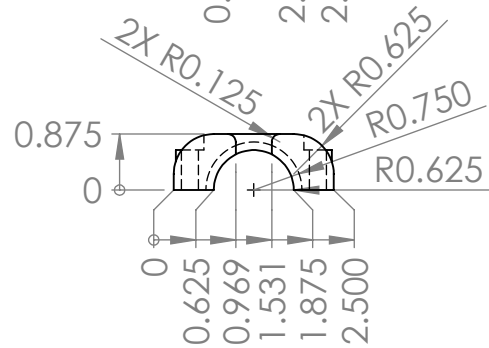
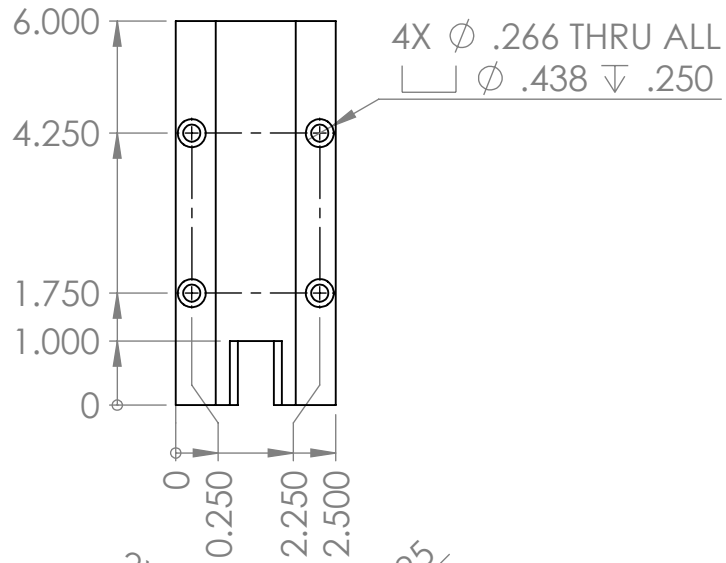
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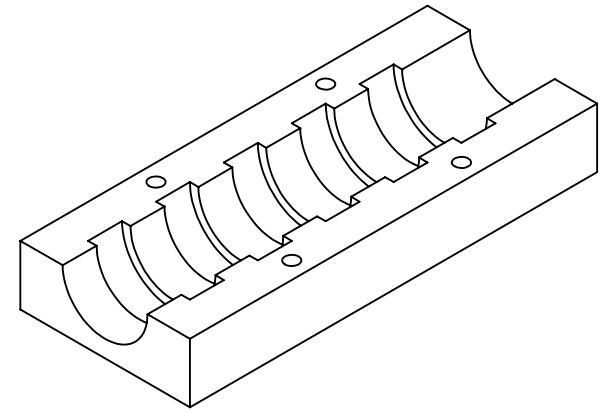
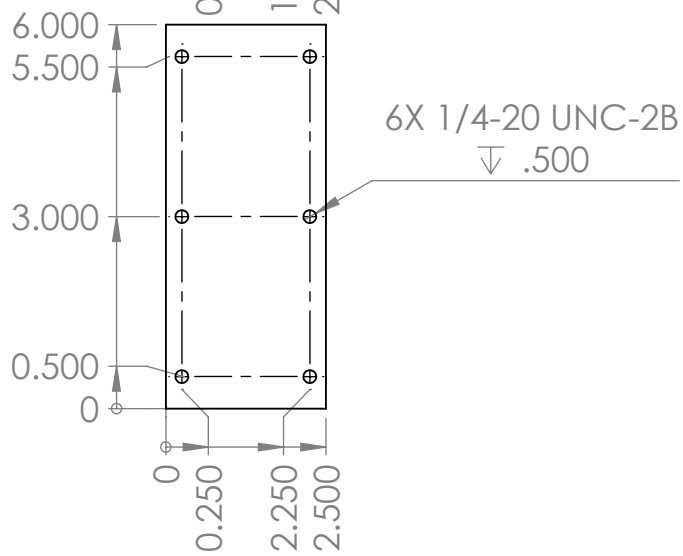
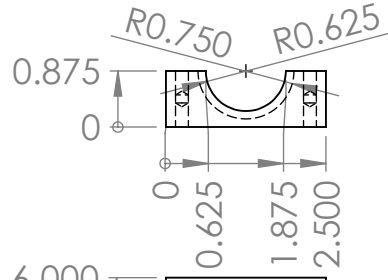
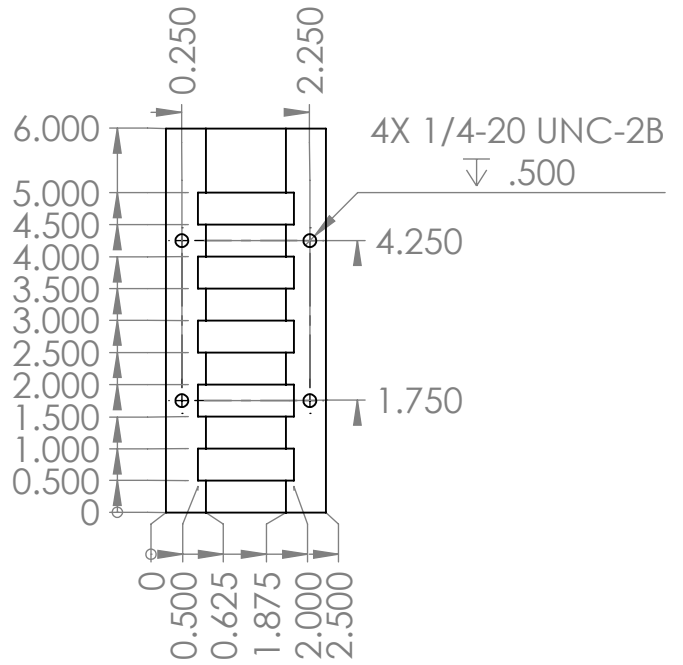
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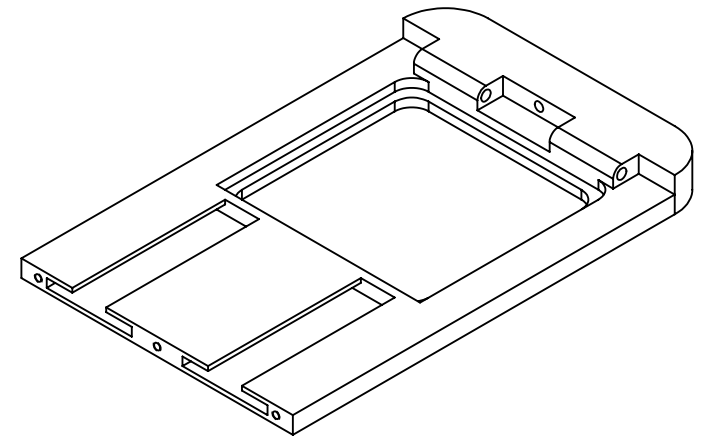
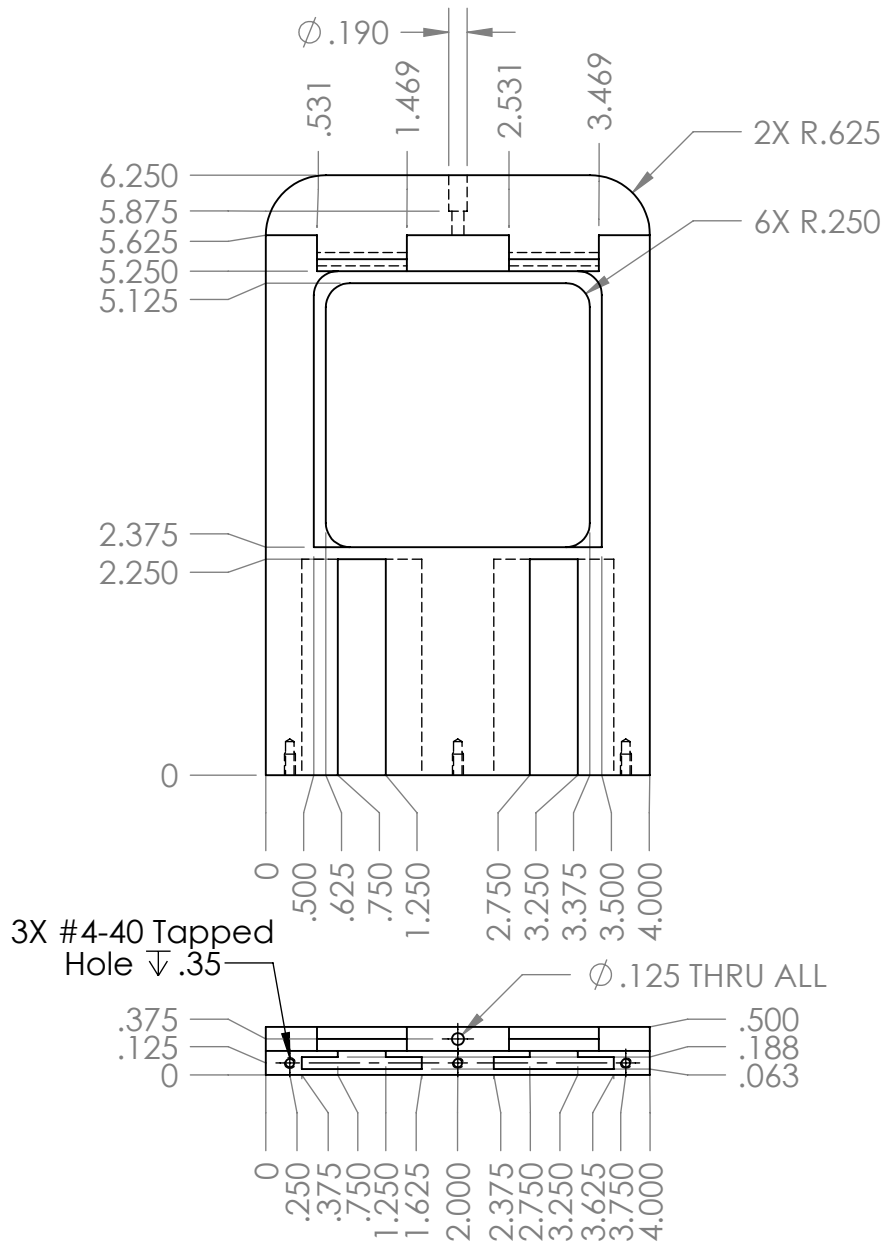
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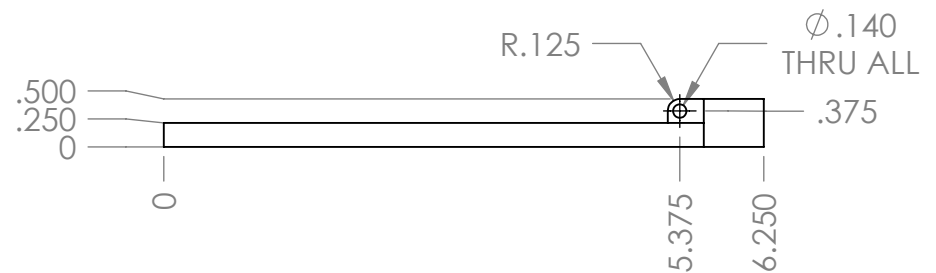
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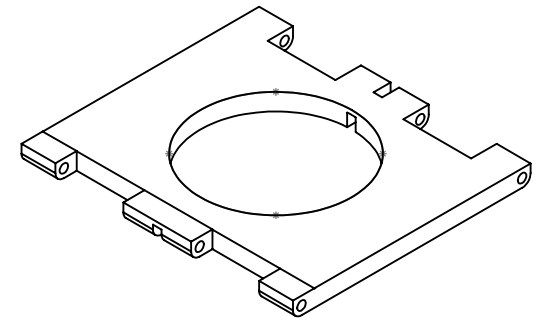
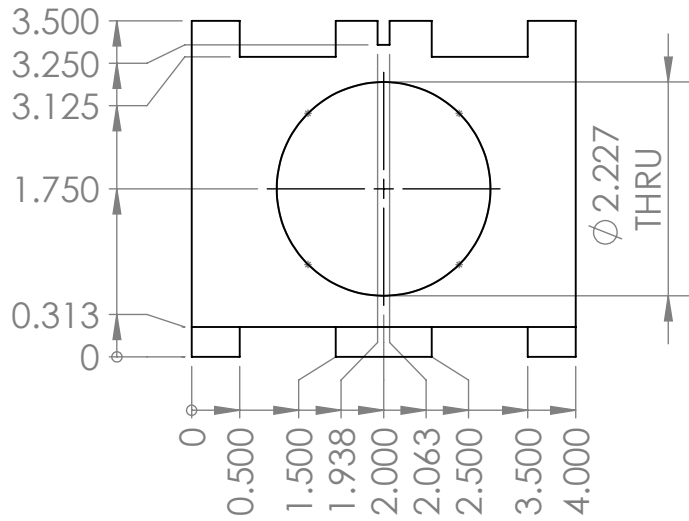
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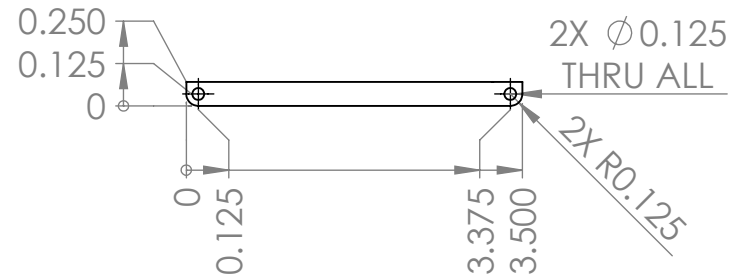
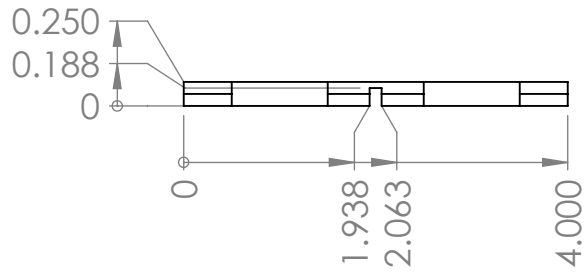
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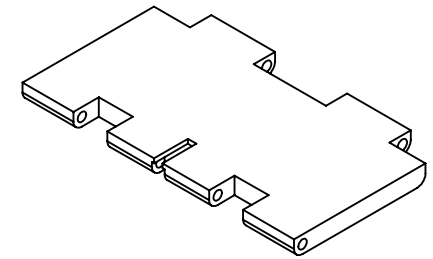
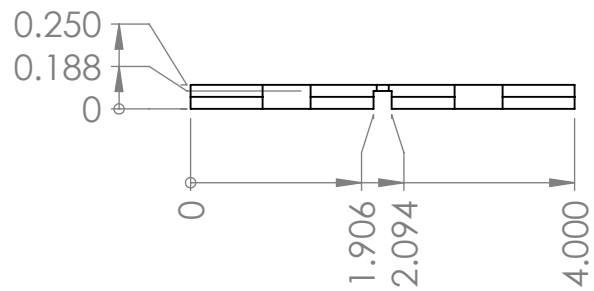
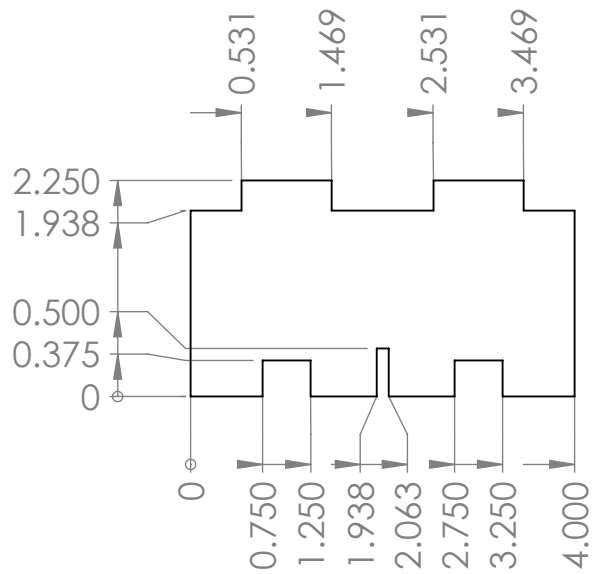
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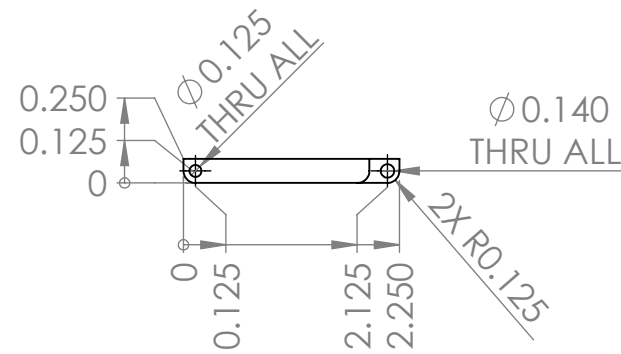
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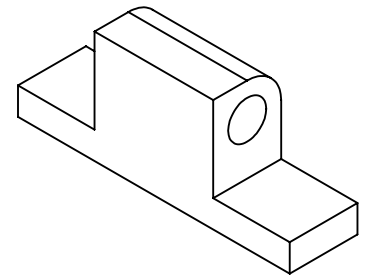
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 Angles ±2

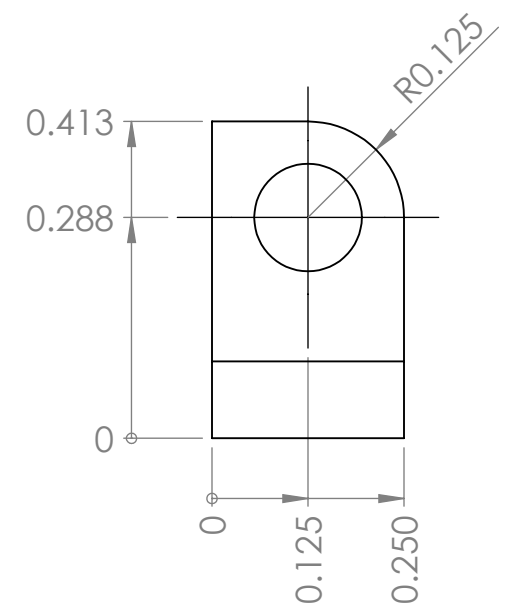
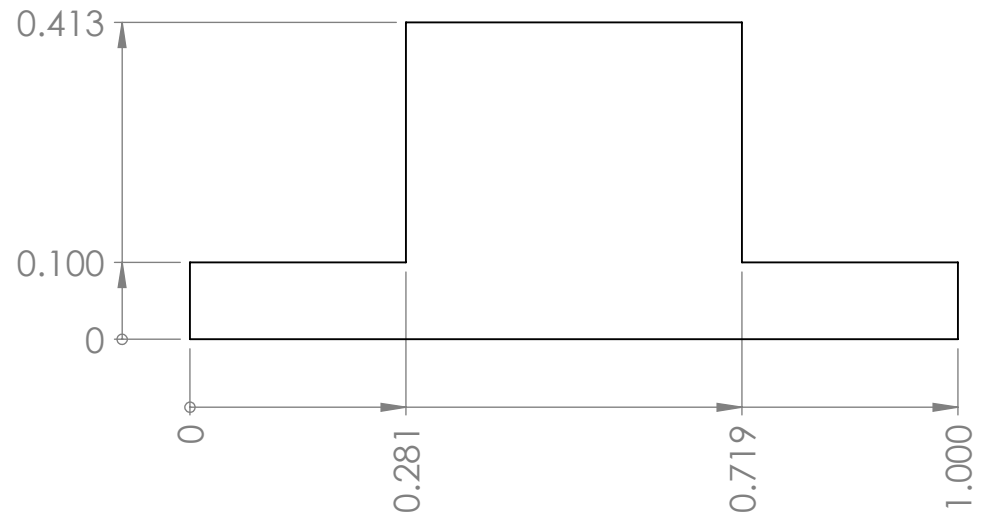
Coupler Link

Drawn by: Steven Baldwin

Scale: 1:2 Size: A Date: 4/28/11



SCALE: 2:1



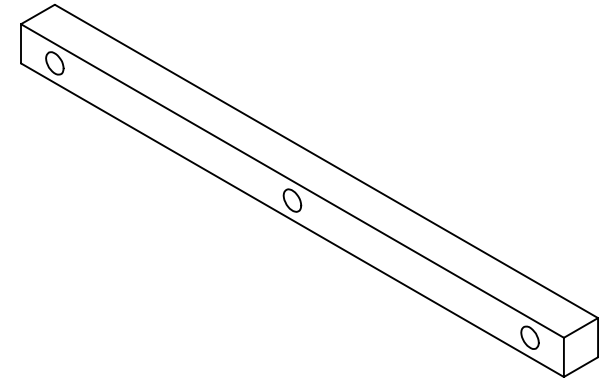
All dimensions are inches and degrees

Follower Link

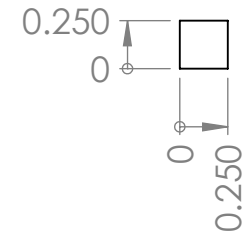
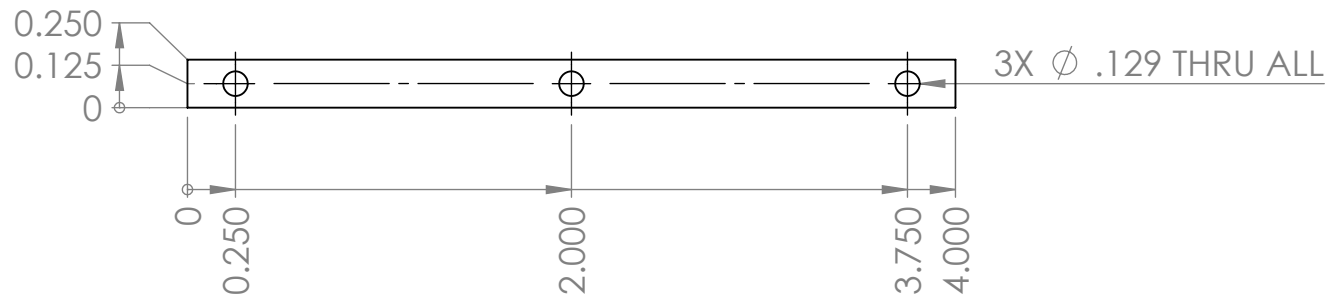
Default Tolerances:
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 .12 ±.020
 .123 ±.005
 Angles ±2

Drawn by: Steven Baldwin

Scale: 4:1 Size: A Date: 4/28/11



SCALE: 1:1



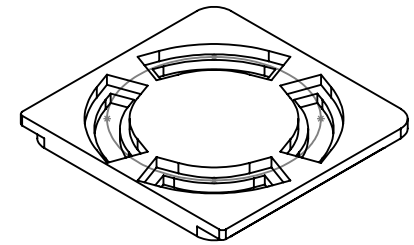
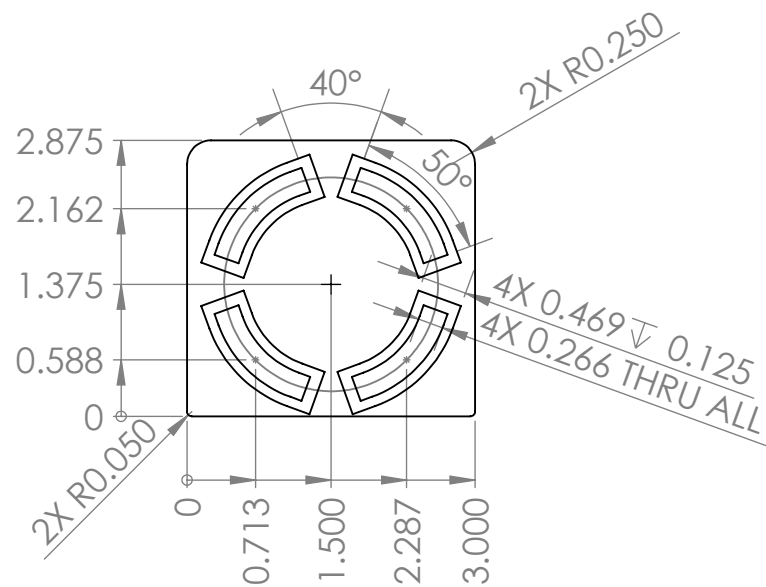
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Default Tolerances:
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 Angles ±2

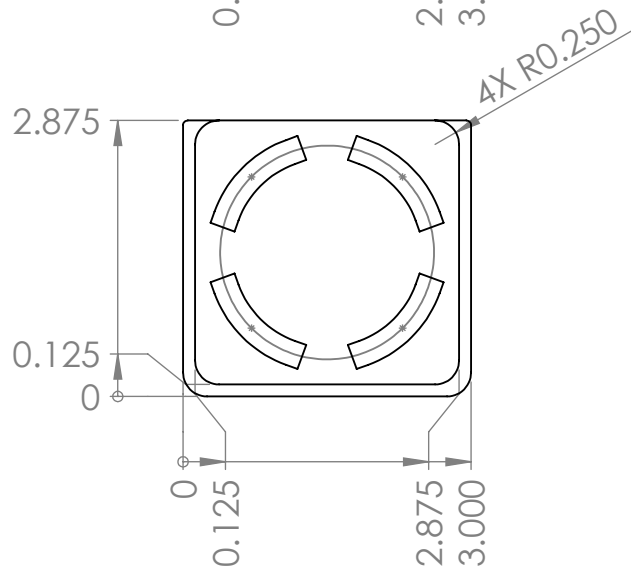
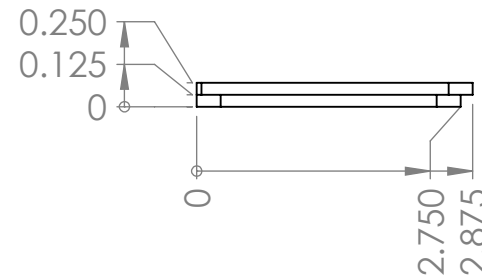
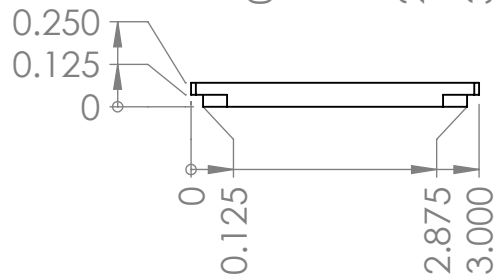
Track Cap

Drawn by: Steven Baldwin

Scale: 1:1 Size: A Date: 4/28/11



SCALE: 1:2



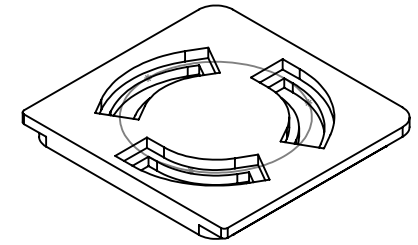
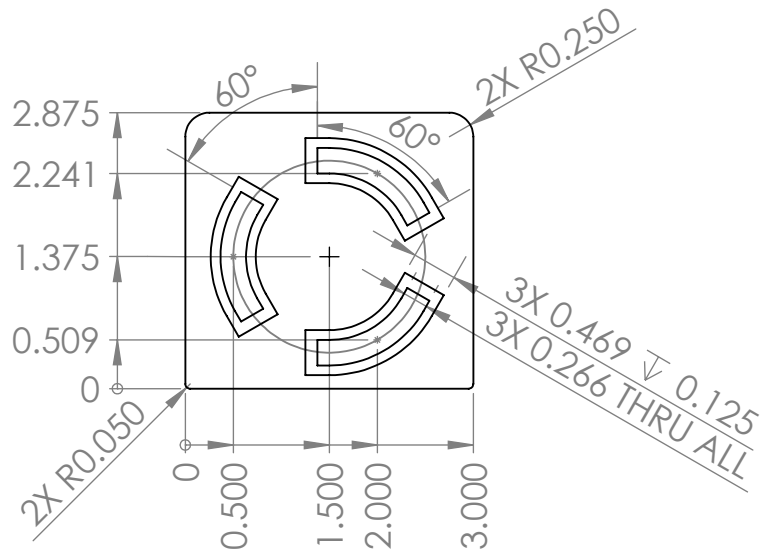
All dimensions are inches and degrees

Default Tolerances:
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 .12 ±.020
 .123 ±.005
 Angles ±2

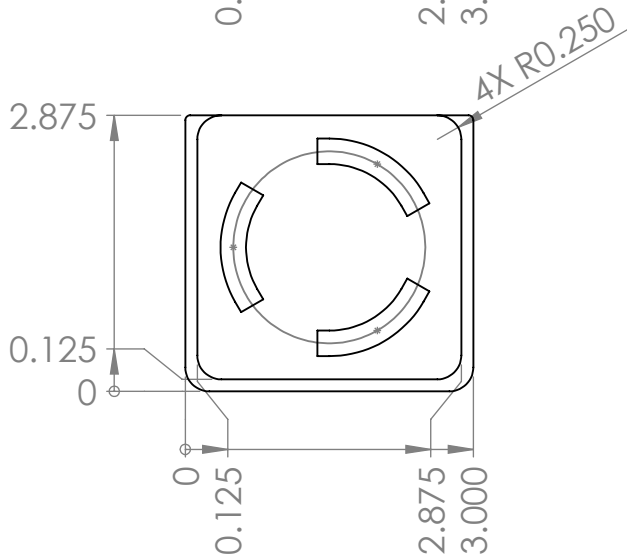
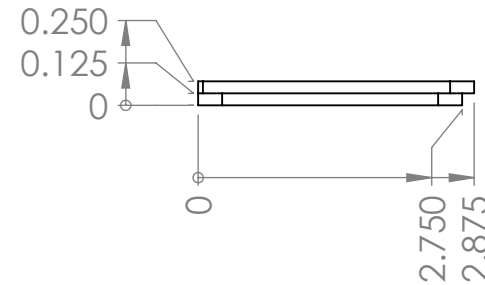
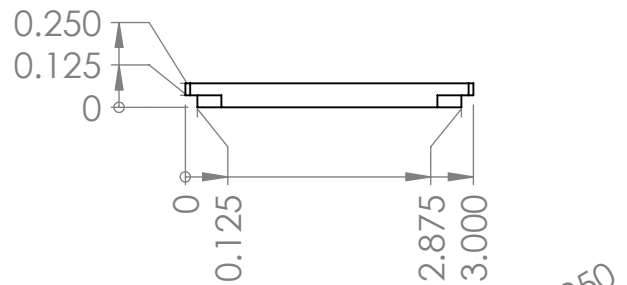
Four Bolt Pattern Insert

Drawn by: Steven Baldwin

Scale: 1:2 Size: A Date: 4/28/11



SCALE: 1:2



All dimensions are inches and degrees

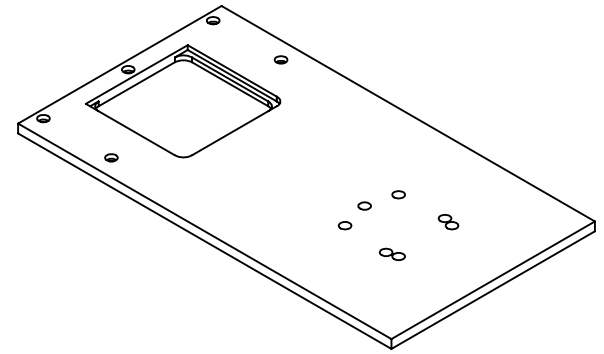
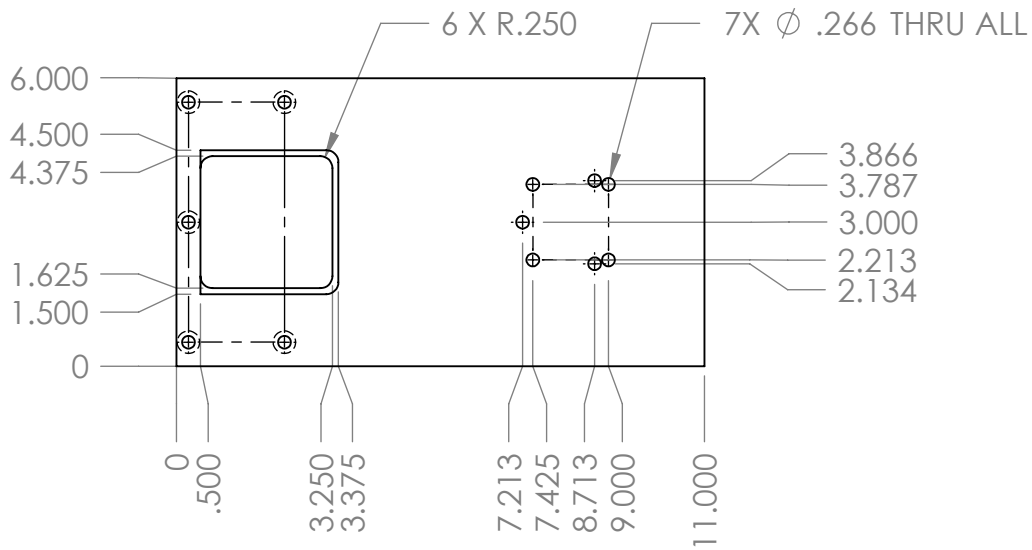
Burton Bolt Pattern Insert

Default Tolerances:

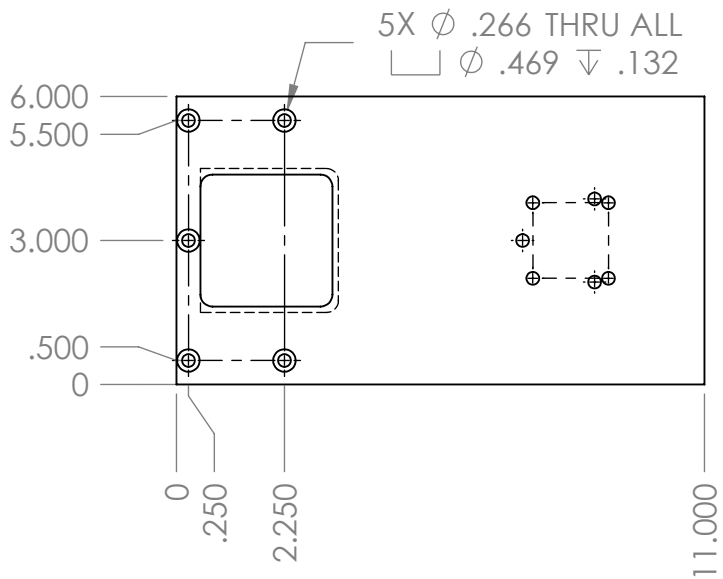
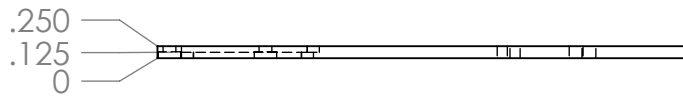
.1 ±.050
.12 ±.020
.123 ±.005
Angles ±2

Drawn by: Steven Baldwin

Scale: 1:2 Size: A Date: 4/28/11



SCALE: 1:4



All dimensions are inches and degrees

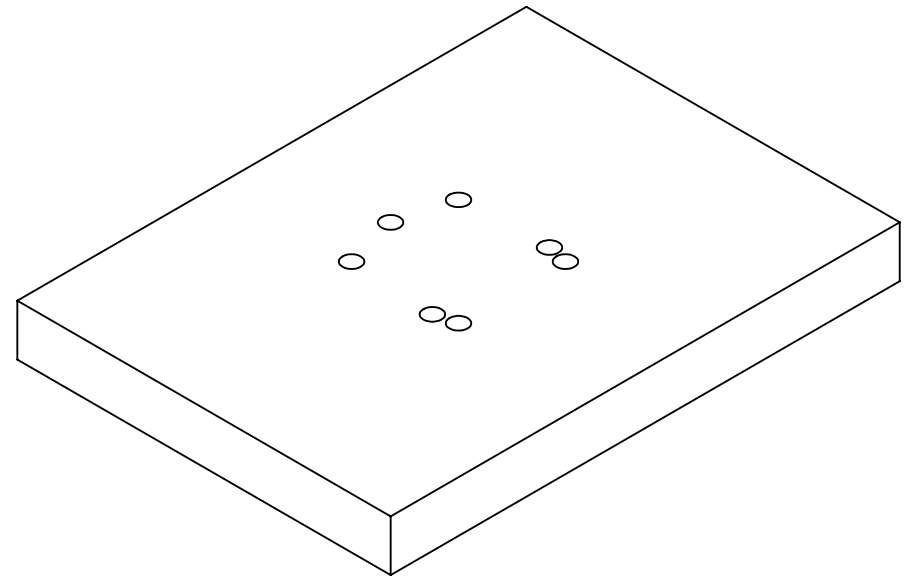
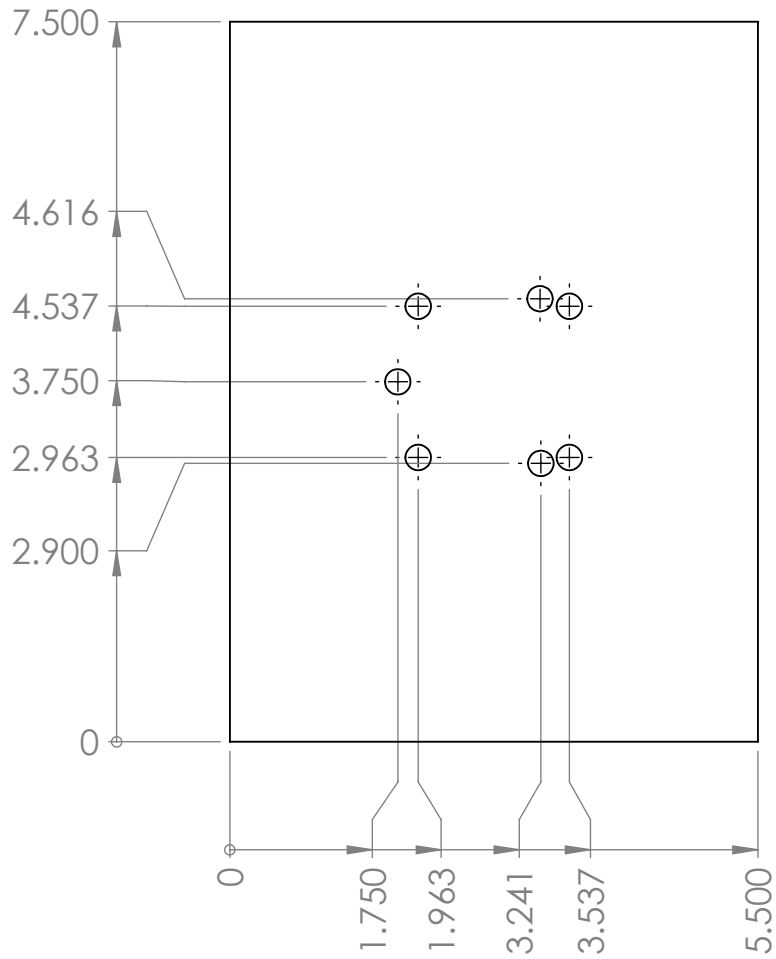
Base Plate

Default Tolerances:

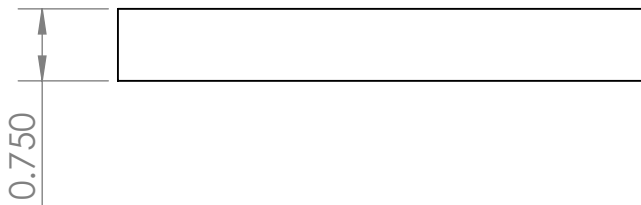
.1 ±.050
.12 ±.020
.123 ±.005
Angles ±2

Drawn by: Steven Baldwin

Scale: 1:4 Size: A Date: 4/28/11



SCALE: 1:2



All dimensions are inches and degrees

Default Tolerances:

.1	±.050
.12	±.020
.123	±.005
Angles	±2

Riser

Drawn by: Steven Baldwin

Scale: 1:2

Size: A

Date: 4/28/11

Appendix B – Material Properties from CES EduPack 2010

Polyoxymethylene (Acetal, POM)

Description

The material

POM was first marketed by DuPont in 1959 as Delrin. It is similar to nylon but is stiffer, and has better fatigue and water resistance - nylons, however, have better impact and abrasion resistance. It is rarely used without modifications: most often filled with glass fiber, flame retardant additives or blended with PTFE or PU. The last, POM/PU blend, has good toughness. POM is used where requirements for good moldability, fatigue resistance and stiffness justify its high price relative to mass polymers, like polyethylene, which are polymerized from cheaper raw materials using lower energy input.

Composition (summary)

$(CH_2-O)_n$

Image



General properties

Density	86.8	-	89.3	lb/ft ³
Price	1.51	-	1.72	USD/lb

Mechanical properties

Young's modulus	0.363	-	0.725	10 ⁶ psi
Shear modulus	0.122	-	0.33	10 ⁶ psi
Bulk modulus	0.638	-	0.667	10 ⁶ psi
Poisson's ratio	0.33	-	0.407	
Yield strength (elastic limit)	7.05	-	10.5	ksi
Tensile strength	8.7	-	13	ksi
Compressive strength	10.9	-	18	ksi
Elongation	10	-	75	% strain
Hardness - Vickers	14.6	-	24.8	HV
Fatigue strength at 10 ⁷ cycles	* 3.18	-	4.97	ksi

Fracture toughness	1.55	-	3.82	ksi.in ^{0.5}
Mechanical loss coefficient (tan delta)	* 0.00638	-	0.017	
Thermal properties				
Melting point	320	-	363	°F
Glass temperature	-0.67	-	17.3	°F
Maximum service temperature	170	-	206	°F
Minimum service temperature	-190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.128	-	0.203	BTU.ft/h.ft ² .F
Specific heat capacity	0.326	-	0.342	BTU/lb.°F
Thermal expansion coefficient	42.1	-	112	µstrain/°F
Electrical properties				
Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e20	-	3e21	µohm.cm
Dielectric constant (relative permittivity)	3.6	-	4	
Dissipation factor (dielectric loss tangent)	9.5e-4	-	0.005	
Dielectric strength (dielectric breakdown)	384	-	521	V/mil
Optical properties				
Transparency	Opaque			
Processability				
Castability	1	-	2	
Moldability	4	-	5	
Machinability	3	-	4	
Weldability	4	-	5	
Eco properties				
Embodied energy, primary production	* 1.08e4	-	1.19e4	kcal/lb
CO2 footprint, primary production	* 3.8	-	4.2	lb/lb
Recycle	True			
Recycle mark				



Supporting information

Design guidelines

POM is easy to mold by blow molding, injection molding or sheet molding, but shrinkage on cooling limits the minimum recommended wall thickness for injection molding to 0.1mm. As manufactured, POM is gray but it can be colored. It can be extruded to produce shapes of constant cross section such as fibers and pipes. The high crystallinity leads to increased shrinkage upon cooling. It must be processed in the temperature range 190-230 C and may require drying before forming because it is hygroscopic. Joining can be done using ultrasonic welding, but POM's low coefficient of friction requires welding methods that use high energy and long ultrasonic exposure; adhesive bonding is an alternative. POM is a good electrical insulator. Without coPolymerization or the addition of blocking groups, POM degrades easily.

Technical notes

The repeating unit of POM is - (CH₂O)_n and the resulting molecule is linear and highly crystalline. Consequently, POM is easily moldable, has good fatigue resistance and stiffness, and is water resistant. In its pure form, POM degrades easily by dePolymerization from the ends of the polymer chain by a process called 'unzipping'. The addition of 'blocking groups' at the ends of the polymer chains or coPolymerization with cyclic ethers such as ethylene oxide prevents unzipping and hence degradation.

Typical uses

POM is more expensive than commodity polymers such as PE, so is limited to high performance applications in which its natural lubricity is exploited. It is found in fuel-system; seat-belt components; steering columns; window-support brackets and handles; shower heads, ballcocks, faucet cartridges, and various fittings; quality toys; garden sprayers; stereo cassette parts; butane lighter bodies; zippers; telephone components; couplings; pump impellers; conveyor plates; gears; sprockets; springs; gears; cams; bushings; clips; lugs; door handles; window cranks; housings; seat-belt components; watch gears; conveyor links; aerosols; mechanical pen and pencil parts; milk pumps; coffee spigots; filter housings; food conveyors; cams; gears; TV tuner arms; automotive underhood components.

Tradenames

Acetron, Delrin, Fulton, Latan, Lupital, Plaslube, Tenac, Thermocomp, Ultraform

Links

Reference

ProcessUniverse

Producers

No warranty is given for the accuracy of this data. Values marked * are estimates.

Polyamides (Nylons, PA)

Description

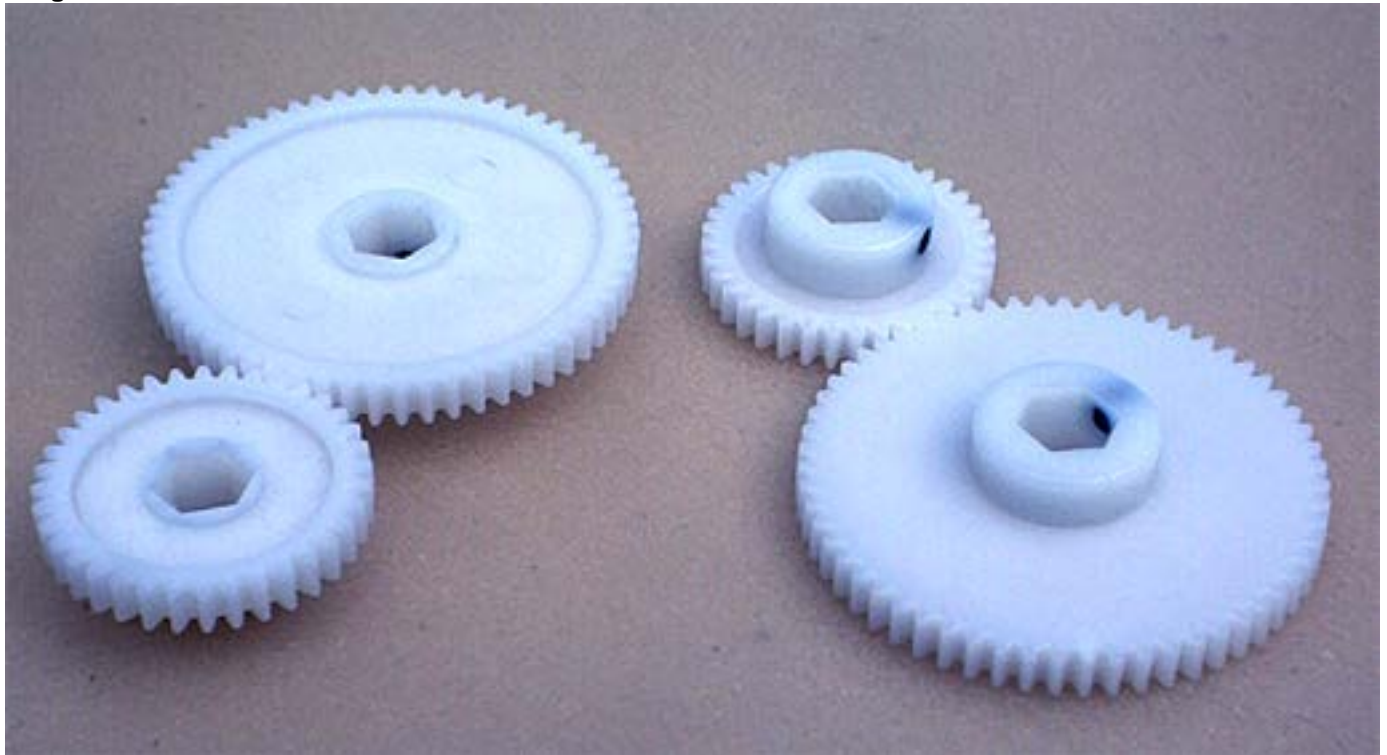
The material

Back in 1945, the war in Europe just ended, the two most prized luxuries were cigarettes and nylons. Nylon (PA) can be drawn to fibers as fine as silk, and was widely used as a substitute for it. Today, newer fibers have eroded its dominance in garment design, but nylon-fiber ropes, and nylon as reinforcement for rubber (in car tires) and other polymers (PTFE, for roofs) remains important. It is used in product design for tough casings, frames and handles, and - reinforced with glass - as bearings gears and other load-bearing parts. There are many grades (Nylon 6, Nylon 66, Nylon 11....) each with slightly different properties.

Composition (summary)

$(\text{NH}(\text{CH}_2)_5\text{CO})_n$

Image



Caption

Polyamides are tough, wear well and have low coefficient of friction.

General properties

Density	69.9	-	71.2	lb/ft ³
Price	* 1.49	-	1.64	USD/lb

Mechanical properties

Young's modulus	0.38	-	0.464	10 ⁶ psi
Shear modulus	* 0.141	-	0.172	10 ⁶ psi
Bulk modulus	0.537	-	0.566	10 ⁶ psi
Poisson's ratio	0.34	-	0.36	
Yield strength (elastic limit)	7.25	-	13.7	ksi
Tensile strength	13.1	-	23.9	ksi
Compressive strength	7.98	-	15.1	ksi
Elongation	30	-	100	% strain

Hardness - Vickers	25.8	-	28.4	HV
Fatigue strength at 10 ⁷ cycles	* 5.22	-	9.57	ksi
Fracture toughness	* 2.02	-	5.11	ksi.in ^{0.5}
Mechanical loss coefficient (tan delta)	* 0.0125	-	0.0153	
Thermal properties				
Melting point	410	-	428	°F
Glass temperature	111	-	133	°F
Maximum service temperature	230	-	284	°F
Minimum service temperature	* -190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.135	-	0.146	BTU.ft/h.ft ² .F
Specific heat capacity	* 0.382	-	0.398	BTU/lb.°F
Thermal expansion coefficient	80	-	83	µstrain/°F
Electrical properties				
Electrical conductor or insulator?	Good insulator			
Electrical resistivity	* 1.5e19	-	1.4e20	µohm.cm
Dielectric constant (relative permittivity)	3.7	-	3.9	
Dissipation factor (dielectric loss tangent)	0.014	-	0.03	
Dielectric strength (dielectric breakdown)	384	-	417	V/mil
Optical properties				
Transparency	Translucent			
Refractive index	1.52	-	1.53	
Processability				
Castability	1	-	2	
Moldability	4	-	5	
Machinability	3	-	4	
Weldability	5	-		
Eco properties				
Embodied energy, primary production	1.31e4	-	1.46e4	kcal/lb
CO2 footprint, primary production	5.5	-	5.6	lb/lb
Recycle	True			
Recycle mark				



Supporting information

Design guidelines

Nylons are tough, strong and have a low coefficient of friction, with useful properties over a wide range of temperature (-80 to +120 C). They are easy to injection mold, machine and finish, can be thermally or ultrasonically bonded, or joined with epoxy, phenol-formaldehyde or polyester adhesives. Certain grades of nylon can be electroplated allowing metallization, and most accept print well. A blend of PPO/Nylon is used in fenders, exterior body parts. Nylon fibers are strong, tough, elastic and glossy, easily spun into yarns or blended with other materials. Nylons absorb up to 4% water; to prevent dimensional changes, they must be conditioned before molding, allowing them to establishing equilibrium with normal atmospheric humidity. Nylons have poor resistance to strong acids, oxidizing agents and solvents, particularly in transparent grades.

Technical notes

The density, stiffness, strength, ductility and toughness of Nylons all lie near the average for unreinforced polymers. Their thermal conductivities and thermal expansion are a little lower than average. Reinforcement with mineral, glass powder or glass fiber increases the modulus, strength and density.

Semi-crystalline nylon is distinguished by a numeric code for the material class indicating the number of carbon atoms between two nitrogen atoms in the molecular chain. The amorphous material is transparent; the semi-crystalline material is opal white.

Typical uses

Light duty gears, bushings, sprockets and bearings; electrical equipment housings, lenses, containers, tanks, tubing, furniture casters, plumbing connections, bicycle wheel covers, ketchup bottles, chairs, toothbrush bristles, handles, bearings, food packaging. Nylons are used as hot-melt adhesives for book bindings; as fibers - ropes, fishing line, carpeting, car upholstery and stockings; as aramid fibers - cables, ropes, protective clothing, air filtration bags and electrical insulation.

Tradenames

Adell, Akulon, Albis, Amilan, Ashlene, Capron, Celanese, Chemlon, Durethan, Gapex, Grilon, Grivory, Hylon, Kopa, Latamid, Lubrilon, Magnacomp, Maranyl, Minlon, NSC, Nivionplast, Novamid, Nydur, Nylamid, Nylene, Nypel, Orgamide, Radilon, Schulamid, Selar, Sniamid, Star-C, Star-L, Staramide, Texalon, Ultramid, Vestamid, Wellamid, Zytel

Links

Reference

ProcessUniverse

Producers

No warranty is given for the accuracy of this data. Values marked * are estimates.

Acrylonitrile butadiene styrene (ABS)

Description

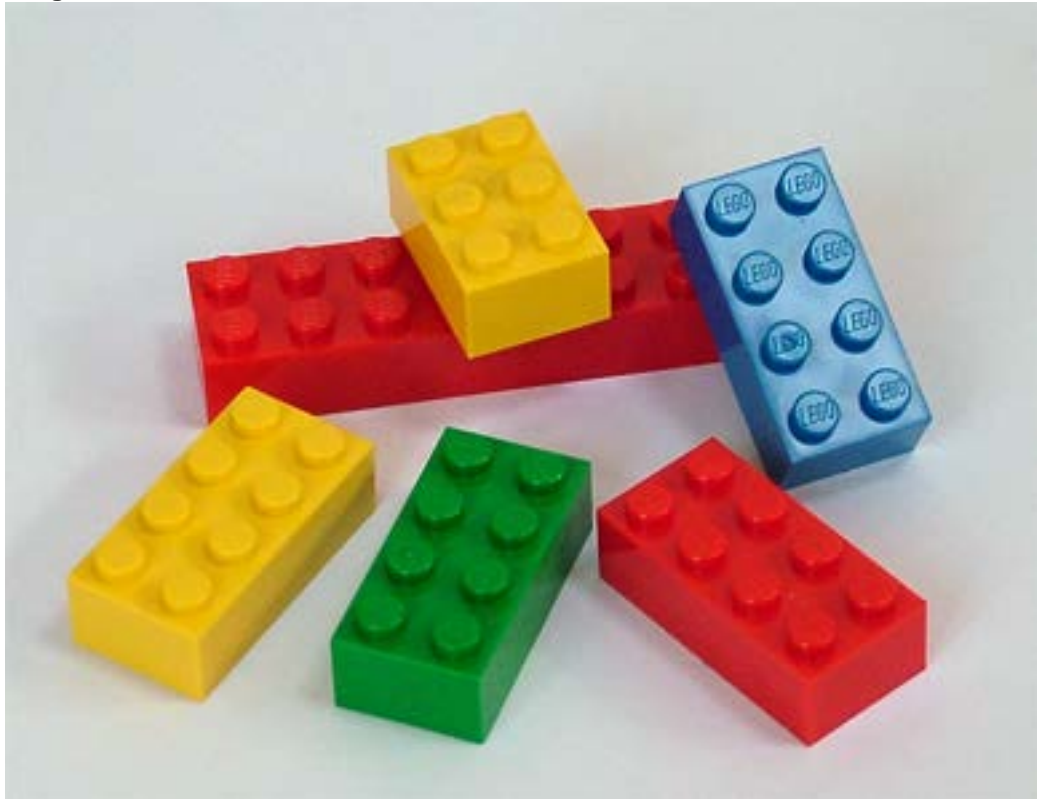
The material

ABS (Acrylonitrile-butadiene-styrene) is tough, resilient, and easily molded. It is usually opaque, although some grades can now be transparent, and it can be given vivid colors. ABS-PVC alloys are tougher than standard ABS and, in self-extinguishing grades, are used for the casings of power tools.

Composition (summary)

$(CH_2-CH-C_6H_4)_n$

Image



Caption

The picture says a lot: ABS allows detailed moldings, accepts color well, and is non-toxic and tough enough to survive the worst that children can do to it.

General properties

Density	63.1	-	75.5	lb/ft ³
Price	0.898	-	1.1	USD/lb

Mechanical properties

Young's modulus	0.16	-	0.421	10 ⁶ psi
Shear modulus	0.0462	-	0.15	10 ⁶ psi
Bulk modulus	0.551	-	0.58	10 ⁶ psi
Poisson's ratio	0.391	-	0.422	
Yield strength (elastic limit)	2.68	-	7.4	ksi
Tensile strength	4	-	8.01	ksi
Compressive strength	4.5	-	12.5	ksi
Elongation	1.5	-	100	% strain
Hardness - Vickers	5.6	-	15.3	HV
Fatigue strength at 10 ⁷ cycles	1.6	-	3.2	ksi
Fracture toughness	1.08	-	3.9	ksi.in ^{0.5}
Mechanical loss coefficient (tan delta)	0.0138	-	0.0446	

Thermal properties

Glass temperature	190	-	262	°F
Maximum service temperature	143	-	170	°F
Minimum service temperature	-190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.109	-	0.194	BTU.ft/h.ft ² .F
Specific heat capacity	0.331	-	0.458	BTU/lb.°F
Thermal expansion coefficient	47	-	130	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e21	-	3e22	µohm.cm
Dielectric constant (relative permittivity)	2.8	-	3.2	
Dissipation factor (dielectric loss tangent)	0.003	-	0.007	
Dielectric strength (dielectric breakdown)	351	-	551	V/mil

Optical properties

Transparency	Opaque			
Refractive index	1.53	-	1.54	

Processability

Castability	1	-	2	
Moldability	4	-	5	
Machinability	3	-	4	
Weldability	5			

Eco properties

Embodied energy, primary production	* 9.86e3	-	1.11e4	kcal/lb
CO2 footprint, primary production	* 3.27	-	3.62	lb/lb
Recycle	True			

Recycle mark



Supporting information

Design guidelines

ABS has the highest impact resistance of all polymers. It takes color well. Integral metallics are possible (as in GE Plastics' Magix.) ABS is UV resistant for outdoor application if stabilizers are added. It is hygroscopic (may need to be oven dried before thermoforming) and can be damaged by petroleum-based machining oils. ASA (acrylic-styrene-acrylonitrile) has very high gloss; its natural color is off-white but others are available. It has good chemical and temperature resistance and high impact resistance at low temperatures. UL-approved grades are available. SAN (styrene-acrylonitrile) has the good processing attributes of polystyrene but greater strength, stiffness, toughness, and chemical and heat resistance. By adding glass fiber the rigidity can be increased dramatically. It is transparent (over 90% in the visible range but less for UV light) and has good color, depending on the amount of acrylonitrile that is added this can vary from water white to pale yellow, but without a protective coating, sunlight causes yellowing and loss of strength, slowed by UV stabilizers. All three can be extruded, compression molded or formed to sheet that is then vacuum thermo-formed. They can be joined by ultrasonic or hot-plate welding, or bonded with polyester, epoxy, isocyanate or nitrile-phenolic adhesives.

Technical notes

ABS is a terpolymer - one made by copolymerizing 3 monomers: acrylonitrile, butadiene and styrene. The acrylonitrile gives thermal and chemical resistance, rubber-like butadiene gives ductility and strength, the styrene gives a glossy surface, ease of machining and a lower cost. In ASA, the butadiene component (which gives poor UV resistance) is replaced by an acrylic ester. Without the addition of butyl, ABS

becomes, SAN - a similar material with lower impact resistance or toughness. It is the stiffest of the thermoplastics and has excellent resistance to acids, alkalis, salts and many solvents.

Typical uses

Safety helmets; camper tops; automotive instrument panels and other interior components; pipe fittings; home-security devices and housings for small appliances; communications equipment; business machines; plumbing hardware; automobile grilles; wheel covers; mirror housings; refrigerator liners; luggage shells; tote trays; mower shrouds; boat hulls; large components for recreational vehicles; weather seals; glass beading; refrigerator breaker strips; conduit; pipe for drain-waste-vent (DWV) systems.

Tradenames

Claradex, Comalloy, Cycogel, Cycolac, Hanalac, Lastilac, Lupos, Lustran ABS, Magnum, Multibase, Novodur, Polyfabs, Polylac, Porene, Ronfalin, Sinkral, Terluran, Toyolac, Tufrex, Ultrastyr

Links

Reference

ProcessUniverse

Producers

No warranty is given for the accuracy of this data. Values marked * are estimates.