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MX Snow Ski

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MX SNOWSKI

Senior Project



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Abstract: Living in the Pacific Northwest has many perks when it comes to enjoying the outdoors. All of the seasons can be enjoyed, as well as being completely surrounded by beautiful rolling hills and mountains. Being someone who continuously enjoys the outdoors year-round it's always fun to try new hobbies. The problem with owning a dirt bike is that most people ride during the dryer and warmer seasons of the year. This project would enable the bike to be ridden even during the snowy winter season. Riding a dirt bike in snow has been recently explored by only a few companies the past few years. Why not design our own working system? A Honda Cr250r dirt bike became the test model and a front mount for a snow ski was designed. This ski would replace the front wheel/tire, while a paddle tire would be implemented at the rear of the bike. After all thirteen parts are machined from the CNC, table mill, band saw, and surface grinders, the device is considered complete and will be properly mounted to the dirt bike. When tested, the dirt bike should handle well in the snow by making tight turns, long sweeping turns, and tracking straight with ease. The ski mount device will also allow the front ski to pivot in the upward position from 20-45°, while also pivoting downward at least 10-25°. This will allow a rider to enjoy dirt biking all year-round.

Introduction

Engineering Problem

This project was motivated by a need for a device that would allow a person to ride a dirt bike in all the seasons that are encountered in Washington State. Most people ride a motocross bike exclusively from spring time through fall; the plan is to change that so an individual can ride during the winter season as well. This project will consist of three main phases such as developing a design, making the parts, and testing the final product. The final product will consist of a front-mount snow ski assembly that will fit where the front tire on a motocross bike currently is, whilst utilizing a sand tire on the rear wheel to keep costs down.

Motivation

The motocross bike was bought about two months ago (August 2014) and has only seen the sight of dirt, mud, and large puddles with its current owner. The bike doesn't realize it will be encountering snow in the near future. This is cool because MX bikes have never been bought with the intentions to be used in snow, until the past few years. There are only a few companies producing snow kits for MX bikes and the designs will continually change and adapt to the needs of the riders.

This calls for multiple different designs that will allow the rider to choose the kit that fits best for their needs or if the purchase is strictly for a kit that is more aesthetically pleasing. Being involved and greatly interested in motorsports is the main motivation for this project. As a rider and dirt bike enthusiast only the best materials will be utilized in the development of this project. The plan is to use a strong-lightweight metal for all the basic components (ski-mount, spindle, fork Linkage and support). As for the ski, one will be purchased online to allow more focus and emphasis on the other components of the project.

The demand for lightweight components in motorsports is large. The reasoning for lightweight components is so the overall weight of the bike remains low, since the weight distribution towards the front of an MX bike (steering column especially) determines how easily the bike is going to handle without having to wrestle the handlebars to get it to turn and track smoothly. The other reason and motive behind utilizing a lightweight metal is for when the rider hits a large obstacle covered by snow, such as a stump or rock; this is essential to keep the steering and suspension from being ruined or needing to be replaced, since new fork suspension costs an upwards of 2000 – \$3000 versus a ski spindle and mount that cost 50 - \$100. The metal will be built with the intention of being light-weight and strong.

Function Statements

The MX bike platform that will be used for the design and testing process will be a 2005 Honda CR 250R and it will utilize a sand tire (or tire with equal or greater grip) for the testing process of the project. The project must be capable of performing a few simple tasks with ease of the operator:

1. Must support a motocross bike and rider, whilst tracking through the snow.
2. To allow the rider to make turns at low and high speeds.
3. The ski shall not inhibit proper function of the front suspension/forks.
4. The spindle shall not rotate from its original mounted position.
5. The ski must slide forward in the proper direction with ease.

Requirements

The MX SnowSki will hold tight tolerances in the manufacture process to ensure proper function ability. The design shall not be overly complex so that an average mechanic can easily install the finished product. The project must pass more technical criteria which involves proper mechanical function and structural integrity:

1. The total weight of the assembly should be less than 10 lbs.
2. The ski should be able to rotate to a 20-45° incline past horizontal equilibrium (when the bike is on flat ground).
3. The ski should be able to rotate to a 15-30° decline past horizontal equilibrium.
4. The spindle shall not rotate >2° when properly installed onto the pre-existing front forks of the motocross bike.
5. The column must be able to support a 500 lb load

Engineering Merit

The spindle is a significant piece for the project and will be optimized to have good structural integrity, while keeping the part lightweight for good handling characteristics. The spindle is the main component that utilizes smaller parts like brackets, mounts, and miscellaneous hardware that will control the placement and function of the ski and pre-existing front fork suspension. The ski is just as important and will be purchased through a company that has been part of the motivation for this project. The design utilizes a few keels on the bottom of the ski that are a key feature for greater turning stability and for creating an edge when sharp turns are desirable.

In order to justify the design and use of each piece, many equations will be utilized to determine the forces, moments, stress, strain, and deflection when necessary using the following equations: $\sum F_x=0$, $\sum F_y=0$, $\sum M_o=0$, $\sigma=P/A$, $\tau=V/A$, $\sigma_f=3PL/2bd^2$, & $\delta=PL^3/48EI$ [1].

Scope of Effort

The scope of the project will be focused upon making the bigger components, such as the spindle, ski, mounting bracket, and the components to restrict unnecessary movement. All the necessary hardware (i.e. bolts) will be bought or provided by outside sources. The evaluation and testing part of the project will focus mainly on the components produced during the design process by using some of the pre-existing hardware or parts.

Success Statement

This project will be considered successful if all the requirements above are met within the time-frame of a school year, while all major components will be manufactured in the CWU machine shop, materials lab, or by an outside source/sponsor. This should also help keep the cost around the goal of six-hundred dollars.

The bike will also encounter a few tests with a rider to check the ski's stability in the snow (or sand if snow is unattainable). The MX SnowSki will be required to make turns at low and high speeds, which will be tested in 1st or 2nd gear for the low speed test and 3rd, 4th or 5th gear shall be used for the high speed turn test. This testing process should be filmed either by the rider in a first-person view, or from a spectator in a third-person view to successfully show the handling of the bike. The bike will also go through quick slalom-like turns and will be tested in sitting and standing positions to check the differences between handling.

The MX SnowSki shall also take no longer than 1.5 hours to completely install onto the front of the bike. Basic tools should be used, such as screw drivers, wrenches, and ratchet systems.

Design & Analysis

Approach

There are a few different methods to be considered when going about making the MX SnowSki components. The material and machines that will be used to produce these parts are important and must be utilized correctly to ensure the lowest costs. The spindle is structurally the most important piece to this project, since it controls where all the other components placements and orientations are, relative to the pre-existing forks. The spindle also has a few different designs to be considered. The spindle could consist of two or more machined pieces that would either be bolted or welded together, as well as the possibility of being one large machined piece. For time and material constraints we will probably use a few machined parts to keep from purchasing one large block of 6061 and shaving a lot of unused material off. This will then be bolted to a mounting bracket of 6061 aluminum, which is attached to the SnowSki. The top part of the spindle needs to be bracketed to the forks to keep rotation from occurring as well as housing the stock front axle to keep the assembly in position and good functionality.

The ski itself is the other large component in this project. The SnowSki will be bought, but will need to work and fit properly with our designed components. Originally the ski was designed and a few ways of production were considered, such as an injection mold process or using CWU's CNC machine. Both were taken into consideration, but we soon found out that CWU's injection mold machine wouldn't be capable of the dimensions required for the project. Therefore, a large block of UHMW – PE would need to be purchased and taken to the CNC machine to be milled to spec. This would've cost too much money for the project, and would've resulted in much more than half the material being wasted.

Optimization

To optimize the weight of the spindle, I was going to make sections to be taken out of a solid spindle to lighten the piece up, while ensuring that the integrity of the part isn't lost. This is because the overall weight of the components should stay under 10lbs as stated in the requirements section. I changed this for ease of computing forces and decided to not section the part, but rather to just make the overall dimensions smaller. Tolerances will be kept tight within the assembly and the fitment in between the dirt bike forks and brackets should be near perfect to ensure that rotation of $>2^\circ$ does not occur within the rigid components. The spindle will have multiple bolts to hold the mount and fork-brackets in place and to guarantee failure from occurring from applied loads and shocks.

The SnowSki will differ from normal snowmobile technology. This is since only one ski can be utilized on a dirt bike without large modifications, which would require the front steering column to be widened to accompany two skis with individually acting suspension for each ski. Besides, the reason for using a dirt bike is for a more compact and light-weight version of a snowmobile with the use of only one ski. For the bike to handle and carve well in the snow with a single ski some extra parts need to be considered in the design. The features required will be two or three plastic keels or metal skag inserts, which will aid with achieving a sharp edge when turning in the snow or on light ice applications.

The rotation in the ski shall also be optimized as stated in the requirements: the ski should be able to rotate to a $20-45^\circ$ incline and $15-30^\circ$ decline past horizontal equilibrium (when the bike is on flat ground). This will be optimized through the use of a spindle-to-ski mount or simply by the geometry of the ski and spindle material.

Description

The MX SnowSki assembly will consist of the spindle, fork bracket/supports, fork clamps, and various shafts to accommodate for the front axle and ski mount. All these components will be designed to fit the pre-existing dimensions and intended function ability of the platform dirt bike (2005 CR250). Within this assembly will be various bolts and other hardware that will maintain rigidity in the system and will be specified later in the report. The fork brackets and clamps will work as a clamping system on the front suspension (forks) of the dirt bike. This bracket will then be bolted to the spindle. The spindle is mainly held into position by using the pre-existing front wheel axle, but is also reinforced by the fork bracket to ensure that no rotation occurs in the rigid pieces of the assembly. The fork bracket is located right above the spindle, since this is the only place where it can clamp the suspension system. Right under the spindle is the ski mounting area. This part is what allows limited rotational movement of the ski. The ski is just under the spindle and is held in place using a shoulder bolt that allows for some rotation in the ski. The metal skags will be bolted to the bottom of the ski positioned along each side (if plastic keels aren't used). After the assembly is completely done the bike shall function as stated above.

Spindle, Fork brackets & Axle Shaft:

The picture below is a basic sub-assembly of how the final project will be put together. The two brackets that rise above the rest of the components are a part of the fork clamping system. These will simply clamp over the front suspension (forks) of the dirt bike and will keep the sub-assembly from rotating about the front-wheel axle. The existing axle will pass through the shaft of the sub-assembly and will be bolted in to the forks as if a wheel were in its place. This shaft fits snugly against each fork while being held in place with the axle. This is the main source of integrity for the system as it keeps it from sliding left-to-right along the axle. The spindle is the tall column-like part that is attached to all the other components and is the main load bearing part. The spindle will need to be analyzed and tested to prevent failure from occurring during the test ride portion of the project.

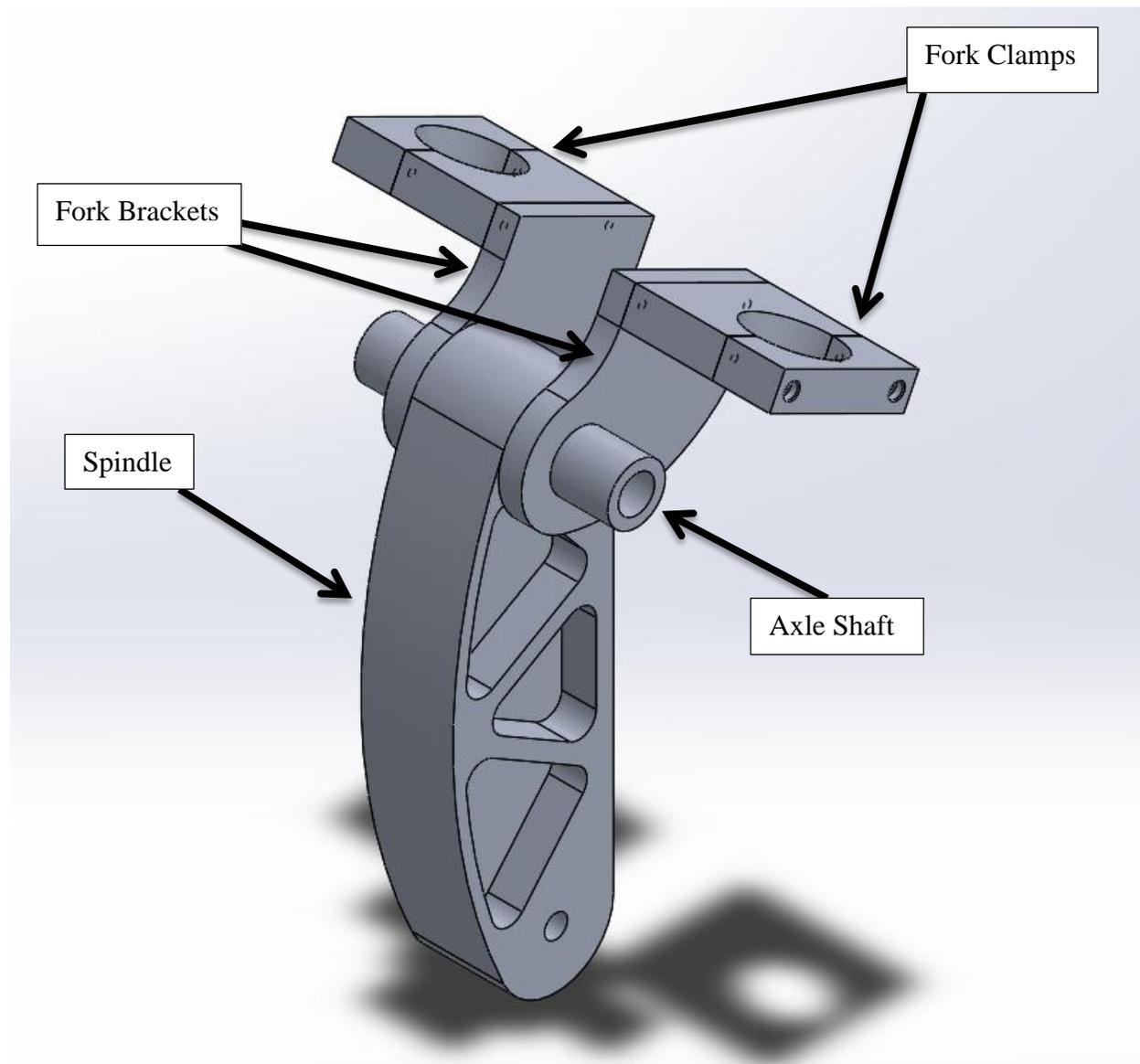


Figure 1: Rendering of the first basic design for the MX SnowSki, with labels to illustrate the different parts. Notice the complicated geometry of the original and much thicker spingle.

SnowSki:

This picture shows a rough rendering of the ski that will be used or designed for this project. You can see a keel that is placed down the middle of the ski to help with turning as well as two hidden keels on each edge of the bottom of the ski. These side keels will help create an edge while turning to keep the ski from sliding out from under the bike and the rider. A front lip is also incorporated to help channel the snow under the wide ski, which is common in water skis, snow skis, snowboards, and wakeboards. The wider the ski the better it will “float” on the snow, and the narrower the ski the better it will carve.

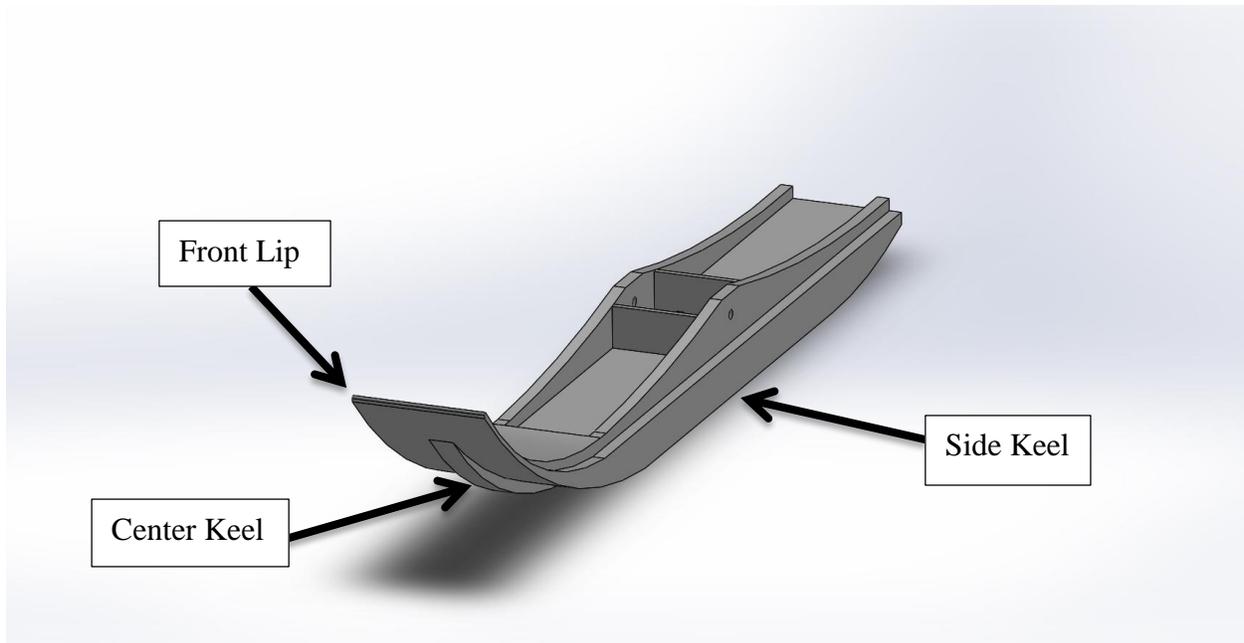


Figure 2: Basic rendering design for a Ski, which includes important components of a ski.

Benchmark

A company based out of Idaho makes a similar product called the Timbersled Mountain Horse, which consists of a large track, suspension, and gear combo for the back of a dirt bike for its main source of propulsion through snow and ice. This rear assembly for the Mountain Horse costs about \$5,300 and is why we will be utilizing a paddle tire in place of the rear wheel [2]. This company also makes a front ski assembly, which is called the Timbersled BackCountry Ski. This ski assembly is well made and optimizes the need for stability and strength in the front of the snow bike. Our design will be similar in regards to function but will optimize the weight and ski stability as well as making the final product look aesthetically pleasing.

Timbersled Mountain Horse: Retail ~ \$5,300



Figure 3: KTM brand dirt bike with a full Timbersled Mountain Horse snow setup.

Timbersled BackCountry Ski: Retail ~ \$425 (Ski) & ~\$300 (Fit kit)



Figure 4: Timbersled BackCountry front ski setup for a dirt bike.

Performance Predictions

The prediction for our device is that the ski and spindle shall be able to support a 500lb load (A-Pg. 5) without buckling or failing. The device will also keep from rotating about the front wheel axle, since the brackets will snugly fit to the front forks and hold the spindle in place. The front ski shall be able to rotate 20-45° in an incline past horizontal equilibrium as well as 15-30° in decline. The front ski will handle tight and wide sweeping turns in snow without the device failing/breaking. The equations that will most likely be used are the following: $\sum F_x=0$, $\sum F_y=0$, $\sum M_o=0$, $\sigma=P/A$, $\tau=V/A$, $P_{cr}=\pi^2EI/(KL)^2$ (Critical Load for Column), $\sigma_t=3PL/2bd^2$, & $\delta=PL^3/48EI$ [1]. Equations of equilibrium will be used with most if not all predictions.

Description of Analyses

The importance of analysis is to find or confirm that the dimensions used for our parts would be more than sufficient to accomplish our set requirements and success criteria. The analysis first started with the main components of the project to determine the thickness of the materials needed to support the force caused by the mass of the rider and dirt bike; all analyses are in Appendix A. This combined force was estimated to be a total of 500 lb after taking into consideration a safety factor of 2 (A-Page 4). This force would also act directly over the front axle of the bike where the final product would be assembled. The main materials used in the project/analysis are Type 316 Stainless Steel and 6061 Aluminum, which can be found off of the McMaster-Carr website [3]. Most analysis began by finding the forces in equilibrium and then using the resultant force or moment to determine the stress, deflection, and strength of the parts.

Scope of Testing and Evaluation

There are a few separate ways the device will be tested; the first is that the spindle will go through a column loading test on the Tinius-Olsen machine in Central's Hogue Technology Building or by assembling the components onto the bike and adding weight to see how it holds up. The second way of testing the project will be to fully assemble onto the platform/test bike and drive to an elevation where snow is present during the spring time. The riding and testing portions will cover the proper functions and requirements that were listed in the introduction section.

Analysis

Approach:

Analysis began with the components that had the highest importance towards the success of the project (i.e. specific functions, parameters, large load or stress bearing components, etc.). The hardware/bolts were the last pieces of the project to be analyzed, since they would be determined by shear forces from previous test calculations.

Design:

For the design process of the analysis a few different safety factors were used depending on the application/use of the component. A safety factor of two was used when determining the mass of the rider and bike (A-Pg. 4), which would be utilized in many analysis calculations. The spindle is the largest part in the project, while it would also bear the majority of the load. All static loads act through the member, requiring the spindle to be treated as a short column due to the slenderness ratio being less than the column constant (A-Pg. 3). Some dynamic loads/impact forces were taken into consideration to find resultant torques in components to determine the deflection of parts, while using the resultant shear forces to determine the diameters needed for various bolts.

Calculated Parameters:

Parts were designed for proper fitment on a 2005 CR250 MX bike, as well as being optimized for a low overall weight. The calculated parameters of each part mainly considered the optimization of weight, but are also focused towards keeping raw materials smaller to help keep the cost of the project down. Most dimensions were chosen for proper fitment on the MX bike, but were scaled down on thicknesses of materials or hardware to optimize the cost of the project. Each component was analyzed with safety in mind.

- i. **Spindle - Column Analysis:** The spindle is the main load bearing part being designed. The first set of calculations done on the spindle would be done to determine the critical load and critical stress that the part would be able to handle. Unfortunately, this part was such an odd shape it made analysis very difficult to follow out. The part essentially was analyzed as a simple beam using the overall length, width, and smallest thickness, since there were cut outs for weight optimization (A-Pg. 1&2). This first analysis wasn't considered accurate since it did not take into consideration the slenderness ratio and column constant, although it was left in the report for comparison between numbers. This led to a second column analysis of a lighter and more simplistic spindle design. This spindle was still 11.50 inches in length, but had a width of 3 inches and a thickness of an inch. This allowed for a more accurate analysis, which began in finding the radius of gyration, slenderness ratio, and column constant. The slenderness ratio was found to be less than the column constant which determined that the column would be examined as a short column rather than a long column. From here we found that the critical load for the spindle was 97.7 kips (A-Pg. 3) and the critical stress was 32.56 ksi (A-Pg. 4). This gave us numbers that we could compare to our actual load and stress on the spindle. First, we had to find the approximate mass on the front axle of the bike by using the mass of the bike, mass of the rider, and a safety factor of two to find an approximate total of 500 lb_{mass} (which is also equivalent to a 500 lb force) (A-Pg. 4). This column analysis clearly illustrated that the actual stress and load numbers were 0.5% of the critical numbers.
- ii. **Spindle – Cornering/Turning Analysis:** The same total force of 500 lbs will be used for this scenario, but the mx bike will be analyzed as it is making a leaning turn. The bike is set up in a static situation where the load is acting on the spindle at an angle. From here we can use equations of equilibrium and the total moments about point B on the spindle to find the force causing the spindle to bend about its weaker axis (A-Pg. 5). The force A_x turned out to be 211.3lb_f, since the spindle was set at an angle of 25°. Using force A_x and the total length of the spindle we were able to compute the total bending moment caused by the force, which was 2,430lb_f-in (A-Pg. 5). Using the calculated moment we were able to find the bending stress, by using the equation $\sigma = Mc/I$, where “c” is 0.5 inches (halfway through the material), and “I” is 0.250in⁴ (A-Pg. 3). The bending stress came out to 4,860 psi. Another crucial part to the turning analysis would be to find the max deflection in the spindle. For this the spindle was analyzed as a cantilever beam, since one side of the spindle would be fixed while the other end would be free to move. The equation used to find the maximum deflection was $X_{max} = X_A = PL^3/3EI$,

where “P” is the load (211.3lb_f, “L” is the length (11.50in), “E” is the elastic modulus ($10 \cdot 10^6$ psi) [4], and “I” is the moment of inertia about the bending axis (0.250 in^4). The maximum deflection caused by the load turned out to be 0.0429 in, which is just under $3/64^{\text{th}}$ inches (A-Pg. 5). This confirms that the part will not fail while testing the turning capabilities.

- iii. Spindle – Frictional Force of Snow on Ski: The purpose of analyzing the frictional force of the snow on the ski is to determine the loading that will be placed on the spindle while moving on flat ground. This could be detrimental to the spindle, depending on how high the corresponding force is. The velocity of the bike as chosen to be a constant 30mph, which is unimportant in this problem, since it isn’t accelerating. Therefore, the corresponding friction force is related to the normal force (N) and the coefficient of sliding friction on snow (μ). The coefficient of friction had a value that ranged in 0.1 - 0.05, so for the purpose of analysis 0.1 was chosen, since it will result in a larger frictional force. The force caused by friction on the bottom of the ski turned out to be 50 lb_f (A-Pg. 6). To find the force on the spindle we would use our knowledge of moments about a point and used the force on the bottom of the ski. From here we found that the corresponding force acting on the spindle is 63 lb_f (A-Pg. 6) and a moment of 725 lb_f-in acting at the top of the spindle. We are now able to find the bending stress and deflection due to these forces and the corresponding stress was 483 psi and a deflection of 0.00142 inches (A-Pg. 7). These calculations are negligible and the frictional force caused by snow can be ignored.

- iv. Spindle – Shock Load: The reasoning behind this set of analysis was to determine if the spindle dimensions were sufficient enough to sustain an impact from riding the mx bike off a 10 foot drop off to flat ground. This would take into consideration the front suspension (forks) of the bike and the stock spring coefficient and compression distance. Using the same 500lb force as calculated for previous problems (A-Pg. 4), we used a combination of energy and work equations to find the distance the suspension would compress from impact and found that the front forks would compress the full distance of 12.5 inches (A-Pg. 8). From here we could find the force captured by the spring, which turned out to be 600 lb_f (A-Pg. 8). Unfortunately, the compression distance of the springs was initially calculated to be more than the springs actual compression distance. This means that the force caused by impact that is acting on the spindle is more than what the spring absorbed. For this scenario we needed to find the velocity in the y-direction right at the instant before impact occurs by using potential and kinetic energy equations. From here we used work and kinetic energy equations to find the force of impact from $F = m(V_y)^2 / 2s$, where “m” is the total mass of the rider and bike, “V_y” is the velocity right before impact, and “s” is the stopping distance/compression distance of the impact. To get the highest force of impact possible the compression of the springs was not taken into consideration and a compression distance of 2 inches was used for the snow/ground, thus resulting in a force of 30,054 lb_f (A-Pg. 8). This resulting force is a “worst case scenario” and the load and stress found in the spindle were still 1/3 of the critical load (30.05kip < 97.7kip) and stress (10,018psi < 10.02ksi) (A-Pg. 9).

- v. Spindle – Inclined Hill Impact: Since the bike would be tested outside where snow is present we wanted to do analysis in many different scenarios to make sure it would withstand any situation. This problem found an impact force on the front of the spindle by using $F=m*\Delta v/\Delta t$, which came out to about 2900 lb_f (A-Pg. 10) perpendicular to the 30° incline. By using geometry the horizontal force on the spindle turned out to be 1450 lb_f and from this we found that a torque/moment of 16,675 lb_f-in (A-Pg. 11) was present at the fixed-end of the spindle.
- vi. Bolts – Spindle Bolt Size: To determine the diameter of the bolts needed the largest torque caused by the “Inclined Hill Impact” analysis will be used, 16,675 lb_f-in (A-Pg. 11). The bolts that are going to be used are ‘Type 316 Stainless Steel’ that have a shear strength of 42,000 psi (McMaster-Carr website) [3]. Taking into account that 4 bolts will be used the shear force per bolt is 4,388 lb_f and we found that the diameter of each bolt needs to be at least 0.365 inches, so a nominal size of 0.375in (3/8”) was chosen (A-Pg. 12).
- vii. Bolts – Fork Bracket Bolt Size: These bolts are important to keep the whole assembly from rotating and keeping them fixed about the axle. These bolts will also be determined by using the same torque calculated from the “Inclined Hill Impact” analysis, 16,675 lb_f-in (A-Pg. 11), while also using ‘Type 316 SS’. These bolts are a little smaller than the spindle bolts, since they are a little farther away from where the moment/torque is acting. Using the same concepts and equations from the previous bolt analysis we found that the minimum diameter of the 4 bolts had to be 0.2146 inches, so a nominal size of 0.25in (1/4”) was chosen (A-Pg. 13).

Device Assembly:

To assemble the device, most parts will be bolted together, but there will be two shafts that will need to be welded to each of the fork brackets as well as two shafts that need to be welded to the bottom of the spindle for correct ski assembly. These shafts will serve the purpose of spacers to keep the assembly centered in between the front forks (suspension) of the MX bike. These shafts/spacers will not carry a critical load because they will fit securely around the original wheel axle. The spindle will assemble to the ski through the bolt provided by the ski manufacturer, which is a 3/8” bolt. The fork brackets will be on each side of the spindle and will bolt together holding the spindle in place. From there the axle will be put through the shaft and spindle and will be tightened up to the left and right fork. The fork brackets will line up with the forks and will be bolted and held in place by the fork clamps. The bolts on the spindle, fork clamps, and ski will all be snugged up.

Tolerances:

The tolerances on each separate part will be kept to 0.012 inches to ensure that they will line up and fit on the MX bike. The key is to make sure that there isn't too much play in the assembly so the finished part doesn't rotate about the axle and mess up the forks.

Risk

There is a risk factor involved with this device, since it will be put through many tests with an operator riding at varying speeds, making quick turns, sweeping turns, and possibly encountering ice or other dangerous riding conditions. The parts need to keep from breaking to ensure that the rider will not be put into a dangerous situation that can't be fixed while moving. The rider will perform the "test ride" session in proper riding gear including but not limited to a helmet, gloves, chest protector, and boots.

Failure Mode Analysis & Operational Limits

If the MX SnowSki were to fail during the testing portion of the project it would most likely occur due to a shearing force directly on the bolts. The bolts main effort is it to keep the spindle from rotating about the front axle. This shearing failure would be caused by a larger force/torque than previously calculated in the analysis section (A-Pg. 12 & 13). The only way a serious injury/failure would occur is if all four of the bolts failed simultaneously. This failure would result in the spindle and ski rotating under or in front of the dirt bike, causing the front end of the dirt bike to plunge into the ground, acting like a pole-vault and sending the rider and back end of the dirt bike to go toppling over the front. The other mode of failure would be through the fork brackets bending too far while taking a leaning hard turn, although most of the load will be absorbed by the pre-existing front axle and the shafts that enclose the axle.

Safety Factors

The safety factors included take into account the safety of the rider and the purpose of the components. A basic safety factor of 2 was included in the total combined weight of the rider and dirt bike, which was incorporated in the basic force calculations in Appendix A. The safety factor turned out to be about 3 for the shock load on the spindle (A-Pg. 8 & 9), while the previous analysis problems proved a much higher safety factor. For the hardware, the factor for determining the bolt diameters were 1.5 (A-Pg. 12 & 13).

Methods and Construction

Description

This project was designed with the intention of being built at CWU with the available resources in the machining and materials labs. The work for the project will be within the constraints of the technology available by using the appropriate machines when needed, such as machine lathes, mills, CNC's, and drill presses. The technology available to us was a limiting factor for this project since the ski was originally going to be designed, built, and tested as well. Unfortunately, the injection-mold machine wouldn't produce the correct geometry of the part, since the ski would be quite large.

The finished device is a single assembly consisting of seven machined parts, one ski, and miscellaneous bolts and other hardware. The majority of the parts will be machined on a mill, since most of the parts won't work with a lathe and also have a few complicated geometries for a CNC machine. The spindle, fork brackets, and fork clamps will heavily rely on the milling machine for correct dimensioning and a drill press for the bolt holes. The axle shafts will be simpler to machine and could be done in a lathe. There is not a specific sequence for when the parts need to be finished, but the bigger and more complicated parts like the spindle and fork brackets will be the main focus. The axle shafts will only need to be bored to the correct diameter, since the raw material will be bought as round tubing. When the axle shafts are bored to the correct diameter they will be welded to the completed fork brackets and ready for installation later. None of the machined parts were obtained from outside sources, but the ski was bought off the internet from IceAge Manufacturing [5] and the hardware will be bought from McMaster-Carr [3] or cheaper online sources.

Drawing Tree

Please refer to the drawing tree located in APPENDIX C. The left side of the drawing tree represents the parts being made, while the right side is the hardware. The parts side first starts off with buying the proper materials that are listed in APPENDIX D. The materials will come in the mail shortly after being purchased and need to be collected so they can be machined and inspected afterwards for correct dimensioning. From here the axle shafts and fork brackets are welded together to be concentric about the axle hole. All the parts will be collected and the dirt bike will be prepared by taking off the wheel, fork guards, and front brake. The right side of the drawing tree represents the hardware that needs to be purchased, collected, and prepared for installation. From here the parts can be installed onto the MX bike by using the provided hardware and basic hand tools.

Testing Method

Introduction

The testing portion of the project would take into account the requirements set earlier in the report. These requirements included: that the total weight of assembly would be ≤ 10 lbs, the ski should rotate $20-45^\circ$ to its incline and $15-30^\circ$ to its decline, the spindle shall not rotate $> 2^\circ$ when installed on forks, and the column must be able to support a 500 lb load.

The main parameters of interest are the angles achieved by the ski, the angle of the spindle when installed on the bike, and if the column is able to support a 500 lb load. The reason that the total weight of the assembly is not as important is because it does not impact the function of the ski during the test ride portion.

Unfortunately, the ski will mostly likely not see snow for testing. It will be tested at sand dunes that are near Ellensburg, WA, which will be available through public access or certified with the use of a discover pass. Predictions for the ski's performance are hard to gauge, since it won't be tested on its intended surface. The kinetic/sliding coefficient of friction for plastic on snow is a maximum of 0.1, while the coefficient for plastic on sand is about 0.2-0.3.

We will acquire our test data through observation, assessment, an angle finder, and a scale. The angle finder will be used to record the ski and spindle angles. The scale will be used for the weight of the assembly. The observations and assessments will be provided during the test ride portion of the test.

The testing evaluation schedule takes place from April 6th – May 18th. Check APPENDIX E for the Gantt chart/schedule.

Method/Approach

There are a number of resources that will be needed to proceed with the testing portion of the project. The test bike is the main resource needed. The bike is a 2005 Honda CR250r, which should be equipped with a paddle (sand) tire and in running condition. Another resource requires that if snow is not testable, then sand should be used. A transportation resource is needed as well to transport the test bike to the various evaluation sites.

The data will be recorded in various ways depending on the tests being performed. An angle finder should be placed on the front ski while the test bike is on its stand; this test procedure will allow the front ski to rotate freely so that the maximum incline and decline angles can be found. The rest of the data will be acquired through observations and multiple assessments performed during the test ride. No computer programs will be required to process data, since pressures, temperatures, etc. won't need to be recorded using a logger or equivalent machine. A number of the tests will be basic pass or fail recordings with a description of the performance outcomes.

Some operational limits are: the ski should not rotate past the maximum angle requirements in the incline/decline position, the spindle (column) should not rotate past its maximum constraint, and the assembly should not weigh more than its requirement. No operational limits are set for the test ride portion, but are rather set for the static functions of the SnowSki.

The precision of the testing will be maintained throughout all tests, since the ski will only achieve one set answer for the angle tests and similar results for the other procedures. The accuracy will be determined by the difficulty of each of the set goals/requirements. If the results aren't close to the set requirements, then the accuracy will be low and will prove that the initial goals were set unrealistically.

The data shall be initially recorded/stored on a testing sheet and then transferred onto the official evaluation sheet located in APPENDIX G of this report. The data won't need to be manipulated in excel or similar programs because no data points will need to be plotted.

The data will be presented in a table format as illustrated in APPENDIX G.

Test Procedure

The test ride portion took place at the Beverly Sand Dunes near Mattawa, WA off of highway 243 and was executed on April 24th, 2015 at around 8:30am. The testing would involve many different tasks to be created, which are listed on the evaluation sheet in APPENDIX G. This required success with the given tasks: the ski needed to support the bike and rider whilst tracking through the snow, low/high speed turns, proper function of the front suspension, the ski must slide forward in the proper direction with ease, and the ski should handle tight turns as well as wide sweeping turns. The testing ended prematurely due to the dirt bike reaching high temperatures; the high engine temperatures that were achieved could damage the bike if ran at an extended time period. The bike had a radiator hose fail due to the high temperatures achieved. The rubber hose had gotten very hot and brittle, which caused the radiator hose to separate and a small puncture hole was found where a slow coolant leak appeared.

The risk of injury for the riding portion of the test was high due to the bike wanting to bite into the ground. This caused the bike to appear very front heavy. If the bike was moving at a high speed and the throttle was completely backed off, the bike would perform an endo. An endo is a dirt biking term often referring to an end-over, which is when the rear of the bike comes over the front of the bike as if the machine were performing a cartwheel. To manage the safety of test riding the bike, the bike had to come to a rolling stop in the sand by slowly "rolling" off the throttle. Rolling off the throttle means to slowly ease off of the accelerator until it the machine stops.

The bike was in a test ready condition, but the testing didn't go as well as planned. If there had been snow for testing we believe that the testing would've gone as planned, because the ski would have slid much easier, rather than digging in the sand. There is reason to believe that the metal carbide on the bottom of the ski was the main culprit for digging into the sand and wanting to bury the front end of the bike. If the ski had less aggressive skags on the bottom the bike would've moved easier in the snow, but would've sacrificed turning and handling. When winter arrives next year maybe the dirt bike and ski will be pulled out for testing in its intended testing conditions.

Deliverables

The following are the test results, which include the parameter values as well as the calculated values.

SnowSki Evaluation

Evaluator: Jordan Olson

Function Tests:

Task:	Expectation:	Date & Time Performed:	Performance/ Results:	Pass or Fail (P/F):	Description:
Total Weight of Assembly	10 lbs	5/20/2015	6.7 lbs	P	The parts were assembled and weighed on a scale. (Included bolts/hardware, no ski.)
Ski Rotation: Incline	20-45°	4/17/2015	37.5°	P	Bike was elevated on stand so ski could rotate freely. Angle finder was measurement tool.
Ski Rotation: Decline	15-30°	4/17/2015	25°	P	Bike was elevated on stand so ski could rotate freely. Angle finder was measurement tool.
Spindle Rotation	$\leq 2^\circ$	4/17/2015	0°	P	Spindle didn't rotate. Fit was snug. Therefore, no measurement tool was needed.
Column Load	500 lbs	N/A	Not performed. Need proper work holding.	N/A	Column experienced ~400lb load when bike performed endo during test ride.

The success criteria values for testing the ski's functions were constructed due to observations made at the snow mobile expo visited this past October 2014 in Puyallup, WA. This technology is so new and unexplored that it was hard coming up with requirements for the project, but these requirements were made so that the project had to hit certain marks to pass.

Evaluator: Jordan Olson

Testing Compound/Location: Beverly Dunes, WA

Riding Conditions (Terrain/weather): Sand / Dry & Clear

Test Ride:

Task:	Date & Time Performed:	Pass or Fail (P/F):	Description:
Support bike and rider, whilst tracking through the snow	4/24/2015	P	Although testing was in the sand the MX SnowSki completed this task well. No bolts or machined components failed.
Low speed turns	4/24/2015	P	The bike was able to turn in the sand while traveling at low speeds. The ski held a nice edge and kept from sliding out.
High speed turns	4/24/2015	F	The bike was not able to achieve the preferred speed. This was due to the excessive drag from the sand, which restricted the bike from sliding easily.
Proper function of front suspension/forks	4/24/2015	P	The front suspension of the dirt bike functioned flawlessly. The forks were able to compress and rebound just as easily with the ski.
Ski must slide forward in the proper direction with ease	4/24/2015	F	The ski did not slide forward with ease. Stopping required planning, because the bike was hard to get going due to the excessive drag.
Handling: Tight turns	4/24/2015	P	The bike handled tight turns. The operator was able to take a corner strong, but not with a lot of speed.
Handling: Wide sweeping turns	4/24/2015	P	The bike excelled in wide sweeping turns because of a lower amount of drag from the sand. Speed was also easier to carry through the turns.

The success criteria for the test ride was chosen for optimization of how the bike would handle and ride. If the project passed all the tests then it would've signified that the bike would be easy to ride and anyone could hop on the bike and try it out for themselves. The tasks are basic things that you would like a dirt bike, snowmobile, or quad to achieve while riding in lesser than optimum conditions.

Conclusion:

The project did not pass all the tests to our expectations, but did well for the conditions that it was given. If the testing process could've taken place during the winter quarter of the school year or if there was access to snow during the spring quarter then the opportunity for a more accurate test would be present. Although, the ski didn't pass every test, there were no failures within any of the components. Every component/part remained intact after testing had finished. Also, all the hardware holding the components together stayed in good working order.

Budget

Part Suppliers

The materials for this project will all be bought, either from sources via the internet or local hardware stores. The raw materials will most likely be bought from McMaster-Carr [3] or another reputable source. The hardware for the project will be also be purchased through McMaster-Carr's [3] website or from local hardware stores. The total cost for the project was originally found using the McMaster-Carr website, but lower raw material prices were found from Online Metals [6] website and were shipped from Seattle, WA. The amount actually paid for the raw materials and hardware can be found in the "Actual Cost" column in the Parts Cost table. The parts list can be found in APPENDIX D.

Estimated Total Cost

The original estimated budget for the completed project was \$500. The original budget took into account buying all the materials and hardware, but also the construction of a ski. Since the construction of a ski would greatly overshoot the \$500 budget, it was decided to purchase a ski and stick to making the rest of the project. The materials for the rest of the project turned out to be around \$125, and the new estimated total budget turned out to be \$614.49, just over the original estimated budget, which can be found in APPENDIX D.

Funding Source(s)

There are no current outside sources of funding, such as clubs, sponsors, etc. As of now all the funding for this project will come out of pocket. A total of \$150.00 was donated by Roy and Judy Liljestrom to help with material and hardware costs for the project.

Schedule

Description

The schedule is shown visually in the form of a Gantt chart, which is located in APPENDIX F. Gantt charts are beneficial towards illustrating a project schedule. These charts model the start and finish dates of key elements by using color identifiers, along with listing the estimated and actual times that were spent working on each task. Estimated times are set for each task and when a task is finished then the actual time gets put into the chart by the project manager/principal investigator. The first highlighted cell in a column represents that the task needs to be started that week, while the end of the highlighted cells represents the week the task shall be finished. The benefit of using such a chart allows a project to stay on track towards finishing at its set date; this also enforces the completion of tasks before new ones can be started. This allows a project to stay organized and should be referred to as often as possible to keep on track. For this project, it is shown that the total estimated time until completion is 190.4 hours, while it shall be finished by the end of the week of June 15, 2015.

Discussion

Design Evolution

The project first started out with a trip to the annual snowmobile expo hosted at the Puyallup Fairgrounds (Western Washington Fair) by the Washington State Snowmobile Association in October of 2014. The project was slow to get going until attending the expo. Most of the confusion arose from how the project needed to be designed and what components were crucial for a successful project. The first design of the spindle represented a complex looking column with weight reducing cut-outs of triangular shapes on each side of the spindle, while the front face of the spindle was curved rather than flat. This returned an inaccurate analysis of the part, which would lead to a new and improved design.

The spindle was redesigned as a simpler column with rounded ends and flat faces, rather than a curved front face. This allowed the analysis of the spindle to be a more accurate and simpler representation. This had shown that not only did the spindle become lighter in weight (which would be optimized even further), but the calculations would better represent the actual characteristics of the component.

The other components were designed to retrofit the project onto preexisting dimensions on the model bike used in this project, which is a 2005 CR250. The dimensions were taken by a digital caliper and a ruler.

Project Risk Analysis

There is a sufficient amount of risk involved in the testing portion of this project. The reason being is that the final component will be put through rigorous tests incorporating the test bike and rider moving at variable speeds, combining sharp and sweeping turns, and also riding in a standing and sitting position. If the part is to fail, the bike and rider could be sent flying through the air, have the bike land on the test subject, and/or hit an obstacle. Any of these scenarios are possible, but to help reduce the risk of injury the rider will wear proper safety/riding attire.

Conclusion

The MX SnowSki will be considered a successful project by the end of the school year if the finished product can withstand the multiple test ride scenarios with the combined load of the rider and dirt bike. The ski shall also be able to rotate to the specified angles for both the incline and decline positions, while the spindle won't allow any rotation about the axle when properly installed onto the dirt bike. The total mass of the assembly will remain under 10 lbs. The test riding portion will be proven its success through the use of video and picture footage taken in third-person view by a spectator, or from the rider's first-person view.

Acknowledgments

The MX SnowSki project crew would like to give appreciation to the MET program staff, Dr. Johnson, Professor Pringle, Professor Beardsley, Mr. Burvee, and Mr. LeBlanc for their time and dedication to the MET program and students. We would also like to thank and recognize Central Washington University for allowing us to utilize the machine shop, computer lab, and materials lab facilities to design, build, and test our project. Big thanks go out to Roy and Judy Liljestrom for their donation of \$150.00 to the project. Without the support of the organization and individuals listed this project wouldn't have been possible.

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APPENDIX

APPENDIX A – Analyses

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Appendix A 1: Original spindle critical load design.

Jordan Olson MET 495 11/10/2014

Given: Spindle - First Design

- Column loading
- Fixed-Pinned, $K=0.7$
- 6061 Aluminum, $E=10,000ksi$
- Analyze as simple column w/ $L=11.50''$
- $W=3.50''$, $t=0.50''$ (smallest)

Find:

- Determine if $P_{critical} > 500lb$

Soln:

(Determining smallest moment of inertia, I , value)

a-a axis:

$$I_{a-a} = \frac{bh^3}{12} = \frac{(0.5in)(3.5in)^3}{12}$$

$$I_{a-a} = 1.7865in^4$$

b-b axis:

$$I_{b-b} = \frac{bh^3}{12} = \frac{(3.5in)(0.5in)^3}{12}$$

$$I_{b-b} = 0.03646in^4$$

Determine if $P_{critical} > P_{actual} = 500lb$

$$P_{cr} = \frac{\pi^2 EI}{L^2} = \frac{\pi^2 (10 \times 10^6 \frac{lb}{in^2})(0.03646in^4)}{(11.50in)^2}$$

$P_{cr} = 27,210 \text{ lb}$

Didn't take slenderness ratio into account for short or long column

Appendix A 2: Critical stress in original design.

Jordan Olson MET 495 11/10/2014

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Given: Previous Spindle Problem/Description

Find: Critical Stress in simple column, σ_{cr}

Soln: $P_{cr} = 47.3 \times 10^6 \text{ lb}$, $I_{b-b} = 0.03646 \text{ in}^4$

radius of gyration $r = \sqrt{I/A} = \sqrt{\frac{I_{b-b}}{A_{b-b}}}$

$A_{b-b} = b \cdot h = (.5 \text{ in}) (3.5 \text{ in})$
 $A_{b-b} = 1.75 \text{ in}^2$

$r = \sqrt{\frac{0.03646 \text{ in}^4}{1.75 \text{ in}^2}}$
 $r = 0.144$

Determine critical stress

$$\sigma_{cr} = \frac{\pi^2 E}{(L/r)^2} = \frac{\pi^2 \cdot (10 \times 10^6 \frac{\text{lb}}{\text{in}^2})}{(\frac{11.5 \text{ in}}{0.144 \text{ in}})^2}$$

$$\sigma_{cr} = 15.475 \times 10^3 \text{ psi} = 15.48 \text{ ksi}$$

Didn't take slenderness ratio into account for short or long column.

Appendix A 3: Redesigned spindle, short column, and critical load.

Jordan Olson MET 495 11/11/2014 3

Given: Spindle - Weight Optimized Design

- Column loading
- Fixed Pinned, $K=0.7$
- CoCo1 Aluminum (McMaster-Carr)
 - $E = 10 \times 10^6$ psi
 - $\sigma_{yield} = 35,000$ psi
- $M_{riden} = 160$ lb, $M_{bike} = 230$ lb, 5/8 mass on Part
- $L = 11.50$ " , $W = 3.00$ " , $t = 1.00$ "
- S.F. = 2.0

Find:

- Determine Critical load and stress
- Compare to given load and stress

Soln:

(Determine if column needs short or long column analysis)

→ Slenderness Ratio $> C_c$ then long column

Radius of Gyration, $r = \sqrt{\frac{I}{A}}$

Area = $(b)(h) = (1in)(3in)$

$A = 3in^2$

$r = \sqrt{\frac{0.250in^4}{3in^2}}$

$r = 0.289in$

Slenderness Ratio: $SR = \frac{KL}{r} = \frac{(0.7)(11.50in)}{0.289in}$

$SR = 27.855$

$SR < C_c$, since $27.86 < 75.10$

∴ Analyze problem as short column

$P_{cr} = A\sigma_y \left[1 - \frac{\sigma_y (KL/r)^2}{4\pi^2 E} \right]$

$P_{cr} = (3in^2)(35,000 \frac{lb}{in^2}) \left[1 - \frac{(35,000 \frac{lb}{in^2})(27.855)^2}{4\pi^2 (10 \times 10^6 \frac{lb}{in^2})} \right]$

Critical Load: $P_{cr} = 97.7 \times 10^3 lb = 97.7 \text{ kip}$

Thickness, $t = 1.00$ "

$L = 11.50$ "

$W = 3.00$ "

I -values

$I_{a-a} = \frac{bh^3}{12} = \frac{(1in)(3in)^3}{12}$

$I_{a-a} = 2.25in^4$

$I_{b-b} = \frac{bh^3}{12} = \frac{(3in)(1in)^3}{12}$

$I_{b-b} = 0.250in^4$

Use I_{b-b} for lowest critical load & stresses

Column Constant, C_c

$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yield}}} = \sqrt{\frac{2\pi^2 \cdot (10 \times 10^6 \frac{lb}{in^2})}{(35,000 \frac{lb}{in^2})}}$

$C_c = 75.10$

Appendix A 4: Redesigned spindle with determined load and critical stress.

Jordan Olson MET 495 11/11/2014 4

Critical Stress of Spindle:

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{97,700 \text{ lb}}{3 \text{ in}^2}$$

$$\sigma_{cr} = 32,567 \text{ psi} = \boxed{32.56 \text{ ksi}} < \underline{\sigma_{yield} = 35 \text{ ksi}}$$

Comparing to load of Rider & Dirt Bike

$$\text{Total bike mass} = 230 \text{ lbm}$$

$$\text{Total rider mass} = 160 \text{ lbm}$$

$$+ 390 \text{ lbm}$$

$\approx \frac{5}{8}$ of mass over front axle vs rear

$$\therefore 390 \text{ lbm} \left(\frac{5}{8}\right) = 243.75 \text{ lbm} \approx \underline{250 \text{ lbm}}$$

$$M = M_{\text{actual}} \cdot SF = (250 \text{ lbm})(2.0)$$

$$M_{\text{tot}} = \underline{500 \text{ lbm}}$$

$$P_{\text{load}} = M_{\text{tot}} \cdot g = (500 \text{ lbm}) \left(32.2 \frac{\text{ft}}{\text{s}^2}\right) \left(\frac{1 \text{ lbf}}{32.2 \frac{\text{lbm} \cdot \text{ft}}{\text{s}^2}}\right)$$

$$P_{\text{load}} = \underline{500 \text{ lbf}}$$

$$\sigma_{\text{load}} = \frac{P_{\text{load}}}{A} = \frac{500 \text{ lbf}}{3 \text{ in}^2} = 166.7 \text{ psi}$$

$$\sigma_{\text{load}} < \sigma_{cr}$$

$$166.7 \text{ psi} < 32.56 \text{ ksi}$$

$$P_{\text{load}} < P_{cr}$$

$$500 \text{ lb} < 97.7 \text{ kip}$$

Appendix A 5: Spindle deflection due to cornering/turning scenario.

Jordan Olson MET 495 11/11/2014

Given: Spindle Cornering/Turning Analysis

- Dirt bike cornering @ $\theta = 25^\circ$ slope
- $P_{load} = 500 \text{ lbf}$
- $L = 11.50''$, thickness, $t = 1.00''$, $w = 3.00''$

Find:

- Determine bending moment caused by reaction A_x .
- Determine bending stress and deflection.

Soln:

$$A_x = P \sin \theta$$

$$A_x = (500 \text{ lbf}) \sin 25^\circ$$

$$A_x = 211.3 \text{ lbf}$$

$$A_y = (500 \text{ lbf}) \cos 25^\circ$$

$$A_y = 453.2 \text{ lbf}$$

$$M_B = A_x \cdot L$$

$$M_B = (211.3 \text{ lbf})(11.50 \text{ in})$$

$$M_B = 2,430 \text{ lbf} \cdot \text{in}$$

Bending Stress

$$\sigma = \frac{M_b c}{I} \quad I_{b-b} = 0.250 \text{ in}^4$$

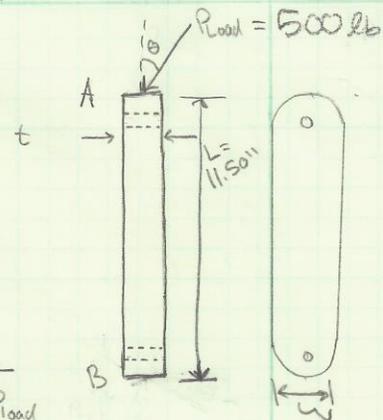
$$\sigma = \frac{(2,430 \text{ lbf} \cdot \text{in})(0.5 \text{ in})}{(0.250 \text{ in}^4)} = 4,860 \text{ psi}$$

Deflection @ point A

$$X_A = X_{max} = \frac{PL^3}{3EI} = \frac{A_x L^3}{3EI_{b-b}}$$

$$X_A = \frac{(211.3 \text{ lbf})(11.50 \text{ in})^3}{3(10 \times 10^6 \frac{\text{lbf}}{\text{in}^2})(0.25 \text{ in}^4)}$$

$$X_A = 42.85 \times 10^{-3} \text{ in} = 0.0429 \text{ in}$$



Appendix A 6: Frictional force and reaction forces/moments from ski on snow.

Jordan Olson MET 495 11/16/2014

Given:
 $V = 30 \text{ mph}$
 $m = 500 \text{ lb}_m$
 $\mu = 0.1 - 0.05$ (use 0.1, since it's higher)
 $E_{\text{steel-Al}} = 10 \times 10^6 \text{ psi}$

Find:

- Frictional force acting on bottom of ski;
- Moment caused at point A
- Max deflection on Spindle if equivalent forced placed at point B & Bending Stress in member.

Soln: Motion, Constant V

FBD

Frictional Force on Ski:

$$+\uparrow \sum F_y = 0: N - mg = 0$$

$$N = mg = (500 \text{ lb}_m) \left(32.2 \frac{\text{ft}}{\text{s}^2} \right) \left(\frac{1 \text{ lbf}}{32.2 \text{ lb}_m \cdot \frac{\text{ft}}{\text{s}^2}} \right)$$

$$N = 500 \text{ lbf}$$

$$+\rightarrow \sum F_x = 0: F_{\text{friction}} = F_{\text{Applied}}$$

$$F_f = \mu N = (0.1)(500 \text{ lbf})$$

$$F_{\text{friction}} = 50 \text{ lbf}$$

$$\therefore F_{\text{App}} = 50 \text{ lbf}$$

Moment caused @ A

$$+\curvearrowright \sum M_A = 0: M_A = F_f \cdot d$$

$$M_A = (50 \text{ lbf})(14.50")$$

$$M_A = 725 \text{ lbf} \cdot \text{in} = 60.4 \text{ lbf} \cdot \text{ft}$$

Equiv. B

$$+\curvearrowright M_A = 0: M_A = F_B \cdot d$$

$$F_B = \frac{M_A}{d} = \frac{725 \text{ lbf} \cdot \text{in}}{11.50 \text{ in}}$$

$$F_B = 63 \text{ lbf}$$

Appendix A 7: Max deflection of spindle through b-b axis.

Jordan Olson MET 495 11/16/2014

Max Deflection of Spindle

$$I_{aa} = \frac{b h^3}{12} = \frac{1.00 \text{ in} (3.00 \text{ in})^3}{12}$$

$$I_{aa} = 2.25 \text{ in}^4$$

$$X_B = X_{\max} = \frac{P L^3}{3 E I} = \frac{F_B L^3}{3 E I}$$

$$X_{\max} = \frac{(632 \text{ lbf}) (11.50 \text{ in})^3}{3 (10 \times 10^6 \frac{\text{lbf}}{\text{in}^2}) (2.25 \text{ in}^4)}$$

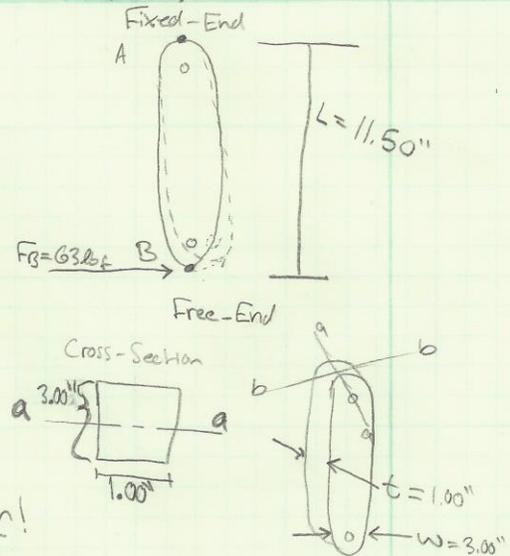
$$X_{\max} = 0.00142 \text{ in}$$

← negligible deflection!

Bending Stress

$$\sigma = \frac{M c}{I} = \frac{(725 \text{ lbf} \cdot \text{in}) (1.5 \text{ in})}{(2.25 \text{ in}^4)} = 483 \text{ psi}$$

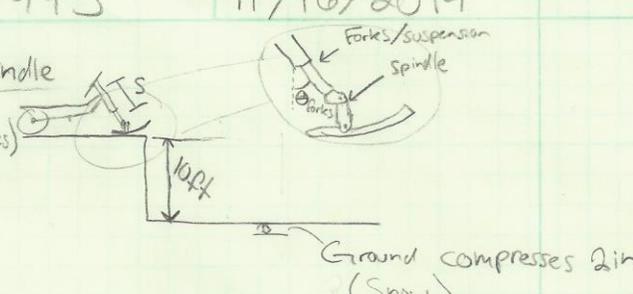
← negligible stress!



Appendix A 8: Shock load/force on spindle.

Jordan Olson MET 495 11/16/2014

Given: Shock Load on Spindle



$k_{forks} = 0.430 \frac{kg}{mm} = 24.08 \frac{lb}{in}$ (2 forks)
 $\theta_{forks} = 26.5^\circ$ (2005 Cr250)
 $m = 500 lb_m$ (rider & bike)
 $g = 32.2 \frac{ft}{s^2}$
 $S_{spr} = 12.5 in$, $S_{grnd} = 2 in$

Find:

- Force acting on column from impact
- Stress in column

Soln:

Force in Spring

$$mgh = \frac{1}{2} (k+k) x^2 \Rightarrow x = \sqrt{\frac{2mgh}{2k}}$$

$$x = \sqrt{\frac{(500 lb_m)(32.2 \frac{ft}{s^2})(10 ft)(12 lb_m \cdot ft}{s^2})}{(24.08 \frac{lb}{in})(12)}} = 4.16 ft = 49.92 in > 12.5 in$$

of fork springs

$F = kx \rightarrow F = 2kx = 2(24.08 \frac{lb}{in})(12.5 in)$

$F = 600 lb_f$

More than enough energy to compress front forks (suspension)

Energy harnessed before bottoming out

Force impact > Force absorbed in spring?

main equations

$$KE = \frac{1}{2} m v_y^2$$

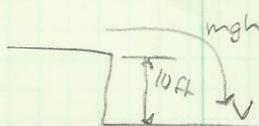
$$PE = KE$$

$$mgh = \frac{1}{2} m v_y^2$$

$$Work = F \cdot S_{gr}$$

$$PE = mgh$$

$$v_y = \sqrt{2gh} = \sqrt{2(32.2 \frac{ft}{s^2})(10 ft)}$$

$$v_y = 25.37 \frac{ft}{s} = 25.4 \frac{ft}{sec}$$


Work = KE

$$F \cdot S_{gr} = \frac{1}{2} m v_y^2$$

$$F_{impact} = \frac{m v_y^2}{2 S_{gr}} = \frac{(500 lb_m)(25.4 \frac{ft}{s})^2}{2(2 in)(\frac{1 ft}{12 in})} = 967,740 lb_m \cdot \frac{ft}{s^2} \left(\frac{1 lb_f}{1 lb_m \cdot 32.2 \frac{ft}{s^2}} \right)$$

$F_{impact} = 30,054 lb_f$

Appendix A 9: Critical load and stress from shock load on spindle.

Jordan Olson | MET 495 | 11/16/2014

$$P_{load} = F_{impact} = 30,054 \text{ lbf}$$

$$P_{load} < P_{cr}$$

$$30.05 \text{ kip} < 97.7 \text{ kip}$$

Reference
Appendix A-Page 3 & 4

Stress in column

$$\sigma_{load} = \frac{P_{load}}{A} = \frac{30,054 \text{ lbf}}{3 \text{ in}^2}$$

$$\sigma_{load} = 10,018 \text{ psi} \approx 10.02 \text{ ksi}$$

∴

$$\sigma_{load} < \sigma_{cr}$$

$$10.02 \text{ ksi} < 32.56 \text{ ksi}$$

This was a worst case scenario only taking into account the compression of the ground/snow. The P_{load} & σ_{load} figures would be much lower if the spring/suspension compression distance was used.

Appendix A 10:

Inclined hill total impact force.

Jordan Olson MET 495 11/16/2014 10

Given: Approaching an inclined hill/impact

$$\theta = 30^\circ$$

$$V_i = 25 \text{ mph} = 36.7 \frac{\text{ft}}{\text{sec}}$$

$$V_f = 20 \text{ mph} = 29.3 \frac{\text{ft}}{\text{sec}}$$

$$M = 500 \text{ lbm}$$

$$S_{sp} = 6 \text{ in}, k_{fork} = 24.08 \frac{\text{lb}}{\text{in}}$$

$$g = 32.2 \frac{\text{ft}}{\text{sec}^2}$$

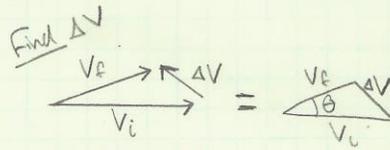
$$\Delta t_{\text{impact}} = 0.1 \text{ sec}$$

Find:

- Force of impact
- Determine horizontal force on bottom of column.
- Resultant Moment @ top of spindle

Soln:

$$F = \frac{d(mv)}{dt} = m \frac{\Delta V}{\Delta t}$$



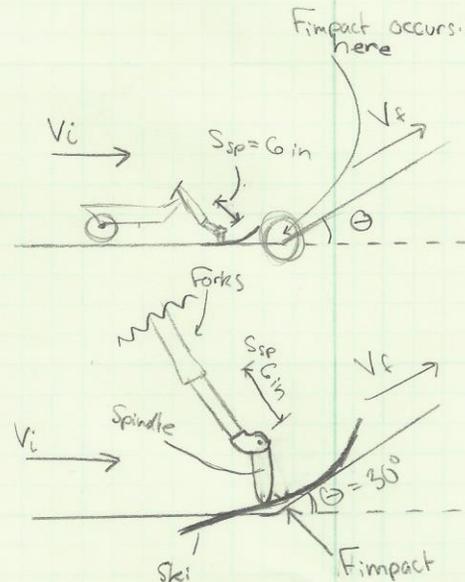
$$\Delta V^2 = V_i^2 + V_f^2 - 2V_i V_f \cos \theta$$

$$\Delta V = \sqrt{(36.7 \frac{\text{ft}}{\text{s}})^2 + (29.3 \frac{\text{ft}}{\text{s}})^2 - 2(36.7 \frac{\text{ft}}{\text{s}})(29.3 \frac{\text{ft}}{\text{s}}) \cos 30^\circ}$$

$$\Delta V = 18.52 \frac{\text{ft}}{\text{s}}$$

$$F = (500 \text{ lbm}) \left(\frac{18.52 \frac{\text{ft}}{\text{s}}}{0.1 \text{ sec}} \right) = \left(92,600 \text{ lbm} \cdot \frac{\text{ft}}{\text{sec}^2} \right) \left(\frac{1 \text{ lbf}}{1 \text{ lbm} \cdot 32.2 \frac{\text{ft}}{\text{sec}^2}} \right)$$

$$F = 2875 \text{ lbf} \approx 2900 \text{ lbf}$$



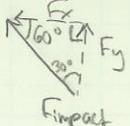
Appendix A 11:

Inclined hill horizontal force and resultant torque/moment.

Jordan Olson | MET 495 11/16/2014 11

Determining horizontal force (F_x)
on Spindle Column

$F_{\text{impact}} = 2900 \text{ lbf}$



$$\sin 30^\circ = \frac{F_x}{F_{\text{imp}}}$$

$$\therefore F_x = F_{\text{impact}} \sin 30^\circ$$

$$F_x = 2900 \text{ lbf} \sin 30^\circ$$

$$F_x = 1450 \text{ lbf}$$

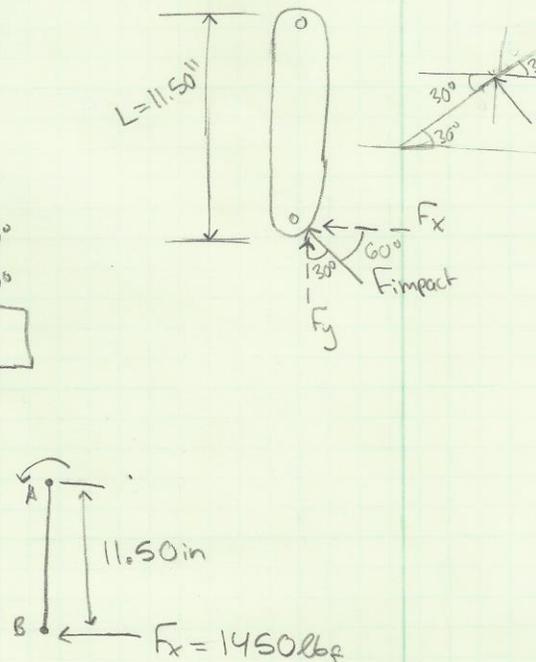
Finding the
Resultant Moment/Torque

$$T_A = M_A = F_x \cdot d$$

$$T_A = (1450 \text{ lbf})(11.50 \text{ in})$$

$$T_A = 16,675 \text{ lbf} \cdot \text{in}$$

$$T_A = 1390 \text{ lbf} \cdot \text{ft}$$



Appendix A 12:

Determining the required spindle bolt diameter.

Jordan Olson MET 495 11/16/2014 12

Given: Determining Spindle Bolt Size

Double-shear
 $N_{bolts} = 4$
 $r = 0.95 \text{ in}$
 $T = 16,675 \text{ lbf} \cdot \text{in}$
 Type 316 Stainless Steel Bolts
 - Tensile Strength = 70,000 psi
 - Shear Strength = $0.6 \cdot T_S = 42,000 \text{ psi}$
 Safety Factor = 1.5

Find:
 - Design Shear strength
 - Required Bolt Diameter

Soln:

$\tau_{fail} = \tau_{allow} \cdot SF$

$\tau_{allow} = 42,000 \text{ psi}$

Cross-Sectional Area of bolt = $\frac{\pi}{4} D^2$

$\tau_{allow} = \frac{V}{A} = \frac{V}{\frac{\pi}{4} D^2} \Rightarrow \frac{\pi D^2}{4} = \frac{V}{\tau}$

$D_{bolt} = \sqrt{\frac{4V}{\pi \tau_{allow}}}$

Find load V from Torque per bolt

$T = V \cdot r \Rightarrow V = \frac{T}{r} = \frac{16,675 \text{ lbf} \cdot \text{in}}{0.95 \text{ in}}$

$V_{total} = 17,552 \text{ lbf}$

$V_{bolt} = \frac{17,552 \text{ lbf}}{4 \text{ bolts}} \Rightarrow V_{bolt} = 4,388 \text{ lbf}$

$D_{bolt} = \sqrt{\frac{4(4,388 \text{ lbf})}{\pi(42,000 \frac{\text{lbf}}{\text{in}^2})}} \Rightarrow D_{bolt} = 0.365$

Choose nominal size of $0.375 \text{ in} = \frac{3}{8}''$

Appendix A 13:

Determining the required fork bracket bolt diameter.

Jordan Olson MET 495 11/16/2014 13

Given: Determining Fork Bracket Bolt Size

Single-shear

$$N_{\text{bolts}} = \frac{2 \text{ bolts}}{\text{bracket}} \cdot 2 \text{ brackets} = 4 \text{ bolts}$$

$$r = 2.75 \text{ in}$$

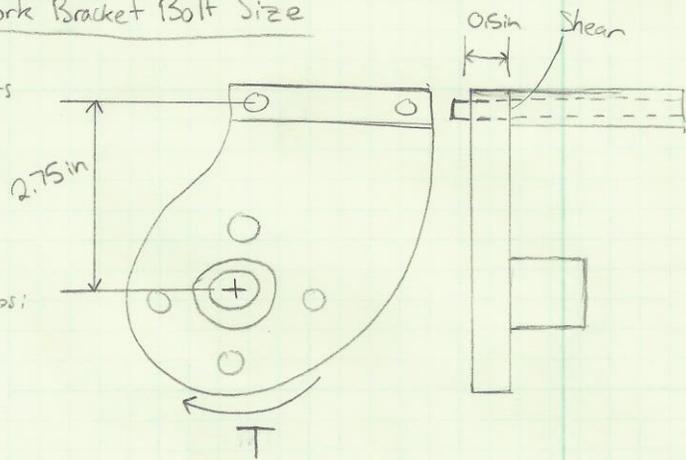
$$T = 16,675 \text{ lbf} \cdot \text{in}$$

Type 316 SS Bolts

$$\text{- Tensile Strength} = 70,000 \text{ psi}$$

$$\text{- Shear Strength} = 0.6 \cdot TS = 42,000 \text{ psi}$$

$$\text{Safety Factor} = 1.5$$



Find:

- Design Shear Strength
- Required bolt Diameter

Soln:

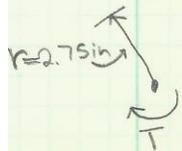
$$\tau_{\text{allow}} = 42,000 \text{ psi}$$

$$\text{Cross-sectional Area of bolt} = \frac{\pi}{4} D^2$$

$$\tau_{\text{allow}} = \frac{V}{A} = \frac{V}{\frac{\pi}{4} D^2} \Rightarrow \frac{\pi}{4} D^2 = \frac{V}{\tau_{\text{allow}}}$$

$$D_{\text{bolt}} = \sqrt{\frac{4V}{\pi \tau_{\text{allow}}}}$$

Find load V from Torque per bolt



$$T = V \cdot r \Rightarrow V = \frac{T}{r} = \frac{16,675 \text{ lbf} \cdot \text{in}}{2.75 \text{ in}}$$

$$V_{\text{total}} = 6063 \text{ lbf}$$

$$V_{\text{bolt}} = \frac{6063 \text{ lbf}}{4 \text{ bolts}} \Rightarrow V_{\text{bolt}} = 1515 \text{ lbf}$$

$$V_{\text{bolt}} \approx 1520 \text{ lbf}$$

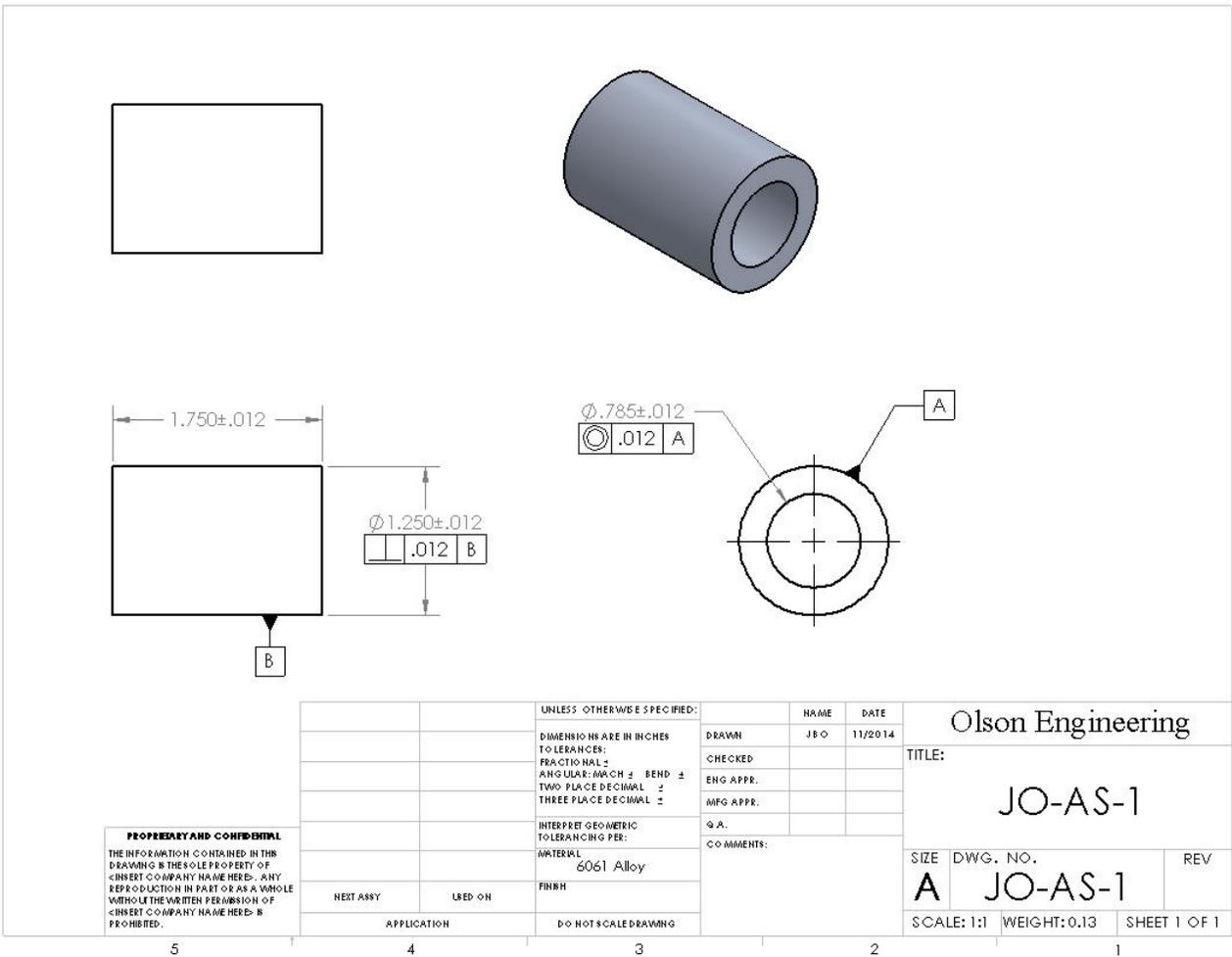
$$D_{\text{bolt}} = \sqrt{\frac{4(1520 \text{ lbf})}{\pi (42,000 \frac{\text{lb}}{\text{in}^2})}} \Rightarrow D_{\text{bolt}} = 0.2146 \text{ in}$$

Choose nominal size of 0.25 in = 1/4"

APPENDIX B – Sketches, Drawings, Part Drawings & Assembly Drawings

Appendix B 1:	Axle Shaft Drawing	42
Appendix B 2:	Fork Clamp (Large) Drawing	43
Appendix B 3:	Fork Clamp (Small) Drawing	44
Appendix B 4:	Fork Clamp Extension Drawing	45
Appendix B 5:	Spindle Drawing	46
Appendix B 6:	Fork Bracket Drawing	47
Appendix B 7:	Ski Shaft Drawing	48
Appendix B 8:	Main Assembly Drawing	49

Appendix B 1: Axle Shaft Drawing

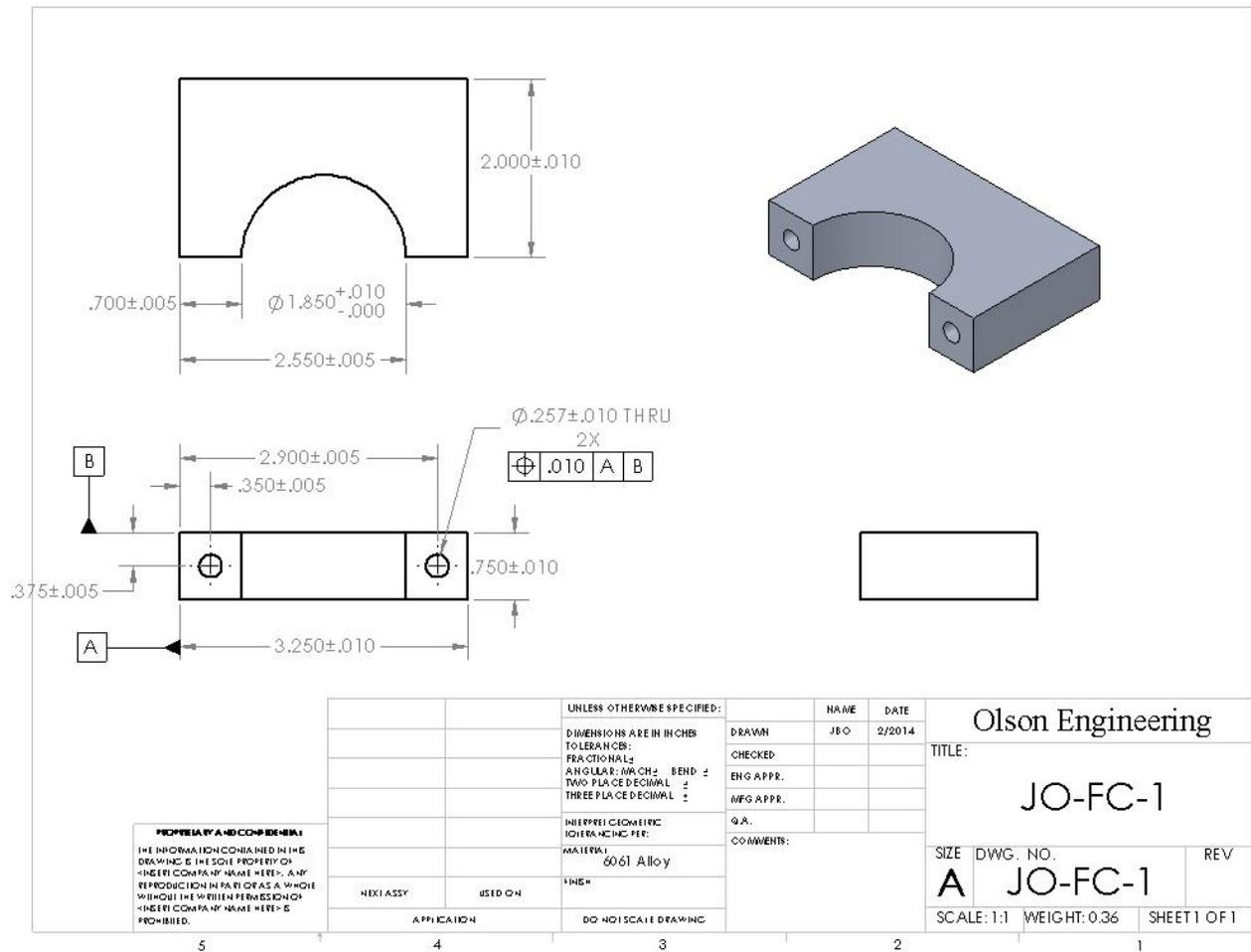


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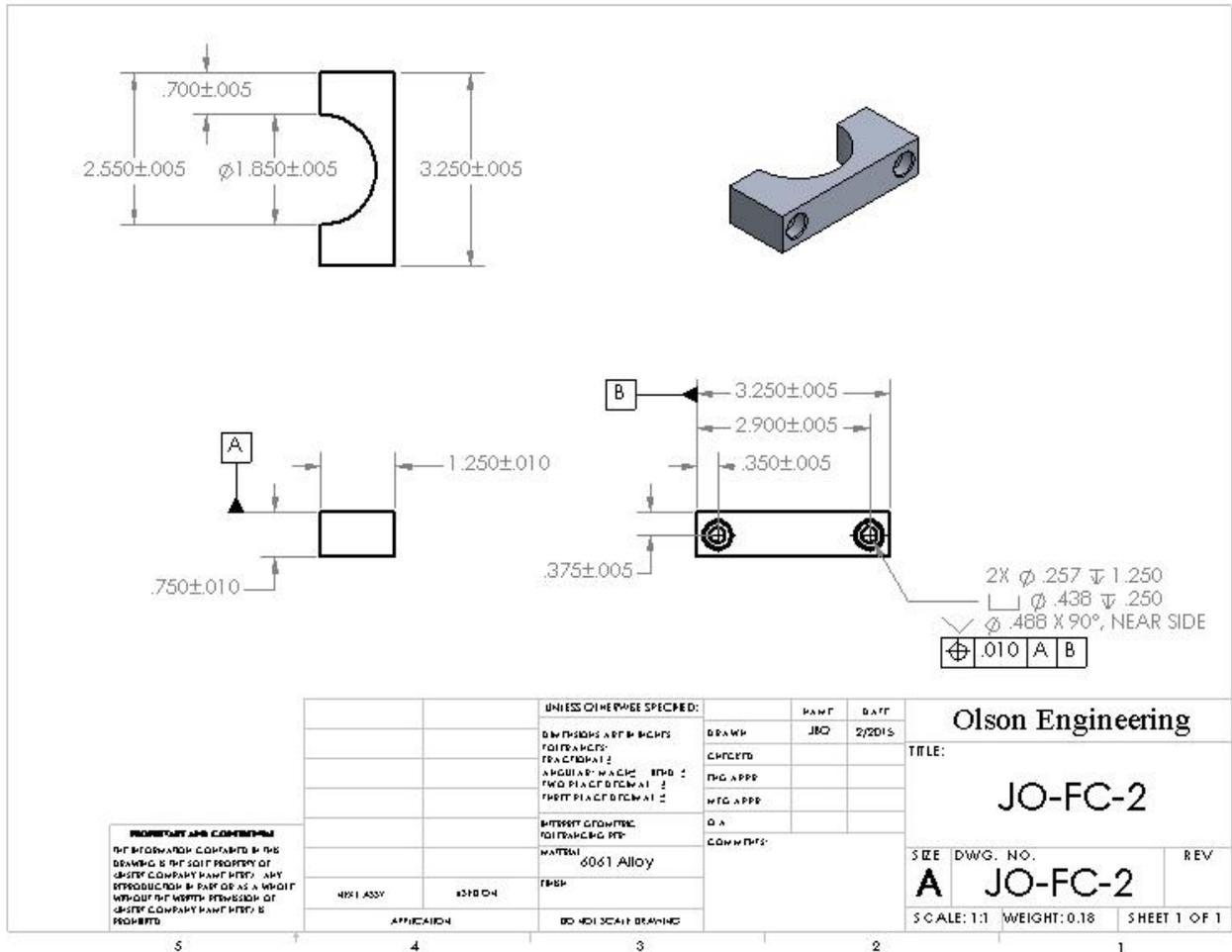
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	Olson Engineering	
		DIMENSIONS ARE IN INCHES		DRAWN	JB	11/2014	TITLE:
		TOLERANCES:		CHECKED			JO-AS-1
		FRACTIONAL ±		ENG APPR.			
		ANGULAR: BACH ± BEND ±		MFG APPR.			
		TWO PLACE DECIMAL ±		Q.A.			
		THREE PLACE DECIMAL ±		COMMENTS:			
		INTERPRET GEOMETRIC TOLERANCING PER:					SIZE DWG. NO. REV
		MATERIAL					A JO-AS-1
NEXT ASSY		USED ON					SCALE: 1:1 WEIGHT: 0.13 SHEET 1 OF 1
APPLICATION		FINISH					
		D= NOT SCALED DRAWING					

5 4 3 2 1

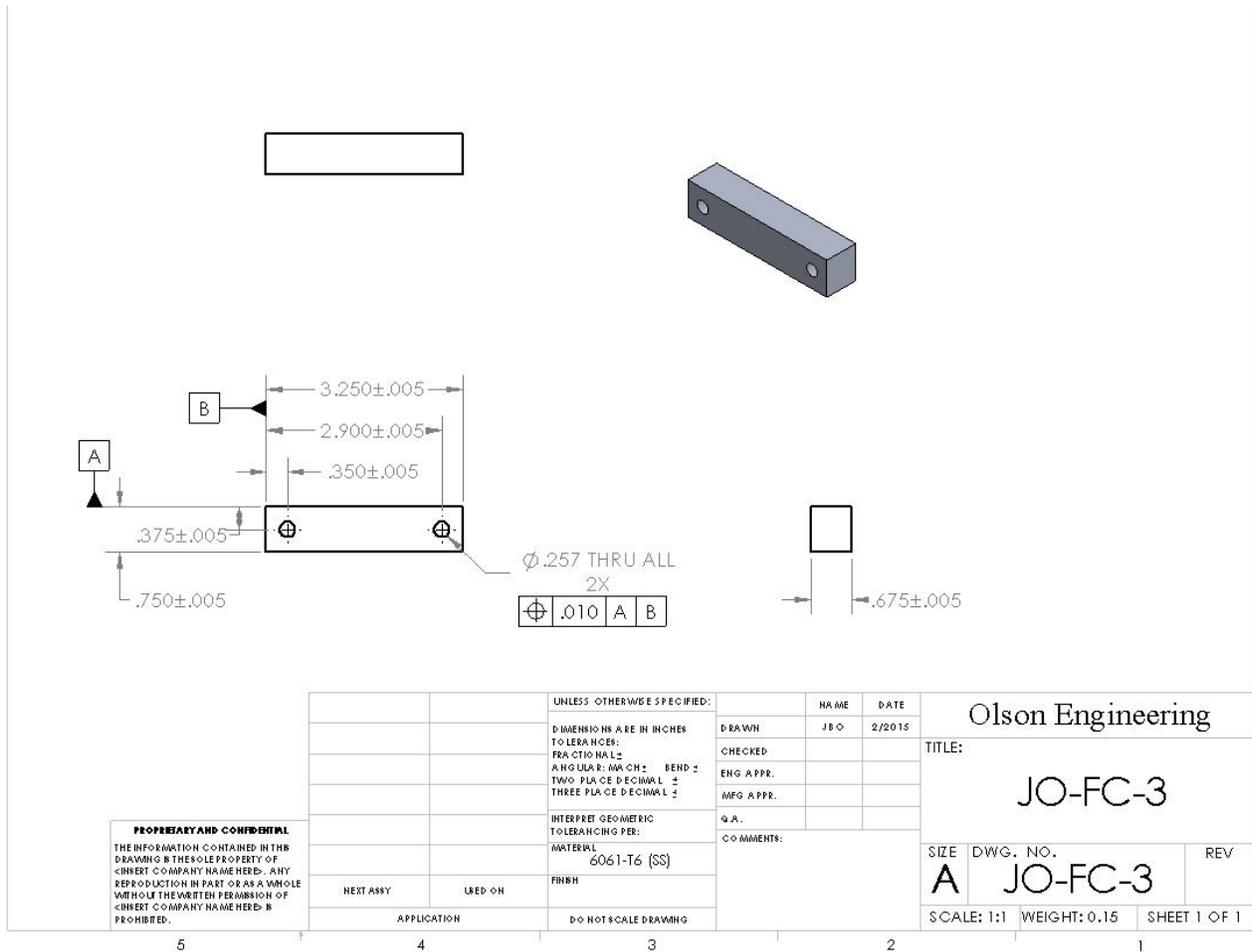
Appendix B 2: Fork Clamp (Large) Drawing



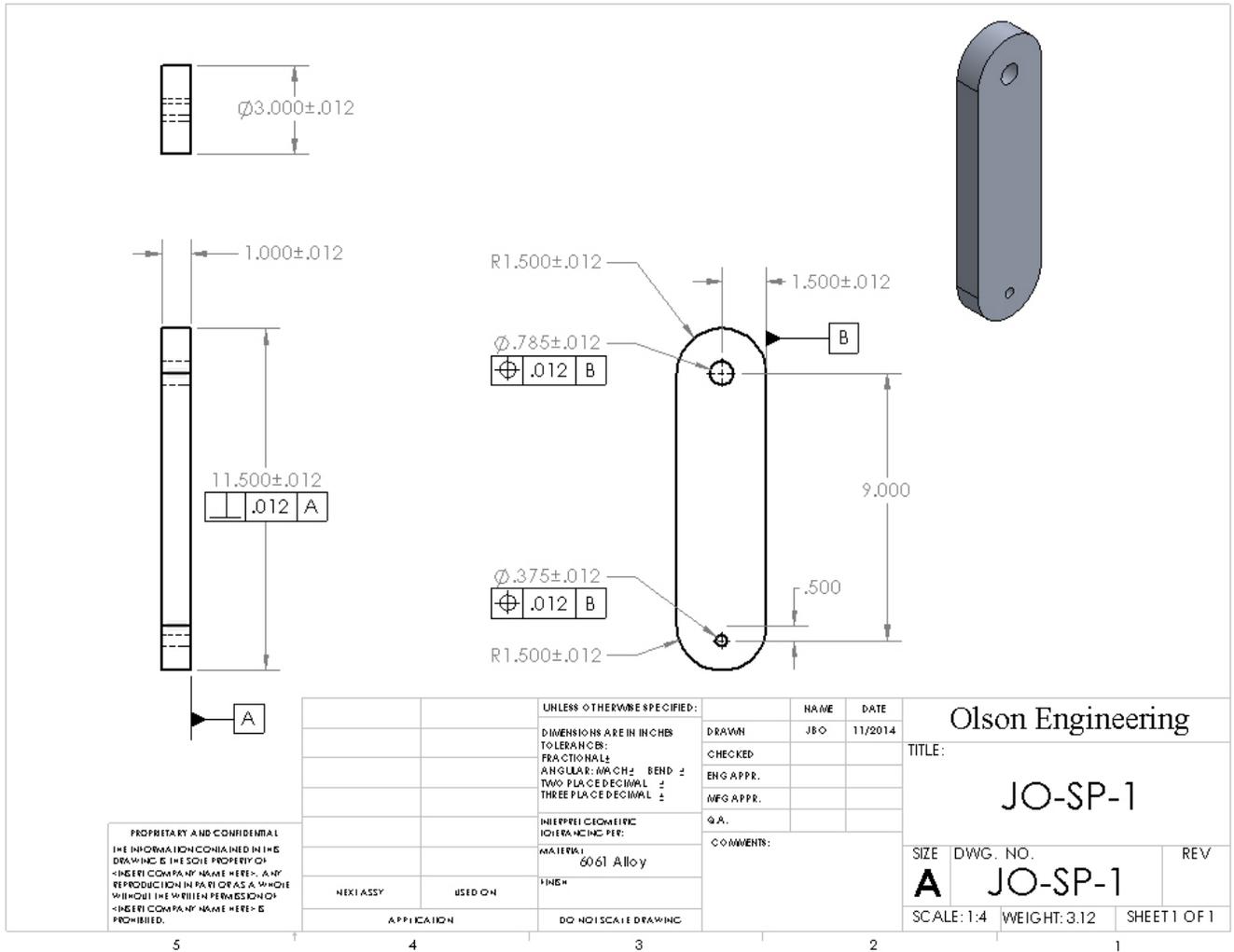
Appendix B 3: Fork Clamp (Small) Drawing



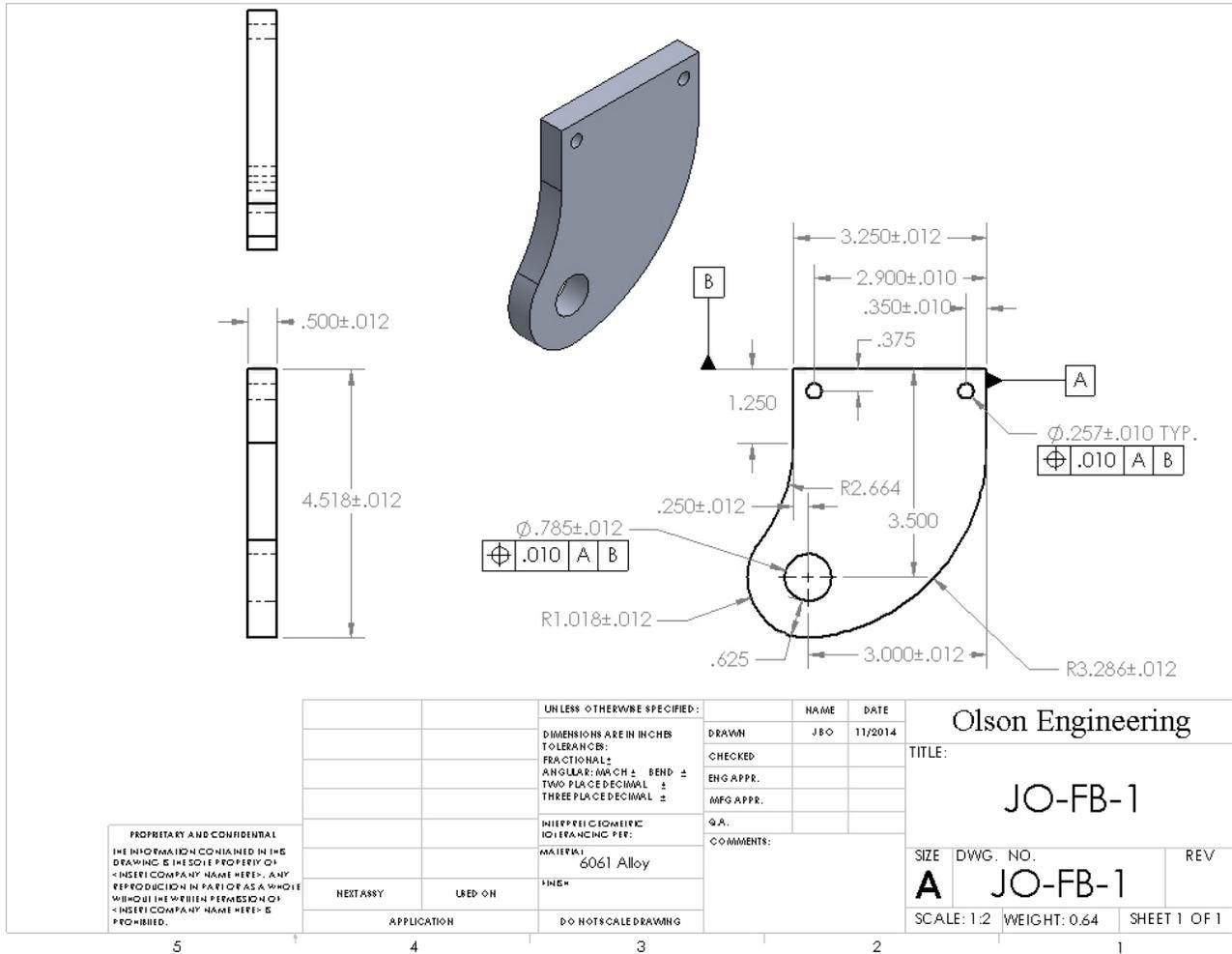
Appendix B 4: Fork Clamp Extension Drawing



Appendix B 5: Spindle Drawing



Appendix B 6: Fork Bracket Drawing

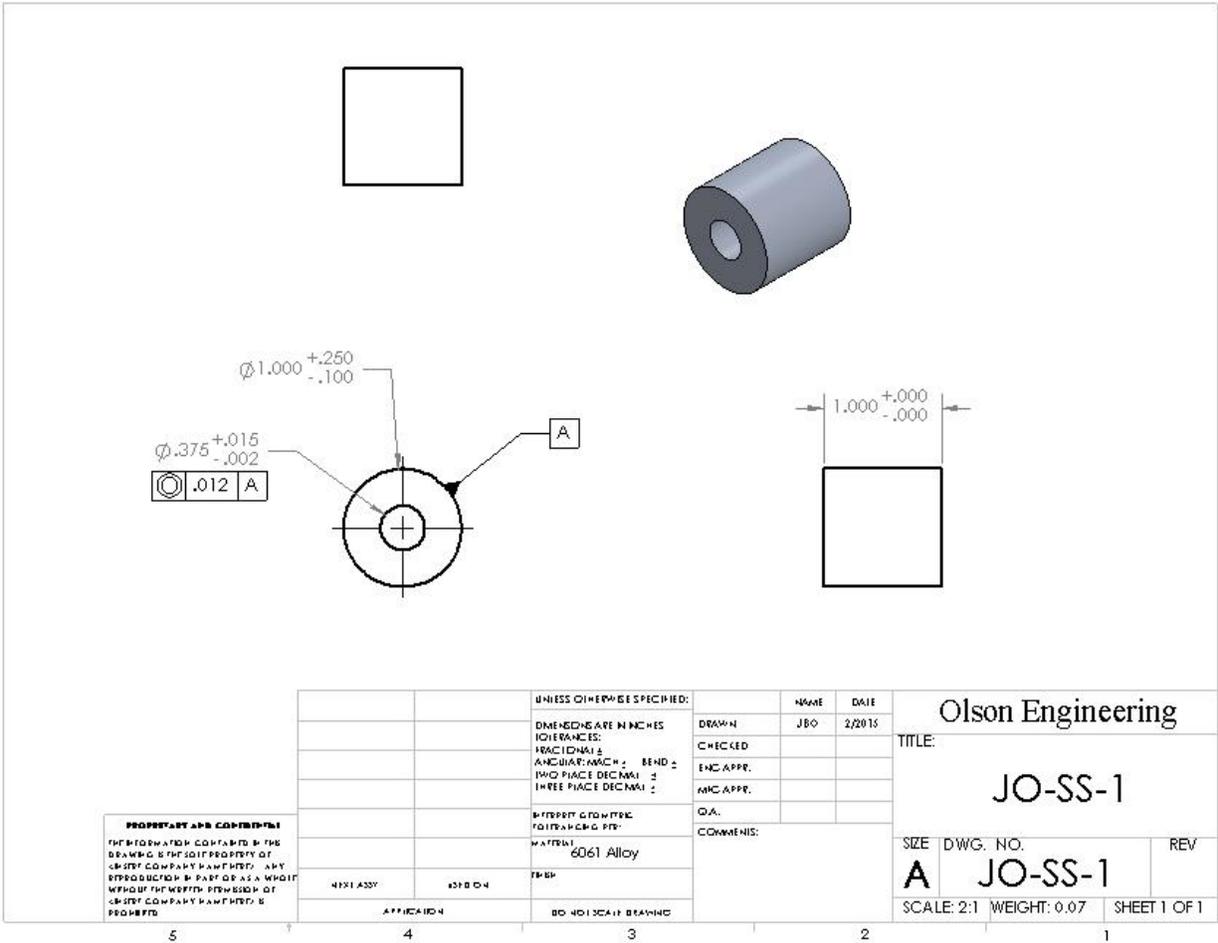


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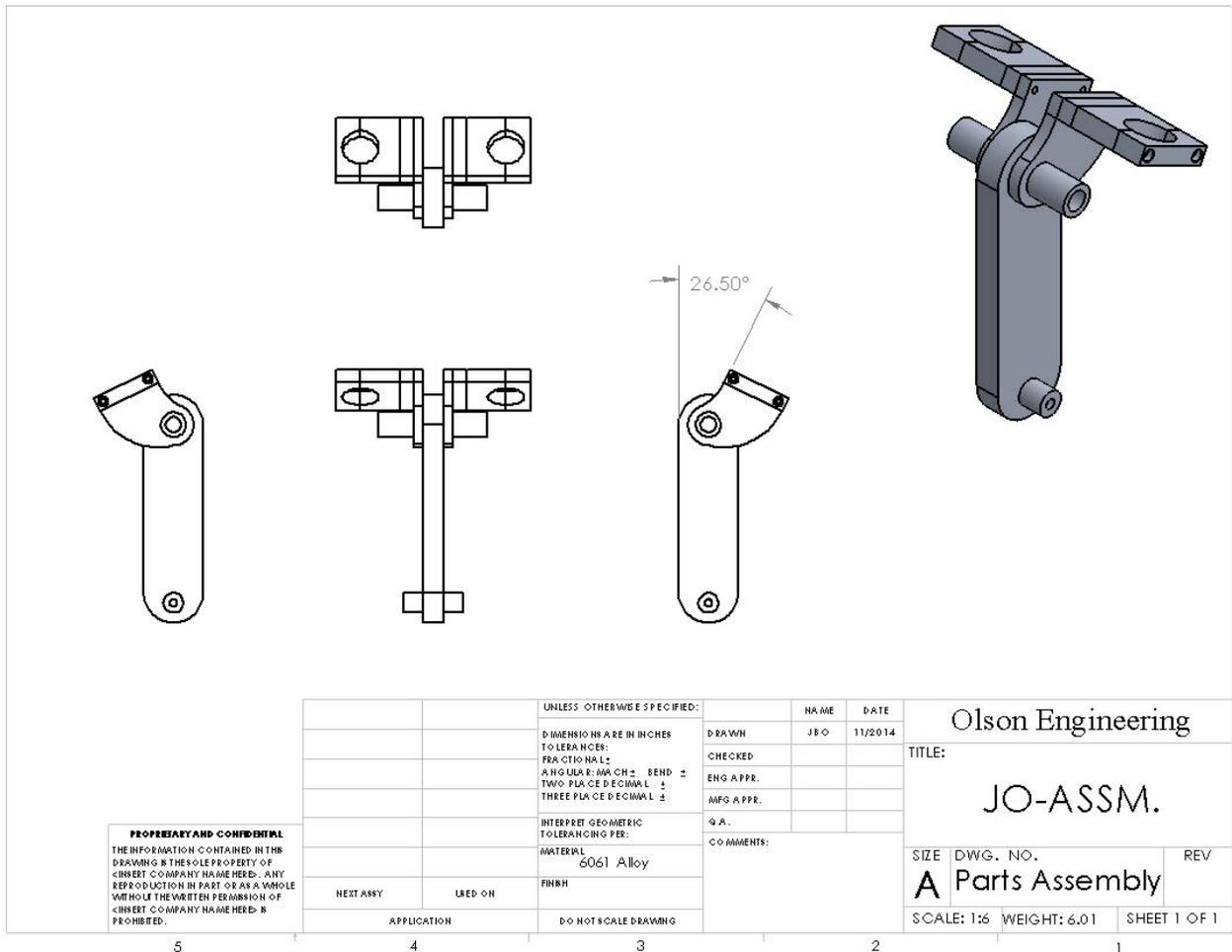
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES		DRAWN	JB
		TOLERANCES:		CHECKED	11/2014
		FRACTIONAL:		ENG APPR.	
		ANGULAR: EACH ± BEND ±		MFG APPR.	
		TWO PLACE DECIMAL ±		Q.A.	
		THREE PLACE DECIMAL ±		COMMENTS:	
		INTERPRETOMETRIC TOLERANCING PER:			
		MATERIAL:			
		6061 Alloy			
		FINISH:			
		DO NOT SCALE DRAWING			
5	4	3	2	1	

Olson Engineering		
TITLE:		
JO-FB-1		
SIZE	DWG. NO.	REV
A	JO-FB-1	
SCALE: 1:2	WEIGHT: 0.64	SHEET 1 OF 1

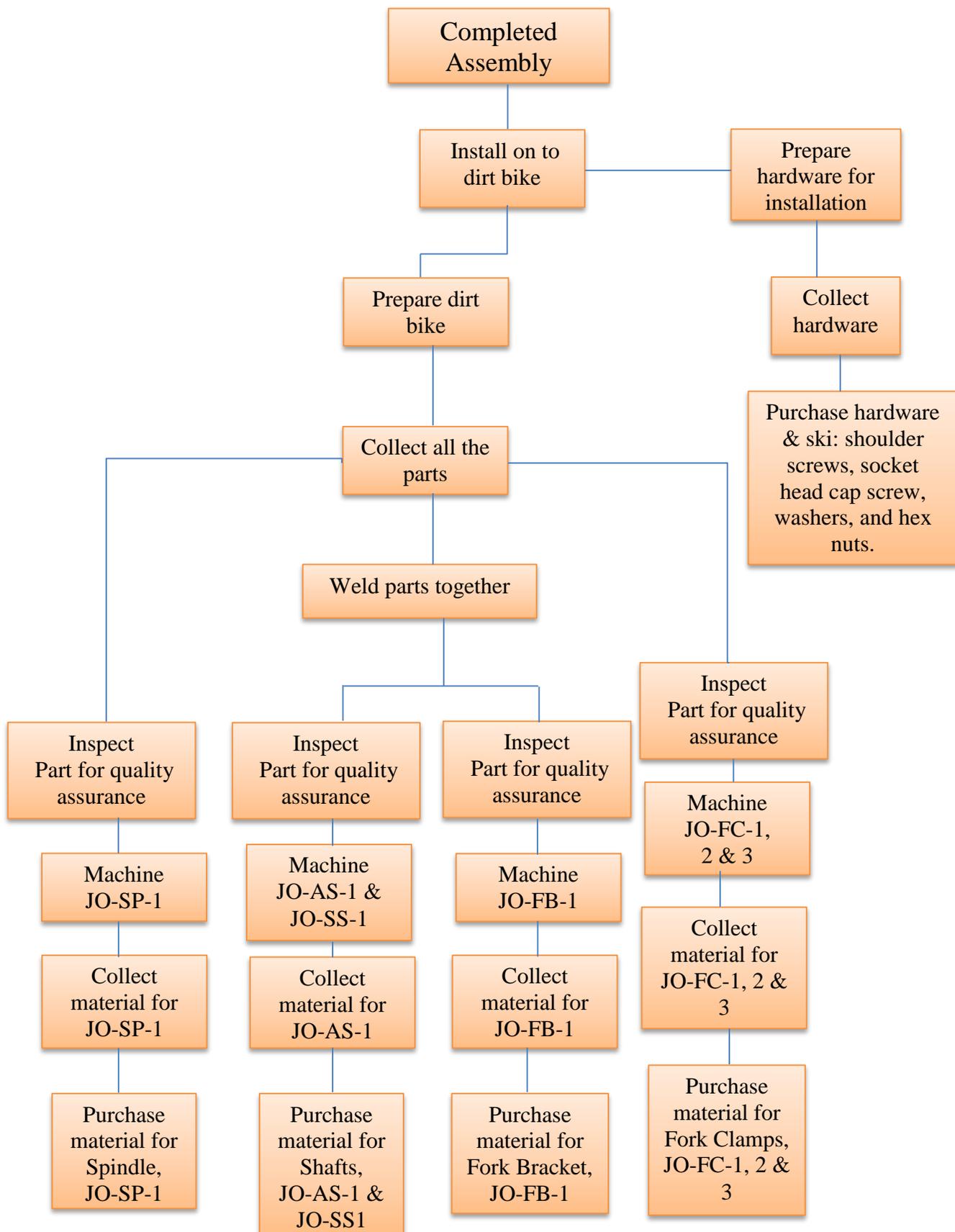
Appendix B 7: Ski Shaft Drawing



Appendix B 8: Main Assembly Drawing



APPENDIX C – Drawing Tree



APPENDIX D – Parts List and Costs

Appendix D 1:	Parts List:	51
Appendix D 2:	Cost & Raw Material List:.....	52

Appendix D 1: Parts List:

MX SnowSki Parts List		
Item No.	Description	Quantity
JO-SP-1	Spindle/Column	1
JO-AS-1	Axle Shaft	2
JO-FB-1	Fork Bracket	2
JO-FC-1	Fork Clamp Inner (Large)	2
JO-FC-2	Fork Clamp Outer (Small)	2
JO-FC-3	Fork Clamp Extension	2
JO-SS-1	Ski Shaft	2
TS-SK-1	Timbsled/Simmons Ski	1

Appendix D 2: Cost & Raw Material List:

Item # / Part #	Description	Material	Cost of Raw Material	Quantity	Location of Purchase	Total Cost	Actual Cost
JO-SP-1 / 8975K239	Spindle/ Column	Rectangular Bar per ft: 1" Thick, 3" Wide	\$ 24.34	1	McMaster-Carr/ Online Metals	\$ 24.34	\$ 16.23
JO-AS-1 / 9056K29	Axle Shaft	Round Tube per 1/2': 1.25" - OD, 3/4" - ID 6061	\$ 7.50	1	McMaster-Carr/ Online Metals	\$ 7.50	\$ 4.91
JO-FB-1 / 8975K215	Fork Bracket	Rectangular Bar per ft: 1/2" Thick, 4" Wide	\$ 19.05	1	McMaster-Carr/ Online Metals	\$ 19.05	\$ 10.82
JO-FC-1 / 8975K78	Fork Clamp Inner (Large)	Rectangular Bar per 1/2': 3/4" Thick, 2" Wide	\$ 8.71	2	McMaster-Carr/ Online Metals	\$ 17.42	\$ 7.28
JO-FC-2 / 8975K486	Fork Clamp Outer (Small)	Rectangular Bar per 1/2': 3/4" Thick, 1.25" Wide	\$ 5.57	2	McMaster-Carr/ Online Metals	\$ 11.14	\$ 4.56
JO-FC-3 / 8975K486	Fork Clamp Extension	Rectangular Bar per 1/2': 3/4" Thick, 2" Wide	\$ 5.57	1	McMaster-Carr/ Online Metals	\$ 5.57	\$ 0.00
JO-SS-1	Ski Shaft	Round Rod per 10"-12":	\$ 4.21	1	Online Metals	\$ 4.21	\$ -
TS-SK-1	Timbsled/ Simmons Ski	Tivar - UHMW PE	\$ 441.85	1	IceAge Manufacturing	\$ 441.85	\$ 441.85
97345A656	Spindle Shoulder Screw	3/8" Dia X2" Long & Type 316 SS	\$ 7.07	4	McMaster-Carr	\$ 28.28	\$ 28.28
92185A512	Socket Head Cap Screw	1/4"-20 X4.5" Long & Type 316 SS	\$ 2.49	4	McMaster-Carr	\$ 9.96	\$ 9.96
93286A045	Washer - Spindle	3/8" - ID, 5/8" - OD 6061-T6	\$ 0.63	4	McMaster-Carr	\$ 2.50	\$ 2.50
93286A044	Washer - Fork Clamps	1/4" - ID, 1/2" - OD 6061-T6	\$ 1.50	4	McMaster-Carr	\$ 5.98	\$ -
94804A030	Hex Nut - Spindle	5/16"-18 Type 316 SS	\$ 0.13	4	McMaster-Carr	\$ 0.54	\$ -
94804A029	Hex Nut - Clamp	1/4"-20 Type 316 SS	\$ 0.09	4	McMaster-Carr	\$ 0.36	\$ -
					Shipping & Handling	\$ 40.00	\$ 24.18
					TOTAL:	\$ 618.70	\$ 550.57

*Item # - Will be used primarily to identify parts being designed/bought for project.

**Part # - The physical identity number of the material or hardware to be bought from the "Location of Purchase" website. This number will be used to identify hardware in the drawing section that doesn't have a corresponding "Item #".

APPENDIX E – Schedule

MX SnowSki																																							
Principal Investigator: Jordan Olson																																							
Task	Description	Est. Time (hrs)	Act. Time (hrs)	SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER			JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE								
				9/22/2014	9/29/2014	10/6/2014	10/13/2014	10/20/2014	10/27/2014	11/3/2014	11/10/2014	11/17/2014	11/24/2014	12/1/2014	12/8/2014	12/15/2014	12/22/2014	12/29/2014	1/5/2015	1/12/2015	1/19/2015	1/26/2015	2/2/2015	2/9/2015	2/16/2015	2/23/2015	3/2/2015	3/9/2015	3/16/2015	3/23/2015	3/30/2015	4/6/2015	4/13/2015	4/20/2015	4/27/2015	5/4/2015	5/11/2015	5/18/2015	5/25/2015
1	<u>Proposal</u>																																						
1a	Outline	4.0	6.0	[Red]																																			
1b	Introduction	5.0	10.0	[Yellow]																																			
1c	Methods	5.0	5.0				[Blue]																																
1d	Analysis	7.0	9.0				[Green]																																
1e	Discussion	4.0	2.2							[Orange]																													
1f	Parts and Budget	2.0	5.0							[Purple]																													
1g	Drawings	8.0	12.0	[Red]																																			
1h	Schedule	8.0	5.5	[Yellow]																																			
1i	Summary & Appendix	6.0	3.0	[Green]																																			
	Subtotal:	49.0	57.7																																				
2	<u>Analysis</u>																																						
2a	Spindle First Design	1.5	2.5				[Blue]																																
2b	Spindle Weight Optimized	1.0	2.5				[Green]																																
2c	Spindle Turning/Cornering	2.0	2.0				[Orange]																																
2d	Friction Force on Ski	1.0	1.0				[Purple]																																
2e	Spindle Max Deflection	2.0	2.0				[Red]																																
2f	Spindle Shock Load	2.0	3.0				[Yellow]																																
2g	Inclined Hill Impact	1.0	2.0				[Blue]																																
2h	Spindle Bolt Size	2.0	2.0				[Green]																																
2i	Fork Bracket Bolt Size	2.0	2.0				[Orange]																																
	Subtotal:	14.5	19.0																																				
3	<u>Documentation</u>																																						
3a	Drawing: JO-SP-1 (Spindle)	2.0	1.5							[Purple]																													
3b	Dwg: JO-AS-1 (Axle Shaft)	1.0	0.5							[Red]																													
3c	Dwg: JO-FB-1 (Fork Bracket)	2.0	1.4							[Yellow]																													
3d	Dwg: JO-FC-1 (Fork Clamp Inner)	2.0	0.6							[Blue]																													
3e	Dwg: JO-FC-2 (Fork Clamp Outer)	2.0	0.5							[Green]																													
3f	Dwg: JO-FC-3 (Fork Clamp Ext.)	0.5	0.2										[Red]																										
3g	Dwg: JO-SS-1 (Ski Shaft)	0.5	0.4													[Purple]																							
3h	ANSI Y14.5 Compliant	6.0	2.2													[Orange]																							
	Subtotal:	16.0	7.3																																				
4	<u>Proposal Modifications</u>																																						
4a	Project Schedule	3.0	1.8																[Purple]																				
4b	Project Parts List/Invoice	2.0	1.4																			[Red]																	
4c	Critical Design Review*	8.0	2.4																			[Yellow]																	
	Subtotal:	13.0	5.6																																				

APPENDIX F – Expertise & Resources

Mentors:

Dr. Craig Johnson
Prof. Charles Pringle
Prof. Roger Beardsley
Mr. Burvee
Mr. Michael LeBlanc

Books/Resources:

Mark's Standard Handbook for Mechanical Engineering: 11th Edition
Machine Elements in Mechanical Design: Fifth Edition

Businesses/Associations/Organizations:

Central Washington University

APPENDIX G – Evaluation Sheet

SnowSki Evaluation

Evaluator: _____

Function Tests:

Task:	Expectation:	Date & Time Performed:	Performance/ Results:	Pass or Fail (P/F):	Description:
Total Weight of Assembly	10 lbs				
Ski Rotation: Incline	20-45°				
Ski Rotation: Decline	15-30°				
Spindle Rotation	$\leq 2^\circ$				
Column Load	500 lbs				

Evaluator: _____
 Testing Compound/Location: _____
 Riding Conditions (Terrain/weather): _____

Test Ride:

Task:	Date & Time Performed:	Pass or Fail (P/F):	Description:
Support bike and rider, whilst tracking through the snow			
Low speed turns			
High speed turns			
Proper function of front suspension/forks			
Ski must slide forward in the proper direction with ease			
Handling: Tight turns			
Handling: Wide sweeping turns			

APPENDIX H – Testing Report

**Refer to Testing Method Section **

APPENDIX I – Testing Data

Function Tests:

Task:	Expectation:	Date & Time Performed:	Performance/ Results:	Pass or Fail (P/F):	Description:
Total Weight of Assembly	10 lbs	5/20/2015	6.7 lbs	P	The parts were assembled and weighed on a scale. (Included bolts/hardware, no ski.)
Ski Rotation: Incline	20-45°	4/17/2015	37.5°	P	Bike was elevated on stand so ski could rotate freely. Angle finder was measurement tool.
Ski Rotation: Decline	15-30°	4/17/2015	25°	P	Bike was elevated on stand so ski could rotate freely. Angle finder was measurement tool.
Spindle Rotation	$\leq 2^\circ$	4/17/2015	0°	P	Spindle didn't rotate. Fit was snug. Therefore, no measurement tool was needed.
Column Load	500 lbs	N/A	Not performed. Need proper work holding.	N/A	Column experienced ~400lb load when bike performed endo during test ride.

Test Ride:

<u>Task:</u>	<u>Date & Time Performed:</u>	<u>Pass or Fail (P/F):</u>	<u>Description:</u>
<u>Support bike and rider, whilst tracking through the snow</u>	<u>4/24/2015</u>	<u>P</u>	<u>Although testing was in the sand the MX SnowSki completed this task well. No bolts or machined components failed.</u>
<u>Low speed turns</u>	<u>4/24/2015</u>	<u>P</u>	<u>The bike was able to turn in the sand while traveling at low speeds. The ski held a nice edge and kept from sliding out.</u>
<u>High speed turns</u>	<u>4/24/2015</u>	<u>F</u>	<u>The bike was not able to achieve the preferred speed. This was due to the excessive drag from the sand, which restricted the bike from sliding easily.</u>
<u>Proper function of front suspension/forks</u>	<u>4/24/2015</u>	<u>P</u>	<u>The front suspension of the dirt bike functioned flawlessly. The forks were able to compress and rebound just as easily with the ski.</u>
<u>Ski must slide forward in the proper direction with ease</u>	<u>4/24/2015</u>	<u>F</u>	<u>The ski did not slide forward with ease. Stopping required planning, because the bike was hard to get going due to the excessive drag.</u>
<u>Handling: Tight turns</u>	<u>4/24/2015</u>	<u>P</u>	<u>The bike handled tight turns. The operator was able to take a corner strong, but not with a lot of speed.</u>
<u>Handling: Wide sweeping turns</u>	<u>4/24/2015</u>	<u>P</u>	<u>The bike excelled in wide sweeping turns because of a lower amount of drag from the sand. Speed was also easier to carry through the turns.</u>

APPENDIX J – Resume

Olympia, WA 98501

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JORDAN OLSON

OBJECTIVE Enthusiastic, hard-working and motivated employee who strives for success, and a long standing career in Mechanical Engineering. I believe that a consistent and dependable work ethic are key factors in a new employee and I bring that commitment to my work. I pay attention to detail and possess the knowledge to design, develop, and test new ideas/concepts.

Throughout my academic career, I have focused on improving my existing abilities as an engineer and look forward to contributing my assets to a future company. I am an open-minded individual looking for a company that supports their staff and encourages them to learn, teach, and work as a cohesive force. I value a business that puts trust in their employees and expects great rewards.

SKILLS & ABILITIES

- 3D SolidWorks Associate Certified
- 2D Computer-Aided Design (CAD)
- Basic & Advanced Machine/CNC Programming
- Statics & Strengths of Materials
- Basic Electricity & Programmable Logic Controller (PLC) Applications
- Hydraulics & Pneumatics
- Mechanical Design
- Thermodynamics, Fluid Dynamics, & Heat Transfer
- Metallurgy, Ceramics & Composites, and Applied Strengths of Materials
- Technology savvy including competency in Microsoft Word, Excel & PowerPoint

EXPERIENCE

GROUNDS CREW, TOTAL GROUNDS MANAGEMENT (TGM)

August 2014 to Present

Landscape and construction crewmember specializing in irrigation ground work using heavy-machinery and common construction tools to dig trenches, assemble and install piping, and mount sprinkler heads for

irrigation. Our crew also installed Electrical lines, actuators, pressure valves, and automation/timing systems. Finally, bushes and trees of various sizes were planted and followed by spreading bark or laying grass seed.

Contracts include: Tacoma Art Museum, Lewis-McChord Military Base, and Regional School grounds.

RANCH HAND/ LANDSCAPER, DRAGON'S GATE FARM

June 2014 to August 2014

Assisted with daily operations of mid-sized farm and residential grounds. Specific responsibilities include: range and pasture upkeep, tend to livestock, maintain equipment, restore employer's personal yard, and install/maintain electrical fencing system, while using farm and landscape equipment.

EDUCATION

CENTRAL WASHINGTON UNIVERSITY, BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING TECHNOLOGY

MET GPA 3.607; Expected graduation date: June 2015

Dean's List & Honor Roll

VOLUNTEER WORK

First Lego League Championship

2014: 8 hours

Provided encouragement/assistance to elementary students towards friendly competition with Lego robotics, problem solving, and innovations.

Puyallup Food Bank

2003-2014:150+ hours

Set-up, clean-up, distribution, packing, and sorting of donated food. Food went to needy families in the Puyallup area during the holiday season. Very heart warming and for a good cause.

Timberline Blazers Football Camp

2008-2010:60+ hours

Assisted in coordination and set up drills for elementary and middle school football players seeking to develop their skills

PROFESSIONAL AFFILIATIONS

American Society of Mechanical Engineers (ASME), Club Officer 2014-2015