2007
Custom Chopper Motorcycle

Group 13

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Table of Contents

Figure Index

I. Abstract

The notion of a small or miniature motorcycle is nothing new. For many decades people have yearned for scaled-down proportions that would mimic a full scale motorcycle in all regions except physical size and cost. Rather than purchasing a motorcycle, the only other alternative is to build your own bike (which this report will discuss in depth) if one has the resources and knowledge to do so. Most likely this will present many challenges from incorporating parts from other industries in order to create a safe working machine. Motorcycle companies and others have invested millions of dollars to ensure the safety and reliability of their products. So when building a bike from scratch, it is best to keep the number of custom made parts needed as low as possible. The means for this includes using as many current production motorcycle parts as possible. This way prices stay low and safety and reliability remain high. The bike in need of building for this senior design class will be a fully functional chopper-clone of a real bike with the exception of street legality due to semester time limitations and unforeseen delays in the state registration process.

II. Background

The term “chopper” dates back to a time period after World War II when grounds men returned home from their duties in the service having much experience with materials handling by the use of motorcycles. Veterans bought up surplus bikes from the military since they were cheap and already had the experience necessary to modify them. The first thing they did was to chop off all the unnecessary items not needed for civilian use. Little did they know they started a new trend that would last throughout the century. Up until the end of the 1960’s most modified motorcycles were dubbed “bobbers”. This meant that everything on the bike excluding the frame was modified. Then in the 1980’s frame modifications caught on and became popular with extreme raked front forks and wide rear tires. These motorcycles are no longer thought of as choppers since they are completely custom from the ground up, however the term chopper still stuck.

With the help of today’s modern culture, custom choppers are now more ordinary than ever due to Daytona’s annual “Bike Week” event and Discovery Channel’s (now TLC) “American Chopper” and “Biker Build Off” TV series. Today’s choppers cost more than ever due to their large V-twin engines, insanely wide rear tires, crazy paint schemes and tons of chrome. Also the size of these motorcycles has reached a new high (length that is) with the introduction of long raked front ends. This looks cool, but unfortunately makes handling more challenging. It is also more uncomfortable to ride a large and heavy motorcycle with unfriendly steering characteristics.

Thus the need for a smaller, easier to control motorcycle which still has the good looks and sound of a real custom chopper motorcycle was born. One such company, Ridley Motorcycles [1] realized this demand for smaller motorcycles and began producing bikes for the public that were not only smaller in physique and pricing but also utilized an automatic transmission, which was something never done before and touted as a "world exclusive". This new motorcycle company as it came to be had a great idea and now produce wonderful bikes, however they are still moderately expensive. They use many custom made parts that can only be acquired through them when in need of repair. It would almost be impossible to try and duplicate one of their bikes or any part since they were created using such specialized machinery in the first place. It is also important to note that motorcycles which are produced for public use are stamped with a VIN and issued a "certificate of origin" for registration purposes. For someone to build their own bike from scratch, this process will be a little more challenging, but can still be done.

Motorcycles have been built at home many times in the past for a fraction of what a store bike would cost. The builder just has to know what parts are available, how the parts will work together and how to connect the parts together to create a safe mechanical device.

III. Review of Current Literature

Bike building is a serious business with tons of research and development implemented into the design and throughput from start to finish. Anyone can build a bike, but it might not be safe, reliable or appealing to the eyes. Sophisticated software and computer controlled equipment now take the guess work out of bike building dynamics. Specifically designed jigs hold the members of the frame in perfect alignment/geometry from side to side for even symmetry while being assembled. Unfortunately for the average Joe, a ton of calculus and differential equations are needed to study and design a frame and steering system worthy of having nice street manners. Since time is of an issue for this project, those methods will not be needed and we shall assume the frame and steering system have perfect geometry.

In the 1970's when modifying motorcycles became mainstream, there were many aspects of a bike which conjured lots of folklore regarding performance. Fitting a large, fat rear tire as many enthusiasts do has its own set of issues. "Adding a wide rear tire and skinny front tire will invariably reduce the stability of the machine, not increase it as the enthusiast hoped when he fitted the fat rear tire" [2]. "With today's knowledge, modifying a motorcycle's geometry, tires and or spring dampening characteristics is a task for skilled individuals only" [2]. Some riders with years of experience still fear hard use of the front brake for they will be flipped over their handlebars. "A corollary to erroneous brake application philosophy is the "chopper" motorcycle which these modified machines feature at the bottom of their grossly extended front forks and in the middle of their spindly front tire, little or no front brake" [2]. This is the very reason so many motorcyclists remove their front brakes; in fear of being thrown over the handlebars during a hard braking event.

> “A motorcycle, during hard deceleration, transfers a substantial portion of the bike/rider mass onto the front wheel. Given the relatively high center of gravity of a motorcycle, and its relatively short wheelbase, the rear tire is necessarily unloaded drastically during deceleration. The same dynamic weight transfer that is unloading the rear tire, causing it to skid with little retarding force, is forcing the front tire against the pavement with great intensity. The front tire is thereby accorded high adhesion, tending to prevent it from locking under all but the very highest brake torque levels. Sure the motorcyclist might on rare occasion brake the front tire to the point of sustained skidding and this may well cause him to tip over on his machine. Most of the time though, the front tire will not fully lock and the machine will lose speed with great rapidity, substantially faster than the best of current production automobiles” [2].

These myths further fueled the chopper motorcyclists envision that “less is more” by removing items not needed for stop/go motion. This logic has even spread to government where law now dictates that one not even need a front brake for building a custom chopper. The “less is more” theory of crude bike building is now found on just about every custom chopper made today and continues to flourish to set them apart from “production” bikes.

IV. Experimental Methods

To build a motorcycle, an engine, frame, tires and wheels are needed. A transmission will be utilized to start/stop and change speeds. There also has to be a way to connect the engine to the transmission and then to the rear wheel. The frame has to be built around these components to hold them in perfect alignment. But which components are used for the build? New or used? Big or small? These are questions that can only be answered by your imagination and wallet depth.

For this project, I plan to use as many parts that I already own as possible. This includes the engine, front and rear tires and rims and a genuine Harley Davidson gas tank. The engine is a 25 horsepower 725cc 90° V-twin made by Kohler. It is used because of the V-twin configuration just like real bikes have to get that "potato" sound at idle. The rear tire is a lawnmower tire from a Dixie Chopper commercial zero turn rider and it is 25" tall by 12" wide. This wide tire with a distinctive tread pattern is also suggestive of the big bikes. The front tire is a bicycle street tire with a stunt bicycle rim with many spokes to withstand the stresses of stunt use. This combination will do well as the rim is chromed and there is no front brake, only a smooth hub which is reminiscent of a real chopper. There are not many parts to begin with, but a preliminary analysis using data from the engine and transmission manufacture will prove worth for later calculations.

The first thing worthy of determining is the speed this motorcycle will be capable of with such a large engine and rear tire. The engine turns a maximum speed of 4000rpm and the rear tire is 25 inches tall. Comet Industries (the maker of the automatic transmission) states "the 94C driver and 90D driven pulleys are capable of a 3.49:1 low range and 0.78:1 high range" [3]. Let it be noted that my clutch actually uses the 100D pulley which is larger than the 90D. This means my low range will be lower, but not have as high of a high range. There is no ratio data available for the 100D, so the 90D data is being used for this project. It would be helpful if Comet provided a speed function in terms of engine rpm input, but sadly they did not. This is because every application is different and speed cannot be directly determined just from engine rpm. So we need to create a function from our engine rpm and tire size. No calculus is needed as this is just a straightforward multiplication of a few constants. Other parts that were ordered and arrived are the final drive belt sprockets. The small is 32 teeth and the large is 70 teeth. These numbers are needed as they form the ratio of the final drive to the rear tire. With these constants all known, the velocity of the rear tire can be determined using equation 15.10' "since vectors **k** and **r** are mutually perpendicular, vector cross products deduce to scalar multiplication" [4]. This equation states that velocity is equal to the radius times the angular rotational speed. The units of this equation must work out to give an output unit of miles per hour. This means the radius is in miles and the angular rotational speed is the inverse of time in hours. As the MathCAD document shows, [see appendix] the variables in the equation are engine rpm and torque converter ratio. Engine rpm varies from about 800 to 4000 and the torque converter ratio is infinitely variable from 0.78 to 3.49. This infinitely variable ratio presents a problem since we can not have two independent input variables, so we must choose an appropriate value for the torque converter. Several values have been chosen for the torque converter ration leaving the engine rpm as the stand alone variable. This is shown on the graph below with the multi colored lines. It is important to note that these lines do not model the speed entirely. There is an unknown speed function that lies somewhere within short segments of each colored line and will jump to the next line as engine rpm increases. Likewise though, the speed cannot be less than the lowest line and cannot be greater than the highest line. The true speed curve will lie somewhere in between these two lines of maxima.

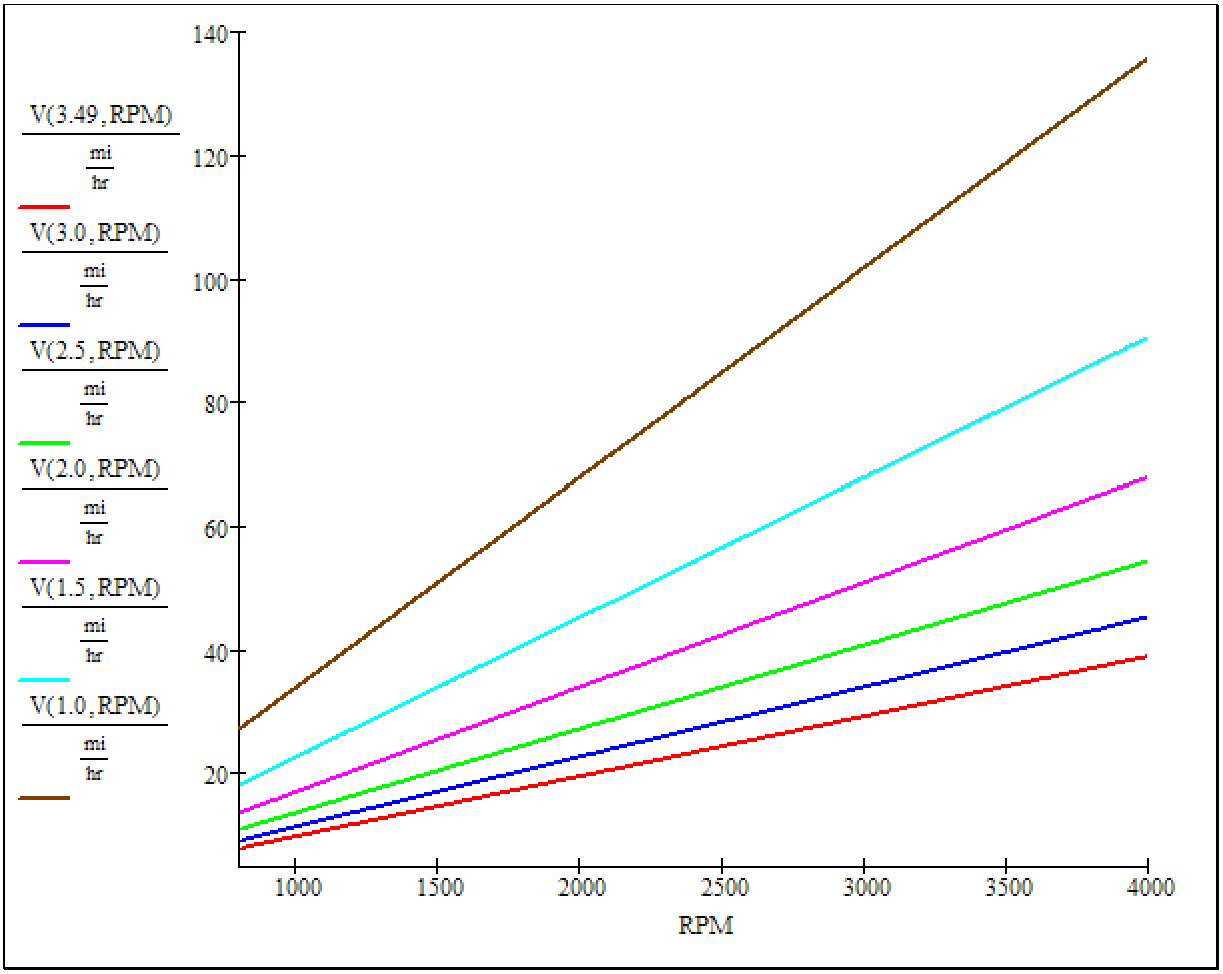

Figure 1: Speed Chart

From this graph, it is evident that the bike is capable of highway speeds. With the engine turning at 3000rpm and a torque converter ratio of 1.0:1, without the need of overdrive the speed is already 100mph! However since the transmission has such a nice low range (3.49:1) city driving will be quite nice with the engine operating at lower speeds.

Now that the speed of the motorcycle is known analytically, the device which holds the rear wheel and brake rotor/belt sprocket components must be created. This device is known as the wheel hub. All current production motorcycles have the rotor and sprocket mount directly to the rim. This is to ease production since fewer parts are needed. Since I am using a lawnmower rim, the rotor and sprocket cannot mount directly to the rim, so the use of two hubs will be needed, one for the rotor side and the other for the pulley side. These hubs will be created from scratch since nothing else like them exists in the world. They will house two sealed ball bearings each which rotate on a fixed axle shaft, just like a real motorcycle, for a total of four sealed ball bearings. The illustration below depicts what needs to be created.

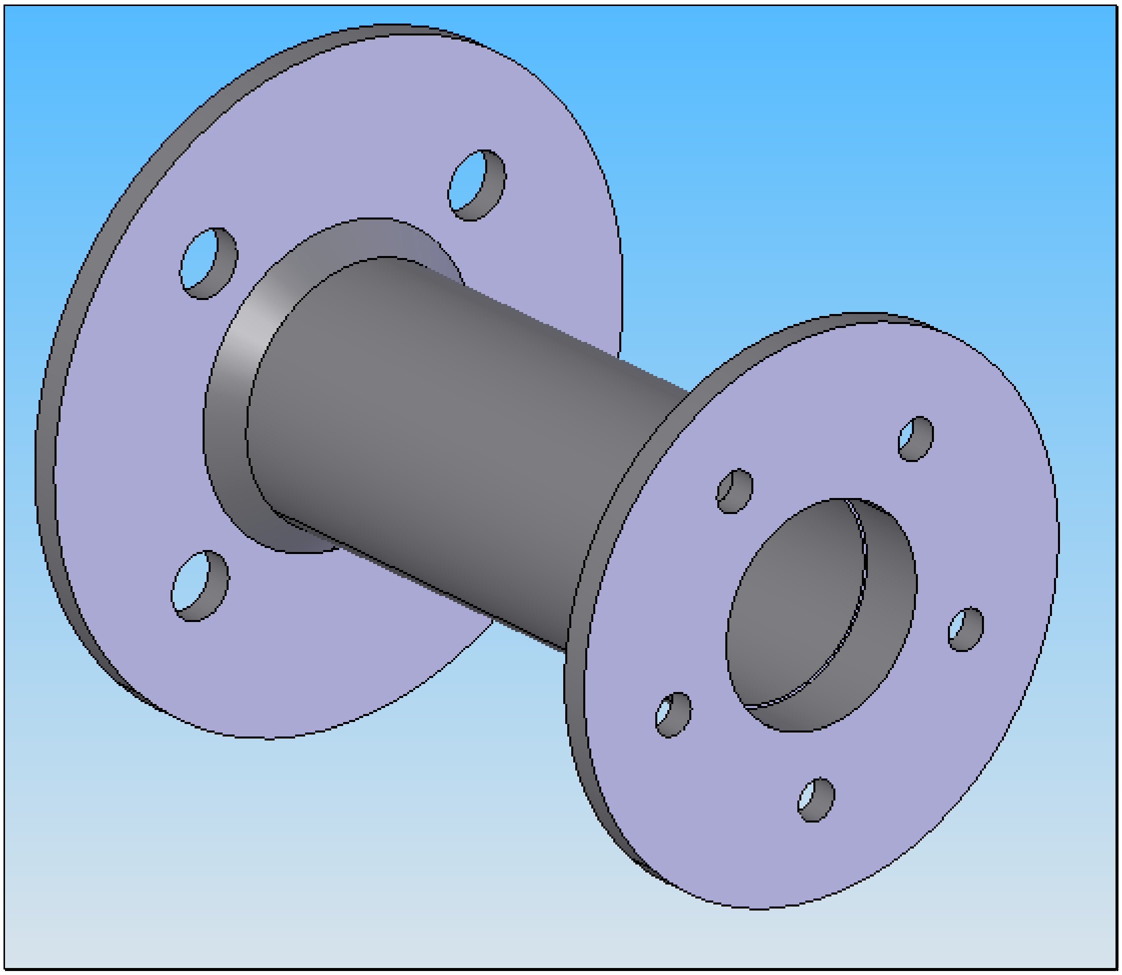

Figure 2: Pulley side drive hub

Our shop does not have a lathe large enough to machine them, so they had to be sent out to a machine shop in Orlando. The ends of the inside are where the bearings will be pressed into. Part of this project is to analyze the parts which are created to see how well they will hold up in real world practice.

To do an analysis of the rear drive hub, the dimensions of the tube need to be known as well as the torque applied by the engine. Kohler states the CH25S makes “40lb*ft of torque at 2800rpm” [6]. This torque is them multiplied by the transmission’s low range and then multiplied again by the final drive pulleys. So the rear drive hub sees a new torque of 305.4lbs*ft. With both pieces of information known, a safety factor can be found from the shear stress developed within the tube. Torque applied to a geometric part produces a shear stress τ (tau) within the part. If only a torque is applied and no other force is acted upon the hub, then a Mohr’s Circle is not needed. Otherwise a Mohr’s Circle is how one can combine multiple forces on a part to determine the stresses within. Since this hub only has a torque being applied, the safety factor is just the yield strength of the metal divided by the actual stress present [5].

The safety factor represents how many times more strong (or safe) a part is until failure will result. Using the methods described in Shigley’s “Mechanical Engineering Design” text, an analytical safety factor of 8.2 was determined [see appendix]. Not surprisingly, COSMOS Works which is an FEA package Add-In for SolidWorks determined a safety factor of 8.7. It is also worth noting that the analytical method of determining the safety factor was by the Maximum Shear Stress (MSS) failure theory. SolidWorks uses the Von Mises (otherwise known as Distortion Energy) failure theory which is less conservative than MSS. Had I used Von Mises or SolidWorks used MSS, our safety factors may have been the same. With numbers this high, this hub is very safe given the small power levels of the engine.

The use of SolidWorks helped greatly to visualize what is happening to the hub as it is loaded (torqued) by the engine. Three screen shots were taken of the report COSMOS generated; they are 1.) Von Mises stress 2.) Displacement and 3.) Factor of Safety.

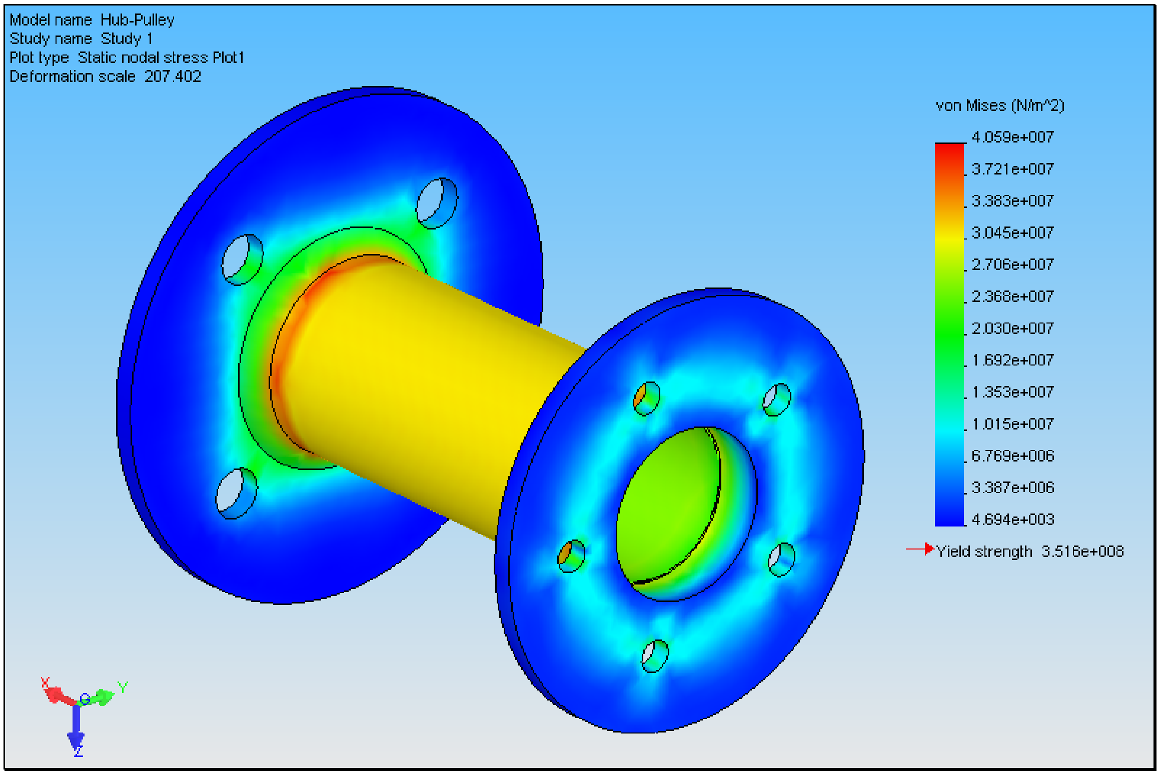

Figure 3: Von Mises stress

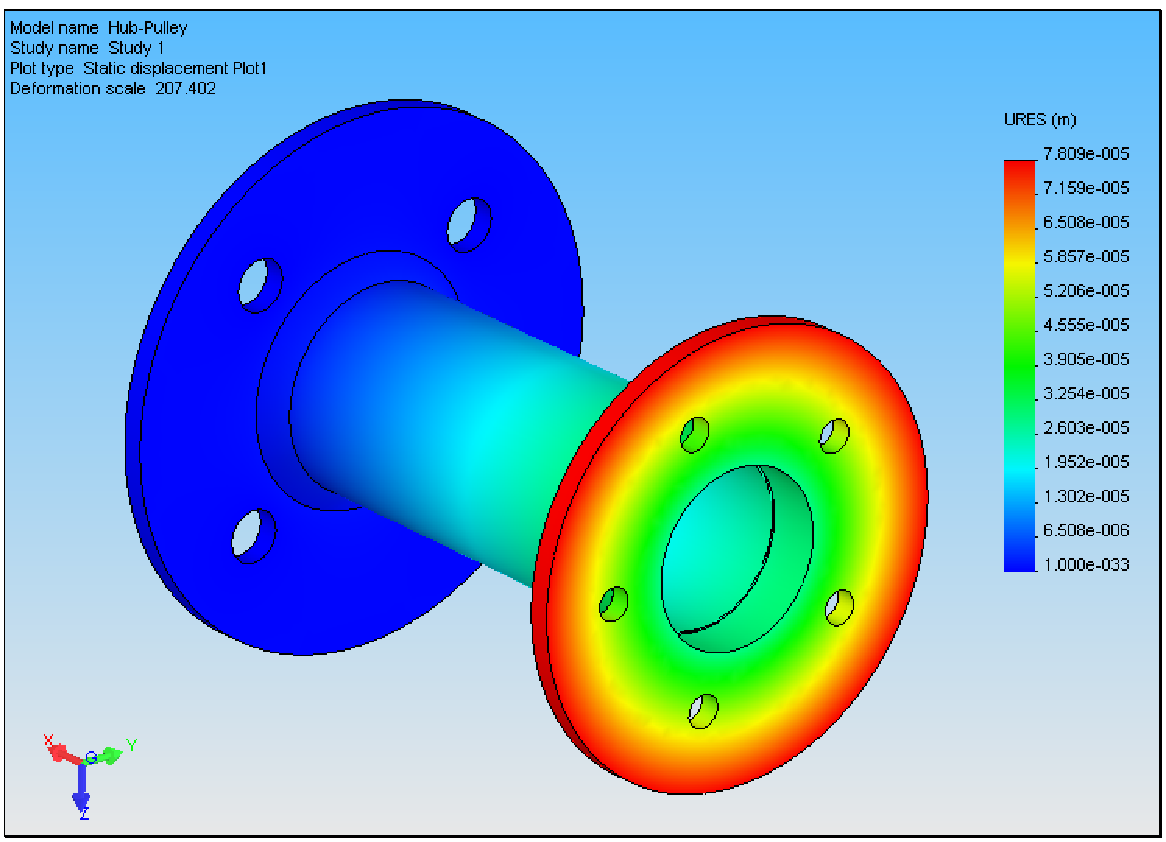

Figure 4: Displacement

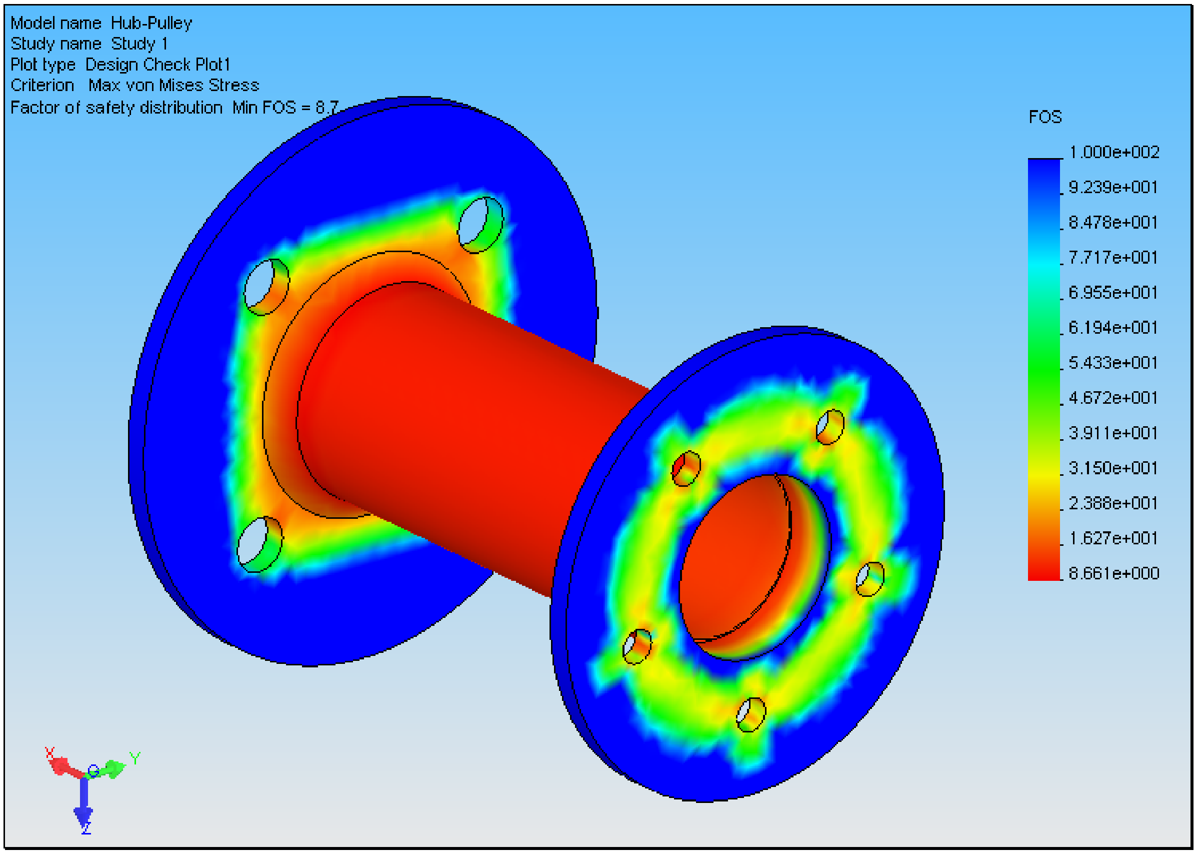

Figure 5: Factor of Safety

Production motorcycles have the rim rotating on bearings over a fixed axle shaft. The axle is there to hold the rim/wheel, not to transmit power. One other important distinction about production bikes is that the axle can be slid rearward or forward to tighten up the belt or chain. This means the transmission and engine are mounted stationary to the frame. For my motorcycle, the engine and transmission are meant to slide to adjust the belt tension. This means the axle can be mounted stationary to the frame without the need for a slotted connection. With this solid mounting of the rear axle shaft, the axle can be treated as a beam with two loadings from the frame rails and four reaction forces from the bearings in the hubs. Using singularity functions provides a means to graph the loadings of the axle as a function of the distance (X-position). Unfortunately since this beam is of the indeterminate type (meaning there are more reactions than loadings) we need more equations to complete the singularity functions.

There are six unknowns total, two constants of integration and four reaction forces. This means we need two equations of equilibrium and four conditional equations derived from the deflection function [see appendix]. With the unknowns now known, the *loading* singularity function Q(x) can now be obtained. This function does not tell us much by itself, but after one integration gives the shear diagram, the second integration gives the moment diagram, the third integration gives the slope diagram and the fourth integration gives the deflection diagram. These four integrations are quite simple as they are just polynomials. The information we get from these diagrams is monumental as the shear and moment diagrams give the locations of maximum loadings for further calculations. The slope diagram shows the angle the beam will flex and the deflection diagram actually shows how much the beam will flex. Determining the safety factor will depend on the outcome of the diagrams, so it is important that all parts of the equations not include any mathematical mistakes. Since this axle carries a human life, it is vital that it be properly considered before being built.

One very important aspect regarding the design of the hubs are the bearings used. It is noted that when the axle is loaded, for sure it will bend, causing the ball bearings to be misaligned the slightest amount. “For spherical ball bearings, the misalignment should not exceed 0.0087 radians” [5]. It turns out, according to the slope diagram, that each of the four bearings has a different slope, some more than others. But even the bearing with the most slope is only 0.00101 radians which falls well below the critical value. So from this standpoint, the bearings will not fail due to misalignment.

On with the axle, according to the MathCAD worksheet [see appendix] the total amount of axle shaft deflection is only five thousandths of an inch! This slight amount of flex is hardly worth worrying over, but from an engineer’s eyes, it was well worth looking into. More information can still be obtained from these diagrams. A final safety factor can be determined by means of a failure theory method which will complete the analysis of the rear axle shaft. Case A uses the maximum shear stress and its corresponding moment while Case B uses the maximum moment with its corresponding shear stress. This ensures a proper design by taking the lower safety factor in the end. Also note that now we need to utilize a Mohr’s Circle since we have multiple unlike stresses on our shaft (normal stress and shear stress). The data a Mohr’s Circle gives is a graphical means of combining unlike stresses which can be further used to determine the principle stresses. Once they are found, the Maximum Shear Stress (MSS) failure theory can be applied to find the safety factor. The MSS theory is “an acceptable but conservative predictor of failure; and since engineers are conservative by nature, it is quite often used” [5]. Wrapping up the study on the axle shaft, we take the lower safety factor of 29.597 as the total safety factor of just the shaft.

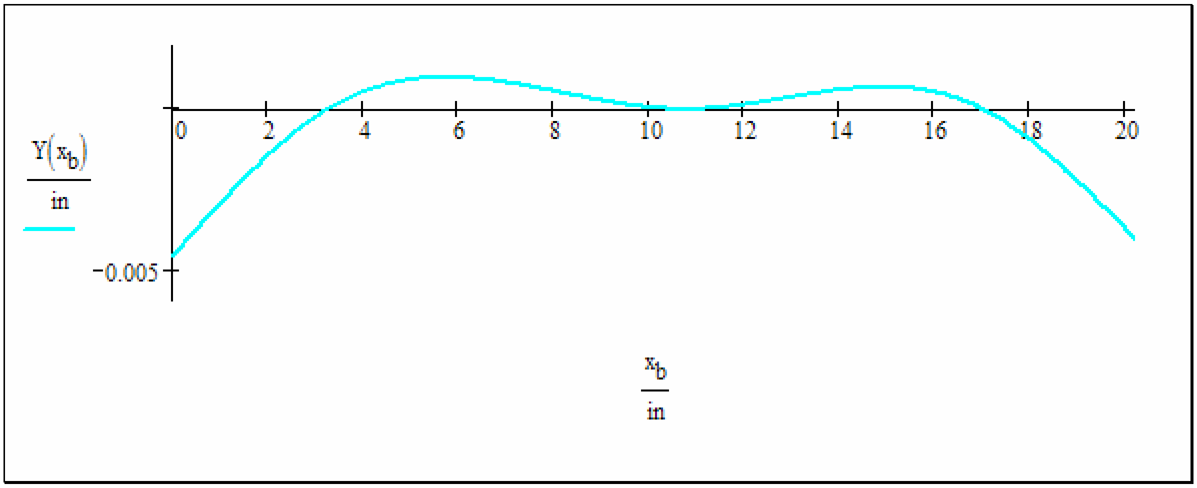

Figure 6: Deflection diagram of axle shaft

Just as predicted, the location of the bearings has zero deflection. This is evident by the points on the line which touch or cross the X axis. At a deflection of five thousandths of an inch and a safety factor of almost thirty, this design is quite safe for human transportation.

With the drive hub and axle shaft completely modeled and finalized, the only other item we knew we might need mathematics to build from would be a cone. Cones are very tricky to make from sheet metal to fold around and meet perfectly with the other side unless a precise method is used to sketch a development view of the cone. Realizing that all cones form a point in space, a mathematical relationship can be arranged between the known parameters (large diameter, small diameter and length) creating a system of two equations and two unknowns. Using MathCAD to simultaneously solve these equations gives the angle of the cone and the inner radius. This information can be used with a program such as AutoCAD to make a perfect sketch which can be printed out and used as a template pattern.

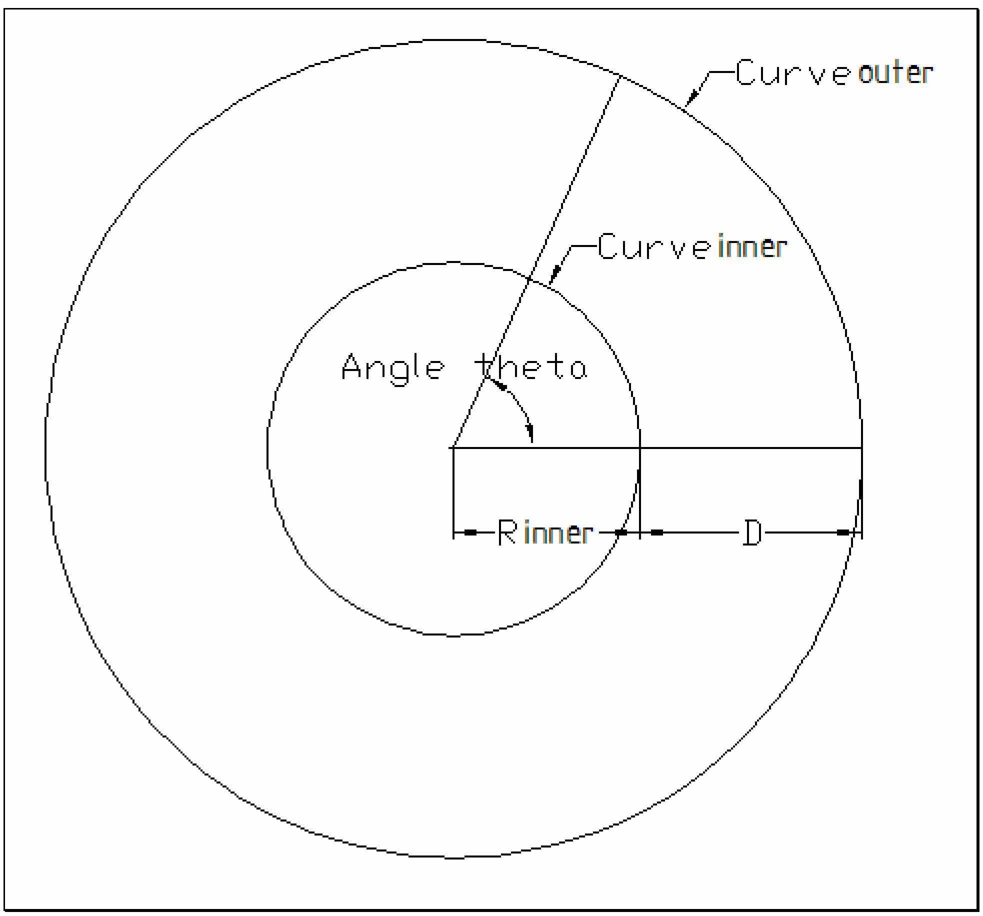

Figure 7: Cone development view

The last aspect of the bike that needs examining/design work is the front fork tubes. The design of the fork is ultimately the most important component of a motorcycle, not just for aesthetics, but for handling and safety reasons. Motorcycles got their designs from bicycles many years ago, so when designers finally got the steering geometry right on a bicycle, it is no surprise that the same geometry was carried over to motorcycle steering. However, modifying the fork assembly for a raked look and adding longer fork tubes can vastly decrease the performance and or safety of the bike.

Chopper motorcycles have long raked front forks which are appealing to the eye, but can cause severe wobbles or death if not properly designed. "A bike is said to be 'safe' as long as it portrays some amount of castor- that being the front tire touches the ground some distance behind the steering axis line" [2].

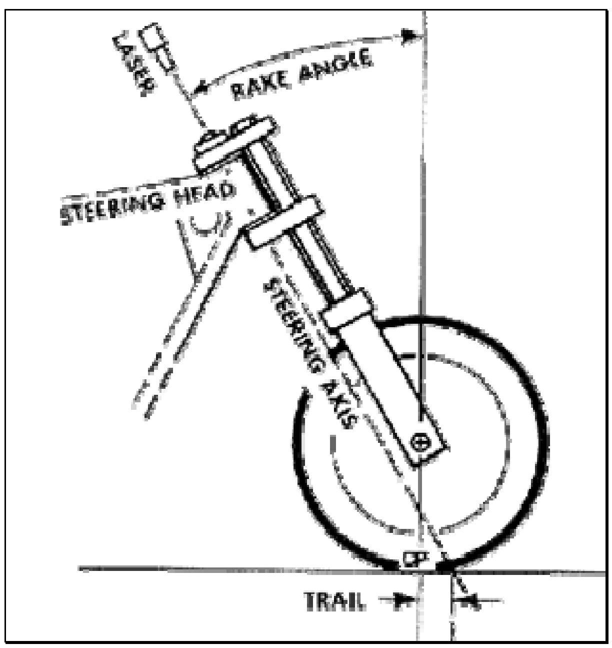

Figure 8: Diagram of steering geometry [7]

As the rake angle increases, the trail distance becomes larger and thus the tire scrubs the ground more, making turning more difficult, but increases stability for straight line cruising. For my case, I would like to examine the strengths of the fork tubes on the bike at a length of 37.25 inches and at a rake angle of 43 degrees. A safety factor can be determined after an analytical analysis of the tubes has been written. However it is noted that this safety factor is not as simple to determine as first thought. The fork tubes are so long and at such an angle that they can be modeled as a beam and a column. The beam situation is easy whereas the column is not so easy. The tubes are welded to the bottom of the triple trees and thus forms a simple cantilever beam. Also for column modeling this represents a fixed/free case which has a C value of 0.25. This fixed/free case is also of the worst possible column design, but unfortunately is unavoidable in motorcycles.

First the downward force acting on the front tire needs to be known. This is done by taking the masses and distances of the major components (engine, rider, countershaft, battery and frame) from the rear axle shaft. "The coordinates of the center of mass of a composite object composed of parts with any number of masses is:" [8]:

$$\bar{x} = \frac{\sum_i xi * mi}{\sum_i mi}$$

Figure 9: Composite Center of Mass

The beam loading is the weight force acting perpendicular to the tubes and creates a moment M_{maxB} and a deflection Y_{max}. The column loading takes the beam's deflection into account and creates moment M_{maxC}. The two moments are then added for M_{total}. Next the maximum stress is calculated. After that the yield stress of 1020 low carbon steel is divided by the maximum stress to get the safety factor. The safety factor of the front fork tubes is 1.865. This seems low compared to the other components on the bike, but remember the tubes are raked at such an angle along with the fork's length which contributes to the low safety factor.

This concludes the experimental methods section of the report. The bike can now be constructed.

V. Experimental Results

In theory, the bike should be well-mannered in the 5mph-50mph speed range. Well-mannered meaning it accelerates and decelerates smoothly and bike is balanced when driving straight, going into a turn and coming out of a turn and steers smoothly due to the raked fork. After final assembly and thorough testing, this was not too far off. Meaning the bike does accelerate smoothly but it takes considerable throttle to get it going. This is due to the high ratio of the final drive pulleys. Also due to the high final drive ratio, the bike does not want to cruise any slower than 10mph because this is the point at which the clutch becomes fully engaged and no longer slips to get the bike moving. The speed chart which was the very first mathematical calculation (Fig. 1) showed that the bike is capable to the 50-60mph speed range. This is exactly true as the transmission shifts into its "midrange gear" which is the 2.0:1 ratio. Pushing the bike to higher speeds was not performed as things may get scary since the tires are not balanced, nor rated for such high speeds (remember they are lawnmower and bicycle parts).

The hub which had a safety factor of 8.3 will not show any signs of weakness. Basically it has already been forgotten about since it is so strong. The same thing can be said about the axle shaft. With its safety factor of almost 30, there is no way to feel five thousandths of deflection when riding the bike. These two components will prove to be the strongest and most reliable parts on the bike for sure.

The handling and steering aspect of the bike turned out better than anticipated. Once moving it is very steady and steers well for all but the sharpest of turns (which is to be expected of a motorcycle with this long of a fork). While the fork had a safety factor of 1.865, driving the bike over rough washboard dirt roads showed only slight flexing of the tubes. Rider fatigue did not occur since the handlebars and seat were ergonomically designed.

Upon the first crank of the engine, it was clearly evident the bike sounded just like a real bike. The combinations of long pipes which expand to larger pipes deepen the exhaust notes for a unique V-twin rumble. One other item that worked surprisingly well was the rear brake. With such a large rotor and lightweight bike, the rear tire will lock up on dirt roads easily due to the power of the hydraulic master cylinder. With a fully functional running/brake light and high/low beam headlight, the bike is that much closer to the real thing.

VI. Conclusion

The Mini Chopper project was indeed a difficult, but highly successful one. The success of this project is due to the careful thought process that went into the planning and design stages back in January 2007. Without the proper planning, sketching and 3D modeling in SolidWorks, the bike may not have been completed on time. All in all I am very happy with the outcome of the bike, both aesthetically and performance/maneuverability. The one thing about the bike I do not like is the high final drive ratio. This is because the small belt sprocket is not really that small. 32 teeth out of 70 is only slightly less than half, and the smallest front drive belt sprocket Harley Davidson makes is 29 teeth. So the significance would only be marginally better, but still better. The largest rear wheel belt sprocket Harley makes is currently being used so that cannot be changed. It just boils down to the fact that real choppers have much larger engines to get them moving with the same ratio sprockets that I have. Another item that I would do differently if another bike were to be built would be the front wheel. Instead of using a bicycle rim and tire a Harley Davidson Sportster front wheel would be used. It is wider, larger and sturdier than a bicycle unit. It also has provisions for a front brake rotor if needed. This will also lessen the length of the fork tubes resulting in less deflection and a greater gyroscopical effect to help maintain better bike balance.

The Comet torque converter variable pulley CVT system works as it should out of the box. However, they are designed for each individual to “fine tune” them by adding or subtracting weight pucks and changing to different spring tensions which will cause the transmission to shift at different RPMs and driving conditions. This fine tuning may be necessary on the bike’s 100D pulley since it did not seem to let the belt run any lower in the sheaves. This means the spring tension is too high. Fortunately Comet sent me an email providing instructions detailing how to change this spring tension. What is even nicer is the fact that there are holes to relocate the end of the spring which will change the spring tension without actually replacing the spring. Once this is done, an improvement in the way the bike changes speeds should be noticed without having to rev the engine as high.

The cost of building this motorcycle was very inexpensive for several reasons. Firstly I already had the engine and paint, secondly I only had one item made out of house and thirdly almost everything was bought using eBay. The total cost is just over $1600 for this project. However the time invested into this project is very high. Starting during spring break, my father and I put in ten hour days to get as much done in as little time as possible. After the main build, six and eight hour days were required to paint and assemble the bike. 195 hours were spent constructing the bike. Many hours were also spent at the computer for MathCAD calculations and SolidWorks models.

After the photo shot in the front yard, it was evident that the goal of this project has been met. The bike looks, sounds and feels like a real custom chopper motorcycle, but at a fraction of the cost. It also is a fraction of what a Ridley would cost and is basically the same thing: a 90 degree engine with a variable pulley CVT system on a smaller chassis than a real chopper. The only thing a Ridley motorcycle has that mine does not is a state registration with the DMV to issue titles. It will be difficult to title my bike though the local DMV but it can be done if and when the time comes. Out of all the components that were analyzed, the lowest safety factor of 1.865 is recorded as the overall safety factor of the bike. So the bike is almost twice as strong as it needs to be for the given masses riding on top. Not bad for a small scale motorcycle.

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[2] Wikipedia. A database of many topics shared and edited my users all over the Internet. Basically a free and endless online encyclopedia. http://en.wikipedia.org/wiki/Main_Page

[3] Biker Build Off. A competition based reality TV show originally aired on Discovery Channel and now is aired on TLC. Well known custom bike builders have one month to design, construct and ride their machines to the location of voters who then choose the winning bike.

[4] Hot Bike Magazine. Magazine dedicated to the custom bike builds.

IX. Appendix

Objective: The objective of my project is to build a miniature chopper style motorcycle that can someday be titled and registered for use on public streets. It will use as many production Harley Davidson parts as possible to keep costs down and reliability high and aid in ease of parts replacement.

Goal: In order to accomplish such a task in a 15 week time window, this project will only focus on a few major aspects of the bike. This includes proper planning and designing of the component, then analyzing the component and finally to build the component.

The major items I have so far include:

- Kohler 25 horsepower 725cc V-Twin engine
- Comet 94C driver and 100D driven Automatic Torque Converter pulleys
- Harley Davidson 70 and 32 tooth drive belt sprockets
- Harley Davidson rear disc brake rotor, caliper and master cylinder
- 25" tall by 13" wide Dixie Chopper rear tire

The Kohler V-twin engine is used for its power, smoothness and most of all the Harley type exhaust rumble. It is small but powerful and will propel the bike up to speeds quickly. The Comet Torque Converter is a simple method of changing speed ratios (transmission) without the need for manually shifting. It features two pulleys where the driver (engine pulley) changes the ride height of the belt on the pulley by means of weighted pucks that react from changing engine RPM. Then the driven pulley compensates by letting the belt ride lower into the pulley for a higher final ratio. Polaris ATV's and all snow mobiles use this type of transmission. Harley Davidson belt sprockets are utilized due to their simplistic nature: no slippage from the cog teeth design and no oiling is required. Not to mention they are quieter and last longer than a conventional chain. The Dixie Chopper rear tire was chosen due to its looks. It is tall and wide which is characteristic of a real full size chopper.

Preliminary Design Phase

For the design work of this project, I am going to work from the engine backwards to the rear hub and axle assembly. From the Kohler website, the engine I have is the CH25S which was later replaced by the CH730. It develops a maximum of 25 horsepower at 3600 rpm and 40 lbs-ft torque at 2800 rpm. This information will be useful for determining final drive speed and torque input to the rear hub assembly.

As previously stated, the transmission is made by Comet Industires and is a system of variable pulleys that allow different ratios. This is basically a fully automatic transmission. The model 94C is the driver unit which mounts to the engine crankshaft. The 100D is the driven unit which mounts to the counter shaft.

To determine how "fast" the bike will travel at the maximum engine speed, we need to know several parameters:

Tire height = 25 inches
Maximum engine speed = 3600 rpm
Front belt sprocket teeth = 32
Rear belt sprocket teeth = 70
Torque Converter function = unknown

Since the torque converter speed function is unknown due to every application being different, we need to make our own speed (velocity) function and leave it in terms of rpm and torque converter ratio (TC). To find the speed of the bike, all we need to know is the velocity of the outer point of the rear tire and how fast the tire is turning.

The easiest way to get the speed in miles per hour is to convert the radius of the tire from inches to miles. Then multiply it by the angular rotation of the rear tire after being geared by the torque converter and belt sprockets. Of course for the fastest case scenario assume a 1:1 torque converter ratio.

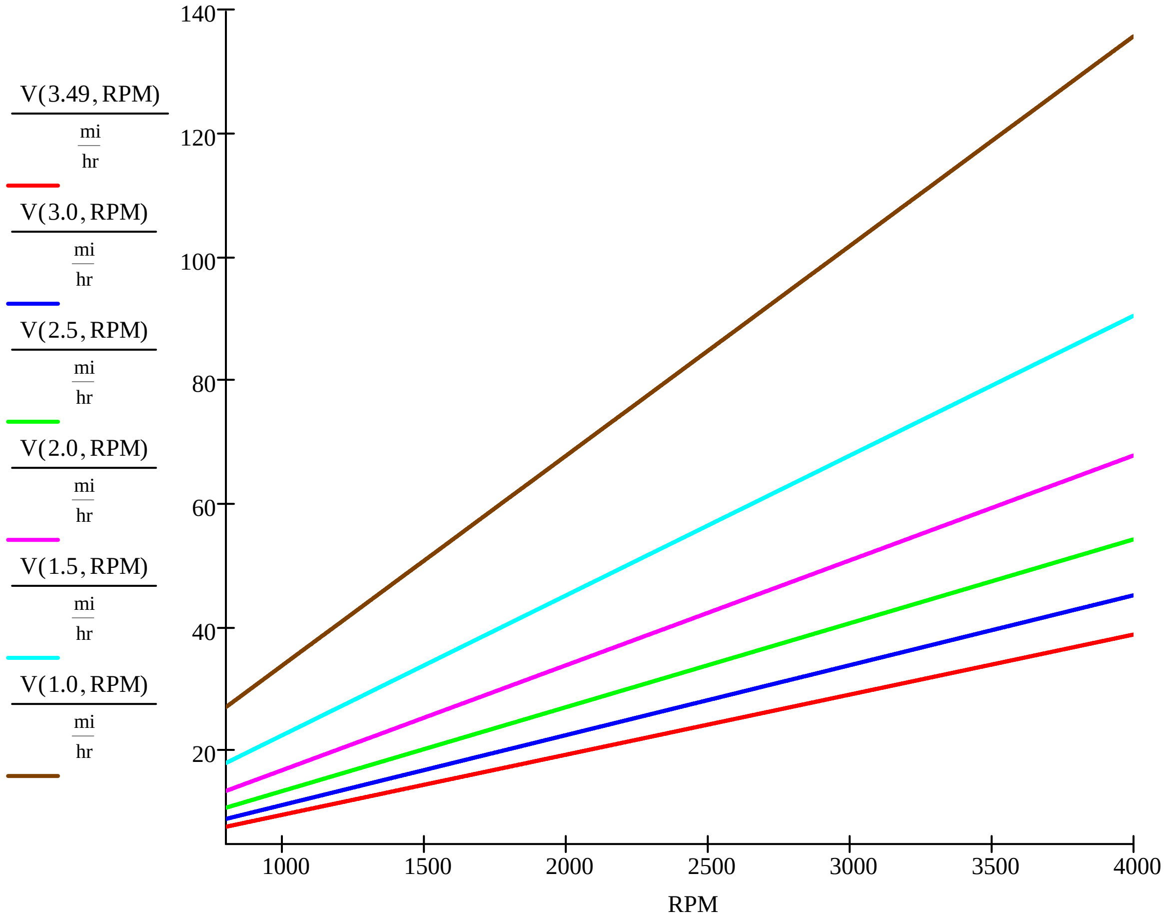
Velocity = radius x angular rotation

We must first define our constants: $radius_{tire} := 12.5in$

$belt\_sprocket_{rear} := 70$

$belt\_sprocket_{front} := 32$

$$V(TC_{ratio}, RPM) := \left(\frac{radius_{tire}}{12 \cdot \frac{in}{ft} \cdot 5280 \cdot \frac{ft}{mi}}\right) \cdot \left(\frac{\frac{RPM \cdot 2 \cdot \pi \cdot \frac{1}{min}}{TC_{ratio}}}{\frac{belt\_sprocket_{rear}}{belt\_sprocket_{front}}}\right)$$



From this graph it is evident that the bike is capable of highway speeds. This may or may not be safe, but that is beyond the scope of this project.

Analyzing Phase

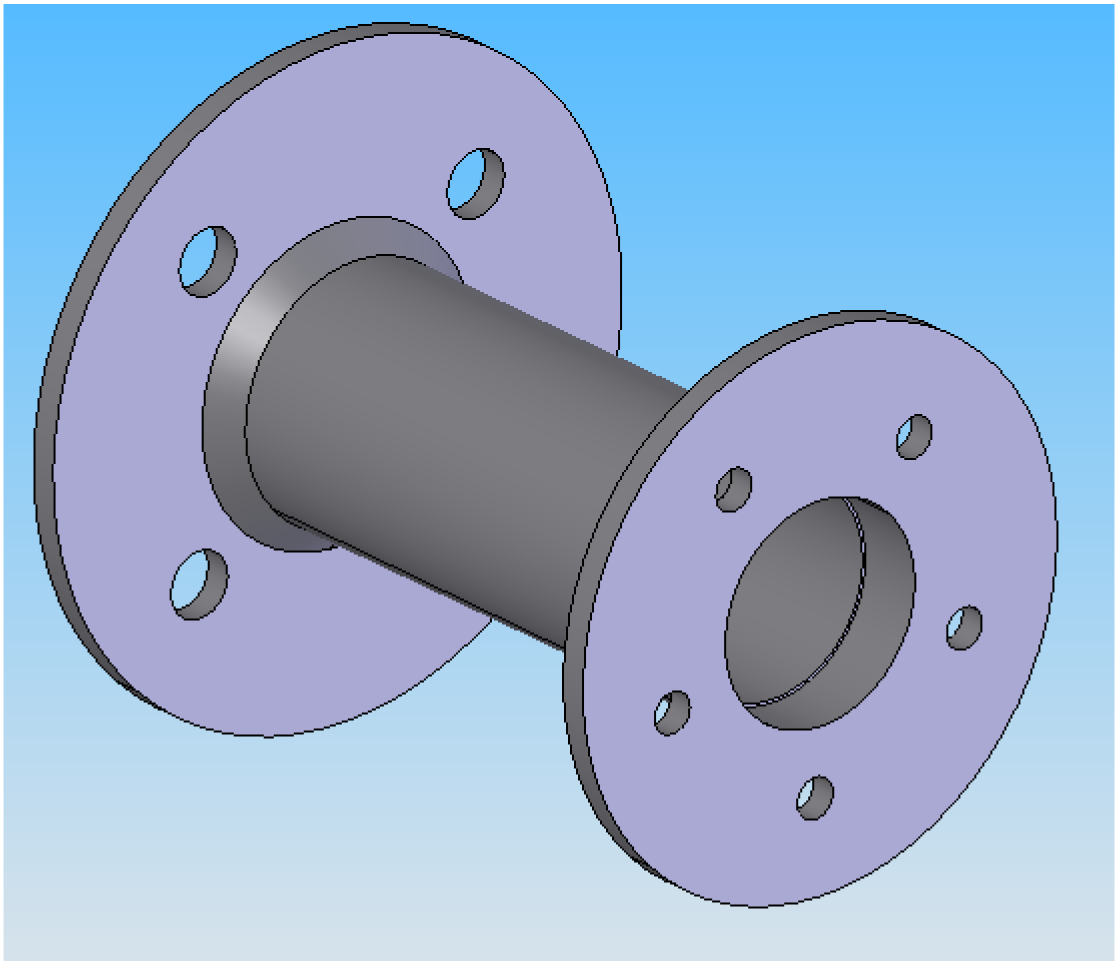
Drive Hub

At this time, attention can now be turned to analyzing the parts needed to construct the rear hub and axle assembly. This will consist of two hubs and one solid round axle shaft which the hubs mount over.

The hub is the assebly which will hold the brake rotor and the drive pulley to the rear wheel. It will also house two sealed ball bearings which will allow the hub assembly to rotate over a fixed 1" diameter stainless steel axle shaft. Two hubs will be used, one for the brake rotor side and the other for the drive pulley. Each hub will be made of tubing for the center section and two flanges at the ends thus forming an "H" shape.

The steel I have selected for the rear hub tube is quite large. This is due to several reasons: 1.) the need for it to be strong, 2.) it will allow the use of common R (inch) series ball bearings and 3.) large surface area to weld the flanges to.

Next the axle hub needs to be examined using the engine's maximum rated torque to see if it can withstand the stress.



The steel tubing (shown in the middle above) is ASTM A53 which is of structural grade. To determine the maximum torsional stress the tube will see depends on several factors. The torsion in the tube will be greatest when the bike is at rest and begins to move while under hard acceleration. The engine will be producing its peak torque while the transmission will be in its lowest "gear". The engine torque is known at the crankshaft but we need to know what it is at the rear hub after going through the transmission and final drive pulleys. All that is needed is a simple multiplication of the gear ratios:

$$T_{engine} := 40 lbf \cdot ft$$

$$TC_{low} := 3.49$$

$$T := T_{engine} \cdot TC_{low} \cdot \left(\frac{belt\_sprocket_{rear}}{belt\_sprocket_{front}} \right)$$

$$T = 305.375\, lbf \cdot ft$$

Now with the torque at the rear hub known, the geometry of the tubing must also be known. The outer diameter is 2.36 inches and the inner diameter is 1.94 inches. Also the stress is greatest at the outermost radius of the tube, so r also equals 2.36 inches.

$$d_o := 2.36in \qquad d_i := 1.94in \qquad r := 2.36in$$

$$J := \frac{\pi}{32} \cdot \left(d_o{}^4 - d_i{}^4 \right)$$

$$\tau_{max} := \frac{T \cdot r}{J}$$

$$\tau_{max} = 5226.11\, psi$$

Since there are so many manufactures of A53 tubing, we will just generalize the yield strength as 43kpsi. Also since the hub will not see any other modes of stress other than torsion, a Mohr's circle is not needed. Torsional stress will translate into torsional shear stress. Dividing the yield strength by the torsional shear stress will give a safety factor for the pulley side hub:

$$YieldStrength_{A53} := 43 \cdot 10^3 psi$$

$$SF_{hub} := \frac{YieldStrength_{A53}}{\tau_{max}}$$

$$SF_{hub} = 8.228$$

With a safety factor a little over 8, this design is much stronger than needed for this application.

Axle Shaft

With the drive hub taken care of, attention is now turned to the axle shaft. Examining this component is necessary to determine the deflection (bending) the axle will undergo when loaded and more importantly show the off-axis angle the sealed ball bearings will see. This is very critical as these bearings are not of the self-aligning type. Even the slightest angle will cause bearing failure due to premature wearing. Using singularity functions will show the deflection of the axle shaft when it is fully loaded. To get these singularity functions, we must know the loadings and reactions and the distances at which they act. We know the distances and the loadings, but we do no know the reactions. In order to get the reactions we need other means of solid mechanics to determine them. Using sum of forces, sum of moments and four conditional deflection equations (after fourth intergration of the loading function) the unknown reactions can be found and thus finalize the deflection equation. The axle shaft is 1.00" diameter and made of 304 stainless steel.

Modulus of Elasticity: $E := 27.6 \cdot 10^{6} psi$ $D := 1.00in$ $F_1 := 200lbf$ $F_2 := 200lbf$

Moment of Inertia: $I := \frac{\pi \cdot (D)^4}{64}$ $I = 0.049\ in^4$ $S_{y.304Stainless} := 190 \cdot 10^{3} psi$

Given

$$0 = (R_1 \cdot 0.5in) + (R_2 \cdot 0.5in) + (R_3 \cdot 0.5in) + (R_4 \cdot 0.5in) - F_1 - F_2$$

$$0 = (R_1 \cdot 0.5in) \cdot 3.25in + (R_2 \cdot 0.5in) \cdot 10.375in + (R_3 \cdot 0.5in) \cdot 11.125in + (R_4 \cdot 0.5in) \cdot 17.0in - F_2 \cdot 20.25in$$

$$0 = \frac{-F_1}{6} \cdot (3.25in - 0in)^3 + \frac{R_1}{24} \cdot (3.25in - 3in)^4 + C_1 \cdot 3.25in + C_2$$

$$0 = \left[\frac{-F_1}{6} \cdot (10.375in - 0in)^3 + \frac{R_1}{24} \cdot (10.375in - 3in)^4 - \frac{R_1}{24} \cdot (10.375in - 3.5in)^4 \ldots \atop + \frac{R_2}{24} \cdot (10.375in - 10.125in)^4 + C_1 \cdot (10.375in) + C_2 \right]$$

$$0 = \begin{bmatrix} \frac{-F_1}{6} \cdot (11.125in - 0in)^3 + \frac{R_1}{24} \cdot (11.125in - 3in)^4 - \frac{R_1}{24} \cdot (11.125in - 3.5in)^4 \ldots \\ + \frac{R_2}{24} \cdot (11.125in - 10.125in)^4 - \frac{R_2}{24} (11.125in - 10.625in)^4 + \frac{R_3}{24} \cdot (11.125in - 10.875in)^4 \ldots \\ + C_1 \cdot (11.125in) + C_2 \end{bmatrix}$$

$$0 = \begin{bmatrix} \frac{-F_1}{6} \cdot (17in - 0in)^3 + \frac{R_1}{24} \cdot (17in - 3in)^4 - \frac{R_1}{24} \cdot (17in - 3.5in)^4 \ldots \\ + \frac{R_2}{24} \cdot (17in - 10.125in)^4 - \frac{R_2}{24} (17in - 10.625in)^4 + \frac{R_3}{24} \cdot (17in - 10.875in)^4 \ldots \\ + -\frac{R_3}{24} \cdot (17in - 11.375in)^4 + R_4 \cdot (17in - 16.75in)^4 + C_1 \cdot (17in) + C_2 \end{bmatrix}$$

$$\begin{pmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ C_1 \\ C_2 \end{pmatrix} := \text{Find}\left(R_1, R_2, R_3, R_4, C_1, C_2\right)$$

$R_1 = 661.507 \frac{\text{lbf}}{\text{in}}$ $R_2 = -285.202 \frac{\text{lbf}}{\text{in}}$ $R_3 = -290.426 \frac{\text{lbf}}{\text{in}}$ $R_4 = 714.122 \frac{\text{lbf}}{\text{in}}$

$C_1 = 2262.154 \,\text{lbf}\cdot\text{in}^2$ $C_2 = -6207.839 \,\text{lbf}\cdot\text{in}^3$

Quick Check: $R_1 \cdot 0.5\text{in} + R_2 \cdot 0.5\text{in} + R_3 \cdot 0.5\text{in} + R_4 \cdot 0.5\text{in} = 400 \,\text{lbf}$

Now with the reactions known, the loading function can be constructed, from which after four integrations, the deflection of the axle can be graphed. Also it is important that the bearings not see any more misalignment than one tenth of a degree. Any more than this could cause premature failure. Below are the loading function "Q(x)" and its four integrations.

$$Q(x) := -F_1\cdot(x - 0in)^{-1} - F_2\cdot(x - 20.25in)^{-1} + R_1\cdot(x - 3in)^{0} - R_1\cdot(x - 3.5in)^{0} \ldots$$
$$+ R_2\cdot(x - 10.125in)^{0} - R_2\cdot(x - 10.625in)^{0} + R_3\cdot(x - 10.875in)^{0} \ldots$$
$$+ -R_3\cdot(x - 11.375in)^{0} + R_4\cdot(x - 16.75in)^{0} - R_4\cdot(x - 17.25in)^{0}$$

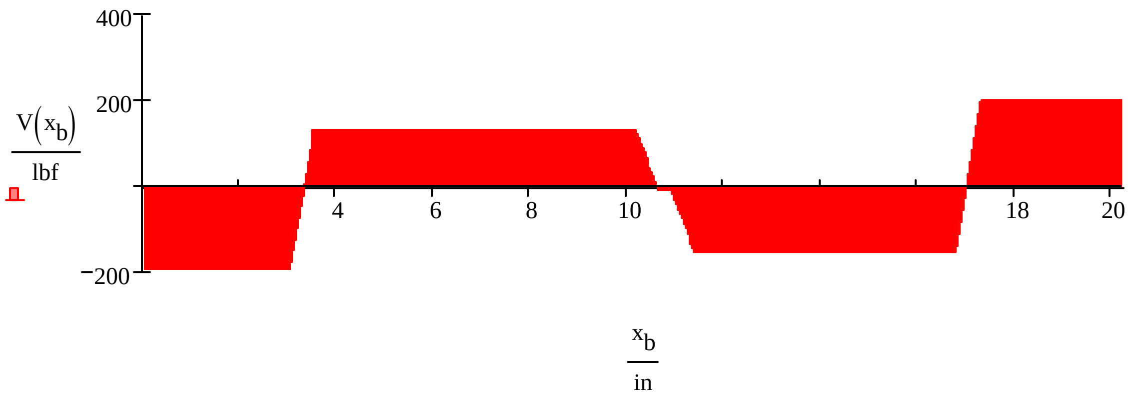
$$V(x) := -F_1\cdot S(x, 0in, 0) - F_2\cdot S(x, 20.25in, 0) + R_1\cdot S(x, 3in, 1) - R_1\cdot S(x, 3.5in, 1) \ldots$$
$$+ R_2\cdot S(x, 10.125in, 1) - R_2\cdot S(x, 10.625in, 1) + R_3\cdot S(x, 10.875in, 1) \ldots$$
$$+ -R_3\cdot S(x, 11.375in, 1) + R_4\cdot S(x, 16.75in, 1) - R_4\cdot S(x, 17.25in, 1)$$

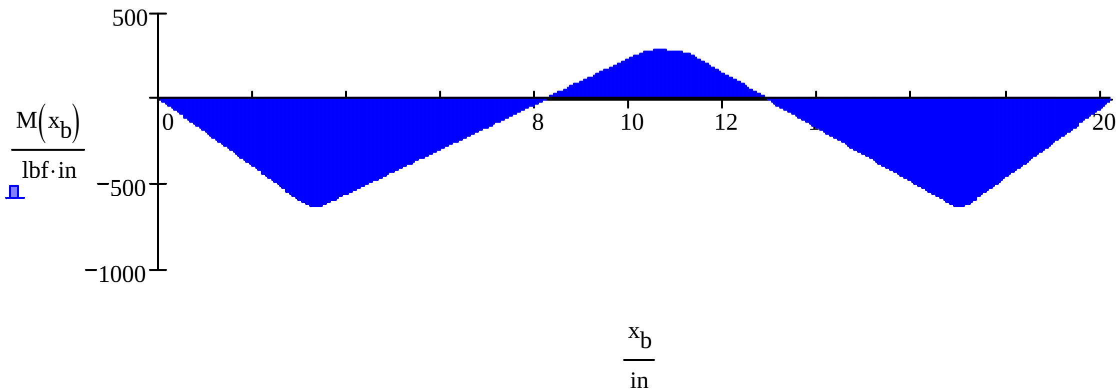
$$M(x) := -F_1\cdot S(x, 0in, 1) - F_2\cdot S(x, 20.25in, 1) + \frac{R_1}{2}\cdot S(x, 3in, 2) - \frac{R_1}{2}\cdot S(x, 3.5in, 2) \ldots$$
$$+ \frac{R_2}{2}\cdot S(x, 10.125in, 2) - \frac{R_2}{2}\cdot S(x, 10.625in, 2) + \frac{R_3}{2}\cdot S(x, 10.875in, 2) \ldots$$
$$+ \frac{-R_3}{2}\cdot S(x, 11.375in, 2) + \frac{R_4}{2}\cdot S(x, 16.75in, 2) - \frac{R_4}{2}\cdot S(x, 17.25in, 2)$$

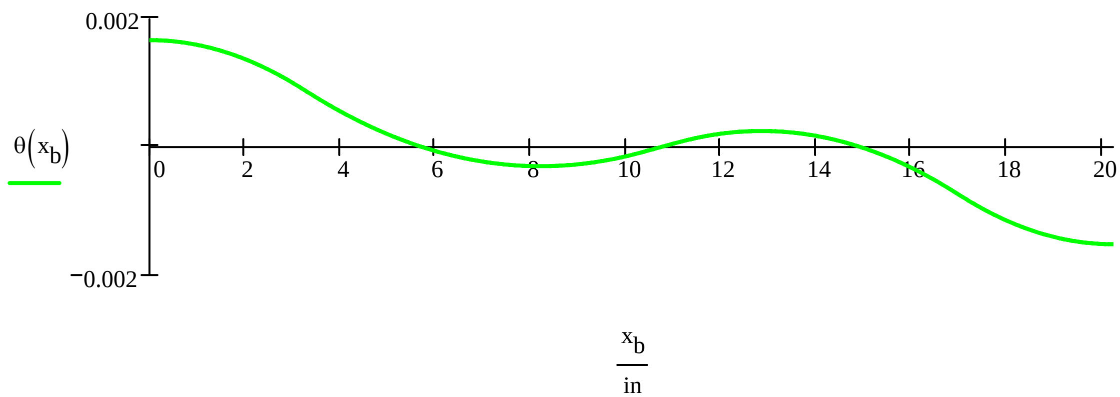
$$\theta(x) := \frac{1}{E\cdot I}\cdot\begin{pmatrix} \frac{-F_1}{2}\cdot S(x, 0\cdot in, 2) - \frac{F_2}{2}\cdot S(x, 20.25\cdot in, 2) + \frac{R_1}{6}\cdot S(x, 3\cdot in, 3) - \frac{R_1}{6}\cdot S(x, 3.5\cdot in, 3) \ldots \\ + \frac{R_2}{6}\cdot S(x, 10.125\cdot in, 3) - \frac{R_2}{6}\cdot S(x, 10.625\cdot in, 3) + \frac{R_3}{6}\cdot S(x, 10.875\cdot in, 3) \ldots \\ + \frac{-R_3}{6}\cdot S(x, 11.375\cdot in, 3) + \frac{R_4}{6}\cdot S(x, 16.75\cdot in, 3) - \frac{R_4}{6}\cdot S(x, 17.25\cdot in, 3) + C_1 \end{pmatrix}$$

$$Y(x) := \frac{1}{E\cdot I}\cdot\begin{pmatrix} \frac{-F_1}{6}\cdot S(x, 0\cdot in, 3) - \frac{F_2}{6}\cdot S(x, 20.25\cdot in, 3) + \frac{R_1}{24}\cdot S(x, 3\cdot in, 4) - \frac{R_1}{24}\cdot S(x, 3.5\cdot in, 4) \ldots \\ + \frac{R_2}{24}\cdot S(x, 10.125\cdot in, 4) - \frac{R_2}{24}\cdot S(x, 10.625\cdot in, 4) + \frac{R_3}{24}\cdot S(x, 10.875\cdot in, 4) \ldots \\ + \frac{-R_3}{24}\cdot S(x, 11.375\cdot in, 4) + \frac{R_4}{24}\cdot S(x, 16.75\cdot in, 4) - \frac{R_4}{24}\cdot S(x, 17.25\cdot in, 4) + C_1\cdot x + C_2 \end{pmatrix}$$

$x_b := 0, 0.001 .. 20.25$



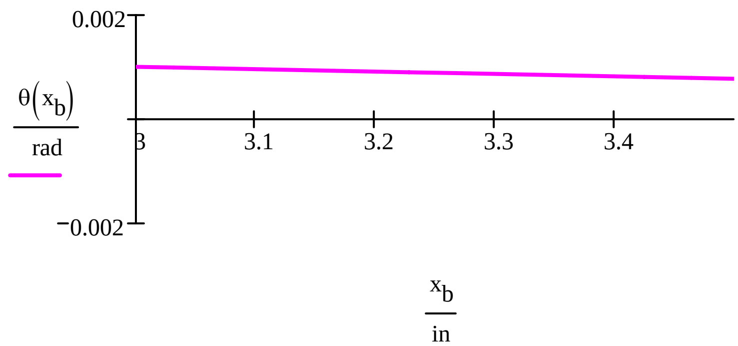




Below are plots of the four bearings. These show the angle in radians they will be operating at. Each is a 0.5 inch wide blow-up of the slope graph above acting at the distances given. For ball bearings, the maximum angle should not exceed 0.0087 rad according to Shigley's "Mechanical Engineering Design" textbook. These values are indeed within the safe zone.

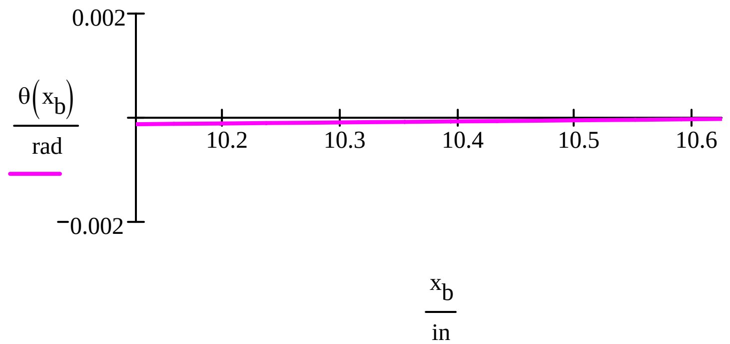
$\theta(3in) = 0.00101\ rad$

$\theta(3.5in) = 0.00078\ rad$



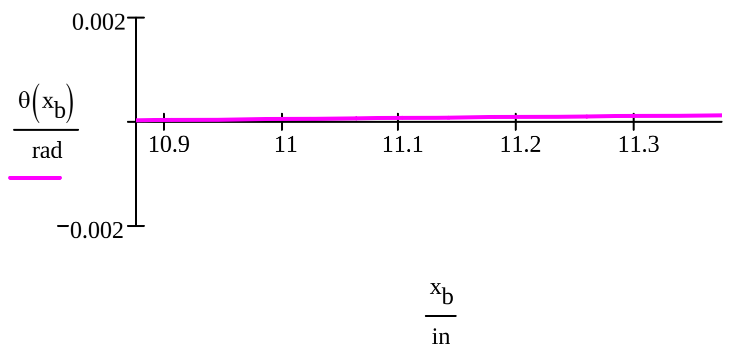
$\theta(10.125in) = -0.00012\ rad$

$\theta(10.625in) = -0.00003\ rad$



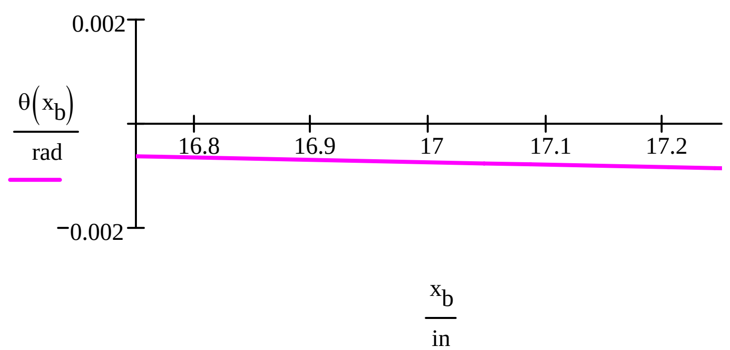
$\theta(10.875in) = 0.00003\ rad$

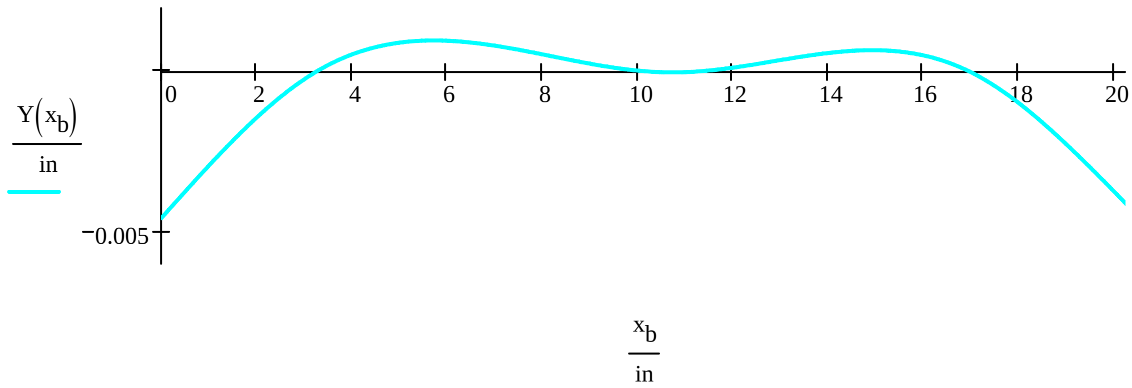
$\theta(11.375in) = 0.00012\ rad$



$\theta(16.75in) = -0.00063\ rad$

$\theta(17.25in) = -0.00086\ rad$





We can see the axle shaft is only going to flex (bend) five thousandths of an inch when fully loaded. This is a very minute amount and can be assumed "safe". But as an engineer, it is my job to fully investigate the axle shaft and determine a safety factor from the situation. A proper design will include both maximum shear (Case A) and maximum moment (Case B) values by the use of a Mohr's circle and MSS theory for failure criteria.

Case A

$V(17.25in) = 200\,lbf$

$M(17.25in) = -600\,lbf \cdot in$

$V_{max.A} := V(17.25in)$

$M_{max.A} := M(17.25in)$

Case B

$V(3.3in) = -1.548\,lbf$

$M(3.3in) = -630.232\,lbf \cdot in$

$V_{max.B} := V(3.3in)$

$M_{max.B} := M(3.3in)$

We now have all of the information available to determine the maximum normal stress and the maximum shear stress. This will allow us to figure the principle stresses by means of a Mohr's Circle which will lead us to an appropriate safety factor for the axle shaft.

$$C := 0.5in \qquad I = 0.049\,in^4 \qquad A := \frac{\pi \cdot D^2}{4}$$

Normal stress A

$$\sigma_A := \frac{M_{max.A} \cdot C}{I} \qquad \sigma_A = -6111.55\,psi$$

Normal stress B

$$\sigma_B := \frac{M_{max.B} \cdot C}{I} \qquad \sigma_B = -6419.492\,psi$$

Shear stress A:

$$\tau_A := \frac{4 \cdot V_{max.A}}{3 \cdot A} \qquad \tau_A = 339.531\,psi$$

Shear stress B:

$$\tau_B := \frac{4 \cdot V_{max.B}}{3 \cdot A} \qquad \tau_B = -2.628\,psi$$

Mohr's Circle Data

$\sigma_{x.A} := \sigma_A \quad \sigma_{y.A} := 0psi \qquad \tau_{xy.A} := \tau_A$

$\sigma_{x.B} := \sigma_B \quad \sigma_{y.B} := 0psi \qquad \tau_{xy.B} := \tau_B$

$$Center_A := \frac{\sigma_{x.A} + \sigma_{y.A}}{2} \qquad Center_B := \frac{\sigma_{x.B} + \sigma_{y.B}}{2}$$

$Center_A = -3055.775\,psi \qquad Center_B = -3209.746\,psi$

$$Radius_A := \sqrt{\left(\frac{\sigma_{x.A} - \sigma_{y.A}}{2}\right)^2 + \tau_{xy.A}^{\ 2}} \qquad Radius_B := \sqrt{\left(\frac{\sigma_{x.B} - \sigma_{y.B}}{2}\right)^2 + \tau_{xy.B}^{\ 2}}$$

$Radius_A = 3074.58\,psi \qquad Radius_B = 3209.747\,psi$

Principle Stresses

$\sigma_{1.A} := Center_A + Radius_A \quad \sigma_{1.A} = 18.805\,psi \qquad \sigma_{1.B} := Center_B + Radius_B \quad \sigma_{1.B} = 0.001\,psi$

$\sigma_{2.A} := 0psi \qquad \sigma_{2.B} := 0psi$

$\sigma_{3.A} := Center_A - Radius_A \quad \sigma_{3.A} = -6130.355\,psi \qquad \sigma_{3.B} := Center_B - Radius_B \quad \sigma_{3.B} = -6419.493\,psi$

Safety Factor

Now we can find the safety factor using the Maximum Shear Stress failure theory:

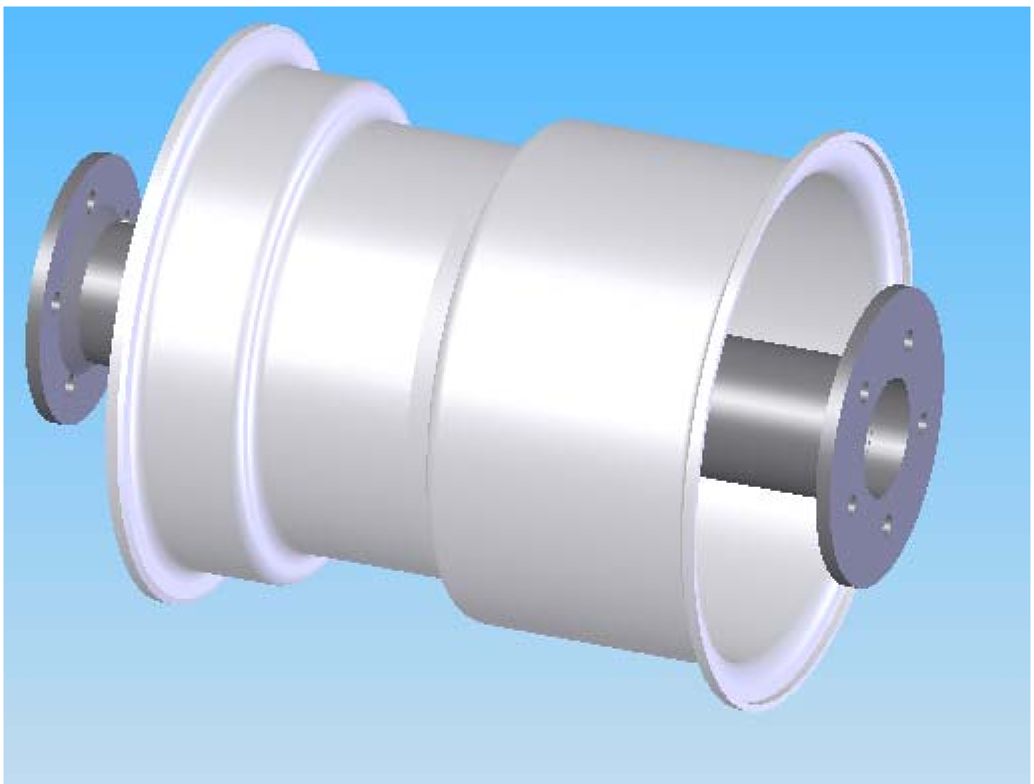
$$SF_{mss.A} := \frac{S_{y.304Stainless}}{\sigma_{1.A} - \sigma_{3.A}}$$

$$SF_{mss.A} = 30.899$$

$$SF_{mss.B} := \frac{S_{y.304Stainless}}{\sigma_{1.B} - \sigma_{3.B}}$$

$$SF_{mss.B} = 29.597$$

The Maximum Shear Stress failure theory was used since it is the most conservative method which will give the lowest possible safety factor. It is good practice to use this theory rather than others especially if human lives are dependant on the structure, such as a motorcycle.

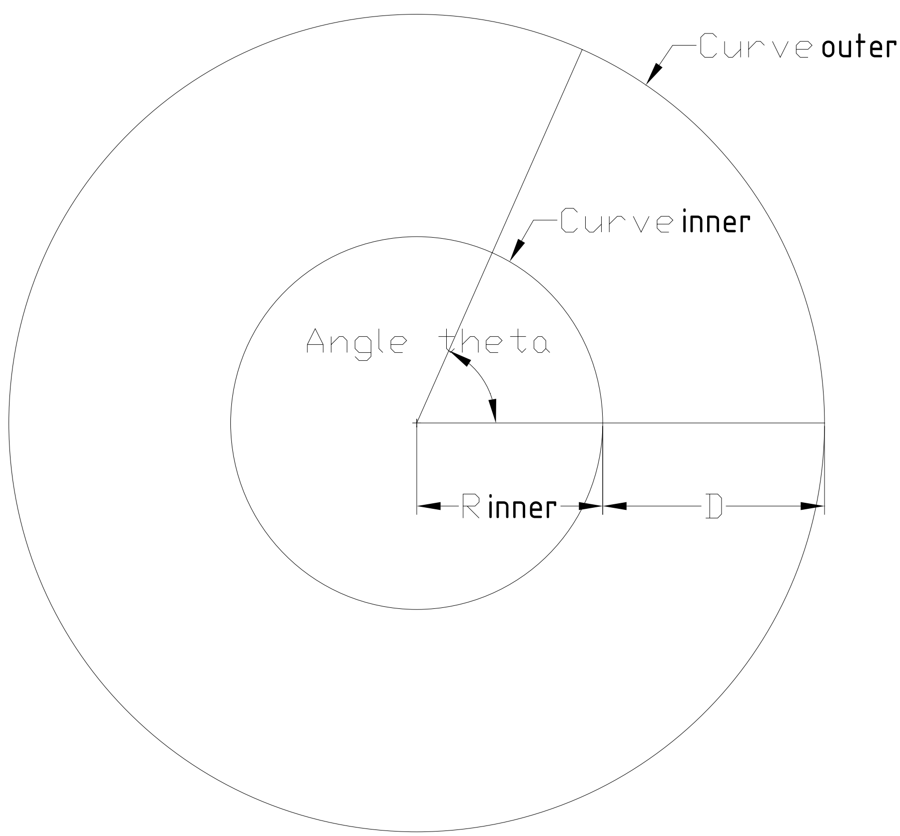


At this stage of the project, I have already begun building the bike. The rear hubs have been made and bolted to the rim with the axle running through just as planned (see above graphic). Also the frame has been constructed with the engine and transmission mounted. It was not until making the exhaust pipes that I came accross the need for another engineering problem. It is not often that conics are used, but when they are, they can be tricky at times. Simply put, I need to go from a small tube to a large tube. Making a cone from a sheet of steel is the easiest way to do so. But to do so takes a precise method rather than just pounding steel (no pun intended) and hoping it fits. So, a mathematical relationship can be formed between the two sizes and length desired.

Cone Development Formula

This method is used when a cone is needed of known large and small diameters as well as the length. This is very useful after printing a sketch in AutoCAD which can be used as a template. The template can then be traced over the sheet metal to be cut out. Once cut out it can then be bent around a pipe, vise or anvil to the correct shape with or without heat. The two edges of the metal will meet perfectly and can be welded to form a solid cone.

Directions: The inputs needed are the D_{large}, D_{small} and Length which are highlighted in yellow. The outputs to be sketched in AutoCAD are R_{inner}, R_{outer} and the angle theta which are given in blue.

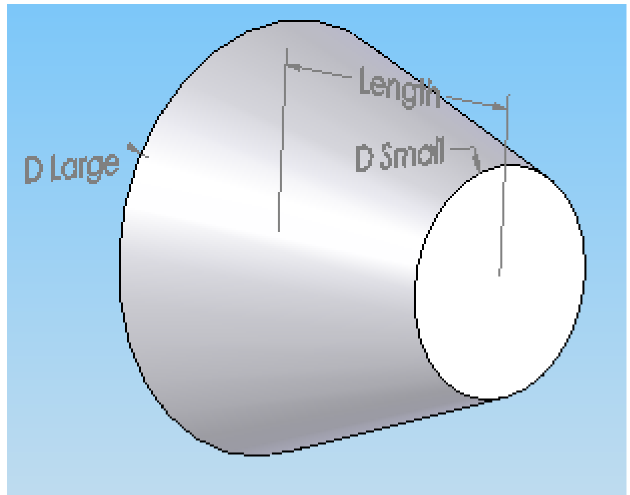


Desired sizes:
(inputs)

$D_{large} := 1.5in$

$D_{small} := 1.155in$

$Length := 2.00in$



$Curve_{outer} := D_{large}\pi$

$Curve_{inner} := D_{small}\pi$

$$D := \sqrt{\left(\frac{D_{large} - D_{small}}{2}\right)^2 + Length^2}$$

Initial Guess:

$R_{inner} := 1in \qquad \theta := 1$

Given

$Curve_{inner} = R_{inner} \cdot \theta$

$Curve_{outer} = (R_{inner} + D) \cdot \theta$

$$\begin{pmatrix} R_{inner} \\ \theta \end{pmatrix} := Find(R_{inner}, \theta)$$

Small Circle: $R_{inner} = 6.721\ in$

Large Circle: $R_{inner} + D = 8.728\ in$

Angle in degrees: $\frac{180}{\pi}\theta = 30.935$

Fork tubes

Turning our attention to the fork tubes, we would like to find the safety factor of the fork tubes knowing the downward force from the combined weights of the bike acting on the tubes at the point of the bottom tripple clamp.

This can be done by first knowing the forces and distances of each major component. Then the center of mass can be determined from the components. Finally a generalized beam of the bike can be modeled after taking the moment about the rear axle and setting it to zero. This will result in the downward force acting on the tubes at the lower tripple clamp.

The constants are defined:

$F_{engine} := 105lbf$ $X_{engine} := 32in$

$F_{rider} := 200lbf$ $X_{rider} := 14in$

$F_{neck} := 25lbf$ $X_{neck} := 48in$

$F_{Cshaft} := 20lbf$ $X_{Cshaft} := 21.5in$

$F_{batt} := 30lbf$ $X_{batt} := 19in$

$\theta := 0.75rad$

To determine the center of mass, no Y coordinates are needed, only X coordinates since we are looking at the bike in a one dimensional view (X distances only).

The equation to find the center of mass is:

$$X_{bar} = \frac{\sum_i x_i \cdot m_i}{\sum_i m_i}$$

So now plugging the constants from above into this equation we get:

$$X_{bar} := \frac{(F_{engine} \cdot X_{engine}) + (F_{rider} \cdot X_{rider}) + (F_{neck} \cdot X_{neck}) + (F_{Cshaft} \cdot X_{Cshaft}) + (F_{batt} \cdot X_{batt})}{(F_{engine} + F_{rider} + F_{neck} + F_{Cshaft} + F_{batt})}$$

$$X_{bar} = 22\,\text{in}$$

And just as a note, the total weight of the bike with rider is:

$$F_{bike} := F_{engine} + F_{rider} + F_{neck} + F_{Cshaft} + F_{batt}$$

$$F_{bike} = 380\,\text{lbf}$$

So now the center of mass is 22 inches forward of the rear axle shaft and is a combination of engine, rider, countershaft, battery and frame (neck) masses. Now the center of mass of the bike is used to determine the axial force in the fork tubes.

The upward force the front tire exerts on the tubes needs to be determined. This can be done using superposition since the "beam" is of such a simple design. First the distance from each axle needs to be known and is denoted as L.

$$L := 77\text{in}$$

$$W_f := \frac{X_{bar}}{L} \cdot F_{bike} \qquad W_r := \frac{L - X_{bar}}{L} \cdot F_{bike}$$

$$W_f = 108.571\,\text{lbf} \qquad W_r = 271.429\,\text{lbf}$$

These are the respective weights each axle shaft will see. Wf is the front wheel force and Wr is the rear wheel force. The weight percentage on each wheel is found:

$$\frac{W_f}{F_{bike}} \cdot 100 = 28.571 \qquad \frac{W_r}{F_{bike}} \cdot 100 = 71.429$$

Now with the weight distribution known, the safety factor of the front forks can now be figured. This is more complicated than what first seems since the front fork tubes have a combination of beam and column loading effects. The fork tubes are made from low carbon 1020 steel.

On page 969 of the Shigley text, case 1 is the proper beam type to model the bike with.
The length of the fork tubes are 37.25 inches.

First, the constants need to be defined:

$$L := 37.25\,in \qquad I := \frac{\pi}{64} \cdot \left[1.00in^4 - (1.0in - 0.240in)^4 \right] \qquad E := 30 \cdot 10^6 psi \qquad S_{y.1020Steel} := 43 \cdot 10^3 psi$$

$$I = 0.033\ in^4$$

Since there are two fork tubes, the force the front wheel exerts from the previous page (Wf) can be divided by two.

$$W_f := \frac{W_f}{2}$$

Part 1: Beam Loading

$$R_1 := W_f \cdot \cos(\theta) \qquad M_1 := R_1 \cdot L \qquad Y_{max} := \frac{R_1 \cdot L^3}{3 \cdot E \cdot I}$$

$$R_1 = 39.72\ lbf \qquad M_1 = 1479.579\ lbf \cdot in \qquad Y_{max} = 0.697\ in$$

$$V_{max} := R_1 \qquad M_{maxB} := M_1$$

Part 2: Column Loading

$P := W_f \cdot \sin(\theta)$ $e := Y_{max}$

$P = 37.003\,\text{lbf}$

$$M_{maxC} := P \cdot e \cdot \sec\left[\left(\frac{4 \cdot L}{2}\right) \cdot \sqrt{\frac{P}{E \cdot I}}\right]$$

$M_{maxC} = 28.762\,\text{lbf} \cdot \text{in}$

Combining Loadings

$M_{total} := M_{maxB} + M_{maxC}$

$M_{total} = 1508.342\,\text{lbf} \cdot \text{in}$

Now the maximum stress from both loadings is given by: $\sigma_{max} = \dfrac{M_{total} \cdot C}{I}$

So, $\sigma_{max} := \dfrac{M_{total} \cdot C}{I}$

$\sigma_{max} = 23055.738\,\text{psi}$

Sigma max is the stress due to bending. We can neglect the effects of shear stress and get away without the need of a Mohr's Circle since the shear stress will be so minute compared to the bending stress.

And finally computing the safety factor:

$$SF_{tubes} := \frac{S_{y.1020Steel}}{\sigma_{max}}$$

$SF_{tubes} = 1.865$

Regarding the column loading, the safety factor can be determined using the critical load divided by the actual load.

$$P_{cr} := \frac{\frac{1}{4}\pi^2 \cdot E \cdot I}{L^2}$$

$$P_{cr} = 1745.015\,\text{lbf}$$

$$SF_{column} := \frac{P_{cr}}{P}$$

$$SF_{column} = 47.158$$

However this is not the true safety factor of the fork system because it only involves the axial (column) loading of the tubes and not the perpendicular (beam) loading. But it is important to note that this portion of the tubes acts as a column and an engineer would always want to expect a high safety factor; which means the actual load on the column is much less than the critical load applied before buckling begins. This calculation above just ensures us that the system will not fail to buckling.

So the overall safety factor of the front fork tubes are 1.865. This seems low compared to the other components on the bike, but remember the tubes are raked at such an angle along with the fork's length which contributes to the low safety factor.

$$S(x, x_0, a) := \begin{cases} \dfrac{0}{in^{|a|}} & \text{if } a < 0 \\ \text{otherwise} & \\ \quad \begin{cases} 0in^{|a|} & \text{if } (x - x_0) < 0 \\ (x - x_0)^a & \text{otherwise} \end{cases} \end{cases}$$

Initial Guesses

$R_1 := 10\dfrac{lbf}{in}$ $R_2 := 10\dfrac{lbf}{in}$ $C_1 := 10lbf \cdot in^2$

$R_3 := 10\dfrac{lbf}{in}$ $R_4 := 10\dfrac{lbf}{in}$ $C_2 := 10lbf \cdot in^3$

X. Work Entry Log

1-16-07: Spoke with Dr. Divo and Salvadore Gerace regarding them being my mentor for this project. They both agreed, but mainly Sal will be my mentor since Dr. Divo mentors other groups.

1-18-07: Brainstormed ideas for a mini-chopper style motorcycle. 1 hr

1-27-07: Submitted project proposal for mini-chopper. Later revised the objective and the goals to be more concise.

2-9-07: Began preliminary design of bike. Speed calculations from engine and transmission manufacture were determined. 2 hrs

2-11-07: Removed and degreased engine and transmission from previous application. Also laid out parts on shop floor for rough size estimate.
4 hrs

2-12-07: Discovered the 1.75" OD x 0.75" ID tapered roller bearings would not work for steering neck. Need to recalculate an appropriate bearing size. Also realized transmission from previous application may not work. Bought tubing for the frame. 4 hrs

2-14-07: Spoke with Sal and he helped me with units in my MathCAD worksheet. Speed chart is now complete for different engine RPMs and transmission ratios. 1 hr

2-16-07: Went to "Jims World of Wheels" in Oviedo, FL for brake pads. Tom gave me a freebie rear drive belt worth over $150! 1 hr

2-20-07: Spoke with Sal regarding the picture pasting in MathCAD. Also needed help with finding unknown reactions on the axle due to the bearings in the hubs. Lastly, determined that with only one mode of stress (torsion) the safety factor for the hub is just the yield strength divided by the torsional stress. 1.5 hrs

2-21-07: Traced the pattern of the hub flanges on ¼" thick steel, later to be cut out by cut-off wheel and grinder. Hole saw to remove the major hole in middle. Also figured how to mount the brake caliper. Then chopped hub tubes to length of the rotor and pulley. 4 hrs

2-24-07: Created steering neck from Timken tapered roller bearings bought from Skycraft surplus. 2 hrs

2-26-07: Took hub flanges and tubes to Sackett Machine Shop in Orlando to be turned for press fitting the flanges on. Said work would cost around $120 to complete and are delayed 3-4 days behind. 2 hrs

3-2-07: Spoke with Sal again regarding the singularity functions in MathCAD. Turns out I had a wrong sign convention and that is all that was needed to throw off the shear, moment, slope and deflection graphs. When the bike is fully loaded, the axle will deflect five thousandths of an inch with a safety factor of almost 30! 1 hr

3-3-07: Got the tubes and flanges from Sackett for $100 cash. Pressed the flanges on the tubes and welded them. Flanges warped some but only a small amount. Then the holes were drilled and tapped for the rotor and pulley. Bearings would not press in after the welding so the holes had to opened up some with a die grinder. After the bearings went in and the holes were drilled/tapped, the rotor and pulley centering rings were made on our lathe out of aluminum and PVC tubing. 9 hrs

3-4-07: Assembled the rear hubs onto the rim. There is an extremely tight fit between the bearings and the axle. So the axle cannot be removed while the hubs are in place. Next I bolted the rotor and pulley to the hub flanges to check for wobbles. Amazingly only the rotor wobbles 50 thousandth out of round. This is too little to worry about. The pulley does not wobble at all. 2 hrs

3-5-07: Set all of the parts on the ground in their proper arrangement and took pictures. Realized the rear frame section will be harder to make than first thought. 2 hrs

3-6-07* through *3-9-07: Collected more parts via eBay. My father has the week of my spring break off to assist me in welding of the tubes.

3-10-07: Started the morning by making the rear axle mount blocks. Then bought one 2x6 and two 2x4's from Home Depot to lay vertical on the concrete floor for a reference point when making the frame. This will clamp the sides of the tire and keep everything in a straight line as we build. This is our "quick-n-easy" jig. Next the rear hub assembly was taken completely apart for cleaning, sanding and then painting. The rim holes were ground flat so the hubs would squeeze the wheel flange as parallel as possible. A tire tube was also added at this time since the tire had a hole in it (reason for being a freebie). Sat down and planned the work load for the following week. My goal is to have the bike on its wheels by the end of spring break with most fabrication completed. 6 hrs

Week of Spring Break, March 12-16 2007

Monday, Day 1: The first thing we did on Day 1 was go to Grainger in Altamonte to buy a sprocket. This will be used to mount the front belt sprocket to the 1" countershaft. Grainger also had 1" locking collars to securely locate the bearings and pulleys on the countershaft. After returning home, we ground off the teeth of the "just purchased" sprocket with a grinder then chucked it in the lathe to true the sides so it would slide into the belt sprocket. After that, holes were drilled into each part so they would rotate as one unit by means of grade 8 bolts and nuts. The tire was over inflated to seat the beads with the new tube installed. Assembled the rear hub after paint finally dried over the weekend. The jig was also constructed to establish a flat surface for measuring and laying the frame's tubing onto. Starting with the bends around the rear tire, the bottom bends were done first and then the top bends. The top and bottom bends needed to be bent tighter than our tubing bender would bend, so that was the stopping point on Day 1. It seemed like Christmas since two major items showed up in the mail: the wider Harley rear belt pulley as well as the Comet 94C driver clutch. 10 hrs

Tuesday, Day 2: Starting where we left off on Day 1, the torch was used to heat the tubes in order to bend them easily in the vise. The ends of the U-bars were then angle cut so they would form a nice closed point where they both meet. A vertical support brace was welded in just under the seat location for rigidity. This structure was then fully welded. Next, the axle mounting triangles were made and welded to the insides of the U-bars. After ground smooth, the axle was finally cut to length. With the axle mounting blocks already clamped to the axle, the U-bar was brought into position and then fully welded to the blocks. The rear section of the frame was now fully complete. One thing we had to keep in mind was the fact that the rear drive belt had to be able to be removed if necessary. This meant the belt would have to slip inside the U-bars. This forced the bottom bends further down only inches above the ground. The torch helped increase ground clearance by adding a shaper bend in the tube than the tubing bender could provide. After visiting Alro for more steel, the larger tube (backbone) was bent and cut to length to run up to the steering neck. With the engine sitting at the correct height, the tube clears the valve covers quite nicely. The steering neck was tacked on later. The frame's down tubes which run underneath the engine were cut a little long and bent for the correct fit. It was getting late and this would wrap up fabrication for Day 2.

My lunch hour was spent calling companies in the Orlando area for a transmission drive belt. Both distributor and retailer said the belt number I gave them was not in their system. So I then called Comet Industries to see if a belt was even available. Don Jackson personally told me they are available and in stock at the manufacturing plant in Indiana and run a cost of $45. I then tried giving more information to my local people and again they were no help other than to tell me they charge a 100% markup fee. This means my $45 belt will cost $90 plus shipping! I left Don a voice mail telling him this strange news that my retailer still could not help me. He then phoned me back telling me he does not want to lose customers and that he would charge me $45 plus shipping and the belt would be sent to me the next day by UPS from the manufacturing plant in Indiana. This was the best news I had all week! 10 hrs

Wednesday, Day 3: The first order of business was to cut and weld the down tubes into place. This required a lot of finesse as we had several angles and lengths happening at the same time. Lots of grinding and re-checking angles with an industrial protractor did the trick. The first disagreement between my dad and I came in the form of how far apart the spacing of the down tubes should be. I urged the "wider is better and looks better" theory while he urged "closer to make it easier to weld to the rear section". After an hour was spent setting up the engine and tranny, we realized that my way would work and look better. The mounts for the counter shaft were cut and notched next. A 3/8" slot needed to be cut in the steel plate. Usually we do this by drilling several holes in line and then filing the edges by hand. This has worked in the past but takes too long. So we used a big die grinder with a metal cutting bit. Unfortunately on the fourth plate the bit broke which bent the chuck so the bit would not unscrew. The built in lock feature broke as we tried to unscrew it by wrenches. We must have applied a tremendous amount of force to shear off the locking pin. This rendered the grinder useless and most likely junk after we just spent $60 for new brushes and bearings.

I finished up the pillow bearing plates before lunch and we had them welded in sometime in the early afternoon after cutting and fitting the mounts for the plates. Then it was time to make the engine mounts. These were easier than the countershaft as it was just four straight tubes. Only two of the tubes needed notching for the engine to slide through which took slightly longer. After dinner, the engine mounts were tacked in place. We then slid the engine in for the first time without the need for wood supports. It was a great feeling to see less and less wood on the bike as we progressed. After closing the shop for the day, I designed the triple clamps in AutoCAD to be printed and cut out and used for a template. Since we ran out of daylight and it was getting late, I figured I could do this first thing in the morning. All in all Day 3 was the best yet since so much got accomplished. 10 hrs

Thursday, Day 4: From the previous night, my first task was to cut out the triple trees out of 4” x ¼” steel plate. This took a while as lots of grinding was needed to get them to the proper shape. Then the drill press was used to drill some large holes for the fork tubes to run through. Work was sped since I had already designed and built the steering neck back in February. While I was working on the triple clamps, I was also helping my dad help me mount the rear disc caliper. This was harder than it seemed since the steel had to be held in such awkward positions to get it tack welded in. A few burns here and there and it was in. After the triple clamps bolted up to the neck, the fork tubes were cut to length and tabs welded at the ends for the bicycle rim to bolt to. Around 4:00pm the bike was finally on its wheels for the first time without the need for any more wood! It was looking better and better. My dad designed and built a kickstand while I mounted the Harley Davidson Sportster gas tank. After the sun went down, we mounted the engine, transmission, gas tank and fork. Unfortunately we stumbled upon our first problem. The bike was very heavy on the left side and took a considerable amount of strength to hold it up. It was amazing how unbalanced it was even though the engine appeared to be in the center of the frame. Talking with my dad we determined a way to move the engine over 1.5 inches. This is why you only tack weld everything into place until the very end! We knew our task for the next day. Even with this somewhat large mistake I felt Day 4 was just as good as Day 3. Mainly because it was the first time I finally saw the bike on its wheels without the need for any more wood. 10 hrs

Friday, Day 5: Right off the bat we cut off the engine and one countershaft brackets. After moving them over exactly 1.5 inches like we determined, before long our mistake was fixed. Now with the bike fully loaded again, it was almost perfectly centered. In the real world, an inch can make the biggest difference. It was not yet 10:00am and our previous attempt to lengthen and widen a fender did not work out so well. So it was off to Northern Tool on Sand Lake Road to buy a larger fender. Sure enough one was in stock and fit our tire perfectly. After lunch we split the fender and welded in the 3 inch section to widen it. That was the easy part. The welds had to be ground off to a smooth finish so not as to look unsightly. After 1.5 hours of grinding, it looked like a nice fender again! Mounting the fender proved tougher than first thought. All of the bolts except for one run through curved surfaces of the fender, making them tricky to mount. After the fender was on, the rear portion of the seat was finished. All in all, Day 5 seemed like it dragged on and on without much getting accomplished. 10 hrs

3-17-07: Cut out a brake pedal from ¼" thick steel. Then used the torch to fold over the brake pad where your foot will press. Welded the pedal to a sleeve with a bushing inside to rotate over the foot peg. Then the mount for the master cylinder was made out of more ¼" steel. A connecting rod was found and bent to connect the foot pedal to the master cylinder. Made an unsuccessful trip to Alro Metals to look for larger tubing for the handlebars. They changed their Saturday store hours again. This time they are no longer open at all on Saturdays. 8 hrs

3-18-07: Went to Home Depot for a lawnmower battery and some angle iron stock. Also bought four 90 degree bends of electrical metal tubing to be used for the exhaust. First thing was to create the exhaust flanges to bolt to the engine's exhaust ports. Then the tubing was cut and rotated to clear the dipstick and the clutch pulleys. A mathematical problem arose from the need to make two cones to go from small tubing to larger tubing. The use of MathCAD to simultaneously solve for the unknowns and then AutoCAD to sketch out the cone in a development view worked perfectly. The printout sketch was traced onto sheet steel and cut out, then hammered around a pipe to get it rolled properly. The seams fit together perfectly and were welded to form a solid cone. The larger tubes were then cut and welded to the proper fit. This finished up the exhaust and was a successful weekend. 8 hrs

3-19-07: Bought a piece of 1" OD x 0.062" wall stainless steel tubing for the handlebar. It was cheap since it was from a previous cut hence the reason for it being stainless steel. Cut angle iron steel from Home Depot to form a rectangle battery tray and welded it together. Then fit it into the rear section of the frame under the seat with flat stock also from Home Depot. Not as productive as some of the other days, but nonetheless the battery is taken care of. 5 hrs

3-21-07: Finished welding the exhaust pipes. Started fabrication of the seat pan. Measured the depth of the elevator which is 8 feet. 2 hrs

3-22-07: Ground the welds smooth on the exhaust pipes. 2 hrs

3-24-07: Finished making the upper seat pan out of wood. This will serve as the mount for the foam to lie on and for the faux leather fabric to be stapled to on the back side. After the seat was finished, the handle bars were created. Several methods for bending the tubes were used to get the desired radius needed for the riser pipes. This finished up the day since we were all hungry for dinner. Bought more bolts at Ace Hardware and an ignition switch from Advance Auto Parts. 8 hrs

3-25-07: Now that the seat was on, I could sit comfortably on the bike to reach into space for creating the handlebars. We started the day by cutting the riser pipes for the handlebar. Then the stainless steel from Alro was used for the actual handlebars. A slot was cut in the risers and handle bar for the throttle cable to slip through. After the handlebars were finished, we rolled the bike outside for some photo shots in the sun/shade. Then it was rolled back into the shop where it was completely taken apart. Once the bike was in 20 pieces again, we decided to weld up the frame and forks completely. This took the rest of the day. 8 hrs

3-26-07: After welding the frame and forks completely, the first thing we did was wire brush all of the welds to remove the powder residue from the welding rods. Then I used an air scribe to remove the slag buildup. After that, the small grinder cut some of the unsightly weld beads off. Then the large die grinder with a small carbide bit was used to shape the weld bead. Next a stone wheel was used in the die grinder to smooth the welds after shaping. Finally sanding by hand was the preferred way to get the frame looking good from the ugly black coating the tubing had. Once it was sanded to a shine, we degreased it with a Prep-Sol cleaning agent. The frame, fork and fender were hung up by wire and then sprayed with DuPont Variprime self-etching primer. These processes took all day and were by far the longest day of the build to date. 8:30am – 7:00pm 10.5 hrs

3-28-07: Coated the frame, fender and fork with gray sealer-primer from a rattle can. Also glued the seat foam to the wood bottom with spray adhesive. 2 hrs

3-29-07: Used automotive spot putty on all of the weld beads (frame and forks) to smooth them out. Fabricated rear brake light mount. 1hr

3-31-07: Trimmed seat foam and wrapped with brown faux leather. Stapled the ends to the bottom side of the wood. Sanded the spot putty on the welds, applied more spot putty. Sanded again. Body filler was also applied to the fender to smooth it out. 6 hrs

4-01-07: Primed frame and fork once again. Spot puttied fender after body filler was sanded and then primed. Fabricated ignition and light switch mount under seat pan. 4 hrs

4-02-07: Drilled holes in frame for brake light mount and for wires to run through. Also applied more putty and primer. 2 hrs

4-04-07: Painted brake pedal, brake rod, kickstand, belt sprocket and belt sprocket hub with black enamel Rustoleum. 1hr

4-05-07: Removed Harley Davidson decals from the gas tank. Then primed and puttied it smooth. 2 hrs

4-06-07: Painted fender and gas tank of a metallic silver. 1 hr

4-07-07: Added three strips of tape onto the fender and gas tank for a pin stripe effect. Next the frame was sanded lightly with 150 grit sandpaper to smooth out the primer-sealer. The frame, fender, gas tank and other small parts were finally sprayed "Bright Amber Metallic". After that dried, the pin stripe tape was peeled off and the clear coat was applied to the frame, fender, gas tank, small parts and rear belt sprocket for the "wet look". There was one catastrophe however. During painting of the fender, somehow it fell off the hook (probably due to Saturday's windy conditions) and landed in the dirt/mulch! The debris stuck to the fender and also left divots in the body filler. Oh no! So it was washed off with water, wet sanded, re-puttied/sanded and then hung up again with better care of the hook location. 6 hrs

4-08-07: Sanded some of the runs from all four layers in the clear coat. Then applied two more coats of clear to finish off the frame, gas tank and fender. 2 hrs

4-09-07: Started by welding a spacer sleeve to the internal throttle and drilled a hole in the handlebar so that the internal throttle could be welded in place. The inner throttle cable was soldered for rigidity and clamped in place. Removed frame from wire hangers and placed on blocks with towels for paint protection. The fender was installed. Next the rear wheel and axle assembly was installed along with the belt. The engine was set in along with the transmission pulleys on the countershaft. The fork was installed temporarily to determine the correct length of throttle cable and how it would attach to the engine. The fork was then removed and prepped for painting metallic silver. However the bad weather caused the silver to dry blotchy and will need repainting.
6 hrs

4-11-07: Repainted the fork silver since the weather was better. Then spoke with Sal regarding issues determining the stress and safety factor for the fork. 1 hr

4-12-07: Clear coated the fork. Painted some other miscellaneous items as well. 1 hr

4-13-07: Installed rear brake light and ran wires through frame. Installed fork assembly with foam inserts around the steering neck bearings. Installed master cylinder with braided brake line. Installed countershaft. A sleeve was needed to use a set of Harley Davidson handlebar grips. Removed rear block and towel so bike now sits on the rear tire. 3 hrs

4-14-07: Made a mount for the headlight. Wired headlight wires through frame backbone. Fixed brake pedal misalignment issue. Installed handle grips. Connected throttle cable to engine. Installed rear drive belt and front belt sprocket. Installed 100D driver pulley. Tightened countershaft bearing bolts. Bought eight grade 8 washers at Ace for engine bolts. Tightened engine bolts. Installed battery along with bungee cords to secure. Wired up headlight switch and ignition switch to seat pan. Bolted seat down for the first time since being fully covered. 9 hrs

4-15-07: Mounted exhaust pipes to engine and frame. Realized there was a problem with the ignition switch and returned it to Advance Auto Parts for a new unit. The new switch was installed in no time. The front wheel and kickstand were also installed. The air compressor was used to blow the sand out of the gas tank then the shut off valve was installed. Gas tank mounting bolts were cut to length and soon the tank was firmly mounted. Next the fuel line and filter was installed. The brake pedal was installed along with the right foot peg rubber grip. The bike was then placed on its wheels after the block of wood was removed from underneath. The brake reservoir was installed along with the hose to master cylinder. Brake fluid was added and the brake system bled of any air. Gasoline was then put in the tank and checked for leaks. Once no leaks of any kind were detected the bike was rolled outside where it started on the second try. It is definitely noisy with the straight pipes. After a minute of warm up, it accelerated through the back yard with ease. Next the bike went for a test drive down the street. This was the first time the bike was ridden and everything seemed to work as expected. 4 hrs

Total hours = 195

XI. Associated Costs

Harley rear brake pads	Jims World of Wheels	53.48
Harley rear drive belt	Jims World of Wheels	0.00
9x10 Rear Steel Wheel	Gempler's Supply	32.00
Inner tube for rear tire	eBay	22.94
1" OD solid stainless and A53 tubing	Alro Metals	14.02
1" OD x 0.120 x 22.5' DOM	Alro Metals	100.30
1" SQx11 GA and 1.5"x0.120 DOM	Alro Metals	47.82
Comet 100D driven clutch pulley	eBay	90.05
Comet 94C driver clutch pulley	eBay	175.99
Comet 1-3/16" drive belt #300641C	Comet Industries	51.65
Machine work	Sackett Machine	100.00
1" Pillow block bearings (2)	eBay	27.66
1" Sealed ball bearings (4)	eBay	20.89
Starter rebuild	Longwood Auto Electric	90.95
Air Filter	Home Depot	15.00
Chrome halogen headlight	eBay	54.10
Harley rear master cylinder	eBay	22.51
Internal twist throttle	eBay	63.05
Grade 8 bolts 1	Ace	20.04
Grade 8 bolts 2	Ace	0.95
Grade 8 bolts 3	Ace	19.68
More 1"OD x 0.120 x 12' DOM	Alro Metals	44.94
Sprocket and (3) 1" locking collars	Grainger	44.43
Fender	Northern Tool	28.00
Battery, angle iron, flatstock, EMT (4)	Home Depot	75.19
18"x12"x16ga steel plate (2)	Lowes	28.60
90 and 35 degree banjo fittings	eBay	18.66
Rear brake light pressure switch	eBay	24.50
60inch throttle cable	eBay	7.99
Grade 8 bolts 4	Ace	22.17
Ignition switch	Advance Auto Parts	9.61
Tan faux leather fabric	Jo-Ann	8.46
Turn signal, switch, filler primer (2)	Auto Zone	17.08
Brakle light, filler primer (2)	Advance Auto Parts	12.37
More filler primer (2)	Advance Auto Parts	9.51
Gas tank petcock	Jims World of Wheels	29.94
Handle bar grips	DEBRIX.com	26.83
Metallic silver spray paint	Advance Auto Parts	5.83
Black high heat paint	Advance Auto Parts	6.18
Grade 8 bolts 5	Ace	3.27
Goodyear 1" ID rubber hose	Amazon Hose & Rubber	4.07
	Total costs	1654.26

Robert Mann
ETG4950 – Sr. Design
Dr. Mehrabian
January 25, 2007

Mini-Chopper Project Proposal

For this project, my primary mentor is that of Salvadore Gerace. He is currently enrolled in the masters program at UCF in the field of mechanical engineering. His office is room 422 of the ENGR1 building. Sal is very knowledgeable in the study of mechanics of materials, stress and strain analysis, failure criteria along with permanent (welding) and non-permanent (bolts and screws) joints. He is a perfect mentor for this as we both have a liking for mechanical devices. Sal also teaches in the ENT department under Dr. Eduardo Divo's supervision, so Dr. Divo will be my secondary mentor as he agreed to this after a personal visit.

- Identify: for this class, I intend to design and build a custom mini chopper style motorcycle. However since there are so many parts to a motorcycle, I will only concentrate on five or so due to the short nature of this class.
- Background history: Minibikes are nothing new. In fact they have been around since the 1950's. When the children started taking a liking to them, the market responded and several companies began mass producing them. Recently with the change of styling of real chopper motorcycles, mini choppers began to follow thus forming the mini-chopper. More information can be found here: http://en.wikipedia.org/wiki/Minibike
- Objectives: to analyze and build a real mini chopper motorcycle that looks and sounds like the real thing…only smaller. Five aspects will be analyzed: rear axle shaft, rear axle hub assembly, front fork assembly, frame design, and transmission/gear train from an engineering standpoint.

PROPOSAL

My senior design project will mainly focus on what I have learned in my core and upper level engineering classes. Applying textbook theory to real world applications is one of the goals of many graduating seniors. Unlike MMAE students who have a whole year to plan and build their sr. design project, ENT is only a 15 week course so I will only focus on a few elements of the bike rather than do an entire FEA of every little detail.

The elements I will mainly be focusing on are the rear axle shaft, rear axle hub assembly, front fork assembly, frame design, and transmission/gear train. All of these elements except for the transmission/gear train will be analyzed looking for failures or weaknesses given the material used. Graphs and charts will be used to show beam deflections. SolidWorks will be used to show the bearings and hub assembly and also a 3D drawing of the frame. Once no weaknesses are found given the material used, engine torque under full acceleration and the estimated rider + engine weight loading, construction can begin on the frame.

Engine	25hp Kohler 725cc V-Twin lawnmower engine
Start/charging	12 volt Denso electric start with 15 amp alternator
Transmission	Comet Automatic Torque Converter pulley system
Final Drive	Harley Davidson 32 tooth and 70 tooth cog belt pulley
Front tire	Kawasaki 20” stunt bicycle with 68 spokes
Rear tire	Dixie Chopper lawnmower 25”x13”-9” four ply
Speed	20mph to 60mph
Controls	Right hand twist grip throttle, right foot rear brake, ignition
Brakes	Harley Davidson 12” rotor with hydraulic caliper (foot operated)
Weight	No more than 250lbs without rider

The Kohler V-twin engine is used for its power, smoothness and most of all the Harley type exhaust rumble. It is small but powerful and will propel the bike up to speeds quickly. The Comet Torque Converter is a simple method of changing speed ratios (transmission) without the need for manually shifting.