Final Design Report

Motor Mouths

Endurance Race
MCEN 3025

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1. Introduction/Background

The purpose of the overall project is to familiarize all the students on the team with the complete engineering design process and to implement their previously obtained knowledge to create a fully functioning drill-powered bike. Projects are the most effective way to apply what each student has learned in a collaborative effort to create a final product. In this case, SOLIDWORKS was used for the design and solid mechanics-based calculations were made to preemptively analyze race conditions and prevent failure. Motor Mouths also utilized an iterative design process based on feedback provided by faculty-driven design reviews. Through this process, the team was able to reduce the possibility of failure due to improper materials and create a more effective design.

The main objective of this project was to create a unique drill-powered bike that would complete the course as many times as possible, while remaining under the budget and weight constraints. The designed bike must be under 50 pounds to compete in the race and should cost less than $200. The budget restraint was implemented to reflect the real-world scenario of creating and selling a product for profit. The drill powered bike would theoretically be sold at $200 therefore incentivizing the team to build with the largest profit margin possible.

Motor Mouths' motivation behind the chosen design was to create a competition-ready bike. Design choices were made specifically for the endurance course requirements. The team decided to use three wheels to increase balance, a lightweight frame to increase efficiency, and a free-wheel to allow for coasting on the downhill sections of the course. Using the highest quality materials, in an efficiently designed bike, while staying within the given constraints would allow for the best outcome during the endurance race.

2. Vehicle Design

Conceptual Designs:

The group's initial design began with a recumbent bicycle having three large bike wheels: two in the back, and one in the front. It was quickly realized that this incurred the problem of needing a differential. Therefore, the design was changed to include two wheels in the front and one in the back.

To be able to move both wheels at the same time while steering, Motor Mouths decided to use a steering system commonly seen on go karts. The steering system was designed to be controlled by the steering column and had steel cables running to the wheel axles which pulled the wheels in the direction the steering wheel was turned.

The power system was designed using the drill as the motor. A cord would wrap around the drill's trigger with the other end attached to a pedal. When the pedal was pressed, the cord would pull on the drill's trigger, thus activating the drill. A key component of the power system is the drill mount, to be later designed.

The braking system for this bike would consist of a disk brake salvaged from another bike attached to the rear wheel. This brake was to be attached to a trigger near the front of the bike, that when pulled would activate a caliper. This caliper would clamp the rotor, therefore stopping the vehicle.

Selected Design:

Prior to the group's design review, a couple of alterations were made to the vehicle's design. Firstly, premade go-kart steering knuckles were utilized (a spindle and bracket system) as opposed to a custom system. Buying this system pre-made saved the group significant amounts of time in manufacturing with more precision overall. Because this system was intended for go-kart sized wheels, the original two front bike wheels were swapped out for much smaller go-kart wheels.

To fabricate the bicycle frame, 1"x1" square steel tubing with wall thickness of 0.065" was used. Appropriate deflection and stress calculations verified the frame would be able to support the weight of the rider; a static point and distributed load were applied. Utilizing two different sized wheels left an eight-inch discrepancy in axle heights. This problem was overcome by cutting a seven-degree angle in the front of the frame. This solution was chosen instead of building up the back end of the frame because it saves manufacturing complexity and material, therefore saving time and money. The only challenge that this approach created was making appropriate jigs to allow for welding.

Initially, Motor Mouths' selected PVC as the steering column material to reduce both weight and cost. The necessary calculations were made to ensure PVC could withstand the torsional stress. The column was to be supported by wood, which was also selected with weight and cost in mind. Revisions to material selections were made after the design review, which are noted in the next section.

Another change that was implemented at this point in the design process was updating the support of the steering column. A stop was added at the front so that the steering column could not fly forward, and it still had enough space to rotate in. The design was also changed so that the steering column support would encase the steering column. This design change was made so that pins could be added before and after the support to give a second method of securing the column in place.

Motor Mouths' initial concept included a wood mount for the drill and shaft supports with ½" bearings (see in appendix for image). Each pillow block bearing was individually supported to allow space for the sprocket and chain. The drill was raised up for easy access to the battery. Therefore, the pillow blocks were also raised up to the same level as the shaft. A u-shaped design was utilized to make extra space for the rear wheel, as well as to reduce weight.

Design Iteration

After the design review, Motor Mouths revised their bicycle design so that more appropriate and reliable materials were used, and both the drill mount and steering system were more consistent with the design intent.

Despite necessary calculations ensuring PVC could withstand torsional stress and serve as the steering column material, Motor Mouths' changed the material to steel tubing to err on the side of caution. Also, the column support components will be made of steel, with a bushing between the support and column to reduce unnecessary friction. Similarly, steel will be used rather than wood to mount the drill and shaft supports. This material is more appropriate because the bearings, which serve as supports for the shaft, will be constantly loaded and the pillow blocks must remain secured to the base of the holder. Furthermore, wood, which was initially selected, risked grain fractures under this sort of stress.

The initial steering system presented problems relating to material selection and unequal tension in the two steel cables; for these reasons, the steering system underwent a moderate redesign. The current design utilizes tie rods rather than steel cables to control the front wheels. This guarantees the wheels will turn as expected and with equal force, whereas the cables would have required oversteering or understeering if the tensions were unequal. The tie rods, not machined in-house, simplify the assembly of the bike and make its symmetry absolute.

During the design review, the issue of material for the drill base not being able to withstand constant loading and torque was voiced. The team addressed this issue by way of redesign in steel. Motor Mouths removed the unnecessary support blocks for the drill to simplify the design and decrease the weight. The u-shaped design remained with the addition of slots over-top of the frame to allow for chain tensioning. The two-hole straps were exchanged for U-bolts, as they better fit the drill. The bearings were also resized to ⅝" to fit the shaft.

3. Vehicle Analysis – Critical Components

Critical Component #1: Drive Shaft

One of the critical components of this design is the drive shaft. It transfers power from the drill to the attached sprocket, which is connected to the chain that transfers power to the cassette on the back wheel. The end of the shaft was machined into a hexagonal shape to fit into the drill mouth. During the manufacturing process, Motor Mouths realized it was not practical to mill the proposed keyway along the length of the shaft as was originally intended. In lieu of this realization, the team purchased a different sprocket without a pre-existing key and instead decided to manufacture set screws. Set screws were utilized to ensure the sprocket and shaft would rotate as a single unit and prevent lateral slippage of the sprocket along the shaft. This critical component would allow the team to power the bike without failure.

The methods used to analyze this critical component were based on estimates for shear and bending that the shaft would encounter (see appendix for detailed torque and bending equation analysis).

Critical Component #2: Vehicle Frame

The second critical component chosen was the vehicle frame because it had to hold the driver's weight without failure throughout the entire race. To analyze this component, it was necessary to consider the beam deflections and the stress from bending. For this manual calculation the team overestimated the driver's weight and considered it a point load. Half of this force was applied to one of the parallel beams and the other half was applied to the other. The results showed that the bending was minimal, deflecting less than a quarter inch, and the yield strength was well above the applied stress (shown in the finite element analysis).

The frame was created out of steel due to its high yield strength and rigidity. The mild steel purchased was machinable and weldable in the machine shop available to the team. A seven-degree angle was cut in the two bars which connected the front and rear wheels. This was created to ensure the front axis support remained parallel to the ground despite the height discrepancy between axles.

Critical Component #3: Steering System

The third critical component of the bike design was the steering system, without which the vehicle would not have turned. It was important that this component have a turning radius that would fit the racecourse track, thus an analysis was needed to find the possible turning radius, considering the front two wheel's turning ability, and the length of the vehicle (see appendix for detailed equation analysis of turning radius).

4. Fabrication

The first component the team manufactured was the frame, which was made of multiple 1"x1" square steel tubing welded together. This was manufactured first to base measurements and other subassemblies off of. Once the frame was welded, the next challenge the team tackled was the steering subassembly. Numerous parts were manufactured including the U-shaped steering support with the attached plate, tie bar support and steering column stop. All the components were made of mild steel. The stop was bent to a 30-degree angle, and the U-bar support was cut at 63 degrees to allow the steering column to sit at a 30-degree angle. Bushings were press-fit into the steering column support plate and stop. These pieces used the steering column itself as a jig for welding.

The team moved on to manufacturing the drive shaft so that it could be used to align the pillow block bearings on the drill plate. The drive shaft was made of hardened ground steel, which required supervision manufacturing in the machine shop. The team machined out the bore of the sprocket to fit on the drive shaft and used the lathe to cut down the face width, so the teeth fit a standard chain. The subassembly consisting of the drive shaft, sprocket, bearings, and drill allowed the team to accurately place and dimension holes for the drill plate. This was made of a 1/8" mild steel plate and had slots for chain tensioning, a cutout for the chain, as well as holes to mount the pillow block bearings and drill. The slots and holes were milled once Motor Mouths mounted the drill plate to the frame. The team was able to machine axle supports to hold up the rear wheel and disk brake caliper. Afterwards, the team welded the knuckles onto the frame to add the premade wheels, as well as the spindle and bracket set.

<u>Issues Discovered During Assembly:</u>

1. The group discovered that the bushing ordered had an inner diameter which was too small to fit over the steering column support. To fix the size of inner diameter, the group lathed out the center of the bushing.
2. The team, when beginning the assembly, also discovered that the original design for mounting the back wheel would not support the dimensions of the wheel's hub. To overcome this issue, Motor Mouths decided to use two wheel-mounting plates which were welded to the back of the frame to support the wheel. In the final design, one of the plates included slots to mount the brake caliper.
3. When assembling the chain, sprocket, pillow blocks, and drive shaft Motor Mouths discovered the chain touched either the side of the pillow blocks or the side of the tire. To remedy this situation, Motor Mouths decided to purchase a smaller tire to replace the original one.

5. Vehicle Testing and Results

Due to the nature of this project, the normal approach to testing (test until failure occurs) is not appropriate. After consultation with faculty, Motor Mouths decided to do a simple deflection test to measure what the actual deflection was as compared to the finite element analysis from SOLIDWORKS. The deflection with the driver sitting on the bike was measured to be ¼” which aligned with the finite element analysis. Furthermore, the driver ran the bike around the track ensuring that all the systems worked in harmony.

Motor Mouths’ most important discovery from the testing phase was the issue with chain tension. Even though the group had provided a method of tensioning the chain via slots in the drill plate, once testing with an actual driver the chain continued to slip off the sprocket. The team attempted to figure out the root cause of the slack in the chain. Some of the hypothesized ideas were that it was pre-stretched because the chain was old, or the drill plate was slipping due to the lack of washers. Once the washer situation was remedied, the team continued testing only to have the issue continue. After further deliberation, Motor Mouths removed two links from the chain. This allowed the team to increase tension on the chain. This, however, did not completely resolve the issue either. Finally, the team found that the issue was that once the driver sat on the bike, the chain stretched so tensioning the chain beforehand was rendered useless. This discovery quickly resolved the issue and the team was able to correctly tension the chain with the driver sitting on the bike.

6. Design Iteration After Testing

Since the vehicle functioned as intended, no changes occurred after iterative testing.

7. Run-off Results and Lessons Learned

The team’s vehicle performed well at run-off. All the key components functioned as designed, and minimal issues were encountered. Although the wires driving the power system were tightened beforehand, the wire around the drill trigger slipped. This required the driver to manually power it for the drill to rotate at full speed. This originally caused a loss of momentum traveling up the hill as it was not initially known that the drill was not providing full power.

Motor Mouths learned a lot about design and manufacturability throughout the iterations of this project. The team realized the importance of knowing the feasibility of machining a material or component. Successful design and manufacturing requires thinking multiple steps ahead and preparing for possible complications.

8. Bill of Materials/Cost

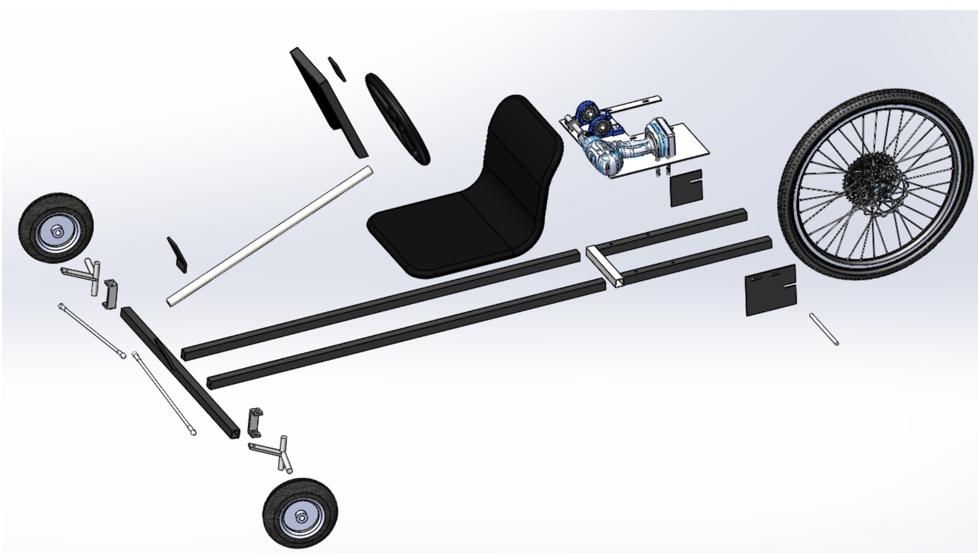
The final cost of the bike was $292.00, which was $92.00 over budget.

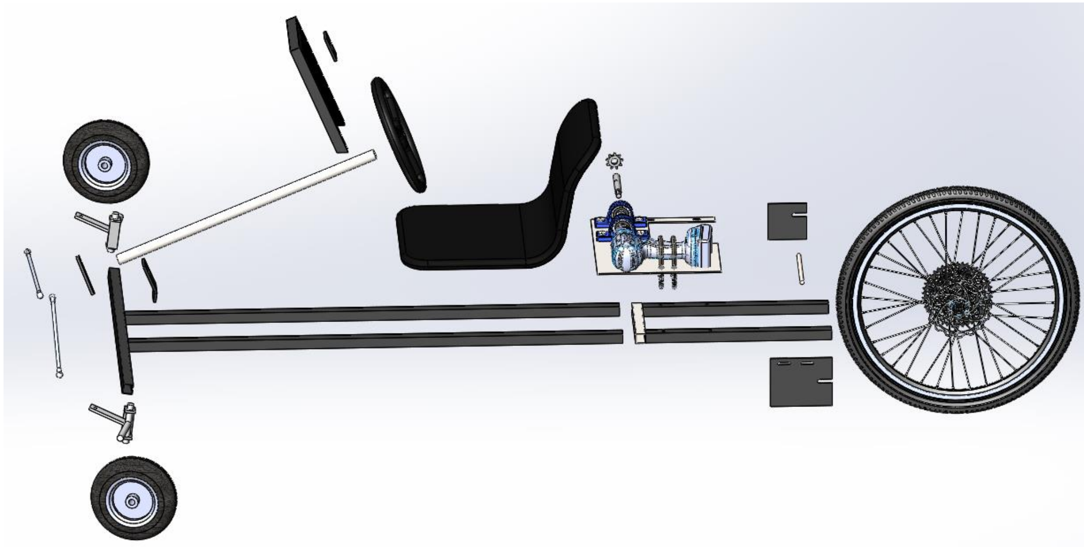
Part	Description	Quantity	Vendor	Price
1"x1"x.065" Wall Rectangular Steel Tube, 96" long	Main/center bars for frame (cut 96" bar in half)	1	Online Metals	$8.00
1"x1"x.065" Wall Rectangular Steel Tube, 48" long	(1) 18" bar for back of frame, (1) 30" for T bar	1	Online Metals	$5.67
1"x1"x.065" Wall Rectangular Steel Tube, 24" long	(1) 18" bar for back of frame, (1) 6" bar for back of frame	1	Online Metals	$3.39
1"x1"x.065" Wall Rectangular Steel Tube, 36" long	Steering column support	1	Online Metals	$4.81

DOM Mild Steel Tube A513 Type 5	1" OD x .065" wall, 2 ft long; steering column	1	Online Metals	$5.20
DOM Mild Steel Tube A513 Type 5	1" for steering column support	1”	Online Metals	$1.08
Hot Rolled Mild Steel Plate A36	Steering column support, .25" thick	4"x3"	Online Metals	$2.40
A1011 Steel, 1/8"	Drill stand base	12"x24"	Online Metals	$12.00
Wheel Hub	Rear bike wheel hub	1	Amazon	$33.71
Sprocket	Steel Machinable-Bore Sprocket, 10 teeth	1	Mcmaster	$12.60
Spindle Set	Go kart spindle set 4.5"x5/8	1	Amazon	$46.88
Tie Rods	Steering design	2	Ebay	$29.96
Go Kart Wheel	Front wheels	2	Tractor Supply Co.	$33.57
Bushings	For steering column supports	2	Igus	$19.47
Drill	Makita XFD11RB	1	Makita	0
Drive Shaft	5/8" Diameter, 4 in. long, Steel (PN 60037827)	1	MSC Direct	$21.80
5/8" Pillow Block Bearing	R8-2RS sealed bearing 1/2"x1-1/8"x5/16", chrome steel	2	Amazon	$32.59
Brake handles, calipers	26" wheel front 79-99 mm reach	1	Amazon	$10.00
Fasteners	For attaching drill stand base, spindle, tie rods		McGuckins	$8.87

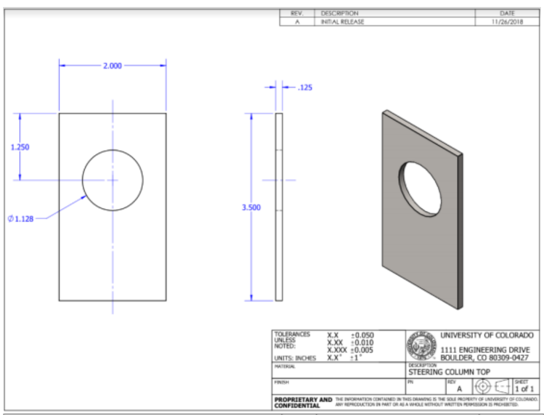
9. Appendix

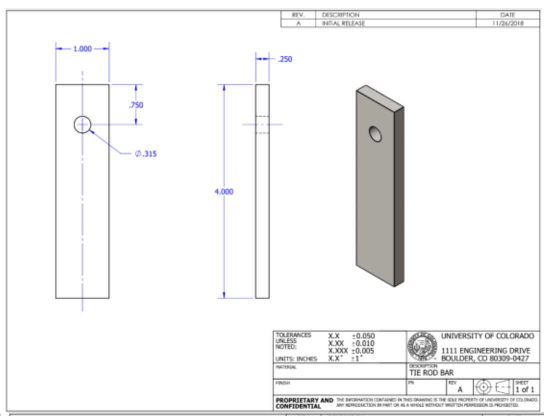
a. Exploded views of entire assembly

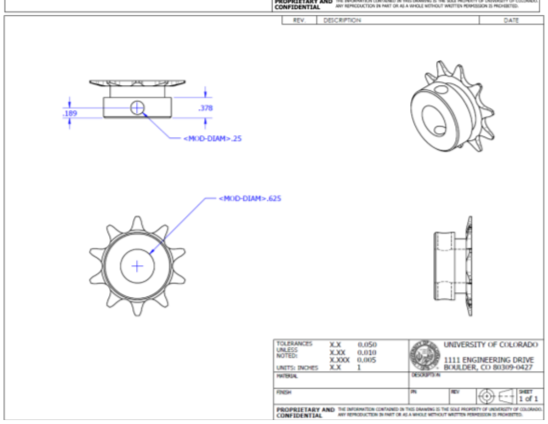


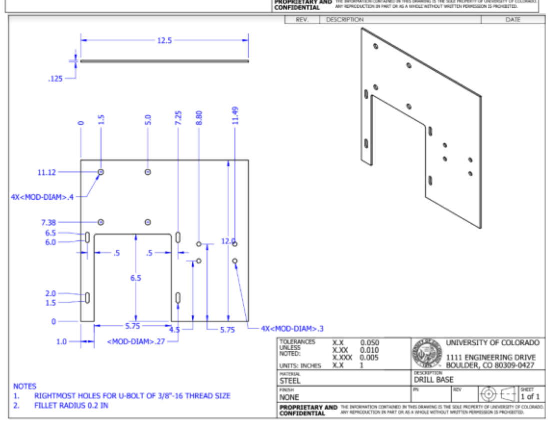


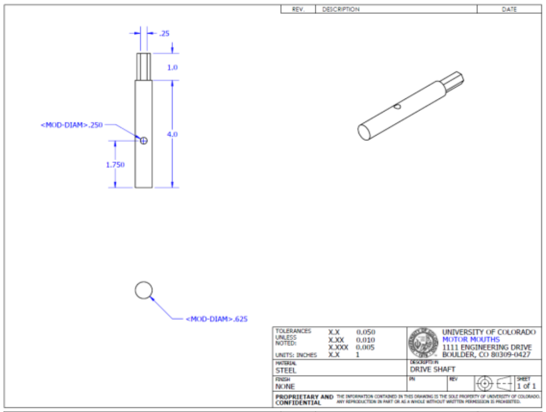
b. Engineering drawings for fabricated parts

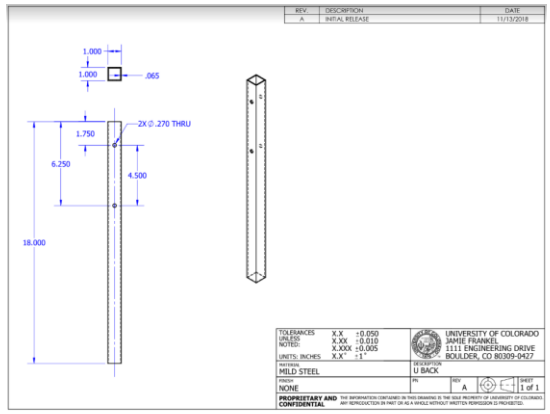


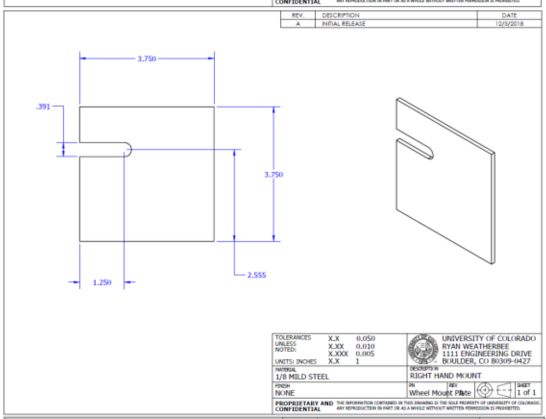


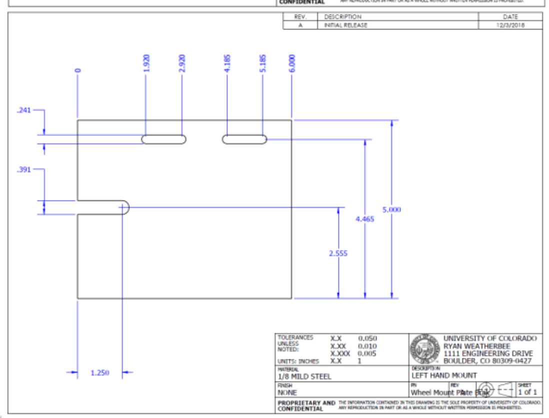


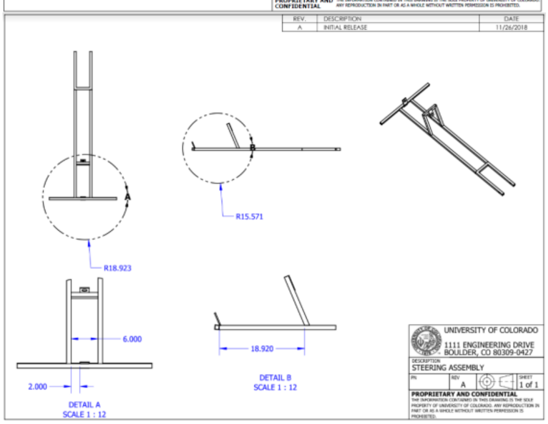


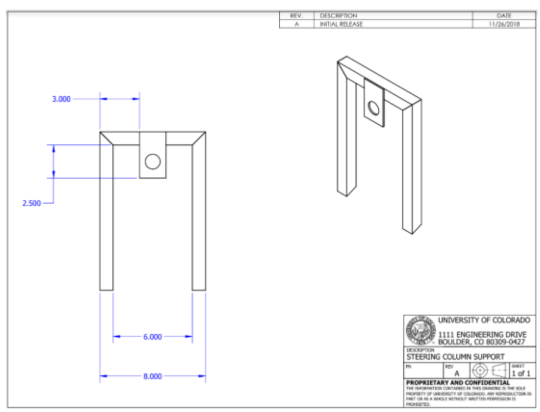












c. Calculations for bike analysis

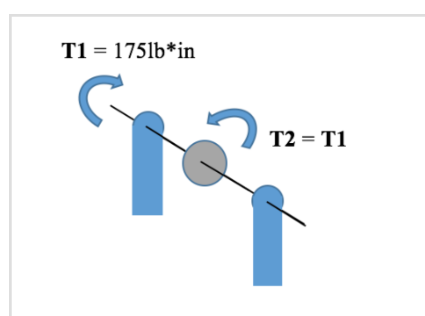
<u>Failure Analysis for Drive Shaft - Shear:</u>

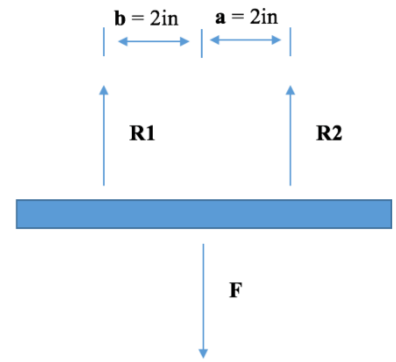
$$J = \frac{\pi}{2}c^4 = \frac{\pi}{2}(0.25)^4 = 6.136 * 10^{-3}$$

$$\tau = \frac{Tc}{J} = (175lb * in)\frac{0.25}{6.136 * 10^{-3}} = 7130.1lb * in$$

$$Sy(aluminum) = 2.176 * 10^6 \rightarrow 2.901 * 10^6 psi$$

$$Sy \gg \tau = 7130.1lb * in \rightarrow this\ will\ not\ fail\ in\ shear$$

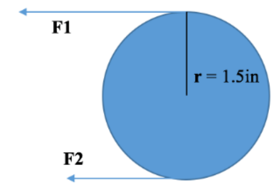




Failure Analysis for Drive Shaft – Bending

$$F1 + F2 = F$$

$$T = F * r \to F = \frac{T}{r} = \frac{175lb}{1.5in} = 116.67lb$$

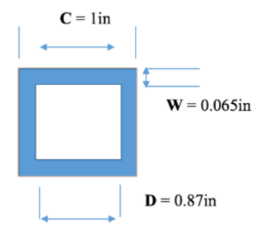


$$R_2 = \frac{1}{2}F = 58.335lb, R_1 = 38.335lb$$

$$\sum M \to 2F - 4R_2 = 0$$

$$d = \frac{1}{2}in, c = \frac{1}{4}in$$

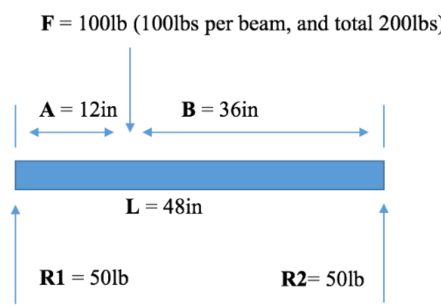
$$I = \frac{\pi}{64}d^4 = \frac{\pi}{64} * 0.5^4 = 3.067962 * 10^{-3}$$



$$\varepsilon = \frac{Mc}{I} = \frac{(116.67lb * in) * \frac{1}{4}}{3.067962 * 10^{-3}} = 9507.13psi \ll Sy\ 2.176 * 10^6 \to 2.901 * 10^6$$

$$\to Will\ not\ fail\ in\ bending$$

Beam Deflection:



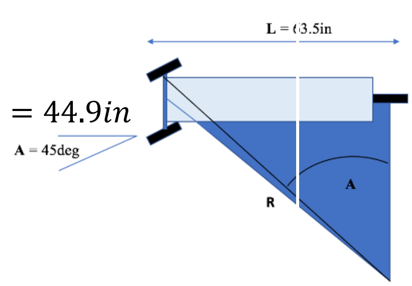
$$E_{steel} = 200 * 10^9 Pa = 2.901 * 10^7 psi$$

$$I = \frac{C^4 - D^4}{12} = \frac{1^4 - 0.87^4}{12}$$

$$y_{max} = -\frac{FL^3}{48 * E_{steel} * I} = -\frac{100lb * 48in^3}{48 * (2.901 * 10^7 psi) * 0.0356in^4} = -0.2231in$$

Turn Radius:

$$R = L * sin\ sin\ (A) = 63.5in * sin\ sin\ (45) = 44.9in$$



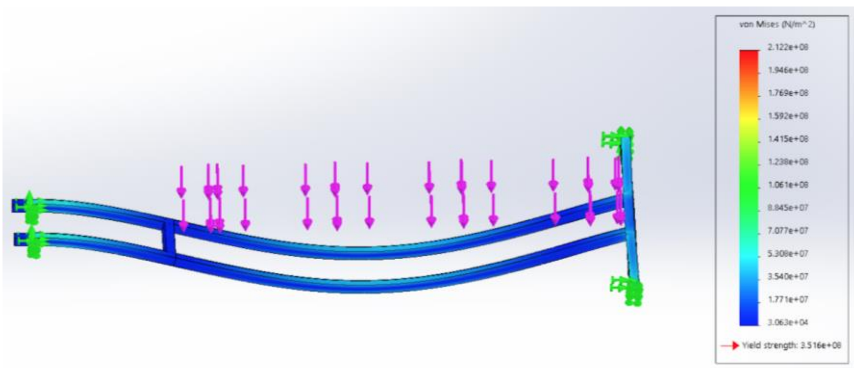
Gear Ratio:

$$V = \left(\frac{17mi}{hour}\right) * \left(\frac{1hour}{60\min}\right) * \left(\frac{5280ft}{1mi}\right) * \left(\frac{12in}{1ft}\right) = 17952in/min$$

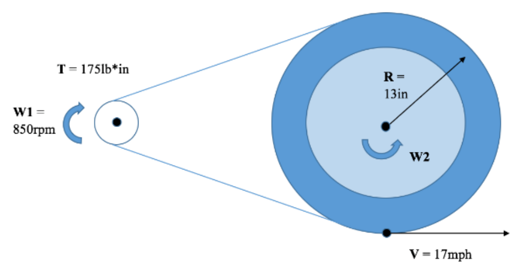
$$V = \frac{w}{R} \qquad w_2 = \frac{\frac{17952in}{\min}}{13in} = \left(\frac{1381rad}{\min}\right) * \left(\frac{1rev}{2\pi rad}\right) = 219.78rpm$$

$$\frac{W1}{W2} = m_g = \frac{850rpm}{219.78rpm} = 3.86$$

Finite Element Analysis of frame calculated using distributed force of 200 lbs:



d) Meeting minutes taken throughout the entire semester



10/8 - In Class - Everyone

- Determined Race
  - Endurance
- Determined people's role
  - Project Manager - Morgan
  - Test Engineer - Jamie
  - CAD Engineer - Isabel
  - Systems Engineer - Ryan
  - Manufacturing Engineer -Lauren
- Listed basic tasks and timeline

Task: Submit project planning document

10/11 - Jamie and Ryan House - Everyone

- Short Meeting
- Between either a tricycle or two-wheel bike (training wheels?)

Task: Think about it individually and meet again on Sunday to determine design

10/14 - Jamie and Ryan House - Everyone

- Decided to do tricycle with one wheel in back and two wheels in front
- Complication to figure out - two-wheel steering system
  - Googled images/videos of steering systems
  - Options
    - Differential steering
    - Both power and steer w/back wheel
    - Switch to two wheels in back while only powering one wheel
    - Two wheels - balance issues
    - Two-wheel w/training wheels - not effective steering
- Design to base steering system off: DIY Drill Powered Go Kart https://www.youtube.com/watch?v=EQyVGVwZnzo

Task: Ask professor for feedback on drawing before submission

10/15 - In Class - Everyone

- Discuss with mentor our design - Josh
  - Do NOT weld bearings! (weld nothing moving or with stainless steel)
  - Axle clamps - to attach bearings to wheels
  - When going downhill and wheel spinning faster than drill
    - Free wheel adapter or bike wheel with freewheel
  - Error in breaking on same wheel as actuating
  - Weight problem - not compact enough
    - Weight saving ideas
      - Front wheels close together
      - Short as Ryan not super tall
  - Problem with aluminum - if fail will rip right out (worry about tear out)
  - Start preparing for design review NOW
- Dimension drawing and add more specifications/details before tomorrow's submission
  - Upstairs in CAD Lab to finish drawings
- Drill attachment
  - Slot and swivel inside? - Ryan idea
- Scheduled design review for Monday October 29th at 2:30pm

Task: Submit Concept Sketches and Start Design Review preparation next meeting

10/18 - ITLL - Everyone

- Steering component problems
  - Difficult to mate in SOLIDWORKS due to odd angles aka would be difficult to make
- Options to fix
  - Universal joint - allows different angles of rotation - but expensive
  - Cables instead of rods - cheaper - allows odd angles
    - One bar to connect two sides so they move together
- Make two connecting rods for seat instead of just one
- Materials
  - PVC instead of steel for the connecting bar with the seat - maybe?
  - PVC for the steering column - Torsion properties?
  - Back fork and front T need to be metal
  - Use bike part for back fork?
- Need support for steering column with groove for it to turn in - wood?
- Calculated

Task: Everyone update SolidWorks for Sunday, talk to Greg Potts next week

10/21 - Jamie and Ryan House - Everyone - Morgan late

- 1"x2"x0.065" (wall) Rectangular Steel Tube (from Speedy Metals) - middle frame bar
  - 48" long for $17.14 (not including shipping)
- 2 PVC pipes on side of middle frame bar for extra support
  - Attachment method - drill through with washers
  - Revised attachment method - pipe fittings (slide over T rod, pipes slide into them)
- 2.5' long front bar (T) which will attach to front wheels - same cross section as middle frame bar
  - New idea: Instead of T, drill straight into middle frame bar to attach rod (1" diam) which connects to front wheels
    - Rectangular front/T bar issues: difficulty in mounting a swivel component for wheels to turn
  - Add square steel pieces on either side of middle frame that T rod goes through (extra support)
- ¾ in (buy 3' long) PVC for steering column - Actual OD 1.050 in
  - 30 degrees from horizontal
- Wooden steering column support; no bearing
- All wheel's bicycle wheels (rather than 2 small front ones)

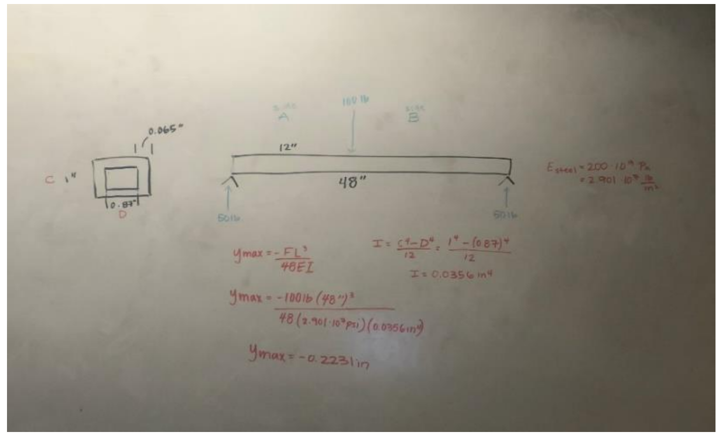
10/22 - In Class - Everyone except Jamie

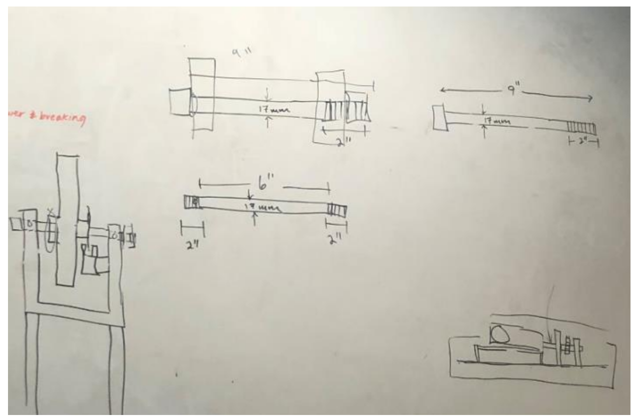
- Talked to Greg Potts - come back anytime
- Lots of suggestions and minor changes, nothing completely contradicting any part of our design so far
  - Buy knuckles
  - Buy anything that is available - it will be cheaper and save time
  - 10% of project costs are materials and the rest are labor costs - your time as engineers is worth money
  - Make sure to have a spring return
  - Use bike braking system, have one handle act as throttle and the other brake
    - Pulling trigger should be good -keep it simple
  - Use shoulder bolt -allows for pivot
  - Buy go kart wheels for front steering
    - designed to fit knuckles
    - Keep bike free wheel in back
    - Bigger driver wheel
  - Include beam calculations
    - Stronger than you think - he will test his body weight
    - Twice weight of driver - safety factor
  - Good bearing blocks to support shafts from drill - MOST IMPORTANT
    - Under lots of force
    - Both sides - have chain run between
  - Bearings
    - ½ inch inside diameter, 1 ⅛ inch outside diameter
    - Watch tolerance!!!
      - +0 tolerances to guarantee will bit inside
  - Buy ground shafting
    - Split costs with another team as will only use about 4 of the 12 inches
  - Hex on the shaft for drill

10/25 - ITLL - Everyone - Isabel Late

- Calculations

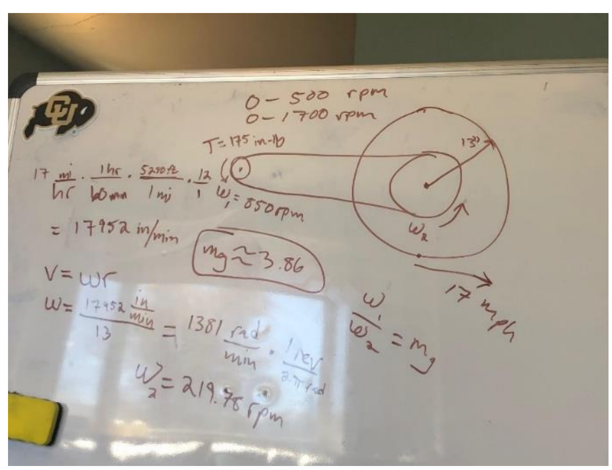
- Gear ratio
    - Deflection
    - Torque on drill shaft
    - Top speed
    - Turn Ratio
- Update CAD
    - New wheels - go kart
    - Knuckles
    - Risers
    - Drill Attachment
    - Breaking system
    - Power system
- Update Budget
    - Wheels - $15.99 x 2 - done
    - Knuckles - $31.94 - done
    - Account for risers - done - no cost
    - Account for power and breaking
    - Hinge
    - Steel cable - done
    - Spring
- Update PowerPoint
    - Less custom components
    - Risers - probably custom
    - Calculations
    - Pics of CAD
    - Stress analysis
- Make up for height difference -Front T frame
    - Angle brackets - no
    - Angle major cross - angle cut - yes!
- Breaking system
    - Brake disk
    - Need wheel with both free wheel and brake disk
    -

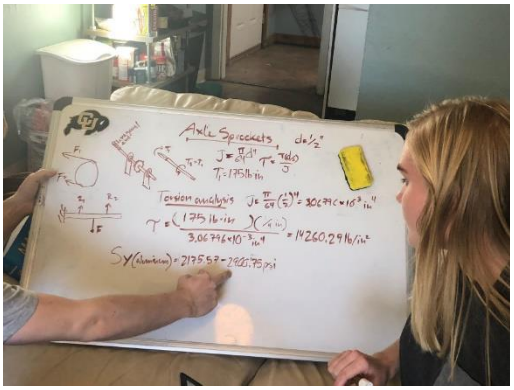




10/28 - Ryan and Jamie House - Everyone

- Agenda: Finish SolidWorks, Finish PowerPoint, Go over presentation
- Lauren - redesign drill stand and budget
- Isabel - Calculations
- Morgan - Presentation
- Ryan and Jamie - CAD
- READY FOR DESIGN REVIEW!!!





10/29 - Design Review **-** Everyone
- NO WOOD OR PVC!!!!
- Got wrecked
- Rework steering and drill mount
- Account for stretching in chain
- Redesign and get checked by TA over the weekend

11/1 - ITLL -Everyone
- Ryan already redesigned steering system
- Isabel started new design of drill mount
- Everyone has metal components and new budget considered
- All together finish new drill mount design to get checked by TA over the weekend
    - U bolts instead of hose clamps? Recommended by Potts but must go through mount not allowing mount to lay directly onto frame. Too idealistic
    - Back to hose clamps

11/3 - Jamie and Ryan House **-** Everyone
- New CAD drawings for redesign
- Find cheaper items for budget
- CAD drill mount

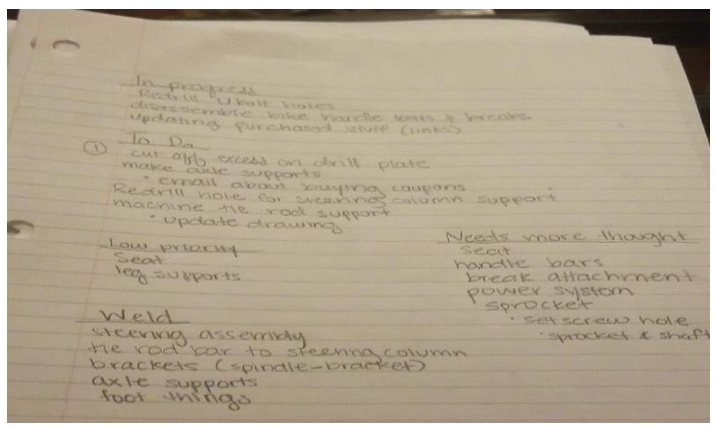
11/4 - Redesign meeting w/TA in Fleming **-** Everyone
- NEED bearing
- Welding may warp
- Talk to Professor Reamon about budget
    - Meant to sell at $200 as reason for not going over budget - lose money
- If stop suddenly from top speed all weight goes through steering column **-** impact
- forces
    - Already calculated for PVC and material now stronger **-** OK?
- Good but bearings

Manufacturing before break:
Divide tasks for efficiency and availability purposes -only met as entire group during lab time
Priority 1: Make bendy part for front of steering
Priority 1.5: Figure out steering tube with Chase and Greg (also run braking and power by them)
Priority 2: Weld steering system
Priority 3: Drill Stand
- Jamie and Ryan ordered materials - upload list/receipts

- Jamie and Ryan welded frame
- Lauren and Isabel – milled Drive Shaft
- Lauren milled plate - Chase cut slots
- Lauren, Isabel and Morgan manufactured and bent the steering support
- Isabel, Lauren and Morgan met - decided to use existing bike steering system, make simple foot supports and designed in CAD

Over break:

- Lauren bought u-clamps, put together drill plate
- Ryan, Lauren and Jamie met, got fasteners and figured out new plan



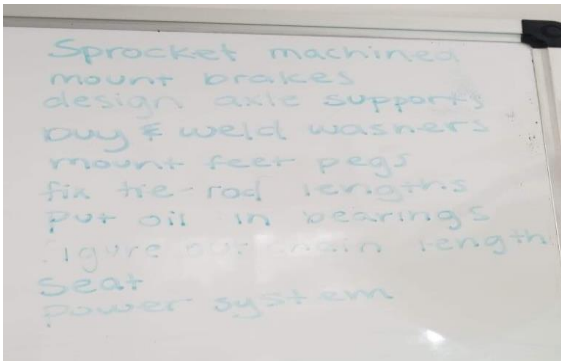
- Ryan and Jamie disassembled bike handlebars and brakes to be used

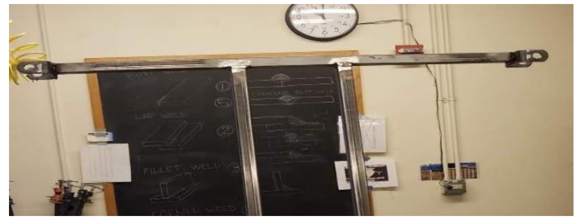
11/26 - Hardware Review (Check) and First Meeting After Break - Everyone

- Lauren - cut excess off drill plate
- Ryan, Jamie, and Lauren - press fit bushing
- Ryan - clearance fit, dugout bushing
- Lauren - spreadsheet updated with links
- Lauren - updated assembly

11/27 - Manufacturing - Everyone at various times

- Jamie and Ryan spent most of day welding rest of frame
- Assembled steering system - IT WORKS!
- Worked on report and created a new to do list





11/28 - Manufacturing - Everyone
- Ryan and Jamie dropped off sprocket and explained braking system
- Lauren and Morgan lathed sprocket face to fit chain and Increased inner diameter to fit onto shaft
- Lauren inserted set screw hole and added ¼-20 screws
- Flipped and reattached plate
- Lauren updated budget

11/29 - Manufacturing and Axle Design - Everyone
- Mounting back wheel
- Got metal wire to pull
- Started one back plate but ran into accuracy errors with Greg and couldn't finish
- Got wire from Shirley to use for braking and trigger systems

Task: New drawing for started plate and drawing for other plate to be manufactured Monday

12/3 - Manufacturing - Everyone
- Jamie and Ryan finished plates
- Isabel and Morgan got lawn chair from Goodwill and sawed-off legs to fit as seat on our frame
- Measured placement of chair on frame, determining that we would not need foot pegs as Ryan's (our driver) feet could reach the front bars of our frame
- Looked for way to attach seat to frame without having to drill holes

12/4- Manufacturing - Everyone
- Welded plates onto fork of bike
- Ryan and Lauren drilled set screw holes into shaft
- Assembled back wheel - everything together except for a trigger system for braking and power
- Bike brought back to Jamie and Ryan's
- Chair zip tied securely to frame

12/5 - Meet at Ryan and Jamie house - Everyone
- Spray painted entire bike matt black - turned out great!
- Picked CU frame
- Cut out section of plate where chain hits
- Braking system attached and works!
- Jamie and Lauren worked on report

12/6 - Meet at Ryan and Jamie house - Everyone
- Came up with plan for power connection

- Ryan, Lauren and Morgan went to McGuckin's to get extra wire and way to attach two wires securely together
- Ryan and Lauren – assembled power and braking system - fed wire around two screws and used clamp around trigger

12/9 - Finishing touches at Ryan and Jamie house - everyone
- Tested on street
- Problems
  - Chain slipped off
  - Drill shut off
- Solutions
  - Took off link in chain
  - Pull trigger slowly to not overload torque
- Painted bike with Chip theme!

12/10 - Run Off!!! - Everyone
- Weighed exactly 50 lbs.
- Ran course 2 ¾ times around
  - Wire stretched so trigger not pressed completely down
  - Ryan had to manually pull trigger most of time
  - Worked on report
  - Disassembled and returned drill
  - Cleaned out locker
  - We made it on the CU Engineering Instagram!

12/11 - Report and locker check out - Everyone
- Worked on formatting and adding testing results to report
- Morgan went to check out locker