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Rider's Aid, E-bike Kit

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Rider Aid

<e-bike kit>

By

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Introduction

Motivation:

The concepts of electric bikes provide those users to experience a relaxing trip, but do not give the benefit of exercise as the traditional bicycles do. Therefore, designing a hybrid electric bike will be the solution for having both advantages by offering cozy sport. The hybrid power provided by the electric engine takes the role of assisting users by various functions such as lower demanding energy and economic strength than electric bicycle supplies most of the work to drive the wheel.

Function Statements:

The Rider Aid is a torque enhancing machine to provide an easier way for cyclist or general users to pedal with less force required, which basically generates power to the wheel from its gear-chained motor.

Scope of Effort:

The Rider Aid also has a strong point that can be installed to almost every existing two or three wheels bike in the market, which means turning into hybrid electric vehicle without extra cost of buying a new one.

Requirements:

The following requirements must be met:

- The net weight of this machine is under 20 pounds.
- The installation time must be lesser than 15 minutes.
- A fully charged battery can run up to 10 miles.
- Total cost is under 100 dollars.
- It is compatible with operation of existing bicycle.

Success Criteria:

1. Take the road trip for a fully charged battery and use travel distance for determine the project is succeeded. The power generated must increase the rotational speed by 20 percent compared to the ordinary bike. The way to test it is using a constant power motor attach to the shaft of the pedal as a simulation of running the bike, then measure the rear

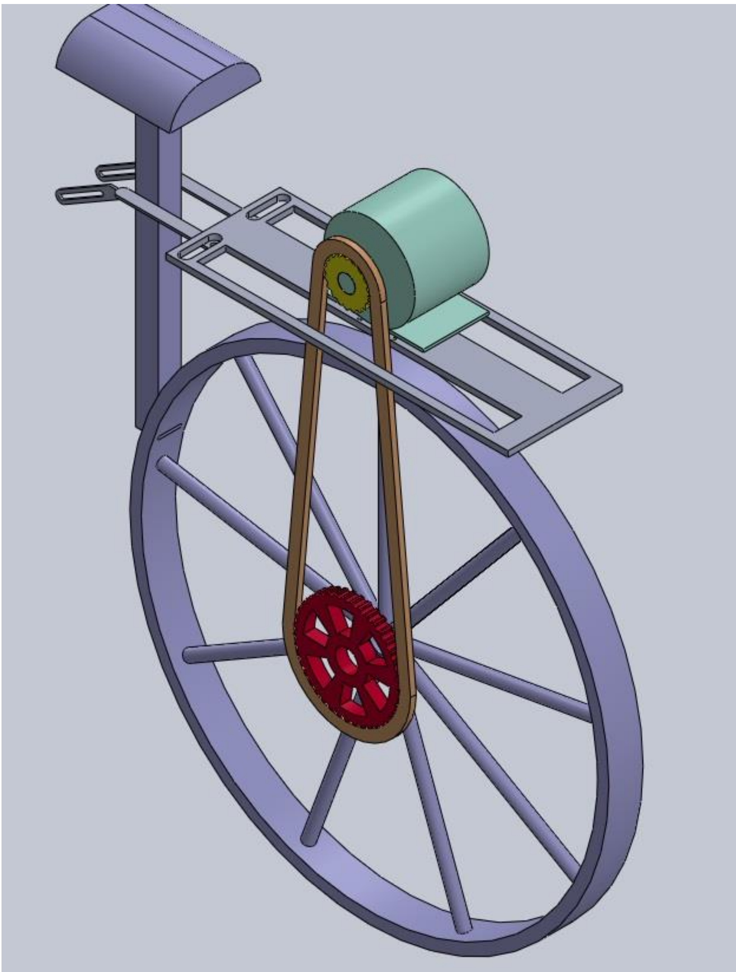
wheel rotational speed as in the unit of revolution per minute to evaluate the output speed of installed bike.

2. Take the model as in step 2, figure out the perimeter of the wheel and the average revolution for one single battery life, compute and verify the possible traveling distance whether within the manufacturing specification. As a real product, considering all possible obstacles and their resistance by an actual trial, then use this obstacle factor to fulfill the true battery life.
3. During the trial on a road, check the original brake system still stop the hybrid bike to stationary status for an accelerated simulation to ensure the foundational safety.

Engineering Merit:

The performance prediction section explains how to determine the work for a standard user. Assume the following parameters. < Schema of Orientation >

Weight of rider	170 lb.
Bike Weight	17 lb.
Average speed	9.2 mph
Shaft material	9.2 mph



Design and Analysis

Approach:

Basic principle of driving bicycle by manpower is applying force on the pedal and producing torque on the sprocket of rear wheel through mechanical chain, so there are three methods to reinforce speed by the pedal, chain or the rear sprocket. The easiest and most efficient one would be commerce at the sprocket because it could create a problem for user-friendly or safety issue if the device was in the region close to pedal or chain during operation. On the contrary, the area around the wheel sprocket is relatively less detrimental to the nature of riding wheelers.

In order to supply greater torque on the rear sprocket, elongating the force arm or intensifying the force could be one of the possible solutions. But considering the limited size of the bike, the scale of the module needs to under the specified frame.

There are two possible solutions that are directly applying the extra torque on the shaft by contact and in the form of force to create that extra torque. It is using another rotating shaft to transmit torque by contact and another solution is applying the train drive to the rear wheel gear.

Assuming the range of material strength, the first analysis was focused on the shear stress when a standard cassette gear attaches to pedaling and motoring chains. By the maximum shear stress under the real cases, compare this number to the yield strength of a commercial gear in order to ensure there will not be any deformation occurred.

Description of Analyses

For the safety purpose and the interest of time to develop the machine, a gear train drive is more suitable method. As the way to achieve this, there are few components need to be designed and determined. Use the Unite Motor in model MY1016 for chain drive in Appendix B-7 for known factors in the following design.

The decision making in choosing bracket is testify the maximum allowable load on the part used. In appendix A-4 the concepts used are the load, bending moment, moment of inertia, bending stress and yield strength which are covered in the region of material science study.

Same as the key chose, the desired parts would better be those already manufactured in the market. The yield strength, allowable load and bending stress analysis are also need to be determined in case of failure.

Benchmark

The company, Superpedestrian, already has a product for its customers to build an electric hybrid bicycle similar to the concept that adding torque to the wheel. It basically asks their customer to provide the scale and the value of the details of the bike, and then produces a new technological rear wheel for the goal to increase speed. The designs and its concepts can be found on their website, superpedestrian.com.

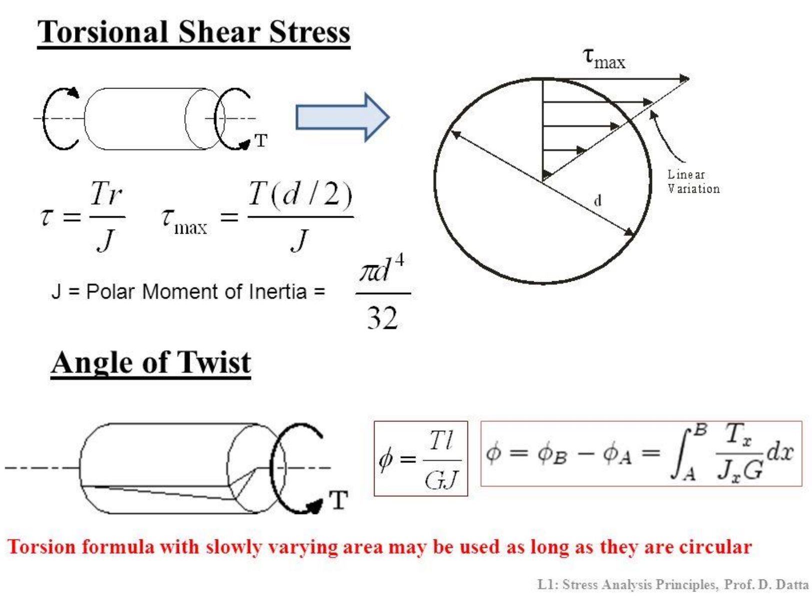
Picture 1 – a similar design by Superpedestrain:

Comparing to Rider Aid, the cost is usually above four hundred dollars, and their product needs to keep maintaining for a greater cost. Also the customers cannot use the same product if they buy a new bike that is not the same size as the previous one, which seems a down side of this device.

Scope of Testing and Evaluation

The work input range for this device is 50 watts to 30 watts and the average work saved is 30.4 %, also the battery needs to run for at least 20 miles. So there are three parameters needs to be tested.

Analysis



Picture 2. Determine failure.

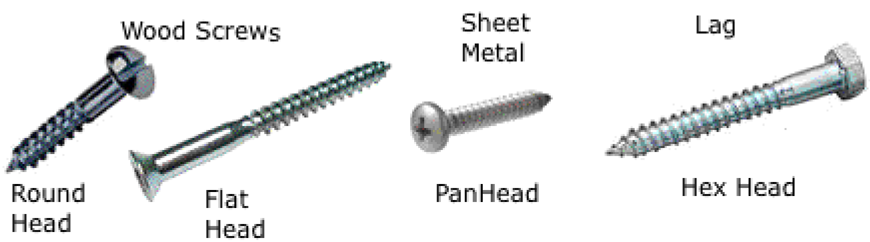
As an accelerating device to our existing wheel, the rider aid has three identical DC motors mounted on the frame and connected to one battery. Each of the DC motors supply power to a cylindrical rubber (any material provides sufficient friction force) mount to give an extra rotational speed to the shaft. The battery is also wired up along the top and head tube to the headset and controlled by a remote installed on the bike stem, so this machine is able to be monitored by the user during the whole trip in case any emergency for safety issue.

Picture 2 shows the idea of building Rider Aid in color of blue, a detail orientation is demonstrated in the drawing of appendix A-6. However, the geometry of the bike still needs to take account since the size of each bicycle, tube width and its shaft are not identical. Therefore, the location of the three motors and their rubber mount need to be adjustable along the frame for dealing different bikes in one model. Using contacting force onto the gear that is not driven by the pedal, additional chain drive mechanism performs a smooth motion and with less stress onto the rotary shaft. The electrical force may also provide supporting energy in the case wheel is driven by the rider mainly.

Material strength:

When it comes to determine the bracket to support onto the bicycle frame, the manufacturing ones are priory choices for the considerations of price and obtainability. The Wald Bike Rear Rack is capable to support the module through the verification in appendix B-2.

The fastening key for this module is the universal screw and the size is constrained by the MY1016 motor nail which is 11/64 inches diameter. A yield strength analysis is discussed in the appendix A-2 for allowable load related to its tensile strength because the shear stress is relatively less.



The electrical section such as wire, battery and remote can be purchase from retail store, it is chosen based on 24V motor and reasonable scale or price. It is illustrated in appendix B-6.

Performance Predictions

By the collecting data in appendix A-5 and assuming the weight of 170lb regular rider and 17 lb. of bike, the average power input is near 19 watts while taking the average of 9.2 mph (Eq. 1), generally the speed increased for installing Rider Aid may reach a higher speed of 16.8

mph (Eq. 2). For this case, the required work to drive the bicycle was saved by 30.4% (Eq.3).

1) $Force = Weight \times Rolling\ Coefficient = (170 + 17) \times 0.004 = 0.75(lbf)$

$$Initial\ Power = Force \times Speed = 0.75 \times 9.2\ (lbf * mph) = 13.72\ (watt)$$

$$Rated\ Power = 13.72 + 7 \times efficiency = 19.72\ (watt)$$

2) $Rated\ Speed = \frac{Rated\ power}{Force} = \frac{19.72}{0.75} = 26.29\ \left(\frac{ft}{s}\right) = 16.8\ (mph)$

3) $Work\ Saved = 1 - \frac{initial\ power}{rated\ power} = 1 - \frac{13.72}{19.72} = 30.4\%$

A detail calculation for multiple power required such as air drag and climbing power is explained in appendix A-1, A-6.

Technical Risk Analysis

Since the safety in almost every regular uses is under the specification of the motors by manufactures, the only possible risk without over the duration is that customer's bicycle is experiencing a downhill causing a higher speed that the motor hub and shaft may not able to suffer. The factor could be derived by a reasonable situation that customer would usually brake the wheel if it exceed a certain amount of speed which assume to be 30 mph. Also the maximum allowable rotation speed preventing wear and tear is assumed to be 2000 rpm as same as 37.9 mph if the standard wheel radius is under 40 inches.

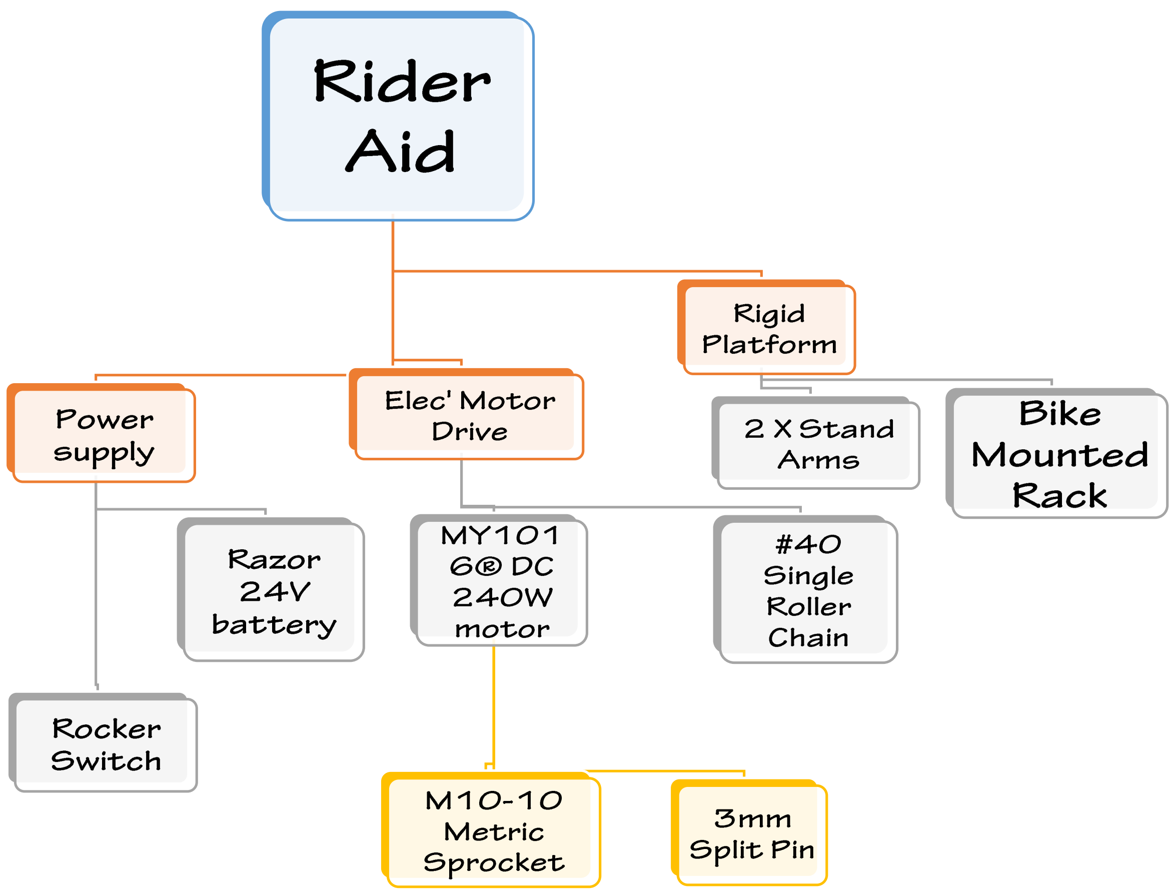
The safety factor for this maximum speed can be estimated by material strength over design load that is equal to 1.26, and it is within the range of factor 1.0 to 1.5. Therefore, the regular uses under 30 mph is not over the limit of the material constrain.

Methods and Construction

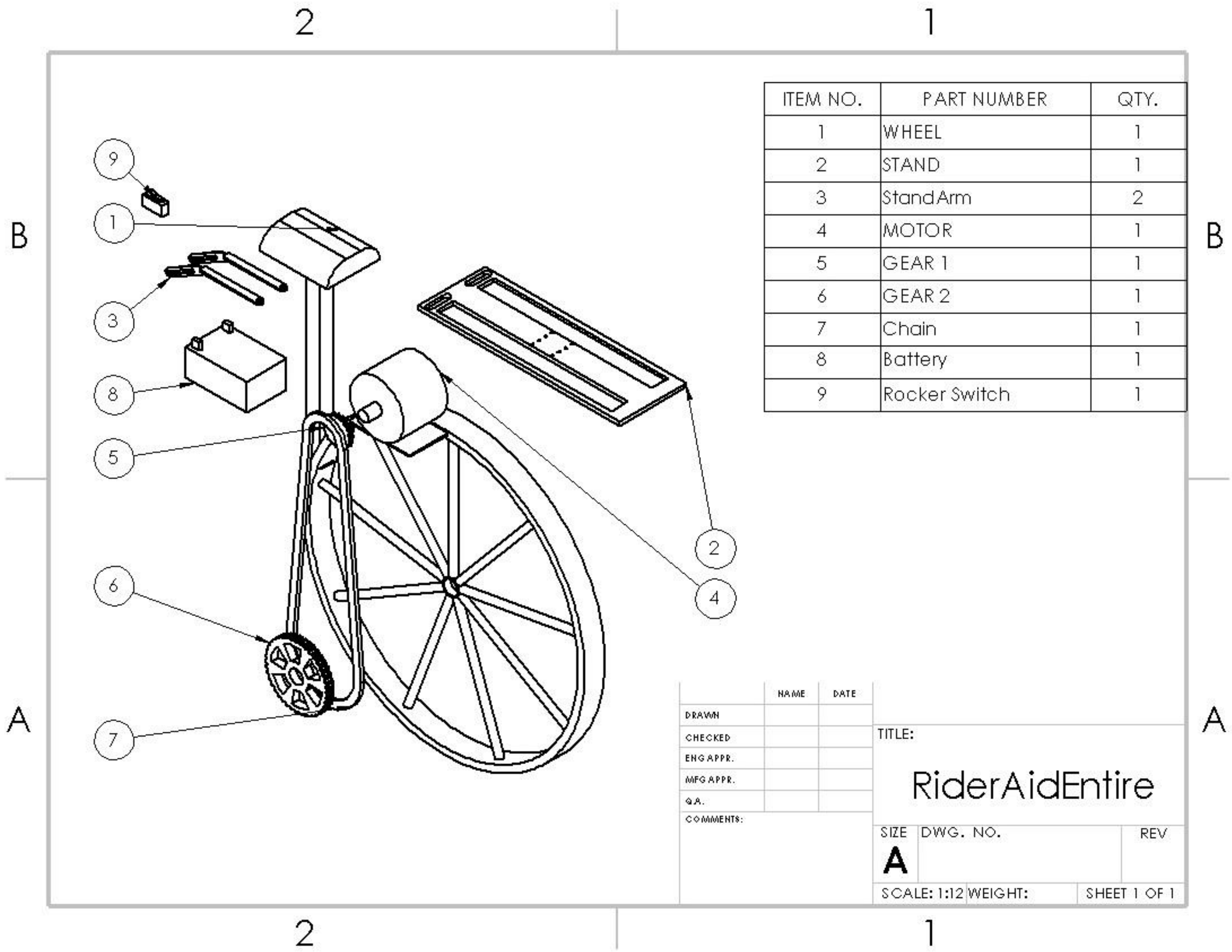
Description:

Almost eight tenth of the bicycle available in the market, it is made by the similar pattern of one side sprocket on the rear wheel, the other side is usually installed simply with kickstand. So it is reliable and amiable to approach an extra device for the bicycle on the side of sprocket to add this chain drive system.

Drawing Tree



Drawing ID’s



Parts list and labels

Major parts, no. refers to Drawing ID. The screws and bolts are not included.

ITEM NO.	NAME	Description	Quantity
2	Bike mounted Rack (STAND)	Drill Holes needed	1
3	STAND ARM	For various size of bikes	2
4	MY1016® DC motor	24V 250W	1
5	M10 metric Sprocket	Metric standard	1
7	#40 single Roller Chain	Roller width	1
8	Razor 24 V Battery	Or any brand with 24V 3-7A	1
9	Rocker Switch	Safe related issues	1

Manufacturing issues

Since this device has to fit with almost every bicycle in the market, the parts such as roller chain, sprocket and battery has been limited to specific type during the process of entire assembly as well as the narrow space of tire to gear.

Another issue was found about the motor trembling when circuit is on, so a drake alternator bracket is recommended to pursue stability and still enable the additional chain tied for needs to support approximate 25 lbs. of motor vertical weight. The DC voltage impulsive device from battery to motor is still under developed to achieve the purpose of hybrid because the whole energy pushing forward was generated by the battery not from pedaling. Since the additional part was chosen, the orientation must be changed to fit time to time as well as methods changed in proposal.

Even though a prototype was made with desired motor, chain drive and battery, and is capable to assist bicycling, geometry measurements of another bicycle were needed to be taken to pursue a high usability of this project for various bike model. Determine few junction points of this device that are able to adjust in the case of bigger bike. Finding similarities of several bike frame to match the installation location of this device for purpose of high applicability.

Rocker switch on throttle facilitates operation as users' wish by one thumb needed. Wire and Zip-ties the switch or other means to make full stop when brake engaged. Multiple hole punched on steel platform so it suits more than just one size of bike; elongate the space between motor and bike by replacing a spring. Try to make the whole installation process within 15 mins to compete with the marketing products. With other factors remain constant, seek solutions to make the bike speed as design function; 7-9 miles per hour.

MASTER LINK NOTICES - There are some commercial master-link tools to assemble or disassemble. But another easy and quick way to do it would be using the GRIPPING PLIERS onto the retaining clip and link edge. It took about an average of 40 seconds to finish it but usually 3 minutes without the suitable tools

Discussion of assembly

In the prototype process, some products have been reordered several times because wearing out issues or limits by another major issue, so those measurement and analysis steps in the beginning need to be prepared and drawn out accurately and plan ahead for extra space. For instance, the slot of bike rack needs to be wider than the width of the tire to allow a smooth operation of the chain because this DC motor is running in a high revolution speed. Some errors were found and reordered the connecting screws set, also the DC voltage of battery with motor, and entire chain gear assembled with motor correctly. It must be careful to select appropriate lubrication to resist and ensure the model can be used in outdoor surrounding by the study in machine design textbook. Machine the additional bracket to achieve the user-friendly function.

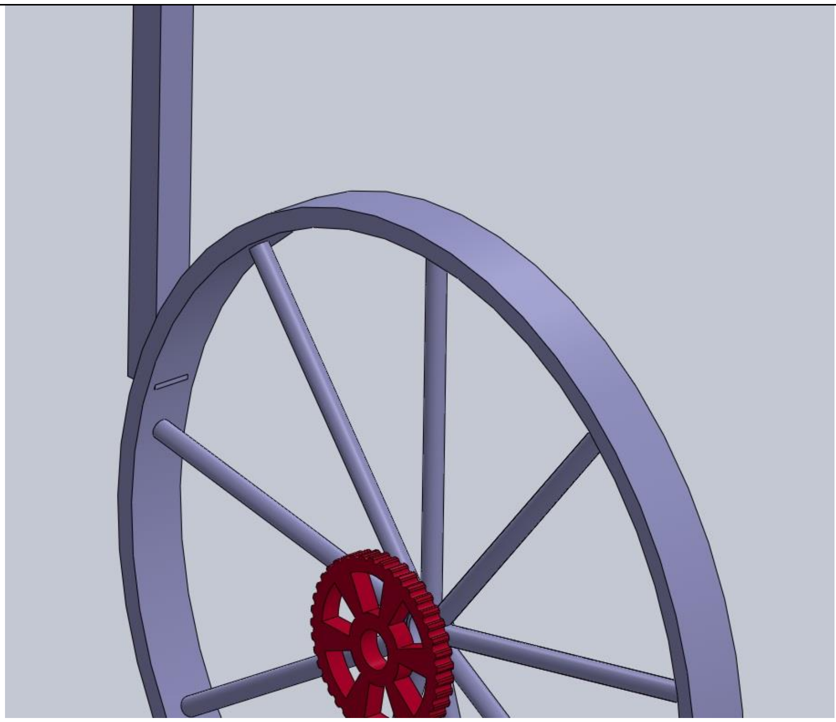
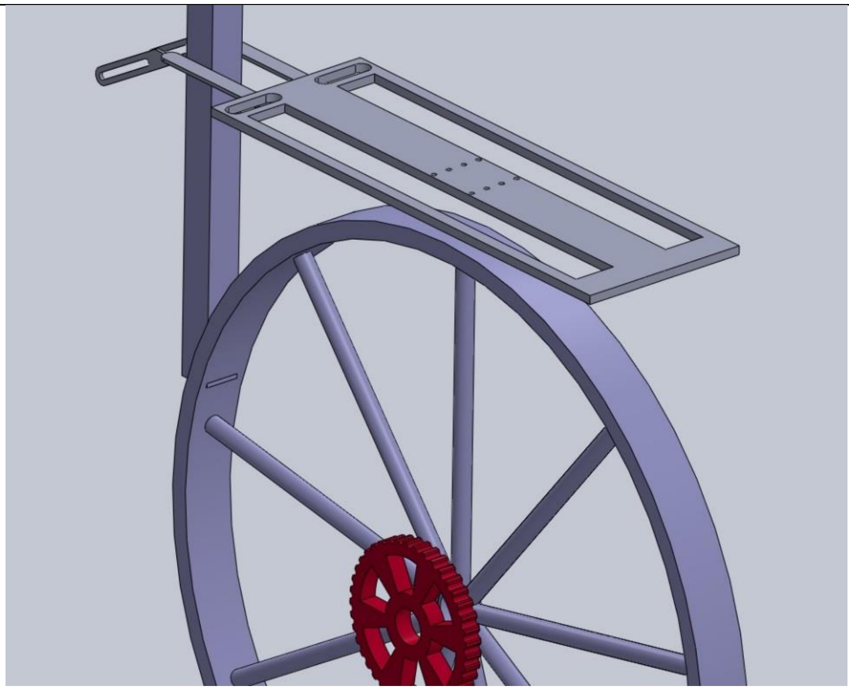
In the middle of the manufacturing, it is required to adjust roller chain and screw set re-purchased at Ace® hardware, and no problem with assembly to the prototype model. More details added to the drawing to make it capable to be manufactured, or looking for existing bracket from market as second solution. Attempt to assemble with purchased parts then use multimeters to check voltage & current to avoid motor break down (test drive in lab).

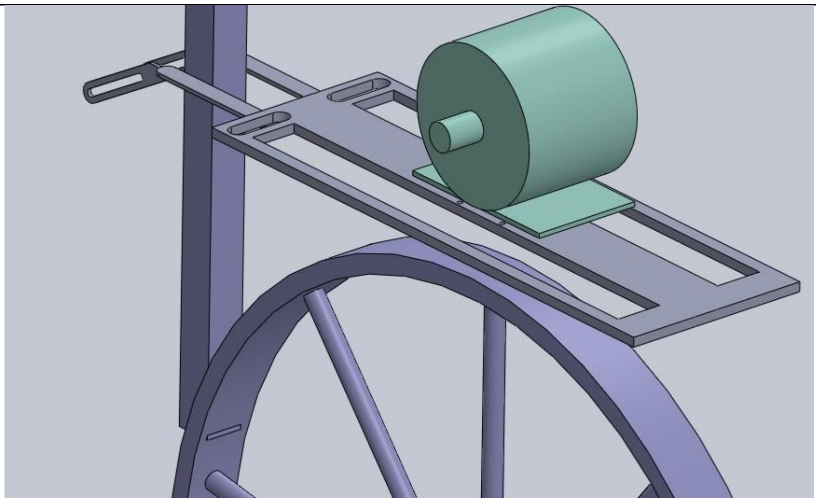
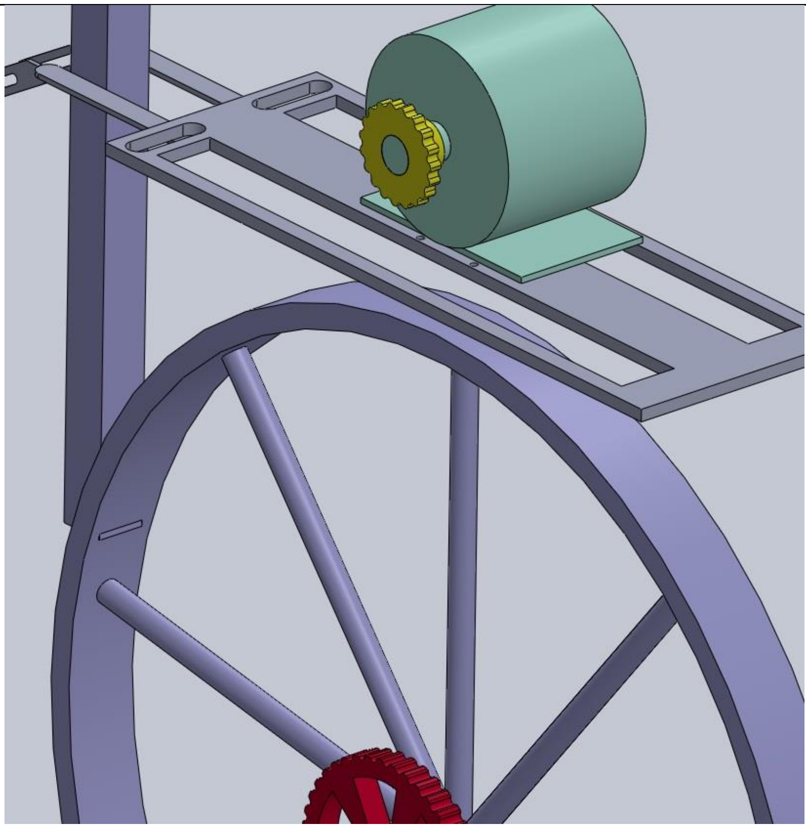
For the proper speed of rotation, the sprocket needs to fit closely to the motor shaft, so the sprocket significantly needs to avoid too much machine work on it. For this MY1016® DC motor and the relative ones are usually made in China or other nations in the area not using US standard to build those products. Therefore, the solution of the right size of sprocket can be found by the metric standard system.

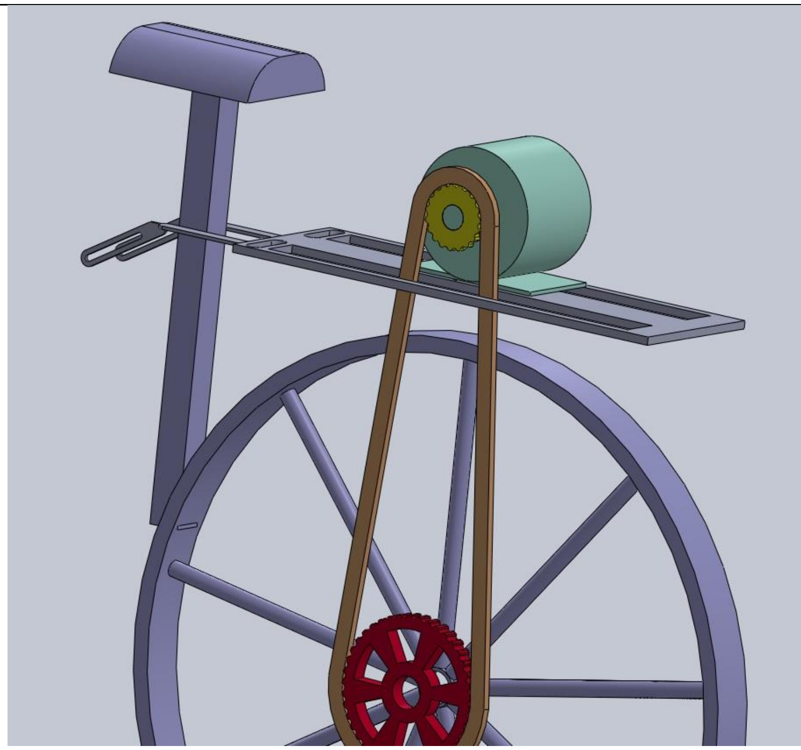
Construction:

Use the designed components in appendix B's drawing, assemble them onto the bike frame with bracket to ensure fixity. One possible issue would be the difference at voltage between motor to battery. As the specification of motor, if the pedaling energy reaches the speed that voltage of motor higher than the battery, in this 24V battery, the motor is actually recharging. But in order to protect the battery is overloaded and heated, a DC voltage adapter might be used in the connecting point of battery and motor.

The following pictures demonstrate the procedures to install:

STEP 1st. For the initial bicycle from customer, identify the location of the gear that is not driven by the rider chain. Remove all the dust and anything possible to interrupt the motion.	
STEP 2nd. Attach the "STAND (B-2)" and STAND-ARMs to the bike seat rod to achieve stability. Be sure there is enough room for battery and wires between motor poles, rear wheel, and the throttle.	

STEP 3rd. Place the MY1016 motor and bolt in with four #8 steel metal screws to the STAND, the holes drilled on the STAND need to be accurate and leave the room for chain and bike gear.	
STEP 4th. Align the sprocket and bike gear vertically, here is somehow the troubles come in and more machine works needed. Drilling multiple holes on the STAND first and find which ones are perfectly align would be a suggested order instead of manufacturing steps on others.	

STEP 5th. After the #40 roller chain is properly wounded on the two gears (red and yellow in the picture), wire up the battery and rocker switch with the order of battery, switch then motor from positive pole to negative. A MASTERLINK is recommended to facilitate placement of chain.	

Testing

Requirements

1. The entire installation process of taking an ordinary bicycle into an electrical assisted one must be within 10 minutes with simple tools in hands.
2. The modified bicycles must reduce the traveling time by half comparing to only the pedaling work.

Parameters of interest: The recorded time from both tests to determine the result. Since this device was designed in order to save time of installation and to speed up an ordinary bicycle, the parameter of time will be the significate factor to determine how much functionality this device can offer.

Predicted performance:

1. Attaching platform rack with 4 screws process, placing motor and battery with 6 screws and total estimated would be 2-4 minutes. The wiring (motor, battery to rocker switch) may take 1 minute. The chaining up (motor sprocket to cassette gear) could be up to 3 minutes. The sum up value is going to be 6 to 9 minutes.
2. Using the raw data of usual time to estimate the motoring time that needs to be at least the same or above to the ordinary time.

Data acquisition: The actual results from each test and further discussion to innovate the construction methods by reviewing the results.

Schedule:

As in the Gantt chart in reference, the tests were scheduled within one hour of presentation, but the preparation and adjustments need to be made ahead of that scheduled period. The first test took about five hours extra in order to machine the parts for eliminating the gaps that might affect the smoothness of installation. Since the second test was fulfilled in motion, it took four hours extra to replace into another thinner bike rear tire to guarantee there will not be any problem when the modified bike was on the road.

Method/Approach:

Resources: A bike repair stand for rear wheel clearance, Timer, A hexagon shape and flat head screwdriver set, and a table for ordered tools layout. Also the timer only for test 2.

Data capture: During each try, the time obtained needs to be the entire process from an ordinary bike to modified one, any interruption make the installation longer shall need to be recorded and considered because an actual customer may encounter those same situations. After finishing each try, make sure to write down discussion or discovery that may reduce the installation time on next attempt. Those feedbacks are important for being a secondary data out of the test.

Test procedure overview: Following the step by step procedure and the required tool is capable to obtain a minimum time results. Taking the discussion from previous attempts and correcting the time-consuming issues before continuing next attempts may shorten the result. In the second test, the method is more straightforward that using comparison of two rides to determine the final result. And it was using the assumption of pure pedaling power is equal to pure motoring power to conclude a fifty percent reduction.

Operational limitations: For safety matters, use the rubber gloves or any nonconductive material at the test to avoid electric shock by the battery, also a pair of appropriate glove can provide a non-greasy process by the roller chain lubricate oil. As instruction in the test sheet, make sure the route has nothing dangerous to obtain the safety purpose.

Precision and accuracy discussion: Using the six data average value to determine the criteria is appropriate for general users. But taking another person to perform the test may help the accuracy because the background knowledge and experiences may vary.

Data manipulation: 1. Sum up the total time at each attempts 2. Average out the numbers 3. Optionally, take another person as performer to verify most of the value stay in the requirements. Test 2: simply comparing both time of ride to check the result.

Data presentation: Only the average number needs to be checked, do not use any single attempt to determine whether pass or fail. The result will be a pass or fail option, either the average number is lesser than the 10 minutes stated requirement.

Test Procedure 1:

Time, place and necessary actions if performed by another person.

Test sheet to collect data:

Data sheet 1	Performer: ____________________________				Date: _______ At: ______	
# Installation Procedures : ______ (Notes for possible improvements)						Tools used
1. Check MY1016 motor, 12V battery, bike rack, spring hinge, rocker switch, wires, screws, roller chain, master links, screwdrivers and timer are orderly displaced on the workbench/table. ____						Work Table
2. Start the timer. Gloves on. _____________________________						Timer + Gloves
3. Mount bike rack, rack arms with 2 screws on the rear wheel frame and 2 screws for bike seat post. And check stability. ____						Hexagon screwdriver
4. Chain up motor sprocket by spring hinge, then cassette gear by Master Link. Using flat head screwdriver can facilitate the link piece assembly and disassembly. ____						Flat head screwdriver + (chain puller, only for chain length)
5. Wire up (positive port battery – motor - rocker switch – battery in order). Twine loose wire on bike tube. ____						N/A
6. Make sure no obstacle in the way of operation then switch on for smooth chaining movement. _______________________________________						N/A
7. Stop the timer and record the results. _____________________________						N/A
Result: Avg 1-6 ________	#1: ___________	#2: ___________	#3: ___________	#4: ___________	#5: ___________	#6: ___________

Deliverables for test 1:

The result sheet:

Data sheet 1	Performer: ___Song___				Date: 04/11/16 At: _SURC_	
# Installation Procedures : ______ (Notes for possible improvements)						Tools used
1. Check MY1016 motor, 12V battery, bike rack, spring hinge, rocker switch, wires, screws, roller chain, master links, screwdrivers and timer are orderly displaced on the workbench/table. ____________________						Work Table
2. Start the timer. Gloves on. ____More than one pair of glove may be better for chaining and wiring___						Timer + Gloves
3. Mount bike rack, rack arms with 2 screws on the rear wheel frame and 2 screws for bike seat post. And check stability. _____Left hand to hold the rack and right hand to screw in if standing on right side of bike. ____________						Hexagon screwdriver
4. Chain up motor sprocket by spring hinge, then cassette gear by Master Link. Using flat head screwdriver can facilitate the link piece assembly and disassembly. ___Use the flat head screwdriver as wrench to lock or unlock the link_______						Flat head screwdriver + (chain puller, only for chain length)
5. Wire up (positive port battery – motor - rocker switch – battery in order). Twine loose wire on bike tube. _____A opposite pattern of wiring order may make the modified bike goes backward by the motor.______________						N/A
6. Make sure no obstacle in the way of operation then switch on for smooth chaining movement. ________________________________						N/A
7. Stop the timer and record the results. ________________________						N/A
Result: Avg 1-6 __08"35,05____	#1: _06"27__	#2: __07"42_	#3: __08"39_	#4: _11"08_	#5: _07"58_	#6: _06"55____

The overall value obtained passed the requirement (08 minutes < 10 mins), but one of the reason to become successful might be that it was performed by the designer. If a costumer do not know any information about the mechanism, the installation may take few minutes extra. Therefore, including a users' manual for instruction is important to get a satisfying result.

Test Procedure 2:

Use data sheet and follow each step to determine result:

Data sheet 2	Performer:_________________	Date:___ At:___
Steps of procedure to be followed		Data entry column:
1. Select a proper route that less possible accident may happen to change the parameter, a flat and slopes combined route is recommended in order to see any critical circumstance this device can overcome.		
2. Start the timer, finish the route and record the traveling time. The timer can be accomplished by another person for safety issue.		TIME Taken _1.___________
3. Check the device is ready and performing another ride for SAME route, such as the connecting chips and bike operation.		Time Taken _2.___________
4. Compare time 1 and time 2 by entering "> "or "< ". Port the numbers from previous columns to compare.		Time 1 vs. Time 2 _____ _____
5. If greater " > " is indicated circle PASS, otherwise circle FAIL		PASS or FAIL

Deliverables for test 2:

Data sheet 2	Performer: ___Song, Abdullah ______	Date: 04/27/16___ At: HOUGE __
Steps of procedure to be followed		Data entry column:
1. Select a proper route that less possible accident may happen to change the parameter, a flat and slopes combined route is recommended in order to see any critical circumstance this device can overcome.		
2. Start the timer, finish the route and record the traveling time. The timer can be accomplished by another person for safety issue.		TIME Taken _1.__00'40"___
3. Check the device is ready and performing another ride for SAME route, such as the connecting chips and bike operation.		Time Taken _2._01'11"_
4. Compare time 1 and time 2 by entering "> "or "< ". Port the numbers from previous columns to compare.		Time 1 vs. Time 2 0'40" < 01'11"
5. If greater " > " is indicate circle PASS, otherwise circle FAIL		PASS or FAIL

- Detailed results with video, goes to:

http://sites.simbla.com/3ca61163-ccd5-cf1c-43f9-cf26f907e0c8/results

Budget / Schedule / Project Management

Since the entire device is within fifty cubit inches and the assembly process is approximately under a week, this model will mostly be an in-house project. Those electronic equipment also can be bought and found in a retail store. Everything constructed and produced will be done using Central Washington technology, resources, and funds. The project is managed through complete in-house resources and expertise. All outsourcing part of this project is through in-house connections. All funds not approved by Central Washington University will be provided out of pocket by the engineering student himself. All parts and costs have been estimated and checked for affordability. All costs are reasonable for what is being produced. The schedule of the project is possible to be finish in an academic quarter. Professionals in the engineering field are available for support and help with accomplishing project duties if there ever is a time where the engineering student is not able to comprehend the task himself.

Proposed Budget

The retail stores such as Fry's and home depot provide most electrical parts and material stock. All needed tools can be purchased from those stores or through online. Only the shell and the rotary shaft need to be custom made under laboratory of Central Washington University. A detailed budget and parts list is available in Appendix C. A majority of the labor needed for the completion of the project will be done by the engineering student himself so it will be free of charge. All expertise and knowledge resources will be provided without additional charge. All labs and equipment of Central Washington University will be available for use without charge too. Funding will be provided by Central Washington University and by the personal funds of the engineering student. Central Washington has already agreed to provide all funds needed for the project, so any last minute, unexpected charges will need to be covered by the engineering student.

Proposed Schedule

From September to the end of next June, the project will span over the course of nine and a half months with a couple breaks from the project. The project will be divided into three phases: Design and Analysis, Construction, and Testing. Phase 1 has spanned from September to the beginning of December, Phase 2 will span from January to the middle of March, and Phase 3 will span from April to June. The estimated total amount of hours to be spent on the project is

422 hours. For just the gripping assembly, the amount of hours is reduced to 380 hours. At the end of the first phase, December 7th, the deliverable is the proposal for the project. At the end of the second phase, March 15th, the built and assembled device is the deliverable. At the end of the third phase, June 8th, the deliverable is the testing report and all evaluation sheets of the device along with the full report and presentation of the gripping assemblies. More detailed deliverable and milestones can be seen in the high level charts for each phase available in Appendix D.

Project Management

The biggest most reliable human resource is the mechanical engineering student running the project. Other human resources are available such as faculty and staff of expertise. All these human resources are employees or professors of Central Washington University offering educational knowledge and support on how to proceed with processes unknown to the engineering student. There are also many spare machinery parts available in the storage areas of the labs such as stepper motors, circuit boards, and controllers. The outside vendors were also viable resources for gathering information on the nature and specifications of the parts they sold. Information was able to be gathered about the original condition of the material or part, the condition of it when shipped, and special guidelines on how to change the condition of the material or part in a safe and appropriate manner. Programs such as MDesign and Solidworks helped with drafting and analyzing the stresses in component parts. The Internet was also resourceful for providing engineering related websites that provided material properties for different materials, formulas for special circumstances in several contexts, and finding cheap and reliable vendors for purchasing parts and material stock.

Conclusion

The basic contributions of adding this device to usual bicycles are providing a broad region of its users, the lower cost of building electric bike and environmentally friendly transportation.

By the support of the power enhancing, the demanders of choosing a bike are possibly increased because cycling will no longer be difficult and arduous, so it may also increases the market of bike production and elevates the chance for cycling sport. Since this device was built in an external form, the cost of having an electric bike would be simply just adding small section to those existing bicycles, which is much lesser than rebuilding entire model. Last, due to the reason that more consumers would choose bike as a transportation, the usage amount of fuel and the emissions of detrimental gases might be reduced and then reach the goal of ecological conservation.

Apart from these benefits, this torque enhance device can be optimized for further purposes such as improving traditional wheelchair, food processor or any small-scale machine that needs extra rotational energy, and it may be achieved by more engineering investment.

The test performed at the classed period was failed because the connecting chips on the battery kept falling off, and it took extra time to stop the bike and reassemble the circuit. This issue might be solved by settling the wiring with clamp chips or directly hooking onto the battery. There might be more trouble come out because this test is using a method in motion. At the trial before class period, the time taken by the motor power only was actually lesser than a pedaling power by the chance of 4 attempts out of 7.

References

Charles Henry (2015-03-15). "Diagram of Crr as a function of V". Retrieved 2015-03-30.

"Validation of a Mathematical Model for Road Cycling Power" by James C. Martin et al., Journal of Applied Biomechanics, Volume 14, Issue 3, August 14, 1998, pp.276 – 291 [1]

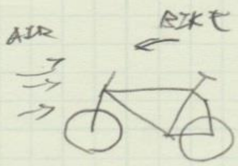
"Sastre wins the 2008 L'Alpe d'Huez stage". July 23, 2008: Velo News. Archived from the original on 19 February 2009. Retrieved 2009-01-14.

Appendix A – Analyses

A-1 Determine regular bike power required

SONG WANG | MET 495 | 20151022 | 1/2

POWER REQUIRED:



GIVEN: BIKE AND RIDER WITH FOLLOWING

$\vec{V}_r$ = SPEED TO ROAD = 9.2 mph

W_r = WEIGHT OF RIDER = 170 lb, BIKE = 17 lb

η = mechanical efficiency of drive chain = 24%.

ρ = AIR DENSITY = 0.0765 lbm/ft³

$\vec{V}_a$ = AIR FLOW SPEED = 0.3 mph

C_D = DRAG COEFFICIENT = 0.12 (STREAMLINED BODY).

A = CROSS-sectional AREA = 6.5 ft²

C_r = ROLLING COEFFICIENT = 0.004

S = SLOPE GRADE AVERAGE = 0.03

Δt = TIME TO SPEED FROM 0 MPH = 1.5 min.

FIND. POWER REQUIRED FOR THIS BIKE.

1) ROLLING RESISTANCE TO OVERCOME, $V_r = 9.2$ mph $= 1.467$ ft/s

$$P_R = \vec{V}_r m g C_r = V_r W_r C_r = 1.467 \frac{ft}{s} (170+17) lb \times 0.004$$

$$= 1.097 \text{ lb ft/s}.$$

2) INITIAL ACCELERATION

$$P_A = \vec{V}_r m \vec{a} = \vec{V}_r m \left(\frac{\Delta \vec{V}}{\Delta t}\right) = 1.467 \text{ ft/s} (170+17) lb \left(\frac{1.467-0}{1.5\times 60}\right) \text{ft/s}$$

$$= 4.468 \text{ lb ft/s}$$

3) AVERAGE CLIMBING

$$P_c = \vec{V}_r m g S = \vec{V}_r W_r S = 1.467 \text{ ft/s} (170+17) lb (0.03)$$

$$= 8.504 \text{ lb ft/s}.$$

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CONT'.

4) AIR DRAG.

$$P_D = V_r \frac{1}{2} \rho V_a^2 C_D A$$

$$= 1.4667 (ft/s) \frac{1}{2} \left(0.0765 \frac{lbm}{ft^3}\right) (1.4667 + 0.44)^2 \, ft^2/s^2 \, (0.12) \times (6.5) \, ft^2$$

$$= 0.1591 \; lbm \, ft^2/s^3 \left(\frac{1 lbf}{32.174 \; lbm \, ft/s^2} \right) = 0.005 \; lb \, ft/s$$

5) TOTAL POWER

$$\Sigma \vec{P} = P_T = P_R + P_A + P_C + P_D$$

$$= 1.097 + 4.468 + 8.504 + 0.005 \; lb \, ft/s$$

$$= 14.074 \; lb \, ft/s.$$

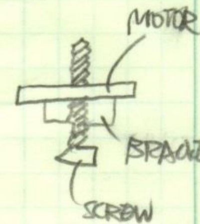
$$= (19.082 \; watts)$$

⇒ THE GENERAL BIKER WITH 187 lb IN WEIGHT NEEDS 19.1(W) to RIDE.

A-2 Designing Key

SDNG WANG | SENIOR PROJECT. | 1/1

KEY ANALYSIS



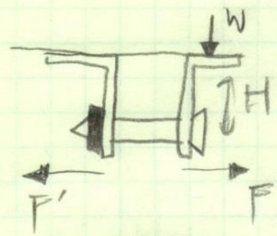
GIVEN: THE SPEC. OF MOTOR NAIL M6, $\frac{11}{64}''$

THICKNESS OF BOTH MOTOR & BRACKET $t = \frac{1}{2}''$

#8 SHEET METAL SCREWS.

$D_1 = 0.164''$ SHANK, $D_2 = 0.112''$ ROOT

$\vec{F}$ = REACTION OF W, $H = 1.0''$

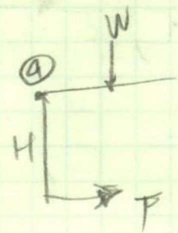


FIND: THIS SCREW ABLE TO HOLD.

SOL: 1). FBD AS LOADS IN TENSILE.

$M_@ = 0 = \vec{W} \times l - \vec{F} \times H$, $\vec{F} = \frac{\vec{W} \times l}{H} = \frac{5lb \times 0.125''}{1''}$

(BRACKET ANALYSIS)



$\vec{F} = 0.647 (lb)$.

2) TENSILE STRENGTH $P = \frac{\vec{F}}{A_{rea}} = \frac{0.647\ lb}{\frac{D_2^2}{4} \times \pi} = 65.67\ psi$

3). FOR STANDARD SHEET METAL SCREW.

S_Y YIELD STRENGTH $\simeq$ 60 ksi.

WHICH IS MUCH HIGHER THAN TENSILE STRENGTH

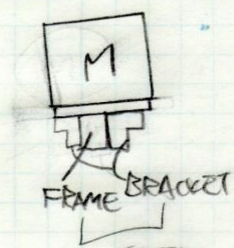
$\Rightarrow$ THIS #8 SHEET METAL SCREW IS OK

A-3 Designing Bracket

SONG WANG | SENIOR PROJECT | 1/1

DESIGNING BRACKET

SIDE VIEW



GIVEN: WEIGHT OF MOTOR M $W_M = 4.3$ lbs.

RATIO OF BIKE & MOTOR GEAR, $R = 4.6$

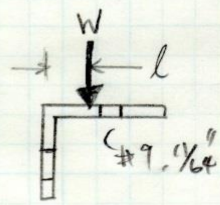
BIKE SPEED $V = 4.2$ mph

DISTANCE CENTER OF MOTOR TO FRAME, $l = 0.125''$

ZMAX 18-GAUGE galvanized steel angle

{ 1.5" x 2" x 1 3/8", T 1/2" ↓ ↔
ALLOWABLE LOADS 245 lb / 175 lb

FBD



FIND: WHETHER THIS ANGLE ABLE TO HOLD.

SOL: 1) MAXIMUM BENDING MOMENT

$M_{at\,W} = W \times l = (W_M + W_{accel}) \times l$

ASSUME THE OPERATING MOTOR REACTION FORCE.

$W = 4.3\,lb \times 1.2 = 5.16\,lb.$

$M_{at\,W} = 5.16 \times 0.125'' = \underline{0.647\,(lb\text{-}in)}$

2). AREA MOMENT OF INERTIA $I = \dfrac{(1\frac{3}{8}'') \times (\frac{1}{2}'')^3}{12} = 0.0143\ in^4$

3) BENDING STRESS $f = \dfrac{M \cdot Y}{I}$ (Y = PERPENDICULAR DISTANCE → NEUTRAL AXIS)

$f = \dfrac{0.647\,lb\text{-}in \cdot (\frac{1}{2}'')/2}{0.0143\ in^4} = 11.31\,(\frac{lb}{in^2}) = 11.31\,(psi).$

4). USUAL STRENGTH YIELD. $S_Y = 35$ ksi. much greater than 11 psi.

OR THE SPECIFIED ALLOWABLE LOADS GREATER THAN MOTOR WEIGHT

⇒ THIS ZMAX STEEL ANGLE IS OK ←

A-4 Obtained speed by material strength

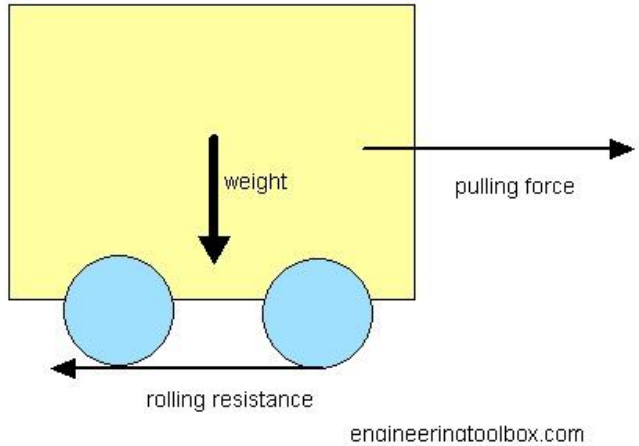
- The minimum speed to crash cassette gear by types of commercial materials.

Minimum speed reaches yield strength, MPH

radius of wheel, in	12	Material	Yield strength, psi	4.5	4.3	4.1	3.9	3.7	3.5	radius of cassette gear
weight of cassette gear, slug * 12, lb.s2/ in	0.16116	forged 7000 series alloy 7075-T7	63000	188.4	180.0	171.7	163.3	154.9	146.5	
time interval, s	0.00005	forged 7000 series alloy 7075-T651	73000	218.3	208.6	198.9	189.2	179.5	169.8	
		Titanium Ti-6Al-4V	128000	382.8	365.8	348.8	331.7	314.7	297.7	
number	0.0117	410 Annealed stainless steel	65000	194.4	185.7	177.1	168.5	159.8	151.2	
in/s to mph	0.05682	Type 302 - Full Hard	170000	508.4	485.8	463.2	440.6	418.0	395.4	
minimum value		Type 304 - Annealed	75000	224.3	214.3	204.3	194.4	184.4	174.4	
		Type 430 - Annealed	65000	194.4	185.7	177.1	168.5	159.8	151.2	

A-5 Reference for determining input force

The force that resists the motion when a body rolls on a surface is called the **rolling resistance** or the **rolling friction**.



The *rolling resistance* can be expressed as

$F_r = c\,W$ (1)

where

F_r = *rolling resistance or rolling friction (N, lb_f)*

c = rolling resistance coefficient - dimensionless (coefficient of rolling friction - CRF)

W = m g = normal force - weight - of the body (N, lb_f)

m = mass of body (kg, lb)

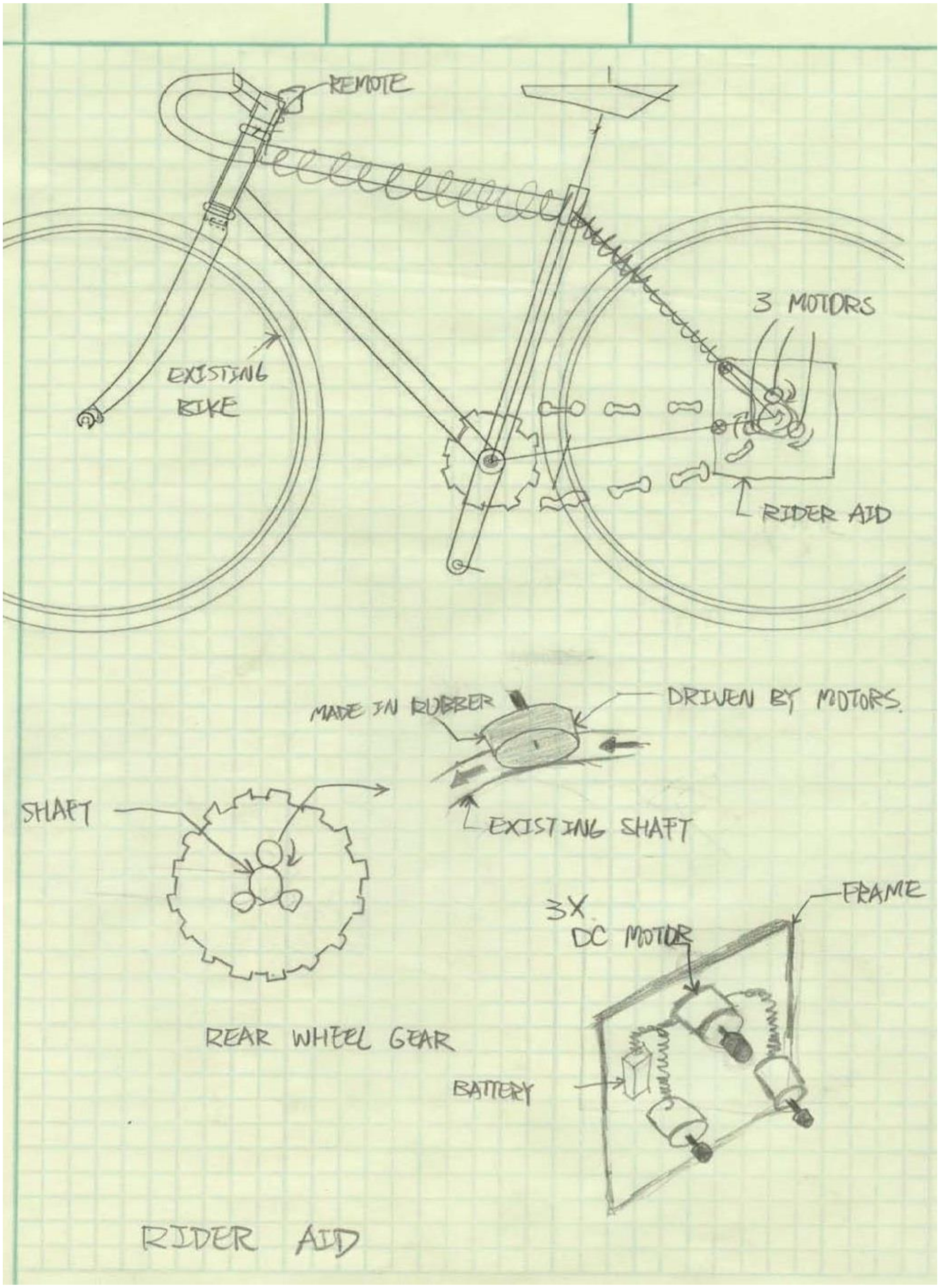
g = accelaration of gravity (9.81 m/s^2, 32.174 ft/s^2)

Rolling Friction Coefficients

Some typical rolling coefficients:

Rolling Resistance Coefficient		
c	***c_l (mm)***	
0.001 - 0.002	0.5	railroad steel wheels on steel rails
0.001		bicycle tire on wooden track
0.002 - 0.005		low resistance tubeless tires
0.002		bicycle tire on concrete
0.004		bicycle tire on asphalt road
0.005		dirty tram rails
0.006 - 0.01		truck tire on asphalt
0.008		bicycle tire on rough paved road
0.01 - 0.015		ordinary car tires on concrete
0.03		car tires on tar or asphalt
0.04 - 0.08		car tire on solid sand
0.2 - 0.4		car tire on loose sand

A-6 Orientation schema



A-6 Determine failure speed

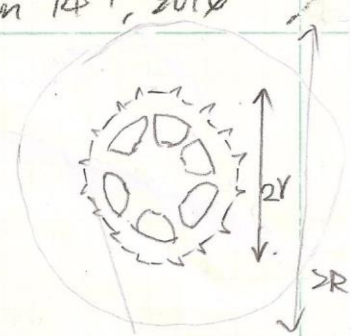
SONG WANG | MET 445 | Jan 14th, 2016

GIVEN: CASSETTE GEAR. YIELD (TENSILE) STRENGTH. $\tau_Y = \tau_{max}$

RADIUS OF ACTION r. (ONTO MOTOR)

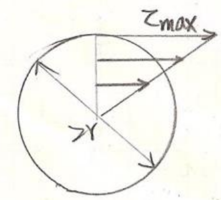
ATTACHES TO BIKE R

TIME INTERVAL, BRAKE, START Δt



FIND: LINEAR VELOCITY REACHES τ_{max}, $\vec{V}_{max}$.

SOL: 1)



THE ABILITY TO RESIST TORQUE ⇒ POLAR MOMENT OF INERTIA. J.

$J = \frac{\pi (2r)^4}{32} = \pi r^4 / 2$. —①

AT $\tau_Y = \tau_{max} = \frac{Tr}{J} = \frac{T \times 2}{\pi r^{4-3}} = \frac{2T}{\pi r^3}$. (SHEAR STRESS)

MAX TORQUE $T = \pi r^3 \tau_Y / 2$ BEARING

2). DERIVE ANGULAR VELOCITY, BY MOMENT OF INERTIA AND TIME INTERVAL. $\omega = \alpha \Delta t$, $T = I\alpha$. $I = \frac{1}{2} M r^2$ —②.

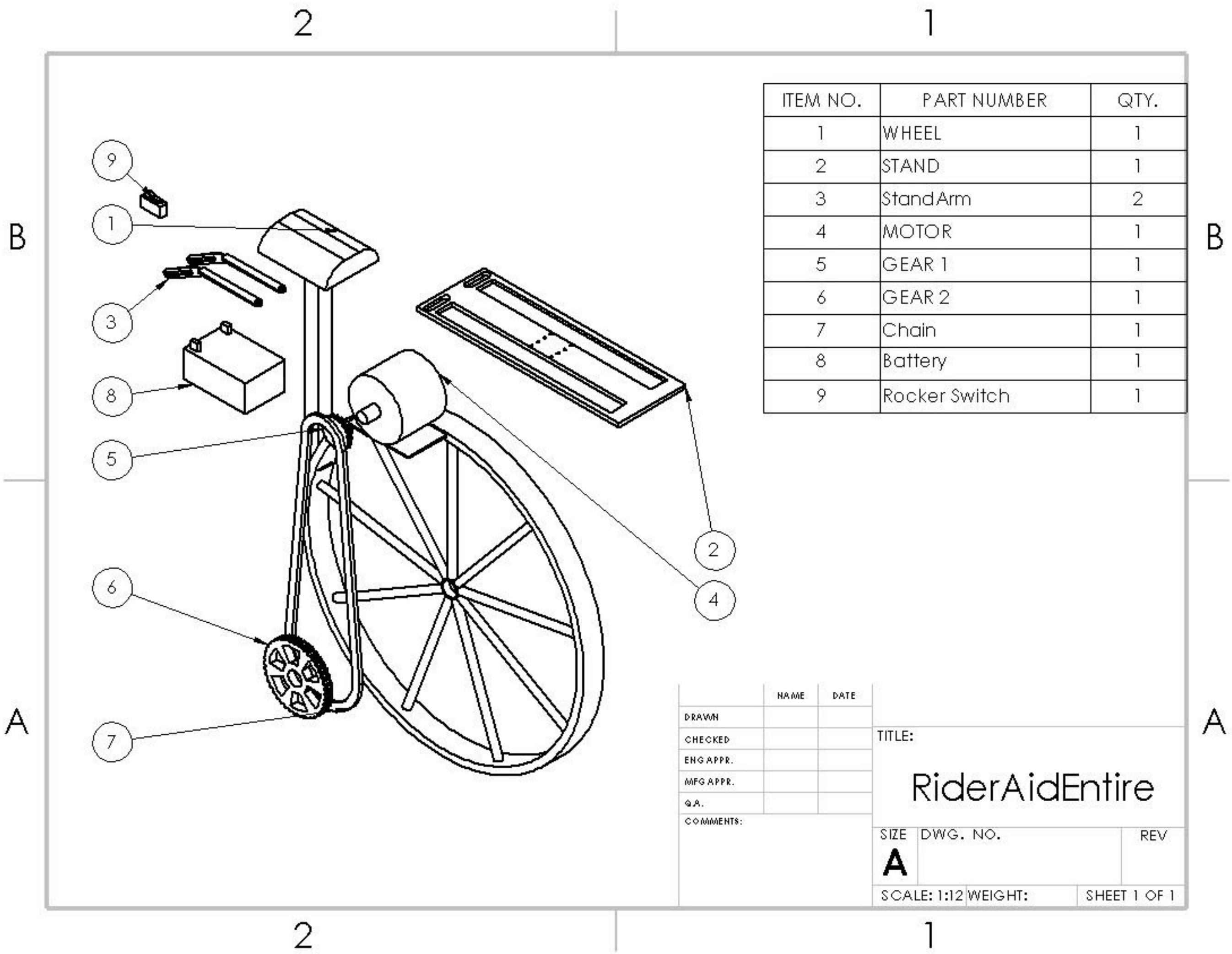
THEN TO LINEAR VELOCITY. $\vec{V} = R\omega$

$$\left[\vec{V} = R\Delta t \frac{\pi r^3 \tau_Y}{2} \frac{2}{M r^2} \right] = \vec{V} = R\Delta t \, \pi r \tau_Y / M$$

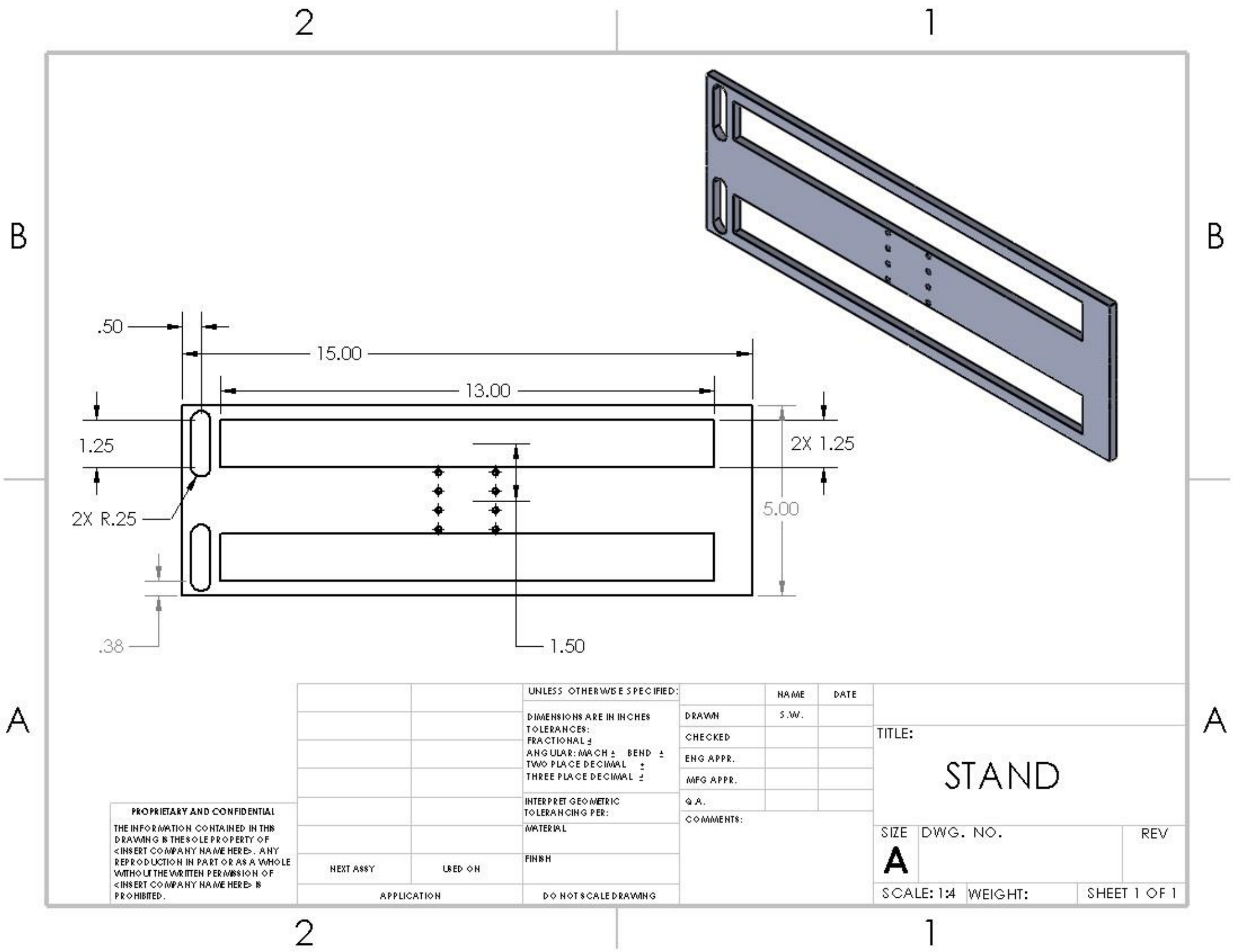
$$\text{MAX } \vec{V} = \frac{(\text{RADIUS OF WHEEL})(\text{TIME INTERVAL})\pi(\text{RADIUS OF CASSETTE})(\text{TENSILE STRENGTH})}{(\text{MASS OF CASSETTE})}$$

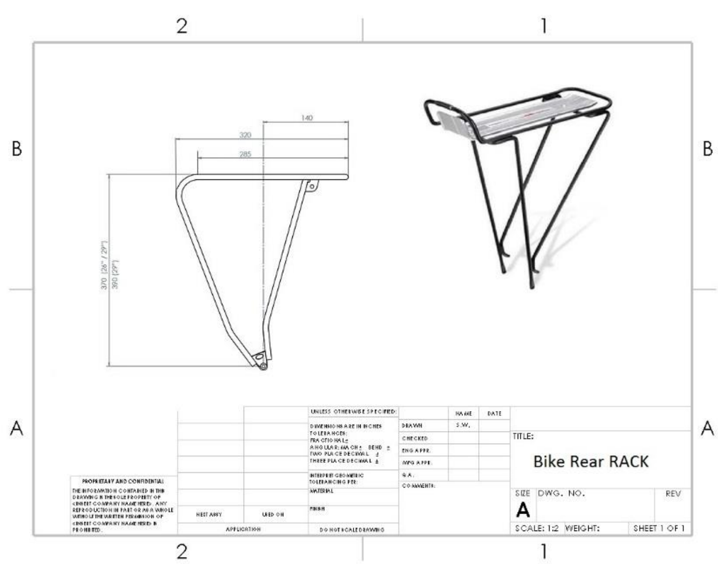
Appendix B – Drawing & Picture

B-1 Model Assembly

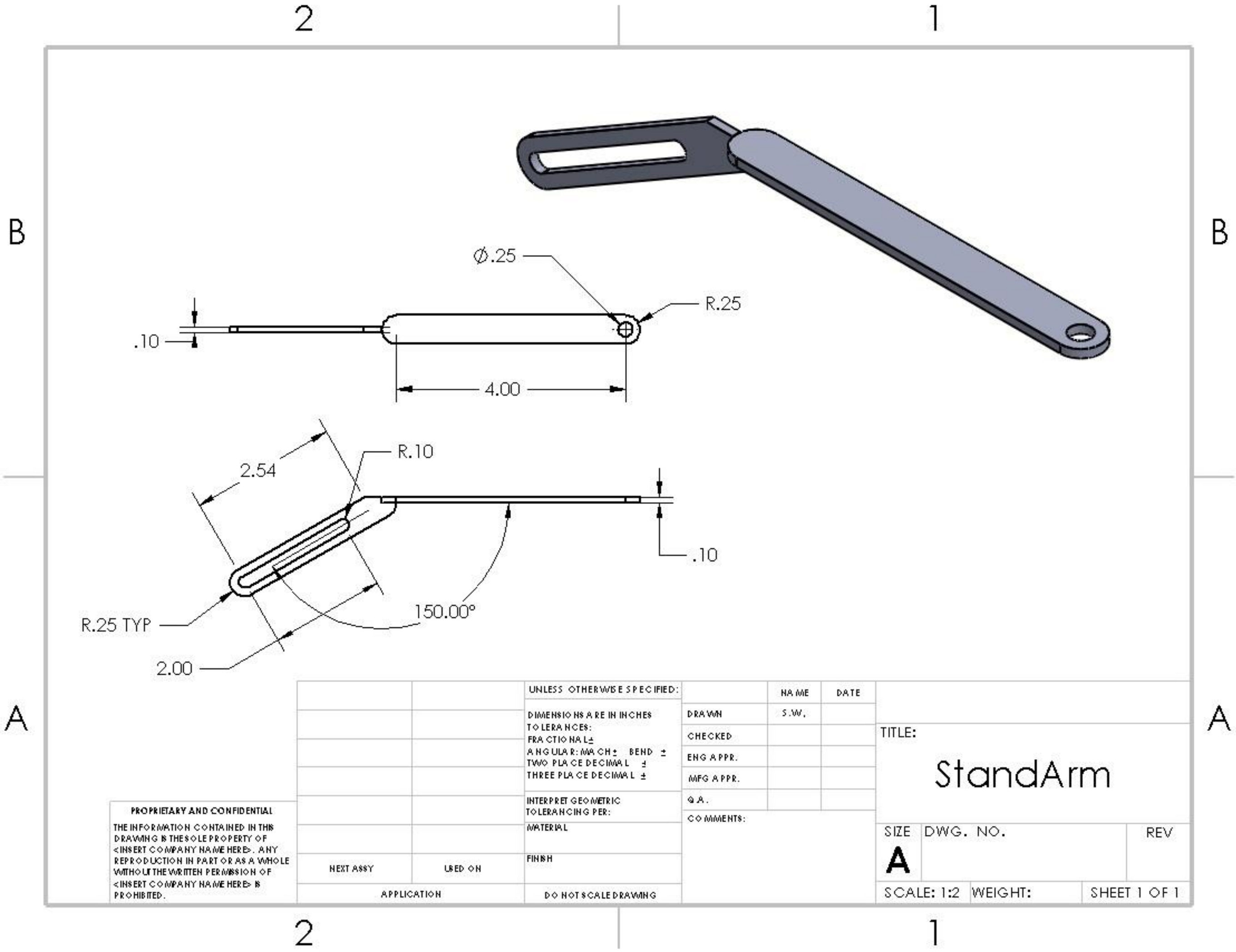


B-2 Bike mounted Rack (STAND)

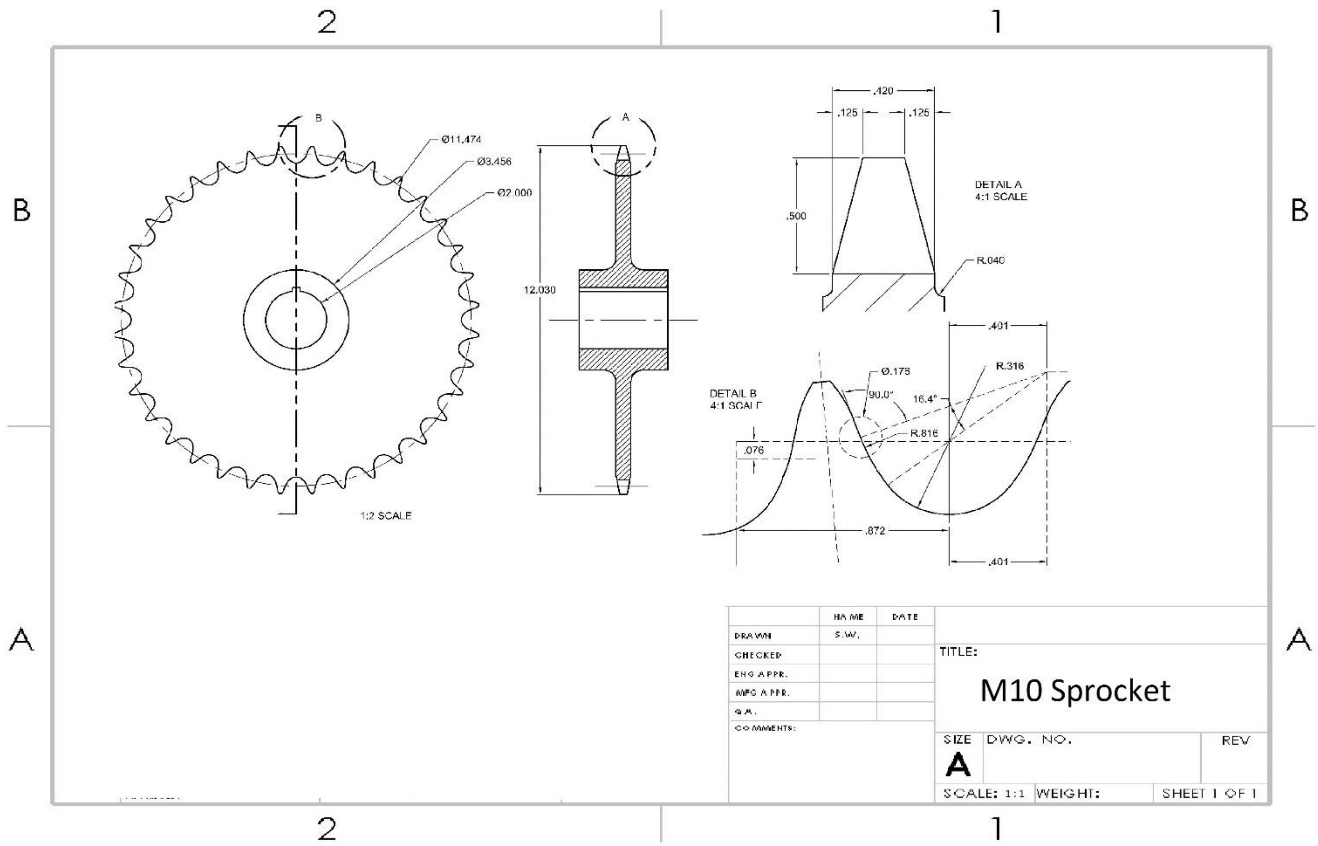




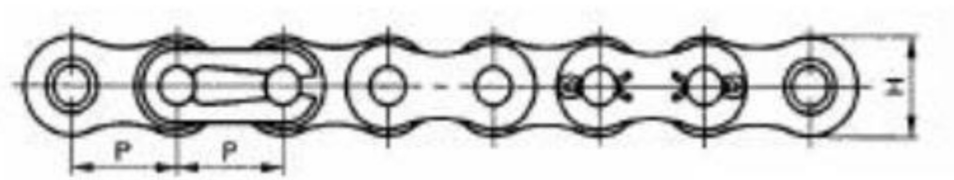
B-3 Stand-Arm for adjustable scale

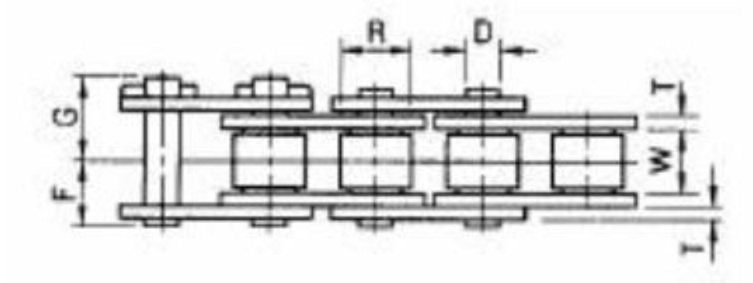


B-4 M10 Sprocket with machine works



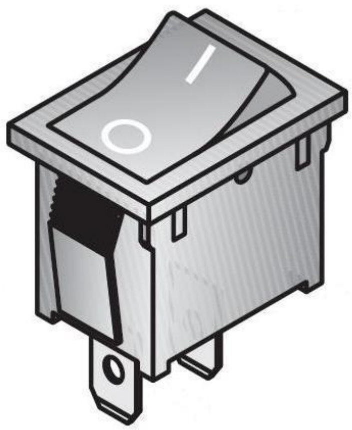
B-5 Standard #40 Chain





Chain Size:	#40 Stainless Steel
Pitch (P):	0.500”
Roller Width (W):	0.312”
Roller Diameter (R):	0.312”
Overall Width (F):	0.640”
Link Plate Height (H):	0.463”
Link Plate Thickness (T):	0.060”
Pin Diameter (D):	0.156”
Tensile Strength:	2,760lbs

B-6 Electrical Section

	1. 24 volt battery or multiple cells in series • Made With Environmentally-Friendly Recycled Green Plastic • Extra Thick Plates Composed Of Pb-Ca-Cn Alloy • Tin Plated Copper Terminals For Better Conductivity • Designed And Manufactured To Outperform Competitor's Equivalent Models • Anti-Corrosion Electrolyte Ensures Longer life • Made With Environmentally Friendly Recycled Green Plastic
	2. Rocker switch • Single-throw and double-throw options • Variety of terminal options • Industry standard mounting dimensions • Mechanical life: min. 100,000 operations
	3. Safe wiring system must overcome high current situation

B-7 Actual Prototype

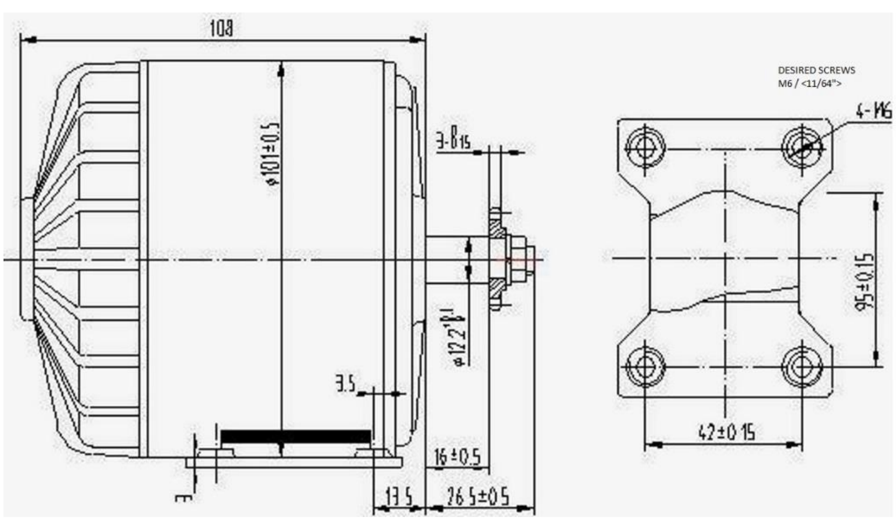
24V 250W
for chain drive scooters

BIG PICTURE

24 Volt 250 Watt 2500RPM Electric Scooter Motor

24V 250W 2500RPM electric scooter motor. Includes 11 tooth sprocket for #25 chain. 12" long power leads with 1/4" push-in connectors. Shaft rotation reversible by reversing power leads. Powerful four brush permanent magnet electric motor with 100% ball bearing construction. Dimensions: 4" wide x 3-1/4" long excluding shaft, 4-1/4" long including shaft. Mounting bracket measures 4-1/2" x 2-1/8 with 4 threaded mounting holes. Weight 4.3 lbs.
Item # MOT-24250X2500

Compatibility: Razor Ground Force go kart and Razor Mini Chopper bike plus many other Chinese-made electric scooters and bikes. Cross references motor number: MY1016, MY1018 and BD250




SPS
SPS1270


XYDJ040204848

Appendix C – Budget List

Hardware	Part name	Manufactures	Quantity	Unit Price	Subtotal Price	Stakeholders
	Motor	United	1	40.89	40.89	CWU
	Cargo rack	Wald	1	11.82	11.82	FUND
	Stand Arm	Self-made	2	1.27	2.54	FUND
	#40 Sprocket	Martin	1	11.25	11.25	FUND
	#40 Chain	Koch	1	9.21	9.21	FUND
	24V battery	Razor	1	7.52	7.52	FUND
	Rocker switch	ACE hardware	1	4.99	4.99	FUND
	Screws, bolts..	CWU Machine	-	-	-	CWU
Labor	Professionals	CWU faculties	-	-	-	CWU
	Laboratory	CWU Machine	-	-	-	CWU
Software	SolidWork	CWU	-	-	-	CWU
Total					41.51	FUND

The expenses excluding those worn out materials is under budget of $100.

Appendix D – Schedule

	Task	Sep 28	Oct 05	Oct 12	Oct 19	Oct 26	Nov 02	Nov 09	Nov 16	Nov 23	Nov 30	Dec 07
	1.Project Outline	•										
	2.Research	•										
	3.Define Subject	•										
	4.Gathering Resource	•	•									
	5.Revise details	•	•	•								
FALL	6.Determine Variables			•	•							
	7.Method decision			•	•	•	•	•				
	8.Sketch schedule						•	•	•			
	9.Budget estimated							•	•	•		
	10.Drawing Tree							•	•	•	•	
	11.Assembly parts										•	•
	12.Proposal closed											•

	Task	Jan 11	Jan 18	Jan 25	Feb 01	Feb 08	Feb 15	Feb 22	Feb 29	Mar 07	Mar 14	
	1.Parts Purchasing	•	•									
	2.Material selecting		•									
WINT	3.Custom making			•	•	•	•		•			
	4.Assembly parts				•	•		•	•			
	5.Adjustment							•		•	•	
	6.Final Form											•

	Task	Mar 28	Apr 04	Apr 11	Apr 18	Apr 25	May 02	May 09	May 16	May 23	May 30
	1.Functions standards	•		•	•						
	2.Check list		•								
SPRN	3.Requirements		•	•	•		•	•			
	4.Finalizing					•	•	•	•	•	○
	5.Presentation		•	•		•					○

NOTE:

● Previously Finished Assignments.

○ Tasks practiced this week. – updating.

◊ Tasks need to be adjusted. –

Appendix E – Resume

SONG WANG

wangso@cwu.edu

OBJECTIVE

Central Washington University BA graduate seeking for engineering employment opportunity.

EXPERIENCE

Oct. 2009 - Oct. 2010	Border Affairs Corp, National Immigration Agency Taoyuan International Airport, Taiwan This is a substitute for the mandatory military service in Taiwan. My duties included statistical report of passenger arrival and departure, number of international fights and multimedia presentation. Then reporting the results to the supervisors in a formal documents.

EDUCATION

2016	Graduated with ABET credited Bachelor Degree in Mechanical Engineering Technology,	Central Washington University, Ellensburg, WA / GPA 3.35
2014	Graduated with Associate Degree in Civil and Mechanical Engineering program,	Bellevue College, Bellevue, WA / GPA 3.27
2009	4 years of study in Department of Water and Soil Conservation,	National Taipei University of Education, Taiwan

OTHERS

Citizen and authorized to work in the US

Capability of Graphical Designing in engineering sense: SolidWork, AutoCad, Rhino and SolidEdge.

Special Ability of computer programming: C#/C++, JavaScript, and HTML 5.0.

Computer skills include Microsoft Office, audio, image and video media.

Fluent in writing, speaking, listening and reading English, Chinese and Japanese.