Shell Eco-marathon

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Midpoint Report

Document

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1. Abstract:

The Shell Eco-marathon competition is designed to encourage research to produce fuel efficient vehicles. Our project team will participate in this event representing the Society for Automotive Engineers at Northern Arizona University. The team has designed and fabricated a prototype vehicle that can produce high fuel efficiency. The powertrain design of the car uses a 50cc gasoline engine coupled with a fuel injection system to improve fuel efficiency. The drivetrain system will employ a dual gear reduction to reduce rotating mass and achieve an average speed of 17 mph. A fiber glass frame encompasses the entire vehicle and has an average drag coefficient of 0.1. To achieve high fuel efficiency, the team developed an engine cycling procedure that consists of ramping the engine to 20 mph and cutting the engine and coasting. From this cycling process, the vehicle is estimated to achieve approximately 800 mpg on a flat surface.

2. Introduction:

The Shell Corporation puts on an annual competition that focuses on increasing the efficiency of fossil fueled vehicles and increasing the interest as well as the efficiency of renewable energy vehicles. The competition will be held in Houston, TX in late April. The prototype vehicle that competes will have to meet rules and regulations set out by Shell. The purpose of this project outlined by the team's client is to design, build, and compete well with a prototype vehicle that will achieve the highest fuel economy possible.

2.1 Client:

The primary client for this project is Dr. John Tester at Northern Arizona University (NAU). Dr. Tester is involved with the student chapter of Society of Automotive Engineers (SAE). Dr. Tester has been the academic advisor for the Shell Eco-marathon for previous competitions. The secondary client for this project is the student chapter SAE because most of the funding is coming directly from the student chapter SAE's budget.

2.2 Need Statement:

Due to the significant number of vehicles running on finite resources as a means of transportation, it has become necessary to research and develop means to stretch those finite resources further. The Shell Corporation has sponsored a competition to promote this research and development in the field of fuel efficiency. The scope of this project is to design, build, test, and present a vehicle that conforms to the set requirements and constraints to produce a vehicle that will produce extremely high fuel efficiency.

2.3 Project Status:

The team has worked diligently on completing the prototype vehicle. The up-to-date progress on the vehicle is currently at 40% completion. The reason for this is outlined below as well as the status of each individual system. Within each individual system the team has outlined how much work has been completed and what still remains.

3. Frame Status:

The status of the frame has had a couple of setbacks. The aluminum tubing intended for the majority of the frame construction was ordered through Industrial Metal Supply in Phoenix. The material selected was 1.00in x .125in 6061-T6. While attempting to bend the tubing, the heat treatment of the aluminum often caused the tubing to fracture. Multiple attempts were made to heat the section of tubing being bent, but with little success, as the tubing continued to fracture after being bent 20 to 30 degrees. The team discussed annealing the material but decided against further heat treating options due to the scale of the project and the likelihood of the softened material kinking while being bent. The frame design was altered, adding more notched and welded joints, to decrease the number of necessary bends. The original design can be seen in Figure 1, while the revised frame can be seen in Figure 2. The current fabrication of the frame can be seen in Figure 3.

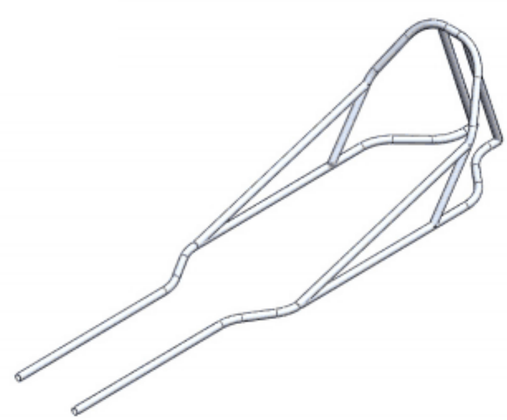


Figure 1: Initial Frame Design

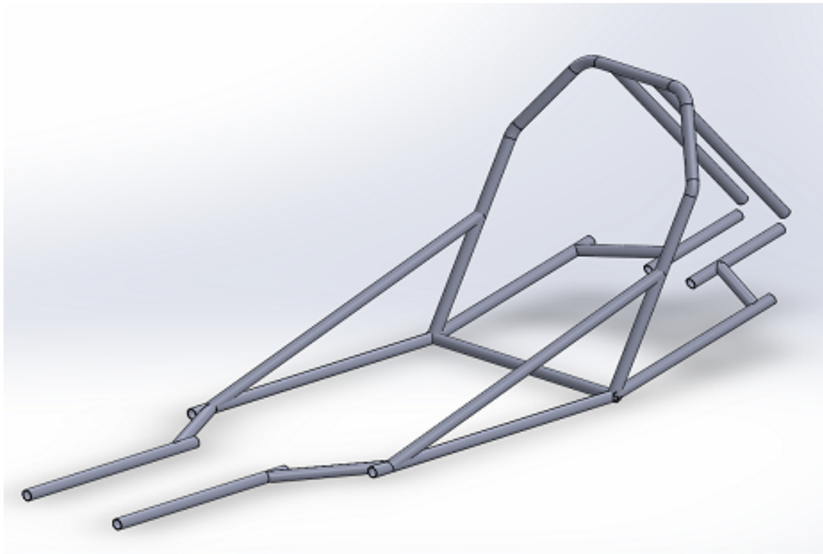


Figure 2: Revised Frame Design

Figure 3: Fabricated Frame

The rear section of the frame also underwent some changes. Initially the rear wheel mount was designed to bolt in at a set position. In order to allow for the drive chain tension adjustment the rear section will now have horizontal dropouts allowing the rear wheel to move fore and aft. This will be accomplished by welding threaded plugs into the frame, to which machined dropouts can bolted. Plugs are currently being machined and initial dropout designs are being analyzed. One dropout design can be seen below in figure 3.

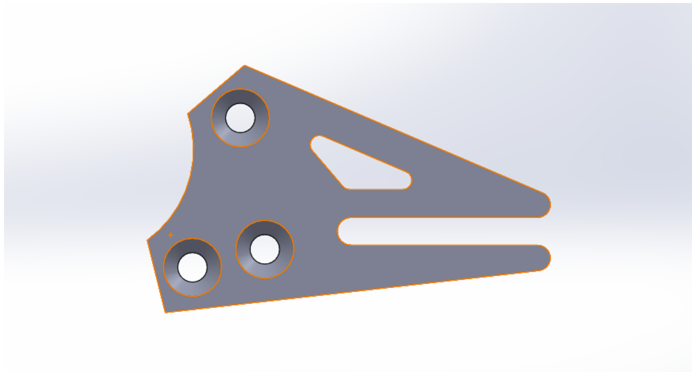


Figure 4: Possible Dropout Design

The flooring material to complete the frame was also delivered and will be attached to the frame in the coming week. Materials have been ordered from FibreGlast to facilitate the construction and finishing of the composite components of the vehicle, including the fairing.

Due to unforeseen setbacks frame construction is still ongoing, but is completed to the degree necessary to begin mounting other vehicle systems. Final machining and welding of the dropouts will complete the structural components of the vehicle.

4. Drivetrain Status:

For the team's chain and sprocket drive, the team will have a secondary drive shaft in order to deliver the calculated gear ratio, which is a 1/20 reduction to the rear whell. The secondary shaft will have two sprockets, the first sprocket has 40 teeth and the second sprocket has 9 teeth. The secondary drive shaft is about 16 inches in diameter which will be supported with two bearings at the end of it. As for the diameter of the secondary shaft, the team used the following equation in order to get the diameter. The team assumed that the highest RPM coming from the engine is about 4000 RPM. Thus and the secondary shaft will have a RPM of 1000, assuming that the shaft is made of AISI 1566 steel:

$$V = \frac{N\,P\,n}{12}$$

Where:

$V = Sproket's\ Velocity$

$N = Number\ of\ Sprocket's\ Teeth$

$P = Chain\ Pitch$

$n = Sproket's\ Speed, RPM$

$$d = \left[\frac{16\,n}{\pi} \left(\frac{\left[4\left(k_f\, M_a\right)^2\right]^{1/2}}{S_e} + \frac{\left[3\left(k_{fs}\, T_m\right)^2\right]^{1/2}}{S_{ut}} \right) \right]^{1/3}$$

Where:

$d = Shaft\ Diameter$

$n = Factor\ of\ Safety$

$S_e = Endurance\ Limit$

$S_{ut} = Tensil\ Strength$

$k_f = Fatigue\ Stress - Concentration\ Factor\ for\ Bending$

$k_{fs} = Fatigue\ Stress - Concentration\ Factor\ for\ Torsion$

$T_m = Midrange\ Torque$

$M_a = Alternating\ bending\ Moments$

After applying the previous equations and using the assumption for the calculation, our secondary shaft will have a diameter of about 0.76 in. Therefore the team chose a final shaft design of 5/8" to give an added factor of safety. The final design will look like figure 6.

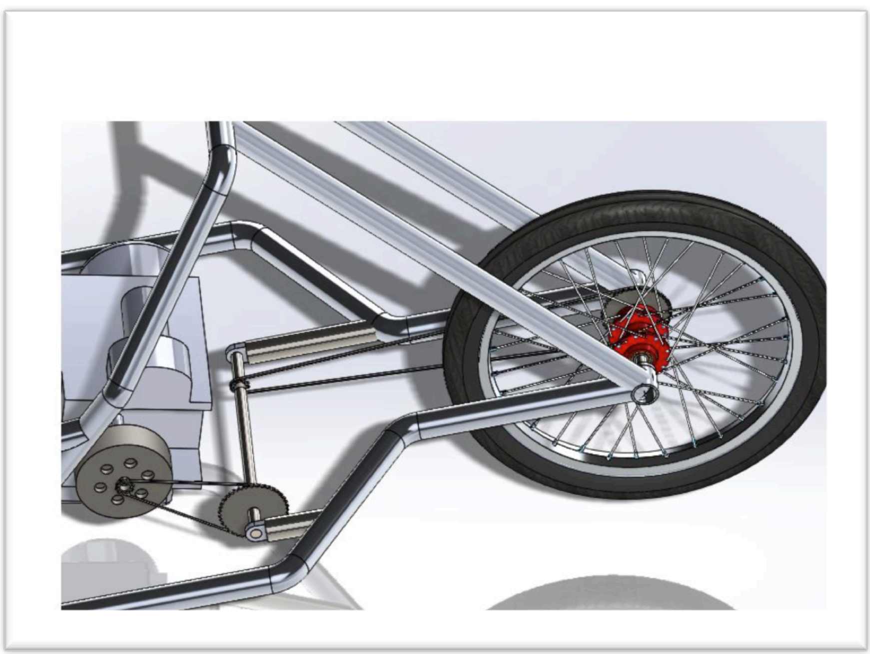


Figure 5: Drivetrain Design

The team is currently waiting on the shipment of the bearings and shaft. The team will need to fabricate several mounting brackets to attach the bearings to the frame. Once the bearings and shafts are in place the chain and chain guard will be installed. All of these tasks will be completed to finish the drivetrain system.

5. Engine Status:

The engine progress can be broken into a few subcategories: initial modification, wiring of components, running, tuning, and car installation. When the engine arrived, it included a CVT transmission that was not a part of the design, so the CVT was removed and the case was trimmed down to lower the weight of the required motor. See Figure 6 for the trimmed motor case. Also, the motor was initially carbureted, so that was replaced with a fuel injection setup from EcoTrons. See Figure 7 for the engine with the integrated fuel injection kit.

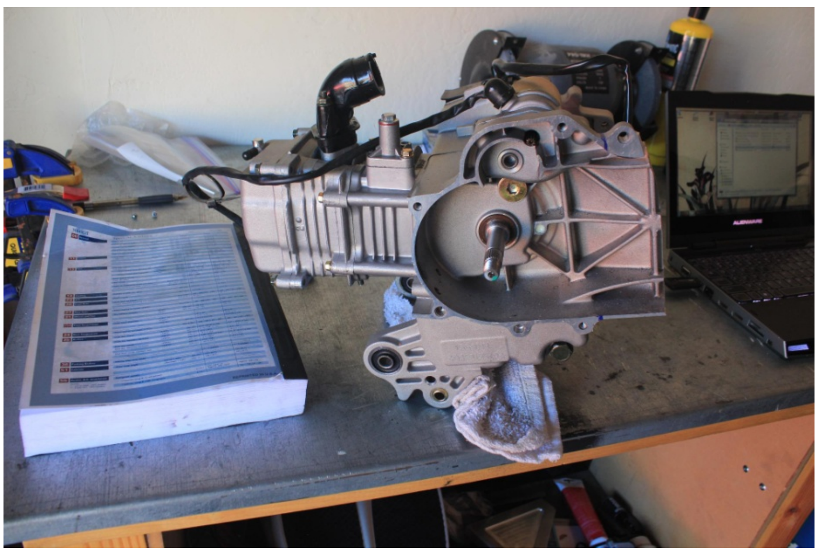


Figure 6: Engine Case Trimmed

Figure 7: Fuel Injected Engine

Once the components were installed, adapting the existing engine wiring to use with the fuel injection system was required. After ordering the necessary adapter parts, the wiring between the fuel injection and the engine was complete. Now, the wiring needs to be verified that it is using the generator to charge the battery.

The engine first fired and ran the week of February 17th, but the tune was incorrect and the motor was using much more fuel than it should. After e-mail correspondence with EcoTrons, the correct base tune was loaded onto the engine management system. As of February 22nd, the engine has a correct base tune for a 50cc engine and only small modifications to the program remain to maximize its efficiency.

The installation of the engine to the car is in process. The frame now has a final design, so motor mounts will be designed accordingly. The mounts will be simple, involving the use of a box aluminum sub frame including mounts for the front and rear of the engine. A CAD model is being developed and will be done shortly. It is an easy piece and parts for it are available at Home Depot, so one the design is finalized, installation time will be short.

In all, the engine is roughly 80% complete. The engine is modified to the point it will be in the car. The engine runs and the correct tune is on the engine management system. Only small modifications to the tune and mount fabrication remain for the engine design process. See Figure 7 for current engine and wiring progress.

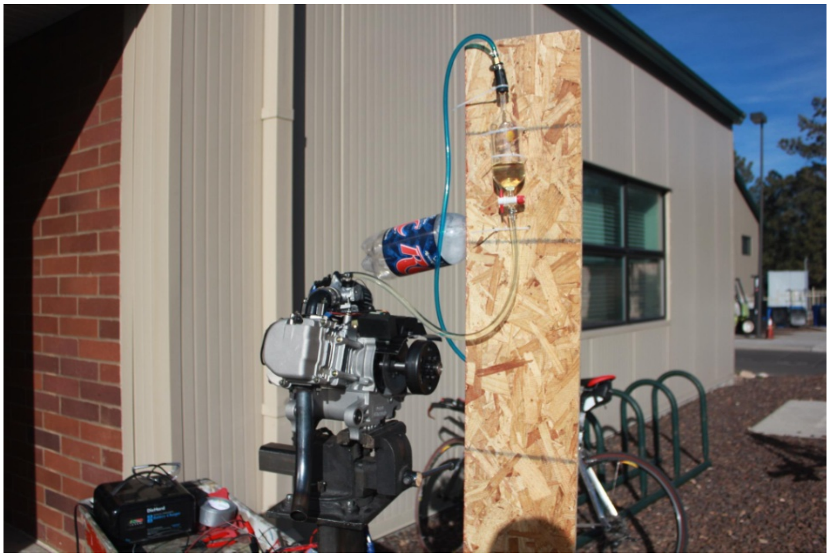


Figure 8: Engine Tuning Testing Set-Up

6. Fuel System Status:

The fuel system for the vehicle has been completed. The team has chosen to make an addition/improvement to the pressure vessel of the fuel system. The team is going to fabricate an acrylic cylinder that will replace the 2-Liter plastic pressure vessel. This addition will eliminate the potential for leaks and can reduce the size of the pressure vessel. See Figure 9 for the current fuel system.

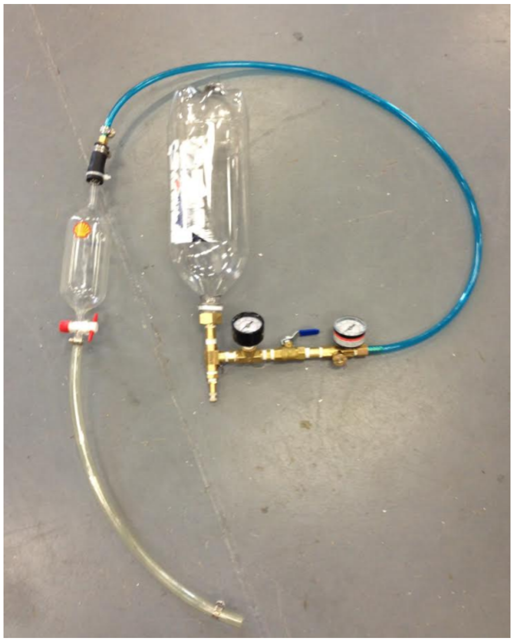


Figure 9: Fuel System

7. Electrical System Status:

The electrical system for the vehicle is at 60% completion. All of the vehicle's electrical components have been purchased and the entire engine electrical needs have been met. The remaining tasks include integrating the electrical system to the final location in the vehicle, attaching the vehicle's horn, adding the external kill switch, and any driving accessories the team chooses to add.

8. Steering Status:

The performance and the efficiency of the steering system is really important aspect to consider. The previous design was a decent fit into the vehicle. It is consisted of primarily components in order to complete the design such as tie rods, steering columns, uprights, steering arms, and steering wheel rod (Fig. 1).

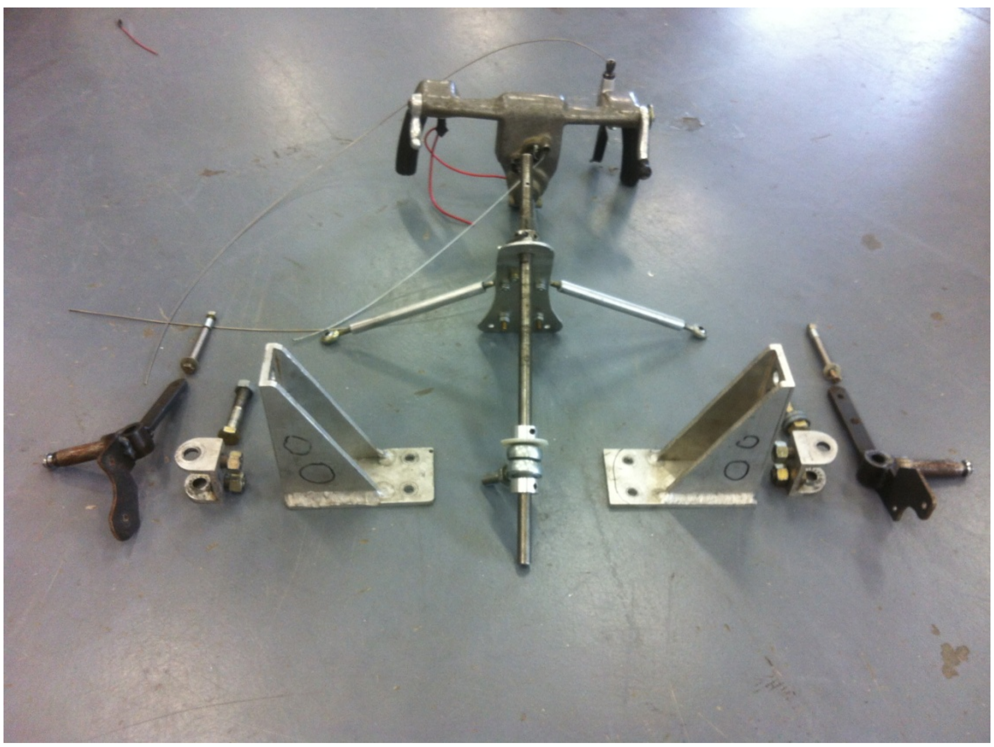


Figure 10: Previous Steering Design

Figure 1 is visualizing the entire system and its components. As shown, the uprights will face each other located at some distance at the front of the vehicle. This will allow the front of the vehicle to be rigid when they are installed. Tires will be inserted into the steering arms and these will be connected to the uprights through a connection part. This setup will allow the steering arms with tires attached to rotate toward the direction desired. Tie rods are very important element in the system since they are installed directly to the steering arms. They will allow pushing the steering arms left or right based on the chosen location. When these parts are assembled together they will make a full steering system (Fig. 2 and Fig. 3).

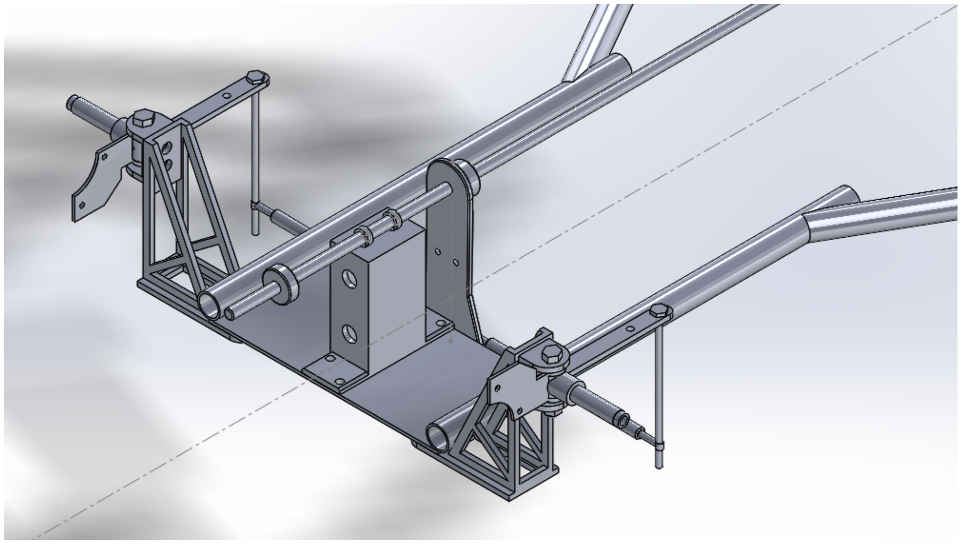


Figure 11: Isometric view of fully assembled steering system

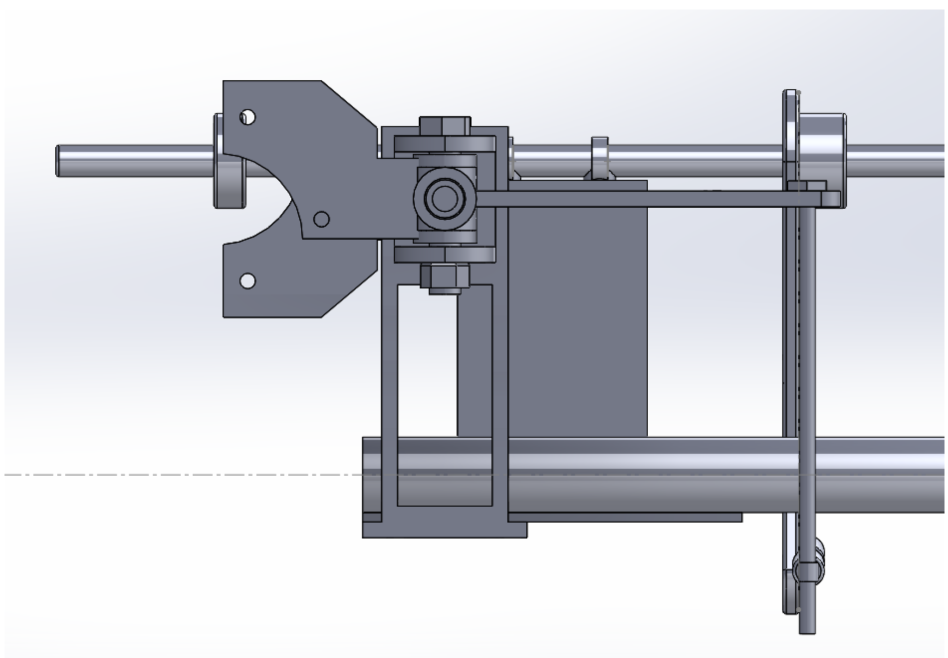


Figure 12: Right view of fully assembled steering system

The advantage of this system is that when installed, it will allow for a tight turns, which is good. Because it will allow for a tight turns, the driver will be in a better controlling position during the competition. Another advantage of this steering design is its size and weight. It is relatively small and light, which will minimize the overall weight of the vehicle since there are not much components involved in this system.

On the other hand, this design has many disadvantages that do not fit with the vehicle's constraints. The most important disadvantage is that it will have a very small width between the centers of the wheels. Meaning, the wheels will be located significantly close to the frame and fairing causing the tires to contact the frame and fairing. This will slow the speed of the vehicle and will negatively affects the tires and fairing. This will, also, cause the vehicle to tip over during the turns and this means it is an automatic disqualification of the competition. Another disadvantage of this steering system is that there will be a substantial small distance between the frame and the ground, which is less than 1.5 inches with no weight placed on the vehicle. Meaning, friction between the frame and the ground could occur at any point. Since these advantages are strongly related to the vehicle's constraints, this system will not be the best option to install on the vehicle.

The available steering design has been modified to meet the vehicle's constraints by fabricating some of the parts such as uprights. Some other parts where machined from scratch such as steering column, tie rods, and cross member. The steering column was machined from scratch to match the distance between wheelbases, which is 24 inches (Fig. 4).

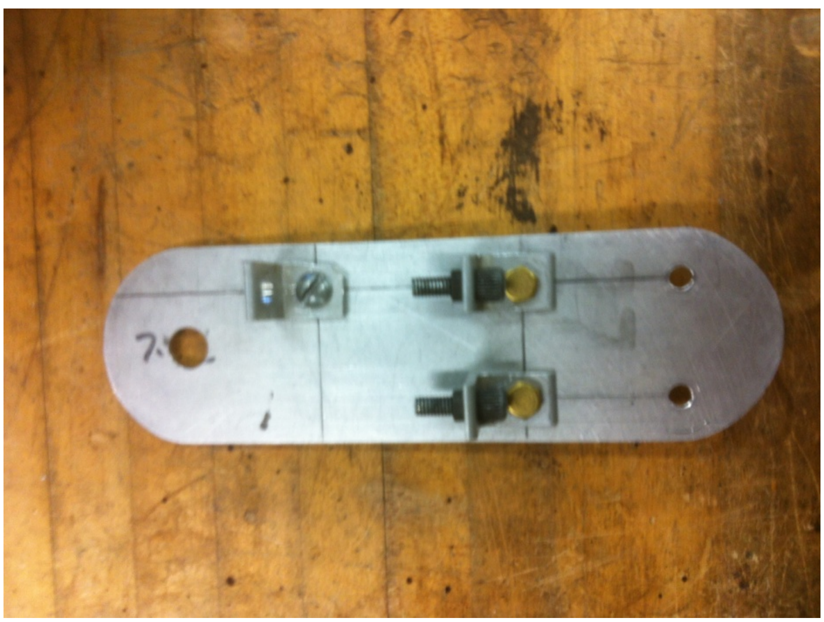


Figure 13: Steering Column

The tie rods where also machined from scratch to match the distance between center wheelbases. Currently, the tie rods are 18 inches long on each side. Therefore, they fit into the system properly. There is also the possibility to re-machine and minimize the size of them if need to exactly match the distance desired between steering arm and steering column (Fig. 5).

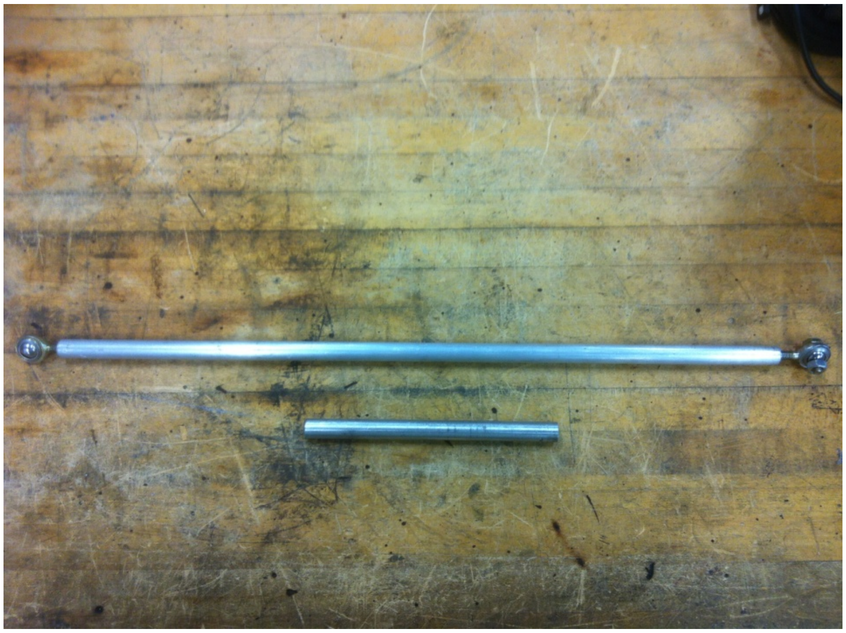


Figure 14: Old vs. Re-machined tie rods

The cross member will act as the steering system base where most parts are going to be mounted on. The cross member is machined to be 22 inches in length and 1.5 inches in height. Putting all the pieces together, a complete updated steering design where the cross member will be resting on the front side of the frame and the uprights will be located at the edges of the cross member. In addition, there will be clamps installed under the frame attaching the cross member to the vehicle's structure (Fig. 6 and Fig. 7).

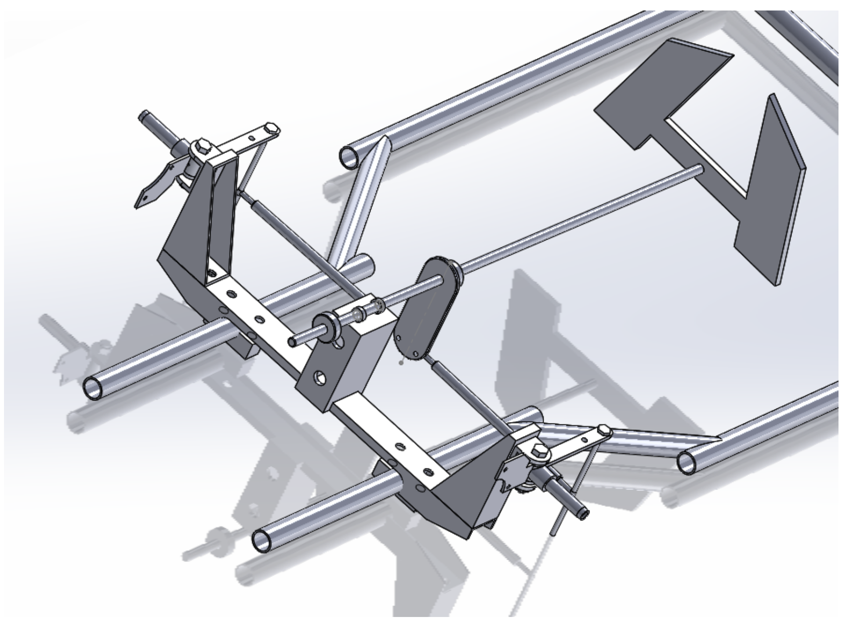


Figure 15: Isometric Top view of the updated steering system

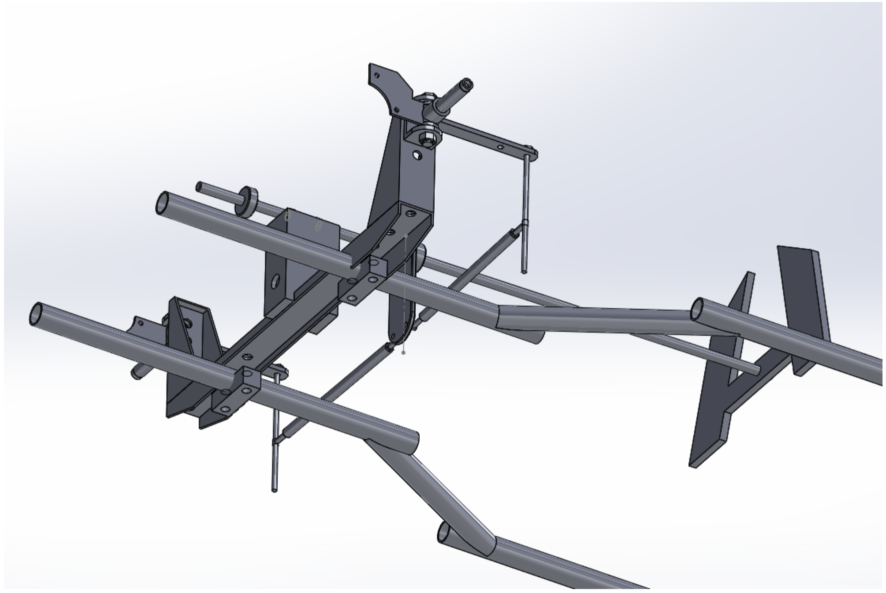


Figure 16: Isometric bottom view of the updated steering system

The most important thing about the updated steering system is that it meets the vehicle's constraints. The advantage of the new steering design is that it will have a decent wheelbase width. This will allow the vehicle to be more stabled and protected against tipping over during turns. Another advantage of this system is that the entire system will be adjustable. Meaning, the cross member can be moved forward and backward along the frame based on the necessity for relocating. Also, the upright will be installed on the cross member and will have the ability to readjust their location inward or outward based on the necessity for relocating. This property is going to insure the steering performance and efficiency because it can be relocated in a certain directions. It will, also, insure the driver's comfortability when operating the vehicle. The other advantage of this design is that the distance between the bottom of the frame and the ground will be more than 2 inches, which enough room between the vehicle and the ground minimizing any sort of erosion. The updated steering design is still under development. Only few parts need to be machined or adjusted, and the entire system will be fully ready for mounting.

9. Braking Status:

Wheels are ready to be installed in the vehicle. One thing that has been to be done on them was replacing the bearings on both wheels. Both wheels are currently having a set of new bearing installed and wheels are ready to be mounted (Fig. 8). All parts are present for braking system such as brake disks, brake calipers, brake pads, and brake handles (Fig. 9). Once the updated steering design is installed, the braking system and the wheels can be mounted (Fig. 10).

Figure 17: New Inner and Outer bearings

Figure 18: Braking System Components

10. Fairing Status

Due to the many issues that arrised with the frame and other vehicle systems, the fairing construction has been pushed back. The reason that the team decided to postpone the completion of the fairing is because as some team members are road testing the prototype, the other half can work solely on the construction of the fairing. The team will create a plug that will then be used to lay the fiber-glass fairing. Once that fiber-glass composite shell is completed, the team can begin fully completed prototype testing.

11. Project Schedule:

Due to some fabrication setbacks, some changes were made to the project timeline. As of now, the priority of the project is to construct and assemble a working vehicle by March 25, which is the date of the second hardware review. By March 25, the fuel, electrical, steering, and braking systems will all be installed on the vehicle and prototype testing can begin. This deadline was set also to complete the vehicle before spring break. The priority to construct the vehicle also changed the construction dates of the fairing. The fairing construction dates were originally from January 1, to March 28, but were changed to March 24 to April 22.

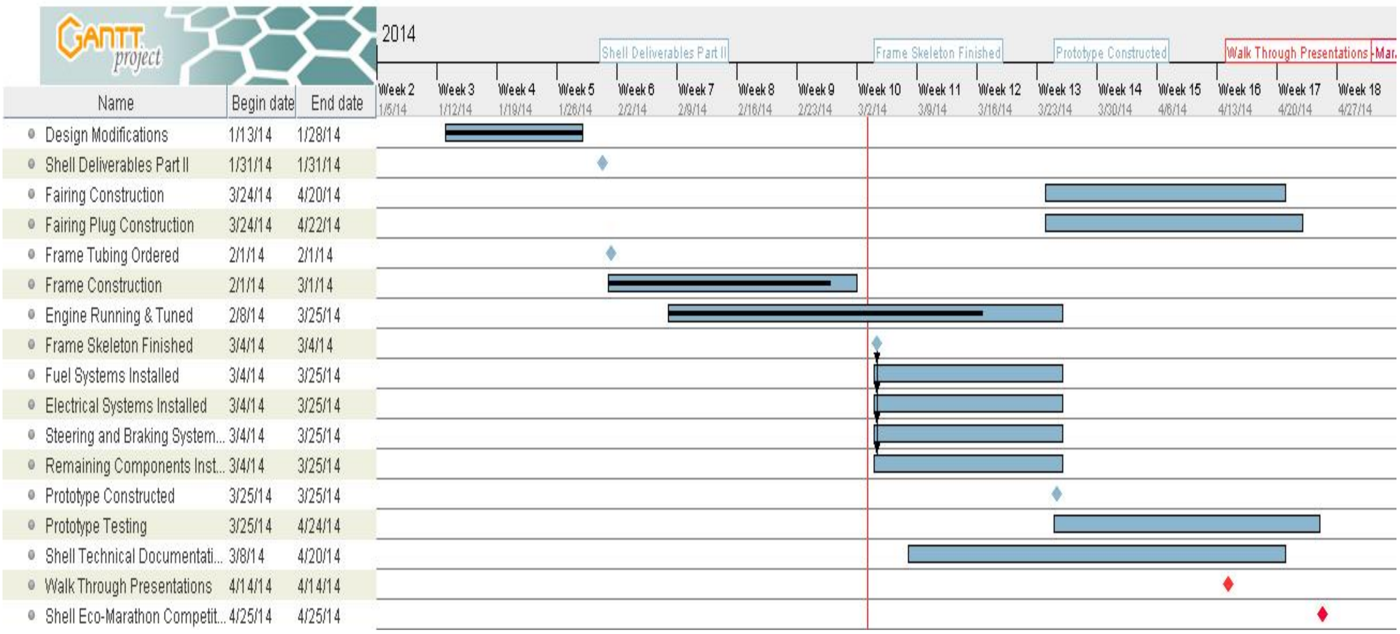
The steering assembly, dropouts to the rear of the frame, and engine mounts are all being fabricated and installed and are nearly complete. These are the final fabrication tasks before the vehicle assembly. The engine is nearly completely tuned with the fuel system for prototype testing. See Appendix A for an updated Gantt Chart.

12. Conclusion:

The team has worked diligently on completing the prototype vehicle. The up-to-date progress on the vehicle is currently at 40% completion. The frame progress has had a couple of setbacks with the aluminum tubing, but a new version that uses notched tubing instead of bends has been created and almost finished. The remaining frame parts that need to be fabricated and installed are the rear wheel dropouts. The drivetrain system is currently waiting on the secondary shaft and bearings to be delivered. The team has done calculations to show exactly what size shaft will be needed. Once the shaft and bearings arrive, the team will fabricate mounts so that the whole drivetrain can be assembled. The engine is currently at 80% completion. The only task remaining related to the engine is an overall vehicle test and tune and finalize the electrical locations. The steering for the prototype is in full fabrication. About half of the needed machined parts are finished. Once all the individual parts are fabricated the team will install and have a functioning steering system. The braking system has been nearly completed with the only exception of connecting the calipers and cables to the controls. The team plans to have a vehicle that is running and has the ability be road tested by March 25th. This road ready vehicle will be the nearly completed vehicle with the exception of the vehicle's fairing.

13. APPENDICIES

APPENDIX A: Gantt Chart



APPENDIX B: Used assumptions & number for calculation the shaft diameter via excel

			For RPM 4000 AISI 1050 CD
Wt2 = F2 = lbf	55.4	w1 = RPM 4000	
Wt3 = F3 = lbf	246.4	w2 = w3 = RPM 1000	
n =	1.5		
Tm = lbf.in =	176.52		
Ma = lbf.in =	466.75		d = in. = 0.76155239
Se = psi =	35900		
Sut = psi =	100000		
Kf	2		
Kfs	1.9		