Solar Powered Electric Vehicle

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Executive Summary

The objective of this project is to design, build and race a solar powered car in the Shell Eco-marathon event. Shell hosts this event each year so that students across the United States can compete and represent their university or college. The car must be solar-powered, allow for one driver, have four wheels, fall within tolerances for overall length, width and height. The car will race at the track and whoever has the most fuel-efficient car will be named winner.

Designing the car is done through modeling software. It is important to front end load the design with modeling so fewer mistakes are made during ordering and fabrication. The most important thing in the design process is the constraints. The car is constrained by the rules of the competition, the budget of the group, the availability of car components and the time and skill of the members. Creative solutions may have to be found to satisfy all constraints such as custom made components or ready-made kits.

The approach is to identify what has been done and what must be done. Modifications to previous designs are done through computer software but actual hardware cannot easily be changed i.e. the custom aluminum frame and purchased suspension components. When designing calculations are made on suspension parts motion and forces experienced.

Progress this semester has been partitioned into different groups namely suspension and powertrain. The suspension has completed the 3D modeling and the construction of front and rear suspension as well as connecting it to the frame. The car is able to stand up symmetrically and the wheels aligned with the suspension. Fabrication of several extra components were created to help make the assembly of the system. Parts ordered include knuckles, hubs, ball joints, disk brakes, control arms, brackets, metal plates along with various tools and accessories.

Finishing the powertrain system is the intent for the next team in spring 2019. The powertrain will need to finish its assembly and design in order to connect to the electrical & the already built suspension system. This holistic stage is set for fall 2018 culminating in a running chassis. A body shell will be designed and constructed to protect and hide the chassis during competition.

Abstract

Designing and constructing a working chassis is vital to compete in the Shell Eco-marathon competition. The suspension team is responsible for the design and feasibility of the suspension system and its components. The powertrain is responsible for the design and uniting electrical systems of the car. Front-end loading plays a critical part in a major project, although to check the dimensions and performance of each component, a 3-D model was created for each part using the software SolidWorks® was used to check the dimensions and performance for each piece. SolidWorks® is a capable program for large scale assemblies with file extensions that can often carry to other programs such as Autodesk® and CREO®. By replicating a 3-D model of each system in SolidWorks® before purchasing individual components improved the overall attachment of the parts connected to the frame. The reason being that measurements and certain dimensions were noted on the modeling software to locate and fit each individual component to the designed frame. This helped with time management since the attachment was already projected before the arrival of components.

Managing a project requires not only the specialist (engineer) but also the manager who follows the budget and effectiveness of purchases. Supply chain logistics requires cost analysis whether to outsource or make in house. It also encompasses the transportation and delivery of materials and parts to where they are needed most. Mangers then control and advise workflow so the project stays on schedule and firefighting, the process of excess relocation of resources, is avoided. Every group member in needs both qualities so work is continuing to improve and each member master certain small portions of the project bring the project together during meetings.

Table of Contents

List of Figures

List of Tables

Background

The solar car project initially started in the 2016-2017 academic year that concluded with the completed body frame. The frame was made from aluminum tubing of square cross section that were welded together. Some 3D modelling and research work for chassis, electrical, suspension and powertrain systems were attempted, but any components for the suspension and powertrain system were purchased. However, no theoretical calculations and finite element analysis were provided. Operational manual lacked details and 3D models had missing parts.

In the academic year 2017-2018, another design team with help of ASME volunteers worked on powertrain and completed some of work. To be exact, tires, CV axles, a differential and hubs were selected. Additionally, the 3D model of powertrain was redesigned in order to add some of missing part. ASME volunteers helped to finish the electrical system and purchased new solar panels. There are still a lot of work left to be done on powertrain such as designing, purchasing, assembling drive shafts, transmission and newly made circuits need to be tested as well.

In Spring 2018, the focus of the senior design team was to plan a good suspension system and to plan optimal ways to connect the suspension parts to body frame of the solar car. The senior design team was split into two sub-teams each of whom was responsible for building front and rear suspensions, respectively.

In Fall 2018, the goal of the senior design team was to design and construct powertrain and suspension systems. The initial approach to this was to split responsibility into powertrain and suspension sub-teams. Due to many challenges faced along the way that included one of powertrain team members quitting, many design constraints created and left by previous senior design teams as well as time constraint and difficulty finding specialized manufacturing companies for machining splines for joints. Both front and rear suspension were assembled and attached to frame, but powertrain team only design to fit one side of the shaft.

Challenges faced when assembling the suspension system was the lack of equipment to construct and fabricate some of the components. This problem was fixed when the team moved to the Design Studio for more room to work with and storage unit was in place for the purchase of new power tool equipment. Another constraint was the dimensional restrictions for the competition requirements and the already designed chassis that limited the room to work with for each specific system. Very unique components needed to be found for the system in order to fit and work in the already designed structure.

Project Description

This should be the overall goal and next steps to take when building a solar. The creation of land transport vehicles powered by renewable energy sources [1] to replace use of fossil fuels in the future & reduce greenhouse gas emissions into the atmosphere has been a key subject for research and innovations. Solar-Powered vehicles are considered as one of the most promising vehicles for the next generation. The senior design team aims to build the most important foundation of a solar car by designing its mechanical systems such as powertrain and suspension in order to participate in the “Shell Eco-Marathon” competition. The solar car project is intended to be a hands-on opportunity for mechanical engineers to apply theoretical knowledge and skills gained in classes and in practical work such as laboratories and internships.

Objectives

The objective of the senior design project is to design and built powertrain and suspension systems of a solar car following the design requirements from the Shell Eco-Marathon competition handbook. The goal for powertrain sub-team is to design and assemble all of powertrain components and connect the electrical system together. The goal for the suspension sub-team is to fully assemble and attach suspension parts to the body frame along with the appropriate design. The overall objective is to have a fully designed foundation in terms of powertrain and suspension in order to help Purdue University Northwest and the student society called American Society of Mechanical Engineers to participate in the competition called "Shell Eco-Marathon" in the future.

Powertrain

The powertrain system of solar car consists of mechanical parts such as chain and sprocket assembly, drive shaft with bearing housing and key, constant velocity axles and custom joints that transmit power generated by electrical components and DC motor to wheels [2]. This system is intended to make the wheels rotate and allow the solar car to move. Work plan for powertrain in Fall 2018 was to design and assemble the entire powertrain system by doing research and planning, re-modeling parts on SolidWorks® and re-designing powertrain to eliminate design constraints created by previous senior design teams. Due to one of powertrain members quitting, time constraint and difficulty finding specialized companies that manufacture splines, the powertrain sub-team does not plan to physically build the powertrain system. All design work will be limited to planning, modeling, ordering new parts, 3D printing and testing for fit to ensure powertrain will be ready to be assembled and physically built by future senior design teams.

Expenses of Student Organization for Approval:

Event Name/Date	**Expense Detail** (List item/s that need to be purchased.)	**Vendor Information**	**Amount**
New Purchase for Solar Car/November 20, 2018	CV Axle KAW-7012 Quantity: 1	Amazon https://www.amazon.com/TrakMotive-KAW-7012-OE-Replacement-Axle/dp/B00N0ZU56Q	$121.36
New Purchase for Solar Car/November 20, 2018	Kawasaki 2003 KVF 360: Hub Part: 49030-7507 Quantity: 1	Kawasaki Parts House https://www.kawasakipartshouse.com/cart	$107.56
New Purchase for Solar Car/November 20, 2018	Kawasaki 2003 KVF 360: Bolts Part: 92151-1392 Quantity: 4	Kawasaki Parts House https://www.kawasakipartshouse.com/cart	$11.80
New Purchase for Solar Car/November 20, 2018	Kawasaki 2003 KVF 360: Pin Cotter Part: 550AA4025 Quantity: 1	Kawasaki Parts House https://www.kawasakipartshouse.com/cart	$2.95
New Purchase for Solar Car/November	Kawasaki 2003 KVF 360: Nut Part: 92210-1381	Kawasaki Parts House https://www.kawasakipartshouse.com/cart	$9.84

Figure 1. Powertrain Purchased Parts.

Research and Plan Powertrain System.

The entire powertrain system was researched to determine exact parts needed for designing powertrain of the solar car. This helped prepare the purchase list and determine the order by which powertrain parts would connect to each other. For example, the powertrain sub-team discovered that one end of constant velocity axle would go through suspension knuckle, wheel hub, brake rotor, lug converter and wheel assembly in that order. Another end of constant velocity axle would connect to drive shaft that is mounted in bearing housing. Next, detailed planning of powertrain connected was planned to see how these parts would join together. As a solution to this, a custom bushing that would have internal splines, press-fit holes and a spot for inserting key was designed for connecting constant velocity axle to drive shaft. Second long joint was designed to connect another end of constant axle to already present motorcycle wheels. Finally, list of new powertrain parts needed to be created to buy and to ensure all parts for powertrain were present for future senior design teams. As a result, new parts needed for powertrain and connections were identified and planned before purchasing. Purchase list was prepared and sent to the secretary at Purdue University Northwest Mechanical and Civil Engineering Department as well as to the advisor for approval. All new powertrain parts successfully arrived and were moved to the design studio.

Re-model Powertrain on SolidWorks®

Initially, it was planned to convert all powertrain CAD models created on Autodesk Inventor and PTC CREO® last semester into SolidWorks®. The decision was made due to CAD software transition of Purdue University Northwest to SolidWorks in Fall 2018. However, it was later discovered that all previously made CREO® files did not open and new models needed to be made again. Another reason for re-modeling powertrain parts was the fact that newly purchased powertrain parts that perfectly fit each other looked dramatically different from powertrain models from last semester. As a result, old and new powertrain parts were all modeled from scratch on SolidWorks® and assembled into the final rear wheel CAD model by the powertrain team. To ensure correct order of parts connecting with each other, sub-assemblies such as wheel-to-constant velocity axle and constant velocity axle-to-drive shaft were made first. At the end of the semester, powertrain models along with rear suspension parts were assembled and diplayed at the senior design presentation.

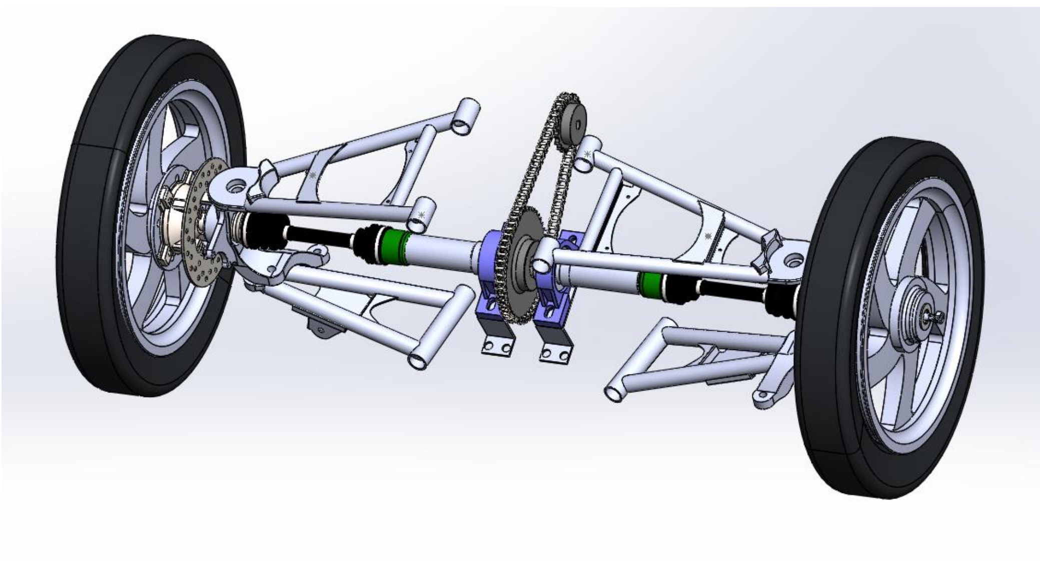

Figure 2. Final Powertrain Assembly.

Re-design Powertrain and Eliminate Design Constraints

In Fall 2018, it was determined that old constant velocity axles and wheel hubs were not compatible with each other and would not connect. It was also determined that constant velocity axle was too long and did not meet total width dimension requirement for the “Shell Eco-Marathon” competition. In addition, key on drive shaft needed to be re-designed and replaced because the old key was completely incompatible. Bearing housing was welded by previous senior design team onto frame, so inserting key that would go through shaft was very problematic. Pulley and belt assembly was needed to be replaced due to suspicion that it would not withstand torque power generated by the current 2000-4000 Watt DC motor.

Therefore, a lot of re-designing work was performed to eliminate these design constraints and solve powertrain issues in Fall 2018. As a result, all of powertrain parts were found and purchased. New constant velocity axles and wheel hubs belonged to the ATV model Kawasaki Praire 360 with year model from 2001-2003. Parts successfully passed tests for physical fit and capability with suspension knuckle and brake rotor parts from Kawasaki Teryx 750. Threads on constant velocity axles were carefully measured with gage tools from MET lab, and unknown spline dimensions and angles were carefully calculated.

CAD models of these powertrain couplings were then 3D printed and tested for physical fit with actual constant velocity axles and the drive shaft. Keys were modeled on CAD for big and small sprockets that are joined together by the chain. Engineering drawings were created for keys and sent to MET lab for manufacturing. Engineering drawings for couplings were sent to the company called “Riverside Spline & Gear” for evaluation and cost estimation for manufacturing. Thus, all powertrain design issues left after previous senior design teams were eliminated and solved.

Figure 3. Re-design Powertrain

Suspension and Steering

The entire suspension system consists of eight control arms (two upper control arms in front and rear suspension as well as two lower control arms in front and rear suspension). Strut assembly, spindles, steering knuckles and spindles, ball joints, hubs, bearings and bushings. The steering system starts with tie rods attached to the suspension system. Tie rods themselves are connected to other steering components in order of connection such as a rack and pinion assembly, a steering shaft, Hooke joints, an intermediate shaft, a steering gearbox, an upper column ending with a steering wheel. The work plan for the suspension system Fall 2018 was completed the CAD Modeling of suspension system to ensure dimensions meet requirements for Eco-Marathon competition by modeling in SolidWorks®. Then, work in the assembly of the suspension system in order to attach to the frame.

Check Parts of Suspension System

As parts are received, dimensions and quality was checked to ensure the parts meet the expectations. The dimensions were checked by using a digital caliper to do the 3D models.

Measure Components and 3D Modeling of Suspension on SolidWorks®

Measured all the new components arrived from last semester by using measuring tools such vernier digital caliper and made 3D modeling of each component of the suspension by using SolidWorks®.

Attach Suspension System by Using Brackets

Manufactured brackets to attach the components of the suspension system to the frame; also, bought some L-brackets to fix the upper and lower control arms to the upper and lower mounting plates. Another option was welding, but since the mounting plates are made of carbon steel, it was difficult to weld the components.

Assemble Suspension System

After assembled in 3D modeling by using SolidWorks® and see that most of the components fit into the frame. The senior design team assembled the front and rear suspension system to the frame by using different types of brackets and following the requirements of the Eco-Marathon competition with a minimum turning radius of 8m for the urban concept competition. It is necessary to know how to calculate the turning radius lead to the side DavData.com. According the side the turning radius is given equation.

Shock absorbers are very important for the geometry of the car, without the shock absorbers the suspension will not be align. It helps to hold up the suspension within a certain distance from the ground to the frame. Also, it helps to absorb the vibration of the car, and reduce effects of traveling when the car is moving. One side of the shock absorber is attached to the upper control arm and the other side is attached to the frame, so this prevent the fall down of the suspension system to the ground.

$$\text{Turning radius} = \frac{\text{width between the center of the front and rear tires}}{\text{sin(the pivit angle of the front wheels) 2}}$$

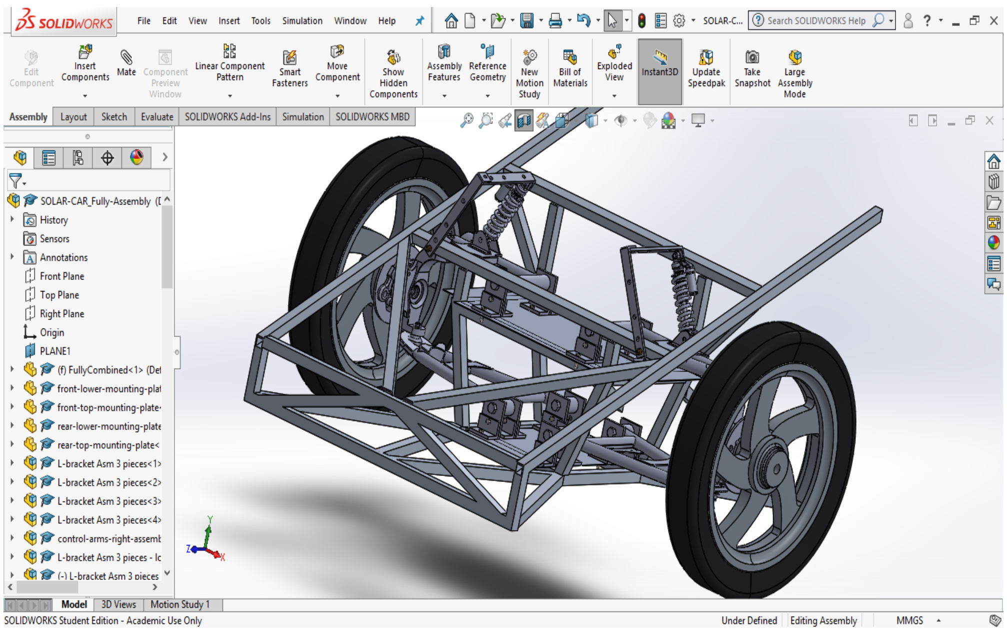

Figure 4. Front Suspension 3D Modeling - Senior Design II - SolidWorks

Wheels

The rim specifications are 17" as the diameter of the rim, and 2.75" as the width of the rim. The rim was selected according with the tables provided by manufacturers based on the tire size and competition requirements. According tire manufacturers specifications, 110 is the tread width in millimeters, 80 is the aspect ratio and R17 the diameter of the rim that is used in inches. These specifications are followed according to the Shell Eco-Marathon competition rules. The order, purchase and assembly of the four wheels was accomplished. The guidelines stated that the rim must have 15 to 17 inches in diameter and the tires must have a width between 80 and 110 mm with a minimum tread of 1.6 mm [3]. All Four models of the wheels were designed in SolidWorks® shown in the picture below in order to testing and checking the material properties for proper fitting.

Figure 5. Wheel 3D Model

Attachment

Brackets were used to attach the components of the solar car. As well as the use of metal mounting brackets to attach the metal plates to the chassis and connect the systems for stability. A different type of mounting brackets were used to attach some parts of the suspension system to their desire mounting metal plate [4]. Likewise, convertors were used to connect components of the suspension system like the hub to the wheels. To successfully build a working solar car, all objectives must be designed, manufactured, researched, assembled and ordered appropriately. The wheel was connected to the converter, which connected to hub, which attached to knuckle and the control arms were attached to the frame.

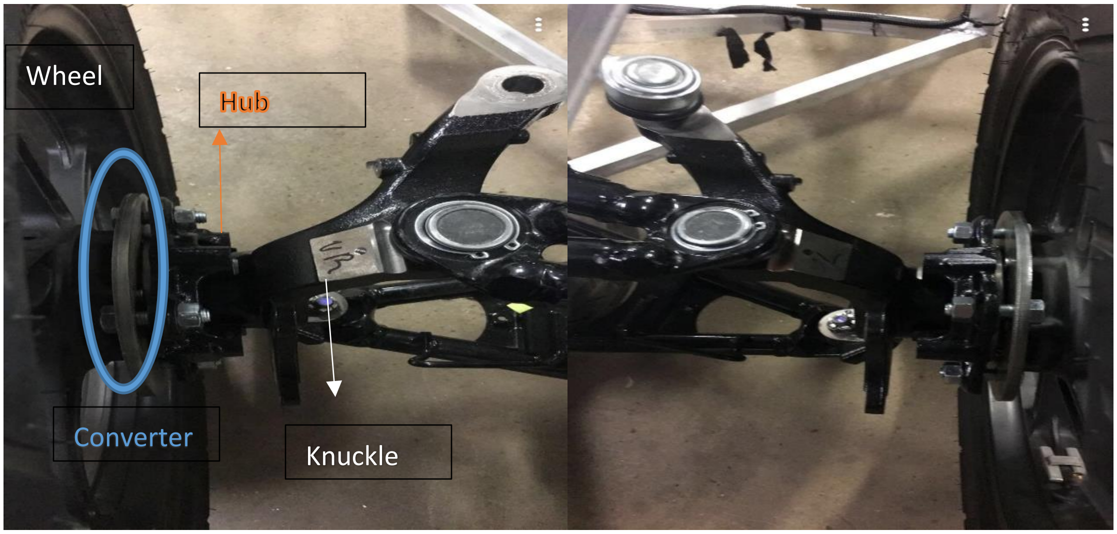

Figure 6: Attachment

Constraints

The requirements and rules are established by the Shell Eco-Marathon competition; in addition, this electric vehicle will participate in the Urban-Concept category. The main issue is the wire frame designed for the vehicle is rather small and does not leave much clearance room on either side or above the roof. This also creates dimensional restraints to the powertrain and suspension components that need to be ordered, purchased and assembled to the electric vehicle. . These dimensional restraints caused several problems on finding components suitable for the solar car. This causes delay in transportation when receiving individual components since it needs to be specially ordered or made. Usually, most automobile companies start manufacturing a car by building each individual section first, then built the outer design suitable to fit the inner components.

The main issue for this project is that the outer design is built, and the rest of the sections have to be a certain measurement in order to fit appropriately. Most modern car components are either larger or too heavy for the frame to either hold or support. The results in the semester took long research for components and materials to fit the frame and still meet the Eco-Shell Marathon requirements. Meaning that some components have to be specially made, or harder to find the correct part, more expensive, and wasting travel time waiting for ordered parts to arrive.

Environmental Impact

Solar car is powered with energy from the sun, and therefore, it is not expected to pollute the atmosphere the same way as fossil-fuel powered vehicles. The only possible harms to the environment associated with solar cars are toxic materials and chemicals used for making photovoltaic cells. Some solar thermal systems contain toxic fluids that can leak and cause negative effect to the environment [7]. Alternatives to fossil fuels reduce carbon footprint at home and abroad, reducing greenhouse gases around the globe. Solar is known to have a favorable impact on the environment. Most of the electricity generated in the United States comes from fossil fuels like coal and natural gas. Extracting and using fossil fuels is expensive and harmful to the environment. By contrast, solar energy is free and readily abundant. By investing in solar energy, you can help reduce our reliance on fossil fuels in favor of one of the most abundant, consistent sources of energy we have available: our sun. That is one of the main reasons Shell encourages all colleges to participate in one of their many solar powered vehicle races in order to innovate and preserve the ecosystem.

Approach

The first approach for this project is to assess what has been already done. Re-evaluating old designs, parts, calculations, CAD models and checking if they are applicable to the goal of designing powertrain and suspension systems of the solar car. Next step is to ensure design requirements for the "Shell Eco-Marathon" competition are fully met. To accomplish this, powertrain and suspension systems are to be modeled and assembled on SolidWorks® to verify dimensions of the parts are correct. Creating needed engineering drawings and 3D printing the parts to test whether the parts are fully compatible is another step. Final approach for powertrain work is limited to design and final approach for suspension is assembling and attaching suspension parts to frame.

Summary of Progress

Most of the information about previous team and what would be done in the future is discussed in this section. The objective of the project is completed the 3D of suspension system and powertrain system to ensure dimensions meet requirements for Eco-Marathon competition. Suspensions parts purchased last semester need to be assembled by the current senior design team. In the future can be used to continue assembling the other parts of the solar car. The goal for this year's team is to develop a complete 3D model with real dimensions of the powertrain and suspension system, design solar car concepts, and to purchase components within the budgetary constraints.

Initial Assumptions

At the beginning of the semester, the senior design team was assumed that the entire car could be built quickly because the previous teams had already finished the body frame and some components for electrical and powertrain systems. But after careful examination, the current team discovered that there were still many things to be completed. To be exact, the suspension system and powertrain systems were never built, the electrical circuits required testing, and various dimensions of the 3D models required adjustment to fit the body frame. The reason was, the previous teams had used Autodesk Inventor, SolidWorks® and the inaccuracy was noticed when drawings were reviewed in PTC CREO®. For the second semester, senior design team decided to use SolidWorks® software for the 3D modeling, which it will make easy to next senior design teams to work with the 3D models.

Completed Parts of the Design

The current senior design team aims to achieve results in order to give an opportunity for the student organization at Purdue University Northwest called American Society of Mechanical Engineers (ASME) to participate in the Eco-Marathon competition by Shell. This should motivate students who want to be work in automotive and renewable energy fields. The academic professor for this project at Purdue University Northwest is Dr. Hansung Kim who is guiding the current team in building a solar powered car to compete in the competition and in reminding rules and specifications set by Shell.

There were three previous teams who worked on the solar car and managed to design the aluminum wire frame, and complete research work for chassis. Since the beginning of the Spring 2018 semester, the current team has been working on the suspension system and powertrain system. The 3D modeling drawing for the front and rear suspension have already been done by using SolidWorks® with the actual dimensions of the purchased components. The senior design team in spring 2018 semester bought the components for the suspension system and some components for the powertrain system in order to start the assembly phase.
Components of suspension system and powertrain system have been modeled with actual dimensions in SolidWorks to ensure that components fit to each other during the assembly of the solar car to the frame. The following figures illustrate some of the work that is been done for first and second semester for the solar car project. The solar car assembly with the suspension and powertrain system is shown in the appendix (Fig. 5).

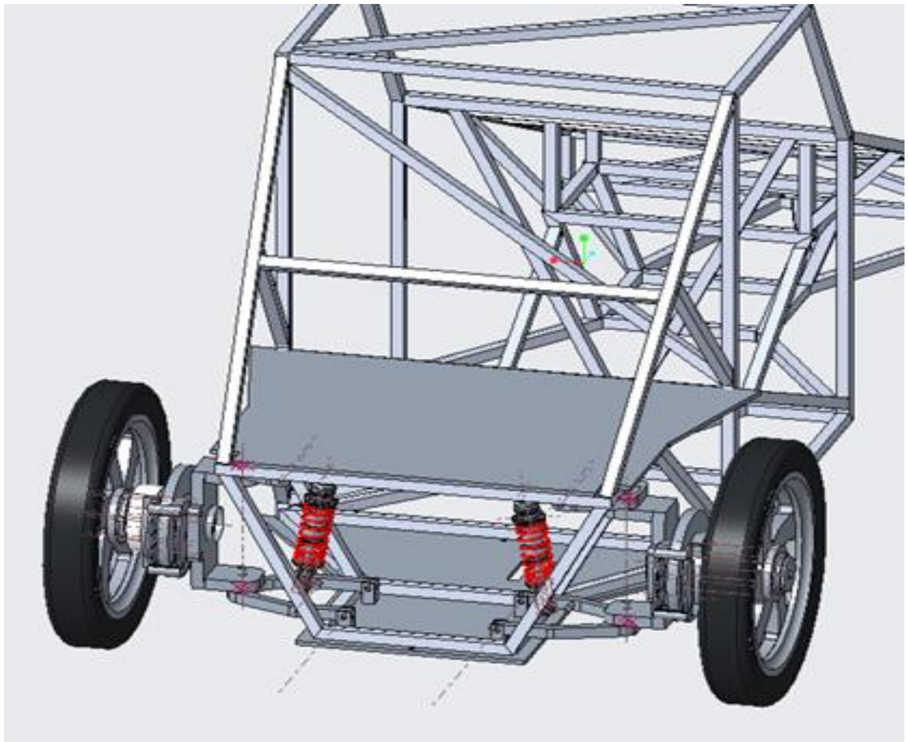

Figure 7. Rear Suspension of the Solar Car – Senior Design I – PTC CREO®.

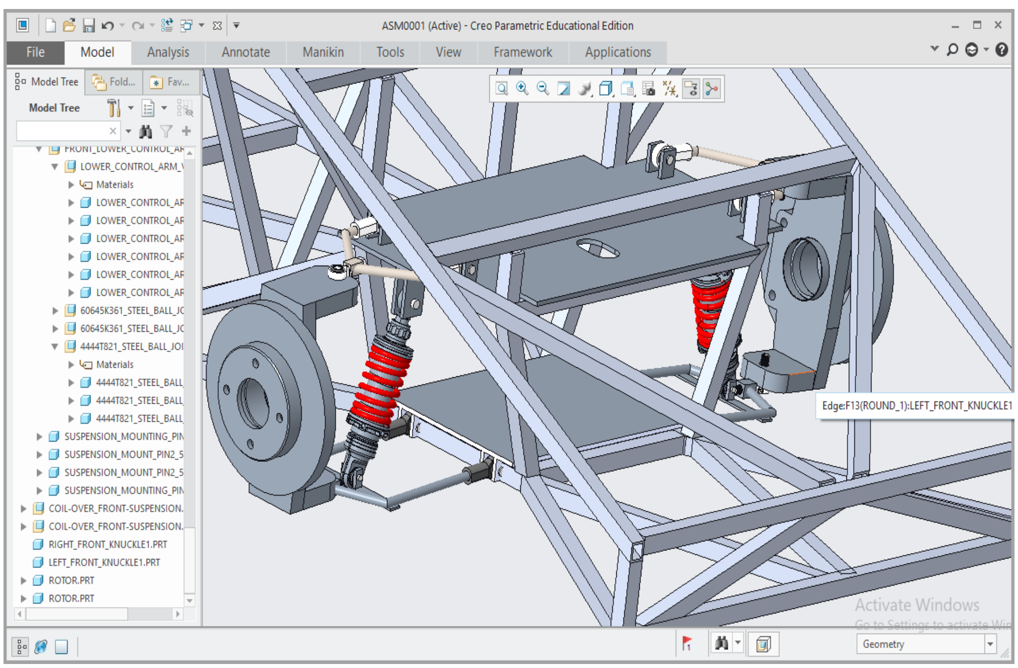

Figure 8. Front Suspension of the Solar Car – Senior Design I – PTC CREO®.

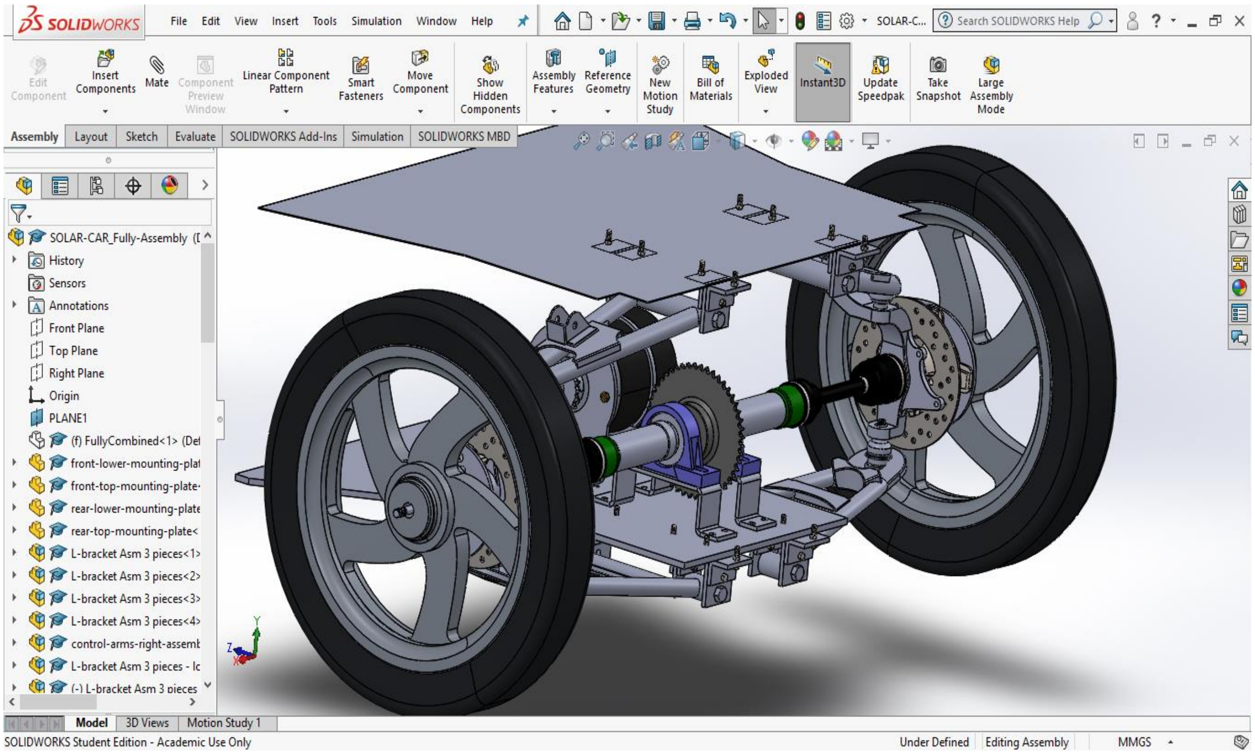

Figure 9:. Rear Suspension with Powertrain System - Senior Design II

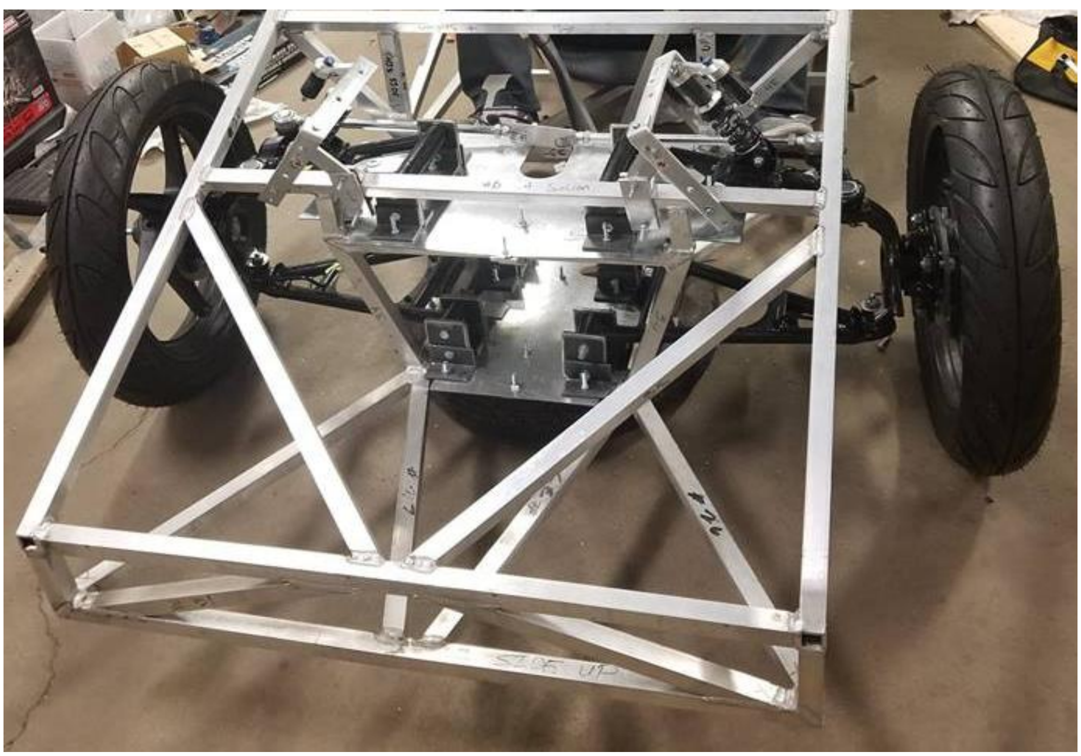

Figure 10: Front Suspension System - Senior Design II

What Remains to Be Done

The senior design team attempted to finish building the entire suspension system in Spring 2018. All needed suspension parts along with some of disc brake system components were purchased for future assembly at the end of Spring 2018. In Fall 2018, the senior design team aimed to design and built the powertrain suspension system. Work that remains to be done by the powertrain sub-team include 3D modeling of powertrain parts on SolidWorks, ordering new powertrain parts and creating engineering drawings for manufacturing custom joints and shaft key as well as 3D printing them for testing fit. In fall 2018, the suspension team had finished modeling and fixing all four suspension system assemblies. As well as assembling and mounting the front suspension to the frame including the attachment of the wheels. What remains for the rear suspension is the powertrain measurements of the axle in order to connect suspension system to body and have the proper dimension for aligning knuckle that connects to the axle from the powertrain system.

Unsolved Technical Issues

Since previous teams all had been utilizing different CAD software, many parts went missing. Likewise, by converting from one file to another file in order to open the 3D models in different software, the dimensions have changed.

The current aluminum wire frame is rather small and does not leave much clearance room on either side or above the roof. Although, the 3D model of the frame has some lot constraints and some dimensions are not accurate with the real frame, which need to be fixed in order to make simulations of the solar car. But to fix the frame modeling is difficult since it has to be fixed in each member truss, so it would be better to create a new 3d model of the frame.

Sample Calculations

Some of the sample calculation is the damping ratio for the wheels. Since the solar car that being built should attain an average speed of at least 15 mph over 10 miles during the entire competition [5].

The spring rate at the wheel:

$$Wheel\ Ratio = K_w = K_s = MR^2$$

$$K_w = wheel\ rate\ (N/m)$$

$$K_s = spring\ rate\ (N/m)$$

$$MR^2 = motion\ ratio\ (unitless)$$

According tire manufacturing specifications, 110mm is the tread width, 80mm aspect ratio and R17 in diameter of the rim. The aspect ratio helps to determine the overall tire diameter, and it is calculated as shown below.

- Multiply the tire width by the aspect ratio:

$$110 \times 0.80 = 88mm$$

- This value is converted from millimeters to inches:

$$88mm \times \frac{1\ inch}{25.4\ mm} = 3.46457\ in.$$

- Double the aspect height:

$$3.46457 \times 2 = 6.92913\ in.$$

- Add inside diameter of tire (rim wheel diameter):

$$6.92913 + 17 = 23.9291\ in.$$

Relevant Financial Data

In Spring 2018, the senior design budget for the solar car project was approximately $2000. Out of this, $1,796.23 was used to purchase front suspension parts and front hubs the specialized online store called BikeBandit. Purchase taxes were waived for BikeBandit [6], because the store was one of the trusted partners of Purdue University Northwest. Additional expenditures used for buying struts from another store called Dennis Kirk totaled $200. Some funds from the student organization American Society of Mechanical Engineers (ASME) was used to buy other necessary parts for the disc brake system. Cost for the entire rear suspension system was estimated to be the same as for the entire front suspension. As for the entire braking system, purchase cost was calculated as less than $1,900. The table 4 below sums up total costs for the Spring 2018 term solar car project:

Table 1. Summary of Part Costs for Spring 2018.

Total cost for the entire front suspension system	**$1,796.23**
Total cost for the entire rear suspension system and the entire braking system	**$3,693.23**

In Fall 2018, more funds became available to continue the solar car project. However, only less than $1,000 was spent to purchase new parts. For suspension, a missing upper control arm, screws, bolts and nuts were ordered. For powertrain, new hubs, constant velocity axles, wheel hub-to-brake rotor bolts were purchased on personal funds that would be reimbursed.

Outcomes

The final outcome of the senior design team was completely 3D modeled and assembled powertrain and suspension systems on SolidWorks®. Suspension parts purchased in Spring 2018 were assembled for the front wheels and suspension attached to the frame. The suspension allowed the vehicle to stand symmetrically above ground leveled to the wheels for easier movability of the car. All powertrain components were found and purchased in Fall 2018, successfully passed tests for physical fit and compatibility, and are ready to be assembled and physically built by next senior design teams.

Conclusions

In conclusion, the objective was to build the mechanical systems of the alternative energy vehicle, powered by solar panels to meet the appropriate standards and requirements of the Shell Eco-Marathon, urban concept competition. The progress on this broad project of building the solar car is significant. The wheel, suspension, and powertrain components were purchased and assembled, as well as a 3-Dimensional design of the parts fitted onto the car by using software modeling tool SolidWorks®. A new design space for better working environment was created in addition to the purchase of power tools to help assemble all the systems. All tasks were completed, except delays were caused due to the dimensional constraint for the competition requirements and the already design area to work with for each specific system.

Recommendations

For future senior design teams, the best advice would be to get familiar with previous work done for powertrain and suspension. Each component from those systems need to be learned in the design studio and compared with existing 3D models. It is useful to research on the internet about function of each component to understand their importance. First potential next step for future senior design teams would be physically building powertrain and rear suspension systems from existing and ready-to-be-assembled physical parts. Learning about different materials and their engineering properties are useful for doing any design work associated with chassis. Carbon fiber is commonly used as body cover. Custom injection molding is another option. However, placing a solar panel needs to be planned first. For building steering, it is recommended to re-model the old steering system on CAD software first, and find parts that will attach to existing rack and pinion assembly. For braking system, some background from HVAC can be helpful in planning and building brake piping. In addition, a single compatible brake pedal needs to be purchased and installed.

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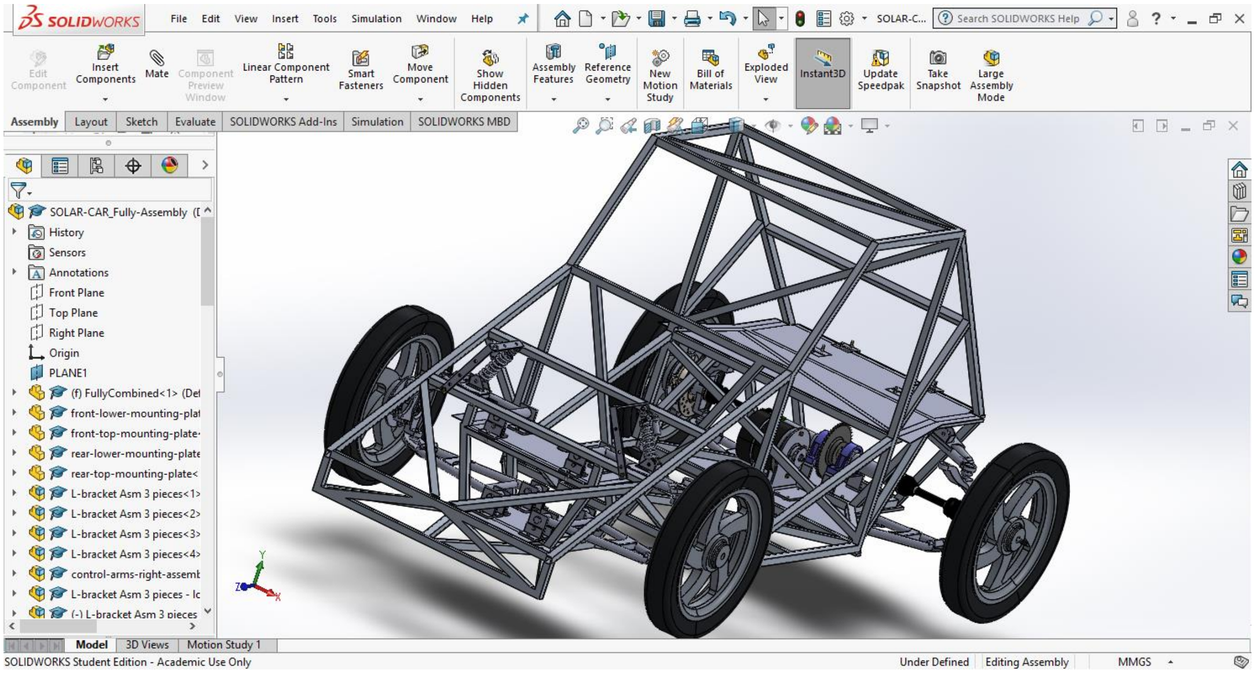
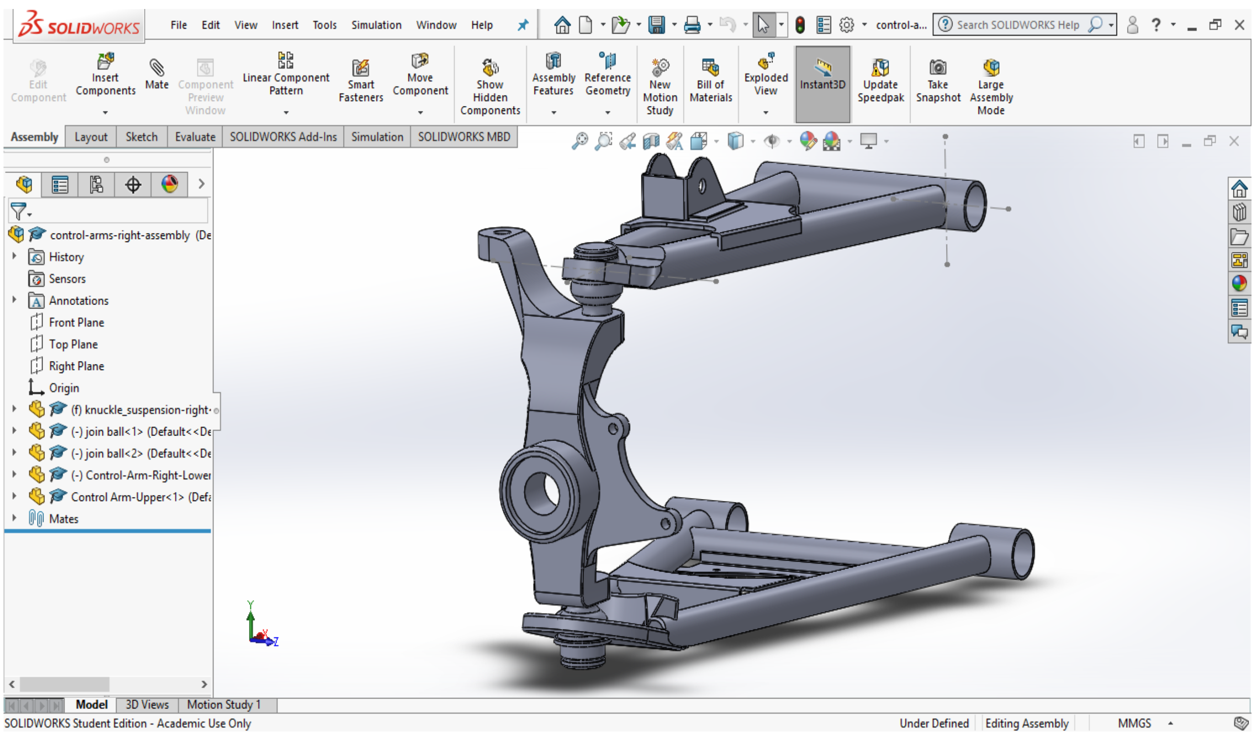
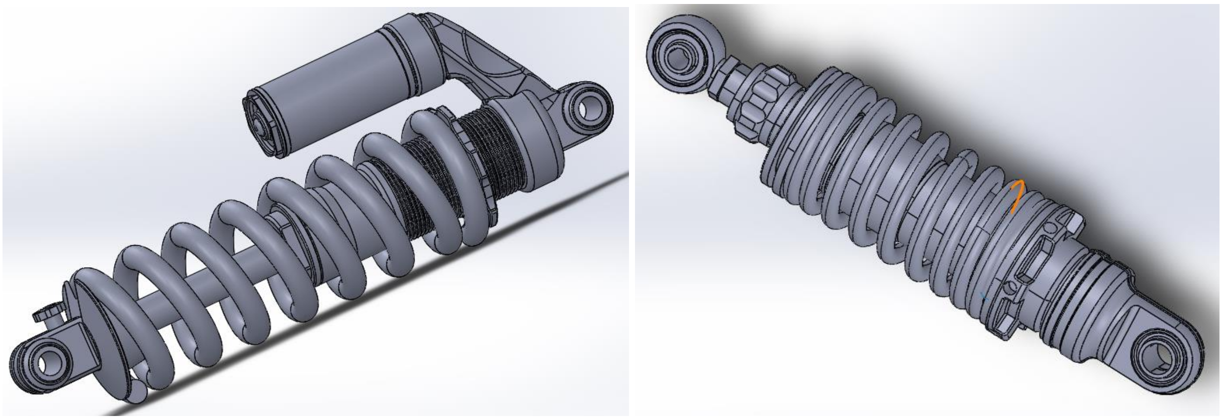
Appendix A: Design of Solar Car



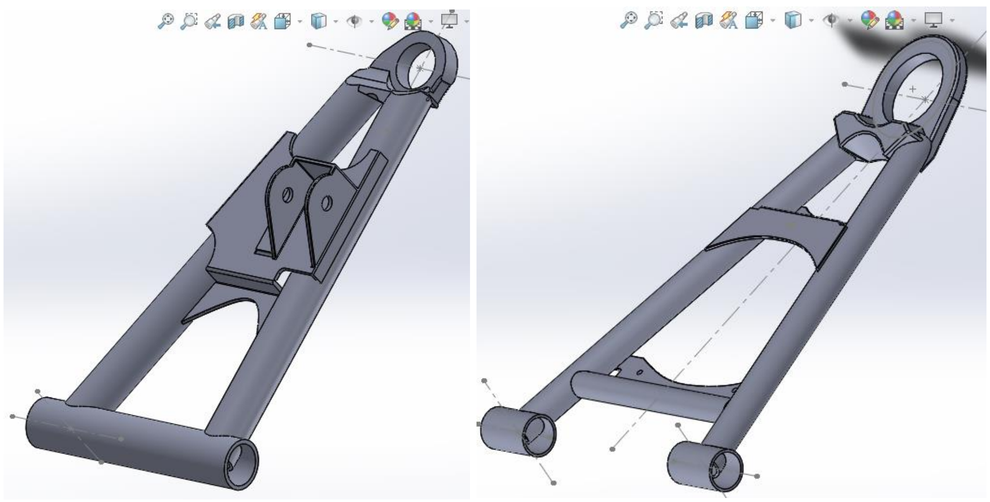
Solar Car Assembly



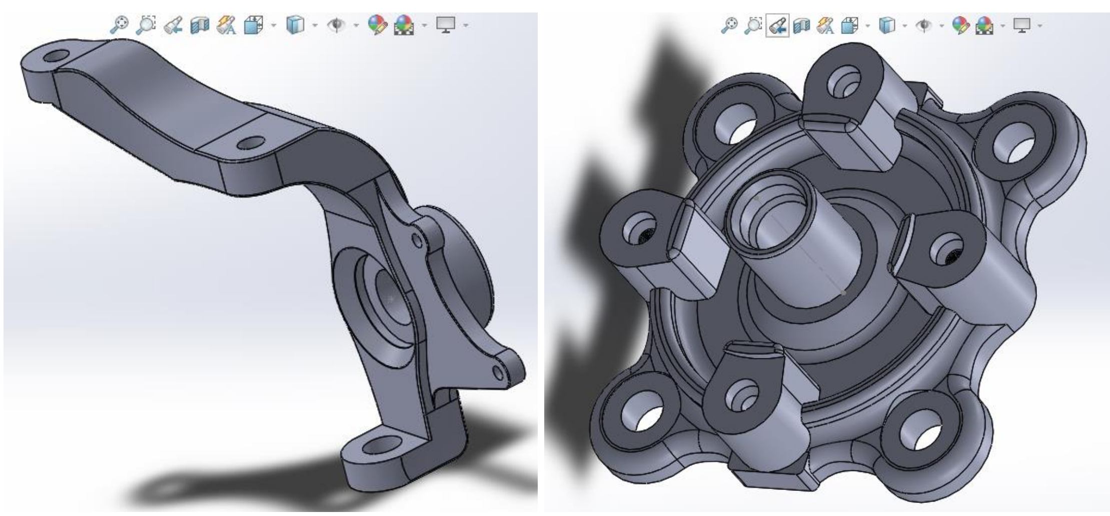
Right Front Suspension Assembly



Shock Absorbers

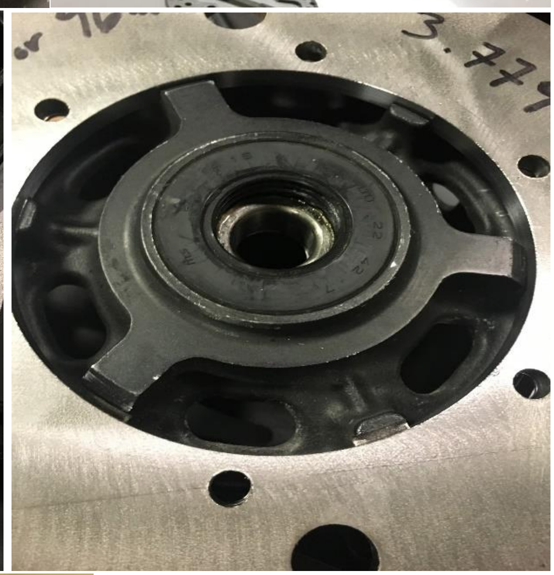


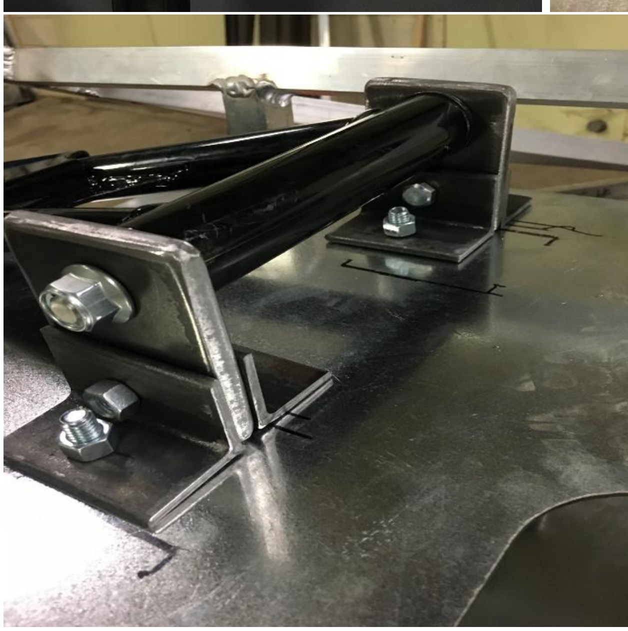
Control Arms



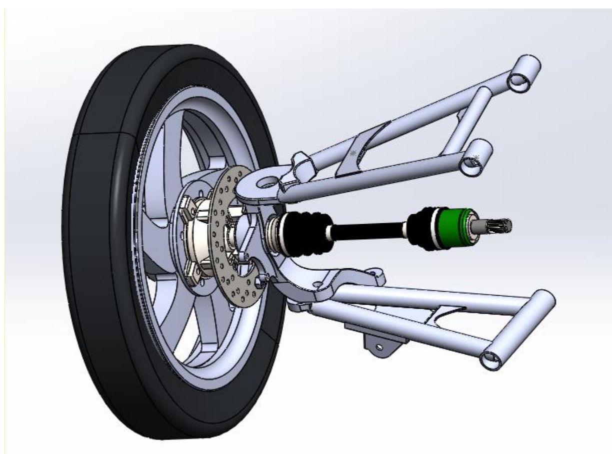
Knuckle and Front-Hub


3.74 in or 96 mm Dia Cut

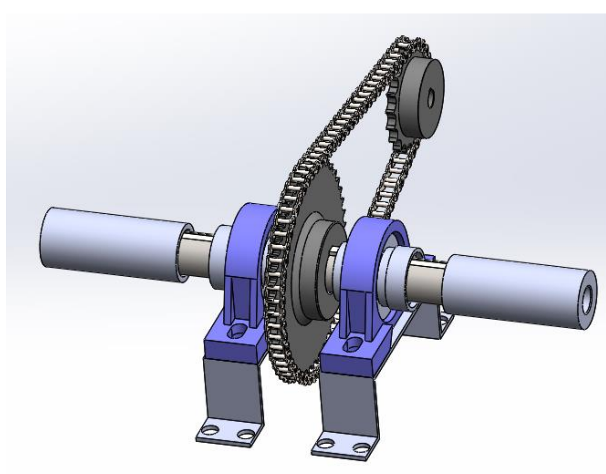




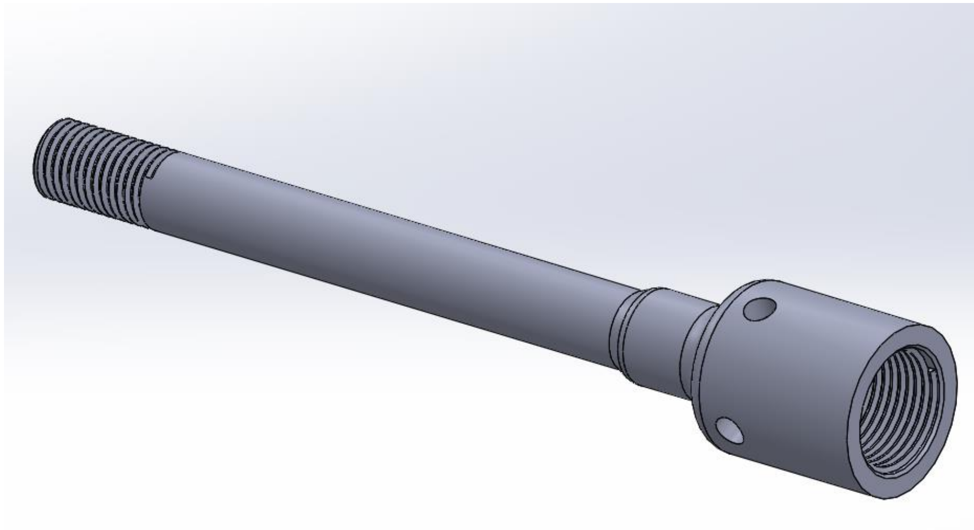
Manufactured Components



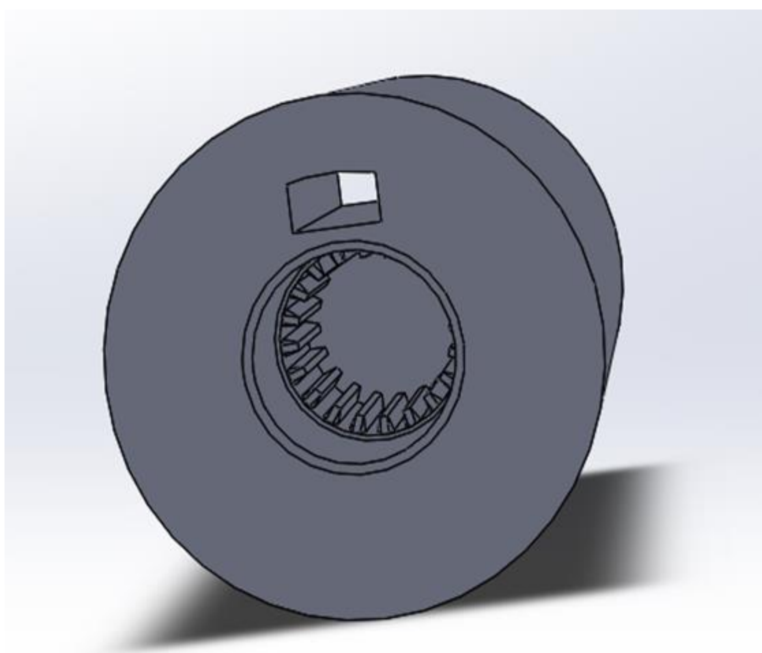
Wheel Sub-Assembly



Drive Shaft Sub-Assembly



Wheel-to-Constant Velocity Connection



Constant Velocity Axle-to-Drive Shaft Connection

Appendix B: Parts Purchased

Front Hubs	Part Detail	Part Number	Vendor	Quantity	Cost
1	PIN-COTTER,4.0X30	2529432	BikeBandit	2	$3.70
2	CAP,WHEEL	752527	BikeBandit	2	$7.90
3	HUB,FR	2403068	BikeBandit	2	$205.90
4	BOLT,12MM	2404430	BikeBandit	8	$39.60
5	WASHER,18.5X52X4.5	2404833	BikeBandit	2	$13.84
6	NUT,FLANGED,18MM	880351	BikeBandit	2	$15.90
Subtotal					**$286.84**

Front Suspension	Part Name	Part Number	Vendor	Quantity	Cost
1	BOLT-FLANGED-SMALL,6X	1792927	BikeBandit	6	$9.00
2	PIN-COTTER,3.0X25	2529426	BikeBandit	4	$3.96
3	"0" RING,18MM	851791	BikeBandit	12	$11.88
4	CAP	2267681	BikeBandit	12	$35.40
5	ARM-SUSP,FR,LWR,LH	2715905	BikeBandit	1	$53.95
6	ARM-SUSP,FR,LWR,RH	2715906	BikeBandit	1	$53.95
7	ARM-SUSP,FR,UPP,LH	3081130	BikeBandit	1	$53.95
8	ARM-SUSP,FR,UPP,RH	3081131	BikeBandit	1	$53.95
9	KNUCKLE,FR,LH	2528748	BikeBandit	1	$114.95
10	KNUCKLE,FR,RH	2528749	BikeBandit	1	$114.95
11	SLEEVE	2402763	BikeBandit	2	$59.90
12	SLEEVE	2402764	BikeBandit	4	$63.80
13	GUARD,FR,LH	2354272	BikeBandit	1	$23.95
14	GUARD,FR,RH	2354273	BikeBandit	1	$23.95
15	JOINT-BALL	1566794	BikeBandit	4	$187.80
16	NUT,LOCK,FLANGED,12MM	858022	BikeBandit	6	$35.70
17	WASHER,7X16X1.2	858688	BikeBandit	6	$17.70
18	WASHER	858987	BikeBandit	4	$15.80
19	RING-SNAP,C-TYPE,32MM	861880	BikeBandit	4	$15.80
20	RING-SNAP	861887	BikeBandit	2	$13.90

21	BEARING-BALL,30X55X32	3308900	BikeBandit	2	$49.90
22	BUSHING	2404306	BikeBandit	12	$59.40
23	BOLT,FLANGED,12X76.5	2404399	BikeBandit	4	$19.80
24	BOLT,FLANGED,12X213	2404451	BikeBandit	2	$27.90
25	NUT,CASTLE,12MM	1793632	BikeBandit	4	$11.40
Subtotal					**$1,132.64**

Front Struts	Part Detail	Part Number	Vendor	Quantity	Cost
1	Drag Specialties 13 in.	585536	Dennis Kirk	1	$269.95
	Black Ride-Height – Adjustable Shocks				
2	10" ATV Scooter Shock	SSJZ368	Dennis Kirk	2	$106.80
	Absorber Suspension – White Red				
Subtotal					**$376.75**