Stony Brook University

STONY BROOK SOLAR BOAT TEAM

Boat #4

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EXECUTIVE SUMMARY

The goals of this year's Stony Brook Solar Boat Team are to improve upon its performance at the IEEE Power Electronics Society's Solar Splash 2014 and compete against other teams at the event. The team was subcategorized into three groups (1) Electrical Engineering (EE), (2) Mechanical Engineering (ME), and (3) Composites (CP). This year, the team decided to once again use the hull from previous years which is manufactured out of carbon fiber. The dry weight of the hull is 30 lbs., making it the lightest hull in the history of Stony Brook Solar Boat Team.

The EE group was in charge of electrical aspects of this board. This covered a broad area of skill sets as it involved power distribution from our solar panels to other subsystems as well as embedded system design. This year, the electrical team focused on implementing a DAQ system that displays feedback data values from a tachometer and the motor controller to an LCD screen. Additionally, two motor controllers were utilized this year (as opposed to one in 2013) to increase the current input to the motors. The reason in doing so was to compensate for the increase in the gear ratio in the drivetrain.

The ME group overlooked the mechanical aspects of the boat, consisting of the drive train, propeller selection, coupling of motors, steering system, and boat assembly. Based on the success of the previous year's performance, the Arneson surface piercing drivetrain design was once again used, only with a shorter propeller shaft. This design change was chosen to reduce weight, drag, and improve handling. As mentioned before, a set of gear ratios (1:1 and 1:1.5) are introduced in the drivetrain assembly. Failures from last year's performance were taken into design considerations and implemented in this year's drivetrain.

The CP group was in charge of designing and manufacturing two 1:4 scale models of new hull designs that will potentially be used in upcoming Solar Splash events. This required the group to first produce a plug, then a fiber glass mold, and finally the finished carbon fiber hull that would be used for testing. Testing was held at Davidson Laboratory located at Stevens Institute of Technology in New Jersey. There, a 300 foot towing tank was utilized to test the scale models for drag, trim, and the ability to plane at various speeds. This project gave new members to learn and acquire carbon fiber tooling skills necessary for building next year's hull.

Contents

CURRENT DESIGN (2012-13)

Hull

In 2013, the team used the same hull that was built in 2012. This hull was designed to have a displacing deep V profile and was fabricated completely from carbon fiber, with reinforcements of honeycomb foam and plywood. This resulted in a strong yet light hull, resistant to exterior damage. The hull is 12 feet (ft) long and 3 feet (ft) wide and its dry weight is 30 pounds (lbs). These factors contributed towards the boat's enhanced performance in the endurance and the slalom races, where sharp turns were a necessity.

Figure 1: 2012-2013 Hull

Solar Array

The solar panels utilized in 2013 included a set of two Kyocera KC50T modules and a Sharp ND-208U2 module. Each of these modules were connected in series and produced a total of 316 Watts (W). A Tri-Star Maximum Power Point Tracking Solar Controller was utilized to efficiently recharge the battery bank in the boat. The system voltage range on the solar controller varied from 12 to 48 volts (V) allowing for multi-configuration battery charging.

Drivetrain

In 2013, the drivetrain design was based on the idea very similar to Arneson surface drive system that is used on many race boats. This design appealed to the team since it was relatively simple and could be kept very light with the rotational inertia as well as be very strong to handle large amount of torque produced by motors. The main components that allowed for implementing such a design were a Constant Velocity (CV) joint and two Lynch Permanent Magnet (PM) DC brushed motors. A chain drive with a gear ratio of 1:1 was utilized for transmitting the torque from the motors to another shaft (lower shaft), which was coupled to the CV joint through a driveshaft with two universal joints (U-joints) at each end. The U-joints compensated for the misalignment of the collinearly of the lower shaft and the CV joint.

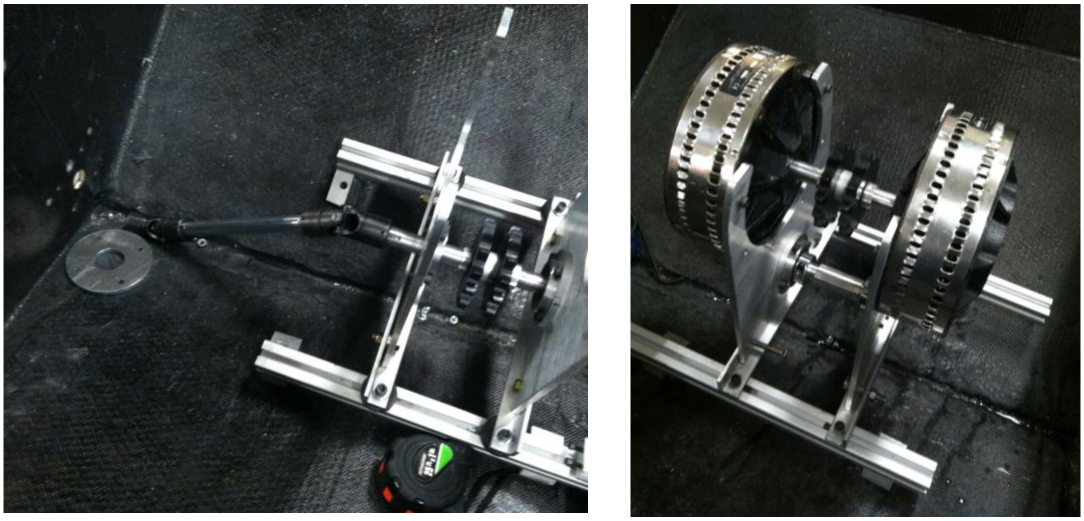

Figure 2: Motor and driveshaft assembly

Propeller

A two-blade custom-made stainless steel solar boat propeller was used by the team to focus mainly on the endurance heat of the competition.

Steering System

The steering system of the 2012-13 boat based on a gimbal housing that allowed for two degrees of freedom of the propeller shaft of the drivetrain, allowing for the movement of the propeller while driving. For controlling the steering, a hydraulic piston cylinder was utilized which was controlled by the user through a steering wheel. As the steering wheel would be turned left/right, a hydraulic reservoir would push/pull the hydraulic fluid resulting in pushing/pulling of the stroke connecting rod of the piston cylinder. This movement of the connecting rod governed the turning of the propeller shaft, pivoting at the gimbal assembly.

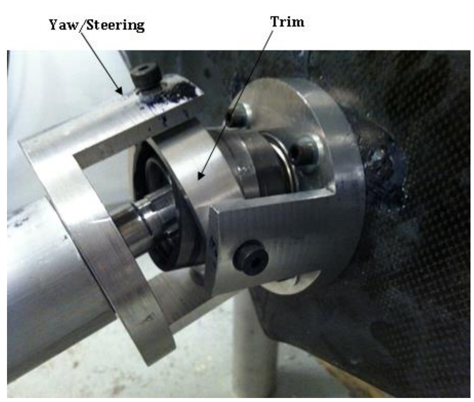

Figure 3: Gimbal Housing Assembly

Electronic Control System

The electronic control system consisted of a Curtis 1205 DC motor control system. The motor controller was capable of switching 400 Amperes (A) of current at a voltage range from 24 V to 36 V DC. A 5 kilo-Ohm (kΩ) potentiometer was used for controlling the signal being sent to the motor controller for drawing the appropriate amount of current from the battery bank to power the motors.

Batteries

In 2012-13, D1200 AGM deep cycle batteries from XS power were used for the competition. Each battery weighed 33.26 pounds (lb) and had a capacity of 44 Ampere hours (A-Hr), with the maximum current being 2600 A. The sprint configuration consisted of three such batteries in series, making a system voltage of 36 V and the endurance configuration made use of two such batteries, making the system voltage to 24 V. The self-consumption current and voltage ratings were 20 mA and 9 V, respectively, allowing for a low theoretical power loss from the solar panels of 0.18 W.

Problems with the Design

In the year of 2012-13, the Solar Boat Team performed relatively well compared to the past few years, attributing to the new drivetrain design. However, even after a radical redesign, the team observed some flaws that needed upgrades. The main encountered problems were:

- Modification of the CV cup of the CV joint proved to be disastrous as machining the case hardening diminished the material's strength. As a result, the cup would heat up undergoing high RPMs in the multiple heats at the competition.
- A two-part epoxy was used to attach the trim rod mount on the propeller shaft housing tube. Unreliability of the epoxy against weathering (water) resulted in the failure of the trim mount from the housing tube, detaching the trim rod from the drivetrain.
- The low current capacity of the motor controller also played a key role in the boat's low maximum speed. The motor controller could only extract 400 A from the batteries, resulting in a reduced performance of the propeller.

DESIGN CONCEPTS

HULL

The objective of this year's hull/composites team was to design a new hull for next year's competition (2015) and learn tooling techniques for making carbon fiber parts. This year's hull is the same as the previous year. The hull developed by the 2011-12 team was fabricated completely from carbon fiber, with reinforcements of honeycomb foam and plywood. The hull has a 3 core 3 cross section, or 3 carbon fiber layers, a honeycomb core, and then 3 more carbon fiber layers on the other side. The deep V shape provides more stability to the boat and enhances its performance in carved turns. The intent in designing this hull was to increase its performance in the endurance heat at the competition. However during the past two competitions, the hull was an inappropriate application to sprint heats because of its large wetter surface area. This resulted in the production of enhanced drag, reducing the boat's speed. Due to the V shape, the wake of the boat also was intermixed with the effects of propeller backwash, contributing to the reduction of the maximum boat speed. Using the carbon fiber techniques learned from making the hull models.

Since it takes time and effort to design and build a carbon fiber monocoque hull, the team collectively decided to spend this year's efforts in designing, evaluating and testing of prototype hulls. Research began last summer in July 2013 after the solar splash competition for redesigning a new hull. The first step involved researching what types of hull are most suitable for an electric boat running on two batteries with speed and maneuverability. Factors that contributed towards the designing of the hull were the weight of the boat, the maximum speed necessary to achieve planing, and stability. With the current solar and electrical system design, the boat is estimated to achieve a top speed of about 20 miles per hour (mph), which is well below any top safety speed for planing hulls. At the same time, 20 miles per hour is not very fast, so planing under 20 mph was another design consideration. A Computer Aided Designing and Engineering (CAD/CAE) software was utilized to build computer models of different hulls. The same software was utilized to run flow simulations to analyze water streamlines around the hulls and determine drag and lift. After running tests on several models, we chose the best two models based on the least drag and largest lift.

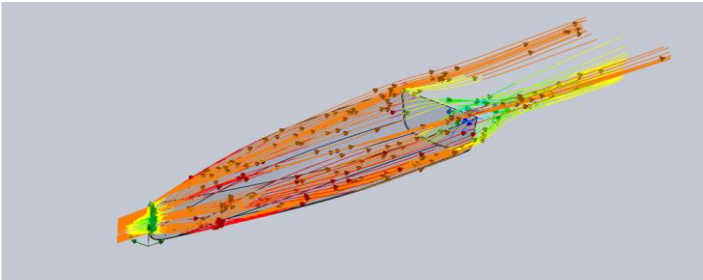

Figure 4: Solidworks CFD Simulation flow lines on one of the prototype hulls

MECHANICAL SYSTEMS

Drivetrain

This year’s drivetrain design concept incorporates implementing a dual gear ratio of 1:1 and 1:1.5 in the surface piercing drivetrain from last year. The main purpose in doing so is to account for both aspects of the competition, i.e., endurance and sprint, respectively. Another major feature that is different from last year is the length of the propeller shaft. Compared to last year’s propeller shaft, this year’s design allows the propeller to sit closer to the hull, minimizing loss of energy along the length of the shaft. The advantage of using a chain drive and gear ratios is that it is simple to implement and allows an easy change of gears just by changing the chain from one set of gears to the other. The surface piercing drive train possesses some of design aspects of inboard and outboard drive trains. The key aspect of this design is that half of the propeller is underwater so there is minimum drag from the propeller. A 15% to 30% increase in speed over other systems, low maintenance, and ability to adjust propeller submergence while underway are some of the pros of this design. The system's ability to make tight turns along with efficient speed will definitely give Stony Brook Solar Boat Team an edge.

Steering System

This year the team opted for a similar design as last year’s which incorporates a hydraulic fluid reservoir transmitting motion through a piston cylinder. Last year’s piston cylinder stroke was 12 inches long that slowed down the steering turning on the wheel. This year, a cylinder with a shorter stoke (3 inches) will be utilized which will allow for a more sensitive steering turning. The concept of this steering system is based on the method of controlling a steering design using a hydraulic piston being actuated via manual pressurization of hydraulic lines. The major advantage of using this design is that it does not require power and is a relatively simple system to build and maintain.

ELECTRICAL SYSTEMS

Motor Controllers

This year’s motor configuration set up is something that the team has been striving to achieve over the past few years, however, the monetary funds has prohibited us to do so. This year, we purchased two new Alltrax motor controllers that each draw continuous 400 A. When put in parallel configuration, the controllers can draw a total of 800 A continuous, however, that is very ambitious to achieve at the current battery limitations. Also as a precautionary measure, we will limit ourselves in not extracting a total of 800 A in a setting as that will drain the batteries faster. We currently use Lynch Permanent Magnet DC brushed motors that appropriately fit this setup easily.

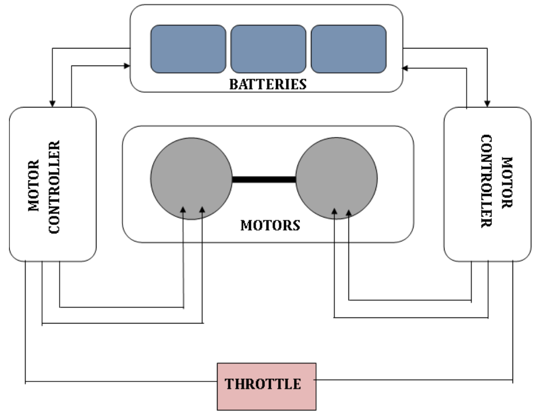

Figure 5: Wiring Diagram for the Motor Controller Configuration

Designing of motor controller is still a big field of research and also a big learning field for undergraduate electrical engineering students. Over the years, the team has been working on prototyping a motor controller but hasn't successfully tested it yet.

Sensors and DAQ

We have been lacking DAQ systems in our boat for the last few competitions, so this year we decided to design a few sensor-feedback systems for the other systems on the boat. An infrared sensor based tachometer has been designed using an Arduino-Uno based microcontroller that will keep record of the RPMs of the motors.

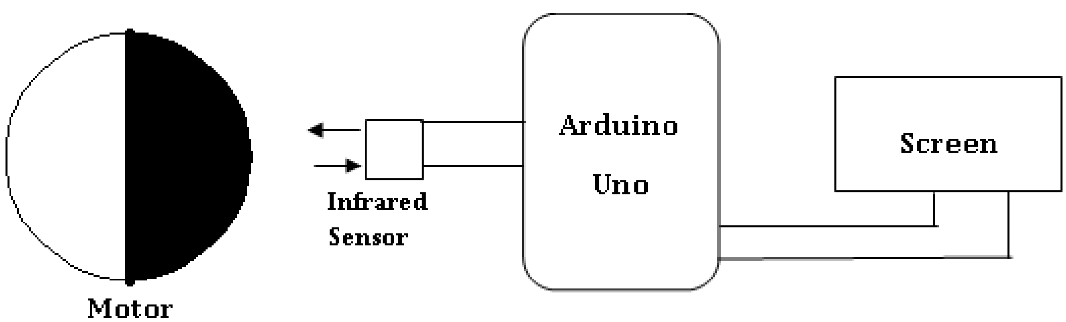

Figure 6: Wiring Diagram for the Tachometer

Other feedback sensor based outputs from the motor controller can be extracted through a Serial COM port in the motor controller through an Arduino and the data can be printed on an LCD screen.

Solar Panels

Three commercial solar panels will be connected in series which will produce a total of 316 W. A Tri-Star Maximum Power Point Tracking Solar Controller will be utilized to efficiently recharge the battery bank in the boat. The system voltage range on the solar controller varied from 12 to 48 volts (V) allowing for multi-configuration battery charging.

DESIGN DESCRIPTION

HULL

The processes involved with building 1/4th scale hull models out of carbon fiber were great learning curves for the team this year. There were several options available to build the model molds. The hull cross sections were plotted on paper and then cut on pieces of economical MDF board. This, along with the wooden dowels holding the cross sections became the skeleton of the hull. We used Styrofoam to fill the voids in between the cross sections and then sanded down the surfaces until they were smooth. A custom hot wire cutter was built that made cutting the Styrofoam easy. Intense bodywork was done until a smoother surface finish was obtained. To make the mold out of tis plug, we applied a layer of mold release and gel coat. After the gel coat hardened, two layers for fiberglass with resin were applied. When the fiberglass cured, then the mold was detached from the plug. Finally, the mold was inspected and any imperfections were sanded down or filled in. Using woven carbon fiber and the wet layout method, we laid down four layers of carbon fiber and applied epoxy. Peel ply release fabric was laid down (to prevent carbon fiber from sticking to vacuum bag) and a breather/absorber cloth was used to absorb excess resin. Finally, the entire mold was encapsulated in a vacuum bag. After curing of the epoxy, several layers of clear coat gel were applied on the carbon fiber to make it waterproof.

Figure 7: Hull Prototype Fabrication

MECHANICAL SYSTEMS

Drivetrain

This year the idea for the drivetrain was based on systems very similar to Arneson surface drive system that is used on many race boats. This system appealed to the team since the design is relatively simple and it can be kept very light with the rotational inertia as well as be very strong to handle large amount of torque produced by motors. The drivetrain was divided into two sub categories: one being the internal drivetrain which included the portion of the drivetrain located in the boat and the second group being the external drive. The internal drivetrain components use two Lynch DC permanent magnet motors coupled by a single shaft. That shaft drives a second shaft which is the link between the internal and external sections. The motor shaft that couples the two motors is a custom shaft that will couple with the motors directly into the armature. This allowed making the system much smaller as neither shaft couplers, nor bearings were needed since the motors were equipped with bearings of their own. The lower shaft sits between a set of roller bearings and all the sprockets are coupled to the shafts by splines. Since the shafts are very similar, manufacturing became easier because the same tooling could be used for both.

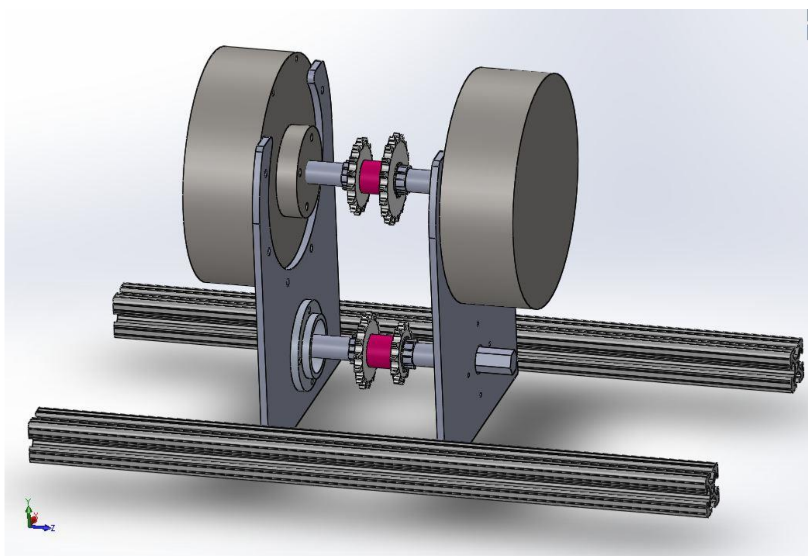

Figure 8: Internal Drivetrain Assembly

As shown in **Figure 8**, the set of sprockets have different gear ratios; a 1:1 for the endurance configuration and a 1:1.5 for the sprint configuration.

For the external section, the design comprised of a surface drive system. With a small and light hull, a surface drive system will allow the boat to reach higher speeds. The one aspect of the surface drive that appealed to the team was its advantage over inboard drive systems. The surface drive is oriented in line with the direction of movement as well as the thrust, unlike an inboard drive system which is typically at an angle with the line of motion, wasting the thrust by pushing up on the boat.

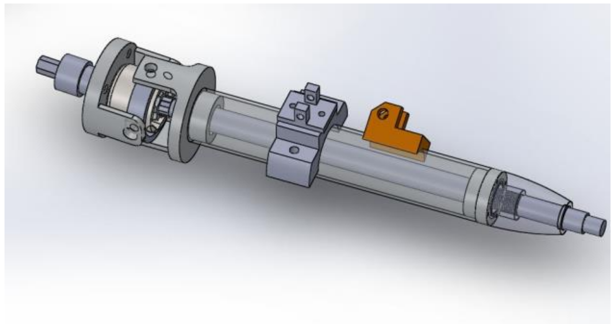

Figure 9: External Drivetrain Assembly

The lower shaft on the internal drive system connects to the CV joint which then goes to the propeller shaft. The superiority of a CV joint over a double u-joint comes from the fact that it provides higher angle tolerance at higher speeds with a significant reduction in size. This allows for the housing to be much smaller and lighter. The CV joint is assembled in a gimbal assembly with two degrees of freedom. This allows for both the trim and steering of the propeller shaft. Tapered roller bearings are used in both the yoke as well as the end cap which provide support for the shaft. The propeller is placed at the end of the shaft.

Another design aspect that was drastically improved this year included the introduction of splines couplers to utilize the splines on the CV joint. This will help in attaining secured coupling of the mechanical parts. As shown in **Figure 10**, the transparent parts with internal and external splines.

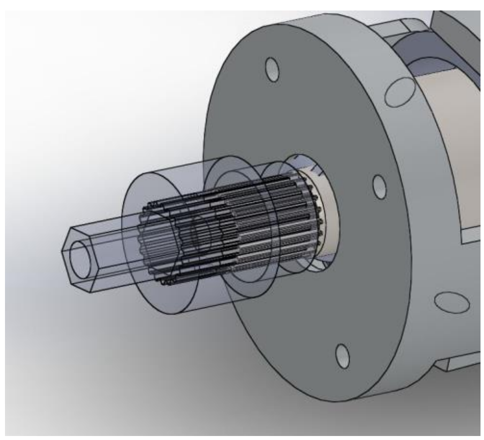

Figure 10: Splined couplers

Steering System

The steering system utilized designing of various customized mounts for the hull and the drivetrain housing tube. The mounting of the hydraulic piston cylinder includes rod ends connecting the piston to the mounts on the hull and the housing tube. For the trim angle adjustment, a trim rod with ends connecting two rod ends, each mounted on the hull and the housing tube is utilized. The threads on each end of the trim rod allow for the change in the trim angle that can be adjusted manually.

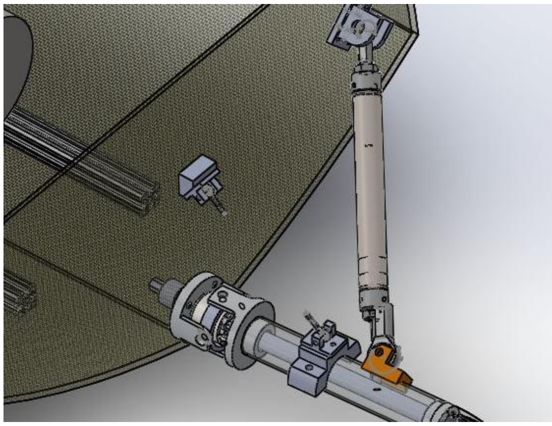

Figure 11: Steering Assembly

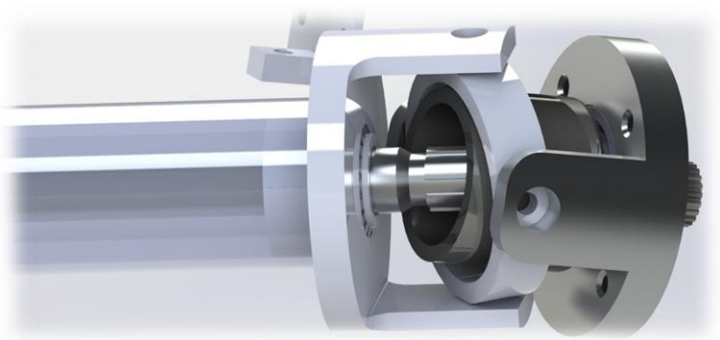

Figure 12: Three Piece Gimbal Assembly

DESIGN EVALUATION

HULL

We ran several tests on two carbon fiber 1/4th models at the 300 feet long towing tank at Stevens Institute under the generosity of the Davidson Laboratory. We ran tests at simulated scales of 5, 7.5, 10, 12.5, 15, 17.5, 20, and 22.5 miles per hour (mph) on both of our hulls. From this test, we gathered useful data in drag, trim, and heave. Additionally, the lab operators provided some additional tips when building our actual hull including building sharper chines and edge, correcting the center of gravity 35-40% back so the hull doesn't hit max trim too early. From the tests, the first model hull was seen to hit the maximum trim (when the hull starts to plane) at 10-15 mph at 14 degrees while the second model hull hit the maximum trim at 10 degrees at the same speed range. Since both hulls exhibited similar drag coefficients of 2.0, the first hull design will be used for building the full scale hull (**Figure 13**).

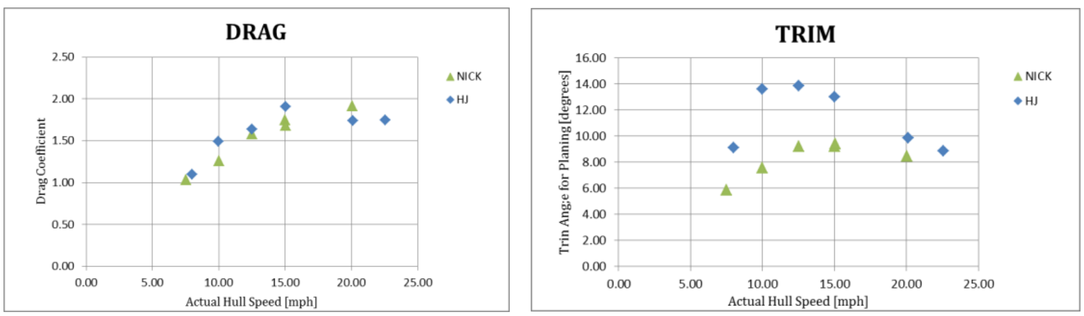

Figure 13: Plots comparing the Drag Coefficients and Trim Angles for planing of two different hulls

MECHANICAL SYSTEMS

Drivetrain

Once the drive shafts were modeled, a Finite Element Analysis (FEA) was done to make sure failure would not occur. The propeller shaft being the thinnest of the drive shafts had the most spots for stress concentration for failure to occur. The material of the shaft was 7075-T6 tempered aluminum. This material was chosen due to its light weight and high strength. This is also very easy to machine and very economical to use. For the fixture constraints, two bearing supports, located where the tapered roller bearing were located, were used. One face of each spline was also used as a fixed constrain which simulated the reaction force from the star of the CV joint due to the torque applied from the motors. Since at maximum continuous amperage, which is 400 A for each motor, the rated torque is 35 ft lbs, therefore, two motors produce70 ft-lbs of torque, which was used as the load for this simulation. A static test was used since it produces the greatest torque by the motor. From the simulation, it was calculated that the maximum stress was 331 ksi which led to a minimum factor of safety of 1.53. This was expected to be the area with lowest FOS.

Therefore, in the simulation, a finer mesh was applied to allow for more accurate results, which resulted in longer run times for the simulations.

Figure 14: Machined splines on the Propeller Shaft

The motor shaft was another area of concern due to the interface between the armatures and the shafts. Also, this shaft had a smaller diameter section among the other shafts. For this simulation, the bearing fixtures were placed according to the model. The end that sits in the armature was held as a fixed point. The torque from the motors was applied to the splines which hold the sprockets. As expected, the highest stress concentration was at the base of the splines. As can be observed form the figure, red areas occur by the base of the splines. The ring towards the outside is non-existent and only shows due to the bearing support constraints for the simulations. The highest value of stress that was found was calculated to be 99 ksi. It was much lower than the propeller shaft, due to the diameter at the spline being larger, even when the diameter at the armature is smaller than any section at the propeller shaft.

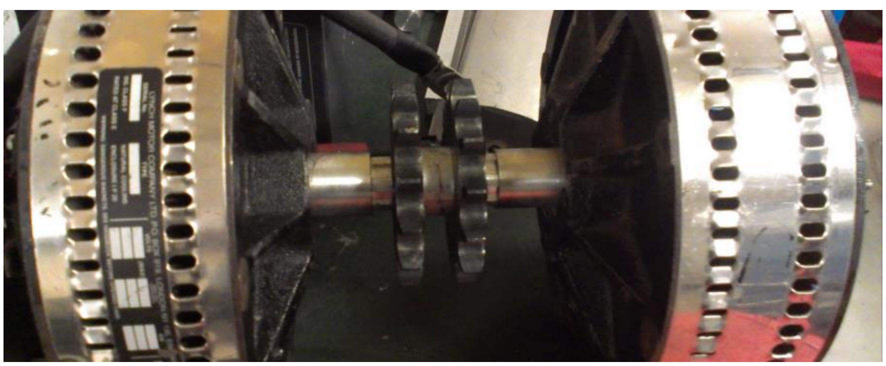

Figure 15: Motor Shaft Assembly

Another major part that was thought to be more prone to failure is the spline coupler, connecting the CV joint to the U joint on the driveshaft through splines (**Figure 16**). Initially the part was designed to be manufactured out of 6061 Aluminum stock. However, FEA showed a maximum displacement of 0.0635408 mm on the splines. To be precautionary, reconsideration of the selected material was thought and 4140 Machinable Steel was selected to fabricated this part. Since cutting splines can only be done by either broaching or through a Wire-EDM process, it was decided to fabricate the splines using the Wire-EDM for more accuracy.

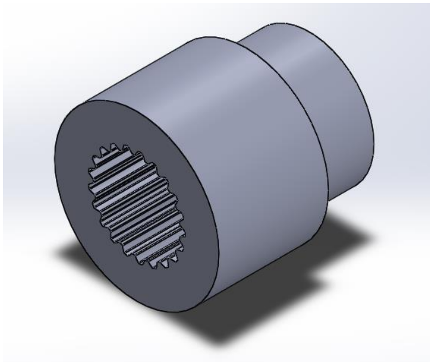

Figure 16: Spline Coupler

Steering System

Compared to last year's setup, this year's steering system is mechanically more secured and is less likely to fail during different heats at the competition. The trim rod mount, that is more prone to fail, is reinforced with strong mechanical U bolts which couples it to the drivetrain housing tube, as shown in **Figure 17.**

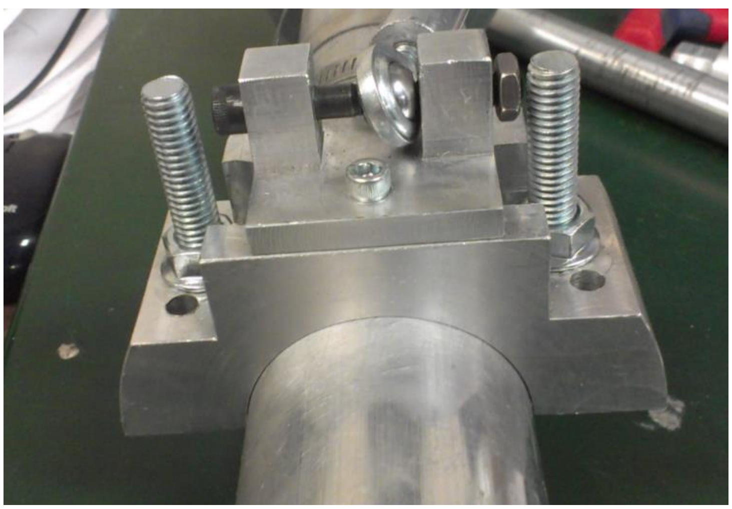

Figure 17: Trim Rod Mount

ELECTRICAL SYSTEMS

Motor Controllers

Testing of the motor controller has produced successful results that will help the team achieve high performance during competition. With the addition of a higher gear ratio and the amount of current being extracted from the batteries, the propeller will be able to run at higher RPMs without slipping. This will help the boat move at a faster speed which yet to be documented.

Sensors and DAQ

The sensor and DAQ systems that are being introduced this year will help us monitor multiple facets of the electrical systems on the boat which will certainly help during the endurance races.

Solar Panels

Our team has been trying new techniques each year to custom fabricate solar panels. The biggest challenge has been lamination of solar cells. This year, the team tries to laminate solar cells by sandwiching the cells in between two layers of EVA. Vacuum and heat are required to cure the EVA sheets; however, our attempt in doing so resulted in cracking of the cells. We are currently in the process of researching the best method to laminate cells and hope to find a solution soon.

TESTING PROCEDURES AND RESULTS

Testing of each individual sub system has been done but because of the time constraints very little testing of the entire vehicle has been done. The electrical systems have been tested on the bench and the mechanical systems have been tested in the previous year's boat. Systems perform as expected but we will still need a bit of calibration before competition.

Discussion

The team this year set to tackle many of our previous year's problems, mainly power consumption. Everything about this boat has been re-evaluated from the ground up. The biggest achievement is in the way we design and build our hulls. We have documented a process we hope to continue into the future as well as relationships with local companies that will benefit our club immensely. We have really come a long way in terms of the way we design, build and fabricate things since we started and we hope that this boat improves the team's performance at the competition. We've learned a lot and hope to continue learning as we compete each year in the Solar Splash competition.

PROJECT MANAGEMENT

Team Member Organization and Responsibilities

In preparation of the 2014 Solar Splash Competition, Solar Boat Team decided to divide each of the design projects to one individual. This person is considered the project leader and is responsible for designing and manufacturing the design project. In addition, he is to create a timetable of the project and keep to the agenda. Naturally, project leaders would ask members to assist them in completing the project by handing the members a task. Members were also encouraged to come to the Solar Boat Team shop and lend a hand whenever they were available.

Project Planning and Schedule

The design process for the 2014 boat started after the 2013 competition. Weekly general body meetings, Executive board meeting and workdays have been held since September 2013 to finish the project in time. Design projects also started taking form within the month. Upon completion of the system designs, manufacturing began in the Fall semester as soon as stock material was ordered through the generous sponsors and donors at Stony Brook University and outside.

Financial and Fund Raising

For fund raising, this year's Executive board decided to compile a sponsorship package for departments on campus at Stony Brook University and the local industries around the campus. Financial aid for this year's competition was provided by the Mechanical Engineering Department, the College of Engineering and Applied Sciences (CEAS), and the Office of Vice President of Research at Stony Brook University. Solar Boat Team also received carbon fiber donation from Hexcel Corporation and indirect assistance from Nordan Composite Technologies.

Strategy for Team Continuity and Sustainability

Currently, the team comprises of a couple of individuals from Mechanical and Electrical Engineering backgrounds. In order to expand the club, the team is always encouraging students to join. This is done by word of mouth, spreading what the club has to offer through friends, professors, and engineering departments. In addition, Solar Boat Team attends numerous on-campus and off-campus events. Participating in events allows the team to showcase their work. Aside from the size of the club, the team is doing fairly well. Though the team is limited to the few resources available in the team shop, the team can always use the resources provided by the student shop. With permission, the team also has access to some of the professors' resources. In addition, the team is always looking for local companies who can donate some of their resources for the teams cause.

CONCLUSION

This year's Stony Brook Solar Boat Team has accomplished most of the goals that were set for this year's competition. There were some failure attempts on certain systems that the team wanted to implement on this year's boat, however, each step we take has become a successful learning curve. The team has made great strides this year in fabrication and design philosophies. The Stony Brook Solar Boat team in its current state is has learned a great deal towards building a better boat. The team's biggest limitation always has been aid from the university and corporations. Being a fledgling club, we do not have access to many of the sophisticated tools other teams may take for granted. Despite this, our club has stride to design and fabricate some of the most advanced systems for the Solar Splash competition. By improving every year, our club gets more recognition and with that more funding.

We also have been keeping good relations with some of the United States' Solar Car teams. This has most certainly opened another door for sharing of knowledge as there is a good amount of information that we can obtain from their experiences in building a solar vehicle.

We hope that we are successful in the 2014 Solar Splash Competition and we come back knowing much more than we did going in. We also hope that by being successful we can continue to improve our team's ability to create the next best thing at competition. We would like to thank those who have supported us this year and thank members who have work hard, on top of school work, to assist us in our efforts.

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APPENDIX A: BATTERY DOCUMENTATION

D1200

MSRP $349.99

Weight Lbs. – 33.26
Weight Kgs. – 15.10

Length – 7.8 in
Height – 6.69 in
Width – 6.54 in

MAX Amps – 2600
Ah – 44

MSRP – $349.99

M6 Terminal Hardware Included

3 Year Warranty

Suggested Accessories: **i-Bar**, **545**(billet aluminum hold down), **586**("tall" SAE posts)

XS Power AGM Batteries

MATERIAL SAFETY DATA SHEET

D680, D975, D1200, D5100, D5100R, D3400, S20LBS, S19LBS, S19BS, S14LBS, S14BS, S50BS

Valve Regulated (VRLA) Batteries
Absorbed Electrolyte (AGM)

SECTION 1: PRODUCT IDENTIFICATION AND COMPANY IDENTIFICATION

Manufacturer's Name:
Key Components Inc, d/b/a XS Power
7501 Strawberry Plains Pike
Knoxville, TN 37924

The information contained within is provided as a service to our customers and is for their information only. The information and recommendations set forth herein are made in good faith and are believed to be accurate at the date compiled. XS Power makes no warranty expressed or implied.

Chemical Family/Classification
Electric Storage Battery

Date issued: March 14, 2007 (rev. 6/10/08)

Emergency Telephone
CHEMTREC Domestic: 800-424-9300
CHEMTREC International: 703-527-3887

Telephone: XS Power 865-688-5811

Web:
http://www.xspowerbatteries.com

SECTION 2: HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

COMPONENTS	Approximate % BY WEIGHT	CAS#	OSHA PEL	ACGIH TLV	NIOSH
Inorganic Lead/ Lead Compounds	65%-75%	7439-92-1	50	150	10
Tin	<0.5%	7440-31-5	2000	2000	N/A
Calcium	<0.1%	7440-70-2	N/A	N/A	N/A
Sulfuric Acid/Battery Electrolyte 1.300sg 40wt%	14-20%	7664-93-9	1000	1000	1000
Fiberglass Separator	5%	–	N/A	N/A	N/A
Case Material: Acrylonitrile Butadiene Styrene(ABS)	5-10%	9003-56-9	N/A	N/A	N/A

Inorganic lead and electrolyte (sulfuric acid) are the main components of every Valve Regulated Lead Acid battery supplied by XS Power. Other ingredients may be present dependent upon the specific battery type. For additional information contact XS Power Technical Department.

SECTION 3: PHYSICAL/CHEMICAL CHARACTERISTICS

Components	Density	Melting Points	Solubility (H_2O)	Odor	Appearance
Lead	11.34	621 F°	None	None	Silver-Gray
Lead Sulfate	6.20	1950 F°	40mg/l(60 F°)	None	White Powder
Lead Dioxide	9.40	554 F°	None	None	Brown Powder
Sulfuric Acid	About 1.30	203-240 F°	100%	Sharp penetrating pungent	Clear Colorless Liquid
Fiberglass Separator	N/A	N/A	Slight	None	White Fibrous
Case Material: Acrylonitrile Butadine Styrene (ABS)	N/A	N/A	None	None	Solid

SECTION 4: FLAMMABILITY DATA

Components	Flashpoint	Explosive Limit	Comments
Lead and Sulfuric Acid	None	None	None
Hydrogen		LEL = 4.1%	Sealed batteries can emit hydrogen if overcharged (float voltage> 2.40 VPC)
Fiberglass Separator	N/A	N/A	Toxic vapors may be released. In case of fire, wear self contained breathing apparatus
Acrylonitrile Butadine Styrene (ABS)	None	N/A	Temp over 527°F (300°C) may release combus tible gases. In case of fire, wear self contained breathing apparatus

SECTION 5: REACTIVITY DATA

Stability	Unstable		Conditions to Avoid
	Stable	x	Prolonged overcharge on high current, ignition sources. Sulfuric acid remains stable at all temperatures

Incompatibility (Materials to Avoid)

Sulfuric acid: Contact with combustibles and organic materials may cause fire and explosion. Also reacts violently with strong reducing agents, metals, sulfur trioxide gas, strong oxidizers, and water. Contact with metals may product toxic sulfur dioxide fumes and may release flammable hydrogen gas.
Lead Compounds: Avoid contact with strong acids, bases, halides, halogenates, potassium nitrate, permanganate, peroxides, nascent hydrogen, and reducing agents.

Hazardous Decomposition or Byproducts

Sulfuric acid: Sulfur trioxide, carbon monoxide, sulfuric acid mist, sulfur dioxide, and hydrogen sulfide.
Lead Compounds: High temperatures above the melting point are likely to produce toxic metal fume, vapor, or dust; contact with strong acid or base or presence of nascent hydrogen may generate highly toxic arsine gas. Hazardous Polymerization.

SECTION 5: REACTIVITY DATA (CONTINUED)

Polymerization: Sulfuric acid will not polymerize
Decomposition Products: Sulfuric Dioxide, Trioxide, Hydrogen Sulfide, Hydrogen.
Conditions to Avoid: Prohibit smoking, sparks, etc. from battery charging area. Avoid mixing acid with other chemicals.

SECTION 6: HEALTH HAZARD DATA

Routes of Entry

Sulfuric acid: Harmful by all routes of entry.
Lead compounds: Hazardous Exposure can occur only when product is heated, oxidized, or otherwise processed or damaged to create dust, vapor or fume.

Inhalation

Sulfuric Acid: Breathing sulfuric acid vapors and mists may cause severe respiratory problems.
Lead Compounds: Dust or fumes may cause irritation of upper respiratory tract or lungs.
Fiberglass Separator: Fiberglass is an irritant to the upper respiratory tract, skin and eyes. For exposure up to 10F°/ use MSA Comfoll with type H filter. Above 10F use Ultra Twin with type H filter. This product is not considered carcinogenic by NTP or OSHA.

Skin Contact

Sulfuric acid: Severe irritation, burns, cornea damage, and possible blindness.
Lead Compounds: May cause eye irritation.

Ingestion

Sulfuric acid: May cause severe irritation of the mouth, throat, esophagus, and stomach.
Lead Compounds: May cause abdominal pain, nausea, vomiting, diarrhea, and severe cramping. Acute ingestion should be treated by a physician.

Eye Contact

Sulfuric acid: Severe irritation, burns, cornea damage and possible blindness.
Lead Compounds: May cause eye irritation.

Acute Health Hazards

Sulfuric acid: Severe skin irritation, burns, damage to cornea may cause blindness, upper respiratory irritation.
Lead Compounds: May cause abdominal pain, nausea, headaches, vomiting, loss of appetite, severe cramping, muscular aches and weakness, and difficulty sleeping. The toxic effects of lead are cumulative and slow to appear. It affects the kidneys, reproductive and central nervous systems. The symptoms of lead overexposure are listed above. Exposure to lead from a battery most often occurs during lead reclamation operations through the breathing or ingestion of lead dust or fumes.

Chronic Health Hazards

Sulfuric acid: Possible scarring of the cornea, inflammation of the nose, throat and bronchial tubes, possible erosion of tooth enamel.
Lead Compounds: May cause anemia, damage to kidneys and nervous system, and damage to reproductive system in both males and females.

SECTION 6: HEALTH HAZARD DATA (CONTINUED)

Carcinogenicity

Sulfuric acid: The National Toxicological Program (NTP) and The International Agency for Research on Cancer (IARC) have classified strong inorganic acid mist containing sulfuric acid as a Category 1 carcinogen, a substance that is carcinogenic to humans. The ACGIH has classified strong inorganic acid mist containing sulfuric acid as an A2 carcinogen (suspected human carcinogen). These classifications do not apply to liquid forms of sulfuric acid or sulfuric acid solutions contained within a battery. Inorganic acid mist (sulfuric acid mist) is not generated under normal use of this product. Misuse of the product, such as overcharging, may result in the generation of sulfuric acid mist.
Lead Compounds: Human studies are inconclusive regarding lead exposure and an increased cancer risk. The EPA and the International Agency for Research on Cancer (IARC) have categorized lead and inorganic lead compounds as a B2 classification (probable/possible human carcinogen) based on sufficient animal evidence and inadequate human evidence.

Medical Conditions Generally Aggravated by Exposure

Inorganic lead and its compounds can aggravate chronic forms of kidney, liver, and neurological diseases. Contact of battery electrolyte (acid) with the skin may aggravate skin diseases such as eczema and contact dermatitis. Overexposure to sulfuric acid mist may case lung damage and aggravate pulmonary conditions.

Emergency and First Aid Procedures

Inhalation
Sulfuric acid: Remove to fresh air immediately. If breathing is difficult, give oxygen
Lead Compounds: Remove from exposure, gargle, wash nose and lips, consult physician

Ingestion
Sulfuric acid: Do not induce vomiting, consult a physician immediately.
Lead Compounds: Consult a physician immediately

Eyes
Sulfuric acid: Flush immediately with water for 15 minutes, consult a physician.
Lead Compounds: Flush immediately with water for 15 minutes, consult a physician

Skin
Sulfuric acid: Flush with large amounts of water for at least 15 minutes, remove any contaminated clothing. If irritation develops seek medical attention.
Lead Compounds: Wash with soap and water.

SECTION 7: PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken in Case Material is Released or Spilled

There is no release of material unless the case is damaged or battery is misused/overcharged. If release occurs stop flow of material, contain/absorb all spills with dry sand, earth, or vermiculite. Do not use combustible materials. Neutralize spilled material with soda ash, sodium bicarbonate, lime, etc. Wear acid-resistant clothing, boots, gloves, and face shield. Dispose of as hazardous waste. Do not discharge acid to sewer

Waste Disposal Method

Spent Batteries - send to secondary lead smelter for recycling. Follow applicable federal, state and local regulations Neutralize as in preceding step. Collect neutralized material in sealed container and handle as hazardous waste as applicable. A copy of this MSDS must be supplied to any scrap dealer or secondary lead smelter with the battery.

Precautions to be Taken in Handling and Storing
Store batteries in a cool, dry, well ventilated area that are separated from incompatible materials and any activities which may generate flames, sparks, or heat. Keep all metallic articles that could contact the negative and positive terminals on a battery and create a short circuit condition.

SECTION 7: PRECAUTIONS FOR SAFE HANDLING AND USE (CONTINUED)

Electrical Safety

Due to the battery's low internal resistance and high power density, high levels of short circuit current can be developed across the battery terminals. Do not rest tools or cables on the battery. Use insulated tools only. Follow all installation instructions and diagrams when installing or maintaining battery systems.

Fiberglass Separator

Fiberglass is an irritant to the upper respiratory tract, skin and eyes. For exposure up to 10F°/ use MSA Comfoll with type H filter. Above 10F use Ultra Twin with type H filter. This product is not considered carcinogenic by NTP or OSHA.

SECTION 8: CONTROL MEASURES

Respiratory Protection

None required under normal conditions. If battery is overcharged and concentrations of sulfuric acid are known to exceed PEL use NIOSH or MSH approved respiratory protection.

Engineering Controls

Store and handle batteries in a well ventilated area. If mechanical ventilation is used, components must be acid resistant

Protective Gloves

None needed under normal conditions. If battery case is damaged use rubber or plastic elbow length gauntlets

Eye Protection

None needed under normal conditions. If handling damaged or broken batteries use chemical splash goggles or face shield

Other Protective Clothing or Equipment

None needed under normal conditions. In case of damaged or broken battery use an acid resistant apron. Under severe exposure or emergency conditions wear acid resistant clothing.

Work Hygienic Practices

Handle batteries carefully to avoid damaging the case. Do not allow metallic articles to contact the battery terminals during handling. Avoid contact with the internal components of the battery.

SECTION 9: REGULATORY INFORMATION

NFPA Hazard Rating for Sulfuric Acid

Transportation Batteries. Non-Restricted Status

North America Surface and Air Shipments

Our nonspillable lead acid batteries are listed in the U.S. Department of Transportation's (DOT) hazardous materials regulations but are *excepted* from these regulations since they meet all of the following requirements found at 49 CFR 173.159(d) – NMFC # 60680 Class 65.

- When offered for transport, the batteries are protected against short circuits and securely packaged as required by 49 CFR 173.159(d) (1);
- The batteries and outer packaging are marked with the words NONSPILLABLE BATTERY as required by 49 CFR 173.159(d) (2); and
- The batteries comply with the vibration and pressure differential tests found in 49 CFR 173.159(d) (3) and "crack test" found at 49 CFR 173.159(d) (4).

SECTION 9: REGULATORY INFORMATION (CONTINUED)

International

Our non-spillable lead acid batteries also are excepted from the international hazardous materials (also known as "dangerous goods") regulations since they comply with the following requirements:

- The vibration and pressure differential tests found in Packing Instruction 806 and Special Provision A67 of the International Air Transport Association (IATA) Dangerous Goods Regulations;

The vibration and pressure differential tests found in Packing Instruction 806 and Special Provision A67 of the International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air; and

- The vibration, pressure differential, and "crack" tests found in Special Provision 238.1 and 238.2 of the International Maritime Dangerous Goods (IMDG) Code.

Regulatory Information

RCRA: Spent lead acid batteries are not regulated as hazardous waste by the EPA when recycled, however state and international regulations may very.

CERCLA (superfund) and EPCRA:

(a) Reportable Quantity (RQ) for spilled 100% sulfuric acid under CERCLA (superfund) and EPCRA (Emergency Planning Community Right to Know Act is 1,000lbs. State and local reportable quantities for spilled sulfuric acid may vary.

(b) Sulfuric acid is a listed "Extremely Hazardous Substance" under EPCRA with a Threshold Planning Quantity (TPQ) of 1,000lbs.

(c) EPCRA Section 302 Notification is required if 1,000lbs. or more of sulfuric acid is present at one site. The quantity of sulfuric acid will vary by battery type. Contact XS Power for additional information.

(d) EPCRA Section 312 Tier 2 reporting is required for batteries for batteries if sulfuric acid is present in quantities of 500lbs. or more and/or lead is present in quantities of 10,00lbs. or more.

(e) Supplier Notification: This product contains toxic chemicals which may be reportable under EPCRA Section 313 Toxic Chemical Release Inventory (Form R) requirements. If you are a manufacturing facility under SIC codes 20 through 39 the following information is provided to enable you to complete the required reports:

(f)

Toxic Chemical	CAS Number	Approximate % by weight
Lead	7439-92-1	60
Sulfuric Acid	7664-93-9 10-	30
Arsenic	7440-38-2	0.2

If you distribute this product to other manufacturers in SIC codes 20 through 39, this information must be provided with the first shipment in a calendar year. The Section 313 supplier notification requirement does not apply to batteries which are "consumer products". Not present in all battery types. Contact XS Power for further information.

TSCA

Ingredients in XS Power batteries are listed in the TSCA Registry as follows:

Components	CAS Number	TSCA Status
Electrolyte Sulfuric Acid (H2SO4)	7664-93-9	Listed
Inorganic Lead Compound: Lead (Pb)	7439-92-1	Listed
Lead Oxide (PbO)	1317-36-8	Listed
Lead Sulfate (PbSO4)	7446-14-2	Listed
Arsenic (As)	7440-38-2	Listed
Calcium (Ca)	7440-70-2	Listed
Tin (Sn)	7440-31-5	Listed

APPENDIX B: FLOTATION CALCULATIONS

$$Volume\ of\ the\ carbon\ fiber\ hull: 2163.025\ in^3$$

$Density\ of\ 3\ layer\ carbon\ fiber\ with\ resin, assuming\ a\ 50\%\ fiber\ to\ resin\ ratio: 1.60\,\frac{gm}{cc} =$

$0.0578\ \ lb/in^3$

$$\therefore Weight\ of\ hull = 125.44\ lbs.$$

$$Also, weight\ of\ water\ displaced\ by\ hull\ of\ submerged\ completely\ in\ water: 2163.025 \times 0.0361 = 78.085\ lbs.$$

Major Systems	Weight	Weight of water displaced
	lbs.	*lbs.*
3x Batteries	99	36.84
Drivetrain	10	5.19
Motor	20	17.68
3xSolar Panels	30	175.64
Seat	5	84.99
Hull	125.44	78.35
Total:	289.44	395.69

For a safety factor greater than 20%, we will need a buoyant force of 420 lbs., which means:

$$Foam\ needed = \frac{420 - 78.35}{62.4} \cong 5.5\ cubic\ feet\ of\ foam$$

In order to meet the required safety factors for the competition, 5.5 cubic feet of foam or flotation airbags will be added to the hull.

APPENDIX C: PROOF OF INSURANCE

OFFICE OF GENERAL SERVICES
BUREAU OFRISK AND INSURANCE MANAGEMENT

TO: Whom it may Concern

FROM: Tomlynn Yacono
Director, Bureau of Risk and Insurance Management

SUBJECT: *Statement of Self Retention*

The General Liability exposures of the State of New York as well as those of the State Agencies are self retained. Suits for bodily injury and property damage are brought in the NY State Court of Claims, which is supported by a multi-million dollar annual appropriation.

Employees are protected against suits under Public Officers Law Section 17 for actions or alleged actions that occur while they are acting within the scope of their employment.

If there are any questions or further information is needed, please do not hesitate to contact the OGS Bureau of Insurance at (518) 474-4725.

APPENDIX D: DOCUMENTATION FOR COMMERCIAL MOTOR CONTROLLER

LED Status Indicator

LED Blink Codes:

At power up, # of green blinks indicates configured throttle type:

1 Green = 0-5k-ohm
2 Green = 5k-0-ohm
3 Green = 0-5 Volt
4 Green = EZ-GO inductive (ITS)
5 Green = Yamaha 0-1K
6 Green = Taylor-Dunn 6-10.5V
7 Green = CLUBCAR 5K-3-wire

Normal display status:

Solid Green: Controller ready to run

Solid Red: Controller in programming mode
Solid Yellow: Controller throttle is wide open, controller is supplying max output, and is not in current limit.

Trouble Shooting

Error code display: # of RED blinks indicates any error conditions that might exist:

1 Red = Throttle Position Sensor Over Range. Check for open wires.
2 Red = Under Temperature. Controller below -25C
3 Red = HPD. Throttle hasn't gone to zero during this power on cycle.
4 Red = Over Temperature. Controller over 95C
5 Red = unused
6 Red = Battery Under Voltage detected. Battery V < under voltage slider
7 Red = Battery Over Voltage detected. Battery V > over-voltage slider

AXE

LIMITED WARRANTY

Alltrax, Inc., (hereafter Alltrax) warrants that the product purchased is free from defects in materials or workmanship for a period of *2 years* from the date of manufacture. This warranty does not apply to defects due directly or indirectly to misuse, abuse, negligence, accidents, repairs, improper installation, submersion, alterations or use contrary to any instructions provided by Alltrax in verbal or written form.

In the event you should need warranty repair, contact Alltrax at (541) 476-3565 to receive warranty service authorization instructions for returning the defective product to Alltrax for evaluation. Products or parts shipped by customer to Alltrax must be sent postage paid and packaged appropriately for safe shipment. Alltrax is not responsible for customer products received without warranty service authorization and may be rejected.

Alltrax reserves the right to repair or replace merchandise at its option at no cost to the customer, except for shipping costs of sending the defect item to Alltrax. Replacement shall mean furnishing the customer with a new equivalent product to the defective item. Alltrax also reserves the right to make changes to any of its products or specifications without notice.

Alltrax assumes no liability for applications assistance or customer product design. Customers shall be responsible for evaluating the appropriateness of the use of any Alltrax product in any application. Customers shall provide adequate design and operating safeguards that are in compliance with standard practices of other similar applications or any standards of any governing agency.

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NO REPRESENTATIVE EMPLOYEE, DISTRIBUTOR OR DEALER OF ALLTRAX HAS THE AUTHORITY TO MAKE OR IMPLY ANY WARRANTY, REPRESENTATION, PROMISE OR AGREEMENT, WHICH IN ANY WAY VARIES THE TERMS OF THIS LIMITED WARRANTY.

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Alltrax, Inc.
1111 Cheney Creek Rd
Grants Pass, OR. 97527
Phone: 541-476-3565
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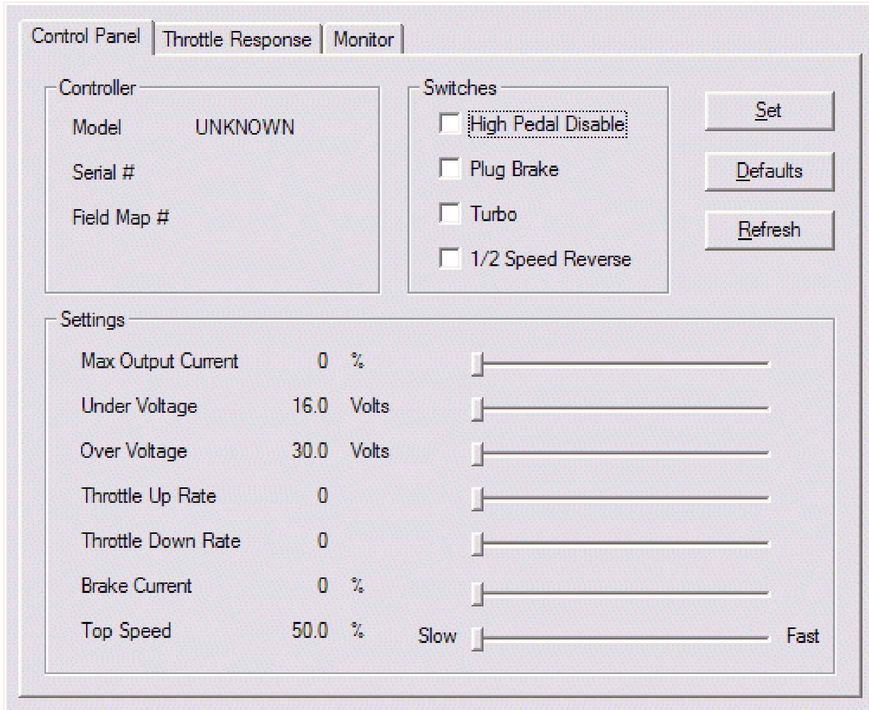
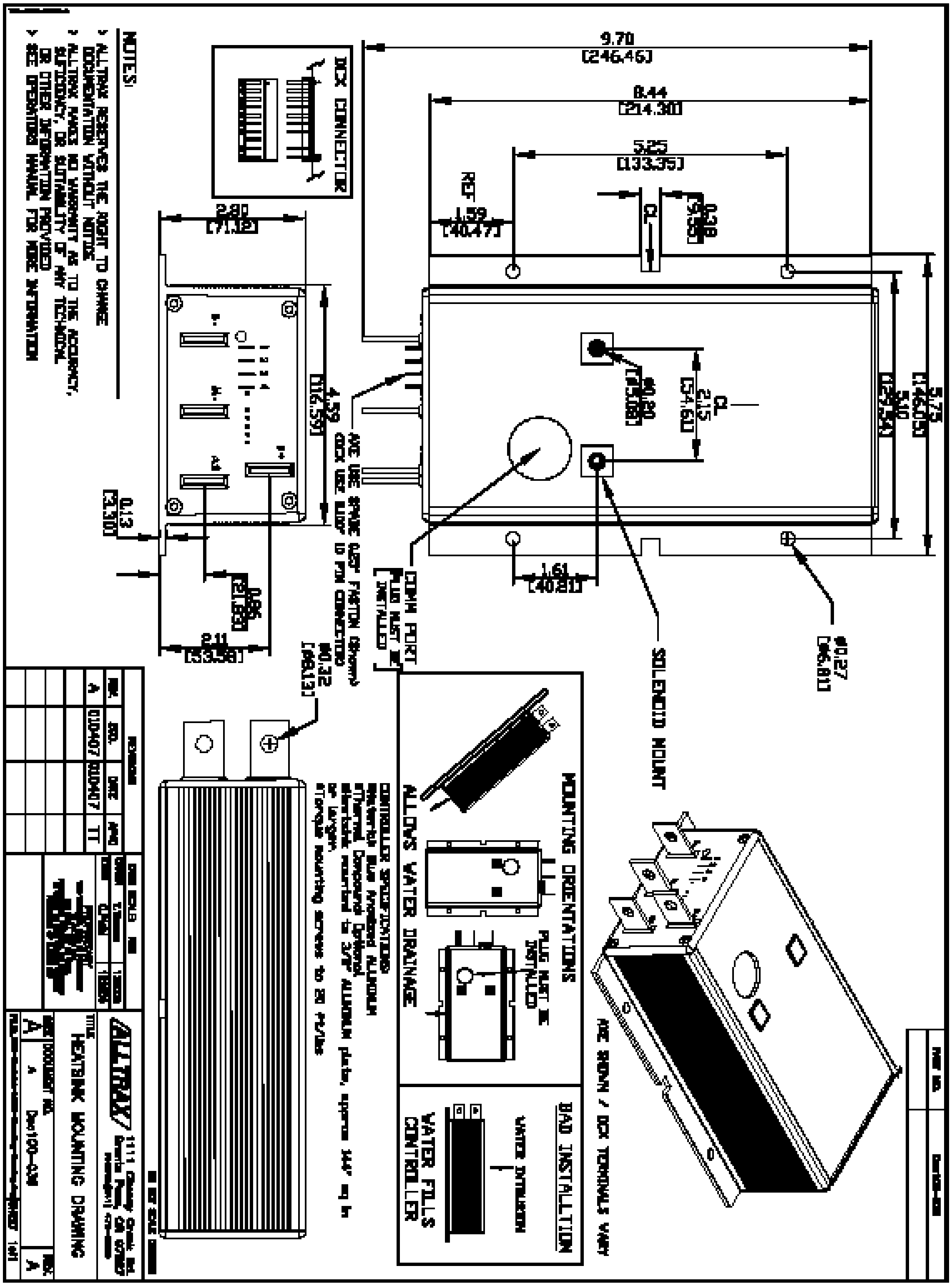
Programming Instructions



Programming GUI


NOTES:
1. ALLTRAX RESERVES THE RIGHT TO CHANGE DOCUMENTATION WITHOUT NOTICE
2. ALLTRAX MAKES NO WARRANTY AS TO THE ACCURACY, SUFFICIENCY, OR SUITABILITY OF ANY TECHNICAL OR OTHER INFORMATION PROVIDED
3. SEE OPERATION MANUAL FOR MORE INFORMATION
DCX CONNECTOR
9.70
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8.44
[214.30]
5.25
[133.35]
REF
1.59
[40.47]
CL
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5.10
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0.86
[21.89]
2.11
[53.58]
1.61
[40.81]
ø0.27
[ø6.81]
SOLENOID MOUNT
COMM PORT
PLUG MUST BE INSTALLED
AXE USE SPADE 0.25" FASTON CONNECTOR
DCX USE 0.32 ø FOR CONNECTOR
ø0.32
[ø8.13]
MOUNTING ORIENTATIONS
ALLOWS WATER DRAINAGE
PLUG MUST BE INSTALLED
BAD INSTALLATION
WATER INTRUSION
WATER FILLS CONTROLLER
AXE SHOWN / DCX TERMINALS VARY
CONTROLLER SPECIFICATIONS
Torque mounting screws to 20 in/lbs
ALLTRAX
HEATSINK MOUNTING DRAWING
A

APPENDIX E: DATASHEET FOR SOLAR CHARGER

MORNINGSTAR
corporation

Product shown with optional meter.

TRISTAR MPPT™

SOLAR CONTROLLER WITH MAXIMUM POWER POINT TRACKING

Morningstar's ***TriStar MPPT*** solar controller with TrakStar Technology™ is an advanced maximum power point tracking (MPPT) battery charger for off-grid photovoltaic (PV) systems up to 3kW. The controller provides the industry's highest peak efficiency of 99% and significantly less power loss compared to other MPPT controllers.

The TriStar MPPT features a smart tracking algorithm that maximizes the energy harvest from the PV by rapidly finding the solar array peak power point with extremely fast sweeping of the entire I-V curve. This product is the first PV controller to include on-board Ethernet for a fully web-enabled interface and includes up to 200 days of data logging.

Key Features and Benefits

Maximizes Energy Harvest

Our TrakStar MPPT Technology features:

- *Better peak power point tracking than other MPPT controllers*
- *Very fast sweeping of the entire I-V curve*
- *Recognition of multiple power points during shading or mixed PV arrays*
- *Excellent performance at sunrise and low solar insolation levels*

Extremely High Reliability

- *Robust thermal design and no cooling fans*
- *Parallel circuit design provides less stress and longer life for electronic components*
- *No mechanical relays*
- *Extensive electronic protections including PV short circuit protection*
- *Epoxy encapsulated inductors and conformally coated printed circuit boards*

Very High Efficiency

- *Peak efficiency of 99%*
- *Proprietary tracking algorithm minimizes power losses*
- *Low self-consumption*
- *Continuous operation at full power to 45°C without need to de-rate*
- *Selected electronic devices with higher ratings to minimize losses from heating*

Extensive Networking and Communications Capabilities

Enables system monitoring, data logging and adjustability. Uses open standard MODBUS™ protocol and Morningstar's MS View software.

- *Meterbus: communications between compatible Morningstar products*
- *Serial RS-232: connection to a personal computer*
- *EIA-485: communications between multiple devices on a bus*
- *Ethernet: fully web-enabled interface to a local network or internet; view from a web browser or send email/text messages.*

Metering and Data Logging

- *Optional TriStar meter and remote meter provides detailed operating data, alarms and faults*
- *Three LED's display system status*
- *Up to 200 days of data logging via meters or communications ports*

System Status:

53.60V	28C	54.2A
2867W		MPPT

Data Logging:

Today Batt 46.4 Vmin	Day: -1 Batt 47.2 Vmin
Today Solar 58.9 Amax	Day: -1 Solar 56.8 Amax
Today Solar 107.2 Vmax	Day: -1 Solar 105.5 Vmax

TRISTAR MPPT™ SOLAR CONTROLLER

TRAKSTAR™ MAXIMUM POWER POINT TRACKING

TECHNICAL SPECIFICATIONS

Electrical

		TS-MPPT-45	TS-MPPT-60
• Maximum Battery Current		45 amps	60 amps
• Nominal Maximum Solar Input	12 Volt	600 Watts	800 Watts
	24 Volt	1200 Watts	1600 Watts
	48 Volt	2400 Watts	3200 Watts

	TS-MPPT-45 and TS-MPPT-60
• Peak Efficiency	99%
• Nominal System Voltage	12, 24, 36 or 48 volts DC
• Max. Solar Open Circuit Voltage	150 volts DC
• Battery Operating Voltage Range	8-72 volts DC
• Maximum Self-consumption	2.7 Watts
• Transient Surge Protection	4500 Watts/port

Electronic Protections

- **Solar:** Overload, Short Circuit, High Voltage
- **Battery:** High Voltage
- **High Temperature**
- **Lightning and Transient Surges**
- **Reverse Current at Night**

Battery Charging

• Charging algorithm	4-stage
• Charging stages	Bulk, Absorption, Float, Equalize
• Temperature Compensation	
Coefficient	–5mV/°C/cell (25° ref)
Range	–30°C to +80°C
Set points	Absorption, Float, Equalize, HVD

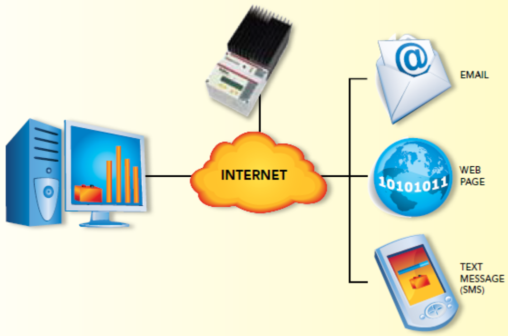
Note: Remote Temperature Sensor is included.

Mechanical

• Dimensions	29.1 x 13.0 x 14.2 cm 11.4 x 5.1 x 5.6 inch
• Weight	4.2 kg / 9.2 lbs.
• Max. Wire Size	35 mm² / 2 AWG
• Conduit knockouts	M20; ½, 1, 1 ¼ inch
• Enclosure	Type 1 (indoor and vented) IP20

Environmental

• Ambient Temperature	–40°C to +45°C
• Storage Temperature	–55°C to +100°C
• Humidity	100% non-condensing
• Tropicalization	Epoxy encapsulation Conformal coating Marine rated terminals



Communication Ports

	TS-MPPT-45	TS-MPPT-60
• MeterBus	Yes	Yes
• RS-232	Yes	Yes
• EIA-485	No	Yes
• Ethernet	No	Yes

Options

- TriStar Meter-2 (TS-M-2)
- TriStar Remote Meter-2 (TS-RM-2)
- Meter Hub (HUB-1)
- Relay Driver (RD-1)

Certifications

- CE Compliant
- ETL Listed (UL1741)
- cETL (CSA C22.2 No. 107.1-01)
- FCC Class B Part 15 Compliant
- Complies with (NEC) U.S. National Electric Code
- RoHS Compliant
- Manufactured in a certified ISO 9001 facility

WARRANTY: *Five year warranty period. Contact Morningstar or your authorized distributor for complete terms.*

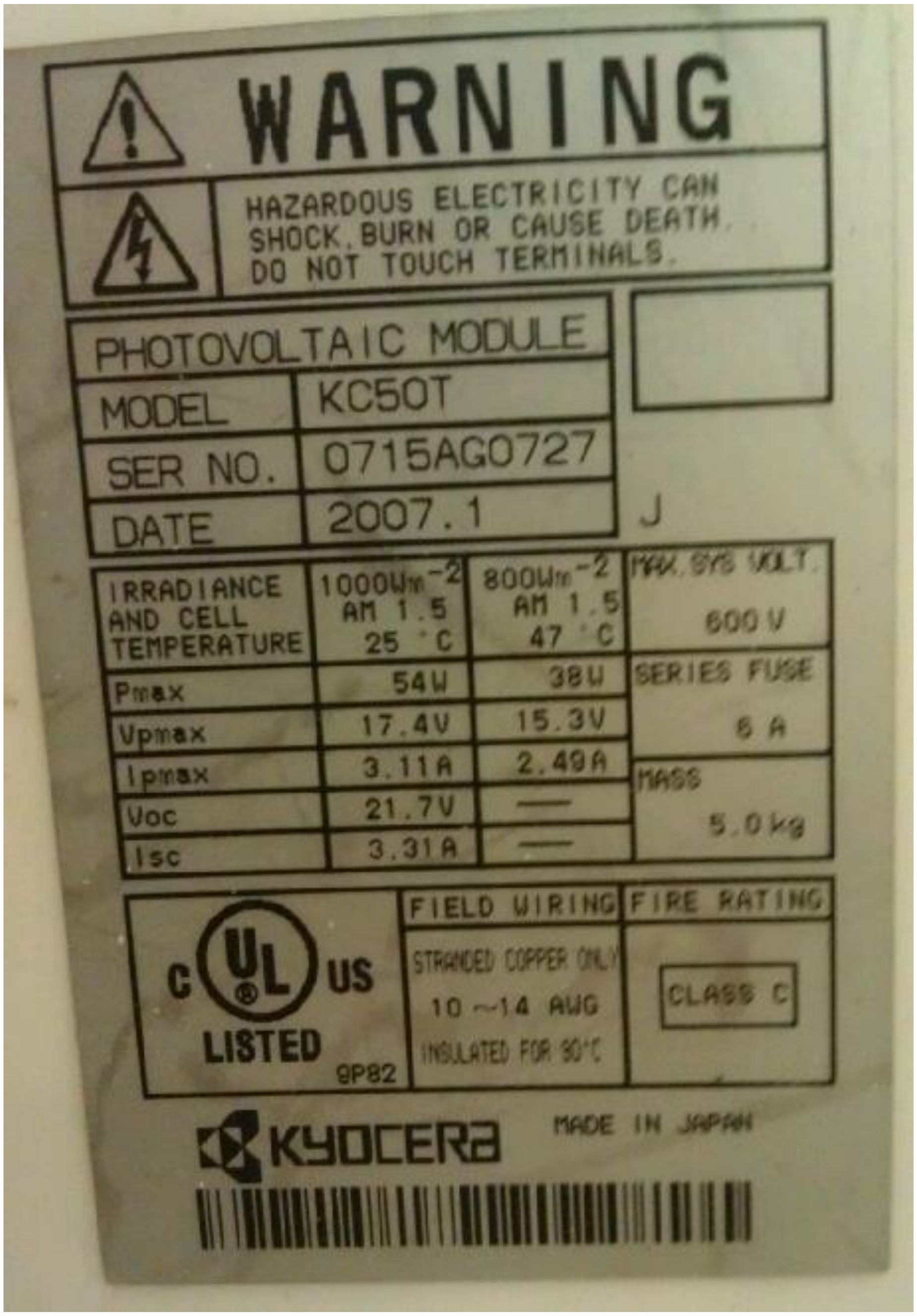
AUTHORIZED MORNINGSTAR DISTRIBUTOR:

MORNINGSTAR corporation

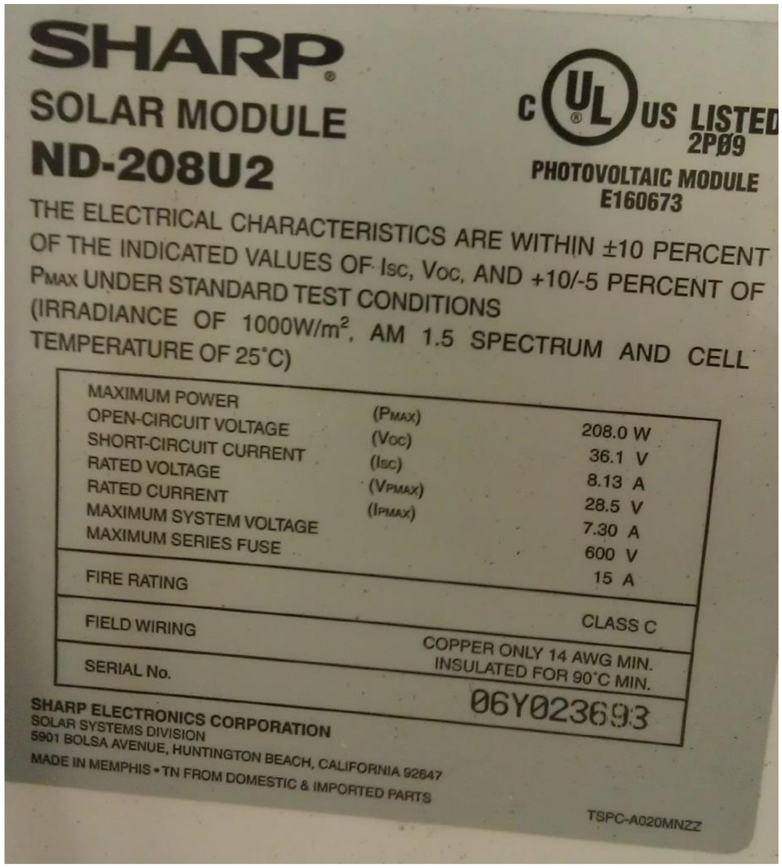
8 Pheasant Run
Newtown, PA 18940 USA
Tel: +1 215-321-4457 Fax: +1 215-321-4458
E-mail: info@morningstarcorp.com
Website: www.morningstarcorp.com

APPENDIX F: SPECIFICATIONS FOR SOLAR CELLS

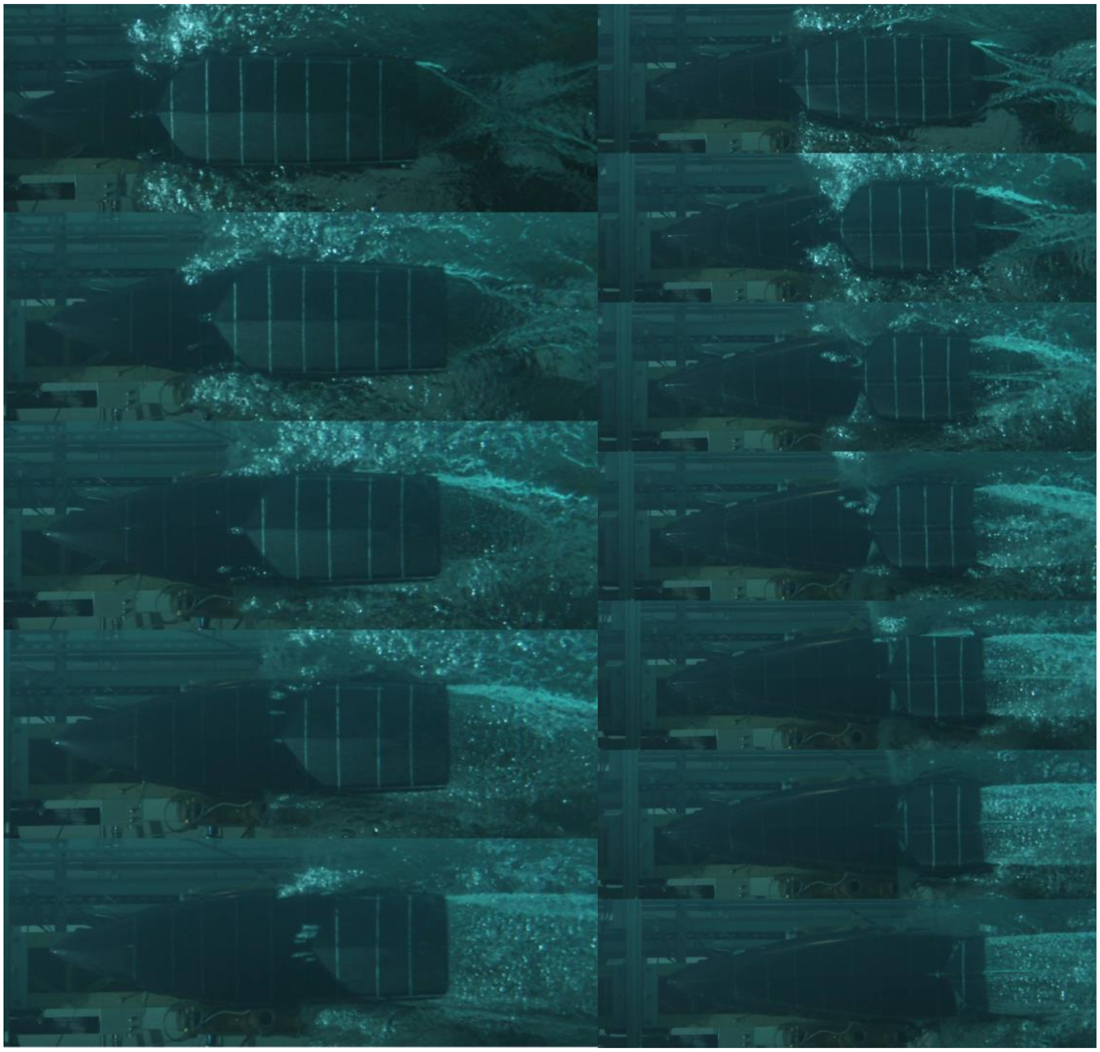
KYOCERA KC 50T Solar Module



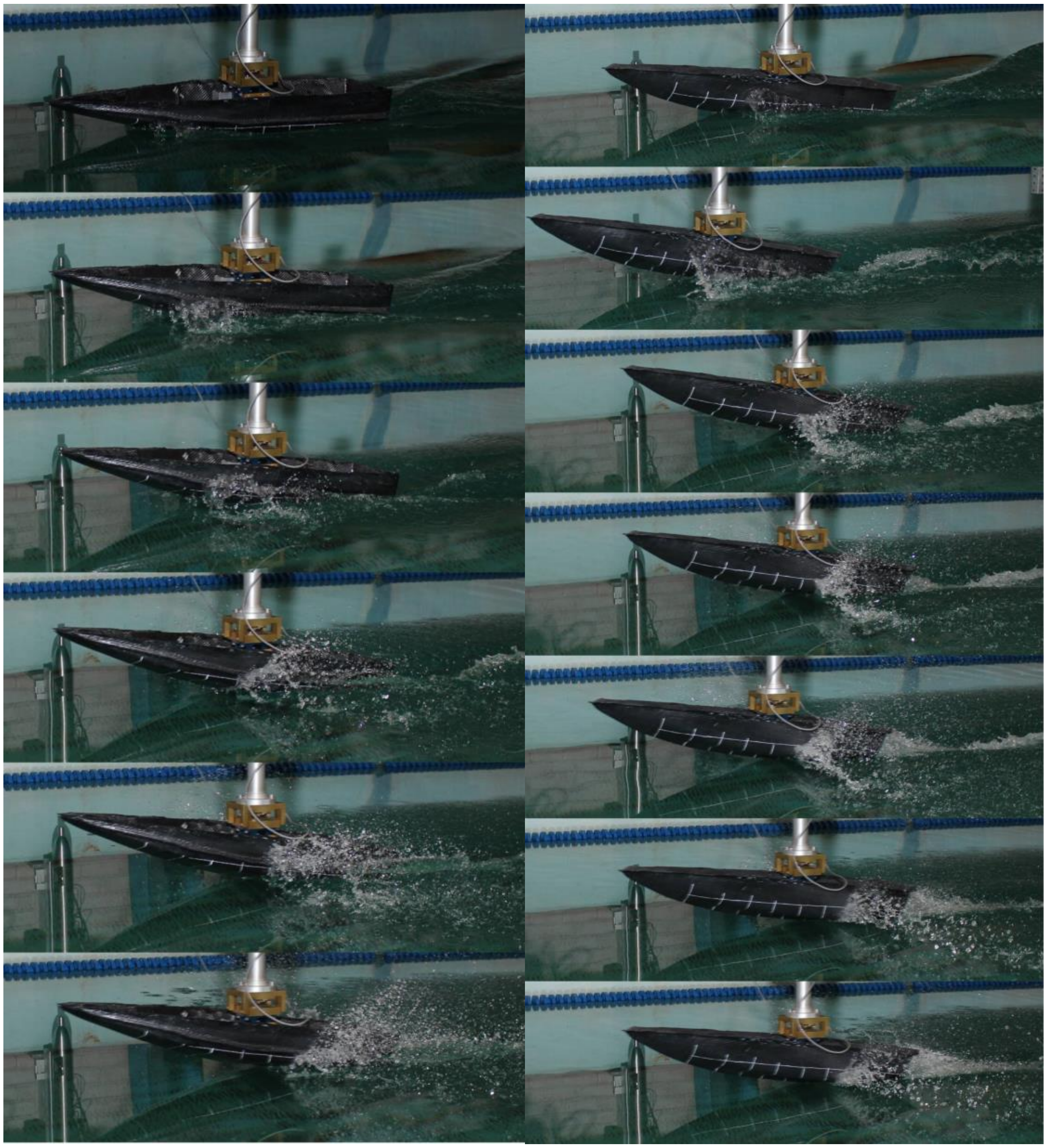
SHARP ND-208U2 Solar Module



APPENDIX G: PICTURES FROM DRAG TESTING OF PLANING HULL PROTOTYPES

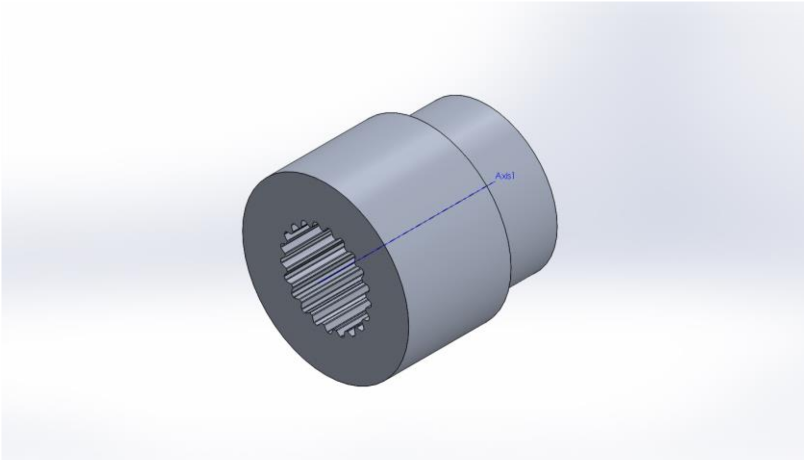


Underwater images of different hulls at different speeds



Side view images of different hulls at different speeds

APPENDIX H: SPLINE COUPLER FINITE ELEMENT ANALYSIS



Simulation of spline coupler

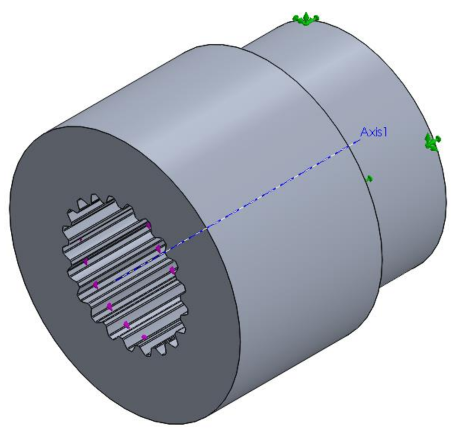
Date: Wednesday, April 02, 2014
Designer: Solidworks
Study name: Study 1
Analysis type: Static

Description

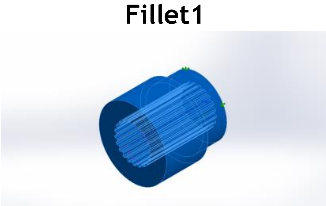
No Data

Assumptions

Model Information



Model name: spline coupler
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Fillet1 	Solid Body	Mass:0.0909491 kg Volume:3.36848e-005 m^3 Density:2700 kg/m^3 Weight:0.891301 N	C:\Users\solarboat\Google Drive\Drivetrain\Internal Drivetrain\spline coupler.SLDPRT Mar 29 15:38:39 2014

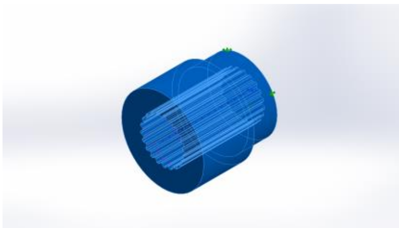
Study Properties

Study name	Study 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (C:\Users\solarboat\Google Drive\Drivetrain\Internal Drivetrain)

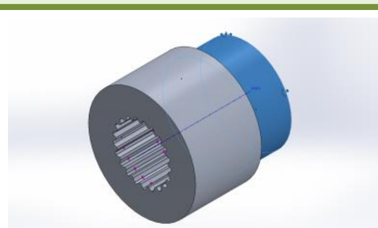
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

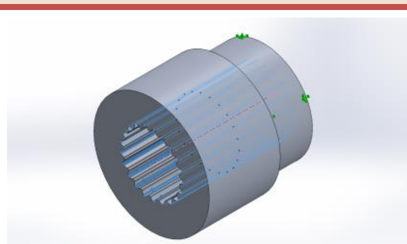
Model Reference	Properties	Components
	**Name:** 6061 Alloy **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 5.51485e+007 N/m^2 **Tensile strength:** 1.24084e+008 N/m^2 **Elastic modulus:** 6.9e+010 N/m^2 **Poisson's ratio:** 0.33 **Mass density:** 2700 kg/m^3 **Shear modulus:** 2.6e+010 N/m^2 **Thermal expansion coefficient:** 2.4e-005 /Kelvin	SolidBody 1(Fillet1)(spline coupler)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-75.4978	57.2902	0.0620964	94.7739
Reaction Moment(N·m)	0	0	0	0

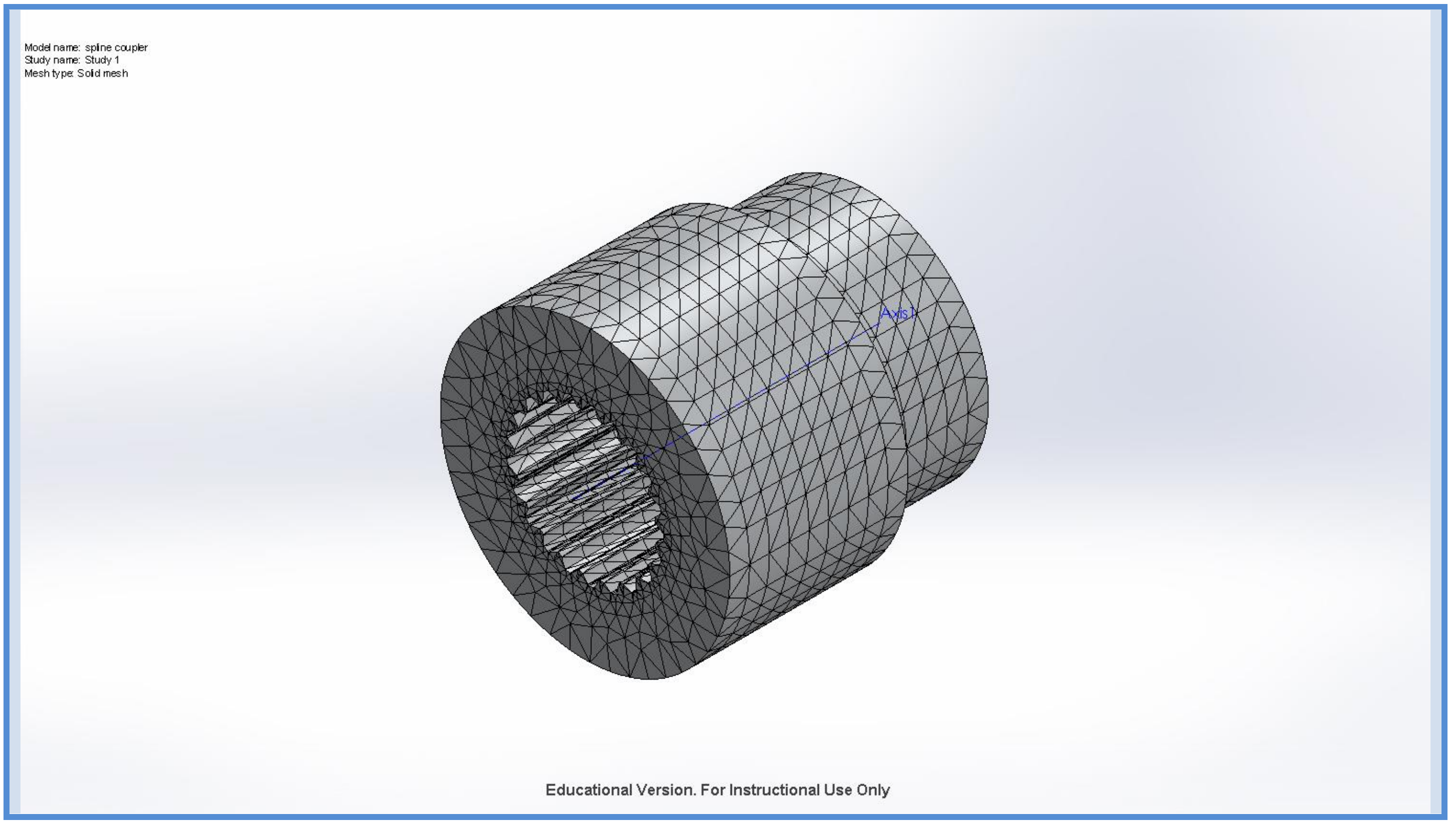
Load name	Load Image	Load Details
Torque-1		**Entities:** 21 face(s) **Reference:** Axis1 **Type:** Apply torque **Value:** 900 lbf·in

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.114473 in
Tolerance	0.00572365 in
Mesh Quality	High

Mesh Information - Details

Total Nodes	42100
Total Elements	26595
Maximum Aspect Ratio	38.321
% of elements with Aspect Ratio < 3	65.6
% of elements with Aspect Ratio > 10	11.6
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:07
Computer name:	SOLARBOAT1



Sensor Details
No Data

Resultant Forces

Reaction Forces

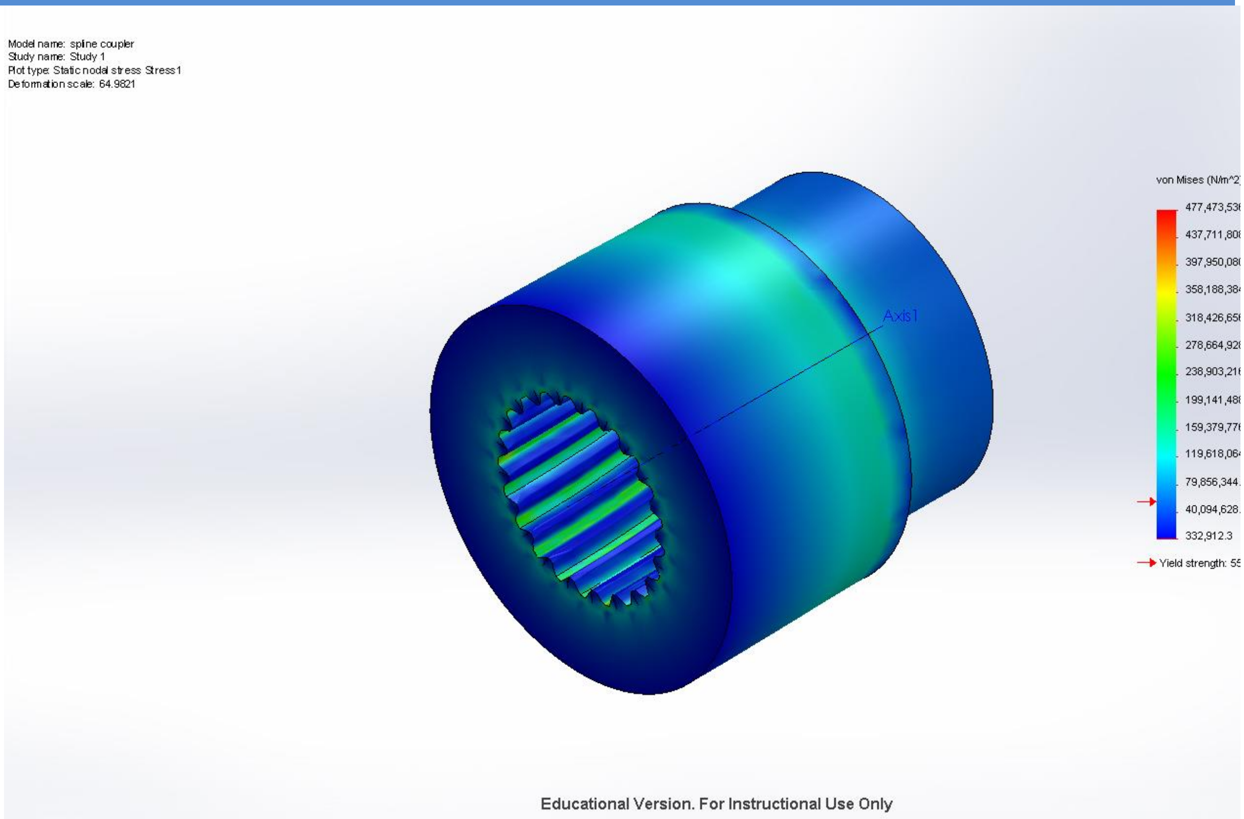
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-75.4978	57.2902	0.0620964	94.7739

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N·m	0	0	0	0

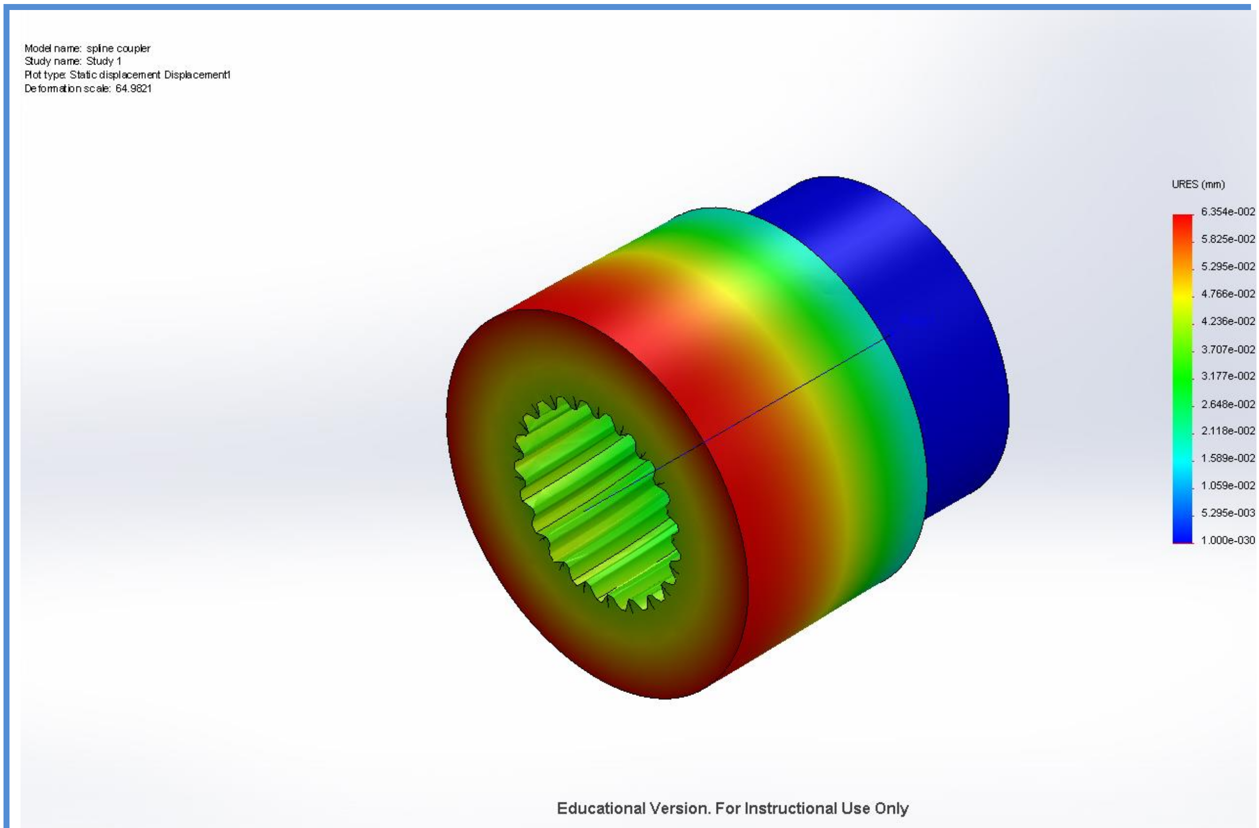
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	332912 N/m^2 Node: 39735	4.77474e+008 N/m^2 Node: 41814



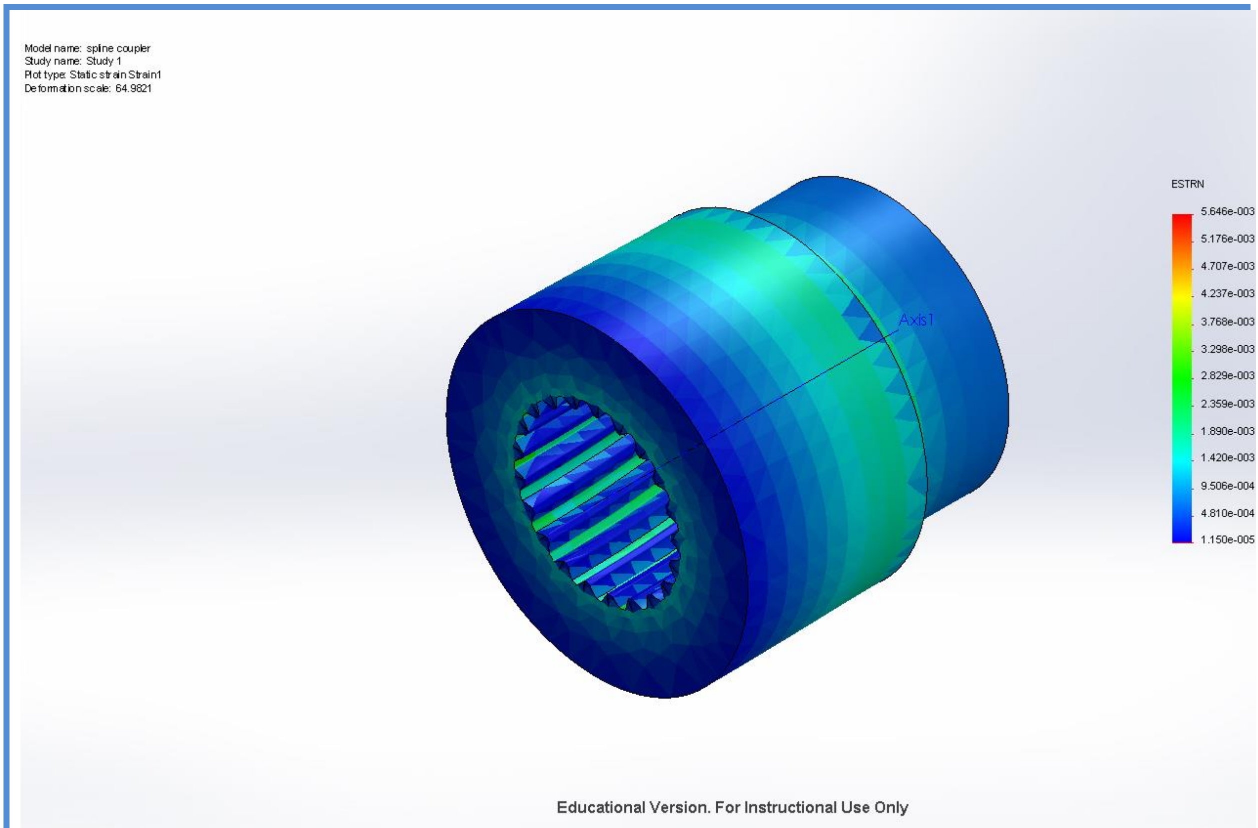
spline coupler-Study 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.0635408 mm Node: 39742



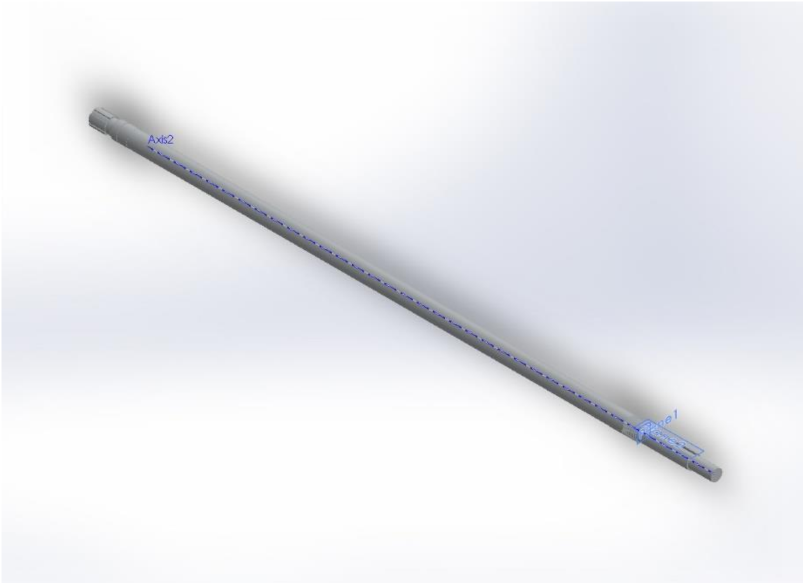
spline coupler-Study 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.15012e-005 Element: 16172	0.00564584 Element: 750



spline coupler-Study 1-Strain-Strain1

APPENDIX I: FINITE ELEMENT ANALYSIS (PROPELLER SHAFT)



Simulation of prop shaft

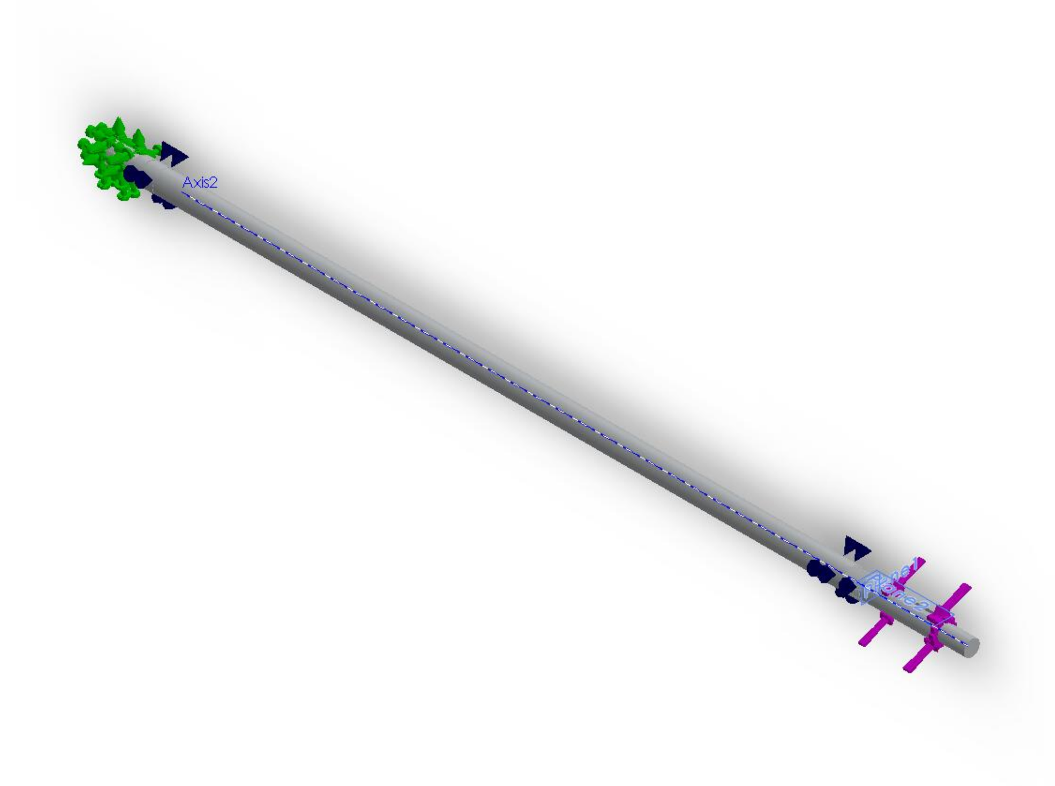
Date: Thursday, May 09, 2013
Designer: Solidworks
Study name: Study 2
Analysis type: Static

Description

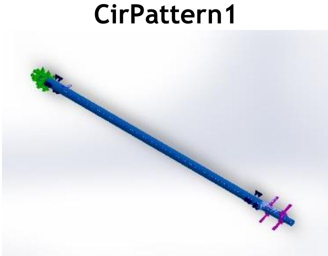
No Data

Assumptions

Model Information



Model name: prop shaft
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
CirPattern1 	Solid Body	Mass:0.857437 kg Volume:0.000305138 m^3 Density:2810 kg/m^3 Weight:8.40288 N	C:\Users\Vinny Calandrino\Google Drive\Solar Boat 2012\Drive Train\sprint drive\prop shaft.SLDPRT May 09 19:13:25 2013

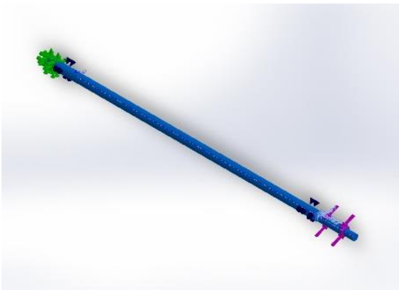
Study Properties

Study name	Study 2
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (C:\Users\Vinny Calandrino\Google Drive\Solar Boat 2012\Drive Train\sprint drive)

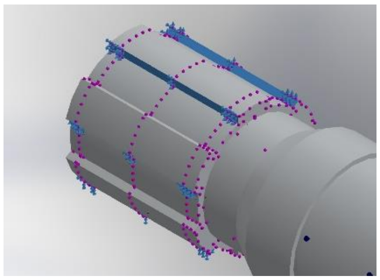
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** 7075-T6 (SN) **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 5.05e+008 N/m^2 **Tensile strength:** 5.7e+008 N/m^2 **Elastic modulus:** 7.2e+010 N/m^2 **Poisson's ratio:** 0.33 **Mass density:** 2810 kg/m^3 **Shear modulus:** 2.69e+010 N/m^2 **Thermal expansion coefficient:** 2.36e-005 /Kelvin	SolidBody 1(CirPattern1)(prop shaft)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 6 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	95.1186	0.970887	-0.408834	95.1244
Reaction Moment(N-m)	0	0	0	0

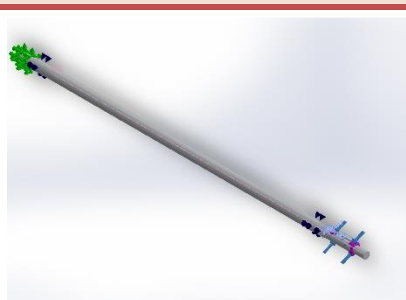
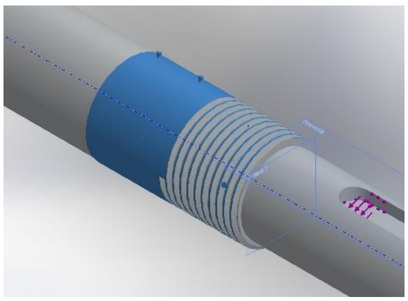
Load name	Load Image	Load Details
Torque-1		**Entities:** 2 face(s) **Reference:** Axis2 **Type:** Apply torque **Value:** 900 lbf-in

Image-3

Image-4

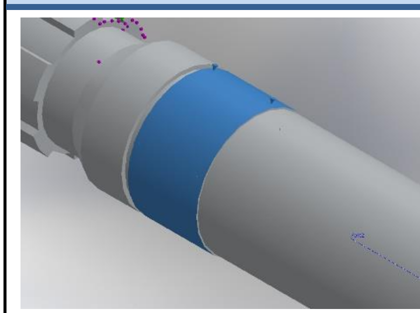
Connector Definitions

Pin/Bolt/Bearing Connector

Model Reference	Connector Details	Strength Details
 Bearing Support-1	**Entities:** 1 face(s) **Type:** Bearing	No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	-0	0	0	0
Shear Force (N)	0	0	0	0
Bending moment (N-m)	0	0	0	0

Model Reference	Connector Details	Strength Details
 Bearing Support-2	**Entities:** 1 face(s) **Type:** Bearing	No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	-0	0	0	0
Shear Force (N)	0	0	0	0
Bending moment (N-m)	0	0	0	0

Contact Information

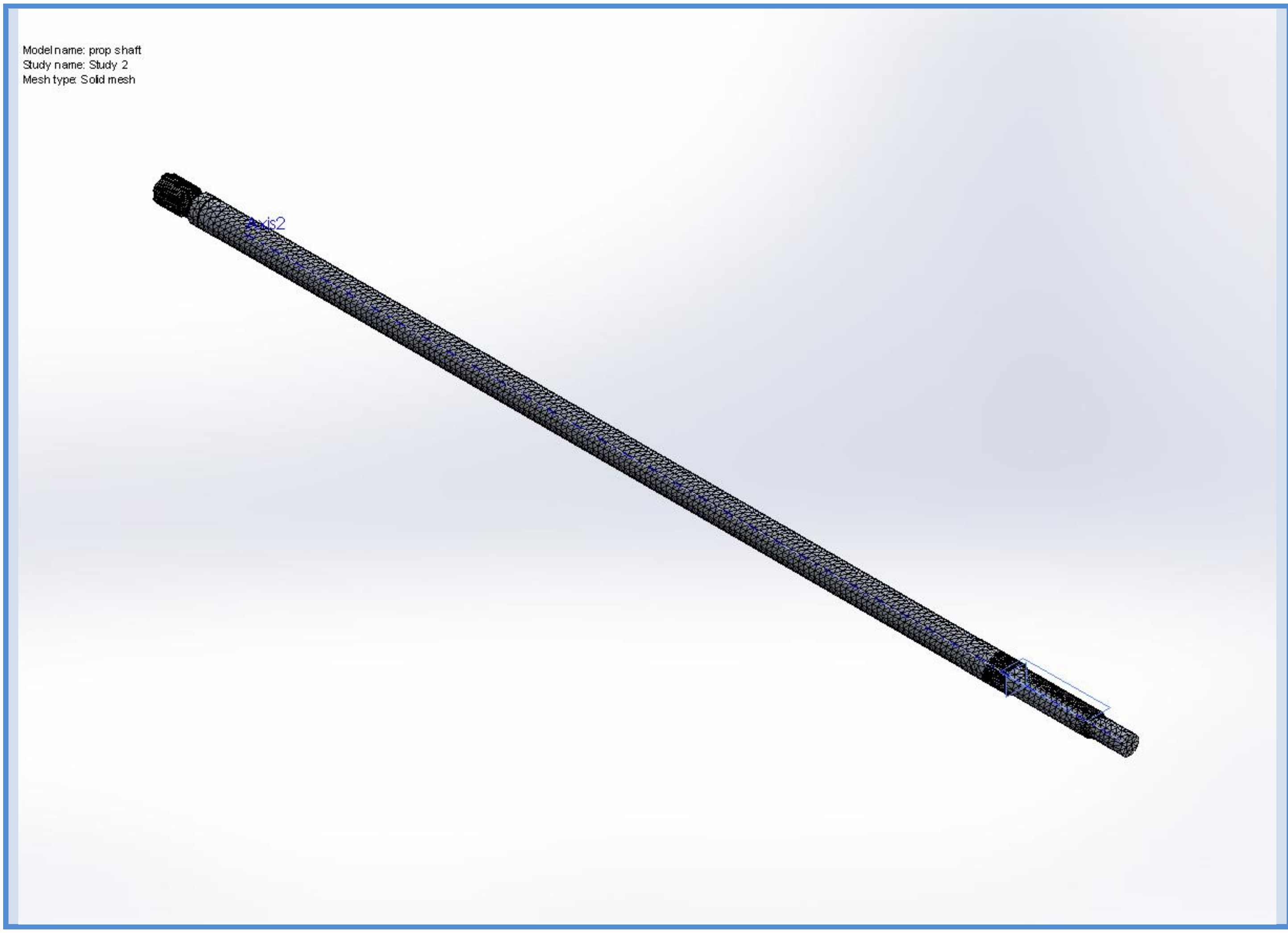
No Data

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	16 Points
Element Size	0.18654 in
Tolerance	0.00932699 in
Mesh Quality	High

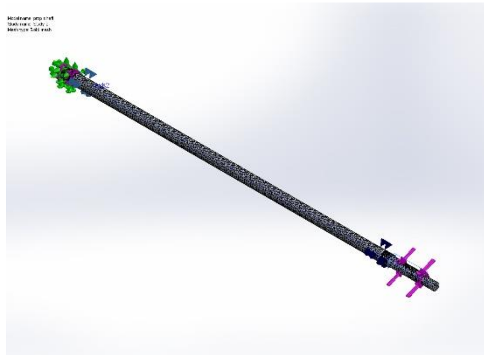
Mesh Information - Details

Total Nodes	58024
Total Elements	36440
Maximum Aspect Ratio	34.188
% of elements with Aspect Ratio < 3	92.5
% of elements with Aspect Ratio > 10	1.13
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:15
Computer name:	VINNYCALANDRINO

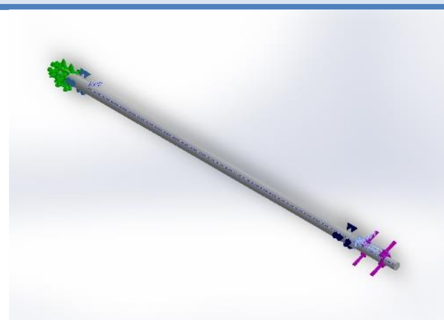


Mesh Control Information:

Mesh Control Name	Mesh Control Image	Mesh Control Details
Control-1		**Entities:** 26 face(s) **Units:** in **Size:** 0.077189 **Ratio:** 1.5

Control-2		**Entities:** 38 face(s) **Units:** in **Size:** 0.0828512 **Ratio:** 1.5

Sensor Details

Sensor name	Location	Sensor Details
Mass1		Value : 1.82840485 lb Entities : Result :Stress Component :VON: von Mises Stress Criterion :Model Max Step Criterion : Across all Steps Step No.:1 Alert Value: NA

Resultant Forces

Reaction Forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	95.1186	0.970887	-0.408834	95.1244

Reaction Moments

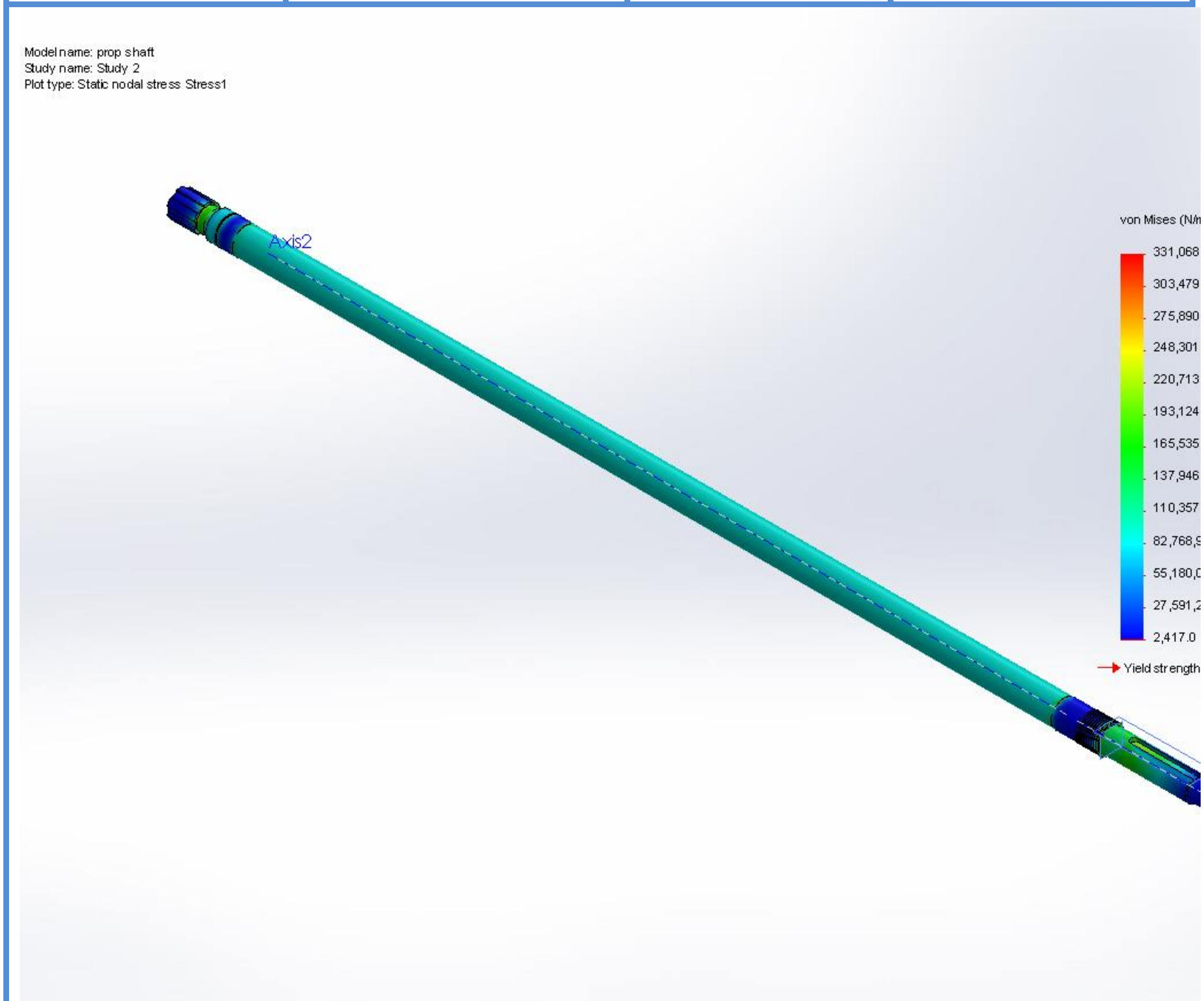
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

Beams

No Data

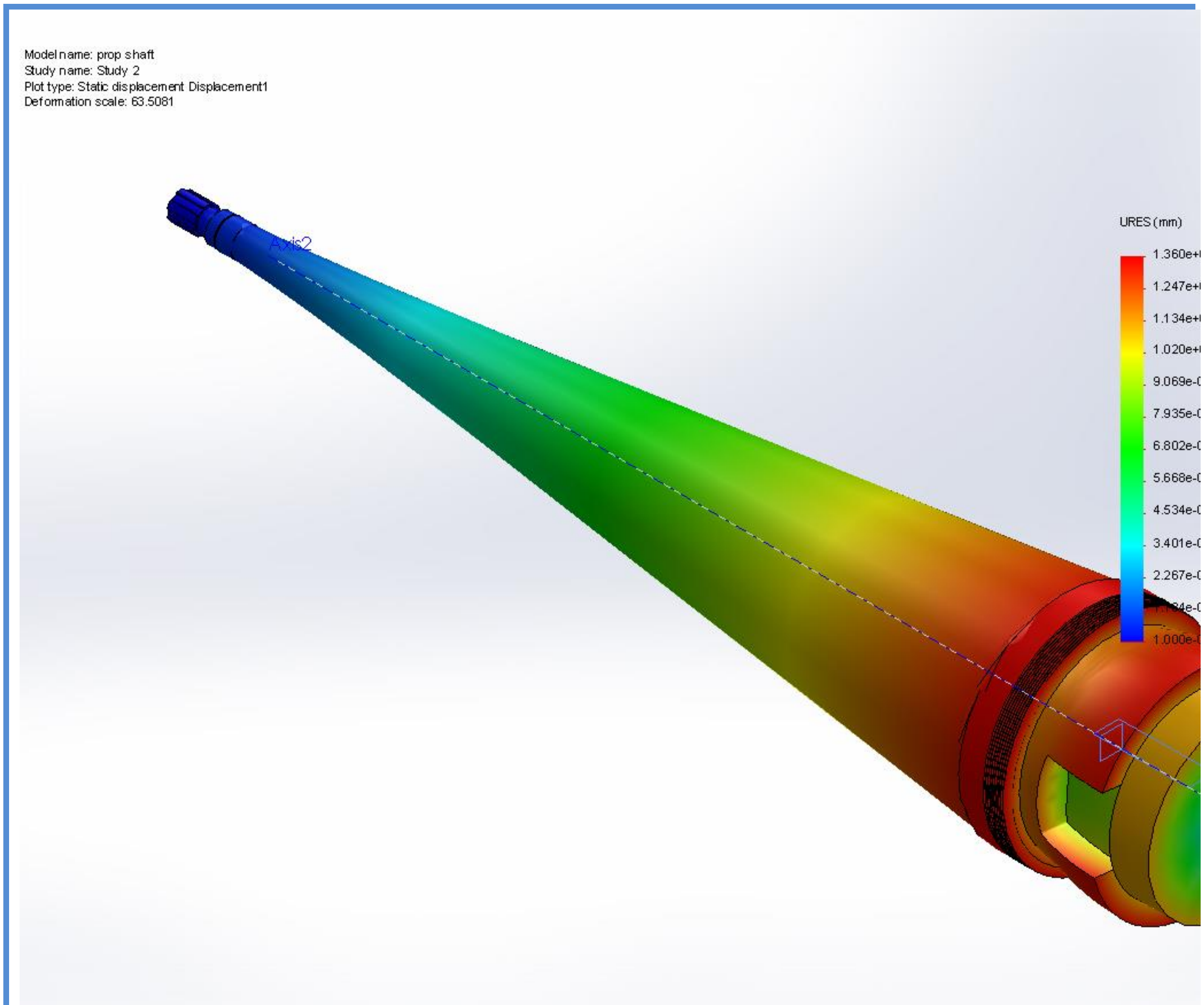
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2416.98 N/m^2 Node: 8237	3.31068e+008 N/m^2 Node: 38319



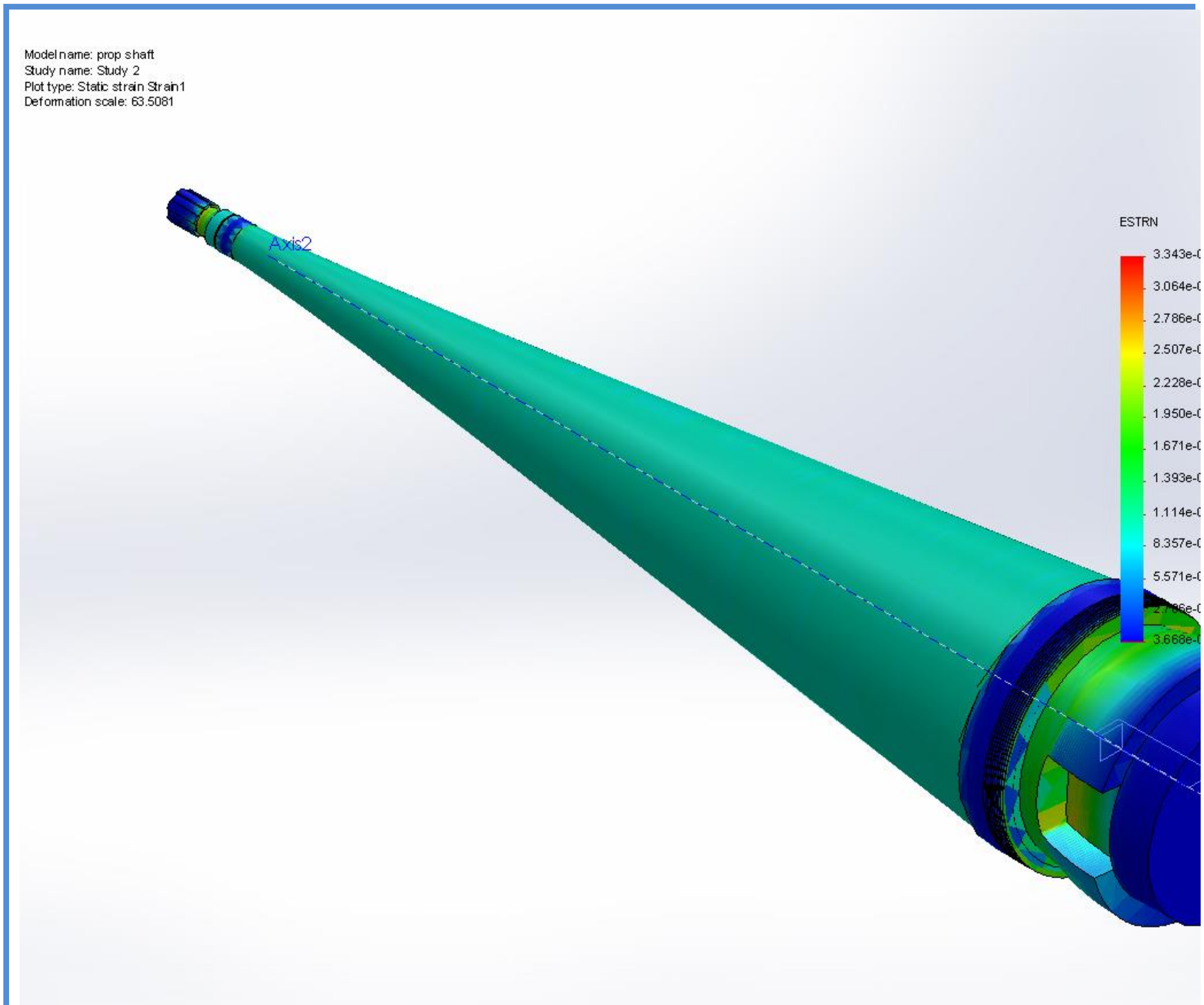
prop shaft-Study 2-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 3082	1.36032 mm Node: 53630



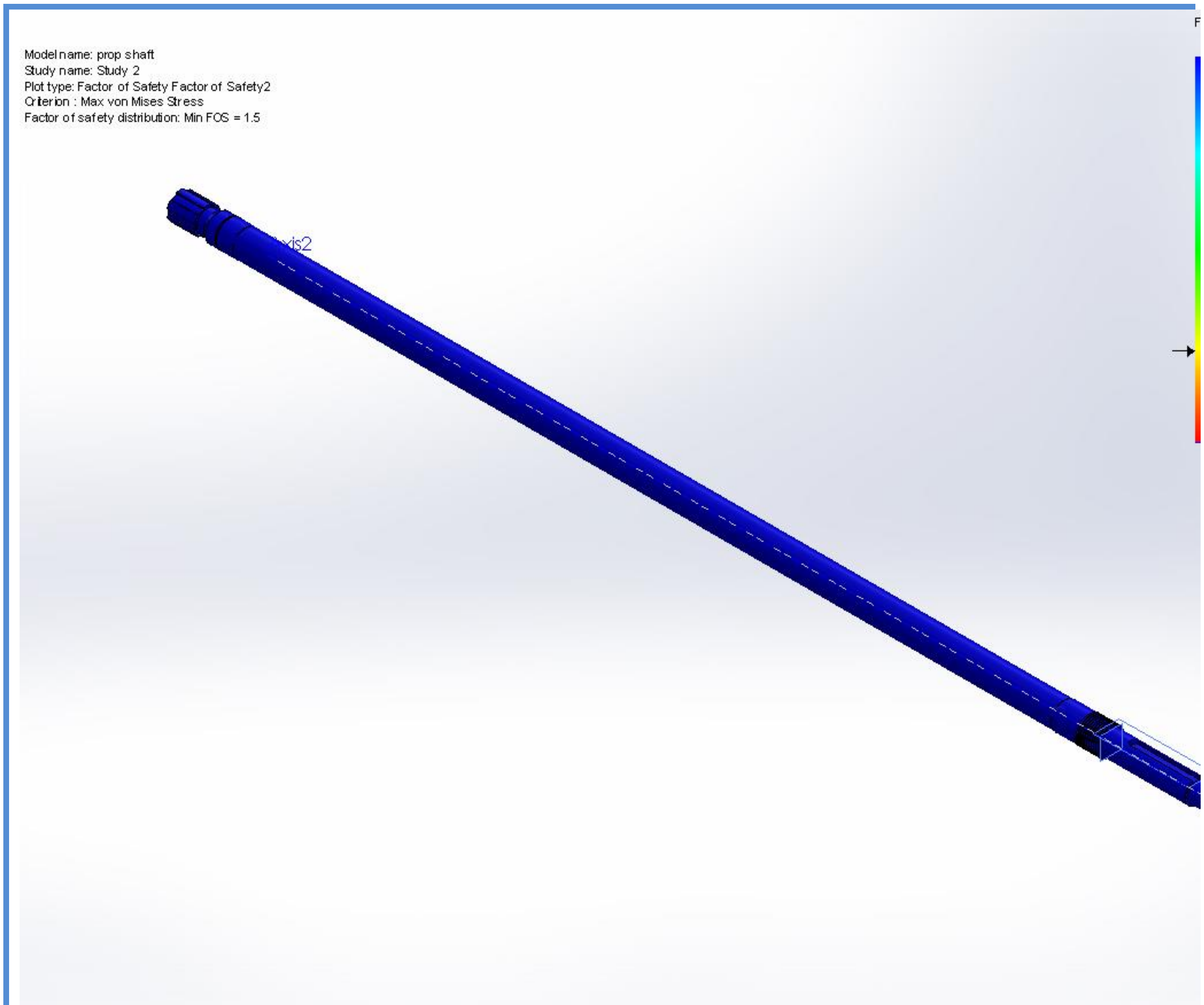
prop shaft-Study 2-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.66842e-008 Element: 10780	0.00334271 Element: 15703



prop shaft-Study 2-Strain-Strain1

Name	Type	Min	Max
Factor of Safety2	Max von Mises Stress	1.52536 Node: 38319	208938 Node: 8237



prop shaft-Study 2-Factor of Safety-Factor of Safety2

Image-2

Image-1

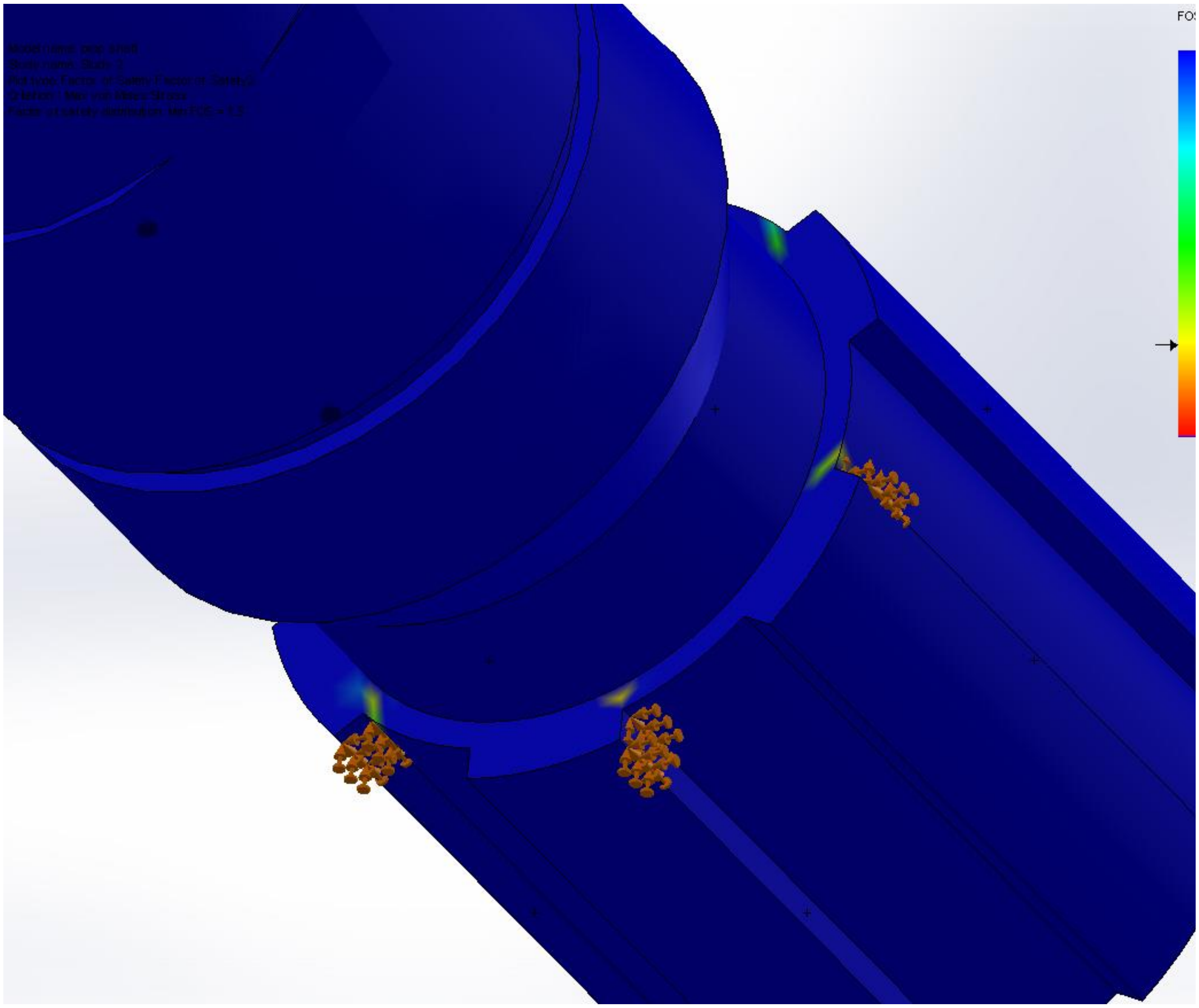


Image-5

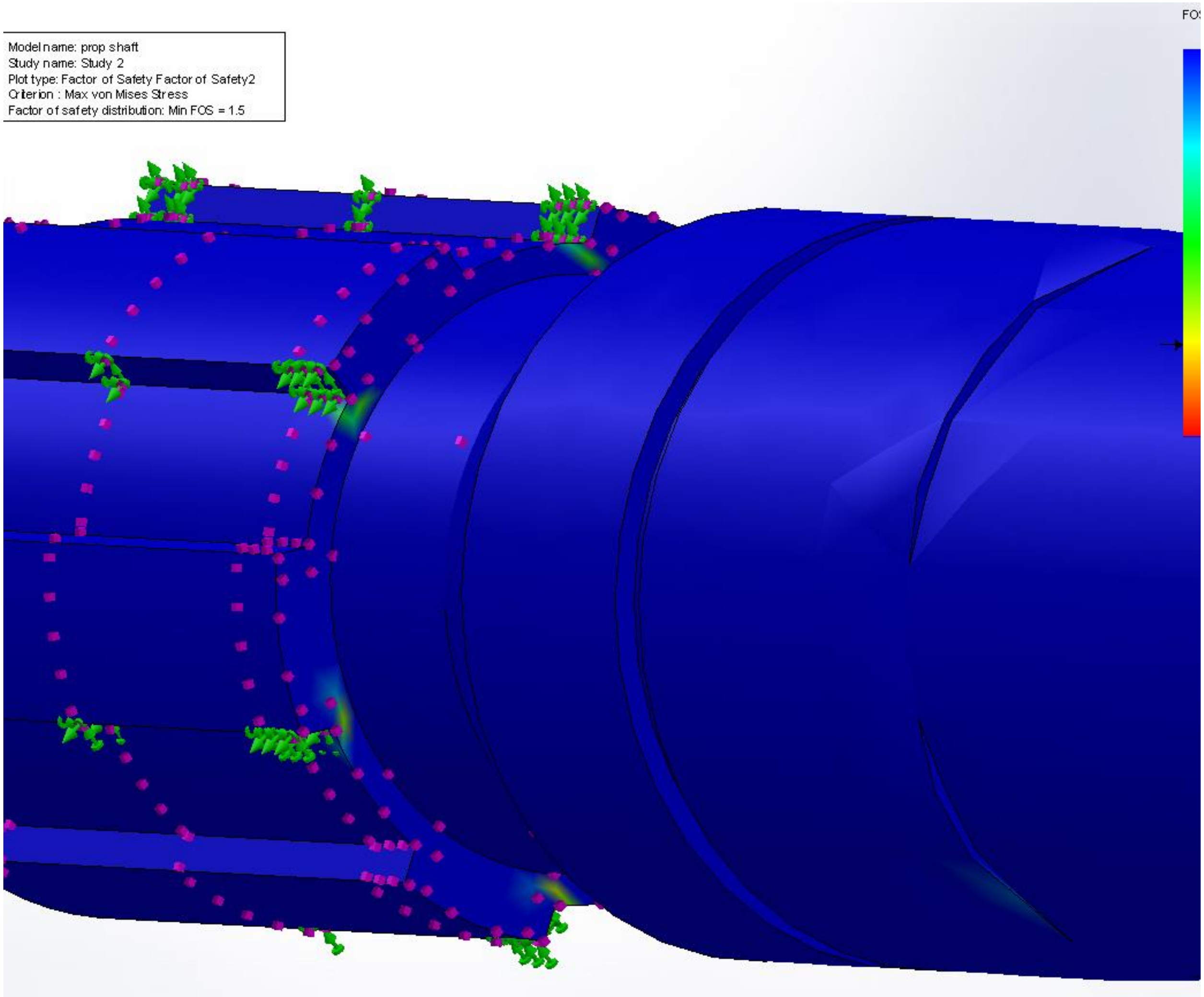

Model name: prop shaft
Study name: Study 2
Plot type: Factor of Safety Factor of Safety2
Criterion : Max von Mises Stress
Factor of safety distribution: Min FOS = 1.5

Image-6

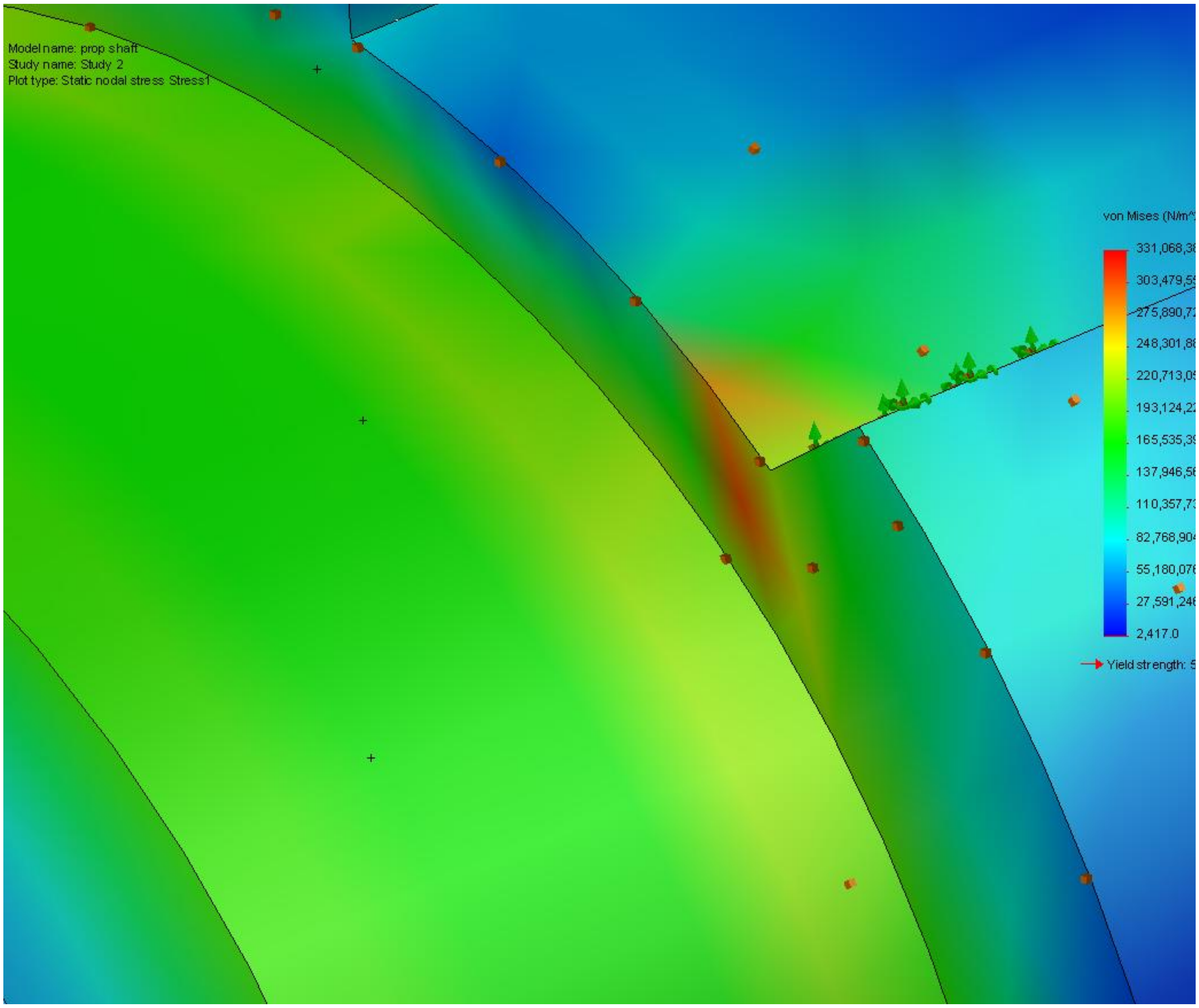

Model name: prop shaft
Study name: Study 2
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
331,068,38
303,479,55
275,890,72
248,301,88
220,713,05
193,124,22
165,535,39
137,946,56
110,357,73
82,768,904
55,180,076
27,591,246
2,417.0
Yield strength: 5

Image-7