Prototype Baja SAE UC 2015, Vehicle # 71.

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ABSTRACT

University of Carabobo, presents its fourth prototype in BAJA SAE OREGON 2015 competition, designed to fulfill the following objectives: a) To manufacture an economical vehicle, b) To optimize manufacturing processes, c) To improve power-weight ratio making a lighter vehicle, for obtaining a better performance. The prototype design contains six study areas: chassis-safety and ergonomics, suspension, transmission, brakes, steering and control systems (telemetry). The CAD / CAM software and studies to prototypes that participated in the previous competitions was used.

INTRODUCTION

For the prototype Baja SAE UC # 71 development, University of Carabobo Baja team focused on analyzing the previous vehicle designed performance and corrected the problems observed in BAJA SAE UTEP 2014 competition, which are: a) low average acceleration, b) skid plate damage during endurance, c) faulty suspension components, d) the judges observations regarding the optimization of the transmission system.

The project objectives are focused to solve on the indicated problems, the materials and miscellaneous standardization, decreasing the vehicle components number, weight reduction, adjusting the vehicle dimensions and improvements to facilitate the vehicle adjustment to the pilot physical conditions ensuring his comfort throughout the development of each test. Each one of these requirements were applied to the 6 areas of study, also implementing a new electronic acquire data system to vehicle performance.

FRAME

Frame design goals:

- To improve the chassis geometry and strength in different scenarios by impact analysis per action suspension system, rollover, frontal and side impacts.
- To reduce weight by varying diameter and thickness of the corresponding tubing of side members and reinforcements.

Design: The leading members were changed, changing welding points to bends in the tubes, providing greater stiffness to each member of the structure. The diameters and thicknesses of the side members and reinforcements are reduced, without affecting stress distribution and its structural rigidity, achieving a weight reduction of 35% over the previous prototype. Folds implemented in SIM member's cockpit, which extend from the RRH to the FBM, to maintain comfort and reduce the pilot cabin longitudinal dimension. At the front is given a tilt angle of 12 ° to the horizontal to improve the operation of the steering and suspension of the previous prototype.

FEA analysis were made to evaluate the core member's performance and distribute thicknesses of the side members and reinforcements, assessing conditions to which the vehicle structure will be subject by the action of the impacts of the suspension, frontal impacts, impacts side, rollover, etc. Material selection is based on the following analysis: a) frontal impact with a load of 5000 N (see Figure 1), b) side impact with a load of 5000 N (see Figure 2), c) rollover, considering the fall of the vehicle with a mass of 250 kg (including pilot mass) to a deceleration of 2g, with load applied on one of the FBM, d) torsion with 5000 N impact loads applied to anchorage points of the dampers front and rear (see Figure 3).

Material selection: Based on the FEA analysis results and the standard minimum specifications, the materials prototype chassis # 71 are AISI 4130 standard for all major, minor and reinforcement members, as this material has flexural rigidity and a bending peak better than AISI 1018 steel, considering the comparison between the bending strength between both materials through inertia ratio with the distance from the tube center to the outermost fiber and the strength of the material [1]. The core members have a diameter of 1.25 "x 0,065" thick, minor members and some reinforcements are 1 "x0.065" and 1 "x0.049", other reinforcements are 0.875 "x0,035".

Manufacturing: To manufacture the chassis, the GTAW welding method was implemented, using a filler ER 70-S

2 for the union of its elements. Additional bases were used to ensure proper integration of the elements according to the design.

SUSPENSION

Suspension design goals:

- To design a variable suspension system, static and dynamic, that will allow an efficient vehicle configuration to improve its performance.
- To implement a rear suspension system of the unequal A-Arm type that will allow the variation of the static and dynamic toe in order to improve the maneuverability of the vehicle in close curves.

Design: For the front suspension, a type A [2] control arm geometry was used, of unequal lengths, that will allow of unequal lengths, that will allow a 13 degrees camber with 5,5 inches of travel in the shock absorber, without interfering with the movement of the rod ends, obtaining as a result a total stroke of 14 inches (extension and compression) The front end shock absorber position was changed taking the mount up to the node that forms the intersection between the FBM and the SIM, thus allowing the distribution of the impacts received by the shock absorber through both members. The rear suspension design has two Á-arms of uneven lengths and similar to the front suspension, with an articulation in the lower A arm that provides a variation of the static and dynamic toe on the Wheel that will provide better maneuverability of the vehicle in narrow curves. The inclination of the shock absorber was changed, taking the upper mount close to the node of the rear arc, bringing the efficiency of the shock absorber to 90% with a 5.5 inches travel. This geometry provides the vehicle with a 12 inch travel (extension and compression) and 11 degrees variation on the camber. Also, with the new configuration, the travel of the ring inside the CV joint was reduced from 40mm to 20mm, that will allow the efficient use of 67 % of the inclination degrees of the CV joint.

Material selection and manufacturing: To manufacture the lower A-arms, steel piping AISI 4130 of 1" x 0,065" was used, and for the lower A-arms, 1" x 0,049" piping was used, and 0,875" in diameter and 0,035" in thickness for the front and rear respectively. To manufacture the A-arms, the welding method used was the TIG / MIG using steel and wood molds to ensure the correct assembly of the components. To manufacture the rear uprights, machined aluminum was used in a CNC milling machine. To manufacture the rear hubs, AISI 4140 steel was used and duly machines in a lathe and CNC milling machine. To reduce the weight of the rear hubs, the FEA analysis was used, in order to determine the sections that would allow to remove unnecessary material (See Figure 4).

STEERING

Steering design goals:

- Lowering turn radius based on Ackerman Criteria.
- To improve prototype's maneuverability by reducing steering wheel's angle, manufacturing a new steering box.

Design: prototype's geometry was based on Ackerman criteria[3], static Ackerman was used on knuckle's design using the 82% of it, prototype's correct width and wheelbase were also defined focused on lowering turn radius starting on 2 meters (2m) from 2014's prototype to 1,60 meters(1,6m) in the 2015's prototype. (See Figure 5). Meanwhile, to improve steering's capacity taking advantage of chassis attack angle, pitman arm was placed in front of wheel's turning axle allowing to increase turn radius of it. The new steering box consists on a rack and pinion system, where the amount of teeth were calculated in order to change rack's travel and reduce steering wheel movement from 7/8 in 2014 to 5/8 of a turn in 2015 prototype.

Material selection: Steering system's fabrication materials are AISI 4140 Steel for Rack and Pinion, AISI 1020 Steel for pitman Arms, AISI 4130 steel for steering arms and steering shaft and 6061-T6 Aluminum for steering box cover.

Manufacturing: In the Steering system's tubing cuts were used a manual cutter, and AISI 1020 steel billets were machined using a lathing process to create steering arm ends and steering shaft. For Rack and pinion fabrication, a milling machine process was used, and finally in the steering box cover fabrication was used a CNC Milling machine model Leadwell V20i.

TRANSMISSION

Transmission design goals:

- To optimize the transmission system as compared to previous prototypes, a gear transmission was designed.
- To establish a transmission ratio that would allow the maximum engine torque and to increase acceleration capabilities.

Design: Starting from the Briggs & Stratton 205232 0036-F1 engine characteristics that provides 19.66 Nm (14.50 lbs-ft) of torque at 2800 RPM and 10 HP at 3800 RPM and using a CVT pulley system identical to the one on the previous prototype. With this arrangement, a double reduction ratio is obtained in order to complete the transmission system. For the design of the system, a double reduction spur gear system was considered with 65 and 18 teeth in one gear and in the other pair 75 and 18 teeth. This will allow for a reduction ratio of 6.453: 1 [4]. For the gear box cover an aluminum structure was designed that will allow for a compact assembly, with surfaces that allow for a uniform load distribution, with internal ribs that will also provide a rigid and strong structure that will withstand torsion loads with Little material in the sections with light weight and ease of manufacture and without affecting its resistance.

Material selection: For the 65 and 75 teeth gear, AISI 4340 steel was used based on the FEA Analysis, considering the stresses involved. (See Figure 6)Fatigue conditions were also analyzed in terms of wear; therefore, good results in terms of bending and strength were obtained. For the shafts AISI 4140 steel was used and covers of the gear reduction box an A380 aluminum material was chosen according to availability in our country. This material provided good machineability and good results as it was evaluated according to FEA Analysis. (See Figure 7)

Manufacturing: To manufacture the shafts, CNC lathes were used in order to provide the required components precision. The 18-teeth gears were machined on the shafts in order to reduce the number of components during the assembly. To reduce the weight on the 75 y 65 teeth gears, the loads acting on the teeth were simulated thus allowing the drilling of holes in them and obtaining a 33% and 28% weight reduction respectively. Thermal treatments were applied to the gears in order to increase their hardness and strength against wear with a penetration of 0.7 to 0.8 mm on the surface. For the gear box covers, a CNC milling machine was used in order to improve the finishing and to obtain a higher precision in the machining.

BRAKES

Brakes design goals:

- To increase the braking pressure, still using the same pumps and calipers as the previous prototype.
- To design disks adjusted to the required measures and with a geometry according to an efficient thermal distribution.

Design: Considering the increase torque of the system in the transmission for the new prototype, the increase in brake pressure was obtained by changing the ratio in the brake pedal distance from 5:1 in the 2014 prototype to 7:1 in the new prototype. (See Figure 8), making it easier for the pilot to apply a lesser load on the pedal to activate the system and increasing the fluid pressure [5]. Also, new brake discs were designed and “custom made” including a better thermal distribution and fatigue to reduce weight and resulting in a rear disk of 7.5 inches in diameter, and the two front discs of 6 inches in diameter. Both the calipers and pumps used in the previous prototype were kept in this new prototype. For see rotor brake disc, (See Figure 9)

Material selection: According to the design, the different components of the brake system were made of 6063-T5 Aluminum for the pedal support, pumps base and brake pedal. AISI 4140 steel was used for the rear disc support and 1020 steel for the front and rear discs.

Manufacturing: To manufacture the brake discs and the brake pedal components, a water metal cutting procedure was used, and they were ground afterwards. Components such as the rear disc support, the pumps base and the pedal support were machine don a CNC milling machine.

ERGONOMICS AND SAFETY

Ergonomics and safety design goals:

- To design a seat focused on improving –on track-driver’s comfort.
- Improving vehicle’s Aerodynamics focused on body work.

Design: lateral support for torso was added in order to design a more comfortable seat during cornering, keeping driver’s correct position in this situation [6]. Considering weight reduction general criteria, single inside mount strut used in 2014 prototype was changed, using now a two –held to chassis- pieces reducing weight by 2.2kg.

In body work, front section was design in order to be removable and provide an easy access to brake and steering adjust systems. A double wall skid plate was designed in order to bring more safety to the driver and minimizing gaps on it, lateral sections and firewall were designed to be independently attached to chassis.

Material selection: for safety parts and seat Materials like body work and seat base was used a 3003-h5 aluminum sheet with 6mm thickness. For seat bottom and lateral support padding, 2” and 1“yellow foam was used respectively. 300mm of 1” thick silver and 200mm of 1” green foam were used for seat back. 2m of -fire proof- drill fabric was used. Seat mounts and seat lateral support are made of AISI 1020x 0.090in thick steel.

Manufacturing: for Seat manufacture an aluminum base strut was used, with steel seat back support, adding different foam thickness until getting the shape wanted, then attached to chassis trough screw and bolts. Body work, firewall, skid plate and panels were attached to chassis with rivets, except for front section which is attached with screws, so they can be easily remove.

TELEMETRY

Telemetry design goals:

- To obtain remote information and in real time of the parameters of the prototype (RPM, speed, fuel level and acceleration) to determine the dynamic status of the prototype performance. This information can be saved for reference. An ECU, an OBD communication and an integrated ELM327 model will be used in order to visualize the program parameters already existing and commercially available [7][8][9].

Design: The design is centered on an Arduino microcontroller which emulates the OBD communication and processes the data corresponding to the parameters that are obtained through sensors located in different places of the prototype. Such parameters and sent afterwards to the wireless communication modules, model Xbee Pro 900 HP.

Material selection: For the wireless transmission modules various DiGi models were evaluated and that worked at 900 MHz, while concerning the microcontroller, 3 different brands were evaluated taking into consideration the processing speed, the availability of analog inputs and a comfortable interconnection with the wireless transmission module. The sensors selection was made comparing the different sensors that produced the same objective and choosing the one with the highest response speed and the lowest power consumption as well as the lowest cost.

Manufacturing: The interconnection of all the devices was carried out inside a box that contains the Arduino, the Wireless Proto Shield and the wireless transmission module. In this shield, all the necessary connections were made for the energy supply and grounding of the sensors, as well as the accelerometer and the circuit that processes the RPM signal.

CONCLUSION

The 2015 design presents a cheaper version of the vehicle, lighter, more compact and resistant. It also optimizes the transmission, increases the the distance from the ground to the skid plate, improved acceleration and a better geometry of the suspension system for a better performance on the track and a better configuration prior to competition. The number of parts manufactured per hour was also increased thus reducing costs. A data collection system was implemented that will allow for the information to be collected in real time for parameters such as speed, acceleration and fuel level.

ACKNOWLEDGMENTS

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CONTACT

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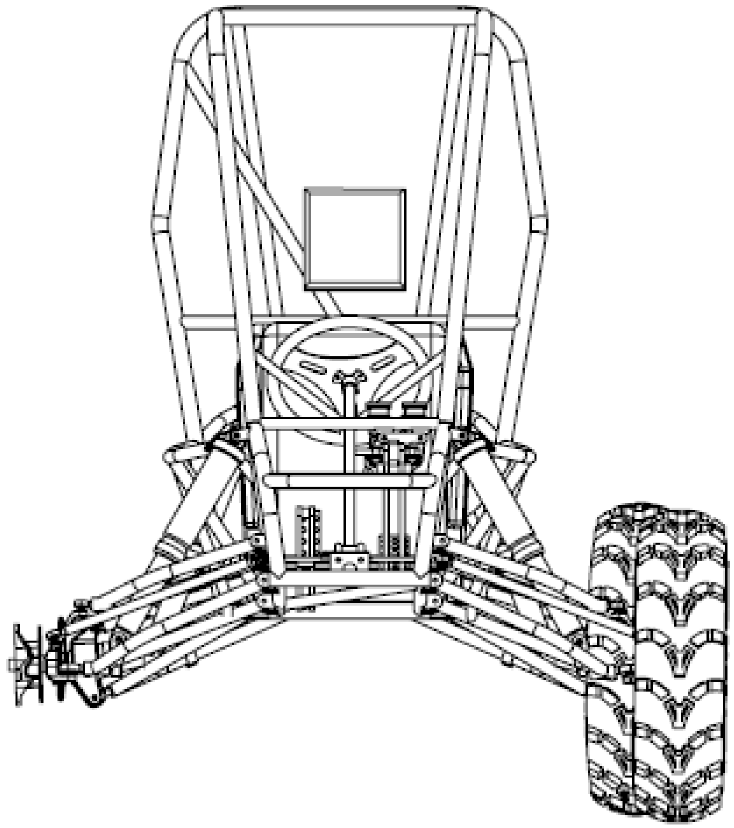
DEFINITIONS, ACRONYMS, ABBREVIATIONS

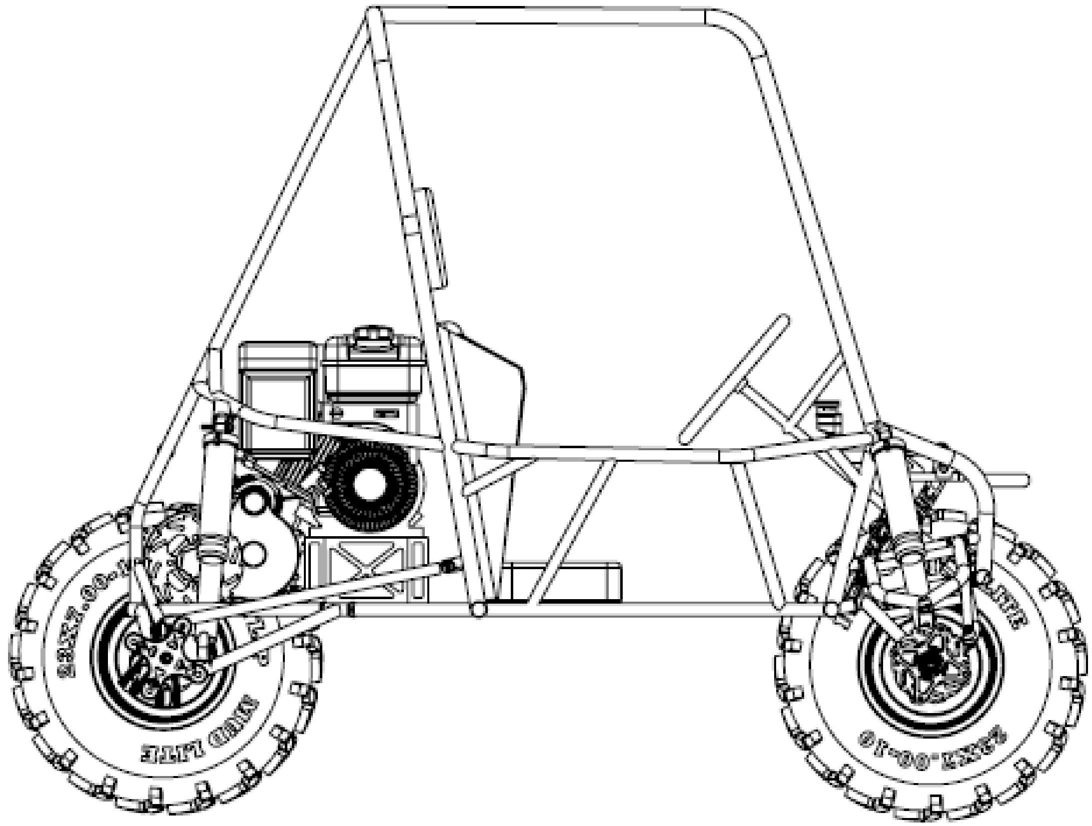
CNC: Computer Numerical Control
CVT: Continuously Variable Transmission
ECU: Engine Control Unit
ELM327: It's a programmed microcontroller produced by ELM Electronics.
FEA: Finite Element Analysis.
FBM: Front Bracing Member
GTAW: Gas Tugstene Arc Welding
OBD: On Board Diagnostics
SIM: Side impact member
RRH: Rear Roll Hoop



	SUPERFICIAL FINISH	GEOMETRICAL TOLERANCE	TOLERANCE AND SETTINGS	OTHER RULES

		Date	Name	
University of Carabobo Mechanical Engeniering	DRAWING	03-27-15	Wilmer Rodriguez	
	REVIEW	03-29-15	Daniel Cavero	

Scale 1:10	FRONT VIEW	PROTOTYPE BAJA SAE UC # 71



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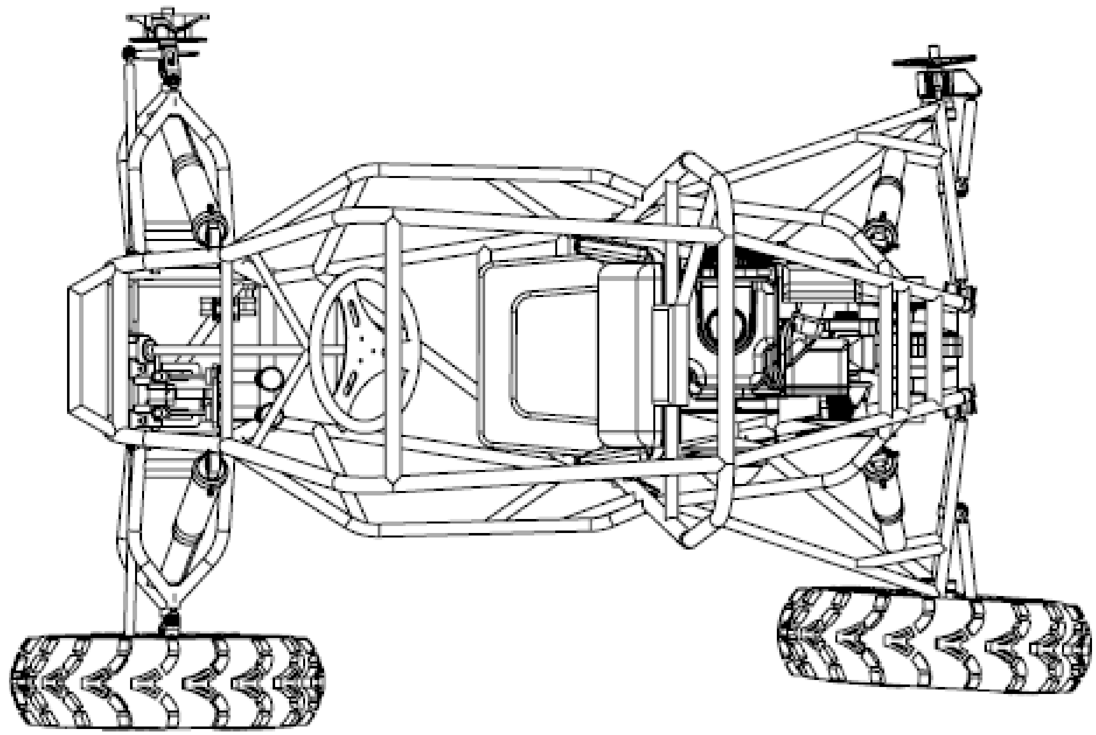
		Date	Name	
University of Carabobo Mechanical Engeniering	DRAWING	03-27-15	Wilmer Rodriguez	
	REVIEW	03-29-15	Daniel Cavero	

Scale 1:10	SIDE VIEW	PROTOTYPE BAJA SAE UC # 71



	SUPERFICIAL FINISH	GEOMETRICAL TOLERANCE	TOLERANCE AND SETTINGS	OTHER RULES

University of Carabobo Mechanical Engeniering		Date	Name	
	DRAWING	03-27-15	Wilmer Rodriguez	
	REVIEW	03-29-15	Daniel Cavero	

Scale 1:10	TOP VIEW	PROTOTYPE BAJA SAE UC # 71

Figure 1: Front Impact

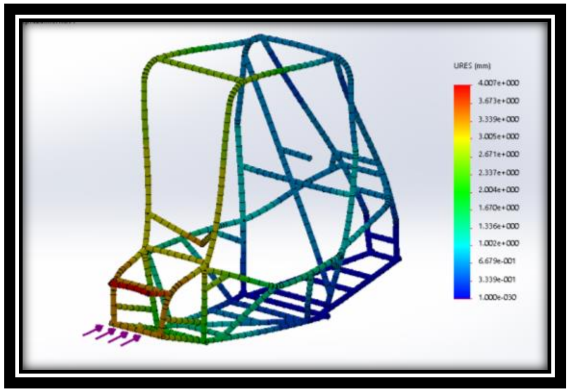


Figure 2: Side Impact

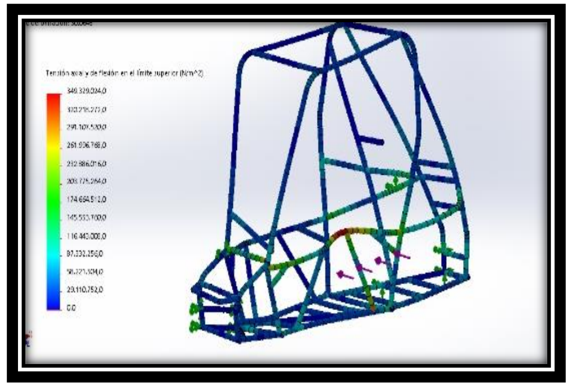


Figure 3: Rear shock Impact

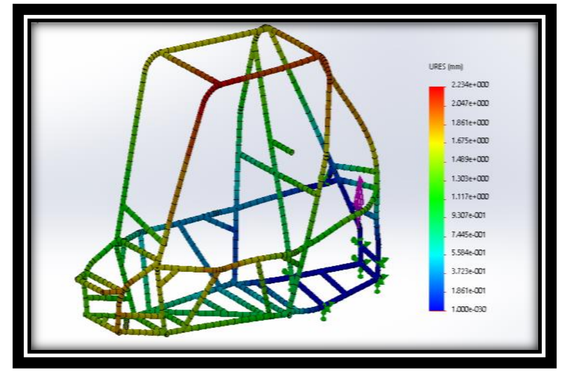


Figure 4: Rear Hub

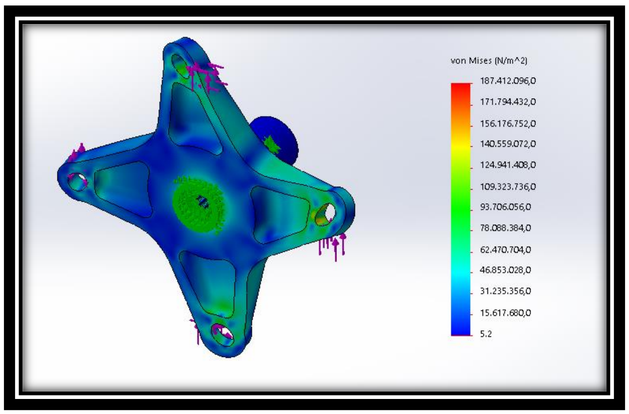


Figure 5: Steering Knuckle

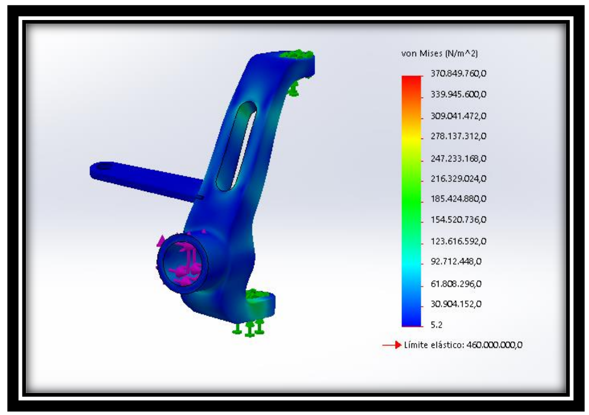


Figure 6: Gear 75 teeth

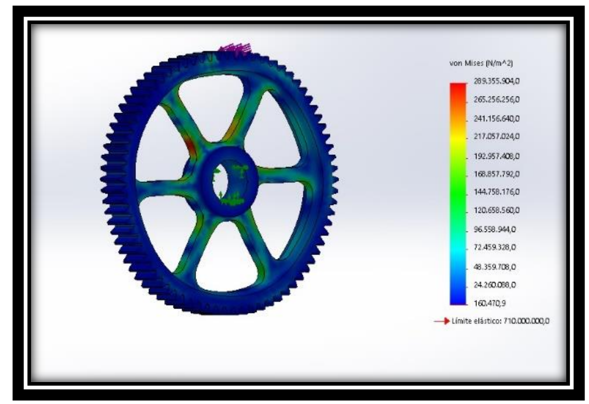


Figure 7: Gear box cover

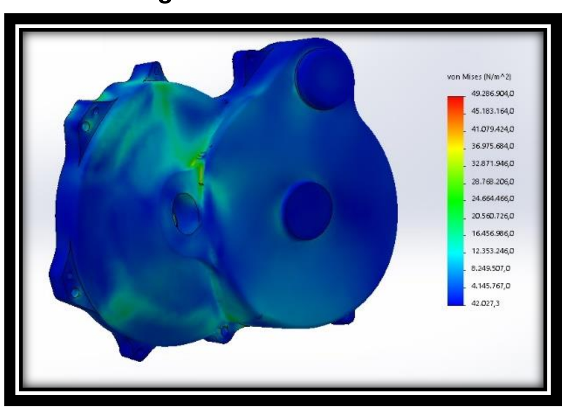


Figure 8: Pedal Assembly

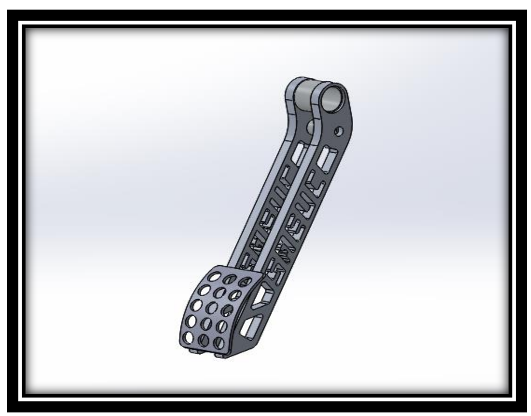


Figure 9: Rear brake disc / FDS