Design and Theory of Powertrain of Formula Student {FSAE} Car

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Abstract - *In this paper the design and analysis of a powertrain is specified for the FORMULA STUDENT race car. Over the years, much of the design of this system has been carried out through an iterative trial and error process, so the study attempts to identify the scientific and engineering principles pertaining to the design of this system. The paper discusses the theory and basic design criteria of the drivetrain that is used to transmit the power and torque to the wheels and tyres. The main objective was to design and fabricate a more reliable and robust powertrain by making the system as light as possible. We needed this system to be light in weight as we had to increase the power to weight ratio. Also, the design parameters that are associated with the design principles are considered and taken into account for proper results and validation. By keeping our design and manufacturing in accordance to the FORMULA BHARAT & SAE SUPRA rules we have reached our goals.*

***Key Words*: Drivetrain, sprocket-differential.**

1. Introduction.

In design, development and fabrication of a formula style race car, the powertrain is an important system which deals with the transmission of power from the engine to the wheels and all necessary components in between. The major components of the drivetrain are engine, intake, transmission, differential, axles, and wheels. Every single one of these parts needed to be selected for a specific goal and properties, and are integrated with the other subsystems. Keeping in line with our goals for simplicity and affordability while remaining competitive, all available options for each element were researched to identify the best for the application. Once the powertrain is designed and fabricated, it is important to ensure that it is tested to verify the package meets the design requirements that were previously established. After the powertrain testing has finished, it is then essential to implement the package into the entire vehicle design. This is where component packaging will be determined. While these sections have been separated into distinct categories, there is a very close tie between each of them.

2. Basic Project criteri

There are a few constraints that apply to all aspects of designing a drivetrain of a formula style car and these are discussed in detail in the majority of the following sections in such a way that the complete powertrain is designed in correspondence to the SAE-SUPRA & FORMULA BHARAT rule books.

Weight: Weight reduction is a want, that applies to every aspect of the drivetrain. This weight reduction allows the vehicle to retain maximum power to weight ratio.

Durability / Reliability: It is crucial that we develop robust drivetrain design that will allow maximum power and torque to be transmitted to the wheels and tyres. The complete drivetrain is designed to withstand unexpected external forces and stresses.

Aesthetics / Neatness: One of the important aspects in making the drivetrain or complete vehicle is neatness. All the systems attributed to the FSAE car are well manufactured. If this is not taken into consideration this will result in sloppy assemblies and a negative aesthetic quality.

Performance: While the focus this year was on creating durable designs there was a desire to have everything perform well to allow the team to not only finish, but excel in the competition.

3. Drivetrain Theory.

Drivetrain is a system that couples the engine to the wheels & tyres, which makes use of the mechanical engine power to rotate the axles.

We use theoretical data from the HONDA CBR 250R specs sheet, papers on performance drivetrain and several books on automotive transmission.

Now for designing the transmission system i.e the drivetrain, we need to consider the desired maximum weight of the vehicle, acceleration, maximum top speed, and maximum torque on the wheels.

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Table -1: Specifications of Engine

Type of engine	Single cylinder
Displacement	249.60cc
Maximum Power	19.5 KW {26.5 PS} @8500rpm
Maximum torque	22.9 Nm @7000 rpm
Compression ratio	10.7:1
Bore * Stroke	75 * 55 mm
Engine Description	4 stroke liquid cooled, 4 valves, DOHC
Fuel system	PGM Fuel injection

4. Sprocket-Differential.

The sprocket differential is a combination of a differential and a sprocket, in other words it is also known as chain drive differential. As the name goes, this is used to transmit the power from the engine to the remaining drivetrain. Now to get this sprocket-differential manufactured we first designed the sprocket & later replace it with the crown wheel on the open differential. Initially to design the sprocket, we need to consider the desired maximum weight of the vehicle, acceleration, maximum top speed, maximum torque on the wheels. To derive the number of teeth on rear sprocket (sprocket on differential) we have done several iterations of calculations with different number of teeth by which we get our required results. From this we have finalised 45 teeth on the sprocket. So, the secondary reduction ratio is

Reduction Ratio = 45/14 = 3.214

Sprocket material= C40

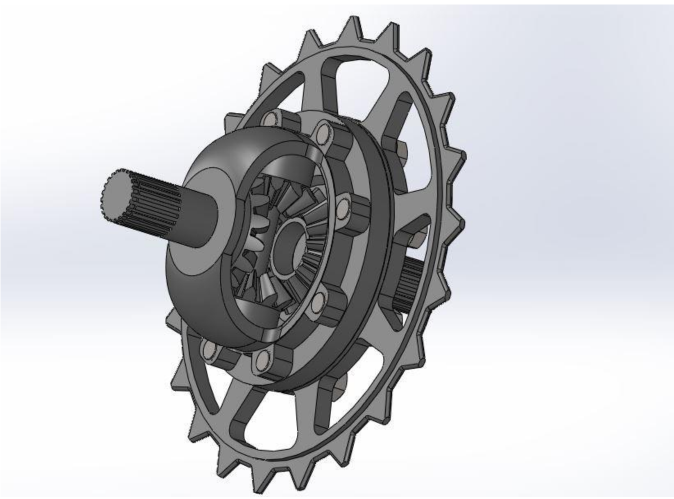

Fig. Sprocket-differential

After the sprocket is designed, we analyse it for stresses & deformation that are caused due to the radial and tangential forces. These radial and tangential forces are the main reasons for causing any of the deformation in the sprocket

Analysis of sprocket:

We use ANSYS & NX NASTRAN for the analysis and validation of the design. Unless the design has been topologically optimised, every part in the assembly weighs more than it need to. Extra weight means excess materials are being used, loads on moving parts are higher than necessary, energy efficiency is also being compromised so we use ANSYS topology optimisation feature.

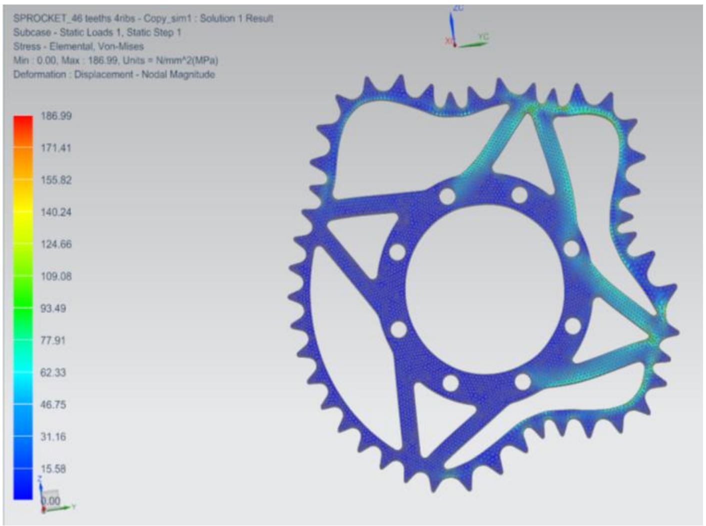

Fig. Stresses on Sprocket

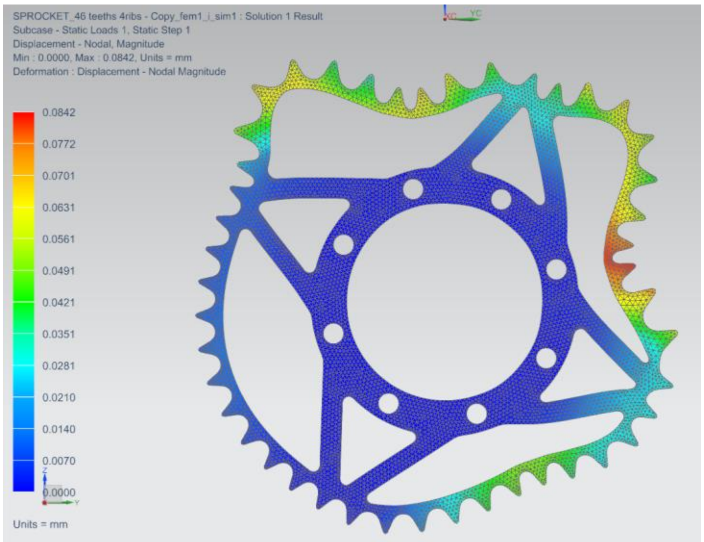

Fig. Deformation of Sprocket

5. Differential Carrier.

The differential carrier is the mounting assembly for the entire sprocket-differential. This differential carriage is mounted on the either side of the differential. The differential has its OEM bearings and a bearing race of the same is made in the carrier. All of this securely mounted on to the rear roll hoop.

Differential carrier mtl: Al 7075 T6

Analysis of Differential carrier:

As for the differential carrier the stresses were seen on the narrow mounting section where it is mounted to the rear roll hoop. After analysing the differential carrier in ANSYS we get the maximum stress that is within the permissible limit of the material used for the differential carrier.

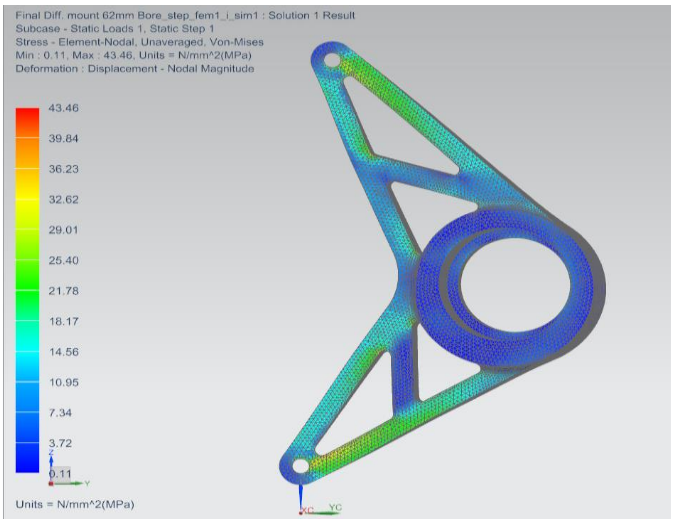

Fig. Stresses on differential carrier

6. Final Assembly.

In the final assembly for the drivetrain the entire sprocket-differential along with its differential carrier is securely mounted to the rear roll hoop. Now the half shafts are fitted into the differential on the either side. While the other side of the half shafts that have CV joints on them are fitted onto the wheel assembly. The figures show the final assembly of the drivetrain that is done on the frame with proper mountings.

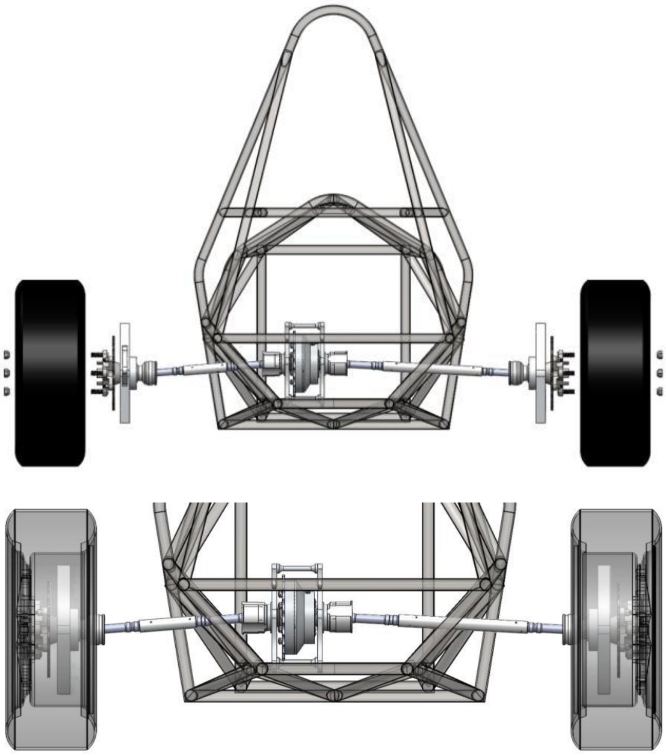

Fig. Final Assembly of the drivetrain

7. Conclusion.

We designed a drivetrain of a FORMULA STUDENT race car. We have achieved the purpose of designing the entire powertrain system according to SAE-SUPRA & FORMULA BHARAT rulebooks and ultimately the achieved high power to weight ratio without compromising the drivers safety.

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