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Research Article

RESEARCH PAPER ON OPTIMIZATION OF FSAE VEHICLE IN DESIGN AND MANUFACTURING

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A R T I C L E I N F O

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A B S T R A C T

The project to build an FSAE vehicle was carried out in Department of Mechanical Engineering, Chandigarh University to compete in the Formula Bharat 2018 – A national level competition, held at "Kari motor speedway". The process used for design and manufacturing of the open cockpit formula student race car, along with considering the driver's safety, was optimized based on material selection, manufacturing processes, selection of drivetrain, differential and gear ratio. Further, to achieve the maximum power output in terms of acceleration and top speed, various simulation processes were done in advanced simulation and designing software and discussed.

INTRODUCTION

Formula Bharat is an engineering design competition organized by Mobility Engineering Consortium which evaluates the design and prototype manufactured by participants in terms of cost, design, performance and marketability. The final decision of which, is taken by FORMULA BHARAT committee. This competition is conducted once in a year where teams of more than 60 universities across the country put their developed prototype up against each other in this competition. The purpose of this research was to make an open cockpit type race car that should successfully compete in the competition. For this, the suitable material selection for chassis, gear ratio for the transmission system, calculation for rack and pinion in steering system, braking system and the overall driver's safety was taken into consideration. To efficiently optimize this process, different CAD software: Solid works, ANSYS v15.0, LOTUS AND CATIA were used, to simulate the actual stress and strain produced on the car.

DESIGN METHODOLOGIES

The 3d model of the Chassis was firstly designed in the Solid works software and further checked under applied load after performing number of iterations for the stress analysis by performing simulation under the desirable conditions. While performing this simulation, the weight of overall components and system on the chassis along with the drivers' weight and the safety of the driver was taken into consideration while finalizing the chassis design after getting the simulation results on the Solid works software.

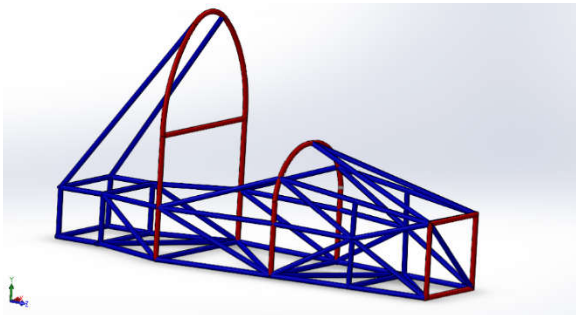

Fig 1 Chassis designed in Solidworks v2017.

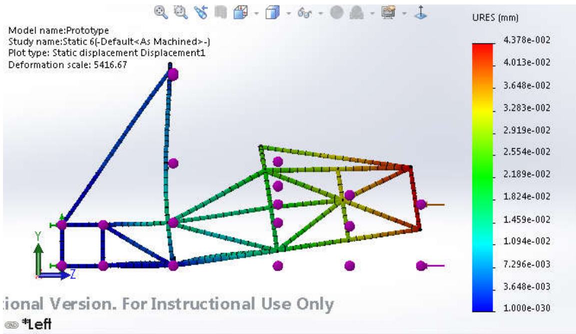

Fig 2 Simulation of chasis under applied load

Chassis Material

The frame was built utilizing AISI 1020 seamless steel pipe space frame design. The simplicity of manufacturability, rigid structural guidelines (disposing of the requirement for material

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testing) and the decreased expense of the steel are the essential advantages that result in the assurance of the steel space outline. The chassis was aimed for a frame weight of 41 kg or less, this was accomplished through careful consideration of member placement and component packaging, the data for the material used is provided in table.1

Table 1 Material properties of AISI1020

Carbon %	0.18-0.23
Density (kg/m3)	7.7 x 103
Tensile yield strength (MPa)	350
Tensile ultimate strength (MPa)	400
Modulus of elasticity (GPa)	200
Poisson's Ratio	0.29

Steering system

Rack and pinion mechanism was chosen because of its different preferences over other directing components i.e.; its physically working framework, ease, basic working and assembling and its brisk reaction system. Steel 8620 material was utilized for rack andAI6061 wasemployed for housing and other components., technical specifications for the steering system are provided in Table2.

Table 2 steering system (technical specifications)

Steering Ratio	1:1 ~ 4:1
Rack length	18"
Rack Travel	0.971 per 90· rotation of steering wheel
Steering angle	24.67 degree
Ackerman angle	19.82 degree
Tie rod ends	12.186"
Steering arm length	4.19"
King to king pin	43"
Steering Wheel Type	Detachable type with quick release steering hub

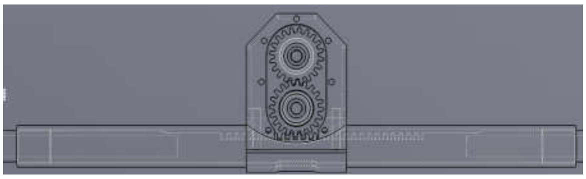

Fig 3 Design of Rack-Pinion assembly in Solid works Software

Transmission

The gear ratio was decided based on the primary tooth gear ratio which depends on the amount of torque and power it can produce.

Lowering the gear ratio increases the top end speed whereas, increasing the gear ratio on the other hand increases the acceleration and bottom end power. Keeping this in consideration secondary gear with 44 or 45 teeth was chosen that resulted in the gear ratio of 2.93 and 3.0.Secondary gear with 45 teeth was chosen over 44 teeth because it has higher pitch diameter which results in higher top speed. The secondary gear ratio of 1:3 was set was designed as it produced the output from the secondary sprocket to the differential producing maximum performance in terms of top speed and acceleration.

A back-wheel drive setup was believed to be the obvious choice. Given the generally short wheel base, weight transfer to the rear tires improves forward push potential in a rear wheel drive vehicle and subsequently, amplifies forward increasing speed.

Once the rear suspension sort of a swing arm was chosen, a chain drive was decided for effortlessness and adequacy. A chain drive takes into consideration simple changes in the measure of length, can accommodate changes in sprocket distance, and is moderately economical, in comparison with shaft drives.

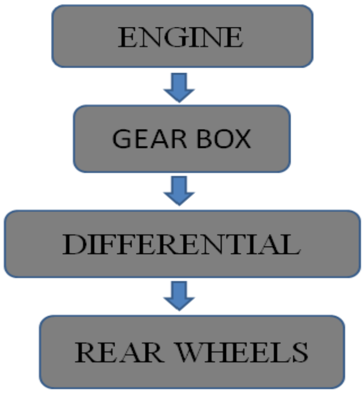

Fig 4 Flow chart

The mechanism that transmits the power developed by the engine of automobile to the driving wheels is called the Transmission System. It is comprised of the following elements-

- Clutch
- The gear box
- Chain Drive
- Differential
- Rear axle
- Wheel

The Data Originated by Employing the Gear Ratio 1:3 is Shown Below

Engine

KTM RC390
Engine - 373.2 cc
Top Speed- 167 km/h
Power- 30.04 kW (40.29 hp) @ 8,600 rpm
Torque- 32.92 N-m @ 6,800 rpm
Gear Box- 6 Speed

Chain Drive

Power transmitted through a chain and two sprockets with (Ratio 1:3)
Drive Sprocket with teeth (Front) - 15
Driven Sprocket with teeth (Rear) - 45
Drive Rpm (Front) - 8600
Driven Rpm (Rear) -2866.66

Basic Sprocket Dimensions

Front Sprocket

No. of teeth - 15
Chain Pitch – 0.625 inches
Diameter- 3.00inches (76.35 mm)

Rear Sprocket

No. of teeth- 45
Chain Pitch- 0.625 inches
Diameter- 8.95 inches (227.577 mm)

Sprocket Centre To Centre Distance

Front Sprocket- 3.00 inches
Rear Sprocket- 8.95 inches
Number of links- 65
Distance C to C- 18.435 inches (468.122 mm)
Chain length- 40.625 inches (1031.87 mm)

Tensile Strain

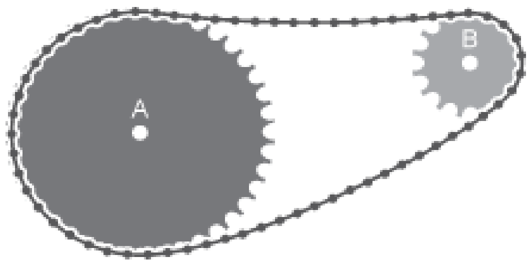

Fig 5 Primary (A) and Secondary (B) gears.

The difference between the sprocket tangential velocities is the tensile strain rate in the chain, mathematically,
$x=\omega_A R_A-\omega_B R_B$,

Where

- x is the tensile strain.
- ω_A, ω_B are the sprocket angular velocities.
- R_A, R_B are the sprocket pitch radii.

$\omega = \frac{\pi DN}{60}$
$\omega_A R_A = 34.1588 * 0.1137885 = 3.8868786$
$\omega_B R_B = 34.3800*0.038175 = 1.324565$
$X = 2.574422$ mm

Brake system

Disk brakes are chosen over drum brakes as they occupy relatively lesser space and are more efficient in terms of their braking efficiency and heat generated in the braking process, which is 60% less as compared to drum brakes. BYBRE 4 piston calipers with integrated master cylinder system of KTM390 for the maximum braking efficiency. The car was designed to couple calipers with a set of AP Racing 19mm bore master cylinders front and rear. Together with a Tilton bias adjustment bar, and 4.8:1 pedal ratio, the system efficiently provides the required braking force to bring the 257 kg car including the driver to a halt.

The dissipation of heat developed due to the transfer of energy of the prototype during the motion was efficiently accomplished by using a penetrated 6.35 mm thick mild carbon steel rotors on the front and back of the vehicle. To serve the purpose, steel material was chosen since it is impervious to twisting and gives sufficient warmth exchange properties. The rotors are penetrated to give better cushion nibble and molding and additionally to diminish weight however much as could be expected.

Suspension

The suspension was designed in LOTUS Software taking into consideration that it acquires low weight. At the expense of customizability, the suspension was designed to be financially cost effective, sturdy, and lightweight. Test results were offset with the designed hypothetical plan to deliver the final suspension geometry. This brought about the wheelbase of 1600.2mm.

Figure.3 represents the Isometric views of front and rear wishbone configuration.

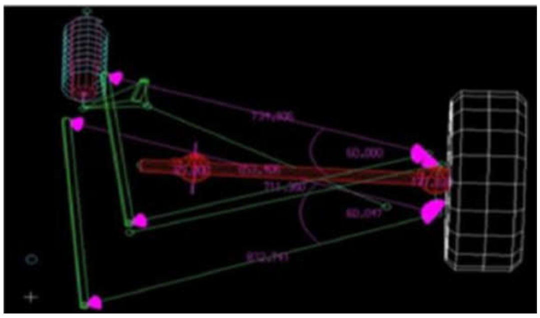

Fig 6 Front configuration

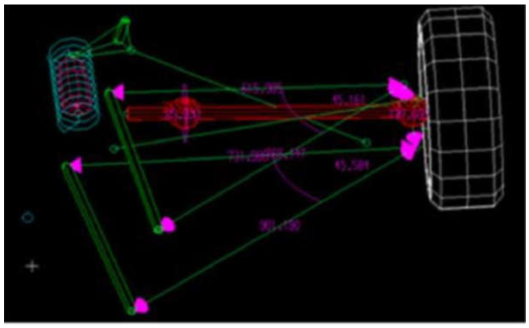

Fig 7 Rear Configuration

Driver's safety

The driver's safety is an integral part of any vehicle while it is designed and manufactured. Firewall (Glass wool packed in between thin GI sheets of thickness 0.5) was mounted behind the backseat of the driver to protect the driver from the heat originated because of engine on the back side. It also protects the driver from getting hurt in case of any fire incident. Impact Attenuator (IMPAXX™ 700 Energy Absorbing Foam)was mounted on the front side of the chassis which absorbs approximately 70% the stress during collision according to the IA report. It is an environmentally-friendly, recyclable material and meets governmental flammability requirements for interior automotive components. IMPAXX foam is a non-CFC, non-HCFC, non-HFC material.

CONCLUSION

The paper discusses the basic underlying requirements needed to design and manufacture a formula student race car. The optimization of the components and assemblies which are to be mounted on the chassis was done by performing simulations and applying desirable data, using advanced modelling and simulation software's along with selection of the suitable chassis material for the prototype. Best possible gear ratio of 1:3 for the formula race car was decided to achieve the maximum acceleration and top speed at the same time. Improvement in the design have also been made keeping in consideration the driver's safety.

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