DESIGN OF STUDENT FORMULA-1 VEHICLE SYSTEMS

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ABSTRACT

This paper is for design and details of various systems related with student formula one vehicle. This includes all design considerations, calculations and FEA analysis of various components used in the vehicle systems. Vehicle systems are designed to met international standards considering all safety regarding driver and of systems while being in affordable price. The important factors which are considered during design are for high performance, safety; various technical requirements and interchangeability principle which will be remain effective at very high speed more than 100 km/hr.[6]This study aims to design, develop a roll cage and other systems for student formula one vehicle in accordance with the rulebook of SUPRA 2015 provided by SAE INDIAfor designing the whole vehicle it started with design of single components individually with reference of other components also to avoid any mistake in working as a whole system.The main design aspects are performance, reliability, endurance strength and also low cost. To check design at various steps of design procedure we also done with Design Failure Mode Effect Analysis (DFMEA) and also Design Validation Plan Report techniques so that design with get perfectly done with set standard parameters to meet international specifications.

Keywords: Finite Element Analysis, Impact attenuator, Roll Cage, SUPRA SAE INDIA Rulebook, Suspension.

I. INTRODUCTION

Student formula one is a pre-stage of final formula one vehicle which is used for high speed racing at specially made racing circuits considering all safety parameters and international standards. It is single seater racing vehicle which include design of various systems and subsystems to work as a single unit for high performance. All the set parameters were set before designing by considering various international specifications regarding formula one vehicle. The main parameters kept in mind for designing were high performance, reliability, ease in maintenance, low cost, safety of driver and with all international technical standards.[6] After the specifications and parameters were set the design process is carried out and finally to check whether the design is accurate or not 3-D model of vehicle is made in solid works and also analyses is to check for various impacts on vehicle for any future accidents.

II. DESIGN CONSIDERATIONS

By keeping following parameters in mind all design specifications are stated to meet it so that formula one vehicle will get more endurance in performanceat all stages.[6][7]

- High performance
- Driver safety and Ergonomics.
- Impact attenuator design and installation.
- Maneuverability of all systems.
- Maximum control with suspension system.
- Cost of the all systems.
- Safe engineering practices.

For ease of designing all components were designed individually along with mutual specifications transfer for interchangeability. [7]

- Roll Cage
- Suspension System
- Steering System
- Braking System
- Powertrain system.

2.1. Roll Cage

Roll Cage is askeleton of any vehicle of cross section of pipe which is used for providing primary support for all systems and subsystems of vehicle. For high speed operation and also by safety considerations the material should be strong enough to withstand against heavy load and stresses while being light in weight and in cost also.[6] As per the market research three materials were selected for roll cage materialswhichare AISI 1018, AISI 1020 and AISI 4130 chromoly. Every material having different parameters and properties as follows, from them AISI 4130 is selected due to its advantages over other materials in ultimate strength and the low in weight mentioned in following table.

Material → / Properties ↓	AISI 1018	AISI 1020	AISI 4130
Carbon %	0.15-0.20	0.18-0.23	0.28-0.33
Density (Kg/m3)	7.87×103	7.7×103	7.85×103
Tensile Yield Strenght (MPa)	370	350	435
Tensile Ultimate Strenght (MPa)	440	400	560
Modulus of Elasticity (GPa)	205	200	210
Poisson's Ratio	0.29	0.29	0.29

Fig.1Material comparison for Roll Cage material

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Outer Diameter of pipe cross section: 25.4 mm (1 Inch)

Thickness: 2 mm

After selection of material next step is to draw 3-D model of roll cage with all considering set parameters of various systems and sub systems.

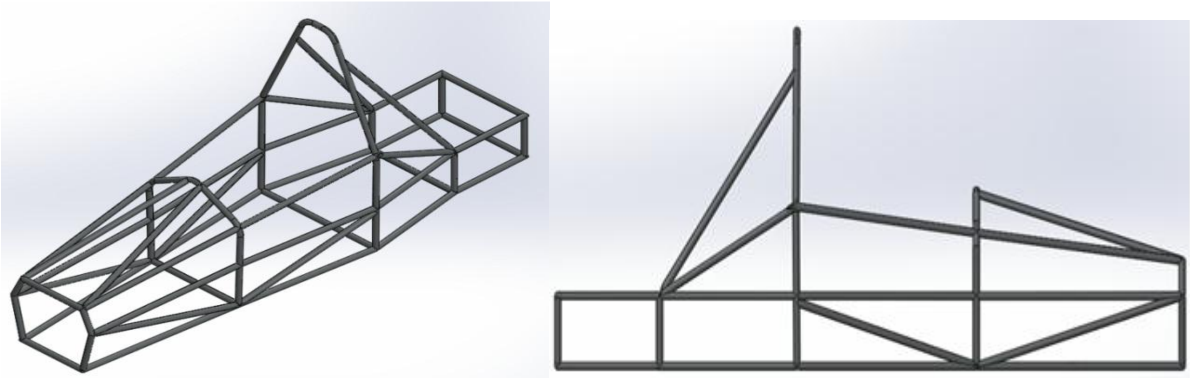


Fig.2Roll Cage 3-D model (Isometric view and Side view).

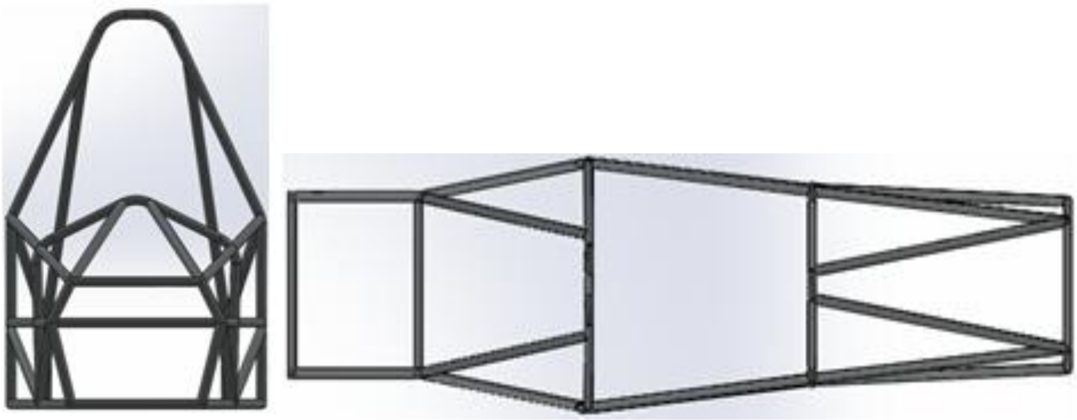
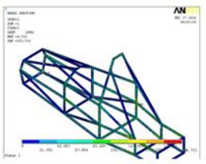
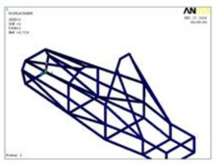
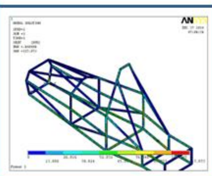
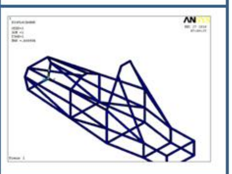
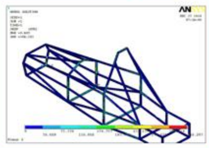
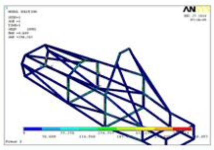


Fig.3Roll Cage 3-D model (Front view and Top view).

2.1.1FEA Analysis Roll Cage model in ANSYS Software

Type of Impact	Force (N)	Stress (N/mm)	Deformn (mm)	F.O.S.	Stress Analysys	Deformation Analysys
Front Impact	10 G	213.05	5.1	2. 01		
Rear Impact	10 G	131.95	0.86	3.26		
Side Impact	4G	348.20	4.80	1.37		

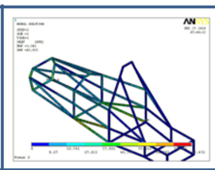
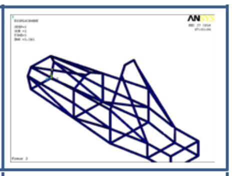
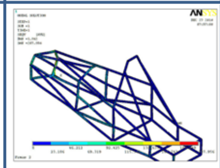
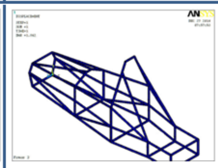
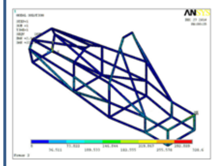
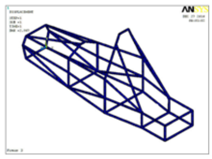
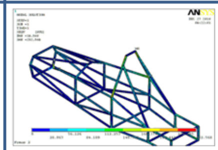
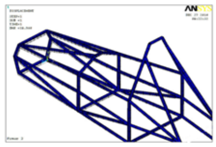
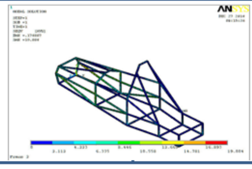
Torsion Test	2G	166.66	4.80	2.87		
Front Bump	3G	207.95	1.96	2.31		
Rear Bump	3G	328.6	2.94	1.46		
Heave Loading	Front 1373.4 Rear 2060.1	252.56	18.56	1.90		
Drop Test			1.96	2.31		

Fig.4FEA Analysis Roll Cage.

2.2. Suspension System

As we were designing formula one vehicle which is working at very high speed so while at cornering there will be maximum amount of weight transfer in lateral and longitudinal directions; so to avoid any type of misbalance of vehicle there should be perfect suspension system equipped in vehicle to avoid any type of unexpected situation while cornering at high speed.[3][4] To make this sure while designing by considering all parameters double wishbone is installed in both front and rear side to get more easy control of wheel alignment and wheel travel to get expected result. But especially for rear suspension the amount of stiffness required in suspension is more than front suspension to avoid losses in power transmission while being smooth working of power transmission.

2.2.1Front Suspension

For front suspension there are many choices to select but from them double wishbone type of suspension had been selected because of its high load handling capacity and rigid support to the wheel geometry. It is ease to control Camber angle, Castor angleand KingPin inclination angle with double wishbone system. For this the parameters which are considered are as follows; [1]

- Length of spring: 150 mm
- Total length (spring + damper): 400 mm
- Wire diameter: 8 mm
- Mean coil diameter: 60 mm
- No. of active turns: 20

- Total no. of turns: 22

2.2.2Rear Suspension

For rear suspension it should be rigid enough to provide more stiffness to wheel travel otherwise it may create problems for transmitting power to the wheel from gearbox. Also it should have very low camber angle and castor angle to transmit power effectively.[3] To meet all these requirements the type of system selected for rear is double wishbone suspension which is adjusted to very low camber change phenomenon in damping. For this the parameters which are considered are as follows;[1]

- Length of spring: 100 mm
- Total length (spring + damper): 385 mm
- Wire diameter: 10 mm
- Mean coil diameter: 65 mm
- No. of active turns: 10
- Total no. of turns: 12

Parameter	Front	Rear
Type	Equal non parallel double wishbone	Equal non parallel double wishbone
Damper placing	Vertical through Fulcrum At upper roll cage member	Inclined through Fulcrum At upper roll cage member
Static Roll centre	1.75 inches	2.84 Inches
Motion ratio	0.57:1	0.51:1
Spring rate	35.23 N/mm	44.01 N/mm
Wheel rate	11.44 N/mm	11.44 N/mm
Ride frequency	2 Hz	2 Hz
Static Camber	- 4°	0°
Castor	3°	0°
Kingpin Inclination	3°	2°
C.G height	11. 21 Inches	
Suspension Travel	3 inch Jounce 2 inch Rebound	2 inch Jounce 1 inch Rebound
Spring and Damper	Bullet 500 Rear	Bullet 535 Rear

Fig.5Specifications of suspension system.

2.2.3FEA analysis of Suspension system in ANYSYS

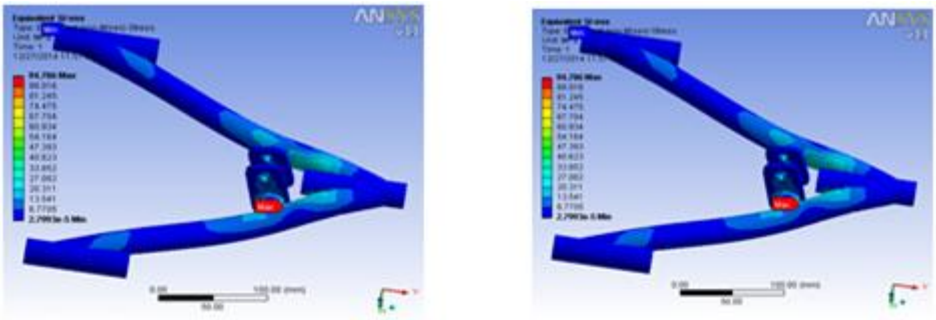


Fig.6 FEA analysis of suspension system in ANYSYS

Front Suspension Rear Suspension

Force applied: 13243 N (3G) Force applied: 13243 N (3G)

Stress produced: 94.78 N/mm^{2}Stress produced: 94.78 N/mm^2

Deformation: 0.032 mm Deformation: 0.032 mm

F.O.S.: 5.06 F.O.S.: 5.06

2.2.4Roll Centre Calculations

At the time of hard cornering at high speed total weight of vehicle get laterally and normally transferredto one side of the vehicle from deviating with C.G.It is having many adverse results of it as it disturbs the handling of driver and also stability of vehicle which may lead to serious accidents or damage to vehicle and driver.[1]So to avoid this there should be minimum deviation of roll center vertically and horizontally.

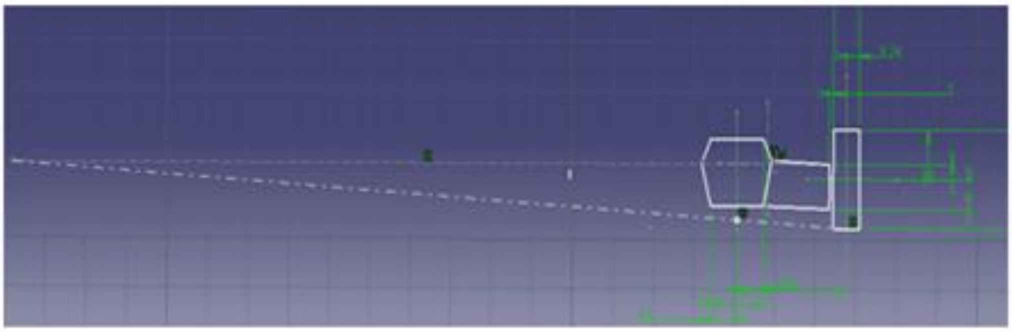


Fig.7 Roll center calculation (Front)[1]

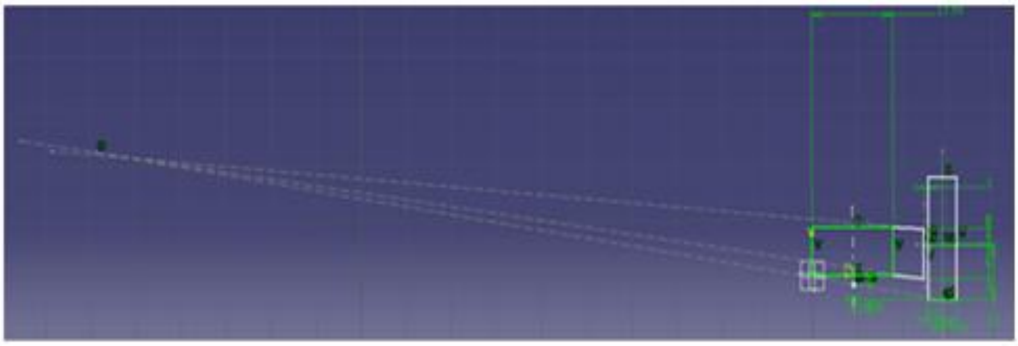


Fig.8 Roll center calculation (Rear)[1]

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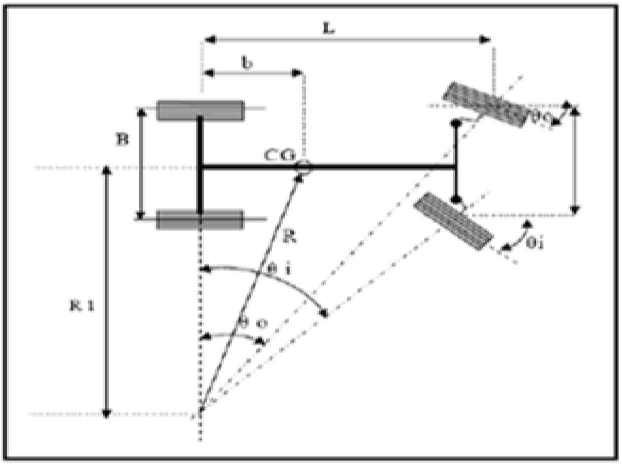
2.3. Steering System

Steering system is the system used for controlling the direction of vehicle while in motion in desired direction. There are many types of steering systems available in automobile sector but as there is racing vehicle there should be minimum lag in steering wheel and should also get steer easily in less time with fewer efforts to avoid jerk to the driver. So from various systems studied as given in following table we used rack and pinion type of steering system due to its maximum durability and easy to adjust the controlling parameters.[2]

PARAMETERS(OUT OF 10)							
Steering System	Cost	Availability	Maneuverability	Weight	Mechanical Advantage	Performance	Total
Rack and pinion	7	9	8	7	6	7	44
Recirculating Ball	5	6	8	6	9	8	42
Worm and Sector	5	4	5	5	7	7	33

Fig.9 Comparison of various steering systems



$$\frac{1}{tan\theta 0} - \frac{1}{tan\theta i} = \frac{L}{B}$$

$$M.R. = \frac{Xi}{Xo} = \frac{2\pi R}{2\pi r} = \frac{66.16}{10.52} = 6.28$$

Fig.10 Ackerman steering geometry and formula for correct steering

Fig.11 Designed steering system

Parameters	Value
Steering wheel lock to lock angle	240^0
Max. rack travel	88 mm
Steering ratio	3.46:1
Turning radius	3.315m
Inner wheel turning angle	30^0
Outer wheel turning angle	17.87^0

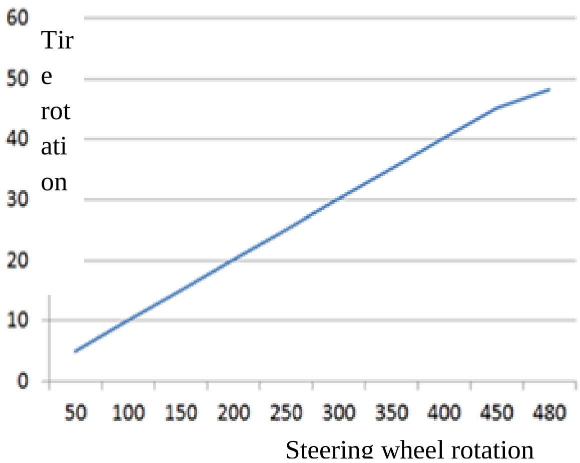


Fig.12 Steering calculations and output parameters

As shown in above table from various calculations the parameters has been selected as per required results and the final system is designed with all dimensions.

2.4. Braking System

Brakes are used for stopping the vehicle within less possible time and distance and also to control the speed of vehicle while vehicle in motion.as per the international standards all wheels of vehicle should be hydraulically operated disc brakes to reduce the stopping distance and efforts applied by driver. [2][3] To implement various components are used directly which are also known as Original Equipment manufacturer products (OEM) which are as follows;

PARAMETER	OEM	VALUE
Master Cylinder	MARUTI 800	25.4 Bore Dia
Caliper	APACHE 180 RTR	29 mm Dia
Disc	APACHE 180 RTR	200 mm
Brake Lines	Maruti 800	-

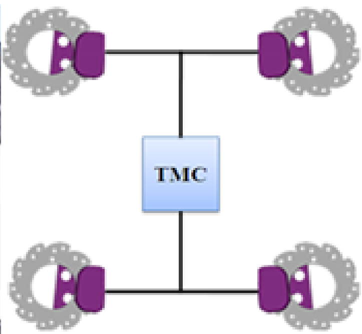


Fig.13OEM Selected **Fig.14Parallel braking system**

Parameter	Front	Rear
ROTOR		
Type	Disc	Disc
Make	Apache RTR 180	Apache RTR 180
CALIPER		
Type	Fixed caliper	Fixed caliper
Make Calliper	Bullet 500	Apache RTR 180

Fig.15Disc and Caliper specifications

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PARAMETERS	VALUES
Pedal Ratio	6:1
Vehicle Speed	60 kmph
Stopping Distance	Dry : 7.86 m
	Wet : 10.48 m
Stopping Time	Dry : 1.41 Sec
	Wet : 1.88 sec
Load Transfer	25 % weight from Rear to Front
Percentage of front Bias	53.5 %
Percentage of Rear Bias	46.5 %

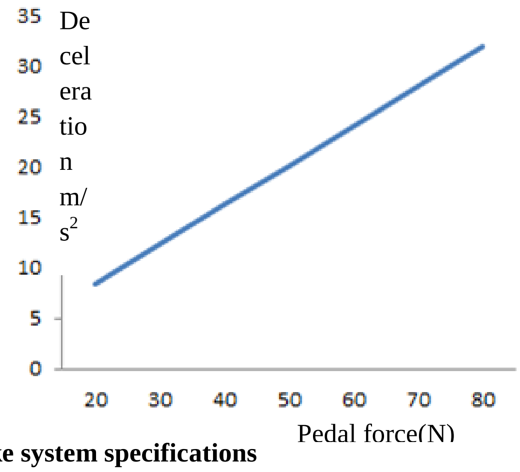

Fig.16Brake system specifications

2.5. Power Train Arrangement

As per international specifications vehicle should equipped with maximum 500cc engine and up to the maximum speed of 100 km/hr. [6][7] The engine and gearbox are selected from comparison of various engines to get maximum performance with high efficiency.

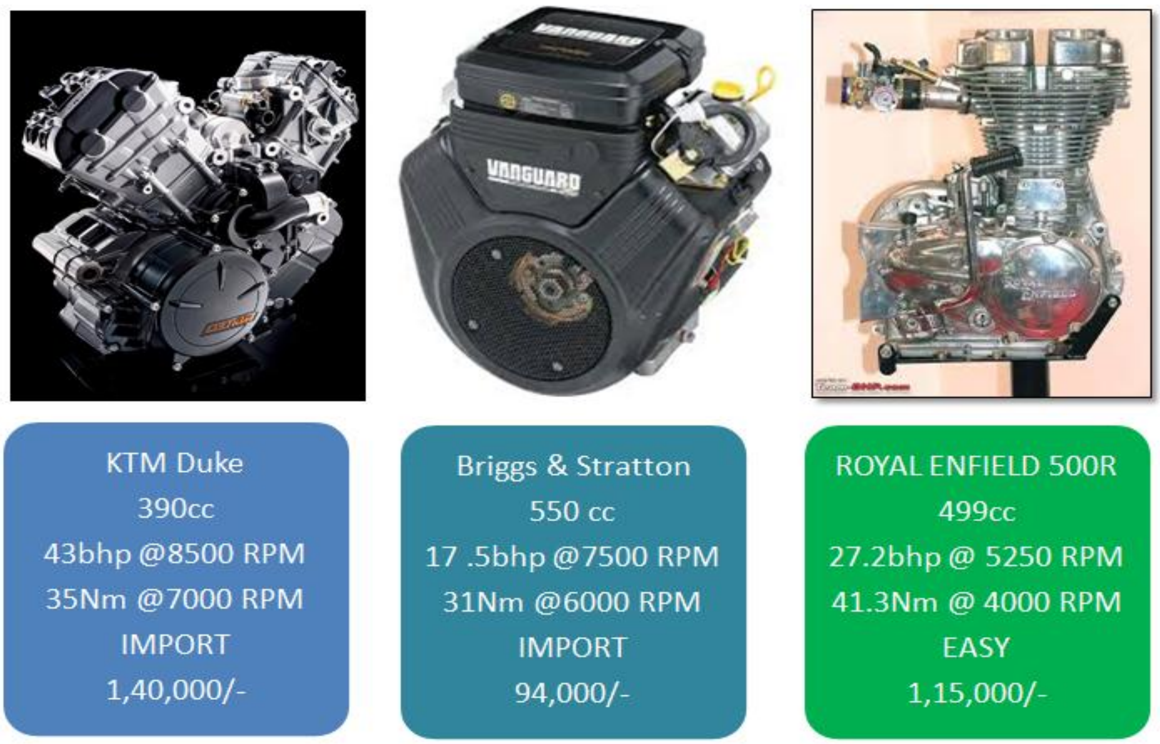

Fig.17 Comparison of various engines with gearboxes available as per requirement

By this comparison we selected engine and gearbox of Royal Enfield 500R to get maximum power output with high efficiency which is meeting our requirements within reasonable cost.

III. CONCLUSION

There are several factors to be considered while designing any vehicle that are common to all engineering vehicles. The chosen design is for the safest & the efficient vehicle for any racing vehicle while being toughest in its class. All the parameters like Reliability, safety, Cost, Performance, aesthetics, ergonomics, Standard dimensions & material were also taken in consideration along with comparison of international specifications.[8] The parts which are going to be manufactured in house have been performed finite element analysis and required actions had been taken to avoid any type of design failure. Also while designing every individual part DFMEA and DVPR has been done which improved our quality standard, factor of safety and other safety parameters also.The designed formula one vehicle is able to withstand against any adverse condition on racing circuit as each component is designed specifically considering all types of failures and safety issues; it is the best vehicle for racing on circuit. Also powertrain is specially designed to get maximum speed and torque for high performance which can be obtained. For designing this vehicle many software's like solid works, Catia, Ansys were used to get more clear and accurate output of designed parameters to meet high accuracy and to reduce any type of any unlike situation.

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