Design and Fabrication of SUPRA [F1] Vehicle

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ABSTRACT:- *The goal of the Team ELITE RACERS was to design, improve, and manufacture a four wheeled student's Formula one vehicle that can handle any racing condition. The 2016 SUPRA SAE car was designed keeping the driver in mind and aimed to improve driver control over the vehicle. This vehicle was also designed for performance, maintainability, and the ability to be mass produced all while providing a fun and exciting driving experience. Motorsports in India are enjoyed among youth, but infrastructure available here is still underdeveloped as compared to the potential of the industry and international Overall width developments. Our aim in designing this is to exploit the vast untapped opportunities in the field of racing which will provide adventure and thrill for the youth and create new business opportunities for the entrepreneurs. Designing these go-carts will create further opportunities for fast developing automobile sector of India in coming future and will create many job opportunities.*

INTRODUCTION

With the rise of motorsports, it has created vast opportunities. For engineers, these opportunities comprise of designing and manufacturing them (motorsport vehicles). To exploit future possibilities in automobile sector as engineers, we have designed a student formula vehicle that will be manufactured to enhance our engineering (designing and manufacturing) as well as entrepreneurship (resource management and marketing) skills.

While designing chassis safety considerations are kept in mind whereas for designing body, seat, steering and other parts aesthetics and ergonomics of the vehicle were considered. The vehicle is designed to provide thrill and adventure to driver.

DESIGN METHODOLOGY:

- DESIGN FOR MANUFACTURING, PROCUREMENT, AND ERGONOMICS –

Using the developed Goals and Constraints, we quickly identified the least flexible areas of design. (Egg. The first step of vehicle design was selection of driver position, then tires and wheels. The uprights and A-Arms were designed around available bearings.)

UNIVERSAL PARTS –

We focused early in the design phase on identifying components with similar function to reduce manufacturing and procurement complexity, reduce cost, and improve reliability

Design Goals

Taking the previous considerations into account, our design priorities became:

- RELIABILITY AND SIMPLICITY
- WEIGHT REDUCTION

Chassis:

Material Selection

The chassis undergoes various kinds of forces during locomotion, it has to stay intact without yielding, and it should be stiff to absorb vibrations, also it should resist high temperatures. The material property of the chassis is an important criterion while designing and manufacturing the car. A tubular space frame chassis was chosen over a monologue chassis despite being heavier because, its manufacturing is cost effective requires simple tools and damages to the chassis can be easily rectified. The two very commonly used materials for making the space frame chassis are Chromium Molybdenum steel (Chromoly) and

SAE-AISI 1018. Both these materials were analyzed for different parameters and finally decided on to use Chromoly steel 4130 for making the tubular space frame chassis because of several reasons.

SAE 1018 grade steel is better in terms of Thermal properties but weaker than Chromoly in terms of strength. But the main priority of design is safety for the driver hence the material with better stiffness and strength was chosen. The material should not cause any failure even under extreme conditions of driving as defined in the rule book. Chromoly steel 4130exhibits better structural property than SAE 1018 Grade steel hence the former was considered as the basic material for building a tubular space frame chassis. Even though the cost of Chromoly is marginally higher than that of SAE 1018 grade steel, considering the safety of the driver material CHROMOLY 4130 STEEL is used.

Table1: Properties of material (SAE AISI 1018&chromoly 4130 STEEL)

PROPERTIES	SAE AISI 1018	CHROMOLY 4130 STEEL
Density(g/cc)	7.8	7.8
Young's modulus (GPa)	210	210
Elongation at break (%)	19	19
Brinell`s hardness	120	200
Strength to weight ratio at yield	38	100
Yield strength (MPa)	360	480
Ultimate strength (MPa)	420	590
Thermal Conductivity:{ambient} (W-mK)	50	42
Thermal Expansion : 20C to 100C (µm/m-K)	11	12
Specific heat capacity (J/kg-K)	370	370

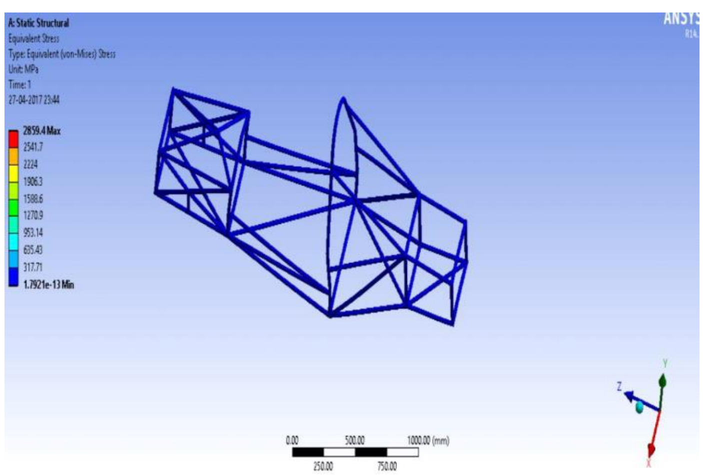

Fig1: Equivalent Stresses

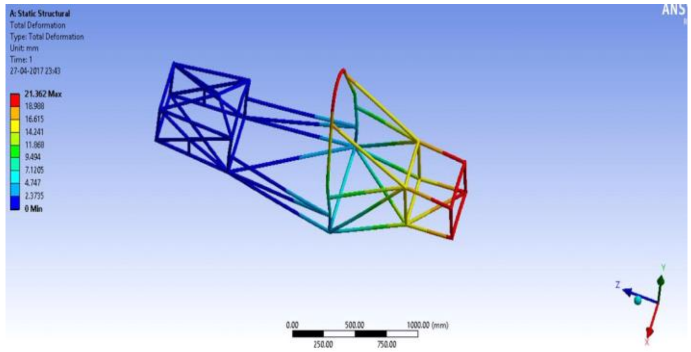

Fig2: Total Deformation

SIMULATION:

Structural analysis of the chassis was done along with design optimization until a convincing design with sufficient rigidity was produced and it cleared all regulations by the SAE Rulebook. The static structural analysis was done in ANSYSWorkbench under different constraints mentioned in the SAE Rule book 2016 [1]. Methods of Stiffnessand rigidity test of the car, were primarily followed throughout the analysisprocess. Application of loads over the chassis was in correspondence to the work of R.P. Singh, 2010 [5]. The maximum deformation is well within the permissible limit ofnot more than 25mm in any direction

PARAMETERS	**FRONT IMPACT**	**SIDE IMPACT**	**REAR IMPACT**	**TORTIONAL**
FORCE(N)	7g	4g	7g	3g
Von mis stress (MPa)	1.7293e+13	1.7296e+008	2.5639e+007	1.4389e+006
Deformation (mm)	.108	1.29	.123	.6
FOS	2.2	2.2	4.6	1.9

Knuckle and Hub

Knuckle is designed considering King Pin Inclination, Caster and keeping max distance between upper and lower ball joints (it reduces weight on A-arms).Knuckle-hub assembly is designed in such a way that it contributes to minimize unsprung weight.

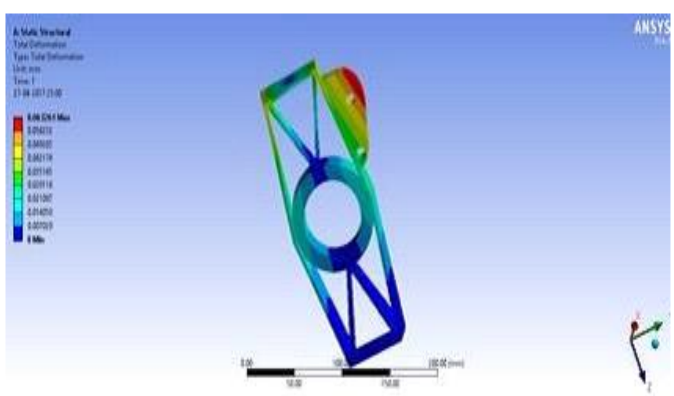

Fig3: REAR KNUCKLE

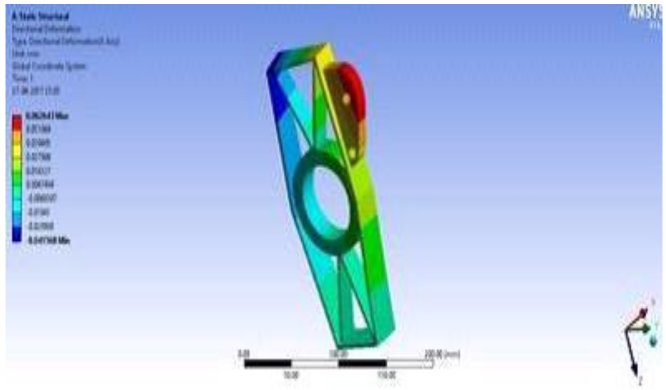

Fig4: Front Knuckle

Table 1: WHEEL UPRIGHT AND KNUCKLE

PARAMETES	HUB	UPRIGHT FRONT	UPRIGHT REAR	ROCKER ARM
Von Miss stress (MPa)	94.314	44.782	8.3159	38.014
Deformation(mm)	0.0687	0.0504	0.00952	0.07055

SUSPENSION:

DESIGN CONSIDERATIONS:

Based on the LITERATURE REVIEW, it was decided that a clean-sheet approach was required to reformulate the design process.Through a literature review and competitive benchmarking, it was determined that the design process should be iterative, with steps taken in the following order:

1. Tire Selection

2. Wheel Selection

3. Track Width and Wheel Base Selection

4. Roll Center Location and Movement

5. Camber Change Optimization

6. Steering Geometry

7. Packaging Constraints

Suspension Geometry:

Wheel base – 1710mm

- REAR Track width – 1150 mm
- FRONT Track width-1250 mm

- Four wheel independent.
- Double an Arm with pushrod actuation on front.
- Provides desired motion ratio with easy adjustability.
- Max. load is transferred to the springs.
- Reduces drag.
- Double an Arm with pushrod actuation. Provides the required stability.
- Static Roll FRONT Centre height of 74mm.
- Static roll REAR Centre height of 93mm.
- Static Camber of 2 degree negative

STEERING:

The basic aim of steering is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears. When the driver turns the steering wheel, a shaft from the steering column turns a steering gear. The steering gear moves tie rods that connect to the front wheels. The tie rods move the front wheels to turn the vehicle right or left.

ACKERMANN PRINCIPLE:-

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii. The Ackermann steering geometry that is applied to all vehicles to unable the correct turning angle of the steering wheel to be generated when negotiating a corner or a curve.

ACKERMANN'S STEERING GEOMETRY

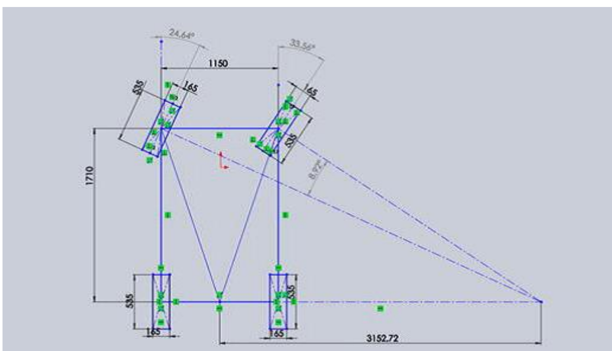

Fig5: Steering Mechanism

Steering Calculations

Wheel Base = 1710 mm

Front Track Width (a) = 1250 mm

Rear Track width (b) = 1150 mm

Track Rod (d) = 910 mm

Track arm (r) = 350 mm

Inner steering angle =

Outer steering angle =φ

Lock to lock angle=180degree

- **STEERING MECHANISM**

1. Slip angle α = sinα = b – d/2

sinα =1150 - 910/2 × 350 = 0.3428

Slip angle α = 20.04º

2. According to Ackermann's steering method,

Sin(α +Ǿ) + Sin(α – φ) = 2sinα

And,cotφ – cot = b/l =1150/1710 =0.6725

Now, assuming Ǿ = 30º and α = 20.04º

Sin(20.04 + 30) + sin(20.04 – φ) = 2sin(20.04)

0.7664 + sin(20.04 – φ) = 0.6853

Therefore, φ = 24.69º

Hence, cotφ – cot

cotφ – cotǾ = 0.4431 ≠ 0.6725

Rack travel = πǾr÷180 = 342.08

But gear ratio = 4:1

Therefore, actual rack travel = 342.08/4 = 85.52 mm

Minimum Turning Radius

Tanα = w/R = a/R

Therefore R = a/tanα = 1150/tan(20.04)

Minimum Turning Radius = 3152.74mm = 3.152 metres.

Fig 6: Steering

- **Brake:**

The objective for the brake system was to design a system that could stop the vehicle in 4meter from 45kph efficiently, safely, and effectively. The final design that was chosen for the vehicle included a front and rear circuit with floating. Calipers, fixed rotors, two 5/8" master cylinders, a reverse swing mount pedal, a pressure transducer switch, and led brake light.

Brake calculations;

Mass of vehicle 315kg

Initial velocity (u) = 15.28 m/s (55kmph)

Final velocity (v) = 0 m/s

Brake rotor diameter = 0.4m

γ =0.3

Percentage of kinetic energy that disc absorbs (90%)

K =0.9

Coefficient of friction for dry pavement μ = 0.9

Stopping distance

S = u2/2gμ

= (15.28)2/2*9.81*0.9

S = 13.22 m

Deceleration of vehicle

a = v2-u2/2*S

= 02-(15.28)2/2*13.22

a = 8.83 m/s

Stopping time

V = u + at

0 = 15.28+8.83*t

t = 1.73sec

a. Energy generated during braking

K. E. = γ K * m (u-v)2/2

K. E. = 9928.66 J

b. Brake power

Pb = K. E. /t

Pb = 5739.10 W

c. calculate the heat flux (Q)

Q = Pb/A

Q = 409935.71 W/m2

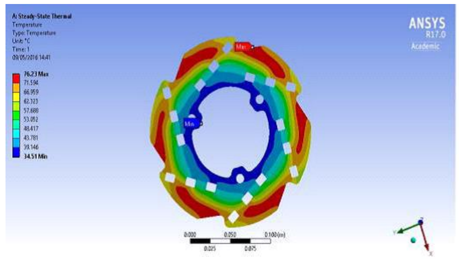

Fig: Analysis of Disc Brake

ENGINE SELECTION CRITERIA: The team of our drive train department made an analysis of the particular engines suitable for our vehicle and landed up on a significant conclusion.

CRITERIA	CBR-250R	KTM 390	RE-500
Displacement(cc)	250	390	500
Compression ratio	10.7	12.8	8.5
Engine power	25BHP@8500rpm	43BHP @9500rpm	27.2BHP @5250 RPM
Torque	22.9N-m@ 7000rpm	35N-m@ 7250rpm	41.3 N-m @ 4000 rpm
Weight	35.4kg	36kg	70kg
Power/weight	0.7062	1.19	0.3857

Thus considering the following details and comparison of engines, engine selected was **KTM DUKE 390cc ENGINE.**

POWERTRAIN SPECIFICATION:

ENGINE MODEL	KTM duke 4strokde SI
NO.OF CYLINDERS	Single
DISPLACEMENT	373.2cc
TRANSMISSION	6clutch constant mesh
CLUTCH	Wet multidisc clutch
COOLANT SYSTEM	Water-cooled

ENGINE WEIGHT	36kg
INTAKE RESTRICTOR DIAMETER	19mm

- **Spherical shaped plenum intake system:**

  The air intake system mainly comprises of three parts restrictor, plenum and runner. The air comes in from the restrictor then flows through the plenum and finally through the runner which feeds the air to intake port of the engine.

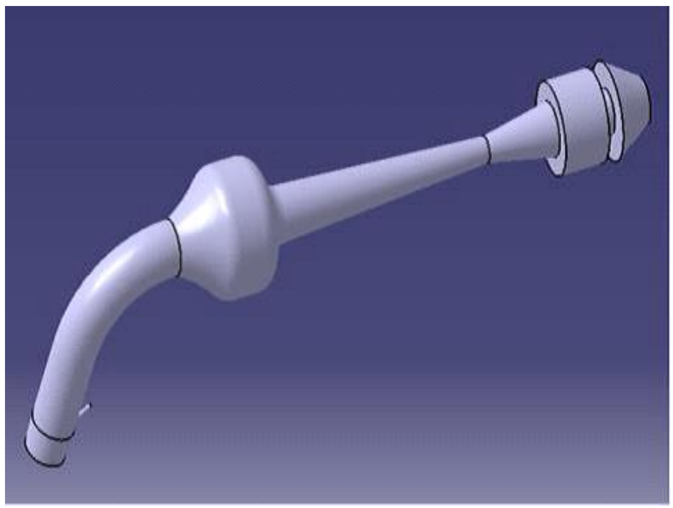

Fig 8: Planum(Air Restrictor)

According to the rule of SUPRA SAE the diameter of the restrictor should be 20mm which limits the engine power capability by reducing the mass of air passing through the restrictor.

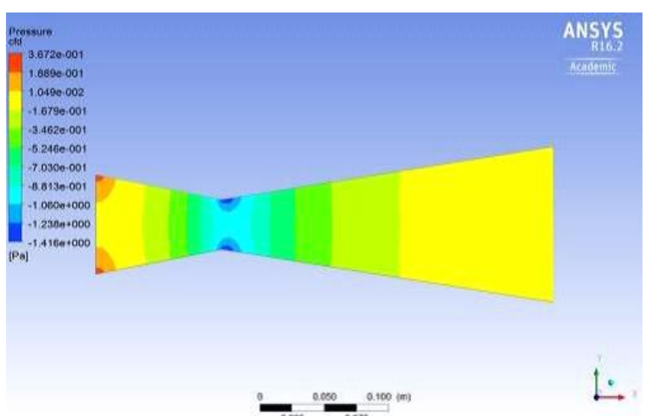

Fig 9: Analysis of Planum

- **ELECTRONIC CONTROL SYSTEM:**

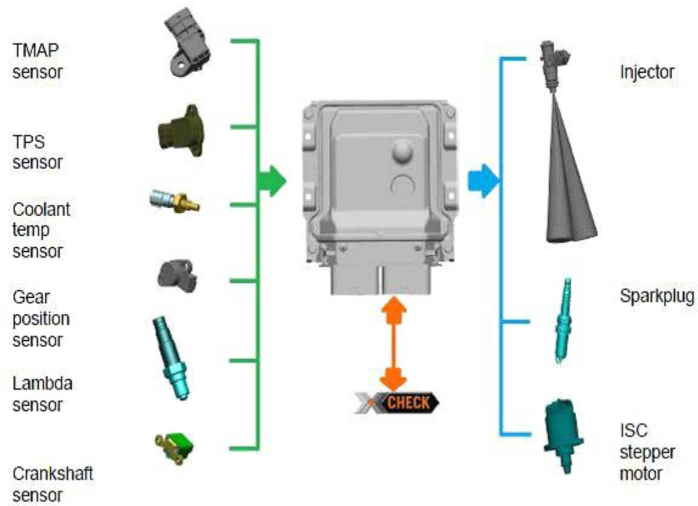

Fig 10: Electronic Control System (ECU)

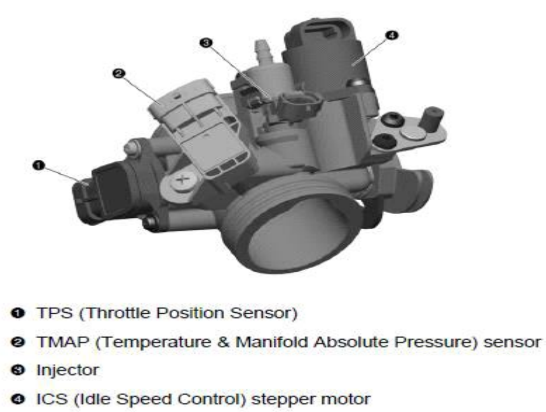

Fig 11: Throttle Body

- **Result:**

1. Maximum stress induced in chassis is 2859.4 MPA.
2. Minimum stress induced in the chassis is 13 MPA.
3. Total deformation is 21.362mm.
4. Intake Restrictor Diameter is 19mm.
5. Slip angle α = 20.04º.
6. Actual rack travel =85.52mm.
7. Minimum Turning Radius =3.152m.

- **Conclusion:** This paper focus on the design, analysis and calculation of various components that is necessary for fabrication of a F1 (SUPRA) car. We have performed various types of static analysis and applied different loading condition on the chassis and it if found to be safe according to their factor of safety. We also learn how to select appropriate material for the safe design of chassis. Successful analysis was performing on the chassis of CAD modal using ANSYS WORKBENCH to determine, equivalent stresses, and total deformation results. The engine is selected and drive train designed such as to give maximum performance in terms of designed such as to give maximum performance in terms of speed as well as fuel economy. We have designed air intake system and also performed CFD analysis. The convergent and divergent angles are selected so as to get minimum pressure loss though the restrictor .The type of steering system used is rack and pinion and all the calculation are done using Ackerman's principle. The design of knuckle is done using SOLIDWORKS and analysis is performed. Detailed calculation of brakes is discussed in this paper. Thus, after all the calculations and analysis, it is finally concluded that this F1 vehicle is safe for fabrication.

- **References**

1) V.B. Bhandari "DESIGN OF MACHINE ELEMENTS" 3rd edition

2) S. Ramamrutham, R. Naraynan "STRENGTH OF MATERIALS" Dhanpat Rai Publication Company.

3) Dr. Kirpal Singh, "AUTOMOBILE ENGINEERING" VOL. 1 by 13th edition 2012, Standard publication, Delhi 13th edition 2013.

4) Dr. Kirpal Singh, "AUTOMOBILE ENGINEERING" VOL. 2 by Standard publication, Delhi 13th edition 2014.

5) B. subramanyam, vishal, Mahesh kollati, k. Praveen kumar' "ANALYSIS OF FORMULA STUDENT RACE CAR", IJERT, vo. 5 issue 10.

6) H. g. phakatkar, chinmau potdar, vrushabh joijode, sushrut jadahv, "DESIGN OF SUSPENSION SYSTEM OF FORMULA STUDENT CAR", IJMPE, volume 4, Issue-2, FEB-2016.