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REVIEW ARTICLE

DESIGN AND ANALYSIS OF A FORMULA VEHICLE BASED ON THE FSAE INTERNATIONAL RULES

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ABSTRACT

Keeping in view the guidelines given in the rulebook of the event Formula SAE 2013 (FSAE 2013), which is organized by SAE International, the chassis of car (which could successfully compete all events) was designed using Solid Works 2013. Various tests were performed using the same software. The weight of the car was set at an upper limit of 300 Kilograms. The front wheel track width was set at 52 inches and the rear wheel track width at 51 inches. Front impact, rear impact and side impact tests were performed, in order to establish the maximum displacement that the vehicle chassis may undergo in the event of collision

INTRODUCTION

(Beckley *et al*., 2013; Milliken and Milliken, 1995; Reimpell *et al*., 2001; Reza, 2008; SAE International, 2013 Event Guide; SAE International, 2013 FSAE Rulebook 2013; Smith, 1978) The main aim of this work is to bring out a successful design for a formula vehicle with new innovations, which would help in increasing the performance of the car in the endurance tests. The guidelines provided by SAE International have been strictly followed. In order to ensure maximum performance at minimum cost, following targets were set:

1) Restrict the weight of car to 300 kg.
2) Achieve 0 Km/Hr to 60 Km/Hr in around 4 seconds.
3) Wheelbase of 1600 mm (63 in).
4) Track width of 1400 mm (55.1 in).

Following are the objectives that were followed while designing the formula vehicle:

1) The vehicle should have very high performance in terms of acceleration, braking and handling, and it should be sufficiently durable to successfully complete all the events described in the Formula SAE 2013 Rules.
2) The vehicle must accommodate drivers whose stature ranges from 5th percentile female to 95th percentile male and must satisfy the requirements of the Formula SAE Rules.
3) Additional design factors to be considered include: aesthetics, cost, ergonomics, maintainability, manufacturability and reliability.

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Design Calculations and Analysis

Kinematic Suspension Design

(240 Edge, 2013; Beckley *et al*., 2013; Milliken and Milliken, 1995; Reimpell *et al*., 2001; Reza, 2008; Wikipedia, 2014). This is one of the most crucial steps in designing a race car. It involves the optimization of the vehicle suspension parameters like camber, caster, KPI etc. The optimized values of parameters is given below:

For Front Suspension

Parameters	Values
Static Camber	-1°
Camber gain in Jounce	-.35°/1 in
Camber Gain in Rebound	.34°/1 in
Caster	5°
KPI	3°
Scrub Radius	3 in
Toe In	-1°
Ground Clearance	2 in
Static Roll Center	2.531 in
Front Track Width	52 in

For Rear Suspension

Parameters	Values
Static Camber	-1°
Camber gain in Jounce	-.58°/1 in
Camber Gain in Rebound	.61°/1 in
Caster	0°
KPI	3°
Scrub Radius	6.5 in
Toe In	0°
Ground Clearance	2 in
Static Roll Center	2.18 in
Rear Track Width	51 in

Anti Dive

The caster angle is 5°. The wheel diameter has been depicted as 20 in (508 mm) and the inner diameter of the wheel is 13 in (330.2 mm).

Anti Squat

The caster angle is 0°. As it is evident, the outside wheel diameter is smaller than the front wheel diameter, at 19.50 in (495.3 mm). However, the inside wheel diameter is the same as the front wheel inside diameter at 13.0 in (330.2 mm).

Chassis Design

(Reimpell *et al*., 2001; SAE International, 2013 Event Guide; SAE International, 2013 FSAE Rulebook 2013). The chassis conforms to all the guidelines in the FSAE rulebook 2013.

Frame Analysis and Validation

(Reimpell *et al*., 2001; Reza, 2008; Smith, 1978)

Front Impact Test

In frontal impact the two bodies are assumed to collide head on. It was calculated that the force of impact would be 18300 N or 18.3 kN. The maximum stress induced was calculated at 184 MPa. The displacement produced in the chassis with an impact load of 18.3 kN is 1.618 mm. The maximum allowable displacement is 25 mm. It is therefore well within the requirement.

Rear Impact Test

In this type of impact, it is assumed that the vehicle in the rear will collide with the vehicle in the front, impacting its rear bulkhead. The force of the impact was calculated at 9150 N or 9.15 kN. The max stress induced was found out to be 816 MPa. The maximum displacement induced at a maximum impact load of 9.15 kN is 1.285 mm, which is the well within the maximum allowable limit of 25 mm.

Side Impact Test

In this test it is assumed that the colliding vehicle will collide on the side of the chassis, impacting the side structural members. The force of impact was calculated at 9150 N or 9.15 kN and the maximum stress induced was found out to be 816 MPa. Keeping the force of impact at 9.15 kN it was found out that the displacement induced at maximum stress of 816 MPa is 1.3003 mm.

Component Design and Validation

(Reza, 2008; Smith, 1978)

Rack and Pinion Steering System

Due to the lightweight and simplicity of rack and pinion, we propose to use custom made steering assemblies designed specifically for these types of race cars.

The specifications of the steering wheel to be used are:

- No. of teeth on pinion = 9
- No. of teeth on rack = 16
- Rack length = 457.2 mm (18 in)
- Rack Gain = 64.516 mm/turn (2.54 in/turn)
- Steering ratio = 6.03

Brakes

The specifications of break are given below

Parameter	Front	Rear
Rotor, outer radii	114.3mm	118mm
Inner radii	79mm	83mm
Placement	Outboard	Inboard
Caliper	2	1
Bore Diameter of Piston	16mm	20mm
Friction radius	101.6mm	100.51mm

The load calculated on the brakes is as follows:

Under static condition:

- Front axle – 135 Kgs
- Rear axle – 165 Kgs

Under dynamic condition:

- Front axle – 190.91 Kgs
- Rear axle – 109.08 Kg

For successful locking all four wheels on braking, the brake torque requirement is:

- For front tires = 332.98 N-m
- For rear tires = 190.276 N-m

The brake torque developed was calculated as:

- Torque developed at front = 693.3 N-m
- Torque developed at rear = 266.56 N-m

Conclusions and Outcomes

The vehicle has been designed according to the rules and parameters set forth by SAE International. The parameters assumed are optimized according to the requirements of this particular vehicle and also according to the undue stresses and force that it may be subjected to during the endurance. The chassis has been designed and validated through frame analysis on the software Solid Works by Dassault Systems. The main outcomes are as follows:

1) This vehicle has passed all the dynamic and static tests performed on the chassis. In the front impact test the displacement of the chassis was 1.618 mm. The rear impact test saw a maximum displacement of 1.285 mm and the side impact test witnessed a maximum displacement of 1.3003 mm. The maximum allowed displacement in all the cases is 25 mm.
2) The roll over test saw maximum forces of 5.055 kN on the front hoop and 8.829 kN on the main hoop. The maximum stress induced due to these forces was 479 MPa. The forces were calculated according to the 3g rule.
3) The wheel upright being used was also designed in Solid Works 2013. The displacement analysis revealed a maximum displacement of 0.044 mm whereas the maximum allowed is 25 mm
4) As is evident, all the components used are well within the specified safety limits. This ensures that the vehicle will be completely safe and will ensure that the driver will escape unhurt in any eventuality

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