Design and Analysis of Hub and Knuckle of FSAE Race Car

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Abstract— The formula SAE series competition gives opportunity to engineering student from around the world to conceive, design, manufacture an open wheel, open cockpit formula style racecar. The upright assembly including knuckle and hub is the most important component for suspension system of FSAE race car. The purpose of upright assembly is to provide physical mounting and linkage from suspension arm to hub and wheel assembly and also to carry brake component. This paper describes information with respect to design, material selection, analysis of upright assembly of FSAE car. the straight lines and good roundness for the curved lines.

Key words: Upright assembly, Knuckle, Hub, Al 7075

I. INTRODUCTION

The purpose of project is to design, analysis and fabrication of front and rear wheel upright assembly of TEAM MH-08 RACING Formula SAE car. The goal is to produce a lighter and performance oriented design of upright assembly in comparison with season 2014-2015 car and thereby contributing in making of car of season 2015-2016 better than its predecessor. Use of conventional upright assembly will increase the overall weight of race car. For FSAE car, weight criteria is a main factor in making of race car and as well as competition point of view. The goal of lighter weight upright assembly can be achieved by less complex design and proper material selection. Also the proper stiffness and reliability can be achieved by analysis of design of upright assembly. The objectives of project is as follows-

1) Light weight to maintain good performance to weight ratio of race car.
2) Optimum stiffness to ensure reliability of upright assembly and to maintain designed geometry of suspension system.
3) Ease of maintenance for enhancingserviceability and setup repeatability.
4) To design and fabricate upright assembly component in house to reduce turn around time and outside dependability.

II. LITERATURE REVIEW

Old Dominion University SAE Formula Club [1]published research paper which shows information about various forces acting on front and rear uprights. The front upright must be able to withstand a variety of forces including braking, steering, lateral loading and supporting the weight of car through the turns. The upright also has to handle these stresses with factor of safety of 3 or greater to withstand emergency situation and crashes. In order for suspension of vehicle to work properly, rear upright must be able to withstand a variety of forces which induces vertical load redistributions from vehicle acceleration and turning as well as lateral forces resulting from cornering.

Advanced Race Car Chassis Technology [2] – It gives formula to calculate load transfer.

$$\text{Load transfer} = \frac{Weight \times Acceleration \times CG\ height}{Track\ width}$$

The weight is the total weight supported by the two tires being analysed. Acceleration is the gravitational force being experienced. In the case of front uprights, deceleration or centrifugal acceleration from turning. CG height is the height of the centre of gravity of the vehicle. Track width is the distance between two tyres being analysed.

Engineering Inspiration[3]–It gives formula for calculationof braking force and torque.

Braking force = Weight * Deceleration force

This formula determines the total braking force of vehicle which divides between brake calipers of FSAE vehicle. The force of each brake caliper produces a torque about the upright that it is connected to, with the moment arm being the radius of the tire. The torque created by the braking force of that tire is determined by,

$$\text{Torque} = \frac{Brake\ force\ of\ wheel \times Radius\ of\ tire}{Speed\ ratio\ of\ rotor\ and\ tire}$$

MatWeb, Material Property Data [4]- Online data sheet gives information about Aluminium 7075-T6 and Aluminium 7075-T65 as per table no.1

component	% weight
Al	87.1-91.4
Cr	0.18-0.28
Cu	1.2-2
Fe	Max 0.5
Mg	2.1-2.9
Mn	Max 0.3
Si	Max 0.4
Ti	Max 0.2
Zn	5.1-6.1

TABLE 1: Component of Al7075

It is very high tensile strength material used for highly stressed structural parts. The T7351 temper offers improved stress corrosion cracking resistance. It is used in air craft fitting, gears and shafts, fuse parts, metal shafts and gears, missile p[arts, regulating valve parts, worm gears keys, aircraft, aerospace and defence application, hike frames, all terrain vehicle ATV sprockets.

G. B. Veereshkumar, C. S. P. Rao, N. Selvaraj, M. S. Bhagyashekar [5] –Aluminium alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing component that are being used for varieties of applications owing to the lighter weight, excellent thermal conductivity properties among several series of aluminium alloys, heat treatable Al6061 and Al7075 are much explored among them. Al6061 alloys are highly corrosion resistant and are of excellent extricable in nature and exhibits moderate strength and finds much application in the fields of construction, automotive and marine applications. Al7075 possesses very high strength, higher toughness and are preferred in aerospace and automobile sector.

III. CAD MODEL OF PROJECT

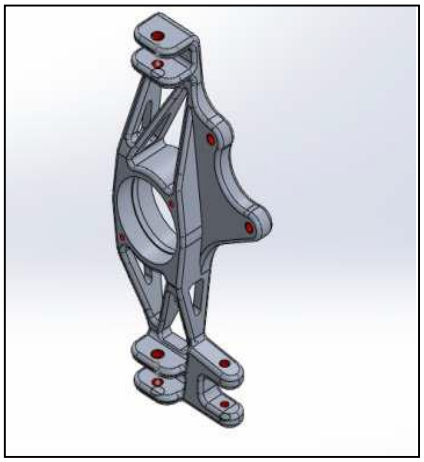

Fig. 1: Front knuckle

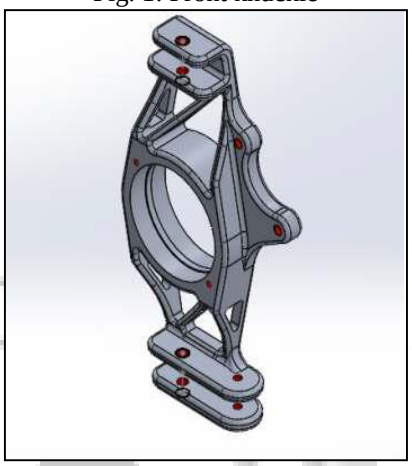

Fig. 2: Rear knuckle

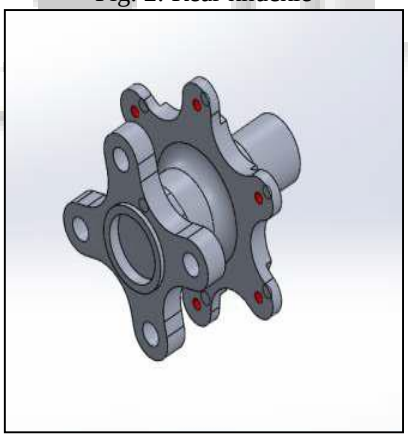

Fig. 3: Front hub

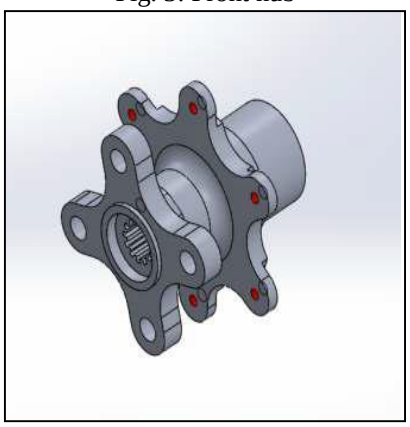

Fig. 4: Rear hub

IV. DESIGN CALCULATIONS

A. *Load transfer* = $\frac{Weight \times acceleration \times CG\ height}{Track\ width}$ *[2]:*

Weight- 280 Kg
Acceleration- 1.5*9.81 N
CG height- 37.5 cm
Track width- 4.5 inch
Design load transfer- 1377.95 N
Load transfer on upright due to turning would increase this load upto 1500 N

B. *Braking Force= Weight * Deceleration G [3]*

*Braking Force= 280 * 1.5 * 9.81= 3237.3 N:*

Bearing used- NTN single raw bearing
For front knuckle- inner diameter is 40 mm and outer diameter is 62 mm.
For rear knuckle, Inner diameter is 60 mm and outer diameter is 85 mm.

V. MATERIAL SELECTION

Properties	Al6061	Al7075
Elastic modulus (GPa)	70-80	70-80
Density (g/cc)	2.7	2.81
Poisson's ratio	0.33	0.33
Hardness (HB500)	30	60
Tensile strength (MPa)	115	115

Table 2: [4]

Mechanical properties are as follows:

Ultimate tensile strength	572 MPa
Tensile yield strength	503 MPa
Elongation at break	11%
Modulus of rigidity	71.17 GPa
Fatigue strength	159 MPa
Fracture toughness	25 MPa-$m^{1/2}$
Shear modulus	26.9 GPa
Shear strength	331 MPa
Machinability	70%

Table 3:[5]

Thermal properties are as follows:

Specific heat capacity	0.96 J/g-ºC
Thermal conductivity	130 W/m-K
Melting point	477-635 ºC
Solidus	477 ºC
Liquidus	635 ºC

Table 4 [5]:

Electrical properties are as follows:

Electrical resistivity	0.15e-006 ohm-cm

Table 5 [5]:

VI. ANALYSIS MODEL OF PROJECT

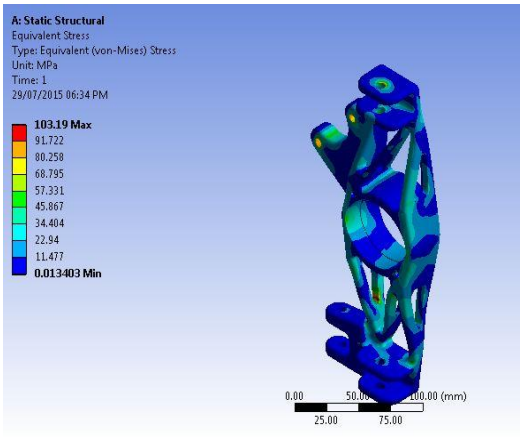

Fig. 5: Front knuckle

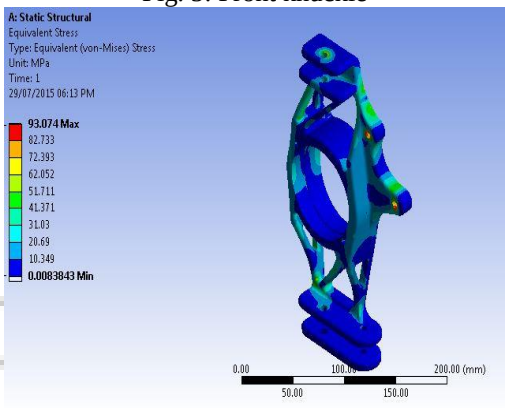

Fig. 6: Rear knuckle

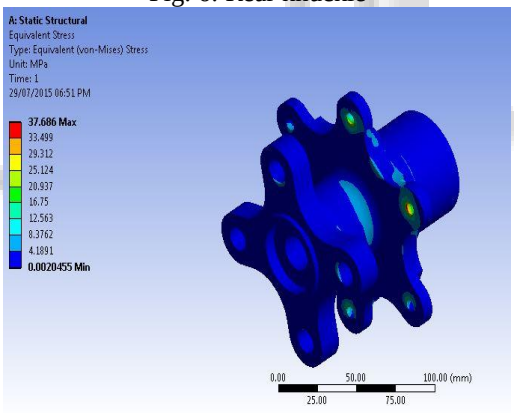

Fig. 7: Front hub

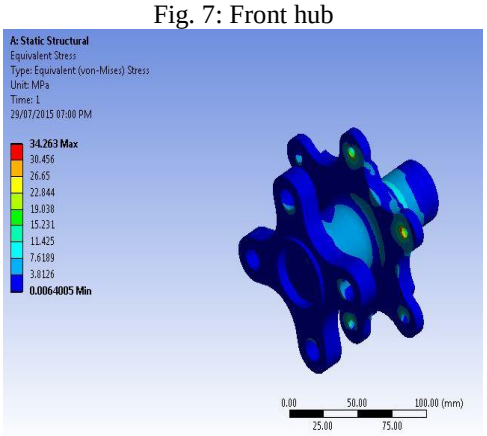

Fig. 8: Rear hub

VII. RESULT OF ANALYSIS

Model	Max. deformation	Max. stress
Front knuckle	15.94 mm	103.91 MPa
Rear knuckle	14.38 mm	93.074MPa
Front hub	2.75 mm	34.263 MPa
Rear hub	1.29 mm	37.686 MPa

Table 6:

VIII. RESULT

Weight of front knuckle is 760 gm. and weight of rear knuckle is 900 gm. The weight of front and rear hub is 1.5 Kg each.

IX. CONCLUSION

Lighter weight of upright assembly and required stiffness is achieved by optimum design calculations and less complex design. Proper material selection of Al7075 is important factor in reducing the weight of upright component without sacrificing in hardness and strength of component. Analysis of upright component is done by using ANSYS software and results obtained from analysis are within limits of requirement. Means, Upright assembly proves its stiffness and durability under stress consideration. Thus, Good performance to weight ratio is achieved.

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