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# Design and optimization of wheel hub for formula ATA race car

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**Abstract -** *Formula ATA is an annual international university level design competition organized by the Society of Automobile Engineers. The purpose of this project is to design and manufacture the wheel hub for Formula FSAE vehicle. The purpose of this wheel hub is to provide a mounting to uprights which links the suspension arms to the chassis and wheel assembly, as well as carrying brake components. It is a load bearing member of the upright system and is constantly moving with the motion of the wheel. The design of the 2k18 upright wheel hub assemblies achieved a total weight reduction of over 500 grams, which improves to a 50% reduction overall. This is achieved with no loss in stiffness according to the Finite Element Analysis in the computer.*

## 1. INTRODUCTION

The motive of our project is to design, analyze and fabricate the wheel hub of our team "THE INTERCEPTORS", an FSAE vehicle. Formula Student is one of numerous competitions that are held for students at university level yet it is one of the largest engineering competitions for student's worldwide. The aim is to supply a lighter and overall performance oriented design of upright meeting in evaluation with season 2017-2018 automobile and thereby contributing in making of automobile of season 2018-2019 higher than its predecessor. Use of conventional upright assembly will increase the overall weight of the race car. For FSAE car, weight standards is a major factor in making of race car and in addition, to opposition factor of view. The intention of lighter weight upright assembly may be achieved by less complex layout and proper material selection. Hence the modified wheel hub is designed for the required fatigue life. Also the proper stiffness and reliability can be achieved by means of evaluation the design of upright meeting. Wheel bearings are as vintage and critical as the wheel itself, thanks to their ability to allow unfastened rotation without the harmful effects of friction and put on. We're going to also cowl the variations between "wheel bearings" or "axle bearings" established at the wheel itself together with "axle shaft bearings" placed in addition inboard alongside axle shafts. Despite the fact that bearings are available in a diffusion of shapes, they all serve the identical basic reason. A Wheel Hub Assembly (WHA), also known as hub assembly, wheel hub unit, wheel hub bearing, etc., is an automotive component utilized in most vehicles, passenger vehicles, and light and heavy vans. The Wheel Hub Assembly is placed among the brake drums or discs and the force axle. A wheel is bolted on it. Relying on the construction, the hub comes geared up with the splined teeth. They mate the enamel at the axle shaft. The axle hub spins alongside the wheels bolted to it and offer the power to the wheels if you want to rotate. The upright connects the control arms to the hub which connects the upright to the wheels allowing the vehicle to move. The uprights also connect to the steering arm, allowing the driver to steer the vehicle, and the caliper, allowing the driver to stop the vehicle. The hub is directly connected to the wheel, and is connected to the upright. The upright is to remain stationary relative to the chassis while the hub is to rotate with the wheel. This is done by placing a bearing between the hub and upright. Typically, a spindle is pressed into the upright and does not rotate and a bearing is pressed into the hub, and the spindle is pressed into the bearings allowing the hub to rotate about the spindle. Unsprang mass is the mass of the wheel, hub, rotor, caliper, uprights, and brake pad. Essentially unsprang mass is the mass that is not supported by the shocks (for example the chassis and everything supported by the chassis is sprung mass). In this case of the current design, it also provides a means of adjustment to the suspension parameters such as camber and steering Ackerman geometry

## 2. DESIGN WORK

The main objectives in this project are to reduce the mass, both the total mass and the unsprung mass of the Wheel Hub, with retained strength and function. Therefore, all containing parts are analysed in the Pre-study to define the current masses. The current parts are both measured in experiments by a scale and measured in Catia, this due to investigate the accuracy of the measurements made in Catia. The new designs are only measured in Catia.

## 3. MATERIAL

The hubs are designed to mate with center locking 10" Keizer rims. The front hubs have been manufactured out of 7075 aluminum by considering weight reduction. The rear hubs incorporate a hardened steel tripod housing coordinated on CMM that is inserted into the hub, eliminating wear issues with the aluminum. EN-24 is the material chosen for rear hubs considering the torque exerted by half shaft into the hubs.

### 3.1 WHEELS

A 10-inch rim is the team's choice to lower the torque to spin the wheel as compared to 13 inch. Hence the time taken for 10 inch wheel to reach peak torque value and rpm for each gear has been reduced comparison to 13 inch wheel, which would thus accelerate the car faster. A smaller wheel size has also aggravated the weight reduction of un-sprung mass.

Fig1: Rim

## 4. FORCES NORMAL CONDITION

To calculate the forces on the wheels, two Free Body Diagrams are performed in Figure the car is seen from the front, and Figure 1 the car is seen from the left side to make assumptions of the forces acting. A "Normal condition"-drive is where no un-normal behavior of the car appears, and the track is smooth with no ruts, wet or loose gravel and tarmac.

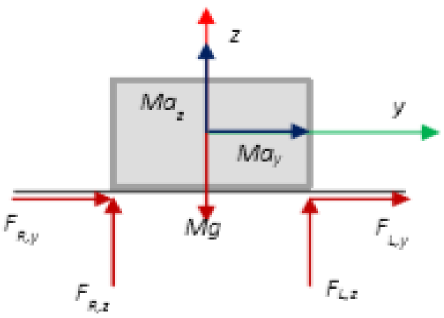


Fig2: Free Body Diagram y-z-plane

To assume and show that the forces acting on the ground is equal or assumed to be equal at the Hub see Figure 2. By static Equations 2 and 3the forces on the system are in equilibrium when the forces at the ground are equal to the forces at the Hub. This assumption will be use in this project as a simplification; some differences will be covered by a Safety Factor.

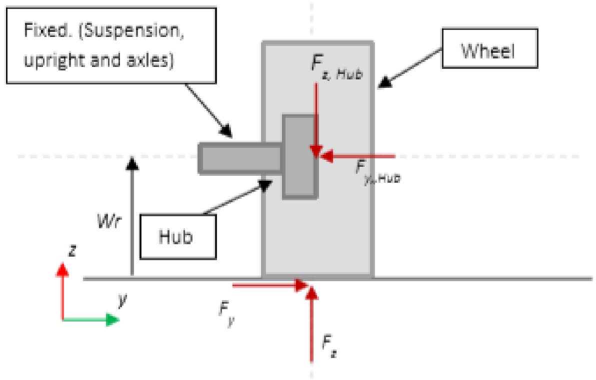


Fig3: Forces on Hub and wheel

### 4.1 ACCELERATION TORQUE

FEA was used to confirm the hub design could withstand the torque applied by both the wheels and the brakes. A moment of 100000 N-mm was applied on the wheel mountings keeping the disc mounting constant. The maximum normal, lateral, and braking force was applied to the front upright while keeping the control arm fixed.

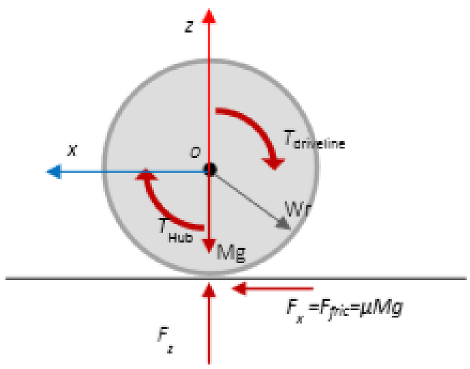


Fig4: Free Body Diagram Torque applied

### 4.2 BRAKING TORQUE

The Wheel Hub is affected through the Brake Disk Adapter which is assembled on the Hub and fixed on the wheel nuts with the rim. The moment acting on the Hub is interesting. Things that has to be consider when making assumptions of this is the Brake Balance, the speed and acc eleration of the car. These data are collected and used in this analysis, see Figure 4 for a plot of Speed vs. time in MATLAB® from the collected data. The Brake Pressure, or Brake Balance is not analysed, and the braking is only calculated related to the total acceleration during the braking.

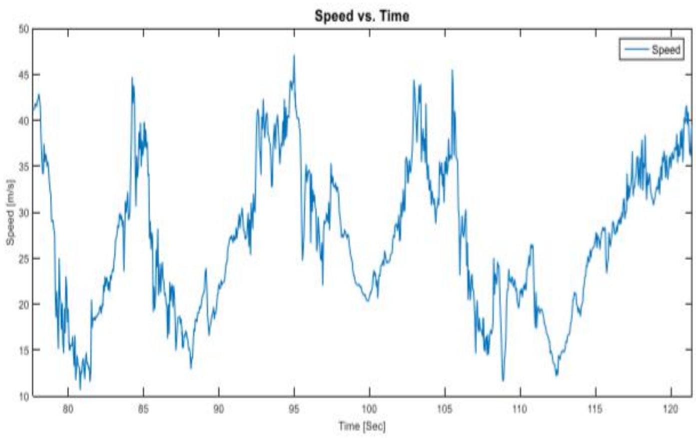


Fig5: Speed vs. Time

The Free Body Diagram in Figure 5 showing the torque acting on the Wheel Hub and the forces from the ground during the braking, assumption this is equal at all four wheels and this calculation performed at the front, or rear right wheel.

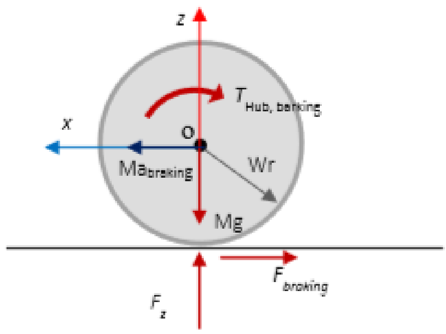


Fig6: Free Body Diagram Braking

By comparing the torque applied in acceleration and the torque caused by the braking is approximate a factor of ten larger, and therefore the most critical torque acting on the Hub.

## 5. CALCULATIONS

Determining the forces acting on the Hub.

The following Forces are acting on the Hub.

a. Torque on the Brake Disk Petal : -

A 130 Nm torque is acting on the Brake Disk Petal.

The Force acting on each hole= $\frac{moment/radius}{No\ of\ holes}$ $= \frac{1300000 \div 100/2}{4}$ = 650N

b. Torque on the Wheel Petal : -

In order to sustain this braking effect the wheel must also provide and equal and opposite torque. Thus the magnitude of torque is same but the direction is opposite.

The Force acting on each hole = $\frac{moment/radius}{No\ of\ holes} = \frac{1300000 \div 100/2}{4}$ = 650N

c. Force due to Side Impact: -

If the vehicle is banged by other vehicle from side or if the vehicle has a collision with the fencing from side, there are chances that the petals might bend. Hence this side impact force must also be considered.

Here the side Impact force is taken to be 2G = 2 × g × vehicle mass

Impact force = 2 × 9.81 × 300 = 5409 N

Impact force on 1 petal = 8829/3 = 1352.2 N

d. Loads on Bearing: -

The load on 1 bearing is 700 N

The load on 2nd bearing is 634 N

The axial load is 1388 N

Selection of Wheel Bolt

Shear Stress on the bolts = $\tau = \frac{syt*0.5}{FOS} = 145 N/mm2$

The force acting on the Wheel Bolt is given by the result

now,

$\tau = \frac{F}{A}$

$145 = \frac{880}{\frac{\pi}{4} dc*dc}$

$D_c = 2.99mm$

$D = d_c/0.8$

D = 2.99/0.8

D = 3.74mm

Selection of Brake Disk Bolt

Shear Stress on the bolts =τ=$\frac{syt*0.5}{FOS}$=68.75N/mm2

The force acting on the Wheel Bolt is given by the result.

now,

$\tau=\frac{F}{A}$

68.75=650/(π/4*dc*dc)

$dc=\sqrt{\frac{650*4}{\pi*68.75}}$

dc=3.46

d=4.33mm

Thus selecting the bolt size of M8.

Design of Wheel Petal

Shear Failure of Petal

Allowable stress in the Hub in shear

= τ=$\frac{syt*0.5}{FOS}$=125.75N/mm2

Force acting on Petal as obtained from result is 880 N.

Now,

$\tau=\frac{F}{A}$

$125.75=\frac{880}{2(t*b)}$

t × b = 3.5

Where,

t= thickness of Wheel Petal

b= distance between the hole and the end of petal

If t = 8mm b= 0.475 mm

Thus the width of the petal is taken to be 7mm

The thickness of the petal is as 8 mm.

Bending of Wheel Petal

This bending is due to the force of 880 N. The radius of effective bending is 49.25 mm

Mb = 880 × 49.25

Mb = 43340 N-mm

Now,

By Flexural Equation: $\frac{Mb}{I}=\frac{\sigma b}{y}$

$\sigma_b=\frac{syt}{FOS}$=503/2=251.5N/mm$^2$

y= 2b/2

2b=d

$I=\frac{1}{12}td^3$

Where,

t= thickness of knuckle

b= width of knuckle

$\frac{43340}{\frac{1}{12}td3}=\frac{251.5}{d/2}$

T*d$^3$=1034

If t= 8mm d = 11.36 mm

Thus, the width of knuckle is 12mm.

The thickness of knuckle is 8 mm.

Total thickness = width + dia of hole =12+14 = 26 mm

Design of Brake Disk Petal

Shear Failure of Petal

Allowable stress in the Hub in shear = τ=$\frac{syt*0.5}{FOS}$ =$\frac{503*0.5}{2}$=125.75N/mm$^2$

$$\frac{Mb}{I}=\frac{\sigma b}{y}$$

$\sigma_b=\frac{syt}{FOS}$=503/2=251.5N/mm$^2$

y= t/2

$I=\frac{1}{12}td^3$

Where,

t= thickness of petal

b= width of petal =27 mm

Force acting on Petal as obtained from result is 880 N.

$$\tau=\frac{F}{A}$$

$$\frac{49540.5}{\frac{1}{12}27t*t*t}=\frac{251.5}{t/2}$$

t = 6.61mm

The thickness of petal is taken as 8 mm

$$125.75=\frac{879.89}{2(t*b)}$$

t × b = 1.7495

Where,

t= thickness of Wheel Petal

b= distance between the hole and the end of petal

If t = 5mm b = 0.35 mm

Thus the width of the petal is taken to be 5mm.

The thickness of the petal is taken as 6mm.

Design of Wheel petal due to Side Impact

The force is obtained from the result for 1 petal = 1962 N

The effective bending Radius = 25.25 mm

Mb = 1962 × 25.25

Mb = 49540.5 N-mm

From the above result it is clear that hub without fillet and triangulation support were more prone to failure than those with fillet and triangulation support.

Besides the stress concentration in the optimized design was less.

## 6. CONCLUSION

The observation made while working through this project is that the possibilities to improve the Wheel Hub is large. The design developed in this project is a big step forward to reduce the unsprung mass of the car. The design will not affect the geometry of the suspension and therefore the behaviour of the car in that aspect. The advantages of change to the re-designed Hub will increase the acceleration of the car and improve the traction between tire and road. The limitations set in this project makes it difficult to make the changes needed to find the optimal design. Even if the design will improve the car by making small changes can an advantage in changing the upright and suspension geometry an even more innovative design with less unsprung mass and advantages in suspension geometry, heat flux etc.

## REFERENCES

[1] Callum W. Watson, The Otimum Weight Distribution For a Formula SAE Vehicle , , University of New South Wales at the Australian Defense Force Academy

[2] Pruthviraj Vitthal Wable and Sahil Sanjog Shah, Design Analysis & Optimization of Hub Used in FSAE Cars, , UG Student, Department of Mechanical Engineering, Trinity College of Engineering and Research, Pune, Maharashtra, India.

[3] Joijode Vrushabh Umesh and Yadav Abhishek, Designing and Optimization of Wheel Assembly of a Formula Student Car, , Mechanical Engineering Department, Vishwakarma Institute of Technology, 666, Upper Indira Nagar, Pune-37, India.

[4] L. Daniel Metz, William F. Miliken, Douglas L. Miliken, Race Car Vehicle Dynamics Workbook, SAE intenationals, 1998.

[5] Óskar Kúld Pétursson, Uprights, wheel hubs and brake system for a new Formula Student race car, School of Science and Engineering Tækni- og verkfræðideild, Kennitala 110489–3239.

[6] Alejandro Diaz ,Osvaldo Fernandez, Ricardo Gonzalez, Christian Ramos, FSAE 2015 Chassis and Suspension Final Report, EML 4905 Senior Design Project, Florida International University.

[7] William Kinkead, ME Connor Morette, ME Adrian Pickering, ME Zachary Sears, Design and Optimization of a Formula SAE Vehicle, Worcester Polytechnic Institute.