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Design Analysis and Fabrication of Wheel Assembly

Anuj Bale[1], Prof.N. P. Jadhav[2]

[1]Mechanical Engineering Department. Pune University, Sinhgad Academy of Engineering Kondhwa Pune, India.
[2]Mechanical Engineering Department. Pune University, Sinhgad Academy of Engineering Kondhwa Pune, India.

Abstract

Tyre is a rubber part which is mounted on a rim which is central part of wheel. In wheel assembly tyre mounted on the rim in between the left and right board flanges over the bead seat area. Wheel convert axle torque into the rotational motion that rotating tyre comes in contact with road surface and rotational motion gets converted into the linear motion of a vehicle, that means wheel assembly is very important part of any automobile without it vehicle cannot displaces from one position to another. Well build road surfaces are not available everywhere in the world. On road there are so many up and downs as well as pot holes which are responsible for impact load on the wheel and rim directly. Wheel is subjected to the loads of passenger, goods in addition with self-weight of vehicle itself, such load act as an alternating load and responsible for induction of alternating stresses into the rim and resulted fatigue failure of rim. Apart from above load wheel rim come in contact with environmental conditions which adversely affects on the rim. Comparative study with wide varieties of aspectson wheel have been made in this paper.

Keywords:ANSYS Workbench, Pro E, Stress Analysis, Hub, Knuckle, Design and Optimization.

1. Introduction

An automobile is said to function appropriately only when all its systems are working as they are required to work. The engine produces power and gives it to the drive train through a clutch. The portion of the drive which transmits this power from the drive train to the wheel and which connects the main frame of the body with the wheels through the suspension arms is known as the Wheel Assembly. It is a part of the final drive. Thus it serves the function of transmitting the power from the drive shaft to the wheels. There are always two types of masses in an automobile – sprung and unsprung mass. All the mass of the vehicle that is damped by the spring is called as the sprung mass. Wheel Assembly weight is not on the damper so it is damp by the spring, it is unsprung Mass. We know that the unsprung mass must be lower than the sprung mass and also should be as least as possible to provide proper drive stability and load balancing of the vehicle. Thus it becomes important to reduce the mass of the wheel assembly and the rims and tires. However while doing the study mass of the wheels, tires and the wheel assembly must be enough to prevent the lateral toppling of the vehicle at the time of cornering or impact care must be taken. There are a lot of forces acting on the wheels in the static and especially in the dynamic condition. Allthe above forces also have an impact on the design of the Wheel Assembly as the wheel assembly is directly connected to wheels. A lot of forces act on the wheel assembly during accelerating, braking, cornering and tilting. A good wheel which can sustain such forces over a longer period of time is good wheel assembly. Thus it is required to design the wheel assembly considering all these factors. Thus utmost care must be taken while designing the Wheel Assembly. The objective of Optimization is always to find the best possible and suitable dimension. This is because optimization does not always mean reducing dimensions it also means finding out the dimensions which will just enough to sustain the forces. Here in this case, R12 rims have been used along with 165×60 wet tires. The Weight of the vehicle is considered to be 300 kg along with the driver. All the forces have been found out on the above basis and according to the above mentioned Wheels. The Wheel Assembly designed in the paper is for Formula Student Vehicle.

2. Components of Wheel Assembly.

As shown in the figure the Wheel Assembly consists of the following Components.

1) Spindle-(1)
2) Knuckle-(1)
3) Hub-(1)
4) Bearings
 a. Taper Roller Bearing- Front-(2)
 b. Deep Groove Ball Bearing-Rear-(1)
5) Nut-(1)
6) Cotter/Split Pin-(1)

Before understanding the procedure it is important to understand how all these components are assembled. Firstly the spindle is taking. The Knuckle is press fitted on the spindle. Then the space between the knuckle and hub is either slide fitted of press fitted on the spindle in order to accommodate the calliper. After wards the inner race of the bearing is press fitted on the spindle. The hub is taken and the outer race of the bearing is press fitted in the hub. Then the hub is positioned on the bearing and then the second bearing's inner race is press fitted on the spindle. Then the nut is tightened on the spindle and a split pin is inserted into the hole made in spindle for positively locking the Wheel Assembly

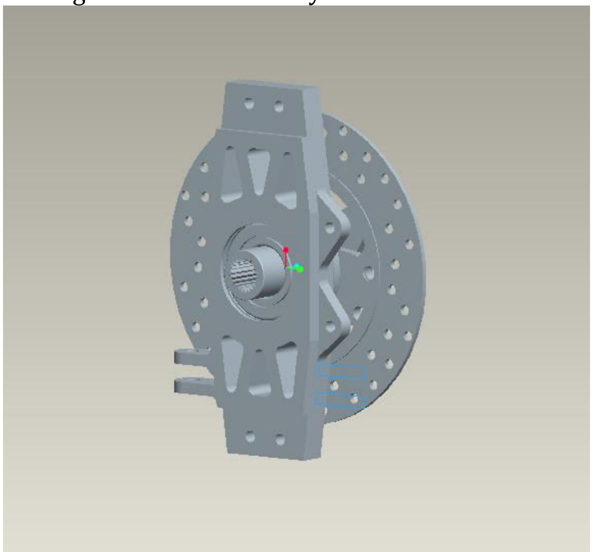

Fig.1 Wheel Assembly Front view

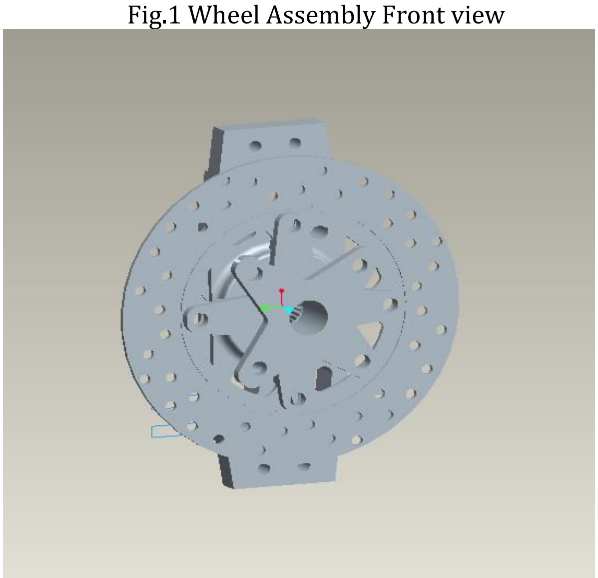

Fig.2 Wheel Assembly Back View-2

Fig.3 Full Assembly Exploded View

3. Design Consideration & Procedure

The first step while designing the wheel assembly is to find out the required parameters in order to design the wheel assembly from the steering and the suspension geometry. The Steering and Suspension Engineer design their geometry, a kinematic representation of various parts in that system, according to the requirement. A Wheel Assembly Design Engineer must refer to these geometries so that in the actual vehicle these parameters are followed. The Steering Geometry has an influence on the Front Wheel Assembly only. The Front Suspension and Rear Suspension Geometry affect the front and rear assemblies. Parameters such as King Pin Angle, Steering Arm angle, Tie rod angle are obtained from the Steering geometry, whereas the Caster angle, the angle of upper A-arm and the lower A-arm, Rear Track width are obtained from Suspension Geometry. Parameters like the Stub length and the front track width are obtained from both Geometries. Considering the Front Wheel Assembly the Parameters are as follows

Caster Angle - 8 deg
Tie Rod Angle: - 3.940
Track Width: - 1270 mm
Wheel Radius: - 303.2 mm
Total length of Knuckle: - 171mm
King Pine Inclination - 6 deg

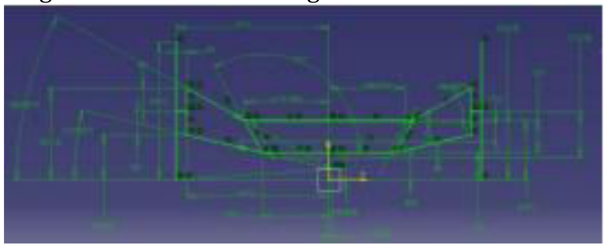

Fig.5 Vehicle Suspension Geometry

The knuckle length is obtained in one view from suspension geometry. Besides it is a matter whether or not to provide inbuilt caster also affect the length. So it is important to find out the actual lengths from these two angles as shown in figure. The effective length of the front knuckle is 85.685 above and 86.761 from the center point from above figure.

4. DESIGN CALCULATIONS

A. Load transfer = $\frac{\text{Weight} \times \text{acceleration} \times \text{CG}}{\text{height Track width}}$

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 up to 1500 N

B. Braking Force= Weight * Deceleration G

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.

5. Analysis and Result

The Wheel assembly is designed by considering various conditions such as cornering, braking, acceleration and also a combination of cornering and braking and acceleration. Then by drawing free body diagrams for all conditions, maximum Lateral, Longitudinal and Normal forces were calculated. By using these forces, the braking torque and applying the suitable boundary condition, finite element analysis on hub is carried out. In order to
The following forces were considered for analysis of wheel assembly

1. Lateral force on hub surface
2. Driving torque
3. Braking torque

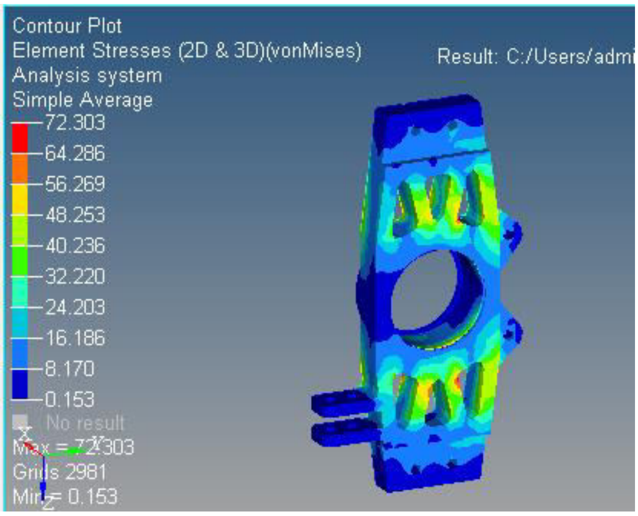

Fig. 5.1: Maximum stress on Knuckle is 62 Mpa

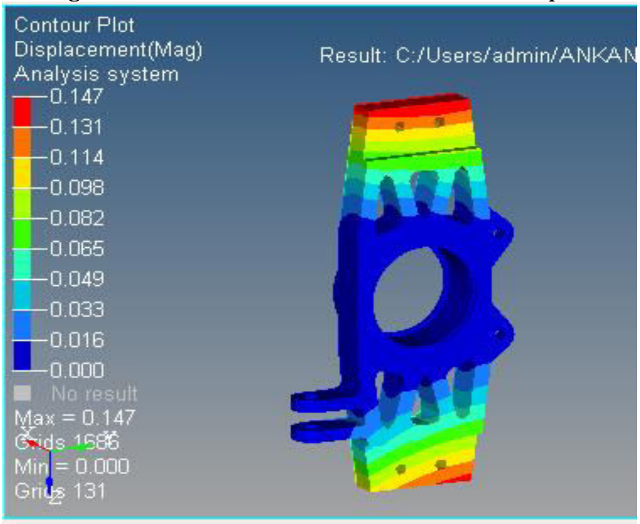

Fig. 5.2: Maximum deformation is 0.147 mm

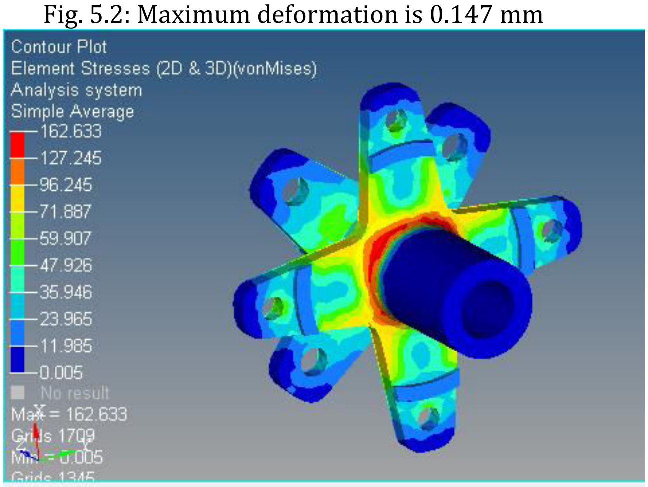

Fig. 5.3: Maximum stress on Hub is 162 Mpa

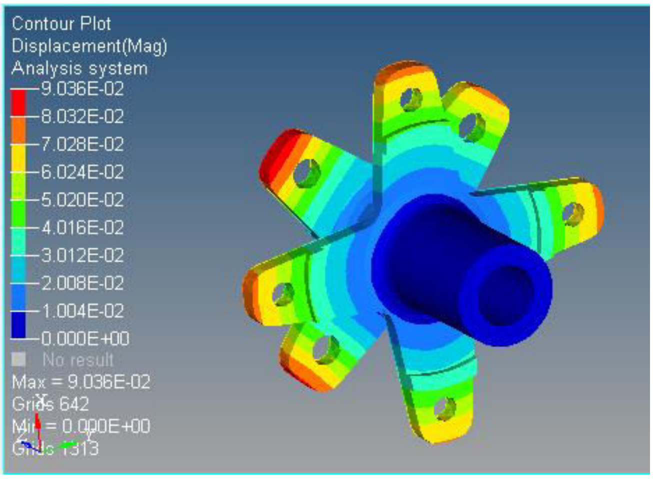

Fig. 5.4: Maximum Deformation is 0.09mm

Fatigue analysis of knuckle

Fatigue Analysis is performed in Ansys Workbench order to calculated life and damage.

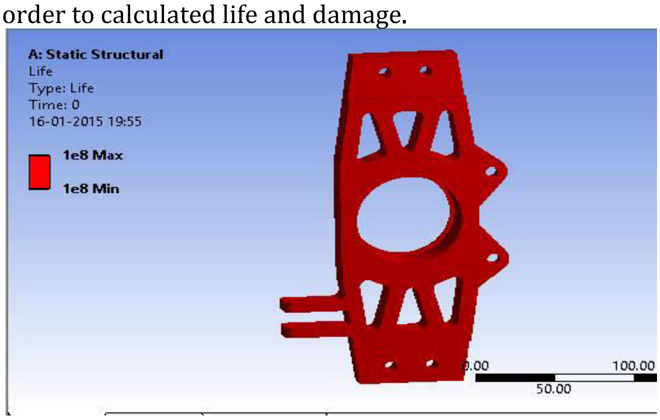

Fig. 5.5: Minimum life available 1e8 cycle

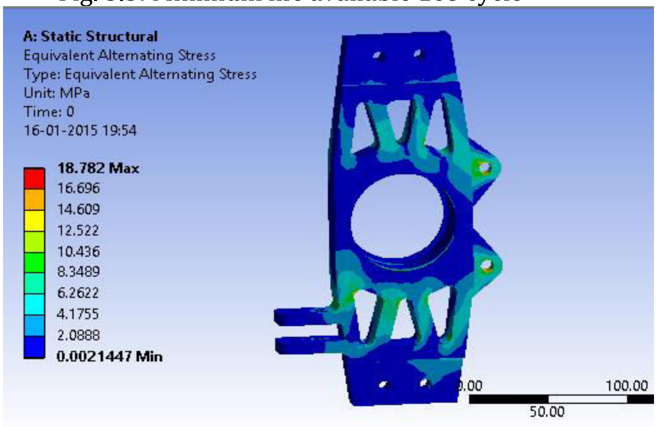

Fig. 5.6: Equivalent Alternating Stress

From the above result it is clear that design is safe under extreme condition.

Below table shows the factor of safety for different component.

Part	Stress(Mpa)	Yield Stress(Mpa)	Fos
Knuckle	62	185	2.98
Hub	162	385	2.37

Part	Material
Knuckle	Aluminium 6063
Hub	Steel

6. Conclusion

Following conclusions can be drawn from the paper,

1) for a component undergoing fatigue loading; the design criteria must always be Fatigue or Endurance Strength.
2) For carrying out optimization, material should be removed from the low stress concentration areas.

Fig. 6.1: Manufacture Wheel Assembly

Fig. 6.1: Manufacture Wheel Assembly View-02

3) In order to minimize stress concentration areas, sharp corners and edges should be avoided.
4) If the component is subjected to fatigue failure like knuckle, then analysis of the components must be carried out in order to obtain actual stresses induced in the component.
5) For accurate results of analysis, mesh quality must be high and failing elements must be less than 3%.

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