ABSTRACT

The alloy wheels have always been a subject of interest among the high performance bikers. A lot of research has been going on the different materials and design for the wheels. With the increase in the engine power and hence top speed of the bikes, it has been very important to select a proper wheels. In case of sudden braking or passing over a path hole, large amount of shear forces are generated into the front wheel. Aluminium alloy wheel is the first alloy commercially used for rims. Recently Magnesium alloys have been used widely due to light weight property. The alloy wheels help in increasing the power to weight ratio of the bike. Static-structural analysis of the wheel has become inevitable before doing experimental analysis. This paper deals with the static analysis of a bike front wheel for the various types of loads acting during sudden braking and passing a bump.

Keywords: alloy wheels, static-structural analysis, Aluminium alloy, power to weight ratio.

1. Introduction:

The main advantage of alloy wheel is that, it weighs about 50% of the steel wheel with almost 90% of the strength. Moreover light alloy wheels are better conductors of heat which helps the wheel dissipate any heat generated by the tires or the brakes. Further, wide rims are possible which improves the stability on cornering. Alloy wheels can be manufactured by maintaining close tolerances also they look better in the appearance. The wheel is made up of a disc and a flange. Disc and flange are usually integral. The wheel is fixed to its hub with bolts. Flanges have a particular shape suitable for keeping the tire in place. The flange is characterized by the diameter and shows a dropped center useful for tire assembly and disassembly. The rim disc is characterized by windows suitable for improving brake cooling and by a central hole able to sustain the wheel before the bolts are tightened.

Unbalanced heavy loads comes on to the front wheel during sudden braking. When braking is increasing, the centre of mass moves forward relative to the front wheel, as the rider moves forward relative to the bike. the suspension on the front wheel compress under the load which puts an extra load on the front wheel.

The physical and isotropic properties of alloys whose static structural analysis is performed are given in the table 1.

<table>
<thead>
<tr>
<th>Table 1. Properties of Alloys</th>
<th>Density (kg/m³)</th>
<th>Young’s Modulus (GPa)</th>
<th>Poisson’s Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Alloy</td>
<td>2770</td>
<td>71</td>
<td>0.33</td>
</tr>
<tr>
<td>Mg-Alloy</td>
<td>1800</td>
<td>45</td>
<td>0.35</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>1600</td>
<td>70</td>
<td>0.1</td>
</tr>
</tbody>
</table>

1.1 Aluminium Alloy:

Aluminium are alloys in which aluminium is the predominant metal. The typical alloying elements are copper, Magnesium, Silicon and Zinc. The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required. Selecting the right alloy for a given application entails considerations of its physical as well as isotropic properties.

1.2 Magnesium Alloy:

The strength-to-weight ratio of the precipitation-hardened magnesium alloys is comparable with that of the strong alloys of aluminium or with the alloy steels. They are also used when great strength is not necessary, but where a thick, light form is desired. The strength of magnesium alloys is reduced at somewhat elevated temperatures; temperatures as low as 200F produce considerable reduction in the yield strength.
Despite the active nature of the metal, magnesium and its alloys have good resistance to corrosion. The rate of corrosion is slow compared with rusting of mild steel in the same atmosphere.

1.3 Carbon Fibre:
Carbon-fiber-reinforced polymer is used extensively in high power automobiles. The high cost of carbon fiber is diminished by the strong strength-to-weight ratio, and low weight is essential for high-performance automobile racing. Race-car manufacturers have also developed methods to give carbon fiber pieces strength in a certain direction, making it strong in a load-bearing direction, but weak in directions where little or no load would be placed on the member. This type of carbon fiber assembly is most widely used in the monocoque chassis assembly of high-performance race-cars.

2. Methodology:
The wheel was designed in ProE. The structural analysis was done in the ANSYS software. Analytically the force and the moments acting on the front wheel.
As the wheel has intricate parts, fine mesh was selected. Fine mesh also gives precise results.

2.1 Force Calculations:
For analysis purpose, worst case condition is considered in first condition wheel locking is considered resulting in very high braking forces, which applies torsional load on wheel hub.
In second case, vehicle hitting bump at very high speed is considered.

![Fig. 1 Forces acting on running wheel](image)

Normal force: weight of the vehicle acting on front wheel
\( \alpha = \text{Steering angle with respect to Z axis, in this case } 10^\circ. \)
Mass of the vehicle = 2017 kg
Case 1:
Vehicle front wheel hitting the bump at very high speed
Speed of the vehicle = 120kmph
Force calculations:
Mass of the vehicle on front wheel = 107 kg at \( 10^\circ \) with z axis
X component of force = 0.18 kN
Y component of force= 1.033 kN
Impact forces due to bump:
Height of bump = 0.15m
Impact force = \( 2\varepsilon\omega_n \)
\[ = 1.7550 \text{ kN} \]
X component : 1.617 kN
Y component : 681.22 N

Case 2:
Wheel locking at very high speed
Vehicle speed: 120 kmph
Forces acting on the wheel:
Frictional force = 524.8 N
Braking force = 1410.9 N
Inertia of the vehicle = 207 Nm
3. Result And Discussion:

Fig. 2 Equivalent Stress in Al-alloy wheel

Fig. 3 Maximum Equivalent Stress due to path-hole

Fig. 3 shows relation between the maximum values of the equivalent stress among the three alloy wheel materials when the wheel passes through a path-hole. Carbon fibre alloy wheel can take the maximum stress of 3.502 MPa. The least stress is taken by the Magnesium alloy wheel.

It is clear that the sudden force generates the compressive stress into the spline attached to the rim and tensile stress in the spline exactly opposite to the point of load.

Fig. 4 Deformation in alloy wheel due to path hole

Fig. 5 Maximum Deformation due to path-hole
Fig. 5 shows the deformation occurring into the wheel rim due to the sudden force due to path-hole. The Magnesium alloy deforms by 16.1 micrometer which is maximum compared to other two kinds. Least deformation is shown by the carbon fibre alloy wheel which is 10 micrometer.

In case of sudden braking, the load is transferred on the front wheel. Also the wheel tends to rotate due to rational inertia. Fig. 8 shows the maximum equivalent stress on the wheel rim in such case. Carbon fibre alloy wheel takes maximum stress of 4.539 MPa while Magnesium alloy wheel takes 4.5 MPa. The ultimate tensile strengths of three alloys is much above the stresses being taken by them.
During sudden braking, the maximum deformation occurs at the circumference of the wheel rim as it has maximum angular velocity. The wheel hub stops as soon as the disc is locked, this creates reaction force at all the points on the rim which tries to stop the wheel motion. The least deformation is shown by the carbon fibre wheel which is 12.86 micrometer. The Mg-Alloy wheel deforms maximum with 20.80 micrometer.

4. Conclusion:
After performing the stress analysis following conclusions are drawn:
- Magnesium alloy and carbon fibre are better replacement for Aluminium alloy wheels.
- Carbon fibre material is the best suited for critical conditions for the wheel.
- Low density and higher strength gives carbon fibre an edge over other two alloy materials.

5. Acknowledgement:
We would like to express our gratitude to Prof. Vijyakumar T. for his fruitful suggestions.

References:
Journal Papers:
[1] Influence of residual stresses in Aluminium wheel design by Marco Antonio Colosio et al., SAE No. 2008-36-0139
[2] Fatigue analysis of Aluminium alloy wheel under radial load by N. Satyanarayana and Ch. Sambhaiah, IJMIE, ISSN no. 2231-6477.
Books: