Mathematical Modeling of alloy wheel rim shape optimization using metaheuristic method

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Abstract. For the all automobile, wheel rim is very important part to control it. The wheel rims are only contact with both dynamic load and impact load. Dynamic load is rotation and the impact load is comes from road condition like speed breakers. Since we try alloy materials to the wheel rim. This alloy wheels are more safety and lighter than the other materials. In this paper, the alloy wheel rim is shape analyzed by the metaheuristic method using ansys workbench software. By using solidworks the 3d model of the wheel rim made. Based on the final deformation of all materials, the best material is selected.

1. Introduction

Magnesium metal or aluminum alloy or combination both is used in current time for fabricate the wheel rim. For improve the car velocity reduce the weight of the alloy wheel by changing its material. Magnesium alloy wheel rim are used as light alloy wheel rim from the starting. To improving of vehicle handling also done by reducing of wheel rim weight. Wheel rim design is different shapes available in the present. They are steel disc wheel, wire spokes wheel and alloy wheel. When the wheel rim weight reduced the tyre performance and life also increased.

But aluminum alloy wheels rim are only used in the present four wheelers. Magnesium alloy is more cost than the Al alloy and it has less density. When the density of the material is reduced its weight also reduced. Maximum studies are based on the light weight alloy and steel alloy.

The tires are works as wheel when it is fitted over the wheel rim. The both performance and function of the vehicle is based and tire and wheel rim. Tier design is based on the wheel rim design only when it was fitted on the wheel rim its perform upto its maximum level. The life of the tier based on the
proper installation of tier in wheel rim [8]. The wheel is known as combination wheel rim, tire and disc. After the assembly disc only its becomes wheel.

2. Nomenclature of the wheel rim

**Wheel**- Its known as combination of tire, wheel rim and disc

**Rim**- This part is intermediate with both vehicle and tire

**Disc**- This component is connecting with the axle hub. It is also important component of the wheel

**Offset**- The space between the center line of the rim and hub is known as offset.

**Flange**- tier beds are hold by this component which is known as flange.

**Beat seat**- Radial direction of the tier hold by this and it is intermediate with the beat face.

**Hump**- This part is used to prevent the tires during the vehicle running.

**Well**- This part used to assemble and disassembly the wheel rim

![Figure 2. Nomenclature](image)

3. Types of wheel rim

3.1. Rim shape

Based on the following the wheel rim shapes are made

3.1.1. DC rim

DC rim is known as drop centre rim. The shape of the rim is like dropped so only it’s called drop centre rim or DC rim. The type rim is helps to easy assembly and disassembly of the tires. The beat seat is five degree taper on this type.
3.1.2. **WDC rim**

Wide drop centre rim is known as WDC rim. This is similar to the drop centre type rim. The well length is larger than the drop centre rim. Height of the lower flange is also different from the drop centre rim. The low aspect tiers hold by this type of rims. The present passenger vehicle are has this type rim only.

3.1.3. **WDCH rim**

Wide drop centre with the hump is known as WDCH rim. This addition helps to the air flow on the wheel rim. The present tubeless tires are in this design only

3.2. **Material based types**

Light alloy and steel are used to fabricate the wheel rim. Some special cases the composite material are used to fabricate the wheel rims

3.2.1. **Aluminum alloy wheel rim**

This material lighter than the other material and the same time it has good strength, thermal conductivity and other mechanical properties. The main benefit of using this material is high precision with light weight. And also aluminum alloy recycling is possible.
3.2.2. Magnesium alloy wheel rim

Aluminum alloy is lighter than the other materials. But this magnesium alloy lighter than the aluminum which means is weight slightly down of 30% from Al weight. And it has high impact resistance with admirable size stability. It is used high ended race cars and feature cars which are high strength with less weight.

3.2.3. Titanium alloy wheel rim

Compared with the aluminum it is 2.5 times strength and corrosion less material. But major drop back cost of the material and cost of the machining too high than the other materials. This material is only on research level.

3.2.4. Composite material wheel rim

The composite alloy wheel rim is mainly made for correct drawbacks on the alloy wheel rims. Less weight is the major thing in the composite alloy wheel rim. Compared with the other alloy wheel rims it is good strength with less weight wheel rim. The development composite wheel rim is continuously going on.

4. Specification of the design model

- Diameter of the tire is 570mm
- Size of the wheel is 355 mm
- Length of the rim is 90 mm
- Width of the rim is 150 mm
- Disc wheel is selected to design
- Height of the flange 17.5 mm
- Radial type tire is selected
- Ratio of the aspect is 65
- Offset of the wheel rim is 85

5. Methodology

5.1. Modeling

Lot of software are available for the 3D modeling. In this paper solidworks software is selected. Because of solidworks software is user friendly than the other software. Beginners are easily made 3D model with accuracy by using this software. Based on the dimensions and details the wheel rim is made which it is shown in the fig 5.
The shown 3D model is drawn by the exact dimensions which are given in the top by using the solidworks software. After the modeling this part file is converted to step file or analyzing.

5.2. Analysis

Ansys workbench software is used to analysis the wheel rim. Ansys software lot of analysis types like thermal analysis, structural analysis, cfx analysis and etc., For this project, the metaheuristic method is selected. By using this method find the shape deformation for select the best alloy material

6. Result and discussion

- After the 3D modeling the design file import to the ANSYS workbench software for analysis.
- Tetra meshing type used to mesh the wheel rim. The meshig model of the wheel rim is shown in the fig 6.

![Figure 6. Meshing](image)

- After the meshing different materials are given to the wheel rim, the input materials are taken from material library. Thetitanium alloy and aluminum alloy are selected from the engineering materials.
- After the meshing the wheel rim has applied loads on its circumference. In here, 200Kpa load is acted on the wheel rim.
- After this select the results which are need. In this paper, the total deformation and stress are selected.
- After the selection of selects, click the solve option to get results
6.1. Stress

6.1.1. Aluminum alloy

![Al alloy stress](image1)

**Figure 7.** Al alloy stress

6.1.2. Titanium alloy

![Titanium alloy stress](image2)

**Figure 8.** Titanium alloy stress

6.2. Total deformation

6.2.1. Aluminum alloy

![Al alloy](image3)

**Figure 9.** Al alloy
6.2.2. Titanium alloy

Figure 10. Titanium alloy

| Table 1. Comparison of results |
|-------------------------------|
|                            | Aluminum alloy | Titanium alloy |
| Stress in Mpa              | 385            | 320.7          |
| Deformation in mm          | 1.757          | 0.4043         |

7. Conclusion

The 3D model of wheel rim is successfully created by the SOLIDWORKS software and it was successfully imported to the ANSYS workbench software. In the ANSYS workbench software, the wheel rim analyzed under 200 Kpa of load on the circumference with two different materials (Titanium alloy and aluminum alloy). And finally the results are comparing with each other. From the comparison the titanium alloy gives better result than the aluminum alloy wheel rim. In the future, all high ended vehicle wheel rims are made by titanium alloy material

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