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Original Research Article

Investigation of Stress and Displacement Distribution in Advanced Steel Rims

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Abstract

Over the years, lightweight rim design has attracted attention. Light alloy materials have been used as rim material for various type of vehicle. The main objective of the study is obtaining a lightweight rim design by using advanced steel. The wheels are crucial parts of vehicle for human safety because of their function. Therefore, verification of the rim design is important in automotive engineering. In this study, finite element analysis method is used to verify the advanced steel design. In addition, the finite element modelling technique is also used to obtain a time- efficient result. The stress and deformation distribution of advanced steel rim design are compared with steel and aluminum alloy rim design. The influence of inflation pressure, vehicle weight and velocity are taken in consideration. The analysis results are presented as von-Mises stress and deformation distribution figures.

Key Words: Automotive rim, Modelling, Stress analysis, Advanced steel

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1. Introduction

Safety is major concern of the automotive engineering design studies. One of safety related parts is wheel. It is clearly critical component due to its function. The wheels carry the vehicle's load and transmit the acceleration, braking and cornering force to the road. Therefore, they have crucial importance for safety [1].

Automotive wheels are extremely improved from the invention of the wheel, finally successful designs were made after years of experience and field testing. For many years, researchers have been studying on various rim designs [1 - 8]. The lightweight designs have taken increasing attention by new materials and manufacturing technologies [8]. The stress and displacement distribution in an aluminum automobile rim was investigated. In that study, a finite element model was developed and influence of opening location and geometry on mechanical performance of an aluminum rim [2]. Finite element analysis method is used to simulate impact tests and known loading conditions [1, 2, 5–9]. Many aluminum alloy wheel studies were conducted and aluminum alloy was used to obtain a lightweight design in literature [10–12]. In recent decades, lightweight steel wheel designs with equivalent mass to typical cast aluminum wheel have been studied [13]. In this study, a comparison of stress and displacement distribution are conducted for steel, aluminum and advanced steel rim designs.

Table 1. Material Properties

	Density (kg/m3)	Young's Modulus (GPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)
Steel[1]	7850	200	250	460
Alum. Alloy[2]	2770	71	280	310
UHSS	7850	200	1100	1500

[1]Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

[2]General aluminium alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.

2. Material

In this study the steel, aluminium alloy and ultra-high strength steel were used. Default mechanical properties of aluminium alloy material and steel according to ANSYS Workbench software program were performed. The ultra-high strength steel properties were taken from material catalogue[14].

3. Finite Element Modeling

A passenger car tire and rim properties were used as reference for study. The maximum load capacity and maximum velocity values of tire were used for finite element analysis. The rim code is 6.5x15 39 4-100 and the rim diameter is 381mm (15”), rim width is 165.1mm (6.5”) and rim offset is 39 mm.

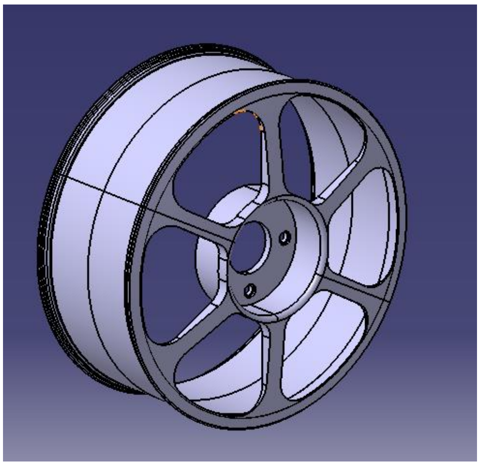

Figure 1. 3D model of rim

The inflation pressure was applied on the rim from the outside circumference as 0.245 MPa (35 Psi). The maximum weight limit of tire was used to determine the radial load. Radial load was assumed and applied as pressure. The radial load distribution was calculated according to cosine function along to 90° portion of the bead seat. The maximum velocity limit of tire was applied to rim as rotational velocity.

4. Result and Discussion

The finite element analysis showed that the highest deformation was occurred for advanced steel rim design due to the lower wall thickness. The wall thickness of advanced steel rim design was reduced to obtain lighter rim. When the weights of the rim designs are compared, it can be seen that the aluminum rim is lightest. However, the highest deformation was occurred for aluminum alloy rim design. The advanced steel rim design stress value was between steel and aluminum rim designs.

Table 2. Analysis Results

	Aluminium Alloy	Advanced Steel	Structural Steel
Weight (kg)	3,79	7,93	11
Total Deformation (mm)	0,71	0,43	0,30
Maximum Stress (MPa)	29,95	66,40	68,32

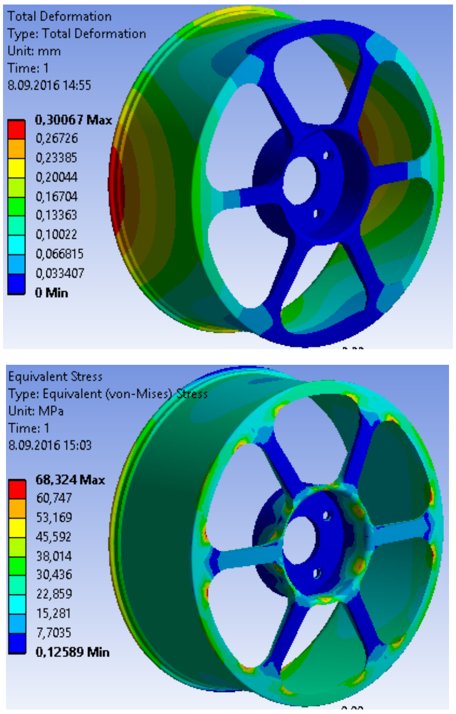

Figure 2. Von-Mises stress & deformation distribution of steel

5. CONCLUSION

In this study, stress and deformation distribution of advanced steel rim design was investigated and the comparison of advanced steel rim design were made with aluminium alloy and steel. Throughout the study following conclusions were obtained;

- The lightest rim design was obtained with aluminium alloy with the highest deformation.
- Using advanced steel provided a significant weight reduction.

The highest von Mises stresses value belongs to the steel.

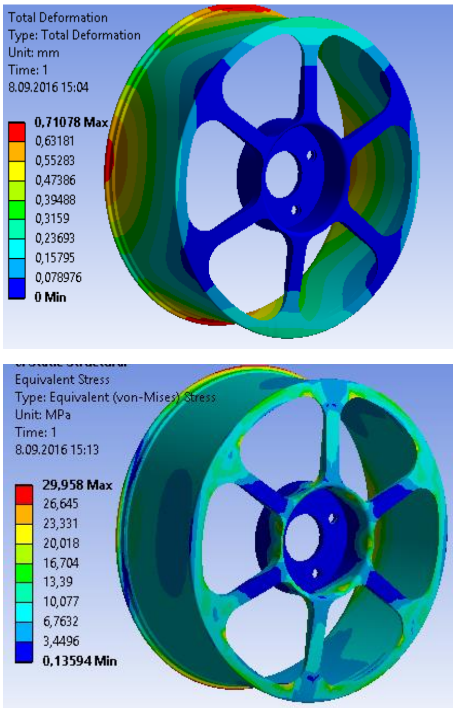

Figure 3. Von-Mises stress & deformation distribution of aluminium

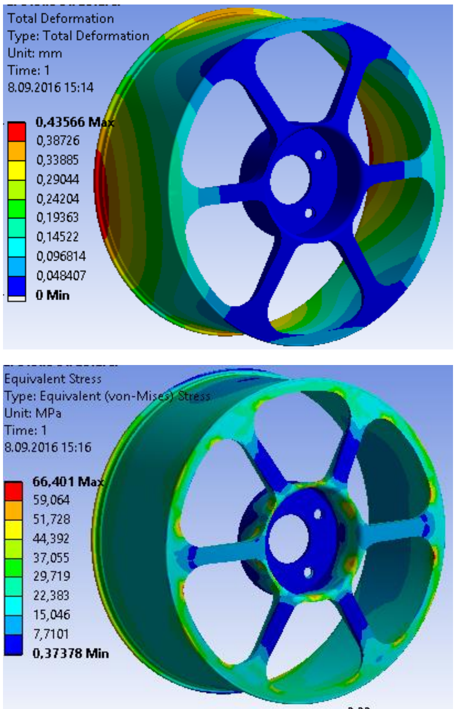

Figure 4. Von-Mises stress & deformation distribution of UHSS

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