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Topology Optimization of Two Wheeler Wheel Rim

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ABSTRACT

Topology is a branch of geometry concerned with the properties remains unchanged when the figure is deformed. The significance of topology is which will help to develop light weight components which are used in manufacturing of two wheeler carts, etc., the result is we get better automobile fuel efficiency. This in turn results to energy conservation and global environmental preservation. In industries several attempts are made to produce lightweight designs. In order to manufacture light weight component our first step is to decrease the weight of the wheel rim. The wheel is designed using CATIA and Imported CATIA 3D Model into Altair Hyper Mesh V13 for doing Pre-processing, Altair Radioss for Solving Structural Analysis and ALTAIR Optistruct Software for doing optimization of the wheel rim. The aim of this work is to develop an optimization procedure in order to reduce the weight of rim component. The focus of this project has been the weight reduction of an aluminium wheel by means of a topology analysis.

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Introduction

Wheels have vital importance for the safety of the vehicle and a special care is needed in order to ensure their durability. The development of the vehicle industry has strongly influenced the design, the material selection and the manufacturing processes of the wheels. The wheels loading manner is a complex one, further improvement and efficient wheel design will be possible only if they're loading will be better understood. In order to achieve an optimum design of the wheel, two requirements are needed: the precise knowledge of the loading and the mechanical properties and allowable stresses of the material, which depend on the vehicle characteristics, service conditions and manufacturing processes. Another possibility is to use the finite element method in order to establish the stresses in the wheel rim and to compare the different design solutions.

In this paper, the wheel rim is analyzed with the finite element method. The static stresses are studied in order to find the zones with higher stress concentration and to suggest the best design solution.

Modelling

With the help of reverse engineering concept the dimension of wheel rim (3, 4, 5 spoke) considered.

Modelling done by CATIA V5R20 software one of the best tools for designing of automotive parts, defence parts, aerospace components, Plastic components. The main purpose of this software is to develop a generative sheet metal design, wireframe and surface design.

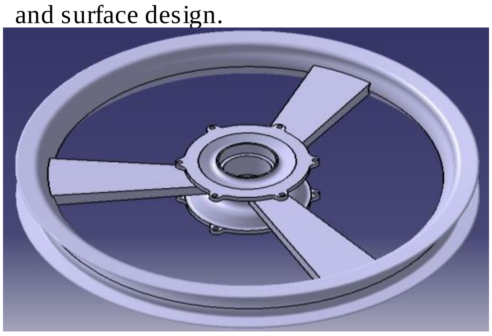

Fig 1. Reference 3D model of 3-spoke wheel rim

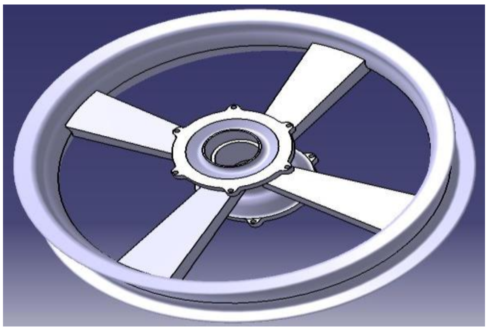

Fig 2. Reference 3D model of 4-spoke wheel rim

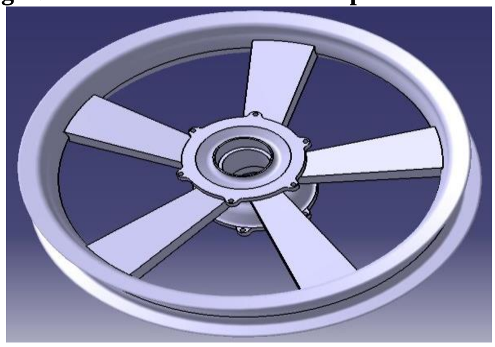

Fig 3. Reference 3D model of 5-spoke wheel rim

Meshing

The CAD model imported into Hyper Mesh V13 for Pre-processing. 3D solid tetra mesh used for meshing of the component. Hyper mesh provides two methods of generating a tetrahedral element mesh.

The volume tetra mesher works directly with surface or solid geometry to automatically generate a tetrahedral mesh without further interaction from the user. Even with complex geometry, this method can often generate a high quality tetra mesh quickly and easily.

The standard tetra mesher requires a surface mesh of tria or quad elements as input, then provides you with a number of options to control the resulting tetrahedral mesh. This offers a

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great deal of control over the tetrahedral mesh, and provides the means to generate a tetrahedral mesh for even the most complex models.
Mesh Type: 3D mesh
Mesh Method: Volume Tetra Mesher
Mesh Element: Tetrahedral
Element Size: 10
Tet. Collapse: 0.1
Vol. Skew: 0.9
Vol. A.R.: 10

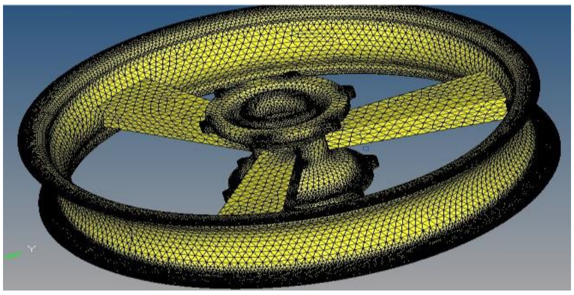


Fig 4. Meshed model of 3-spoke reference wheel rim

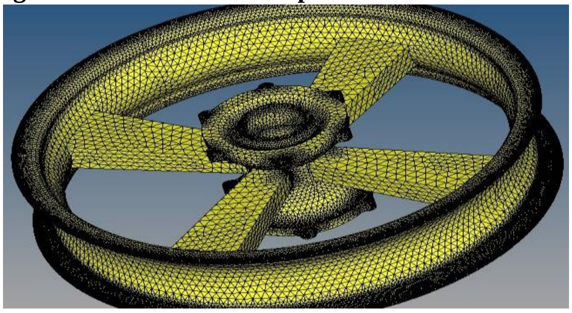


Fig 5. Meshed model of 4-spoke reference wheel rim

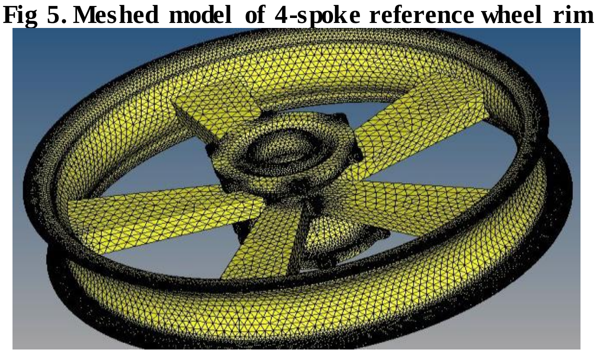


Fig 6. Meshed model of 5-spoke reference wheel rim

Material Properties

Aluminium alloy-201.0-T43 material is used for analysis, which is widely used for manufacturing of two wheeler wheel rim. The specifications of this material are
Mass density= 2800 Kg/m^3
Poisson's ratio= 0.33
Young's modulus= 71000 MPa
Yield strength= 225 MPa
Ultimate Tensile Strength= 273 MPa

Loads and Boundary conditions

Considering load is distributed uniformly over the rim surface. The maximum applicable loads are weight of two wheeler and maximum person sitting in the vehicle (comfortably two persons). Assuming load is distributed to only one wheel. The following calculations are used for analysis
Dead weight of vehicle = 175 Kg
Extra loads= 20 kg
Consider the average weight of person= 75 Kg
Total Weight in Kg's= 175+20+2*75=345 Kg
Total weight in Newton's=345*9. 81=3384.45 N
Assuming 30% of total weight reduced by the suspension system
Therefore, Net weight=W_{Net}= 3384.45*0.7=2369.115 N
Hence Reaction forces are=N_r=2369. 115N
Considering net weight acting on only one wheel rim
Rim surface area=62710 mm^2
Pressure on rim= 2369.115/62710= 0.03778 N/mm^2=0. 03778 MPa

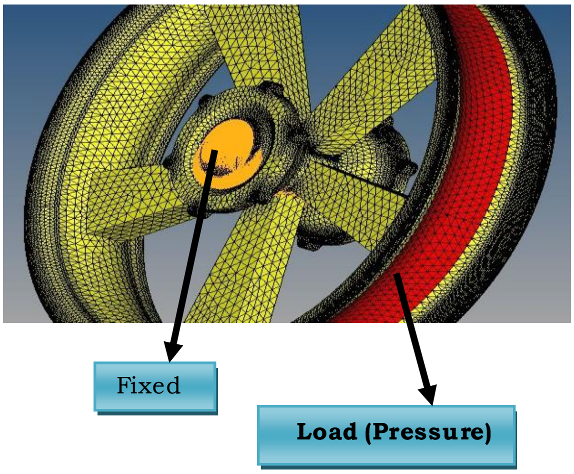


Fig 7. Fixing and Loading Condition

Optimization

Topology optimization of wheel rim done in Altair Optistruct. Topology optimization that optimizes both shape and weight without affecting the function of the component. For this optimization, we must specify, design area and non-design area, volume fraction (percentage of material removes).

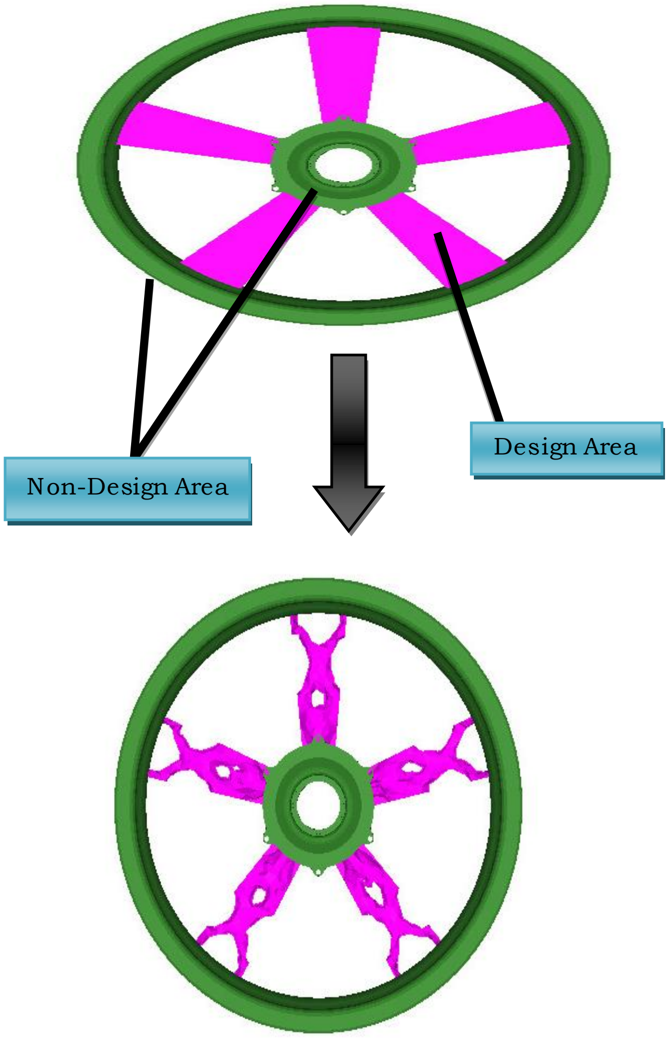


Fig 8. After optimization

Results

The static structural analysis carried out to both reference and optimum designs. The results of displacement and vonmises stresses of 3, 4, 5spoke are following

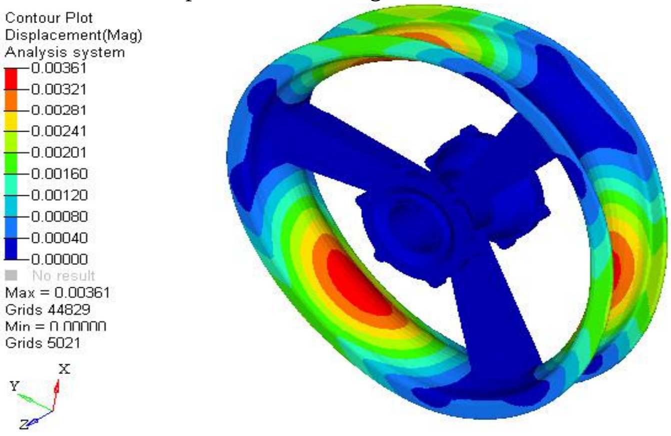


Fig 9. Displacement of 3-spoke reference design

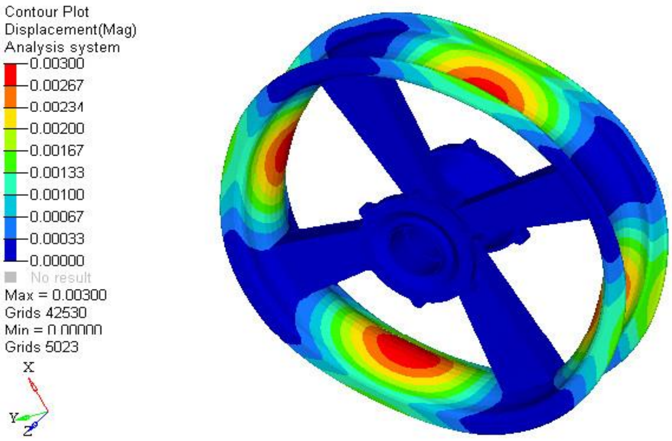


Fig 10. Displacement of 4-spoke reference design

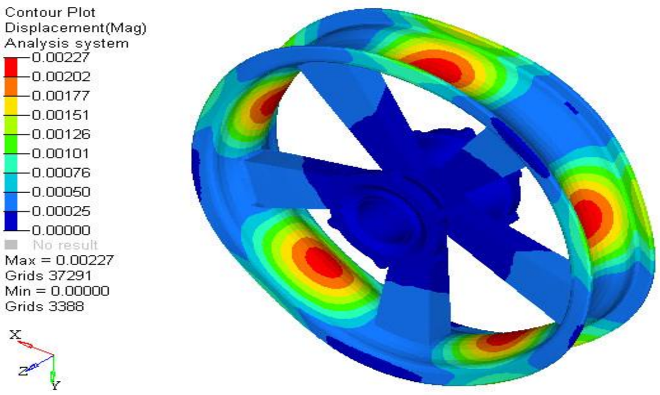


Fig 11. Displacement of 5-spoke reference design

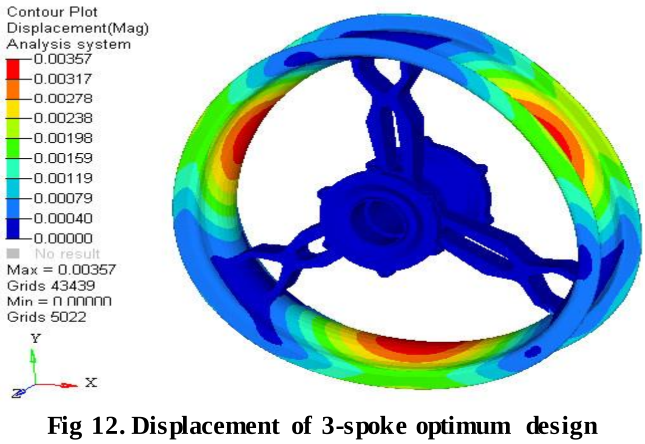


Fig 12. Displacement of 3-spoke optimum design

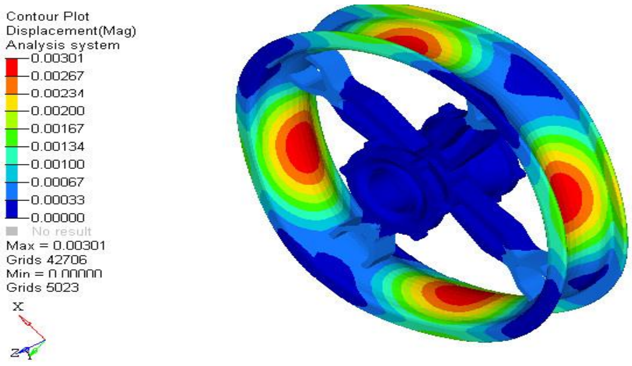


Fig 13. Displacement of 4-spoke optimum design

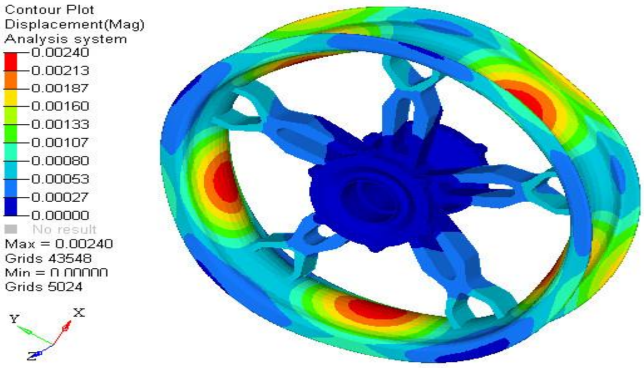


Fig 14. Displacement of 5-spoke optimum design

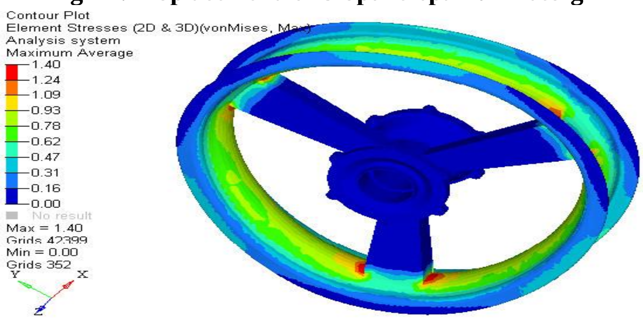


Fig 15. Vonmises stress of 3-spoke reference design

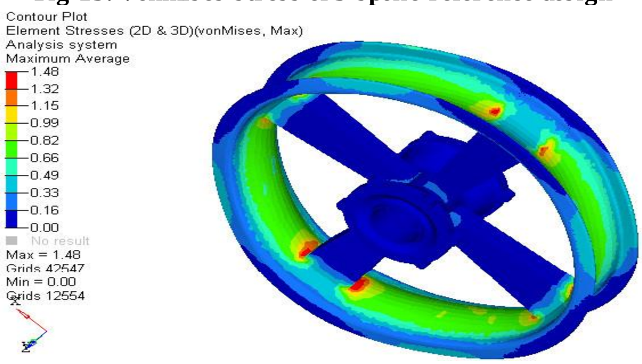


Fig 16. Vonmises stress of 4-spoke reference design

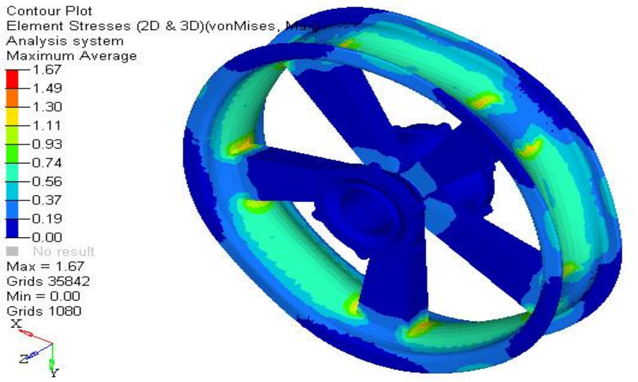


Fig 17. Vonmises stress of 5-spoke reference design

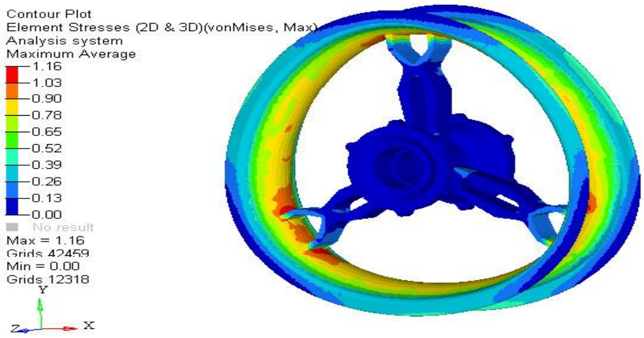


Fig 18. Vonmises stress of 3-spoke optimum design

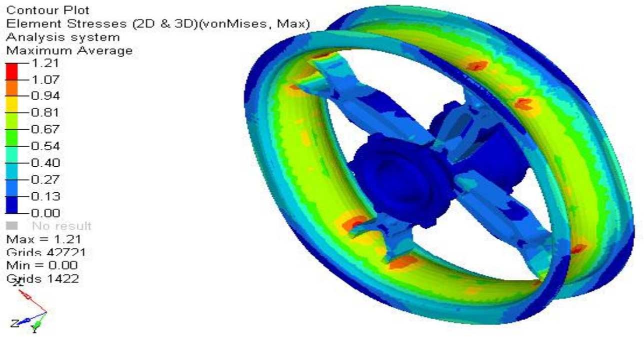


Fig 19. Vonmises stress of 4-spoke optimum design

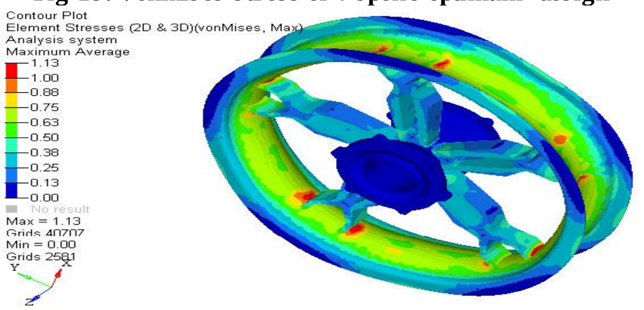


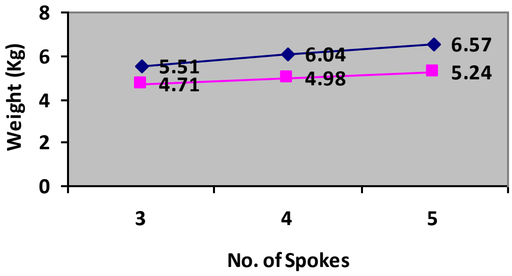
Fig 20. Vonmises stress of 5-spoke optimum design

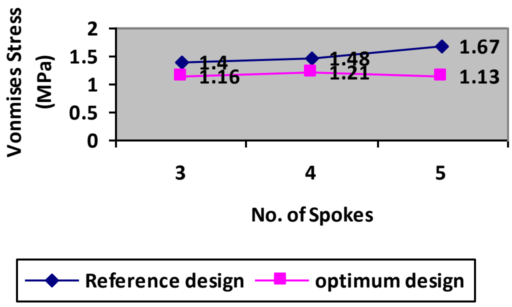
Tabular results

No. of spokes	Reference design			Optimized design		
	Weight (Kg)	**Displacement (mm)**	**Vonmises Stress (MPa)**	**Weight (Kg)**	**Displacement (mm)**	**Vonmises Stress (MPa)**
3	5.51	0.00361	1.40	4.71	0.00357	1.16
4	6.04	0.00300	1.48	4.98	0.00301	1.21
5	6.57	0.00227	1.67	5.24	0.00240	1.13

Comparision

The comparisions made between reference design and optimum design with no. of spokes, weight reduction and stress reduction





No. of spokes	Weight	Stress
3	14.52% ↓	17.14% ↓
4	17.55% ↓	18.24% ↓
5	20.24% ↓	32.33% ↓

Conclusion

Compared to all 5-spoke optimum design having

- Highest weight reduction (20.24%)
- Highest stress reduction (32.33%)
- Negligible increment in displacement (5.73%)

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