Lightweight design and analysis of automobile Wheel based on structural steel

Anivesh Chaudhary[1], Purushottam sahu[2]

[1]*BM College of technology Indore, RGPV, Bhopal*
[2]*Example: Professor, Dept. of Mechanical Engineering,* BM College of technology Indore

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Abstract - *This paper investigates how different tyre wheel designs affect the displacement distribution, equivalent (von-mises) stress, strain, and safety factor of the tyre. It is difficult to estimate all of these data using basic mechanical approximations. Finite Element Model (FEA) is commonly used in the design stage of product development for this purpose. The 3-dimensional models of the wheel were created in the modelling software SOLIDWORKS 2019 and then imported into ANSYS 16.0 using the parasolid format. The model's finite element analysis was completed by meshing the models using solid mesh. For the analysis system, the static condition was chosen. At the bolt, the wheel was constrained in all degrees of freedom.*

Key Words: SOLIDWORKS, ANSYS, FEA, Static Analysis, Fatigue Analysis, Wheel Rim

1. INTRODUCTION

A wheel is a circular block of hard and durable materials with a circular hole bored through the centre through which is placed an axle bearing about which the wheel rotates when a moment is applied to the wheel about its axis by gravity or torque. [1]

The wheels we use today are the result of continuous improvement from 3600 B.C. to the present day, beginning with wooden discs and progressing to modern light weight and durable alloy wheels. The wheel's main function was to roll the entire thing. It was first used as a potter's wheel, and then 300 years later it was used to fit the chariot. After such a long period of development, there are now numerous options available, but those designs have a significant impact on the wheel's performance.

The primary requirements of an automobile wheel are that it be as light as possible in order to reduce fuel consumption while increasing overall performance and handling. It must be extremely strong in order to withstand the load. It should be simple to manufacture. Its material should not deteriorate over time and weathering. If the material comes into contact with corrosion, it must be given appropriate defensive treatment. [2] To overcome the weight and strength issues, the design and material of the wheel should be considered.

Steel or cast/forged aluminum alloys are used to make the wheels. Aluminum is a metal with excellent lightness, corrosion resistance, and other properties. Particularly notable are the rims, which are made of aluminum casting due to its lighter weight and lower cost.

This paper examines the behaviour of six different wheel designs by comparing their result data (weight, deformation, stress, strain, fatigue life, and safety factor). The best design out of the six has less deformation, less stress on the body, and a higher safety factor.

2. The Wheel's Nomenclature

1. Rim: The tyre is introduced in this section.

2. Disc: A piece of the rim that is secured to the hub centre.

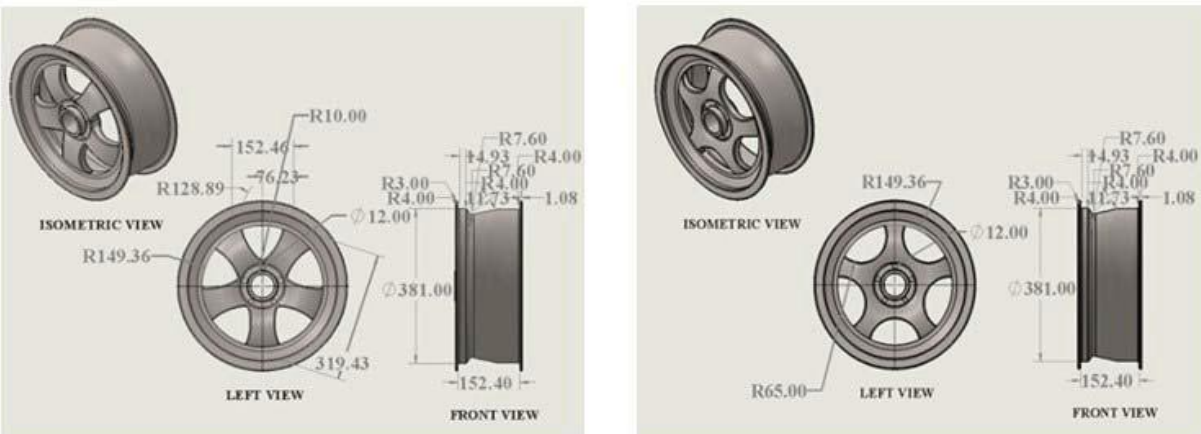
3. Offset: This is the distance between the wheel mounting surface and the rim's focus line.

4. Flange: A rib is a piece of rim that holds the tire's two beds together.

5. Bead Seat: A bead seat is a piece of rim that holds the tyre in an outspread manner and places approaches in contact with the dot face.

Table 2.1 shows that the selected material for the wheel, which is linear isotropic material whose properties are same in all of the directions.

Name:	Structural Steel
Model type:	Linear Elastic Isotropic
Default failure criterion:	Unknown
Yield strength:	3.51571e+08 N/m^2
Tensile strength:	4.20507e+08 N/m^2
Elastic modulus:	2e+11 N/m^2
Poisson's ratio:	0.3
Mass density:	7,850 kg/m^3
Shear modulus:	7.7e+10 N/m^2
Thermal expansion coefficient:	1.5e-05 /Kelvin



(a) (b)

Figure 4.1(a) Wheel Design 1 and (b) Wheel Design 2

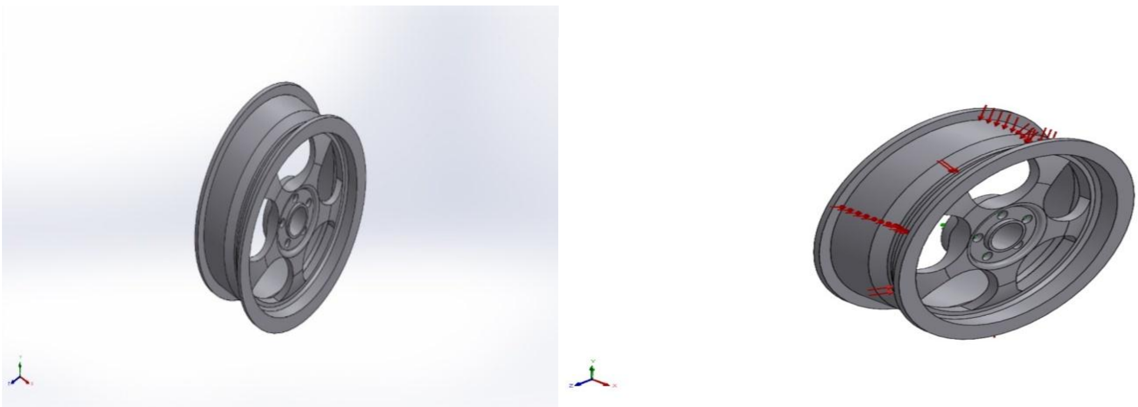


Figure 4.2(a) Wheel Design 1 (b) meshed model

4. Steps of Working

1. Pre-processing

2. Modeling in solid works

3. Export parasoild file to ANSYS 16

4. Selection of analysis system (static structure)

5. Engineering Data (selection of material)

6. Geometry (import parasoild model)

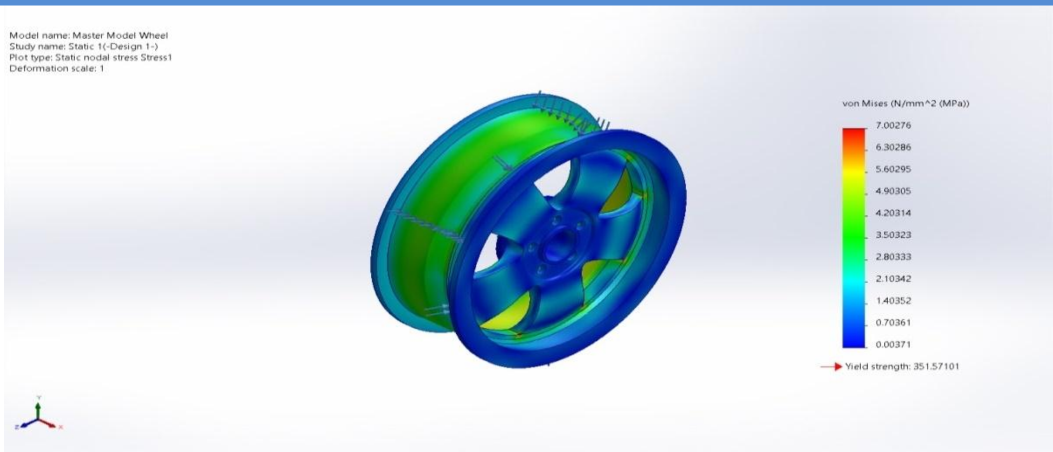
7. Model (Meshing)

8. Post-processing

9. Setup (Boundary condition)

10. Solution

Name	**Type**	**Min**	**Max**
Stress1	**VON: von Mises Stress**	**0.00371N/mm^2 (MPa) Node: 13169**	**7.00276N/mm^2 (MPa) Node: 65**



Master Model Wheel-Static 1-Stress-Stress1

Figure 4 .3 (c) Equivalent (von-mises) stress (Design 1)

Name	**Type**	**Min**	**Max**
Displacement1	**URES: Resultant Deformation**	**0.00000mmNode: 69**	**0.00762mmNode: 71271**

Name	Type	Min	Max

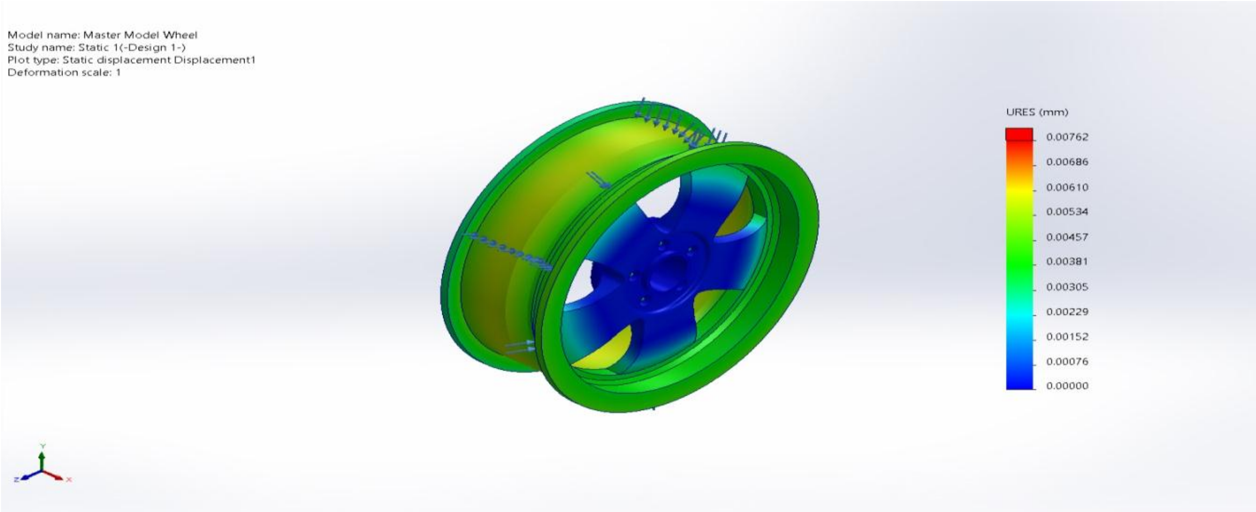
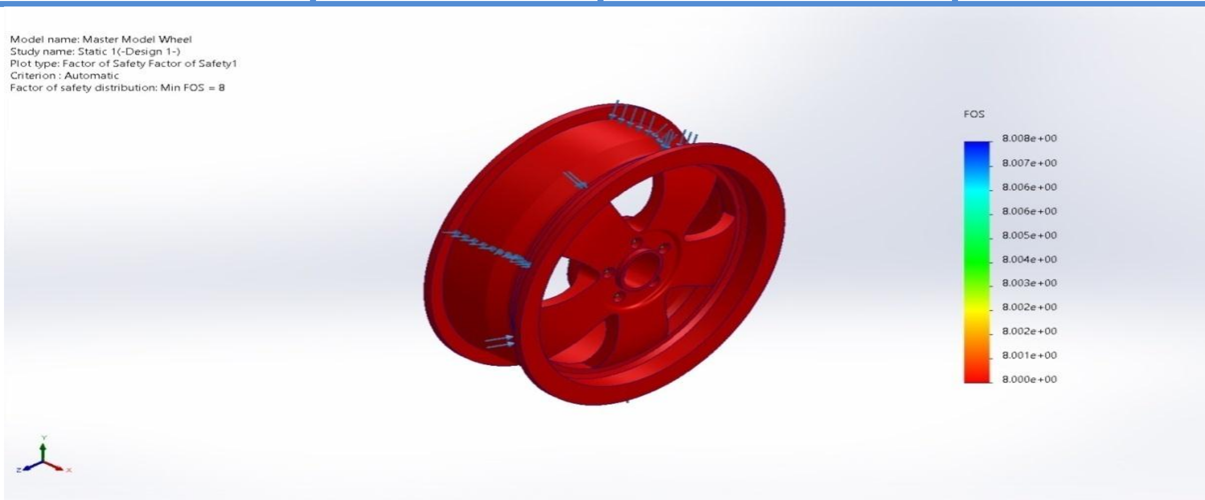


Figure 4.4 (c) Total Deformation (Design 1)

Name	Type	Min	Max
Factor of Safety1	Automatic	8.000e+00Node: 1	8.000e+00Node: 1



Master Model Wheel-Static 1-Factor of Safety-Factor of Safety1

Figure 4.5 (c) Factor of Safety Design 1

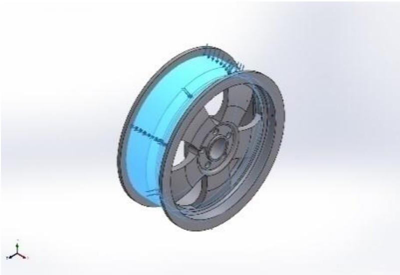
Load name	Load Image	Load Details	
Pressure-1		**Entities:** **Type:** **Value:** **Units:** **Phase Angle:** **Units:**	**5 face(s)** **Normal to selected face** **0.241317** **N/mm^2 (MPa)** **0** **deg**

Figure 4.6 (c) Pressure MPa

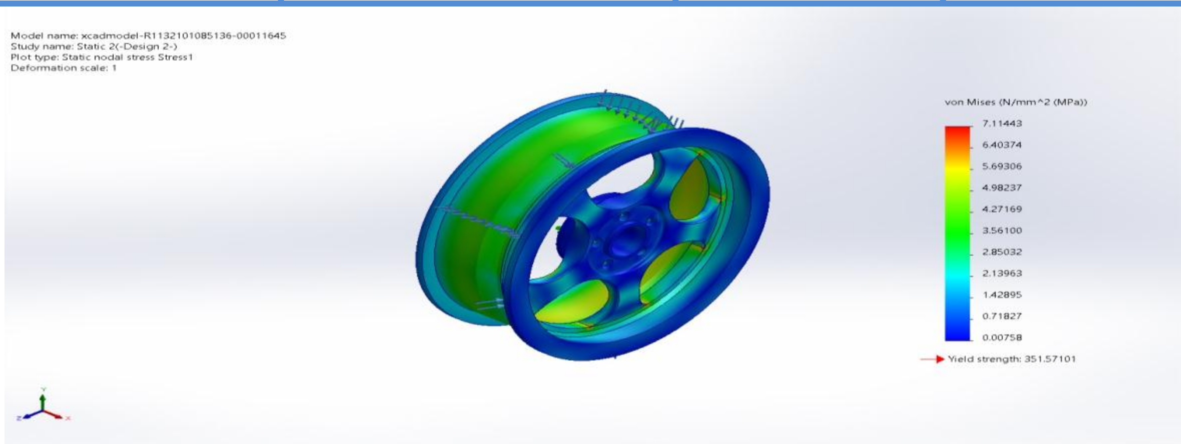
Material Properties

Model Reference	Properties		Components
	**Name:** **Model type:** **Default failure criterion:** **Yield strength:** **Tensile strength:** **Elastic modulus:** **Poisson's ratio:** **Mass density:** **Shear modulus:** **Thermal expansion coefficient:**	Structural Steel Linear Elastic Isotropic Unknown 3.51571e+08 N/m^2 4.20507e+08 N/m^2 2e+11 N/m^2 0.3 7,850 kg/m^3 7.7e+10 N/m^2 1.5e-05 /Kelvin	Solid Body 1(CirPattern5)(xcadmodel-R1132101085136-00011645)
Curve Data/A			

Wheel Design 2

Figure 4.7 (a) Wheel Design 1 (b) meshed model

Name	**Type**	**Min**	**Max**
Stress1	VON: von Mises Stress	0.00758N/mm^2 (MPa) Node: 26596	7.11443N/mm^2 (MPa) Node: 116

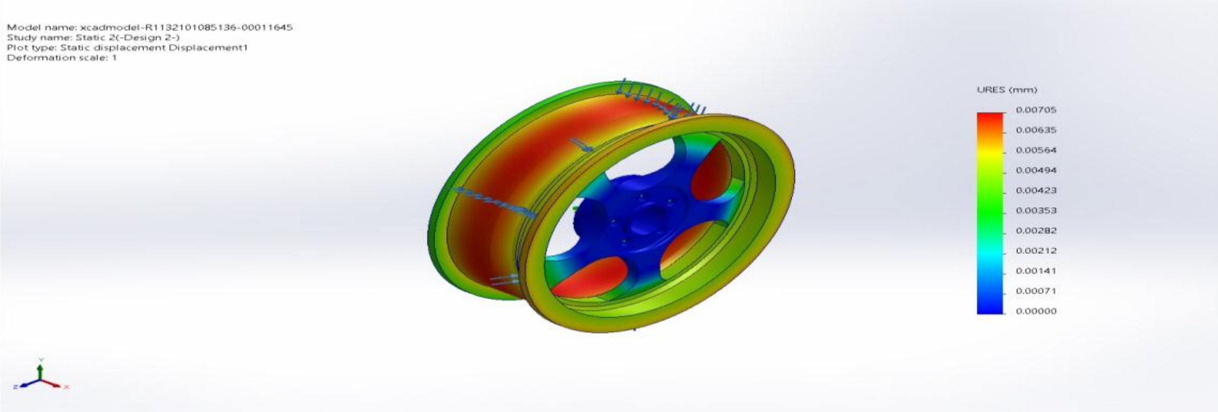


xcadmodel-R1132101085136-00011645-Static 2-Stress-Stress1

Figure 4.8 (c) Equivalent (von-mises) stress (Design 2)

Name	**Type**	**Min**	**Max**
Displacement1	URES: Resultant Deformation	0.00000mm Node: 57	0.00705mm Node: 40967

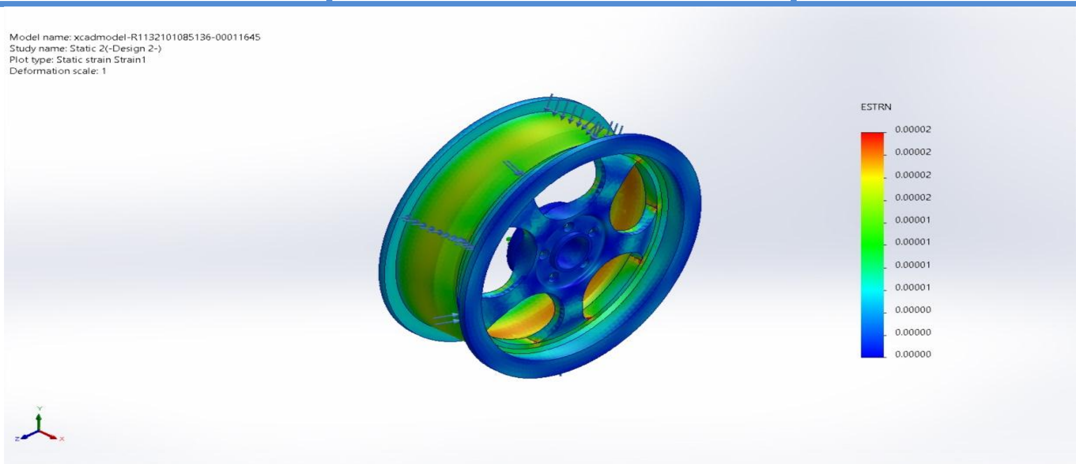
Name	Type	Min	Max



xcadmodel-R1132101085136-00011645-Static 2-Displacement-Displacement1

Figure 4.8 (c) Total Deformation (Design 2)

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.00000 Element: 3565	0.00002 Element: 11148



xcadmodel-R1132101085136-00011645-Static 2-Strain-Strain1

Figure 4.9 (c) Equivalent Strain (Design 2)

Name	Type	Min	Max
Factor of Safety1	Automatic	1.000e+01 Node: 1	1.000e+01 Node: 1

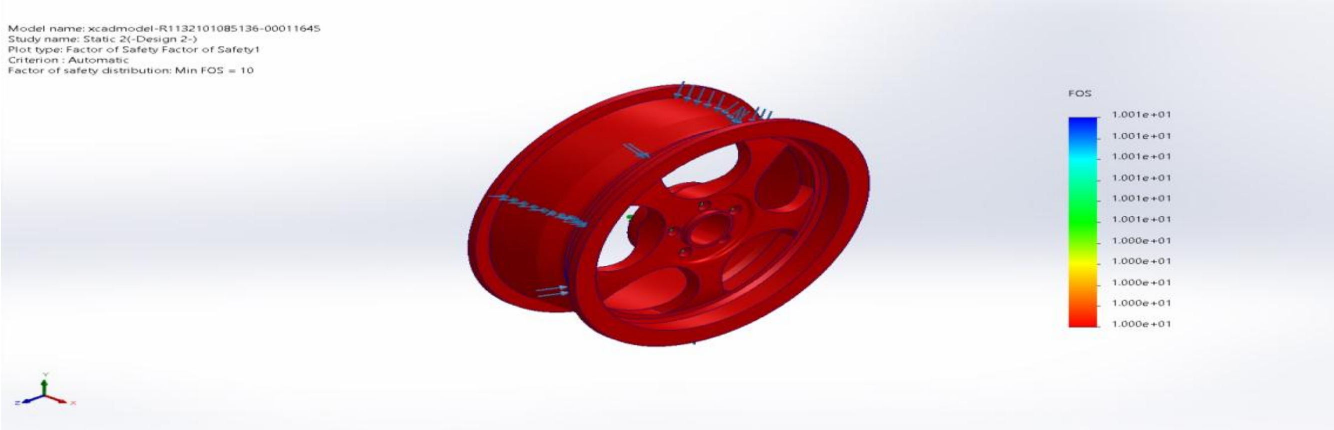
Name	Type	Min	Max
			
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Figure 4.10 (c) Factor of Safety Design 2

Wheel Design 3

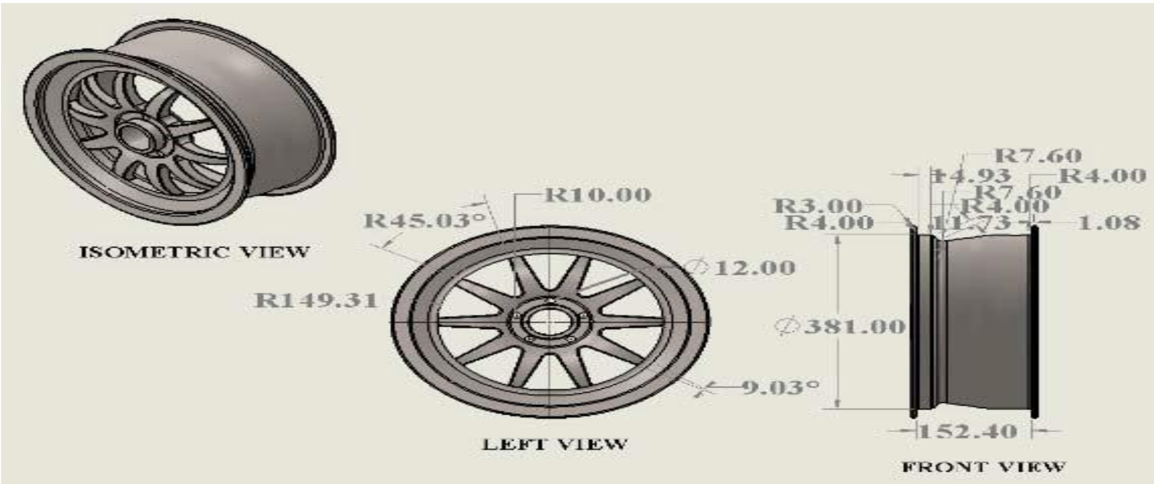


Figure 4.11(a) Wheel Design 3

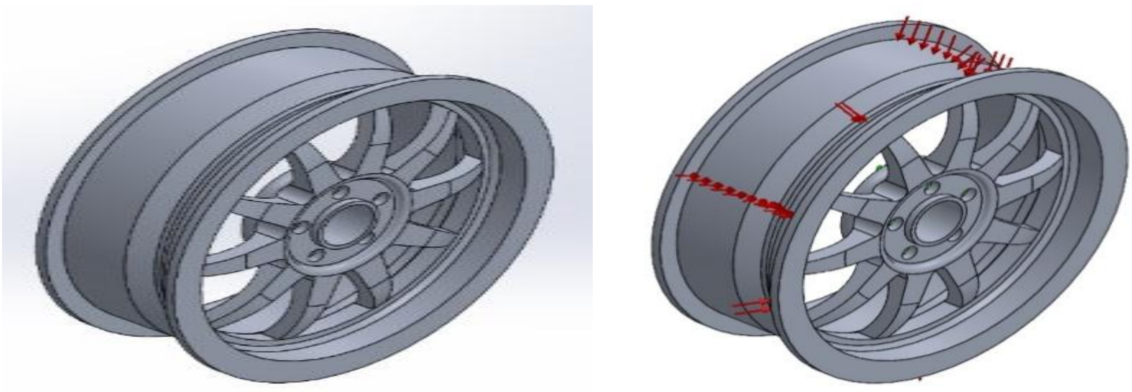
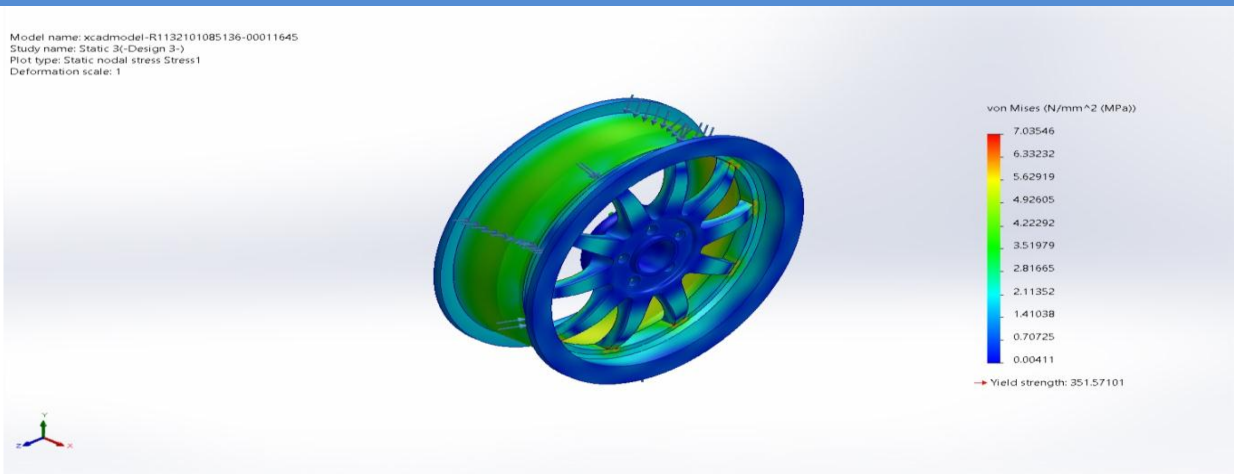


Figure 4.12 (a) Wheel Design 1 (b) meshed model

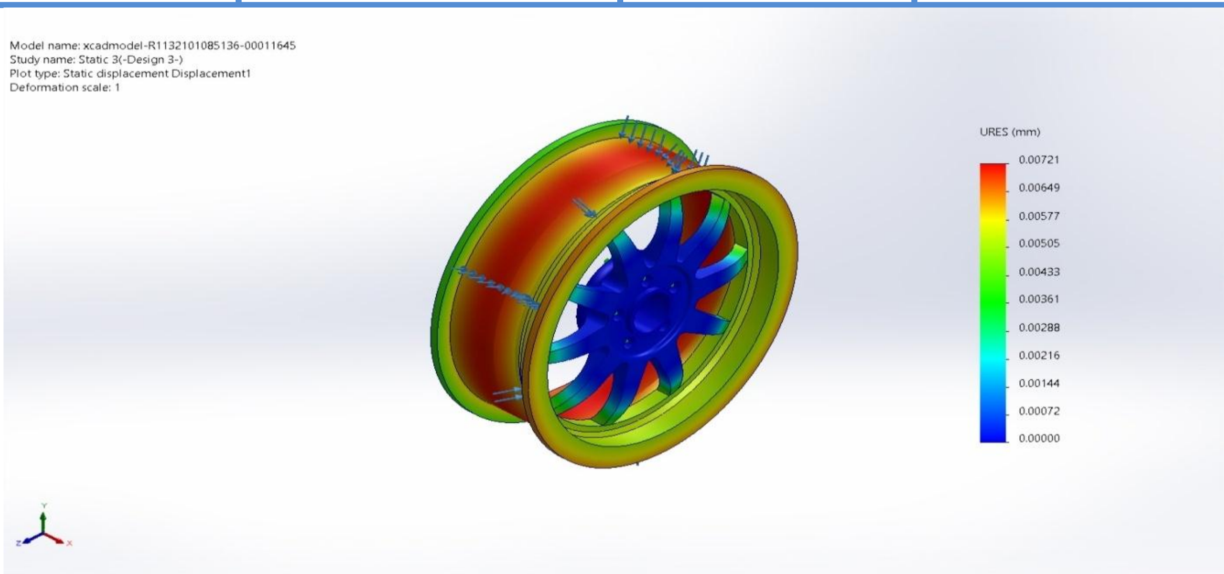
Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.00411N/mm^2 (MPa) Node: 128719	7.03546N/mm^2 (MPa) Node: 125



xcadmodel-R1132101085136-00011645-Static 3-Stress-Stress1

Figure 4.13 (c) Equivalent (von-mises) stress (Design 3)

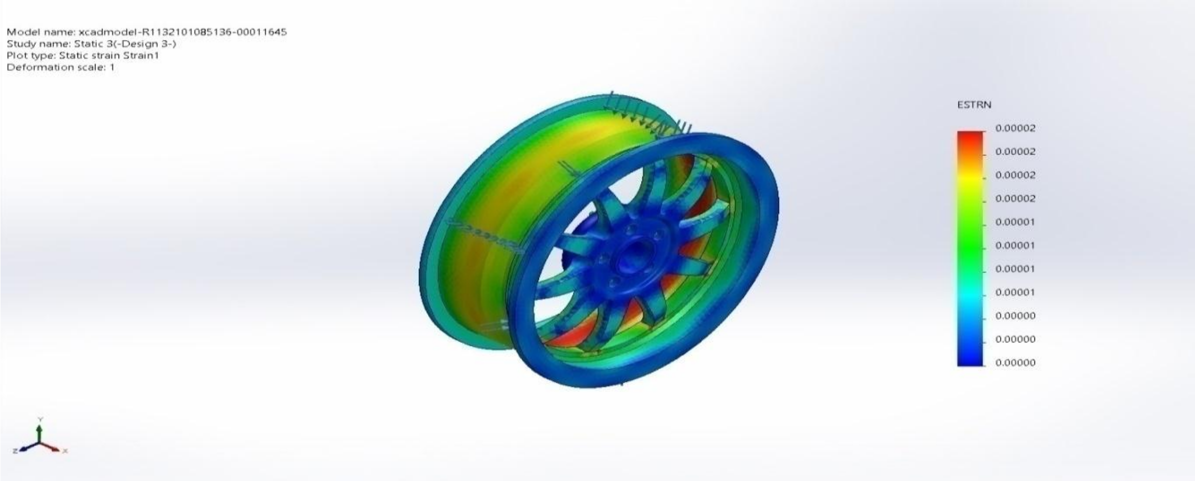
Name	Type	Min	Max
Displacement1	URES: Resultant Deformation	0.00000mm Node: 135	0.00721mm Node: 98823



xcadmodel-R1132101085136-00011645-Static 3-Displacement-Displacement1

Figure 4.14 (c) Total Deformation (Design 3)

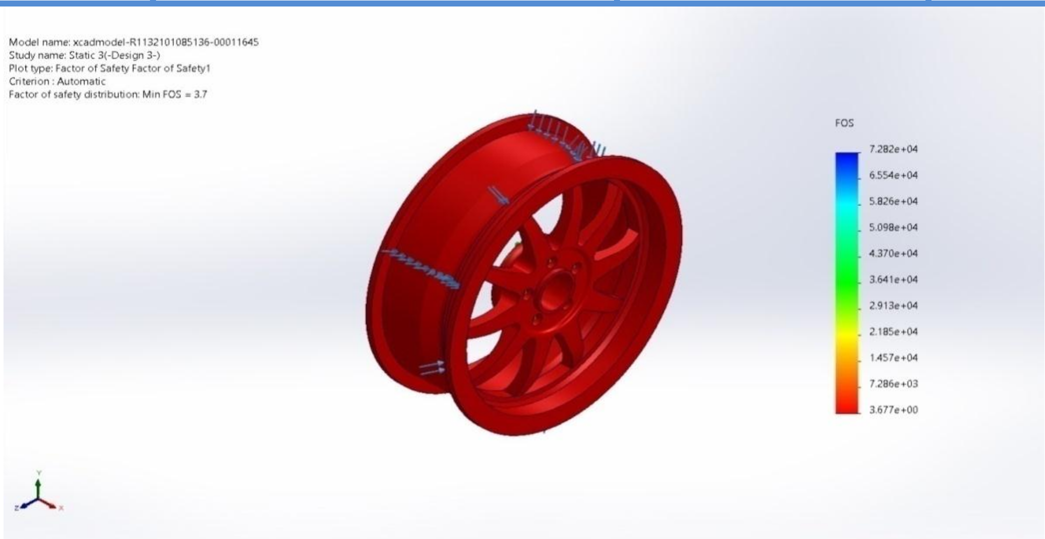
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.00000 Element: 79259	0.00002 Element: 63607



xcadmodel-R1132101085136-00011645-Static 3-Strain-Strain1

Figure 4 .15(c) Equivalent Strain

Name	Type	Min	Max
Factor of Safety1	Automatic	3.677e+00 Node: 119	7.282e+04 Node: 612715



xcadmodel-R1132101085136-00011645-Static 3-Factor of Safety-Factor of Safety1

Figure 4.16 (c) Factor of Safety Design 3

Wheel Design 4

Structural Steel						
	Design 1	**Design 2**	**Design 3**	**Design 4**	**Design 5**	**Design 6**
Weight (Kg)	29.76 kilograms	26.95 kilograms	26.85 kilograms	26.23 kilograms	25.45 kilograms	25.12 kilograms
Deformation(mm)	0.00762mm	0.00705mm	0.00721mm	0.00717mm	0.00831mm	0.00703mm
Stress (MPa)	7.00276N/mm ^2	7.11443N/mm ^2	7.03546N/mm ^2	9.98752N/mm ^2	14.38969N/mm ^2	6.13956N/mm ^2
Factor of Safety Distribution	>8	>8	>10	>10	>12	>15
Pressure (Mpa)	0.241317	0.241317	0.241317	0.241317	0.241317	0.241317
Mesh Element Size (mm)	8	8	8	8	8	8

Conclusion and future scope:

1. The weight of the wheel is reduced from 29.76 kilogram's to 25.12 kilogram's without compromising any of the wheel's physical properties or performance.

2. A mass reduction of 4.64 kg per wheel is achieved, bringing the total mass of the car to 27.84 kg when the spare wheel is included. This mass reduction has the advantages of lowering the total weight of the car and lowering the cost of production.

3. Less weight leads to improved performance and fuel efficiency. There are many indirect benefits to these results, such as reduced air pollution due to lower fuel consumption, saving crude oil means saving natural resources, and so on.

4. According to Ansys data, wheel design 6 is the most appropriate of the six models because it is lighter in weight (27.192kg) and has less deformation (0.00703mm), as well as the highest factor of safety (>15) and the least equivalent stress (6.13956 Mpa)

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