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Comparative study of effect of different types of mesh refinements on static analysis of car wheel RIM

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ABSTRACT

Rim is one of the parts of the wheel on which tyre is mounted and it is connected to the hub. Different materials are used for manufacturing the rim such as Aluminium alloy, Magnesium Alloy, etc. The aim of this paper is to evaluate and compare the result of Static Analysis of different materials with respect to the different types of refinements on a Car Wheel Rim. Modeling and Analysis is done in Catia V5 and ANSYS respectively. Static Analysis with different mesh refinements to be done on the Car Wheel Rim of different materials to validate the best material used for the car wheel rim.

Keywords- *Catia V5, ANSYS, Wheel Rim, Static Analysis, Mesh Refinement.*

1. INTRODUCTION

A car rim is connected to the hub which is the center part of the wheel. Rim is the part that holds the tyres on and allows it to rotate so as to move the vehicle. Alexandru Valentin Raduelescu et.al (2012) analyzed the car rim with the finite element method using the 40º loading test. Fig 1 Shows actual car wheel rim made CATIA V5 software.

The center bore with center cap is fitted on the axle hub. Small holes around the hole goes over the wheel studs and the lug nuts are tightened up thus holding the wheel.

Fig. 1: Car Wheel Rim.

In the static Condition, Center hole fitted on the axle hub takes the weight of the vehicle and the tyre fitted on the rim exerts pressure on the rim.

Types of Wheel/Rim based on material-
A] Wire Spoke Wheel.
B] Steel Disc Wheel.
C] Light Alloy Wheel-
1) Aluminium Alloy Steel.
2) Magnesium Alloy Steel.
3) Titanium Alloy Steel.
4) Composite material Steel.

Specifications of the model wheel rim-
Diameter of Rim (approx) - 560mm
Width of Rim (approx) - 285mm
Wheel type - Light alloy cast wheel.

2. METHODOLOGY

1. Modeling in CATIA V5-

Catia is a computer based software that allows for 3D modeling along with Computer aided design, Computer aided manufacturing and Computer aided engineering. Catia is the best productivity tool that promotes practice in design ensuring the standards of the industry or a company. Below figures show some of the steps of modeling the car wheel rim in Catia V5.
Fig 2(a) shows a hollow part that is a result of a revolved sketch.
Fig 2(b) shows a pad sketch which results in formation of a center disc.

Fig. 2(a)

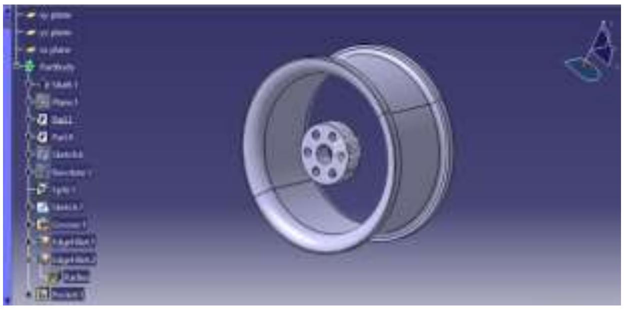


Fig. 2(b)

Fig 2(c) shows spokes which is the outcome of a pad sketch Fig 2(d) shows a circular frame made using a Wireframe and Surface Design. Frame is split to get a smooth curved surface as shown in Fig 2(e) followed by fillet to the edge of spokes.

Fig. 2(c)

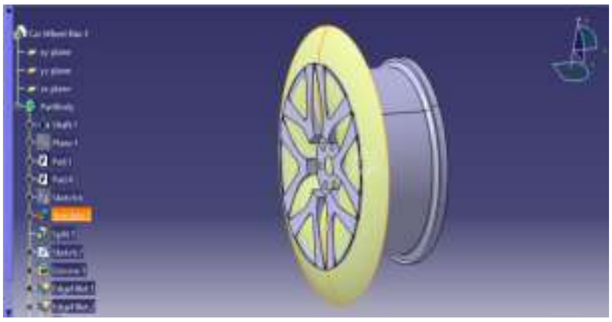


Fig. 2(d)

Fig. 2(e)

2. Analysis in ANSYS (student Version)-

ANSYS is simulation software that allows to test and analyse the product design in any aspect before the actual manufacturing of the product. Also it provides the advantage of testing the designed products with different materials.

For analysis the first step is pre-processing that includes creation of geometry and elements and to apply boundary conditions to the geometry. Static Analysis is used to determine the stress, strain, displacement, fatigue life, etc of the product when subjected to various forces.

2.1 Properties of Materials.

A) Aluminium Alloy.

Young's Modulus	7.1e+10 Pa
Poisson's Ratio	0.33
Density	2770 kg/m^3
Thermal Conductivity	148.62 W/m.°C
Specific Heat	875 J/kg.°C

B) Magnesium Alloy.

Young's Modulus	4.5e+10 Pa
Poisson's Ratio	0.35
Density	1800 kg/m^3
Thermal Conductivity	156 W/m.°C
Specific Heat	1024 J/kg.°C

C) Titanium Alloy.

Young's Modulus	9.6e+10 Pa
Poisson's Ratio	0.36
Density	4620 kg/m^3
Thermal Conductivity	21.9 W/m.°C
Specific Heat	522 J/kg.°C

2.2 Importing the Model.

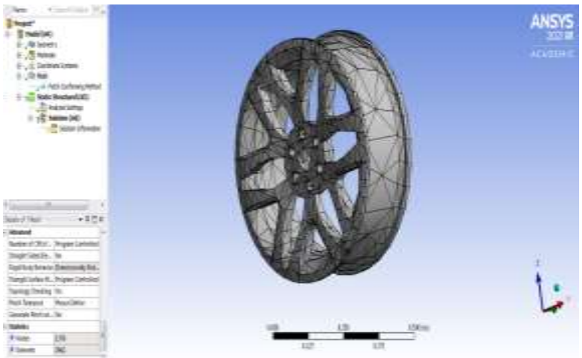
IGES- 'Initial Graphics Exchange Specification' is a file format that allows import and export of computer aided designs. Models created in Catia V5 software or any other software are saved in IGES format which allows the 3D product to get exported without any geometry loss. The IGES file is then imported from Catia V5 to the ANSYS workbench.

2.3 Generating the Mesh.

For generating the mesh a model is inserted where the type of the mesh can be changed accordingly like Tetrahedron, Hex dominant, Sweep, etc. Resolution and Span Angle center is changed to get a different mesh with different nodes and elements. Below figures show the result of different meshing.

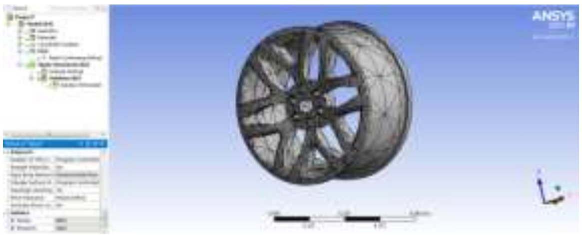
- **Refinement - Coarse.**

Element Order - Linear.



Nodes	1376
Elements	3962

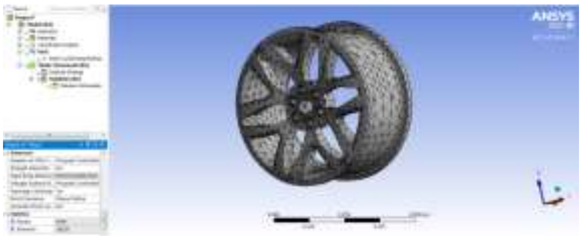
Element Order - Quadratic.



Nodes	8835
Elements	4344

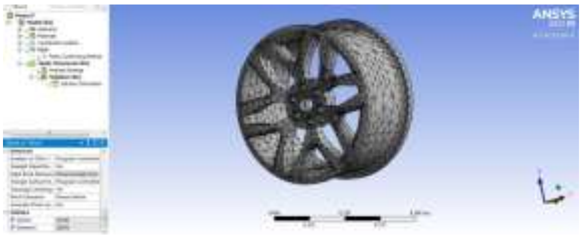
- **Refinement - Medium.**

Element Order - Linear.



Nodes	4146
Elements	14155

Element Order - Quadratic.



Nodes	31708
Elements	18070

- **Refinement - Fine.**

Element Order - Linear.

Nodes	16671
Elements	62102

Element Order - Quadratic.

Nodes	128964
Elements	76303

2.4 Application of load and boundary conditions.

To get static analysis of the rim the model is constrained at six bolt holes by all degrees of freedom in which the bolts are to be placed. Center hole is applied to an approximate force. Outer surface of the rim is subjected to circumferential pressure.
Force (approx) = 1000 N
Circumferential Pressure = 200 kpa

3. RESULT AND COMPARISON

After applying the load and boundary conditions various results are obtained in the form of total deformation, Equivalent Elastic strain, Equivalent (Von mises), etc.

3.1. Aluminium Alloy.

- **Refinement - Coarse.**

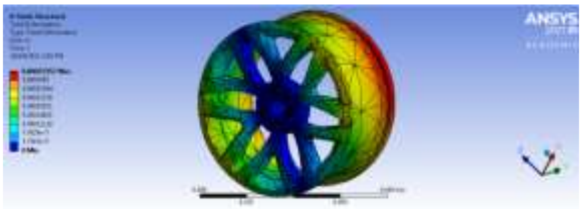


Fig. Total Deformation.

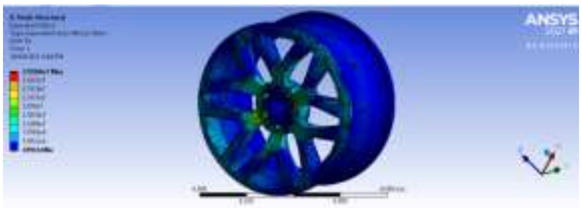


Fig. Equivalent Stress.

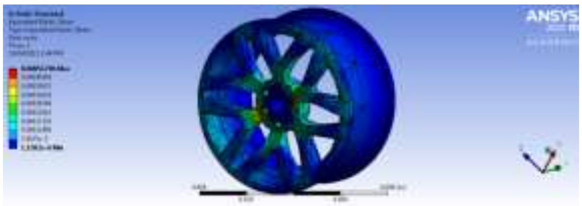


Fig. Equivalent Strain.

- **Refinement - Medium.**

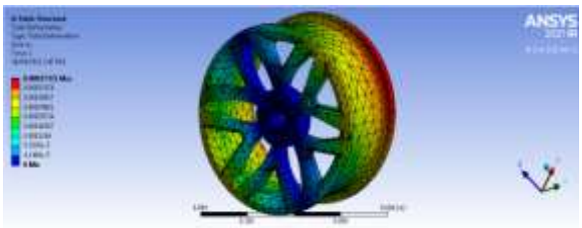


Fig. Total Deformation.

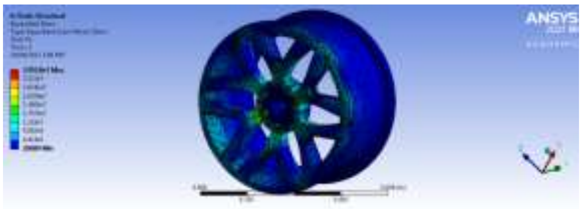


Fig. Equivalent Stress.

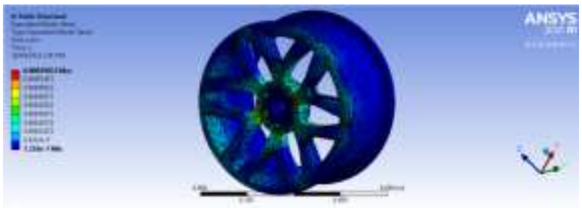


Fig. Equivalent Strain.

- **Refinement - Fine.**

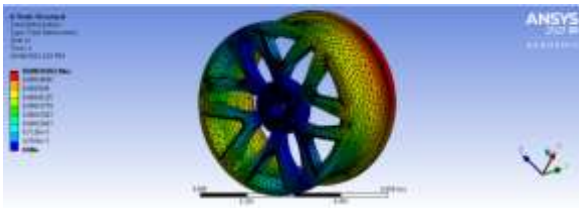


Fig. Total Deformation.

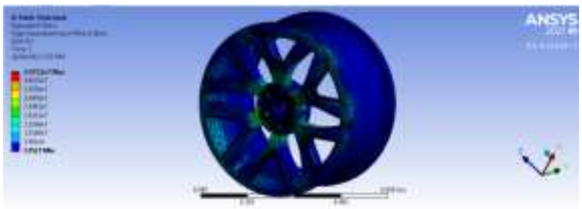


Fig. Equivalent Stress.

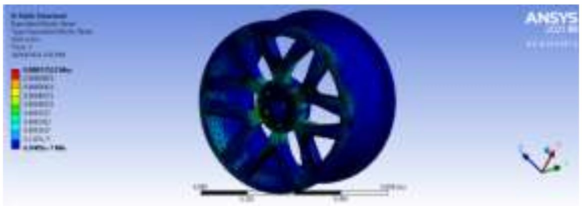


Fig. Equivalent Strain.

3.2. Magnesium Alloy.

- **Refinement - Coarse.**

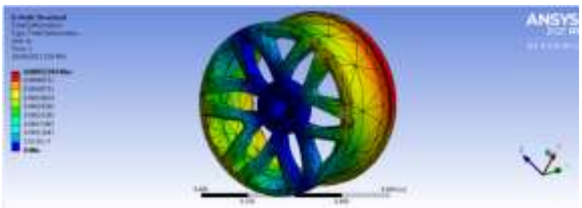


Fig. Total Deformation.

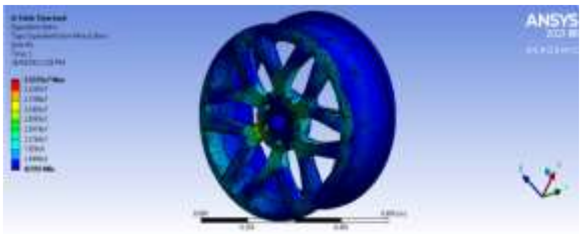


Fig. Equivalent Stress.

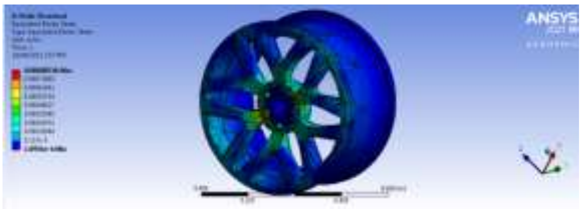


Fig. Equivalent Strain.

- **Refinement - Medium.**

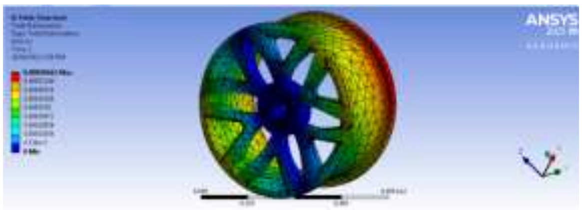


Fig. Total Deformation.

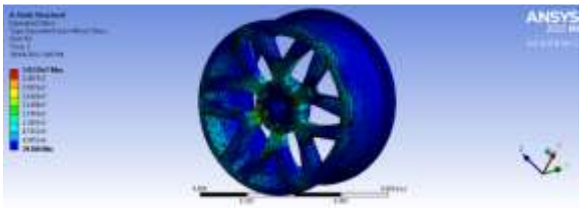


Fig. Equivalent Stress.

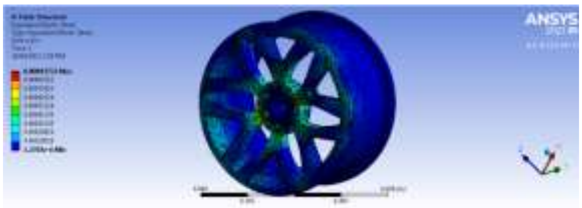


Fig. Equivalent Strain.

- **Refinement - Fine.**

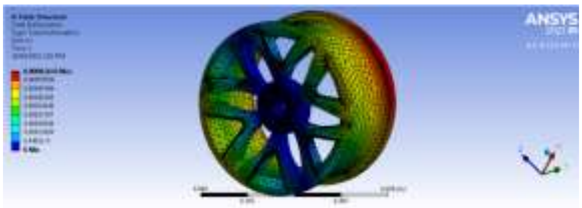


Fig. Total Deformation.

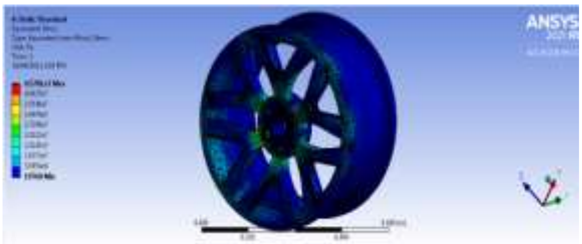


Fig. Equivalent Stress.

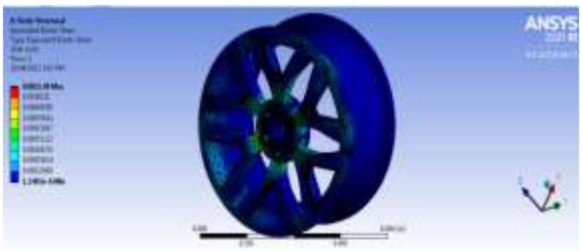


Fig. Equivalent Strain.

3.3. Titanium Alloy.

- **Refinement - Coarse.**

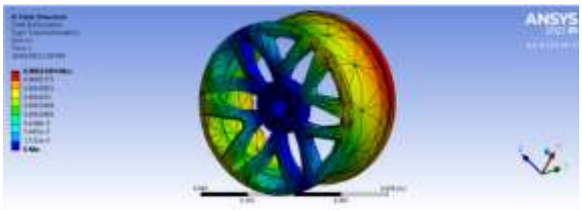


Fig. Total Deformation.

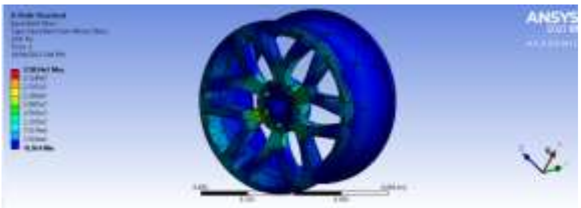


Fig. Equivalent Stress.

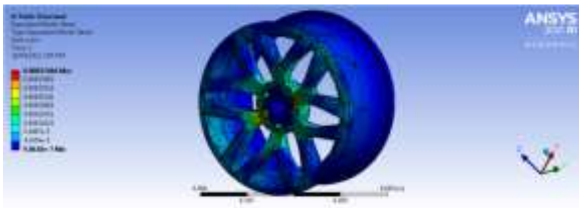


Fig. Equivalent Strain.

- **Refinement - Medium.**

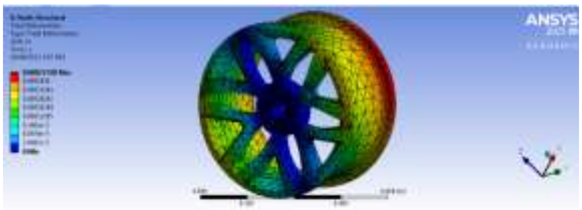


Fig. Total Deformation.

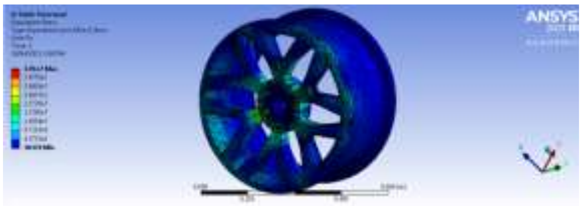


Fig. Equivalent Stress.

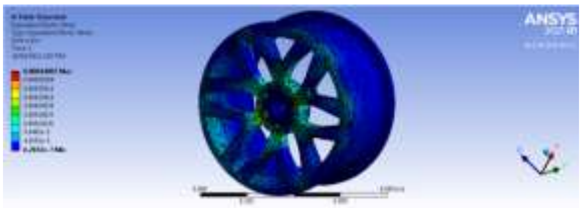


Fig. Equivalent Strain.

- **Refinement - Fine.**

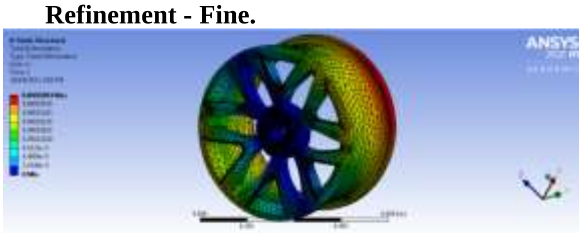


Fig. Total Deformation.

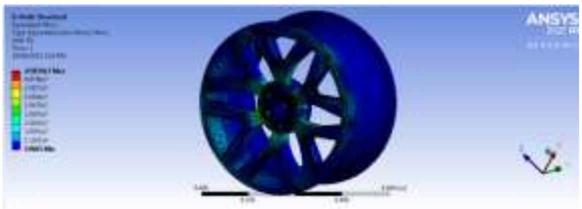


Fig. Equivalent Stress.

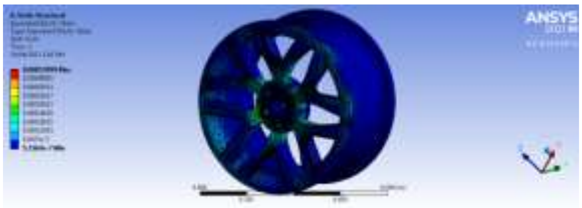


Fig. Equivalent Strain.

3.4. Comparison of results obtained.

- **Refinement - Coarse.**

Results	**Aluminium Alloy**	**Magnesium Alloy**	**Titanium Alloy**
Total Deformation (mm)	0.33357	0.52394	0.24494
Equivalent Stress(Pa)	3.5569e7	3.5215e7	3.5034e7
Equivalent Strain	0.00051296	0.00080536	0.00037666

- **Refinement - Medium.**

Results	**Aluminium Alloy**	**Magnesium Alloy**	**Titanium Alloy**
Total Deformation(mm)	0.37321	0.58662	0.27438
Equivalent Stress(Pa)	3.9518e7	3.9233e7	3.91e7
Equivalent Strain	0.00059023	0.00093722	0.00044097

- **Refinement - Fine.**

Results	Aluminium Alloy	Magnesium Alloy	Titanium Alloy
Total Deformation(mm)	0.39202	0.61643	0.2884
Equivalent Stress(Pa)	4.5711e7	4.5701e7	4.5839e7
Equivalent Strain	0.00072522	0.001149	0.00053999

4. CONCLUSION.

The CAD model of car wheel rim is made in CATIA V5 exported in the IGES format. This IEGS file is imported in ANSYS for analysis. Six bolt holes are made fixed and a force of 1000 N is applied on the center disc. A pressure of 200 kpa is applied along the circumference of the wheel rims made of Aluminium Alloy, Magnesium Alloy and Titanium Alloy. Following are the conclusions made from the results obtained-

1. In meshing, Number of nodes and elements defines the type of refinement. If the number of nodes and elements are small then it is coarse refinement and if they are large then it is fine refinement.

2. Linear element order has comparatively less nodes and elements than Quadratic element order.

3. During generation of the mesh, refinement plays an important role along with the nodes and elements. According to the refinement, Total Deformation, Equivalent Stress, Equivalent Strain values changes with respect to the all three materials.

4. From the table, Titanium Alloy has less deformation and less stress induced than Aluminium Alloy and Magnesium Alloy. So Titanium Alloy is the best metal for preparing the car wheel rim. But considering the high cost of titanium, other two materials are preferred.

5. Stresses induced in the magnesium alloy are less than stresses induced in aluminium alloy. Total Deformation of the magnesium alloy is more than aluminium alloy, along with it, the price of magnesium is also high as compared to aluminium alloy.

6. Since, cost and deformation of magnesium alloy is high, Aluminium alloy is preferred out of all the three materials.

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