FEA ANALYSIS OF CAR RIM

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Abstract - *The rim is the "outer edge of a wheel, holding the tire". It makes up the outer circular design of the wheel on which the inside edge of the tire is mounted on vehicles such as automobiles. A standard automotive steel wheel rim is made from rectangular sheet metal. Design is an important industrial activity that influences the quality of the product being produced. The wheel rim is modeled by using the modeling software SOLIDWORKS. Later this modal is imported to ABAQUS for analysis. Static load analysis has been done by applying a pressure of 5N/mm2. The materials taken for analysis are steel alloy, Aluminum, Magnesium, and Forged Steel. The displacement that occurred to the rim is noted after applying the static load to different materials and maximum principal stresses were also noted, The FEA analysis shows that the stress generated in the optimized component is well below the actual yield stress of the Al alloy. The Fatigue life estimation by finite element analysis, under radial fatigue load conditions, is carried out to analyze the stress distribution and resulting displacement in the alloy wheels. S-N curve of the component depicts that the endurance limit is 90 MPa which is well below the yield stress of the material and safe for the application. The FEA analysis indicated that even after a fatigue cycle of 1020, the damage on the wheel is found only 0.2%.*

Key Words: Wheel Rim, *SolidWorks, ABAQUS, FEA Analysis, Static Load Analysis.*

1. INTRODUCTION

The invention of wheels was a gift to humanity. The Mesopotamians are said to have invented the wheel around 3500 BC. Originally used to make pottery, it later became an important mode of transportation. In 3200 BC, the Mesopotamians used the wheel to transport their chariots for the first time. Wheels became important elements that shaped today's advanced automobile industries after the industrial Revolution. Today, there are many different types of wheels available on the market, and each one has a different movement and safety of the vehicle is the most important criterion in a vehicle and is standardized and certified. Wrapping an iron band around the wooden wheels used on carts and wagons was the first innovative idea for improving a wheel. The pneumatic tire was invented later, and it is still used on roads today in some form or another. Tire and rim improvements have continued over the years, with inventions and enhancements of nylon, cord, rubber, and other materials tried out for various types of tires. As the world discovered steel, iron, and aluminum, and variations of these metals, as well as various types of plastics, the actual rim or wheel was experimented with and changed in design and material. To be clear, plastics are not yet considered suitable for rim structure, but rather for cosmetic purposes, such as covering the rim and improving its appearance. Alloy wheels are made from an aluminum or magnesium alloy. Alloys are metal and other element mixtures. They are typically stronger than pure metals, which are much softer and more ductile. Aluminum and magnesium alloys are typically lighter for the same strength, have better heat conduction, and often have a more aesthetically pleasing appearance than steel wheels. Although steel is an iron and carbon alloy, the term "alloy wheel" is usually reserved for wheels made from nonferrous alloys. Alloy wheels are also purchased for aesthetic reasons, even though the cheaper alloys used are typically not corrosion-resistant. Alloys allow for the use of appealing bare-metal finishes, but these must be sealed with paint or wheel covers. Even if properly protected, the wheels in use will corrode after 3 to 5 years, but refurbishment is now widely available at a cost. Intricate, bold designs are also possible thanks to the manufacturing processes. Steel wheels, on the other hand, are typically pressed from sheet metal and then welded together (often leaving unsightly bumps), and must be painted to prevent corrosion or hidden with wheel covers/hub caps. Static analysis of wheel rims made of materials such as aluminum alloy, steel alloy, and stainless steel is performed in this work. A finite element method is a powerful tool or numerical procedure for obtaining solutions to many engineering analysis problems. A complex region defining a continuum is discretized into simple geometric shapes called finite elements in this method of analysis. The domain under consideration for the analysis is divided into a number of finite elements. Over these elements, the material properties and the governing relationship are considered and expressed in terms of unknown values at the element corner. The hub will be subjected to static analysis of wheel rim constraints. The hub will be subjected to static analysis of wheel rim constraints. The wheel rim is modeled in

SolidWorks software and then imported into ABAQUS software for static analysis in this work.

2. METHODOLOGY

We studied several reputable and international journals and discovered that rims also fail due to improper material selection. To withstand forced stresses and avoid major deformation, the rim material should be ductile. To investigate the various rim materials The 3D model of the Wheel Rim is required first. We used Solid Works, which is a very powerful software for creating complex to complex structures. Here is our model, which we created in Solid Works.

1) SOLIDWORKS

Solid works is a computer-aided design programme that can be used for both professional and personal purposes. While CAD software is known for being difficult to use, Solid Works is known for being user-friendly and simple to use. Solid works EPDM securely stores your design work. You can build 2D and 3D structures, as well as common models. We used various tools to create the 3D Model of the Car Wheel Rim of the Solidworks Software 2021 Version. Modeling becomes much easier for us with the help of these tools. Some of the tools we used were as follows: Revolve, Extrude, Section View, Render, Trim, Symmetric Multiplications, and so on.

2) ABAQUS

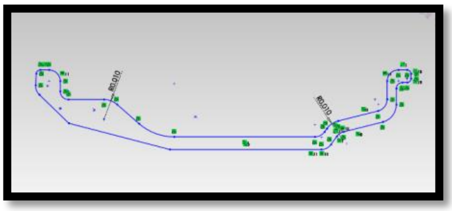
Dassault Systemes SIMULIA's finite element analysis software is called Abaqus. The software suite provides precise, robust, and high-performance solutions for difficult nonlinear problems, large-scale linear dynamics applications, and routine design simulations.

3. MODELLING

Here we used SolidWorks for the complex modeling of the Car wheel Rim for which at many steps we used various kinds of functionaries of the SolidWorks Software. We made the model in the following steps:

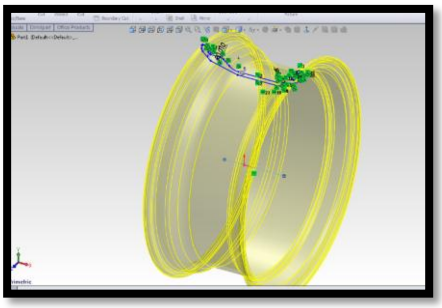
Step 1:

First, we start with the 2D drawing of the model.



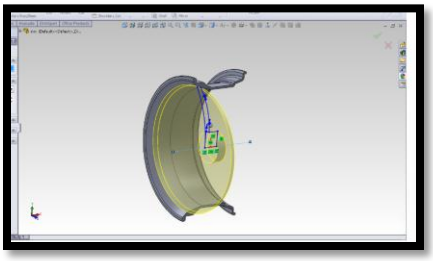
Step 2:

Use a Revolve Command to make this outer part of the rim.



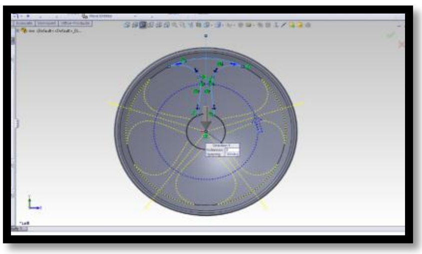
Step 3:

Taking its cross-section, we drew the 2D sketch of its front view.



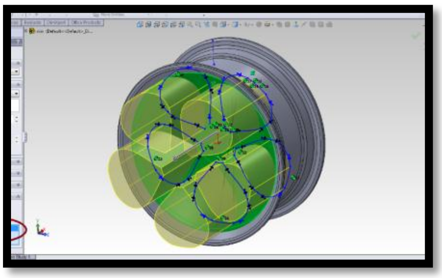
Step 4:

Use circular pattern command and make your selection according to how many arms you want to do your rim.



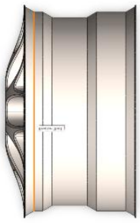
Step 5:

By Using Trim Command, cut the body as per the marked area.



Step 6:

After Drilling the Rim, Different views of the product will be:



SIDE VIEW

FRONT VIEW

ISOMETRIC VIEW

4. RIM NOMENCLATURE

a) Wheel: The wheel is generally composed of a rim and disc.

b) Rim: This is a part where the tire is installed.

c) Disc: This is a part of the rim where it is fixed to the axle hub.

d) Offset: This is a space between the wheel mounting surface where it is bolted to the hub and the center line of the rim.

e) Flange: The flange is a part of the rim that holds both beds of the tire

f) Bead Seat: Bead seat approaches in contact with the bead face and it is a part of the rim that holds the tire in a radial direction.

g) Hump: It is a bump that was put on the bed seat for the bead to prevent the tire from sliding off the rim while the vehicle is moving.

h) Well: This is a part of the rim with depth and width to facilitate tire mounting and removal from the rim.

5. STRUCTURAL ANALYSIS PROCEDURE

The procedure for a static analysis consists of these tasks:

• Build the model

• Set solution control

• Set additional solution options

• Apply the loads

• Solve the analysis

• Can use both linear and non-linear structural elements

• Material properties can be linear or non-linear, isotropic or orthotropic, and constant or temperature dependent.

• Must define stiffness in some form (for example, young's modulus, hyperelastic coefficients, and so on).

• For inertia loads (such as gravity), you must define the data required for mass calculations, such as density.

• For thermal loads (temperatures), you must define the coefficient of thermal expansion.

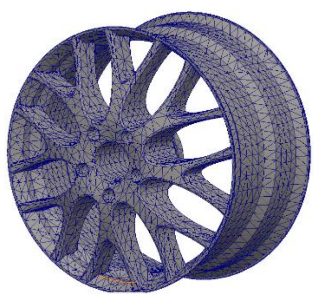
6. MESHING OF MODEL

Mesh Information

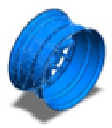
Mesh Type	Solid Mesh
Mesher Used	Standard Mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points for High-quality mesh	16 points
Element Size	17.9945
Tolerance	0.899726 mm
Mesh Quality	High

Mesh Information - Details

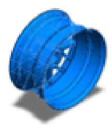
Total Nodes	44885
Total Elements	24352
Maximum Aspect Ratio	89.518
percentage of elements with an aspect ratio < 3	45.7
percentage of elements with an aspect ratio > 10	8.61
Percentage of distorted elements	0.00821
Time to complete mesh (hh : mm: ss)	00:00:41
Computer name	KISHU- KUMAR



7. MATERIAL USED

Model Reference	Properties	Components
	**Name:** Alloy Steel **Model Type:** Linear Elastic Isotropic **Yield Strength:** 6.20422e+08 N/m² **Tensile Strength:** 7.23826e+08 N/m² **Elastic modulus:** 2.1e+11 N/m² **Poisson's Ratio:** 0.28 **Mass Density:** 7,700 kg/m³ **Shear Modulus:** 7.9e+10 N/m² **Thermal Expansion:** 1.3e-05/kelvin	Solid Body2 (Revolve 2) (wheel 1), Solid Body 3(Fillet 35)(wheel1)
Curve Data: N/A		

Material Properties

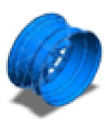
Model Reference	Properties	Components
	**Name:** 1060 Alloy **Model Type:** Linear Elastic Isotropic **Default Failure:** Max von mises Stress **Yield Strength:** 2.75742e+07 N/m² **Tensile Strength:** 6.8935e+07 N/m² **Elastic modulus:** 6.9e+10	Solid Body1 (CirPattern) (wheel 1), Solid Body 2(Revolve 2)(wheel1)

	N/m² **Poisson's Ratio:** 0.33 **Mass Density:** 2,700 kg/m³ **Shear Modulus:** 2.7e+10 N/m² **Thermal Expansion:** 2.4e-05/kelvin	
Curve Data: N/A		

8. ANALYSIS (RESULT AND DISCUSSION)

1)Alloy Steel

a.) Model Information

Document Name and Reference	Treated as	Volumetric properties
	Solid Body	**Mass:** 0.603126 kg **Volume:** 7.8328e-05 m³ **Density:** 7,700 kg/m³ **Weight:** 5.91064 N
Fillet35 	Solid Body	**Mass:** 41.5057 kg **Volume:** 0.00539019 m³ **Density:** 7,700.22 kg/m³ **Weight:** 406.756 N

b.) Load and Fixtures

Fixture name	Fixture Image			Fixture Details
Fixed -1				**Entities:** 10 face(s) **Type:** Fixed Geometry
Resultant Forces				
Components	**X**	**Y**	**Z**	**Resultant**
Reaction Force(N)	23.9151	27.1198	4.17489	36.3984
Reaction Moment (N.m)	0	0	0	0

c.) Resultant Force

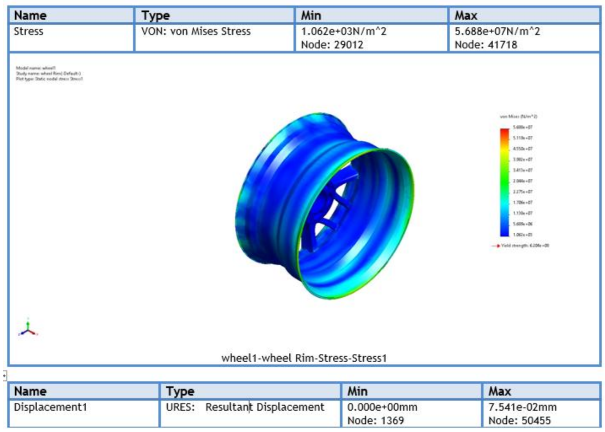
Reaction forces

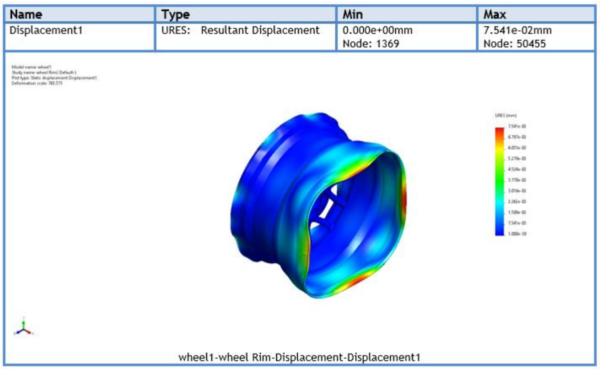
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	23.9151	27.1198	4.17489	36.3984

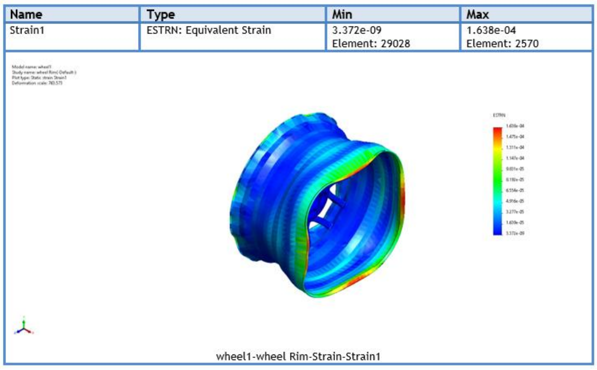
Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.0107538	-0.000980757	0.00043916	0.0108074

d.) Study Results







2) Aluminum Alloy

a.) Model Information

Document Name and Reference	Treated as	Volumetric properties
	Solid Body	**Mass:** 14.5539 kg **Volume:** 0.00539019 m³ **Density:** 2,700.08 kg/m³ **Weight:** 142.629 N
	Solid Body	**Mass:** 41.5539 kg **Volume:** 0.00539019 m³ **Density:** 7700.22 kg/m³ **Weight:** 406.756 N

b.) Load and Fixtures

Fixture name	Fixture Image	Fixture Details		
Fixed -1		**Entities:** 10 face(s) **Type:** Fixed Geometry		
Resultant Forces				
Components	**X**	**Y**	**Z**	**Resultant**
Reaction Force(N)	23.8847	12.7625	6.69692	27.8964
Reaction Moment (N.m)	0	0	0	0

c.) Resultant Force

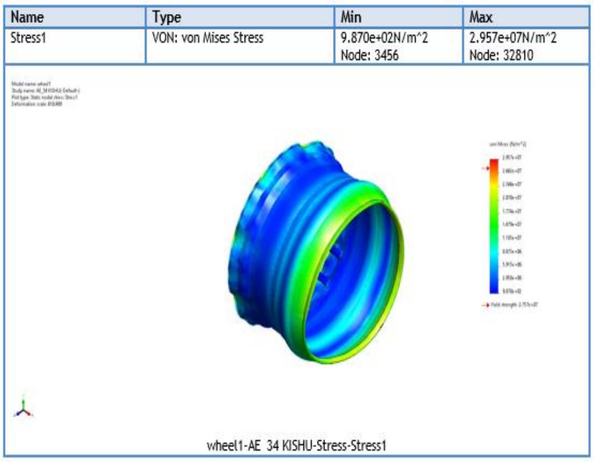
Reaction forces

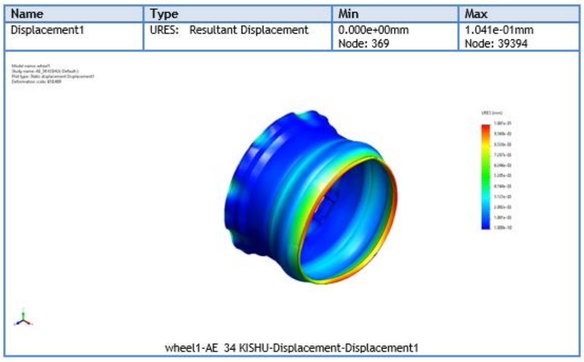
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	23.88	12.7625	6.69692	27.8964

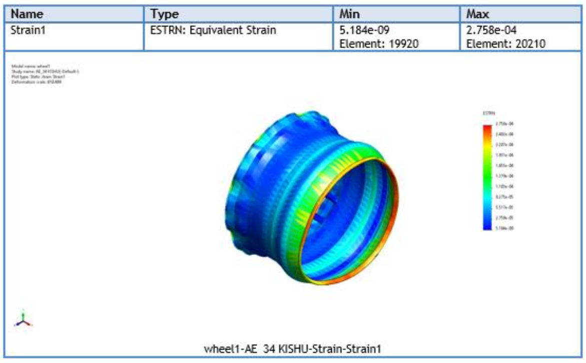
Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.0068619	-0.000134	0.000934716	0.00692656

d.) Study Results







3) Stainless Steel

a.) Model Information

Document Name and Reference	Treated as	Volumetric properties
	Solid Body	**Mass:** 42.0447 kg **Volume:** 0.00539 m³ **Density:** 7,800.23 kg/m³ **Weight:** 5.91064 N
	Solid Body	**Mass:** 0.6109 kg **Volume:** 783e-05 m³ **Density:** 7,800 kg/m³ **Weight:** 5.9874 N

b.) Load and Fixtures

Fixture name	Fixture Image	Fixture Details		
Fixed -1		**Entities:** 10 face(s) **Type:** Fixed Geometry		
Resultant Forces				
Components	**X**	**Y**	**Z**	**Resultant**
Reaction Force(N)	23.884	12.763	6.69649	27.3966
Reaction Moment (N.m)	0	0	0	0

c.) Resultant Force

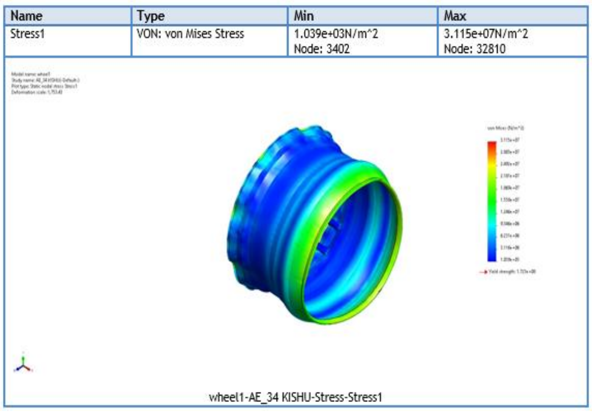
Reaction forces

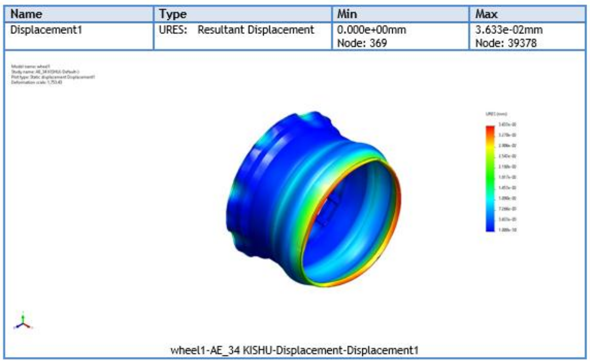
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	23.8848	12.763	6.69649	27.8966

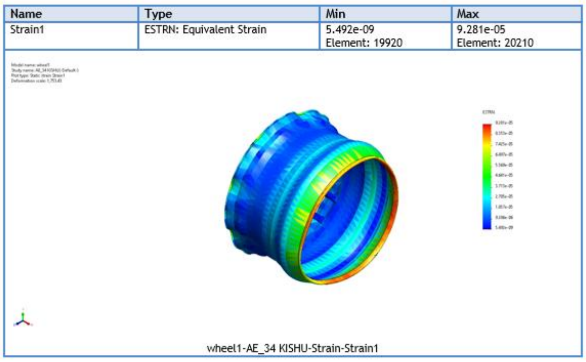
Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.00412	0.000696938	-1.8030 e-025	0.00417

d.) Study Results







3. CONCLUSIONS

The number of cycles to failure in steel alloy is greater than in aluminum alloy, and stainless steel. As a result, steel alloy is more suitable for use in wheel rims than other materials. We can further optimize material thickness to reduce material consumption, and we can improve component life by using an advanced fatigue strain life approach.

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