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Optimization Of Car Rim

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ABSTRACT
The essential of car wheel rim is to provide a firm base on which to fit the tyre. Its dimensions, shape should be suitable to adequately accommodate the particular tyre required for the vehicle. In this project a tyre of car wheel rim belonging to the disc wheel category is considered. Design is an important industrial activity which influences the quality of the product. The wheel rim is modeled by using modeling software catiav5r17. By using this software the time spent in producing the complex 3- D models and the risk involved in the design and manufacturing process can be easily minimized. So the modeling of the wheel rim is made by using CATIA. Later this CATIA modal is imported to ANSYS WORKBENCH 14.5 for analysis work. ANSYS WORKBENCH 14.5 is the latest software used for simulating the different forces, pressure acting on the component and also calculating and viewing the results. By using ANSYS WORKBENCH 14.5 software reduces the time compared with the method of mathematical calculations by a human. ANSYS WORKBENCH 14.5 static structural analysis work is carried out by considered three different materials namely aluminum alloy ,magnesium alloy and structural steel and their relative performances have been observed respectively. In addition to wheel rim is subjected to modal analysis, a part of dynamic analysis is carried out its performance is observed. In this analysis by observing the results of both static and dynamic analysis obtained magnesium alloy is suggested as best material.

I. INTRODUCTION

Automotive wheels have evolved over the decades from early spoke designs of wood and steel, flat steel discs and finally to the stamped metal configurations and modern cast and forged aluminum alloys rims of today's modern vehicles. Historically, successful designs arrived after years of experience and extensive field testing. In recent years, the procedures have been improved by a variety of experimental and analytical methods for structural analysis (strain gauge and finite element methods). Within the past 10 years, durability analysis (fatigue life predication) and reliability methods for dealing with the variations inherent in engineering structure have been applied to the automotive wheel.

Wheels are clearly safety related components and hence fatigue performance and the state of stress in the rim under various loading conditions are prime concerns.

Further, wheels continue to receive a considerable amount of attention as part of industry efforts to reduce weight through material substitution and down gauging. Although wheels are loaded in a complex manner and are highly stressed in the course of their rolling duty, light weight is one of the prime requirements, hence cast and forged aluminum alloys are essential in the design.

Further the current generation automobile have the alloy wheel. This technology up gradation has given multiple choices in respect of material, cross section for rim and arm connecting hub and rim. The newer car are supposed to have lesser weight without compromising the strength. Therefore there is a scope for optimization of wheel design in respect of geometry of car rim, geometry of arm, material etc. The car rim is subjected to static as well as dynamic loading condition. it undergoes bending , twisting, circumferential loading and also impact loading. Therefore it is justified to have a detailed analysis using the technique like FE for the stresses developed during used. It is proposed to analyse the car rim using FE approach for varied geometry parametric parameter for optimization of its weight.

II. OBJECTIVE, SCOPE AND METHODOLOGY

The various car rim geometry for the exiting car rim and certain variation of them in regards to cross section of arm and rim geometry is modeled and the suitable constrained and loading condition will imposed.

These models are analysed using slandered commercial FE software. The result for each of the case are compared for the various design parameter like stress and weight, stress weight and cost this shall further then be compared to chosen the optimum design .

The proposed work included following step

1) Study of literature review of various work reported
2) Selecting some of the commercially available rim design and certain variation of them.
3) CAD model is created using various tool in CATIA V5 i.e. Extrude, revolve, Mirror, Trim etc.
4) FE analysis of the above geometry for different loading and boundary condition is done such as .
   i) The constrained are provided on the hub (central hole) and bolt hole.
   ii) The pressure is applied through the circumference of rim.
   iii) The vertical upward force is applied on the selected nodes within 60.
   iv) The rotational velocity is given to the central axis.
5) Comparison of the result obtained in above step for different material.
6) Choosing the optimum design based on the material and other parameter if any.
7) Natural frequencies and modal shapes are also determined.

In all above cases, FE static analysis is carried out and result are compared with analytical calculation for some cases.

The proposed analysis will be given an opportunity to study the various loading that would come on the car rim during its working and give an insight to the stresses the rim is exposed to.

Further the variation in the geometry and the arm shape are provide different possible approach for design of rim. The optimization is provide the comparison between the variety of design existing and proposed.

Loading for car in static condition

The force act on one wheel in upward direction = 6250 N
Pressure inside the tube = 0.24131 Mpa
The car rim maximum speed = 100 Km/hr

Modeling of car rim

Automobile wheel specification

S	Specification	Value
1	Rim Width	0.128 m
2	Wheel Diameter	0.330 m
3	Offset	0.02 m
5	Centre Base Diameter (CBD)	0.068 m
6	Rim thickness	0.003m
7	Bolt diameter	0.016m
8	Number of bolt holes	4

III. CAR RIM NOMENCLATURE

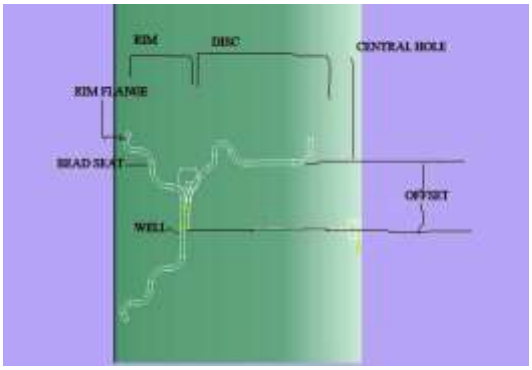


Figure 1 : Car Wheel Nomenclature

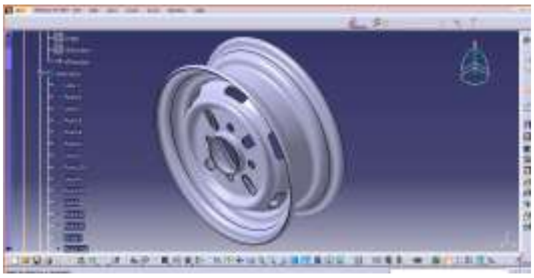


Figure 2: Complete model of car rim.


Figure 3 : various views of car rim

IV. MATERILS SELECTION

SR.NO.	MATERIALS NAME	DENSITY (ρ) Kg/m^3	YOUNGS MODULUS (E) Pa	POISSONS RATIO (1/m)
1	STRCTURAL STEEL	7850	$2*10^{11}$	0.3
2	ALUMINUM ALLOY	2770	$7.1*10^{10}$	0.33
3	MAGNESIUM ALLOY	1800	$4.5*10^{10}$	0.35

V. FINITE ELEMENT ANALYSIS OF CAR RIM

Meshing of model

Fig 4. Meshing of car rim

The element used is tetrahedron Element.

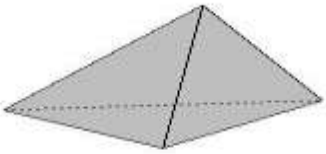


Fig 5: Tetrahedron Element

Support of car rim

The hub portion of car rim is fixed with the help of four bolts. The car rim is mounted on rotating drum of shaft. The blots are fully constrained.

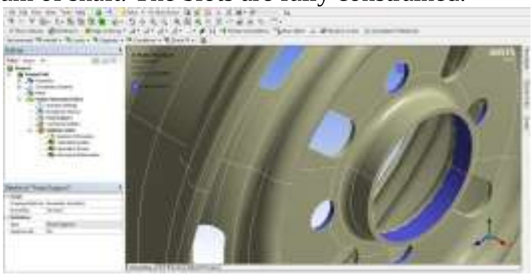


Figure 6 : Constraints on a car rim

Loading and constraint

i) Reactional force (Nodal force) in upward direction as shown in figure 7 the vehicle in static condition touches some portion of the tyre to ground which is in direct contact with rim. This downward weight of the vehicle causes upward reaction so that select the some node in direct contact with the tyre.

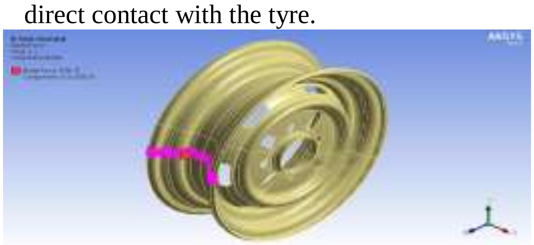


Figure 7 Nodal force

i) Pressure applied on circumference of the rim as shown in figure 8 the tube pressure inside the tyre exert the outward reactional force on the rim surface.

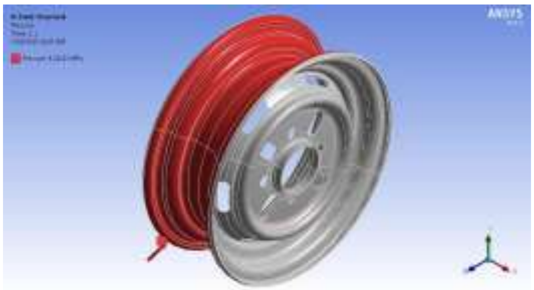


Figure 8 :Pressure along the circumference

ii) Rotational velocity along the central axis i.e. in X-axis as shown in figure 9 the vehicle in running condition causes moment of inertia about their central axis due to weight of the wheel and also the centrifugal force is acted on it because of velocity.

Figure 9: Rotational velocity along the X-axis

All the loading condition (i),(ii),(iii) are applied in combine manner on a car rim . the combine position of loading as shown in figure when the vehicle running on the road it exert reactional force, pressure force and centrifugal force on it.

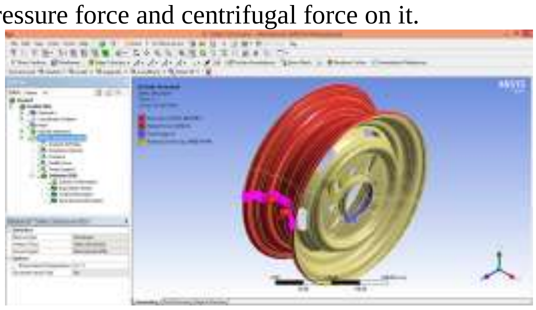


Figure 10 : Combination of all the loading condition.

The first loading condition Nodal force second loading condition Pressure last loading condition is rotation velocity all these applied on the car rim and find out the total deformation, directional deformation and equivalent stresses for different materials .

Total Deformation of Car rim

i) Result by using rotational velocity.
Material aluminum alloy.

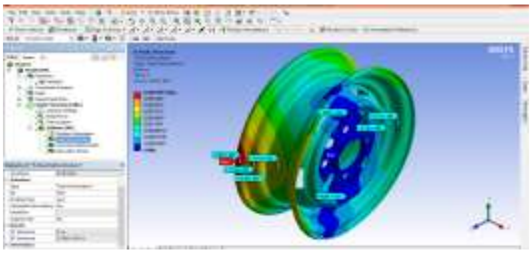


Figure11:-Total Deformation (Al)

Material magnesium alloy.

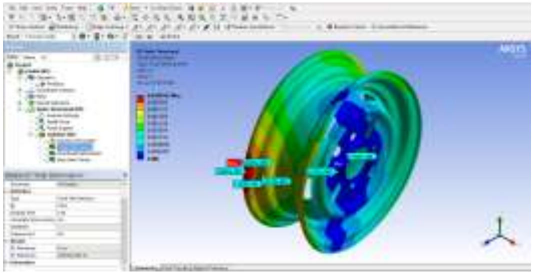


Figure 12 :-Total Deformation (Mg)

Material structural steel.

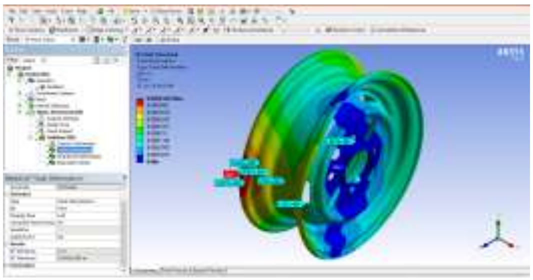


Figure 13:-Total Deformation (STEEL)

Result by using rotational velocity.

Material aluminum alloy.

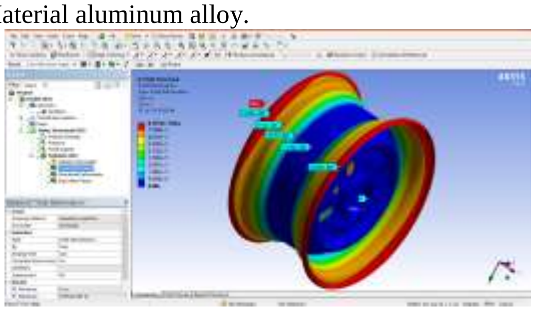


Figure 14:-Total Deformation (Al)

Material magnesium alloy.

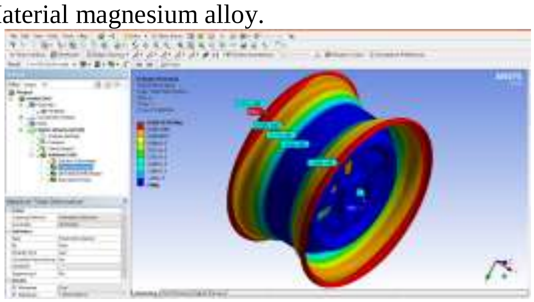


Figure 15:-Total Deformation (Mg)

Material structural steel.

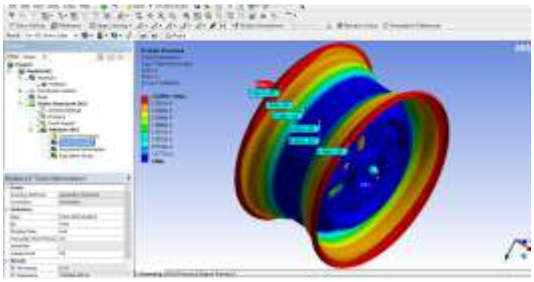


Figure 16:-Total Deformation (STEEL)

Result by using rotational velocity

Material aluminum alloy.

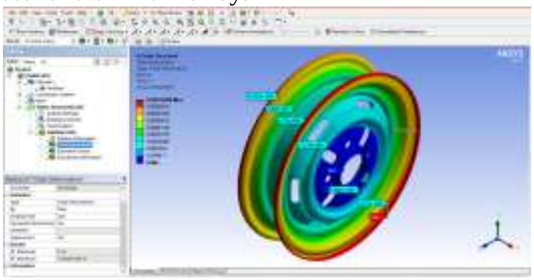


Figure 17.:-Total Deformation (Al)

Material magnesium alloy.

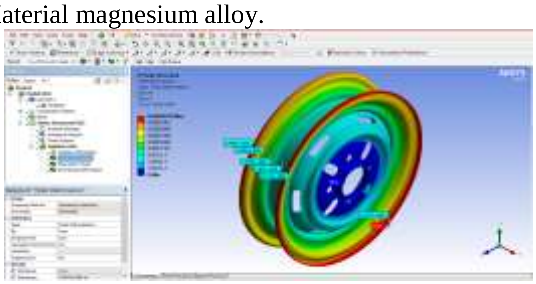


Figure 18:-Total Deformation (Mg)

Material structural steel.

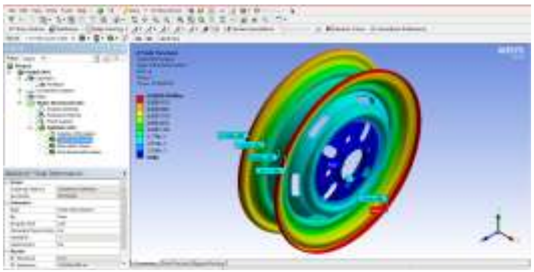


Figure 19:-Total Deformation (STEEL)

Combination of all the boundary condition

Material aluminum alloy.

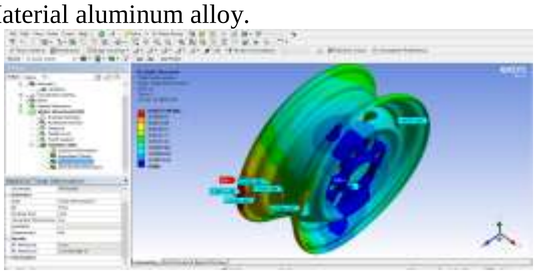


Figure 20:-Total Deformation (Al)

Material magnesium alloy.

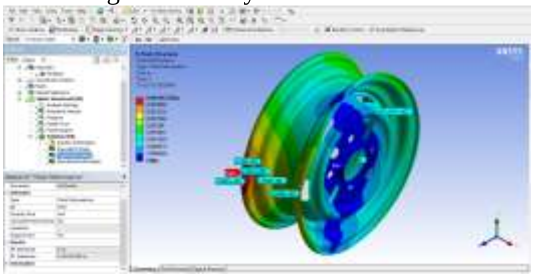


Figure 21:-Total Deformation (Mg)

Material structural steel

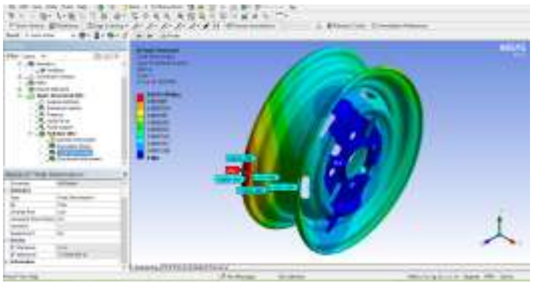
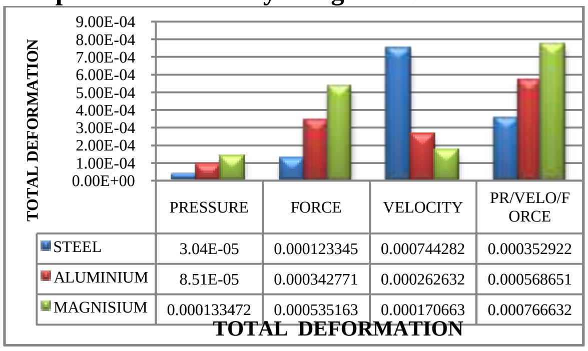


Figure 22 :-Total Deformation (STEEL)

Comparison of result by using chart.



Graph : Variation in Total Deformation due to change of boundary condition and Materials.

Table I: Variation in Total Deformation due to Pressure (Mpa)

SR.NO.	MATERIALS NAME	NODAL FORCE (N)	TOTAL DEFORMATION (m)
1	ALUMINUM ALLOY	6250	0.0025967
2	MAGNESIUM ALLOY	6250	0.0040543
3	STRCTURAL STEEL	6250	0.00093443

Table II: Variation in Total Deformation due to Nodal force (N)

SR.NO.	MATERIALS NAME	ROTATIONAL VELOCITY (RPM)	TOTAL DEFORMATION (m)
1	ALUMINUM ALLOY	9806.9	0.00074428
2	MAGNESIUM ALLOY	9806.9	0.00026979
3	STRCTURAL STEEL	9806.9	0.00026338

Table III: Variation in Total Deformation due to Rotational Velocity (RPM)

SR.NO.	MATERIALS NAME	PRESSURE (Mpa)	TOTAL DEFORMATION (m)
1	ALUMINUM ALLOY	0.24132	8.5054×10^{-5}
2	MAGNESIUM ALLOY	0.24132	0.00013347
3	STRCTURAL STEEL	0.24132	3.0399×10^{-5}

Conclusion from result

TOTAL DEFORMATION

The results obtained from the Graph and Table I, II,III are as follows.

i) For the pressure of 0.24132 Mpa the Total deformation in Structural Steel is minimum as compared to Aluminum alloy and Magnesium alloy.

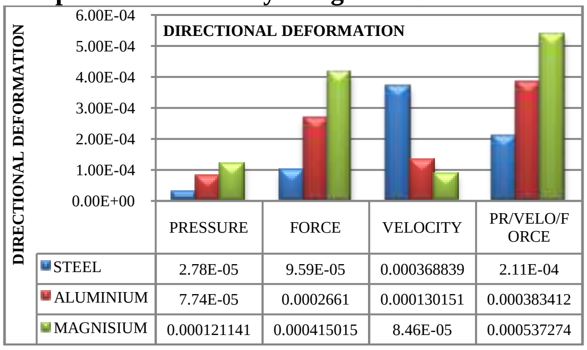
ii) For the Nodal Force 6250 N the Total deformation in Structural Steel is minimum as compared to Aluminum alloy and Magnesium are approximately same.

iii) For the Rotational Velocity 9806.9 RPM the Total deformation in Structural Steel, Aluminum alloy are more as compared to Magnesium alloy.

iv) Combining all the three above Parameter Total deformation in Structural Steel are less as compared to Magnesium alloy and Aluminum alloy.

Since the rigidity of steel rim is high in pressure loading and Nodal force in static condition and in dynamic condition magnesium alloy car rim is having less deformation as compared to two other rims.

The result obtained for Directional deformation of Car rim are shown in graph and table…
Comparison of result by using chart .



Graph : Variation in Directional Deformation due to change of boundary condition and Materials.

Table IV : Variation in Directional Deformation due to Pressure (Mpa)

SR. NO.	MATERIALS NAME	PRESSURE (Mpa)	DIRECTIONAL DEFORMATION (m)
1	ALUMINUM ALLOY	0.24132	7.7412×10^{-5}
2	MAGNESIUM ALLOY	0.24132	0.0001211
3	STRCTURAL STEEL	0.24132	2.7768×10^{-5}

Table V : Variation in Directional Deformation due to Nodal force (N)

SR. NO.	MATERIALS NAME	NODAL FORCE (N)	DIRECTIONAL DEFORMATION (m)
1	ALUMINUM ALLOY	6250	0.0020159
2	MAGNESIUM ALLOY	6250	0.0031441
3	STRCTURAL STEEL	6250	0.00072646

Table VI: Variation in Directional Deformation due to Rotational Velocity (RPM)

SR. NO.	MATERIALS NAME	ROTATIONAL VELOCITY (RPM)	DIRECTIONAL DEFORMATION (m)
1	ALUMINUM ALLOY	9806.9	0.00036884
2	MAGNESIUM ALLOY	9806.9	0.0001354
3	STRCTURAL STEEL	9806.9	0.00012801

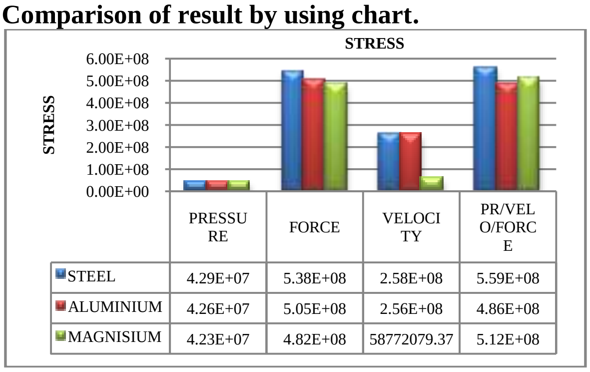
Conclusion form result
DIRECTIONAL DEFORMATION

The results obtained from the Graph and Table IV, V, VI are as follows.

i) For the pressure of 0.24132 Mpa the Directional deformation in Structural Steel is minimum as compared to Aluminum alloy and Magnesium alloy.
ii) For the Nodal Force 6250 N the Directional deformation in Structural Steel is minimum as compared to Aluminum alloy and Magnesium are approximately same.
iii) For the Rotational Velocity 9806.9 RPM the Directional deformation in Structural Steel, Aluminum alloy are more as compared to Magnesium alloy.
iv) Combining all the three above Parameter Directional deformation in Structural Steel are less as compared to Magnesium alloy and Aluminum alloy.

Since the rigidity of steel rim is high in pressure loading and Nodal force in static condition and in dynamic condition magnesium alloy car rim is having less directional deformation as compared to two other rims.

The result obtained for Equivalent Stresses of Car rim are shown in graph and table…
Comparison of result by using chart.



Graph : Variation in stress distribution due to change of boundary condition and Materials.

Table VII : Variation in Stresses due to Pressure (Mpa)

SR.NO.	MATERIALS NAME	PRESSURE (Mpa)	EQUIVALENT STRESSES (Pa)
1	ALUMINUM ALLOY	0.24132	4.2564×10^7
2	MAGNESIUM ALLOY	0.24132	4.2336×10^7
3	STRCTURAL STEEL	0.24132	4.2906×10^7

Table VIII : Variation in Stresses due to Nodal force (N)

SR.NO.	MATERIALS NAME	NODAL FORCE (N)	EQUIVALENT STRESSES (Pa)
1	ALUMINUM ALLOY	6250	5.0522×10^8
2	MAGNESIUM ALLOY	6250	4.8189×10^8
3	STRCTURAL STEEL	6250	5.377×10^8

Table XI : Variation in Stresses due to Rotational Velocity (RPM)

SR.NO.	MATERIALS NAME	ROTATIONAL VELOCITY (RPM)	EQUIVALENT STRESSES (Pa)
1	ALUMINUM ALLOY	9806.9	2.5631×10^8
2	MAGNESIUM ALLOY	9806.9	5.8522×10^7
3	STRCTURAL STEEL	9806.9	2.5769×10^8

5. 9.60.Conclusion of result

Equivalent Stresses

The results obtained from the Graph and Table VII, VIII, XI are as follows.

i) For the pressure of 0.24132 Mpa the Equivalent Stresses in Structural Steel, Aluminum alloy and Magnesium are approximately same.
ii) For the Nodal Force 6250 N the Equivalent Stresses in Structural Steel, Aluminum alloy and Magnesium are approximately same.
iii) For the Rotational Velocity 9806.9 RPM the Equivalent Stresses in Structural Steel, Aluminum alloy are more as compared to Magnesium alloy.
iv) Combining all the three above Parameter Equivalent Stresses Structural Steel are less as compared to Magnesium alloy and Aluminum alloy

Since the rigidity of steel rim is high in pressure loading and Nodal force in static condition and in dynamic condition magnesium alloy car rim is having less Equivalent stresses as compared to two other rims.

VI. CONCLUSION

CAD model of the wheel rim is generated in CATIA and this model is imported to ANSYS for processing work. An amount of pressure 0.24132 Mpa is applied along the circumference, Reaction force on the selected node is 6250 N in Z-direction and Rotational Velocity = 9806.9 rpm along the X-axis is applied on the wheel rims made of different materials like ALUMINIUM ALLOY,STEEL AND MAGNESIUM ALLOY and bolt circle of wheel rim is fixed. Following are the conclusions from the results obtained:

¬ Steel wheel rim is subjected to more stress as compared to Aluminum and Magnesium while pressure, force and Rotational velocity apply combine.
¬ In all cases von-mises stresses are less than ultimate strength.
¬ Total and directional deformation in magnesium is more when compared to steel and aluminum.
¬ Weight of the magnesium rim is less as compared to other.
¬ Since in all the cases von-mises stresses is less than the ultimate strength, taking deflections into account, magnesium is preferred as best material for designed wheel rim.

FINAL REMARKS

¬ Static Structural analysis continues to be an impressive tool in helping model real world problems.
¬ However, Static Structural can be used to give insight into visualization of critical design structure and where the failure occurs in the part is shown directly.

VII. FUTURE SCOPE

Following work may form the scope for future work

- Further work on different Rim materials, different force and rotational velocity validation with experimental data for the optimized design will add value to this work.
- Stress analysis by varying rim thickness of car rim

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