MODELING AND FATIGUE ANALYSIS OF AUTOMOTIVE WHEEL RIM BY COMPOSITE OR NON COMPOSITE MATERIAL

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Abstract

The purpose of the car wheel rim provides a firm base on which to fit the tire. Its dimensions, shape should be suitable to adequately accommodate the particular tire required for the vehicle. In this study a tire of car wheel rim belonging to the disc wheel category is considered. Design in an important industrial activity which influences the quality of the product. The wheel rim is designed by using modelling software cad 2016. In modelling the time spent in producing the complex 3-D models and the risk involved in design and manufacturing process can be easily minimised. So the modelling of the wheel rim is made by using CAD. Later this CAD model is imported to ANSYS for analysis work. ANSYS software is the latest used for simulating the different forces, pressure acting on the component and also for calculating and viewing the results. A solver mode in ANSYS software calculates the stresses, deflections, bending moments and their relations without manual interventions, reduces the time compared with the method of mathematical calculations by a human. ANSYS static analysis work is carried out by considered two different materials namely aluminium and forged steel and their relative performances have been observed respectively. In addition to this rim is subjected to vibration analysis (modal analysis), a part of dynamic analysis is carried out its performance is observed. In this paper by observing the results of both static and modal analysis obtained forged steel is suggested as best material.

Key Words: wheel rim, Stainless Steel, Aluminium Alloy, Pro-E Software, ANSYS Software

1. INTRODUCTION

Archaeologies and historians of today see the introduction of the wheel as the real genesis of any old civilisation. The wheel is perhaps the most significant discovery of old times. The wheel has developed from nothing more than an oversized bearing to a fully integral part of any modem transportation vehicle. The modern vehicle is also seen today a fashion item to complement people's individual requirements. Motor vehicles are produced according to very strict rules to ensure the safety of the passengers. Every component is therefore designed according to the criticality of the component. Wheels are classified as a safety critical component and international cods and criteria are used or design a wheel.

Materials to produce these wheels have become has sophisticated as a design and materials can range from steel to non-ferrous alloys like magnesium and aluminium. Automotive wheels have evolved over the decades from early spoke designs of wood and steel. Carry over's from wagon and bicycle technology, to flat steel discs and finally to the stamped metal configurations and modern cast and forged aluminium alloys rims of today's modern vehicles historically successful designs arrived after years of experience and extensive field testing. Since the 1970's several innovative methods of testing well aided with experimental stress measurements have been initiated

In recent years, the procedures have been improved by a variety of experimental and analytical methods for structural analysis is (strain gauge and finite element methods). Within the past 10 years, durability analysis (fatigue life predication) and reliability method for dealing with variations inherent in engineering structure have been applied to the automotive wheel. Wheel rims affect the braking performance of a vehicle as result of the following for parameters: size, weight, design or ventilation, materials. The size of the wheel rim governs how much space there is between the rim and the brake rotor. By moving up to a higher diameter wheel rim there will be more scope for air flow around the brakes and therefore better cooling. The weight of the wheel rim is an obvious issue. The mass is not only important in terms of the overall weight of the wheel, the rotational inertia of the wheel goes up with more weight as well, causing even more work for the brakes.

2 .LITERATURE REVIEW

DR. TORGAL ET AL a report proposes an evaluation of the fatigue life of steel rims. Static findings on steel wheels are obtained through the use of the ANSYS software programme. Aluminum and structural steel are the two main materials employed. This is used to predict the fatigue life of both wheels. Analyses have revealed that the baseline wheel failed the test and that the crack was initiated near the hub in that case as well.

DAS ET AL the primary goal of this research is to investigate the causes of rim failure. Cracks and bends appear on the rim's surface. An increase in vibration might be caused by tyre damage. An imperfection on the surface of the wheel that could lead to structural collapse due to vibration, pressure, or even rust According to the research, the rim can experience a variety offailures. This study discusses the use of analysis tools to calculate von-misses stresses and deflections.

CHAITANYA ET AL The paper explains how an aluminium alloy wheel for automobile use might be designed with a focus on reducing the wheel's mass. According to the FEA, it is possible to lower the optimum mass of the wheel rim by as much as 30%. The FEA demonstrates that the optimised component's stress is lower than the alloy's actual yield stress. Component S-N curves show that the component's endurance limit is 90 MPa, which is below the yield stress of the material.

3 .FATIGUE MECHANISMS

The basic feature that underlies all the specific fatigue failure mechanisms is the existence of repeated or cyclic stresses at some point of the component. This could be considered the basic definition of fatigue. The cyclic stress sensor strains give origin to damage accumulation until it develops into a crack that finally leads to failure of the component. Keeping in mind the basic assumption for a fatigue failure, different definitions will be provided for the specific fatigue failure mechanisms. The different fatigue failure mechanisms are essentially related to the way those cyclic stresses arise in a specific point of the component, or to the cause of the stresses. Sometimes they are also related to the existenceof other concurrent or synergistic damaging mechanisms such as wear or corrosion.

4 .VEHICLE DYNAMICS

In order for a car to remain controllable the tyre must be in constant contact with the ground and a considerable amount of force must be maintained. To do this the cars suspension system must be able to follow the road and all its imperfections. The suspension response time can be characterized by its natural frequency.

A simple model of the suspension system assumes the sprung mass to be fixed, the tyre rigid and the unsprung mass to oscillate freely ignoring damping. This system is characterized by the equation: From this equation it can be derived that a decrease in the un sprung mass will increase the natural frequency and allow the suspension to respond faster. While the same results can be achieved by increasing the spring stiffness this also decreases the suspension travel and means that the suspension relies on an increasingly smooth track.

As such the ideal unsprang weight is zero, so the suspension can be relatively softly sprung and the wheel can follow all undulations in the road without losing contact. Using a two degree of freedom system taking tyre vertical stiffness into account the equations of motion become:

Unsprang mass

(m1) X acceleration of unsprang mass ($\ddot{x}$)

= − [spring rate (k1) X position of suspension(x)] + [Wheel rate (k2) X

{position of chassis(y)− position of suspension(x)}](2)

Sprung mass (m2) X acceleration of sprung mass ($\ddot{y}$) =

−[Wheel rate (k2)X {position of chassis(y) − position of suspension(x)}]**(3)**

Decreasing m1 will increase $\ddot{x}$which will allow the suspension to keep in constant contactwith the road. An increase in m2 will lower $\ddot{y}$keeping the chassis position relatively constant.

Itis shown then that as $\frac{m2}{m1}$tends towards ∞ the response of the

Suspension is increased and the displacement of the chassis is decreased, providing a more comfortable ride for the driver while improving the handling. To improve the ratio of masses it is possible to use a ballast to increase the sprung mass, however applying newton’s second law of motion to this situation states that this will reduce the accelerationof the car and in a racing situation increase the cars lap times. This leaves the most desirable solution to the problem to reduce the unsprung mass of the vehicle.

5 .METHODOLOGY

1. Design the wheel rim.
2. Material selection.
3. Structure design.
4. Cad modelling.
5. Export to iges format.
6. Import to ansys.
7. Mesh the solid model.
8. Select the analysis method.
9. Put the input value of material.
10. Solve the values by the way of analysis method.
11. Take the result from result data sheet.

6 .MATERIAL SELECTION PEEK

a. PEEK stands for Polyether ether ketone

b. Polyether ether ketone is a colourless organic thermoplastic polymer in thepolyaryletherketone family

c. PEEK is a semi crystalline thermoplastic with excellent mechanical and chemicalresistance properties

d. PEEK polymers are obtained by step–growth polymerization by the alkylation of bi–phenolate salts (Table 1) (Table 2).

Table 1 **Mechanical Property:**

e. l. No	**Mechanical property**	**Aluminium Alloy**	**PEEK**	**PEEK GF 30**	**PEEK 90 HMF 20**	**PEEK 90 HMF 40**
1	Density (kg/m^3)	2685	1520	1320	1370	1450
2	Young's Modulus (MPa)	69000	4060	4100	22000	4500
3	Poisson's Ratio	0.33	0.45	0.46	0.4556	0.48
4	Tensile Yield Strength (MPa)	229	190	100	280	330
5	Compressive Yield Strength (MPa)	250	118	95	270	310
6	Tensile Ultimate Strength(MPa)	279	100	100	100	100

Table 2 **Material Property:**

S. No	**Specification**	**Value**
1	Rim Width	215.9mm
2	Wheel Diameter	480 mm
3	Offset	128 mm
4	Pitch Circle Diameter(PCD)	110 mm
5	Centre Base Diameter (CBD)	70
6	Rim thickness	7
7	Bolt diameter	10
8	Number of bolt holes	5

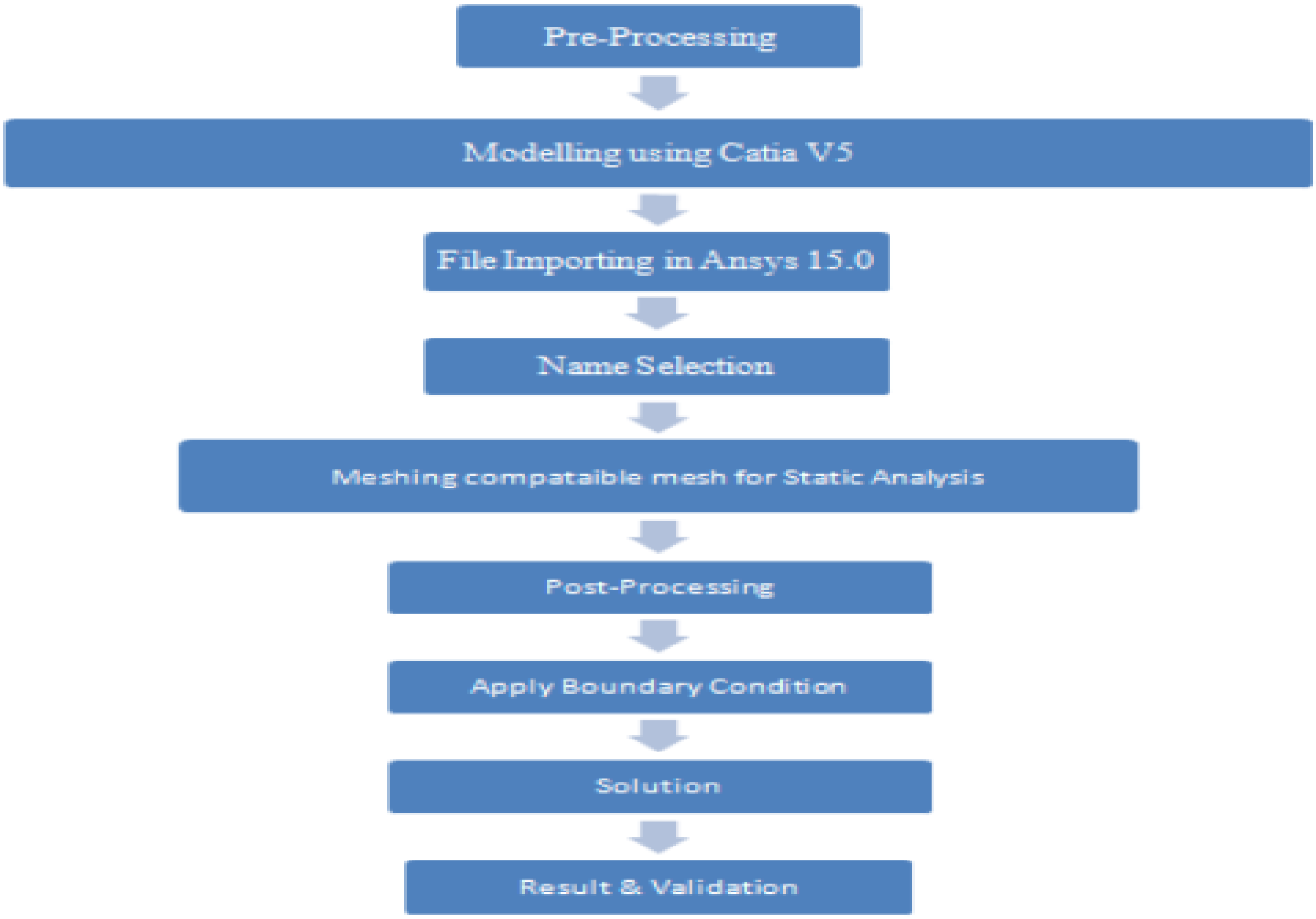
6 . SELECTION OF MATERIAL

Aluminium Alloy: Aluminium is a metal with features of excellent lightness, thermal conductivity, rust confrontation, physical characteristics of casting, low heat, machine processing and reutilizing, etc. This metals main advantage is decreased weight, high precision and design choices of the wheel. This metal is useful for energy preservation because it is possible to re-cycle aluminium easily.

Magnesium Alloy: Magnesium is about 30% lighter than aluminium and also admirable as for size stability and impact resistance. However, its use is mainly restricted to racing, which needs the features of weightlessness and high strength at the expense of weathering resistance and design choice, etc. compared with aluminium.

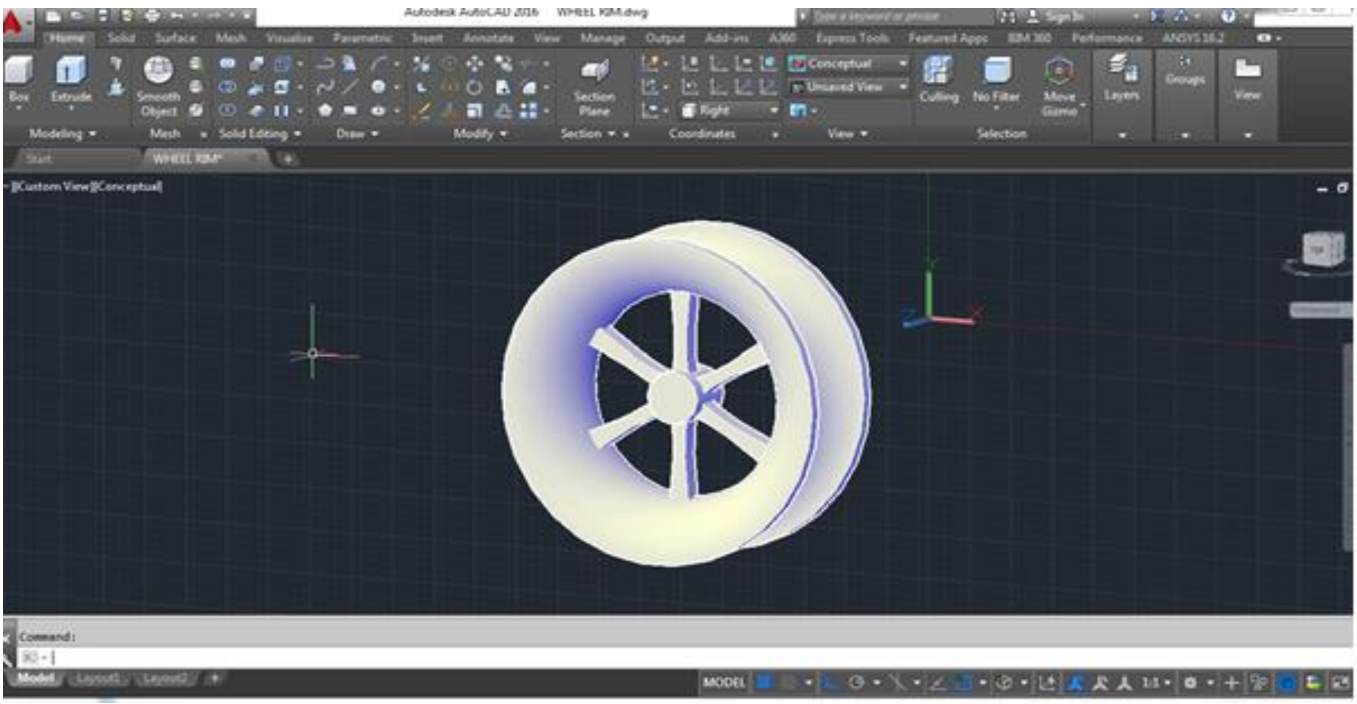
Titanium Alloy: Titanium is an admirable metal for corrosion resistance and strength (about

2.5 times) compared with aluminium, but it is inferior due to machine processing, designing and more cost. It is still in the development stage even though there is some use in the field of racing.. In the real service conditions, the determination of mechanical behaviour of the wheel is important, but the testing and inspection of the wheels during their development process is time consuming and costly. For economic reasons, it is important to reduce the time spent during the development and testing phase of a new wheel. A 3–D stress analysis of Aluminium wheels of the car involves complicated geometry. Therefore, it is difficult to estimate the stresses by using elementary mechanical approximations. For this purpose, Finite Element Analysis (FEA) is generally used in the design stage of product development to investigate the mechanical performance of prototype designs. FEA simulation of the wheel tests can significantly reduce the time and cost required to finalize the wheel design. Thus, the design modifications could be conducted on a component to examine how the change would influence its performance, without making costly alteration to tooling and equipment in real production



Steps of Working

7. CAD DIAGRAM



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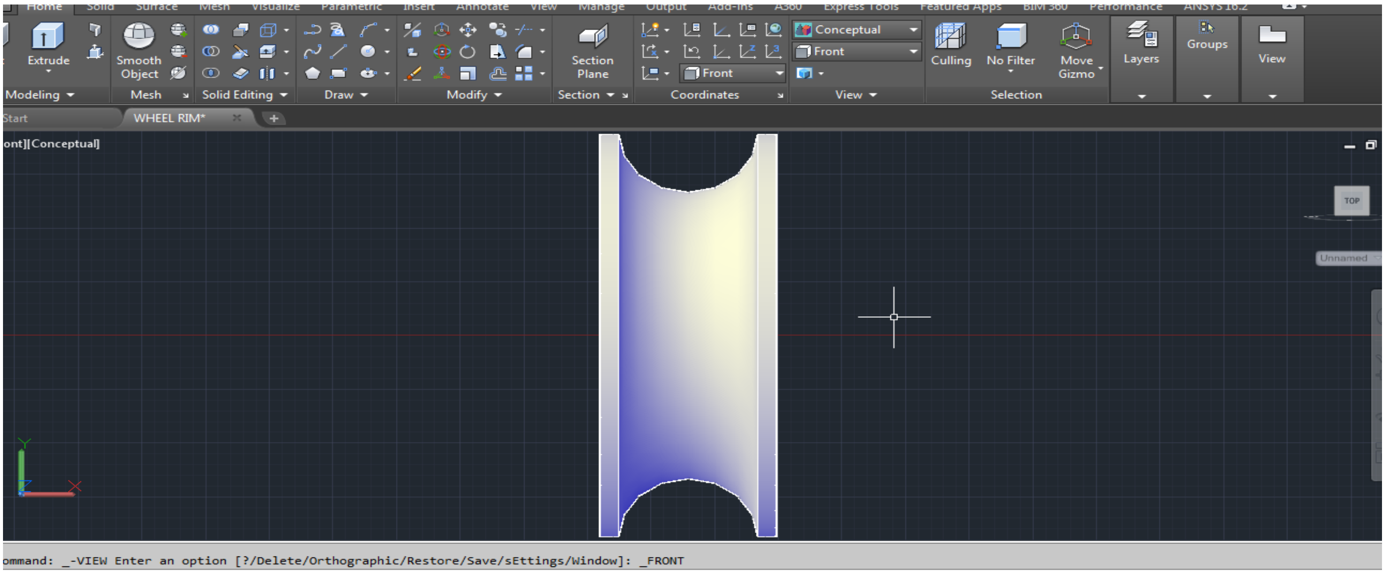
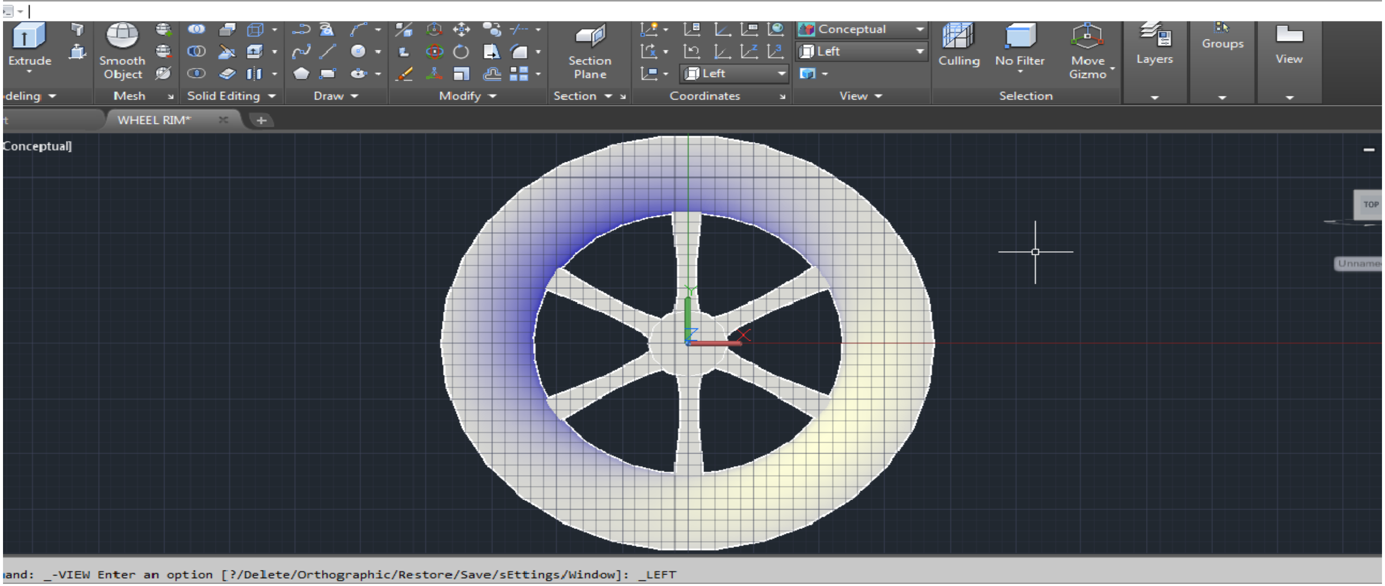
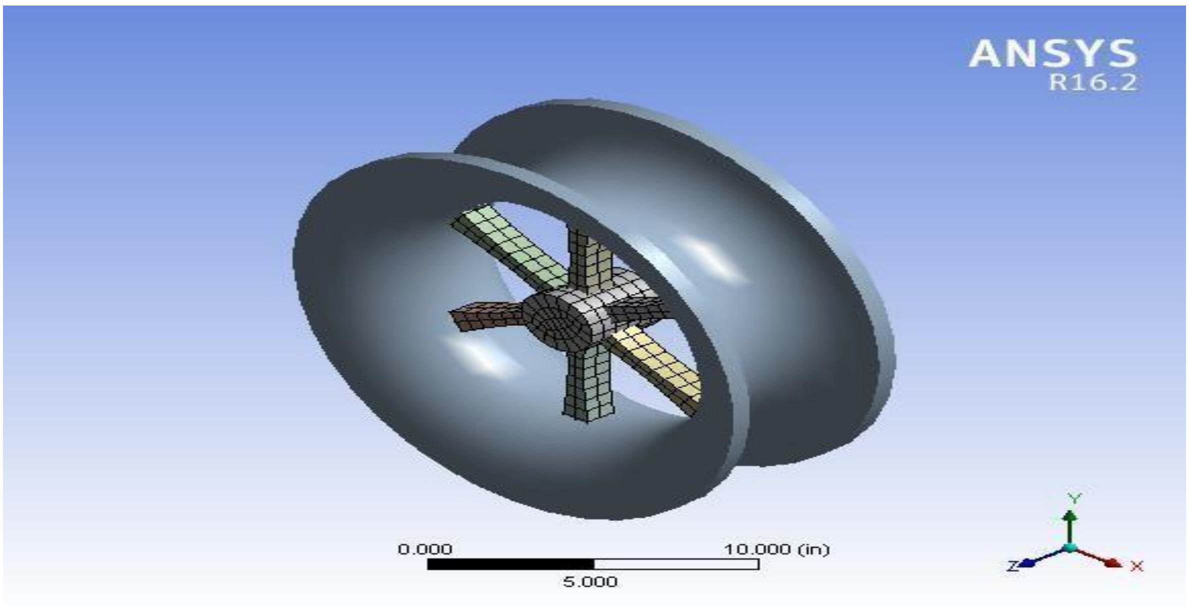
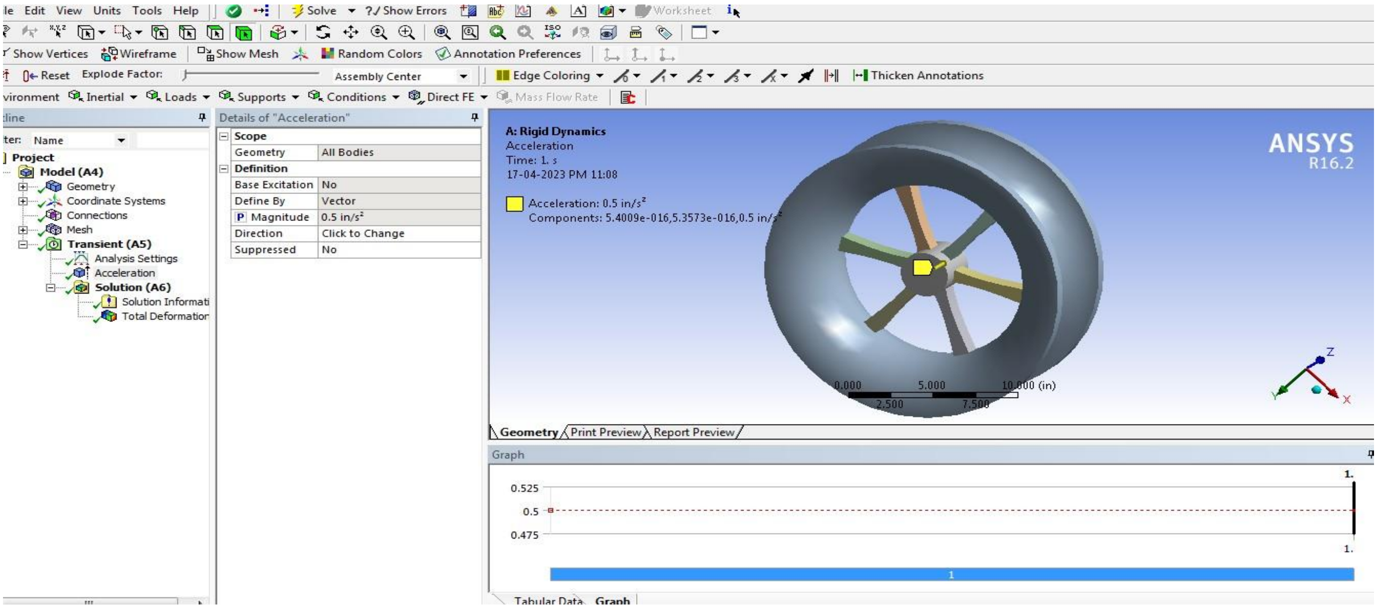




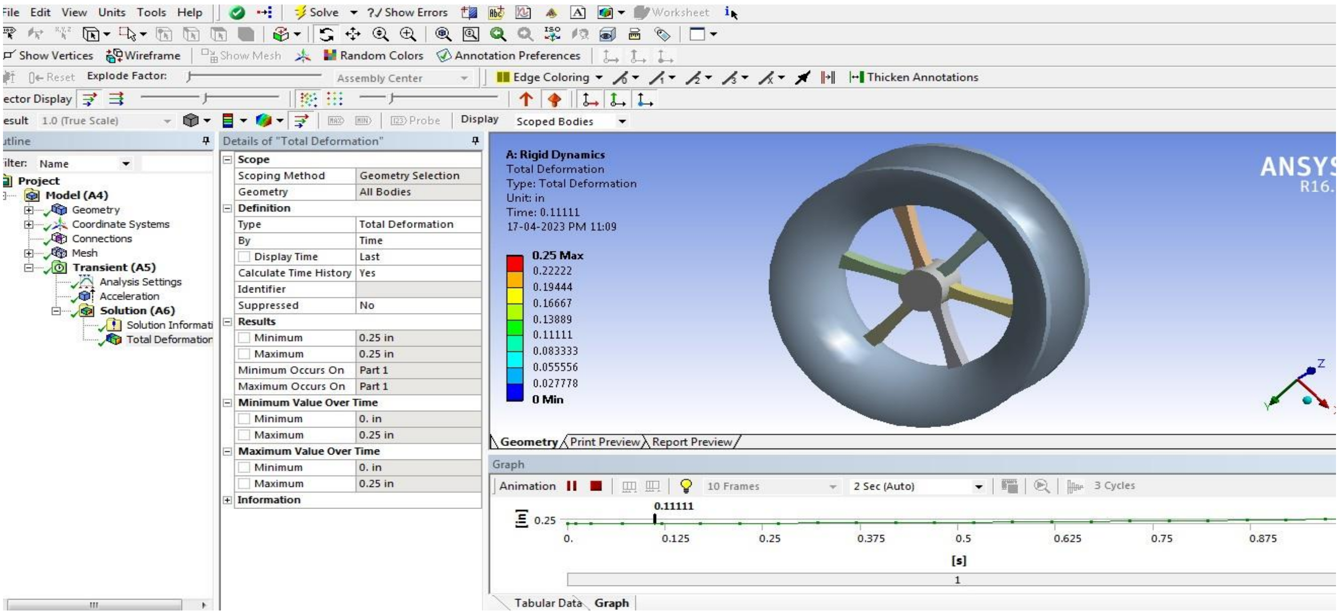
8. MESH TOOL



9 . FORCE APPLY



10 . SIMULATION CHART



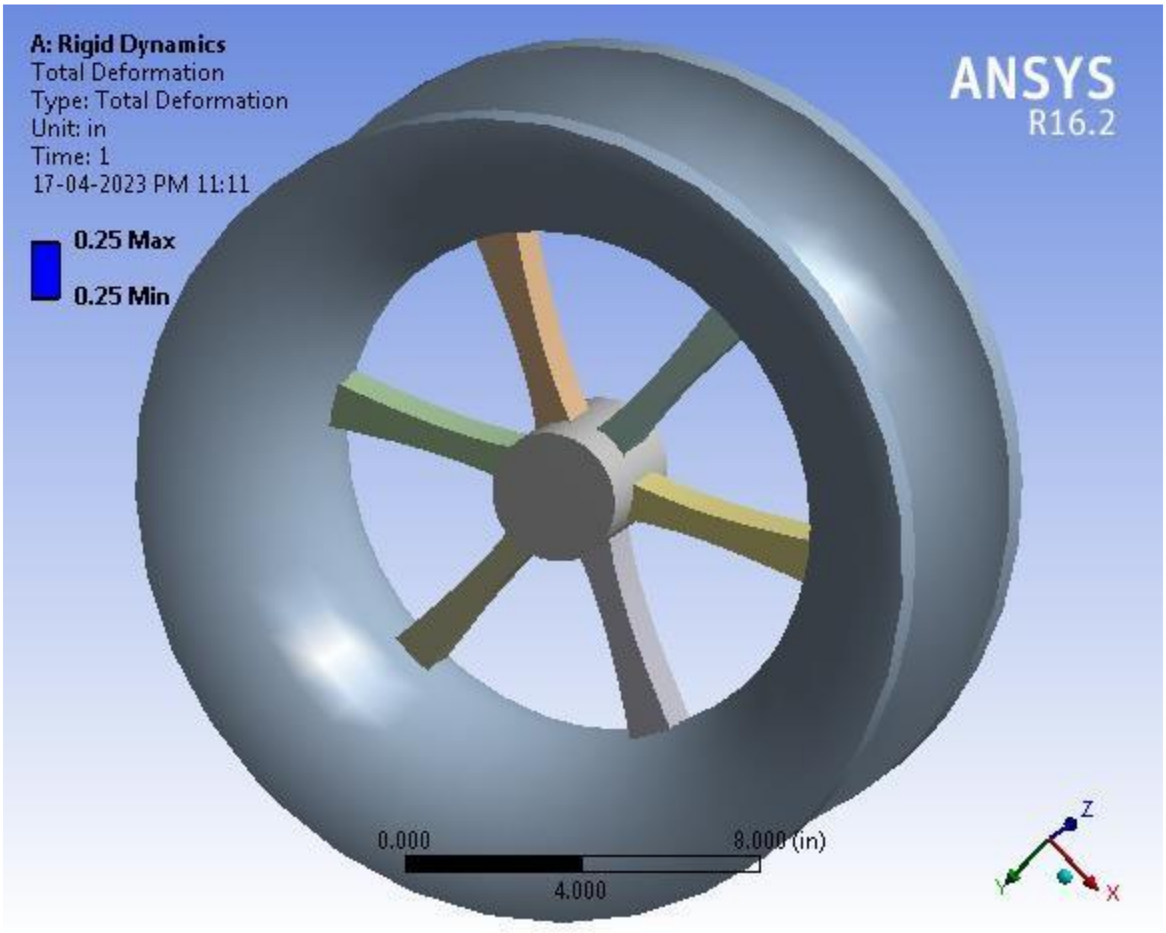
11 . RESULT

Total Deformation

Subject: Author: Prepared For:Date

Sunday, April 16, 2023

Comments:

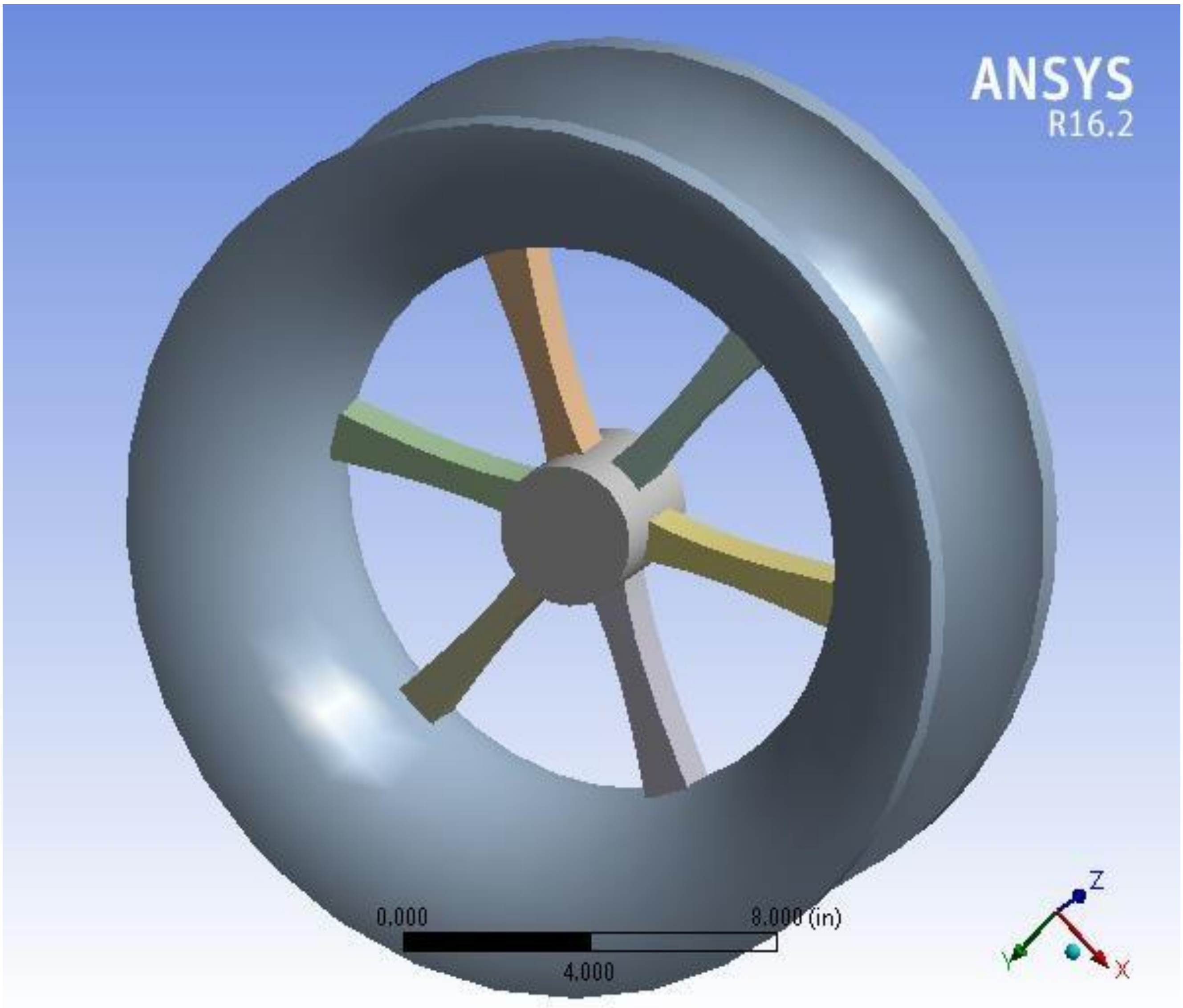


12 . FINAL REPORT

ANSYS

Project

First Saved	Sunday, April 16, 2023
Last Saved	Sunday, April 16, 2023
Product Version	16.2 Release
Save Project Before Solution	No
Save Project After Solution	No



Geometry

TABLE 3

Model (A4) > Geometry

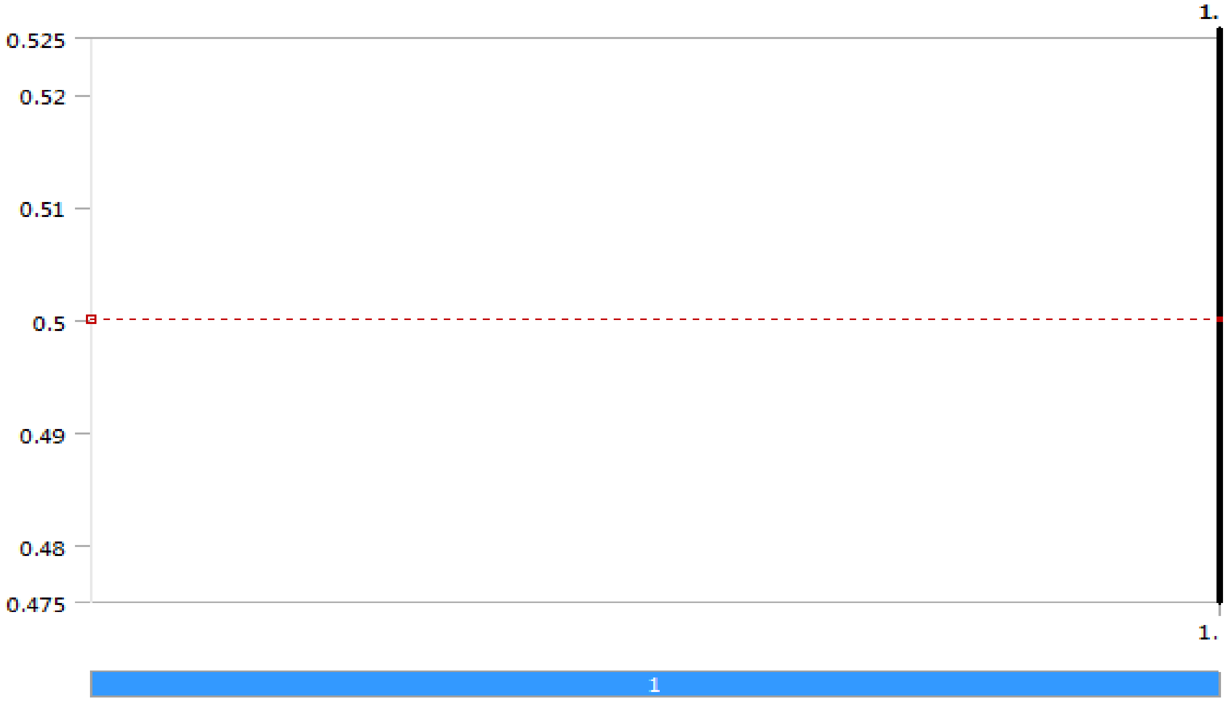
Object Name	*Geometry*
State	Fully Defined
Definition	
Source	D:\2022-2023\paavai ME project\WHEEL RIM\WHEEL RIM.igs NEW.igs
Type	Iges

Length Unit	Meters
Display Style	Body Color
Bounding Box	
Length X	18.777 in
Length Y	18.777 in
Length Z	6.9118 in

Properties	
Volume	373.8 in^3
Mass	106.01 lbm
Scale Factor Value	1.
Statistics	
Bodies	8
Active Bodies	8
Nodes	8
Elements	8
Mesh Metric	None
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Compare Parts On Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\Lenovo\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Decompose Disjoint Geometry	Yes
Transparency	1

Definition								
Suppressed	No							
Stiffness Behavior	Rigid							
Reference Temperature	By Environment							
Material								
Assignment	Structural Steel							
Bounding Box								
Length X	3.0085 in	18.777 in	5.6331 in		1.1608 in	5.6331 in		1.1608 in
Length Y	3.0085 in	18.777 in	3.9225 in		5.8344 in	3.9225 in		5.8344 in
Length Z	3.0821 in	6.9118 in	1.0993 in					
Properties								
Volume	21.91 in³	320.17 in³	5.2869 in³					
Mass	6.2136 lbm	90.799 lbm	1.4994 lbm					
Centroid X	-4.8549e-005 in	2.6704e-004 in	-3.1433 in	-3.1848 in	-4.1435e-002 in	3.1433 in	3.1848 in	4.1435e-002 in
Centroid Y	4.2112e-004 in	-3.4232e-004 in	1.8627 in	-1.7909 in	-3.6535 in	-1.8627 in	1.7909 in	3.6535 in
Centroid Z	29.031 in	28.958 in	29.168 in					
Moment of Inertia Ip1	8.3357 lbm·in²	3052.5 lbm·in²	5.0564 lbm·in²					
Moment of Inertia Ip2	8.3348 lbm·in²	3053.3 lbm·in²	5.1121 lbm·in²					
Moment of Inertia Ip3	6.9142 lbm·in²	5163.3 lbm·in²	0.24852 lbm·in²					
Statistics								
Nodes	1							
Elements	1							
Mesh Metric	None							

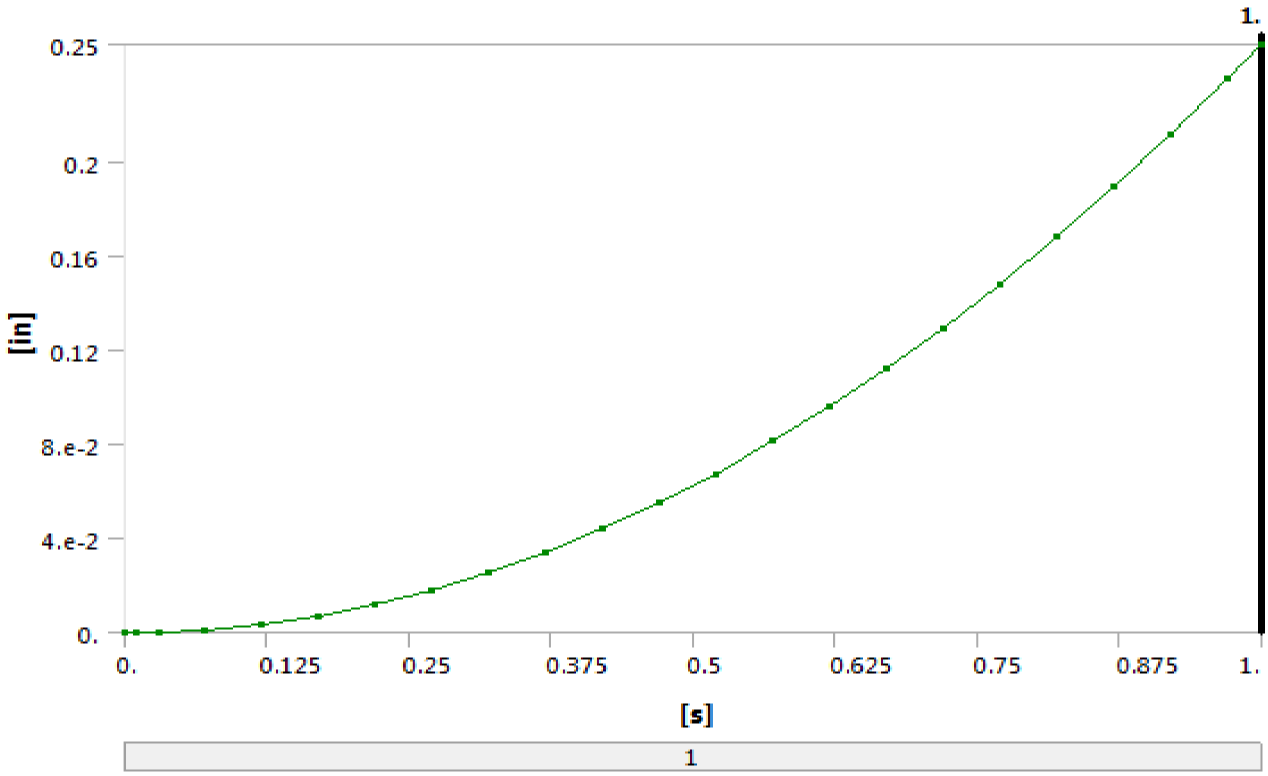
FIGURE 1



Model (A4) > Transient (A5) > Acceleration

FIGURE 2

Model (A4) > Transient (A5) > Solution (A6) > Total Deformation



13 . CONCLUSION

From the analysis we came to know that all the four designs are safe and are within the standard limits Among the four designs simple rim design is more promising than centrifugal rim Followed by pentagonal rim Among the four materials steel alloy is the best material followed by aluminum and magnesium occupies last position as it has more deformation for the same loading condition.

from this results we can then why magnesium alloy material is only used for pretty shorter period restricted to racing cars only From the fatigue analysis aluminum alloy has got more life than that of the steel alloy Even though the safety factor is almost equal for both the materials aluminum is subjected to less damage compared to steel (for same loading conditions) From the above results we define a new material (Al-Mg alloy) which is more promising than other two i.e. these has got less deformations like Aluminum and more lifelike magnesium Under the influence of a radial load, the rim tends to vocalize about the point of contact with maximum displacement occurring at the location of the bead seat.

The inside bead seat reveals the greatest deflection and is concurrently prone to loss of air pressure due to dislodgment of the tire on the rim. Actually failure of alloy wheel occurs mostly at the areas where there is max stress values occur (predicted by analysis software) More deformed areas are also in agreement with theoretical values.

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