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Impact Analysis of Aluminum Alloy Wheel

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ABSTRACT:

Automobile wheels have in the time period spanning the last five decades progressively evolved from the early spoke design of wood and steel the carryovers from wagon and bicycle technology, flat steel discs, and more recently stamped metal configurations. The metal configurations are made from either cast or cast plus forged aluminum alloys in the present and newer generations of ground vehicles. Historically, successful design was arrived after years of experience well aided worth extensive field-testing. Since the 1970's several innovative methods of testing and experimental stress measurements have been initiated.

This project work summarizes the application of Finite Element Techniques for analyzing stress and displacement distribution in vehicle wheels subjected to the conjoint influence of inflation pressure and radial load. The most commonly used considerations in wheel are elucidated. The model is done by using "CATIA" and the analysis is carried out by using "Ansys workbench" finite element package. The wheel is modeled by using six nodded tetrahedron solid elements; the constitutive material model selected for the analysis is linear elastic with isotropic conditions.

Wheel strength with regard to the fractures on edges and other critical points when the wheel strikes an obstacle shall be checked. In order to show the sufficient resistance to fractures it is necessary to carry out an impact test. An impact load (as per SAE standards) is applied on the wheel at a determined angle. Static analysis for the given radial load and the angular velocities of 40, 60, 80, and 120, with the appropriate constraint set of conditions in order to check the wheel strength. Yield strength of the alloy wheel material is checked with the Von-Mises stress obtained, (as per the ISO 7141 - Road Vehicles - Wheels - Impact Test Procedure, and SAE J175 - Impact Test Procedures standards). . And also carried out fatigue calculation for impact test for two materials. Therefore the study states that the innovative design of the wheel is safe for its operating conditions for the given loads specified

1.INTRODUCTION TO ALLOY WHEEL:

Wheel is an important structural member of the vehicular suspension system that supports the static and dynamic loads encountered during vehicle operation. Since the rims, on which cars move, are the most vital elements in a vehicle, they must be designed carefully. Safety and economy are particularly of major concerns when designing a mechanical structure so that the people could use them safely and economically. Style, weight, manufacturability and performance are the four major technical issues related to the design of a new wheel and/or its optimization. The wheels are made of either steel or cast/forge Aluminum alloys. Aluminum is the metal with features of excellent lightness, corrosion resistance, etc. In particular, the rims, which are made of Aluminum casting alloys, are more preferable because of their weight and cost.

Automotive manufacturers have been developing safe, fuel efficient and lightweight vehicular components to meet governmental regulations and industry standards (Stearns, 2000). In the real service conditions, the determination of mechanical behavior 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 Aluminum wheels of the car involves complicated geometry. Therefore, it is difficult to estimate the stresses by using elementary mechanical approximations.

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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.

1.1 TYPES OF WHEEL/RIM:

Steel and light alloy are the main materials used in a wheel however some composite materials including glass-fiber are being used for special wheels.

A. Wire Spoke Wheel:

Wire spoke wheel is a structural member where the outside edge part of the wheel (rim) and the axle mounting part are connected by numerous wires called spokes. Today's vehicles with their high horsepower have made this type of wheel construction obsolete. This type of wheel is still used on classic vehicles. Light alloy wheels have developed in recent years, a design to emphasize this spoke effect to satisfy users fashion requirements.

B. Steel Disc Wheel:

This is a wheel which processes the Steel-made rim and the disc into one by welding, and it is used mainly for passenger vehicle especially original equipment tires.

Fig.1.1 Steel Disc Wheel

C. Light Alloy Wheel:

These wheels based on the use of light metals such as aluminum and magnesium has become popular in the market. This wheel rapidly became popular for the original equipment vehicle in Europe in 1960's and for the replacement tire in United States in 1970's.

D. Aluminum Alloy Wheel:

Aluminum is a metal with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, machine processing and recycling, etc. This metals main advantage is reduced weight, high accuracy and design choices of the wheel. This metal is useful for energy conservation because it is possible to re-cycle aluminum easily.

Fig.1.2 Aluminum Alloy Wheel

1.3 GENERAL WHEEL NOMENCLATURE:

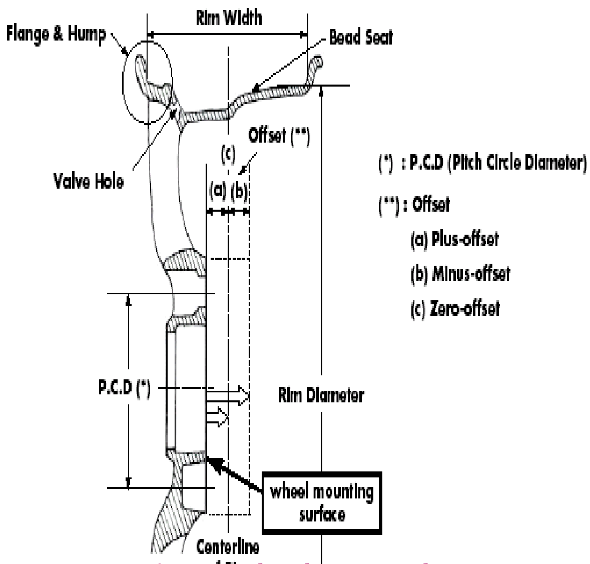

Fig: 1.7 Wheel Nomenclature

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(1) Wheel: Wheel is generally composed of rim and disc.

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

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

(4) Offset: This is a distance between wheel mounting surface where it is bolted to hub and the centerline of rim.

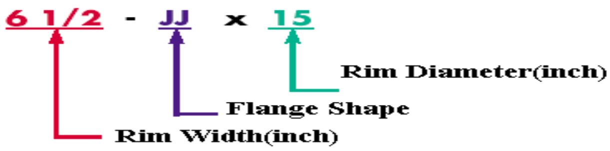
(5) Flange: The flange is a part of rim, which holds the both beads of the tire.

(6) Bead Seat: Bead seat comes in contact with the bead face and is a part of rim, which holds the tire in a radial direction.

(7) Hump: It is bump what was put on the bead seat for the bead to prevent the tire from sliding off the rim while the vehicle is moving.

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

WHEEL SPECIFICATION:



LITERATURE REVIEW:

2.1 Problem Definition The work therefore involves in finding and reducing the stresses and displacements induced in the newly designed aluminum alloy wheel due to static and dynamic loads. The project mainly involves in modeling of the wheel using Catia, and the analysis is performed on the modeled component using ANSYS workbench. Analysis that is performed typically includes static analysis.

2.1.1 Static Analysis :

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads.

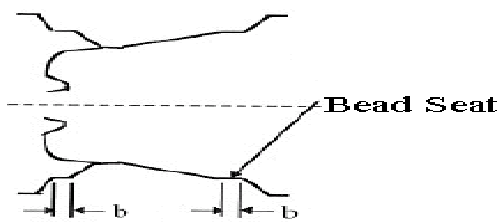
A static analysis can, however include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The following static loads on alloy wheel are applied (i.e. the load is applied on the spoke side and the hole side bead seats of the wheel).

2.2 Problem Description :

The problem stated here is to analyze the stress and the displacement distribution for the given specifications by the company, on the aluminum alloy wheel (stated by the standards of SAE J 175-Impact test procedure and ISO 7141-Road vehicle wheels impact test procedure), which was newly designed by the "Best Cast IT Limited". For the passenger cars of "HYUNDAI and FORD" motor companies. There are many different types of loading conditions that can be adopted for finding the stress and displacement distributions; here in the project work, the loading conditions for finding the stress and displacement on the wheel is as stated below in this chapter.

2.3 Over view of the Loading Conditions:



Loading Methodology:

Presented here is the methodology for modeling the effect of the vehicle weight as it is transferred to the wheel.

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Methods explained are referenced in the published literature and analogies taken from the Ravenna Laboratories, Toyo Tyres. Japan and the an analysis of stress and displacement distribution in a rotating rim subjected to pressure and radial loads by j. Stearns1, P.C. Lam2, and T.S. Srivatsan2. Division of advanced product and process technology the Goodyear tyre and Rubber Company.Akron, Ohio, USA.

Uniform provisions concerning the approval of wheels for passenger cars and their trailers. Transmitted by the Expert from Italy (economic commission for Europe Inland transport committee) .trans/wp.29/grrf/2002/225 July 2002.The wheel is subjected to various types of loadings these loads acting on the bead seat of the wheel as shown in the above figure .For static analysis and transient analysis the loads are applied on bead seat of the wheel.

CHAPTER –III

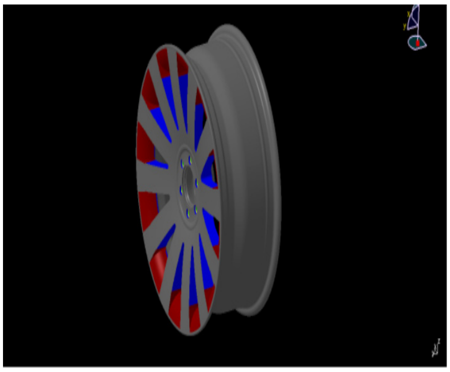
MODELLING:

3.1 CATIA INTRODUCTION:

In early 1980's a MIRAGE-2000 company gave a project (FIGHTER JET) to a Marcel Avions Dassualt's Institute . This institution splitted the project parts and gave it to many dealers for designing it at the time of assembly it became difficult to assemble the components as they were designed in different software's in order to avoid that problem the Dassualt's Institution introduced a software called CATIA (Computer Aided Three Dimensional Interactive Application) in 1980's in later implementation this company improved its feasibility and released the latest versions one by one i.e., V5R5,V5R7,V5R8………V5R19, V5R21.

MODELLING PROCEDURE OF AN ALLOY WHEEL:

Then finally the design obtained of an alloy wheel for the given dimensions is as follows



CHAPTER – IV

EXPERIMENTAL SET UP OF ALLOY WHEELS - IMPACT TEST:

5.1. SCOPE:

This annex specifies a laboratory test procedure to evaluate the axial (lateral) kerb impact collision properties of a wheel manufactured either wholly or partly of light alloys. It is intended for passenger car applications, with the purpose of screening and/or quality control of the wheel. Whether your testing needs are OEM,SAE, ISO, SFI, or individually driven, Smithers is the quality source for your testing needs. ISO 7141 - Road Vehicles - Wheels - Impact Test Procedure. SAE J175 - Impact Test Procedures.

Wheel being prepared for Impact Test. Our procedures meet (or exceed) SAE, SFI, ISO, and JASCO requirements.

5.2. TEST EQUIPMENT:

5.2.1. New wheels, fully processed, representative of wheels intended for passenger car application, fitted with a tyre.

NOTE 1: Tyres and wheels used in the tests should not be used subsequently on a vehicle.

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5.2.2. Impact loading test machine with a vertically acting striker having an impacting face at least 125 mm wide and at least 375 mm long and sharp edges broken by radius or chamfer, in accordance with figure 1. The falling mass, D, within a tolerance of ±2 per cent, expressed in kilograms, shall be as follows:

Formula:D = 0.6 * Fv / g + 180 [kg] (Formula for Impact Test as pre ISO 7141 - Road Vehicles - Wheels - Impact Test Procedure) Where Fv / g is the maximum static wheel loading, as specified by the wheel and/or vehicle manufacturer, expressed in kilograms.

5.3. CALIBRATION:

Ensure, by means of a test calibration adapter, that the 1,000 kg mass (paragraph 5.2.3.) applied vertically to the centre of the wheel fixing as shown in figure 2 causes a deflection of 7.5 mm ± 0.75 mm when measured at the centre of the beam.it to fall.

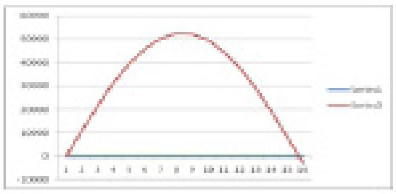
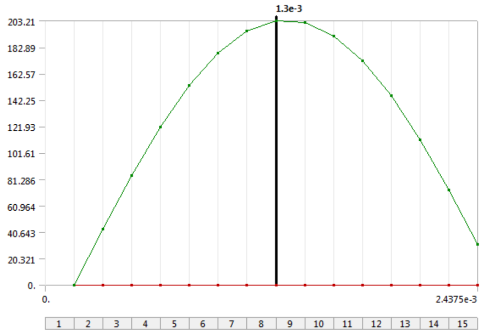


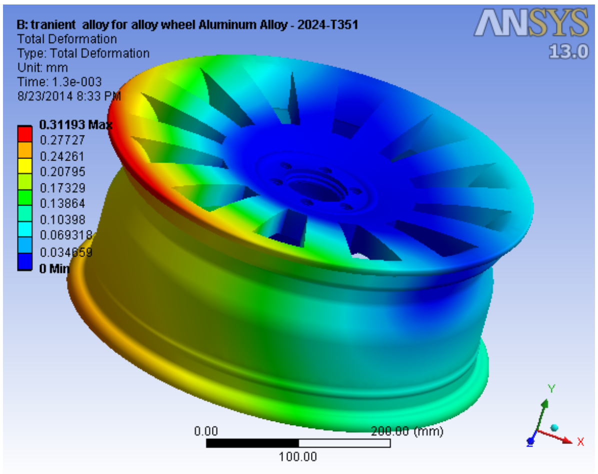
Fig : Half sine pulse load vs time 2.5Msec

Time (sec)	Impact force
0	0
0.000163	11118.45
0.000325	21732.375
0.000488	31360.35
0.00065	39565.575
0.000813	45976.35
0.000975	50301.3
0.001138	52344.075
0.0013	52012.8
0.001463	49321.65
0.001625	44393.475
0.001788	37450.875
0.00195	28809.9
0.002113	18861.675
0.002275	8058.225
0.002438	-3111.3075

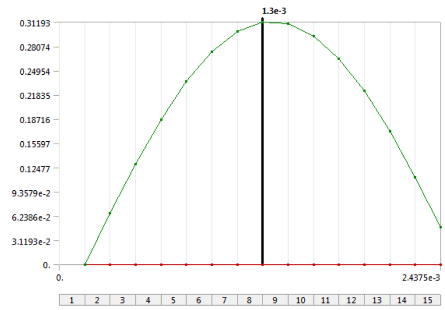
Experimental results for AL 2024-T351 transient analysis Imapct load is acting as for expermntal condition at time 1.1375e-03 the maximum stress is 203.21 and minimum 0.035321Mpa



The graph is represent that time at maximum 1.135e-3 vs von-miss stress 203.21 Mpa



Imapct load is acting as for expermntal condition at time 1.1375e-03 the maximum deformation is 0.31193mm and minimum 0.0 mm



Imapct load is acting as for expermntal condition at time 1.1375e-03 the maximum deformation is 0.31193 mm and minimum 0.0 mm

FIGURE 7
Model (B4) > transient (B5) > Solution (B6) > Fatigue Tool

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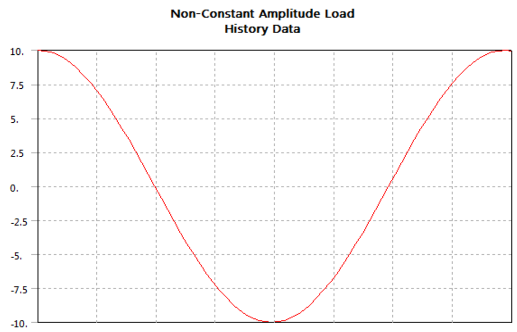
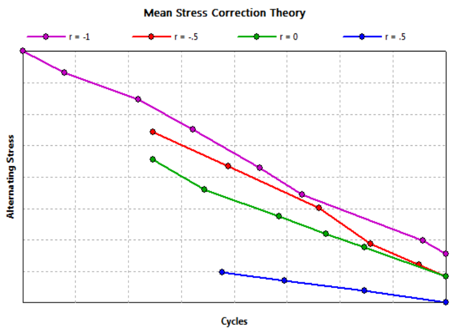
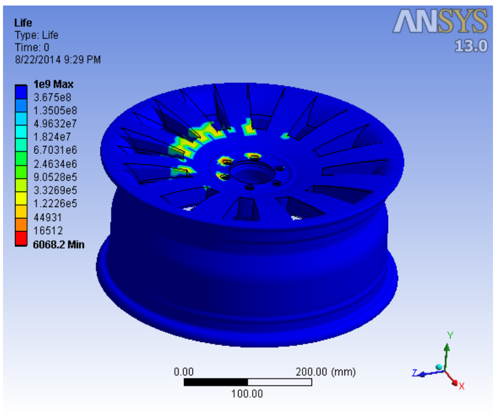
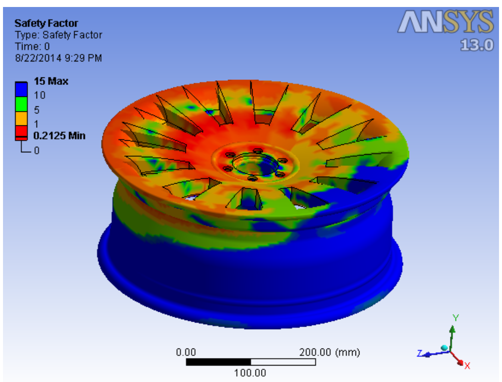


FIGURE 8
Model (B4) > Transient(B5) > Solution (B6) > Fatigue Tool.

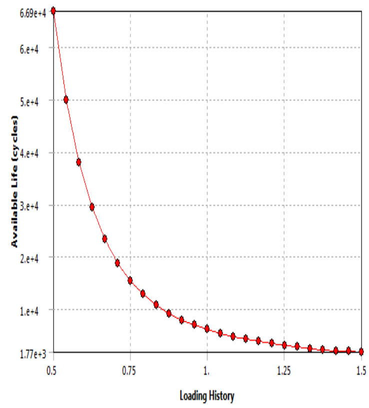


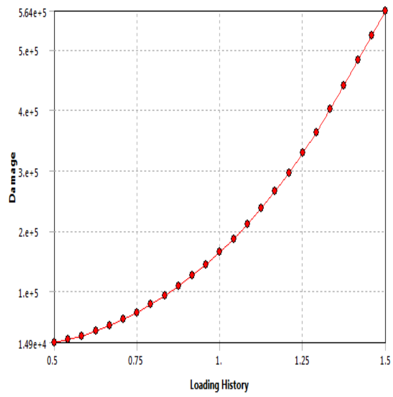


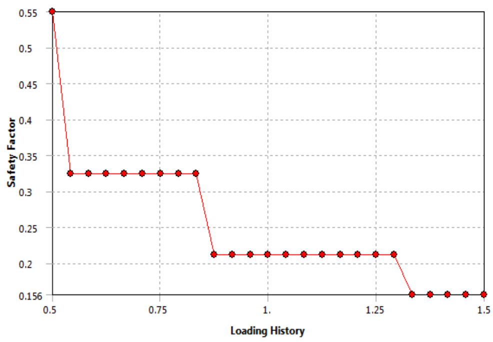
Transient analysis for alloy wheel AL A2024-T351 life maximum 1e9 and minimum 6068.2 cycles

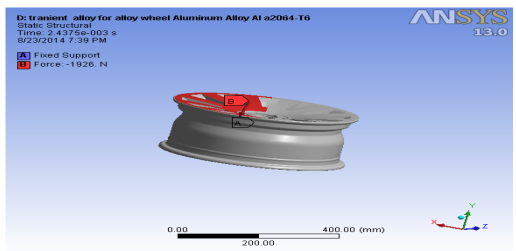


Transient analysis for alloy wheel AL A2024-T351 safety Factor 15.0maximum and minimum 0.2125









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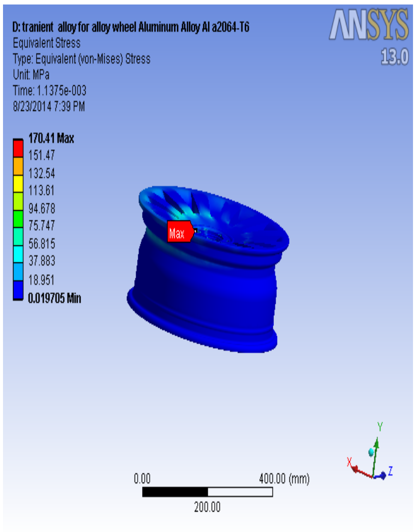
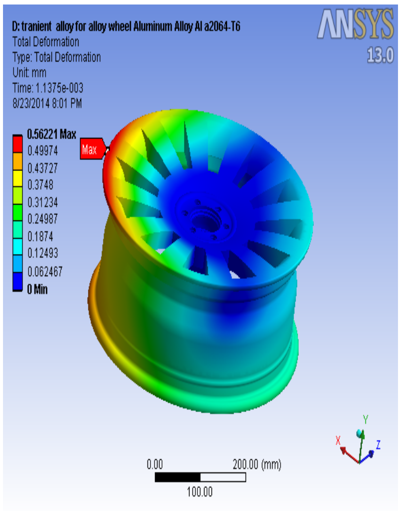
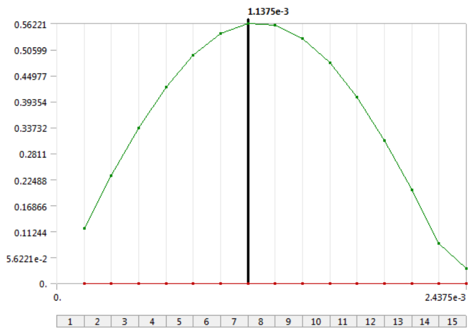


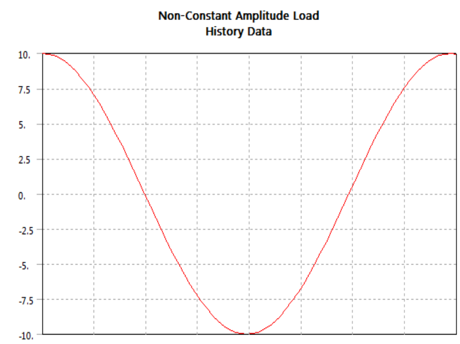
Imapct load is acting as for expermntal condition at time 1.1375e-03 the maximum stress is 170.41Mpa and minimum 0.019705Mpa.

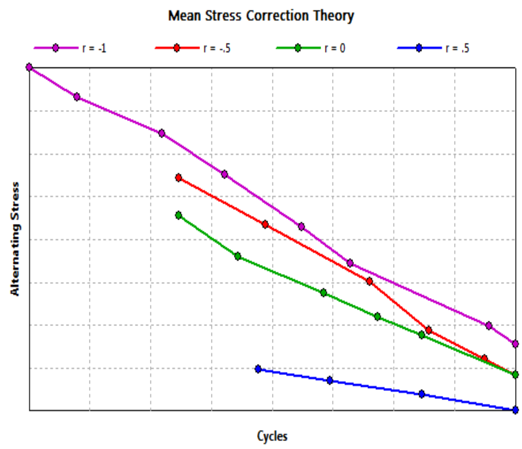


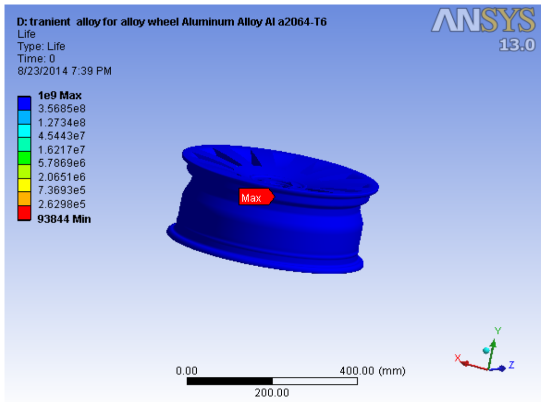
Imapct load is acting as for expermntal condition at time 1.1375e-03 the maximum deformation is 0.56221mm and minimum 0.0 mm.



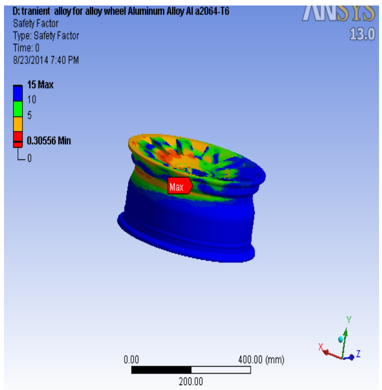
The graph is represent that time at maximum 1.135e-3 vs total deformation 0.21974 mm







Transient analysis for alloy wheel AL A2064-T6 life maximum 1e9 and minimum 93844 cycles



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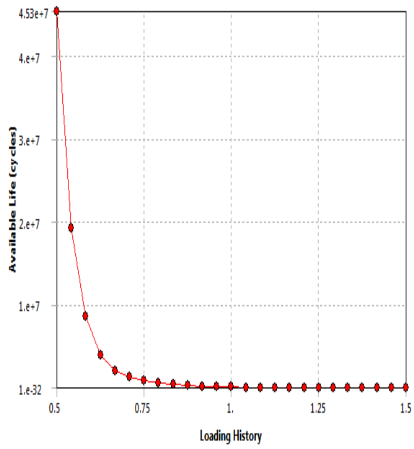
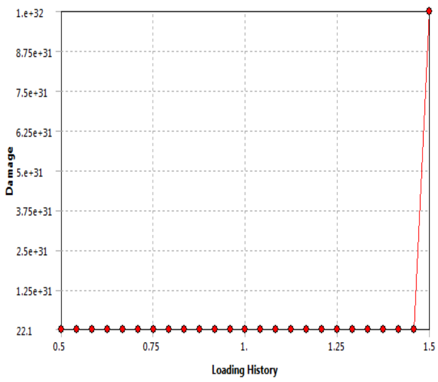
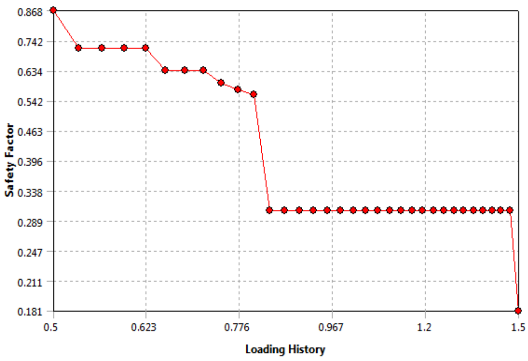
Transient analysis for alloy wheel AL A2064-T6 safety Factor 15.0maximum and minimum 0.30556



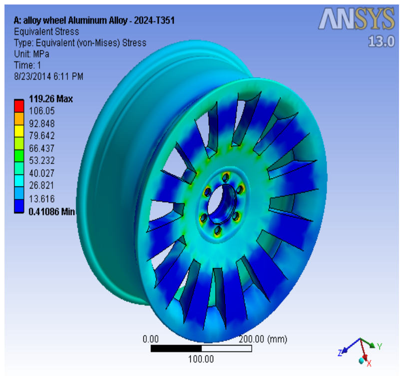




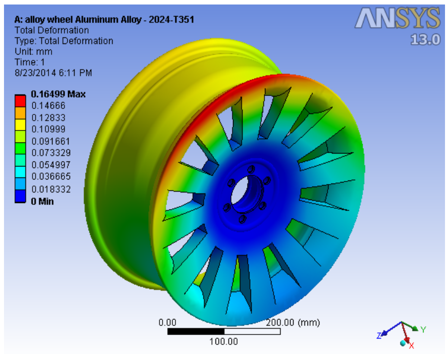
STATIC STRUCTURAL ANALYSIS :

Case- 1

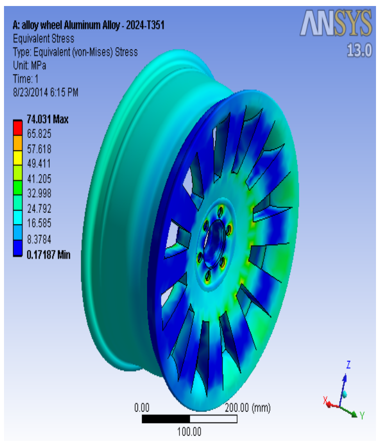
1.1 for 160 KmphMaterial for aluminum alloy al 2024-T6



Static Equivalent Stress for 160kmph AL2024-T351 maximum 119.26Mpa and minimum 0.41086.



Static Total deformation for 160kmph AL2024-T351 maximum 0.16499mm and minimum 0.01.2 Static Structural analysis for 120 Kmph



Static Equivalent Stress for 120kmph AL2024-T351 maximum 74.031Mpa and minimum 0.17187

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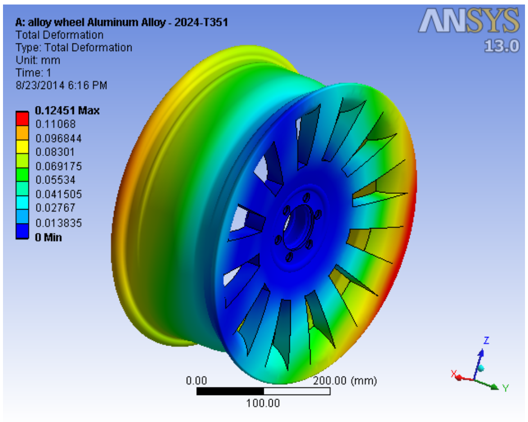
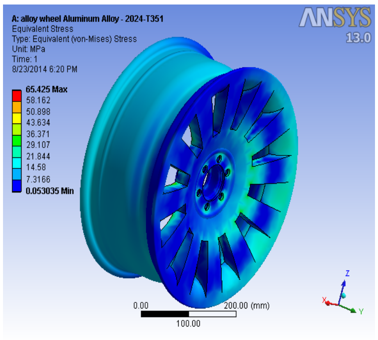
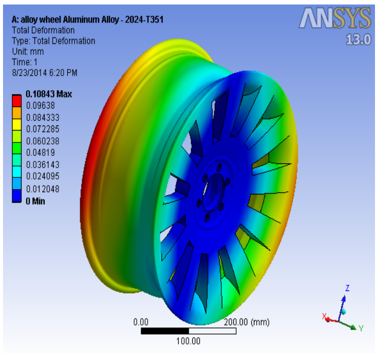


Static Total deformation for 120kmph AL2024-T351 maximum 0.12451mm and minimum 0.0

1.3 Static Structural analysis for 80 Kmph:

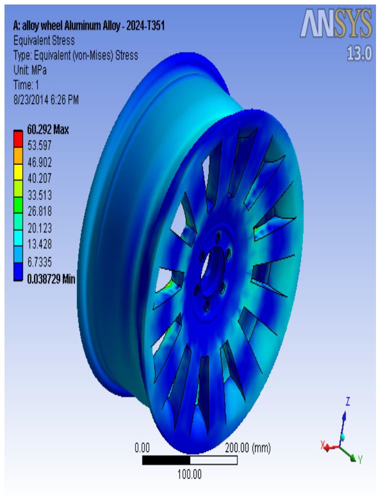


Static Equivalent Stress for 80kmph AL2024-T351 maximum 65.425Mpa and minimum 0.053035.

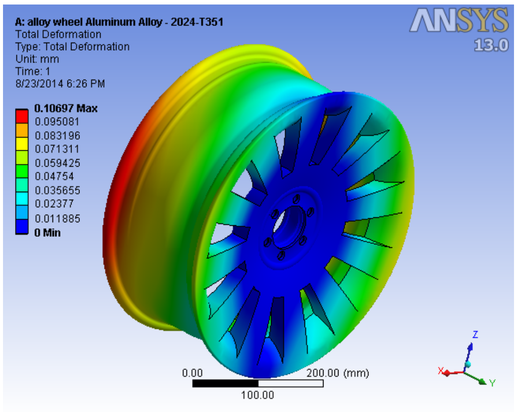


Static Total deformation for 80kmph AL2024-T351 maximum 0.10843 mm and minimum 0.0

1.4Static Structural analysis for 40 Kmph

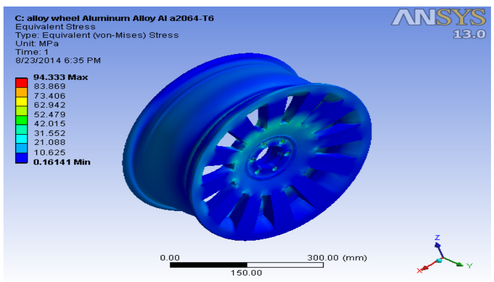


Static Equivalent Stress for 40kmph AL2024-T351 maximum 60.292Mpa and minimum 0.038729.



Static Total deformation for 40kmph AL2024-T351 maximum 0.10697 mm and minimum 0.

Case- 2
for 160 KmphMaterial for aluminum alloy al 2064-T6.



Static Equivalent Stress for 120kmph AL2064-T6 maximum 94.333Mpa and minimum 0.16141Mpa

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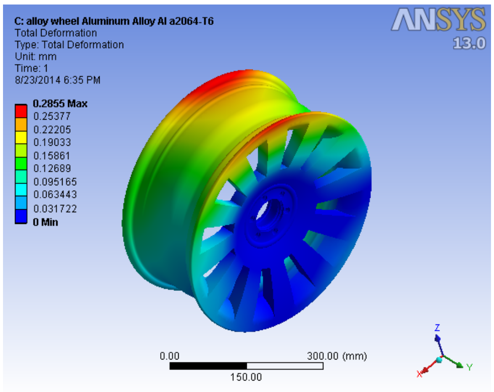
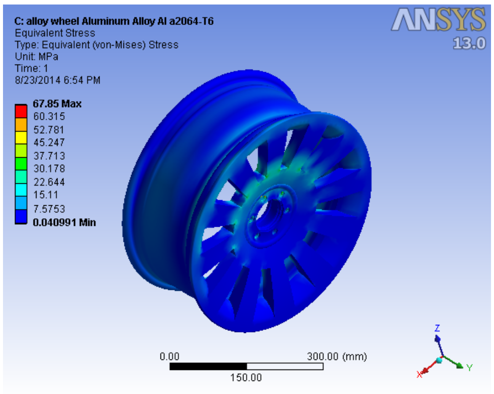
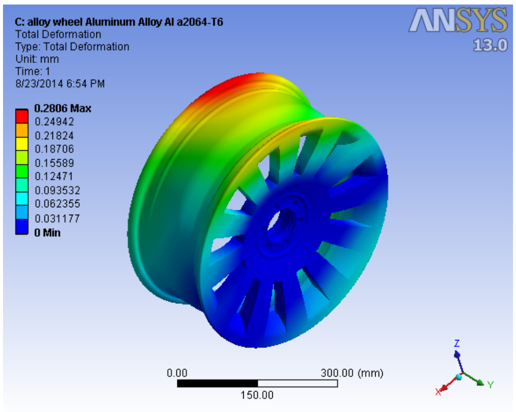


Static Total deformation for 120kmph AL2064-T6 maximum 0.2855 mm and minimum 0.0mm Static Structural analysis for 120 Kmph

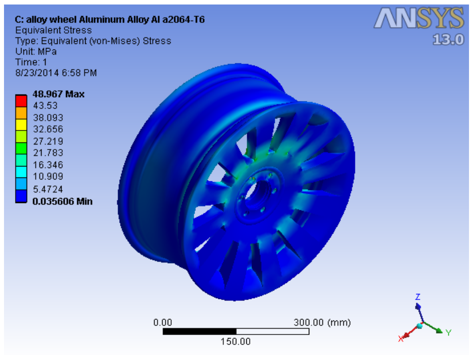


Static Equivalent Stress for 160kmph AL2064-T6 maximum 67.85Mpa and minimum 0.040991Mpa

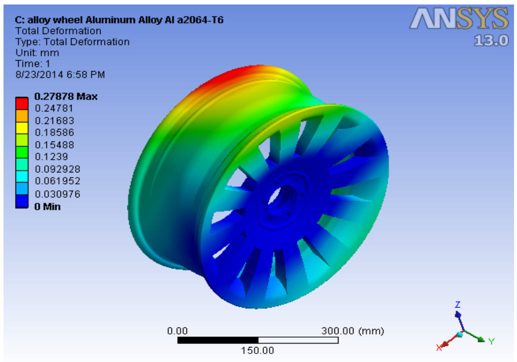


Static Total deformation for 160kmph AL2064-T6 maximum 0.2806 mm and minimum 0.

Static Structural analysis for 80 Kmph

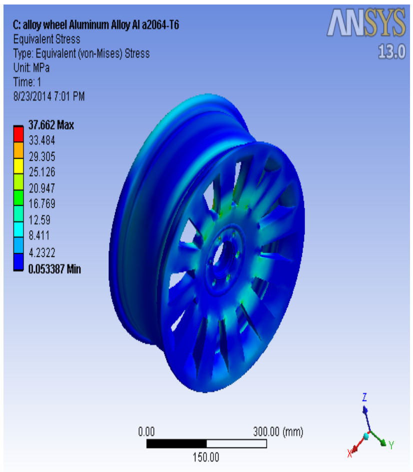


Static Equivalent Stress for 80kmph AL2064-T6 maximum 48.967 Mpa and minimum 0.035606MPa



Static Total deformation for 80kmph AL2064-T6 maximum 0.27878 mm and minimum 0.

Static Structural analysis for40 Kmph



Static Equivalent Stress for 40kmph AL2024-T351 maximum 37.662Mpa and minimum 0.053387Mpa

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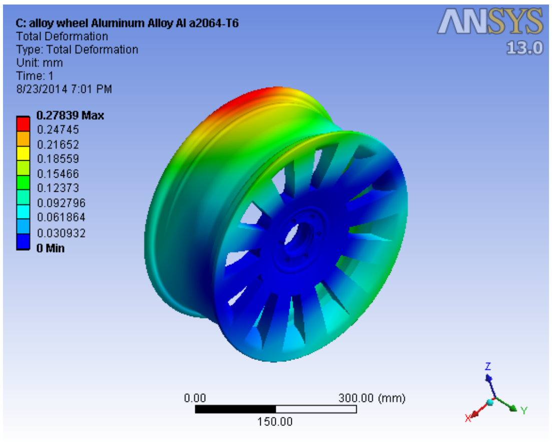

Static Total deformation for 40kmph AL2024-T6 maximum 0.27839 mm and minimum 0.0mm

V.RESULTS IN TABULAR FORM

Material AL2024-T351

S/no	Stress		Speed 160Kmph	Speed 120Kmph	Speed 80Kmph	Speed 40Kmph
1	Static Equivalent Stress in (Mpa)	Max	119.26	74.03	64.425	60.292
		Min	0.41	0.1718	0.053	0.0387
2	Static Total deformation in (MM)	Max	0.164	0.1245	0.1084	0.1069
		Min	0	0	0	0

Material Al 2064-T6

S/no	Stress		Speed 160Kmph	Speed 120Kmph	Speed 80Kmph	Speed 40Kmph
1	Static Equivalent Stress in (Mpa)	Max	94.33	67.58	48.967	37.662
		Min	0.1614	0.04099	0.035	0.0533
2	Static Total deformation in (MM)	Max	0.2855	0.2806	0.2787	0.2783
		Min	0	0	0	0

VI.CONCLUSION:

In this project we finally concluded that by observing various solutions obtained by an analysis process for the two aluminum alloys i.e., for Al a2024, and Al a2064 values of stress, strain, displacement, total life, load factor and damage factor values are better for the Al a2024 then the Al a2064.

As it has a good mechanical properties as well as a good physical properties so this alloy is good and suitable for Car rims, aircraft fittings, gears and shafts, bolts, clock parts, computer parts, couplings, fuse parts, hydraulic valve bodies, missile parts, munitions, nuts, pistons, rectifier parts, worm gears, fastening devices, veterinary and orthopedic equipment, structures. So Al a2024 can be used as the material for an alloy wheel for any light duty vehicles i.e., for a four wheeler vehicles inspite of opting Al a2064.

VII.Scope for Future Work:

In the above proposed work pressure and force acting circumferentially on the wheel rim is only considered, this can be extended to other forces that act on the wheel rim and structural analysis is carried out, this can be extended to transient analysis.

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