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Material Optimization Of The Wheel Rim BY Using Simulation Method

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ABSTRACT

Wheels are one of the most important components of a car. Two wheels, there are two wheels used. One is an alloy wheel and the other is a spoke wheel. Most alloy materials are used to make wheel rims. The main reason for using alloys is to increase the efficiency of the two wheels by reducing the weight. The current concept is to design and modify sequential wheel rims for cars. Flanges are usually made of forged steel or alloy steel due to its excellent properties in terms of strength and affordability the material gives great strength, but increasing its strength increases the weight of the wheels. Therefore, in this study, an attempt was made to replace the steel material with a mixed matrix composite to maintain or increase strength with reduced weight. The rim of the wheel is designed keeping in mind the various loads it carries, such as forces, traction, torsion, shear, bending and sudden loads. Mathematical modeling is performed using each load analysis. Limited factor analysis is performed using ANSYS software to determine the areas of stress concentration. Content and size are modified using the same software. An experimental test of bending stress and Impact strength is to be performed to verify and verify the feasibility of the result obtained in the simulation.

Keyword : - Wheel Rim, Al Matrix, Material Optimization, Ansys.

1. INTRODUCTION

A wheel is a circular block of solid and durable material in which a circular hole is drilled in the center through which an axle bearing is placed around which the wheel rotates when a moment by gravity or torque is applied to the wheel. its hub, which together make one of six simple machines. When placed vertically under a platform or conveyor body, a wheel that rotates on the horizontal axis allows heavy loads to be moved. Alloy rims are automobile wheels made of aluminium or magnesium alloy, or sometimes a mixture of the two. The difference between the alloy rim and the ordinary steel frame is due to their lighter weight, which improves the vehicle's trajectory and speed. A rim is the component holding the tire of vehicle. It is the outer circular wheel design where the inner rim of the tire is attached to vehicles such as cars. For example, on a bicycle wheel, the rim is a large hoop attached to the outer ends of the wheel spokes that hold the tire and inner tube together. In cross sectional shape, the rim is having depth and shallow center outer edge which forms a U-bend shape which indeed supports the edge of frame. Since the rim is where the tire is on the wheel and the rim supports the shape of the tire, the dimensions of the rims are a factor in the vehicle's handling characteristics. For example: rims that are too wide relative to the width of a particular car's tire can lead to more vibration and a less comfortable ride because the sidewalls of the tire have insufficient curvature to flex properly on rough driving surfaces. Oversized rims can cause the tire to rub against the body or suspension components when cornering. Rims that are too narrow relative to the width of the tire can lead to poor handling as the tire can twist sideways in fast corners.

1.1 Nomenclatures Of Wheel Rim

The tire works as a wheel only after it is set up on the rim and is inflated therefore: the tire and wheels assembly affects the function and performance of the vehicle. The tire is designed and manufactured to fit the regular rim and when installed on the right rim the tire will work at its desired level. Wheel: Wheels usually have rims and discs to which the tires are attached. Disc: This is the part of the flange where it is attached to the shaft of the hub. Offset: This is the space between the wheel mounting surface where it bolts to the axle and the center of the line. Flange: A flange is a part of a flange that connects two frame beds. Bead Seat: The wooden seat touches the face of the bead and is part of the flange holding the tire in the radial direction. Bead space: The embroidered seat touches the face of the rim and is part of the rim that holds the tire in a radial direction.

Fig 1: Automobile Wheel Rim

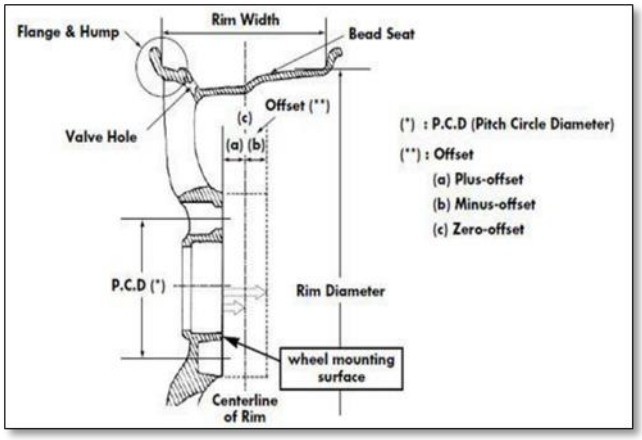

Fig 2: Nomenclatures of Wheel rim.

2. LITERATURE SURVEY

T. Siva Prasad et.al. [1] Explains the A Review on Modelling and Analysis of Car Wheel Rim Using CATIA & ANSYS. In this project, a tire rim belonging to the class of disc wheels is being considered. An amount of 21.3 kPa is applied along the circumference of the aluminum alloy and forged steel rims, and the rim-bolt circle is installed. The aluminum alloy rim is subjected to more displacement compared to forged steel. The aluminum alloy rim is subjected to more displacement compared to forged steel.

Sandip Bhattacharyya et.al. [2] Describes the Failure analysis of cracking in wheel rims – material and manufacturing aspects. The paper discusses about one of the failure types in wheel rims, where the wheel rim thins down locally and cracks at the weld. high yield ratio are prone to localized necking and cracking at the weak HAZ. On the contrary, a material with lower strength and favorable yield ratio can accommodate a weak HAZ by diffused necking characteristics as the material has a favorable microstructure and can bear the forming stresses.

Aman Pandya et.al. [3] Explains the Design Modification and Analysis of Automobile wheel Rim Using Finite Element Analysis. The purpose of the car wheel rim provides a firm base on which to fit the tire. The motorcycle riders are subjected to extreme vibrations due to the vibrations of its engine, improper structural design of the motorcycle and the bad road conditions. So in this project the attempt has been made to reduce the vibrations of vehicle by providing springs instead of the spokes at the wheel.

The framework or the outcomes of literature is the summarised structure of Literature Survey. In this section all the abstracts and point are mentioned and explained in the order of the paper survey done. The summary is the outline of research data collected and analysed, which further will be in application with the organisation of dissertation. The different loading conditions are described from the paper which are utilized for mathematical modelling of the component. A wheel rim is subjected to sudden impact, radial, circumferential and centrifugal kind of loading of which the description and background is been described. The survey is specially been designed to verify the materials that are been used for manufacturing of Wheel rim. The scope has been concluded that the materials that are used for components are generally casted iron with low strength or ANSI Steel grades. Hence we have the scope of modifying the materials with different composites and alloys. Hence forth, the material Al7068 and 7075 are

being selected for optimization. Moreover, the aim of literature is to define the failure analysis in various aspects of loading conditions. The various loading conditions and reactions for design are determined. In this survey, all the forces acting in the wheel rim body has been described which where helpful for the dissertation. The methodology for FEA and experimental investigation is also useful from the survey.

3. PROBLEM STATEMENT

Modify and Analyse the Wheel Rim of an automobile with the help of experimentation and simulation, and compare the results through simulation and experimental investigation. Rims are usually forged steel that is heavier. Therefore, this study sought to replace and find the best alternative material. Works on various load systems, such as snap load, bend load and shear load. Therefore, considering the analysis of the entire pregnancy, the tip must be changed. On the other hand, the weight of the flange should be reduced and the technology of material optimization will be used for this purpose.

4. METHODOLOGY

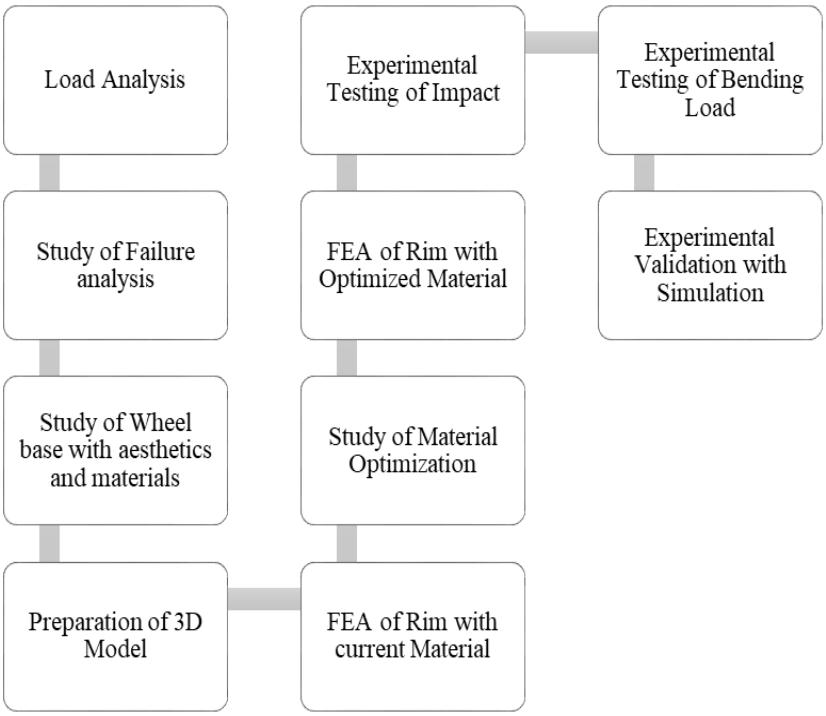

Fig 4 Proposed Methodology for Dissertation

5. MATHEMATICAL MODELLING

The flange used in the case study was used on Hyundai Santro. It is a city car which is produced by the South Korean company called Hyundai between the years 1998 and 2014. The Initial model and base generation of car was launched in the year 1998 and in early 1999. It was also sold in Europe under the Atos Prime name and in South Korea and Indonesia under the Kia Festo name. It was also known as Santro Zip in India from 1998 to 2006. The material used for the flange is C-1008 steel, deeply called AISI 1008 carbon steel. AISI 1008 carbon steel has excellent welding ability, which includes drop, butt, spot and smelt, brazing ability. Steels that mainly contain carbon as an alloying component are called carbon steels. It contains about 1.2% manganese and 0.4% silicon. Nickel, aluminium, chromium, copper and molybdenum are also present in small amounts in carbon steel. Cold rolled steel 1008 is the standard type of carbon steel. This alloy is commonly used in commercial grade cold rolled steel sheets. It is an cost effective common purpose steel grade with medium strength and hardness. As a standard grade, this steel has many applications.

Figure 5: Actual Wheel Rim for Case Study

Table 1: Specifications of Hyundai Santro

Parameter	**Value**
Max Power	68.05 bhp @ 5500 rpm
Max Torque	99.04Nm @4500 rpm
Overall Length (mm)	3650 mm
Overall Width (mm)	1650 mm
Overall Height (mm)	1560 mm
Seating Capacity	05
Kerb Weight (Kgs)	895 Kg
Gross Vehicle Weight (GVW)	1175 Kg
Body Option	Hatchback
Mileage (Petrol Fuel)	14.25 Kmpl

Table 2: Material Properties of AISI Steel

Parameter	**Value**
Tensile Strength (MPa)	358
Yield Strength (MPa)	240
Modulus of Elasticity (GPa)	200
Bulk Modulus (GPa)	158
Shear Modulus (GPa)	77
Poisson's Ratio	0.29
Density (Kg/m^3)	7872

Table 3: Chemical Composition Of AISI 1008

Material	Mn	C	S	P	Fe
Contribution	0.8	0.1	0.05	0.04	Bal

Through the mathematical calculations based on the given specification in table of the case study various loads were calculated these loads are radial load , bending moment on shaft, Rotational Velocity, Twisting Moment, Centrifugal Force and Air Pressure were calculations were done by using mathematical equations which are discussed in the previous paper and table is formulated below.

Table 4: Loading Constraints for FEA

Section of Loading	Notation	Design Loading	Ultimate Loading with FOS = 1.5
Radial Load	P1	7250 N	10875 N
Bending Moment on Shaft	P2	1.677 x 10^6 N.mm	2.51 x 10^6 N.mm
Rotational Velocity	P3	90.29 rad/sec	135 rad/sec
Twisting Moment	P4	53.74 x 10^6 N.mm	80.61 x 10^6 N.mm
Centrifugal Force	P5	5957 N	8935.5
Air pressure of Tire	P6	0.25 MPa	0.375 MPa.

6. FINITE ELEMENT ANALYSIS

FEA is the simulation of an actual practical example using a mathematical oriented technique which is called the finite factor method or Finite Element method or FEM. This process is rooted in mechanical engineering, as well as various other subjects. This is one of the basic principles used to develop simulation software. Engineers can use FEM to perform virtual experiments to reduce the number of physical prototypes and improve their design. First the model is been created in the cad and then imported to the FEA software.

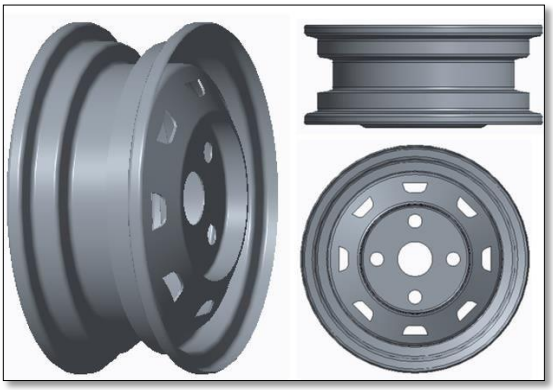

Figure 6 CAD model of Wheel Rim

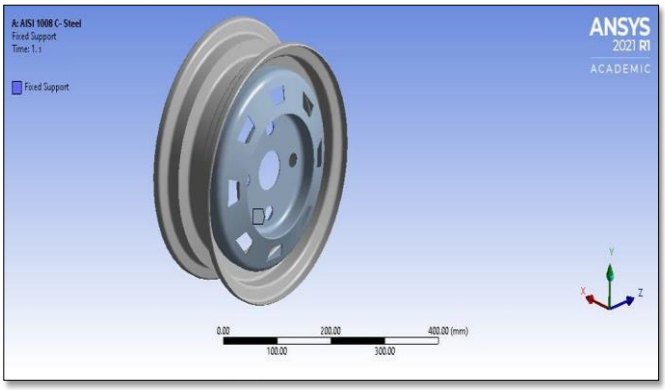

Figure 7 Applying fixed Constraints in FEA

7. NUMERICAL CONSTRAINT FOR OPTIMIZATION

A limit is the constraint is something that prevents something from happening. The stresses created after the initial analysis of the AISI steel flange, are the adaptive limits that are applied to optimize the arm material to select the optimal replacement material. This pressure is in the form of strength, weight, stress, strain, etc.

1. The design constraints for strength of material is been defined between the stress values ranging from 52 MPa to 460 MPa.
2. The design constraints for strain rate of material is been defined between the values ranging from 0.002.
3. The design constraints for total deformation of the material is been defined between the values ranging from 1.0165 mm.

4. The important criteria of weight reduction are vital characteristics of the Suspension arm Wheel rim which will further effect the reduction in cost and manufacturing time. The overall weight of the rim is defined as 3.6 Kg. Hence the functional weight constraint of optimization for modification of wheel rim should be limited to or under 3.6 Kg.
5. The constraint of optimization for fatigue life is determined as 1790 Cycles.
6. The constraint of optimization for damage at regular interval is determined as 5.85 cycles.
7. The safety factor of the wheel rim is 0.1872 constant.
8. Biaxiality indication is the generation of the stress parameters which are occurred at every section of the rim which is 0.99.
9. The fatigue sensitivity is maximum of 15602 loading and will fail eventually at the loading constraint of 1.5. Hence the constraint of optimization for fatigue sensitivity is 15602**.**

8. MATERIAL OPTIMIZATION

Currently, the materials that are used Wheel Rim is AISI 1008 and processed material of Structural Steel. The material possesses considerable strength which is useful for design and manufacturing the part. But the implementation of these materials increases the unnecessary cost of the assembly as it is been famous for its heavy weight. Hence in order to obtain the same strength with considerable reduction in cost, it is necessary to optimize the material.

1. Aluminum is corrosion and rust resistant, withstands the elements well and lasts a lifetime. Although mild steel is prone to rust and corrosion, its heavy weight makes it durable.
2. Aluminum alloys are largely utilized in the automobile and aerospace industries as they are able to conduct thermal treatment to enhance the proprietary properties of resilience, resilience, and resilience. Weight.
3. Aluminum alloys are very light metals, with a high strength-to-weight ratio, and are more cost-effective for equipment requiring a lighter weight than steel with the same strength.
4. While steel is stronger by volume, more aluminum can be used to increase strength while being lighter in weight.
5. AISI mild steel is a section of steel that is strong and less likely to warp, warp or bend underweight, force or heat, but is 2.5 times denser than aluminum, making it heavier for major applications.

Currently, the materials that are used for arm is AISI Steel. The material possesses considerable strength which is useful for design and manufacturing of Low Pressure Component. But the implementation of these materials increases the unnecessary cost of the assembly as it is been used as fabricated component. Hence in order to obtain the same strength with considerable reduction in cost, it is necessary to optimize the material. Hence for the same purpose, materials of Al7068 and Al7075 is been utilized for the same purpose. The alloys have been selected with respect to the properties of Tensile and yield strength that they provide during operating conditions.

8.1 Approach of Optimization using Material Al7068 :

Aluminum alloy 7068 is alloy of the aluminum-magnesium-silicon family which is one of the most common alloys in its series (along with alloys 7075, 7082 and 7063), although it is not significantly featured in the ASTM (North American) standards. It is usually formed by extrusion and rolling, but as a working alloy it is not used in castings. It can also be forged and plated, but this is not a common practice of this alloy. The work cannot be hardened, but heat is usually handled to create a high- strength quenching process but with less flexibility. Aluminum Alloy 7068 has medium strength with good corrosion resistance. Also known as structural alloy. In plate form, aluminum alloy 7068 is the most widely used aluminum alloy in the process. In this section, the feasibility of Al7068 is analysed using Ansys simulation software for finite element methods. The loading conditions and shape topology of the component is kept same as that of AISI Steel but the material is been replaced by Al7068. The different material properties which are uploaded in Ansys Version. The loading conditions are kept same which are explained above. The behaviour of material under stress strain and deformation is been described below.

Table 5: Chemical Composition of Al-7068

Material	Zn	Cr	Cu	Fe	Others
Contribution	7.3	0.05	0.2	0.15	0.15
Material	Mg	Mn	Si	Ti	Al
Contribution	3	0.2	0.12	0.1	Bal.

Table 6: Properties of Al-7068 Material

Parameter	Value
Shear Strength	365 MPa
Ultimate Tensile Strength	710 MPa
Yield Strength	683 MPa
Young's Modulus	71.7 GPa
Shear Modulus	27 GPa
Poisson Ratio	0.33
Density	2850 Kg/m^3
Electrical Resistivity	3.99e-6 Ω-m

The deformation produced in the wheel rim for the material AL7068, the same loading conditions were applied, the value of deformation 1.04 mm and the stress was determined as 449 MPa.

1. The above Figures 5.4 shows the fatigue behaviour of wheel rim using Al-7068 Aluminium Matrix composite under the same loading as that of Steel.
2. With respect to the fatigue analysis, the Fatigue life of Al7068 rim is determined to be 1x108 Cycles.
3. The damage coefficient is determined as 0.00036 whereas the Biaxiality indication is determined to be 0.98.
4. The safety factor obtained for Wheel rim of Al 7068 is found to be 0.183.
5. The Biaxiality indexing of is determined as 0.988

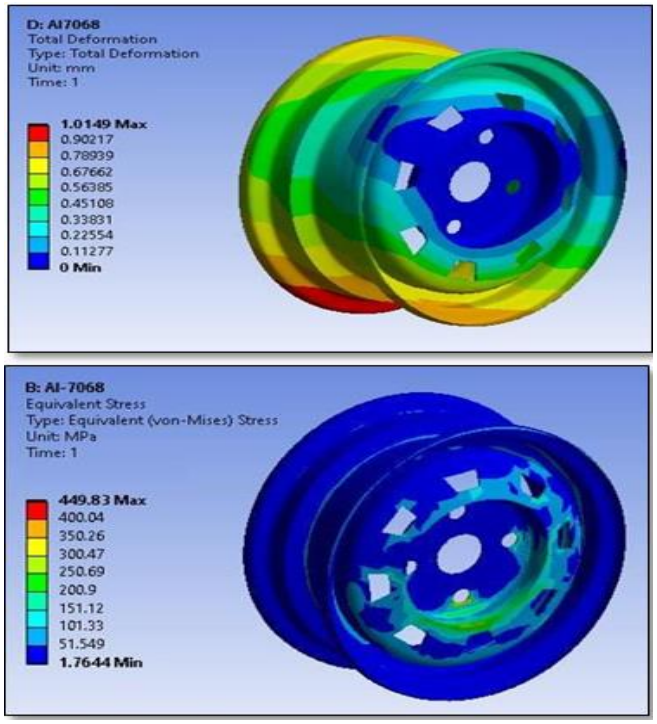

Figure 8: Total Deformation Produced in Wheel Rim for Al7068-T6

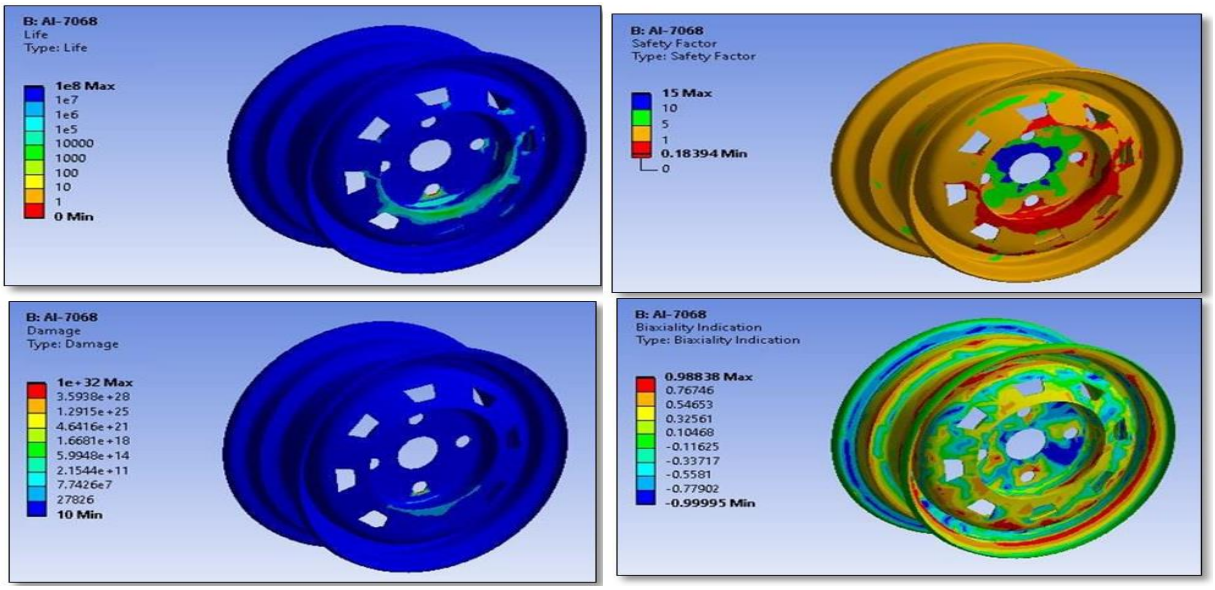

Figure 9: Fatigue Analysis of the Wheel Rim for Al7068-T6

8.2 Approach of Optimization using Material Al7075:

Al 7075 is an aluminum-based alloy that is often used in the aerospace industry. It is the second most common aluminum alloy in the 7000 series after the Aluminum 75 Lodi 7075. The corrosion resistance of these metals is particularly poor. To combat this, it is often coated with pure aluminum. If 2014's unpainted aluminum components come in contact, they should be painted as a measure to protect against rust. Aluminum alloys have the characteristics of strong corrosion resistance and high electrical conductivity. The strength of these alloys increases at subzero temperatures and the strength is lost when these alloys are exposed to high temperatures.

Table 7: Chemical Composition of Al7075-T6

Material	Al	Cr	Cu	Fe	Mg
Contribution	87.1	0.28	1.2	0.5	2.9
Material	**Mn**	**Si**	**Ti**	**Zn**	**Others**
Contribution	0.3	0.4	0.2	6.1	0.15

Table 8: Material Properties of Al7075-T6

Parameter	Value
Shear Strength	365 MPa
Ultimate Tensile Strength	710 MPa
Yield Strength	683 MPa
Young's Modulus	71.7 GPa
Shear Modulus	27 GPa
Poisson Ratio	0.33
Density	2850 Kg/m^3
Electrical Resistivity	3.99e-6 Ω-m

Aluminium alloy 7075 is used in High stress applications like Trusses, Bridges, and Cranes, Transport applications, Ore skips, Beer barrels and Milk churn. In this section, the feasibility of Al7075 is analysed using Ansys simulation software for finite element methods. The loading conditions and shape topology of the component is kept same as that of AISI Steel but the material is been replaced by Al7075. explains the different material properties which are uploaded in Ansys Version. The properties are explained in section 13 and same are uploaded in Ansys. The loading conditions are kept same which are explained in section 5. The behaviour of material under stress strain and deformation is been described below. The deformation produced in the wheel rim for the material AL7075, the same loading conditions were applied, the value of deformation 2.19 mm, which is more than the material of Al7068 and AISI Steel. The stress was determined as 437 MPa.

1. The above Figures 15 shows the fatigue behaviour of wheel rim using Al-7075 Aluminium Matrix composite under the same loading as that of Steel.
2. With respect to the fatigue analysis, the Fatigue life of Al7075 rim is determined to be 1x108 Cycles.
3. The damage coefficient is determined as 0.00038 whereas the Biaxiality indication is determined to be 0.98.
4. The safety factor obtained for Wheel rim of Al 7075 is found to be 0.183.
5. The Biaxiality indexing of is determined as 0.988.

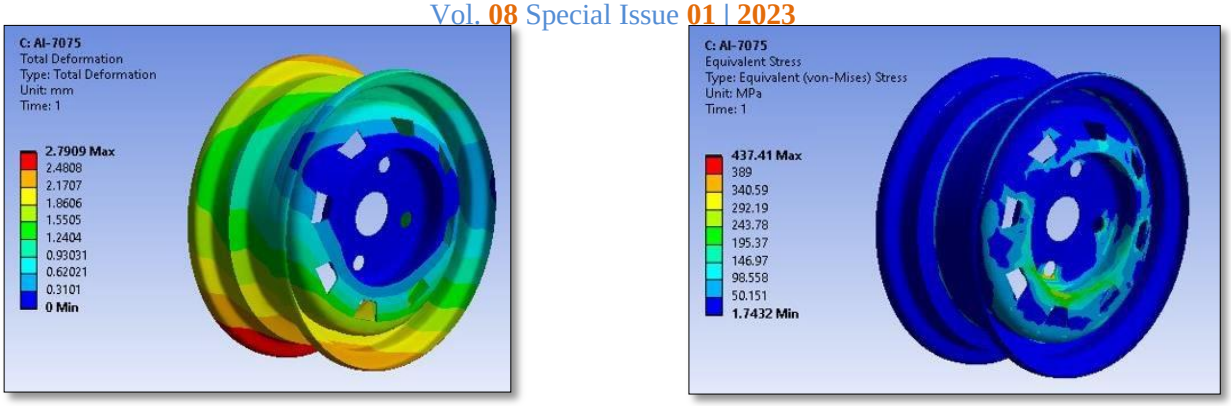

Figure 10: Buckling Behaviour of Wheel rim Made of Al-7075 Material.

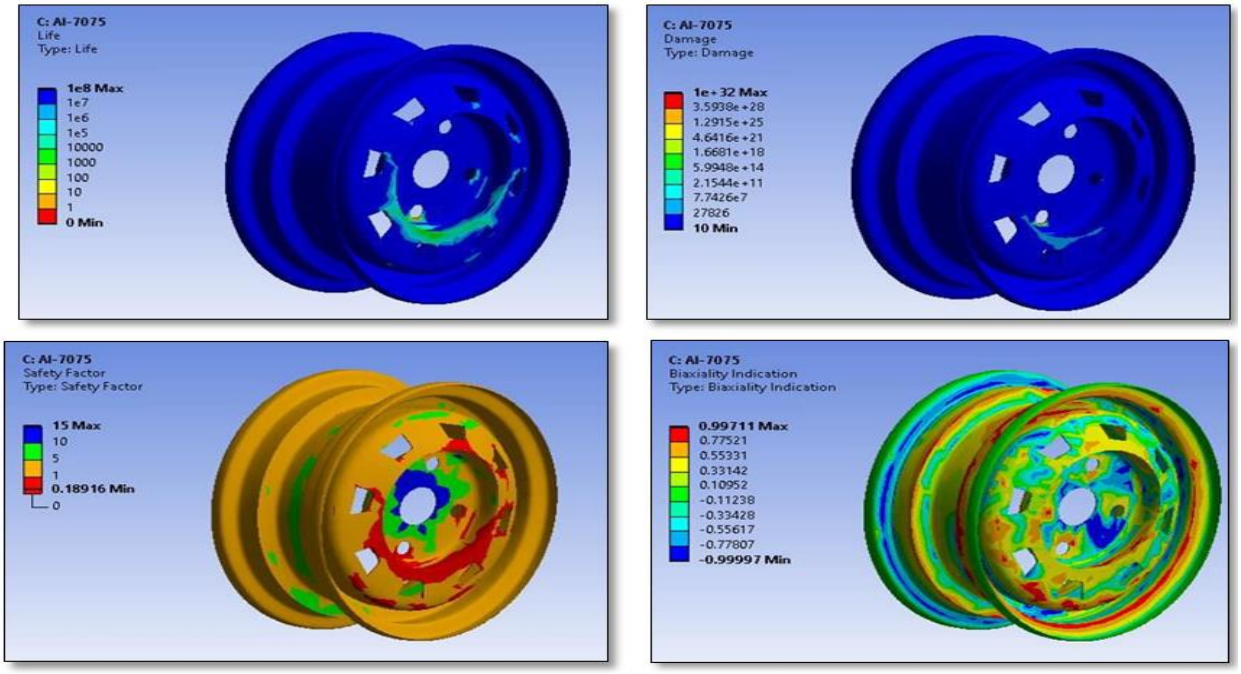

Figure 11: Fatigue Behaviour of the Wheel Rim for Al7075-T6

9. CONCLUSION

1. Load and pressure analysis was studied and mathematical algorithms were developed to determine the loading area and section. Limited element modelling is performed in ANSYS 2021 to define stress-strain and stress simulation.

2. Determine the design limits of physical strength with respect to AISI steels are done. Therefore, in this case, we can say that the material optimized for Al7068 and Al7075 meets the strength standards.

3. The main stresses generated under different loading conditions are similar to other materials. It was found that the stress of aluminum composites is less than that of AISI steels. So the material meets the resistance standards.

4. The deformation is lower for the Al7068 and then higher for the Al7075 than the predecessor of the FG150. Since the stress is beyond the stress range, we can say that Al7068 aluminum composites meet the stress criteria. The AL7075 matrix can also be used but it is still necessary to check the type of deformation, whether it is plastic or flexible.

5. Samples of AISI, Al7068 and Al7075 steels are for pilot testing. The test was performed under the load applied to the outer casing and clamping section. The experimental results of Al7068 are good as a result of bending and under stress.

6. Looking at the fatigue life cycle of Mat Al Matrix Composites, especially looking at the two-axle indexing, damage and life cycle, it was found to be better than AISI steels.

7. The implementation of Al7068 can achieve a weight loss difference of up to 1.6 kg. This weight loss can lead to material and component manufacturing costs, which leads to actual costs.

8. In general, it can be concluded that Al7068 and Al7075 are two alternative materials that can be used specifically for flange bodies.

9. There is still room for research to consider resistance to the effects of two substances. Thus, before implementation, if the impact resistance is to be determined, the content in the applications may be more straightforward

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