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# DESIGN OPTIMIZATION OF A 4 WHEELER MINI SUV ALLOY WHEEL BASED ON BENDING AND RADIAL LOADS USING FINITE ELEMENT ANALYSIS

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## ABSTRACT

As the automotive industry is increasingly demanding on energy saving and environmental protection, people are taking more attention on the lightweight design of automobiles. Wheel is one of the most important parts of a vehicle. It determines a number of parameters such as security, stability, performance and fuel economy. To ensure energy efficiency, the wheels must be as lightweight as possible.

Premium modelled wheels in automobile vehicle is a significant application trends, using magnesium alloy wheels is a valuable way. This thesis discusses design of a new model of automobile wheel. Then bending test and radial test finite element model were established.

Here we are going to consider four different materials namely magnesium alloy, aluminium alloy 6061 and alloy steel, the stress and strain performances of each material will be obtained. Through evaluating and analysing model in the results of the equivalent stress and deformation were compared. This research predicts the reliability of the structural design, some valuable references are provided for the design and development of alloy wheel.

## INTRODUCTION

A wheel could also be a circular device that's capable of rotating on its axis, facilitating movement or transportation while supporting a load (mass), or performing labour in machines. Common examples are found in transport applications. A wheel, alongside an axle overcomes friction by facilitating motion by rolling. In order for wheels to rotate, a flash must be applied to the wheel about its axis, either by way of gravity, or by application of another external force. More generally the term is additionally used for other circular objects that rotate or turn, like a ship's wheel, wheel and flywheel.

## TYPES OF WHEELS:

There are only a couple of sorts of wheels still in use within the automotive industry today.

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They vary significantly in size, shape, and materials used, but all follow the same basic principles.

**Steel Wheel**

The first sort of wheel worth mentioning, and far and away the most-used wheel, is that the strengthen wheel. This caring of wheel contains of numerous pieces of steel, printed into form and characteristically welded composed. This type of wheel is robust, but heavy. They are found on all kinds of auto from sports cars to the larger pickup trucks; the wheels look different but are essentially an equivalent device.

**Rally Wheel**

The second sort of wheel to be mentioned is that the rally wheel. These are essentially steel wheels but they're made somewhat differently, and have a tendency to contain a heavier gauge of steel. Though the inner helping of a steel wheel is characteristically fused to the rim lengthways its whole perimeter, a steel wheel's inner helping is move look like the spokes of a magazine wheel, and is welded accordingly.

**Mag Wheel**

Mag wheels are cast and/or milled wheels typically made up of aluminium or an alloy thereof. They won't to be made from magnesium for his or her light weight and strength, but magnesium catches fire somewhat easily and is extremely difficult to place out. This is unsuccessful, because it's larger to aluminum in each additional way. This tendency also makes it a dangerous metal to figure with, because piles of shavings tend to burst into flame and burn through concrete surfaces once they get too hot.

**Spoke Wheel**

By way of before stated, spoke wheels (occasionally with quite 100 spokes) are motionless in usage nowadays and are general on roadsters and low-riders. They incline to be justly low in weight, and are sensibly robust. They have an "old school" appearance and elegance which is usually highly wanted.

**Centerline Wheel**

Various combinations of those technologies are often wont to produce other, weird wheels. Large earth-moving vehicles just like the more gargantuan dump trucks often have some extent of the vehicle's suspension actually built into the wheel itself, lying between the hub and rim in place of spokes. Also, various companies make wheels which are designed like steel wheels but are made from aluminum -- the foremost famous of those are made by centreline, and therefore the style is actually called the centerline wheel.

**Mounting**

Wheels are mounted to the hub by a mixture of lug bolts, or studs, and lug nuts. The jewelleries are equestrian to the hub, which is devoted to a center carrier or postponement standing. The wheel has fleabags to competition these studs, and is located ended them. The lug mad are then practical and tautened to the good tautness.

**Hub- And Lug- Centrism**

Automobile wheels are careful to be whichever hub-centric or lug-centric, the change existence in what way the wheel is

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placed. If a wheel is off-center, the result's a scarcity of balance and a bent for that wheel to bounce because the radius changes. Hub-centric wheels are centered by the middle bore of the wheel matching the protruding portion of the hub, and lug-centric wheels are centered just by the position and diameter of the lug bolts. Adapter rings are available for a few wheels to center them to the hub, though it's generally not necessary. Certain lug-centric wheels are positioned by a slanting edge on the lug nuts corresponding a bevel on the helm's fleabags.

## INTRODUCTION TO ALLOY WHEEL

Alloy helms are car (car, motorbike and automobile) wheels which are complete up of an blend of aluminum or magnesium metals (or from time to time a mix of both).

Alloy wheels differ from steel wheels during a number of ways:

- Typically lighter weight for an equivalent strength
- Better conductors of heat
- Improved cosmetic arrival

Brighter controls can recover treatment by plummeting unspring mass, letting postponement to shadow the land additional carefully and thus deliver more grasps, though it isn't continuously true that alloy wheels are lighter than the equivalent size steel wheel. Reduction in overall car form can too help to decrease fuel ingesting.

Better heat conduction can help dissipate heat from the brakes, which improves braking performance in additional demanding driving conditions and reduces the prospect of breakdown thanks to overheating.

Fig: Aluminum Alloy Wheel

## LITERATURE SURVEY

**VikasBansal et al.** presented paper on effect of slot on performance of circular pin fin. The study was based on theoretical and computational analysis of circular pin fin made of copper and aluminum. Effect of slot in cross

## HIGH CYCLE FATIGUE OF A DIE CAST AZ91E-T4 MAGNESIUM ALLOY

**M.F.** Horstemeyer a,*, N. Yang b, Ken Gall c, D.L. McDowell d, J. Fan e, P.M. Gullett b. 3 July 2003; accepted 11 November 2003. This study reveals the micro-mechanisms of fatigue crack nucleation and growth in a commercial high-pressure die cast automotiveAZ91E-T4 Mg component. Mechanical fatigue tests were conducted under R ¼ _1 conditions on specimens machined at different locations in the casting at total strain amplitudes ranging from 0.02% to 0.5%. Fracture surfaces of specimens that failed in the high cycle fatigue regime with lives spanning two orders of magnitude were examined using a scanning electron microscope. The difference in lives for the Mg specimens was primarily attributed to a drastic difference in nucleation site sizes, which ranged from several hundred lm’s to several mm’s. A secondary effect may include the influence of average secondary dendrite arm spacing and average grain size. At low crack tip driving forces (Kmax< 3:5 MPa) intact particles and boundaries act as barriers to fatigue crack propagation, and consequently the cracks tended to avoid the inter dendritic regions and progress through the cells, leaving a fine striated pattern in this single-phase region. At high driving forces (Kmax> 3:5 MPa) fractured particles and boundary de-cohesion created weak paths for fatigue crack propagation, and consequently the cracks followed the inter dendritic regions, leaving serrated markings as the crack progressed through this heterogeneous region. The ramifications of the results on future modeling efforts are discussed in detail.

Samples of cast Mg machined from a commercial high-pressure automotive die-casting were tested until failure under completely reversed cycling in laboratory air at room temperature at strain amplitudes ranging from 0.02% to 0.5%. Initial microstructures and fracture surfaces of the failed samples were examined with SEM, and the following observations support these primary.

## CONCLUSIONS:

**(I)** The variability in the fatigue life data in the HCF regime spans over two orders of magnitude. The difference in lives for the specimens machined from the casting is primarily attributed to a difference in the inclusion size that start fatigue cracks, which range from several mm to several hundred lm. Secondary effects may include the influence of average secondary dendrite arm spacing and average grain size, which were found to vary from 15–22 and105–140 lm, respectively. The average secondary dendrite arm spacing and grain size can influence fatigue crack propagation rates, particularly in the micro structurally small fatigue crack regime.

**(II)** At low crack tip driving forces for completely reversed straining (Kmax< 3:5 MPa), intact particles and boundaries can act as barriers to fatigue crack propagation, and consequently the cracks will tend to avoid the inter dendritic regions and progress through the relatively homogeneous dendrite cell interiors, leaving a fine striated pattern in this single-phase region. At high driving forces that correspond to overload conditions (Kmax> 3:5MPa fmp), fractured particles and inclusion de-bonding can create weak paths for fatigue crack propagation, and consequently the cracks will follow the inter dendritic regions and leave serrated marking

## WHEELS AUTO MODELING USING FINITE ELEMENT METHOD

The question always arises buying rims "steel or alloy wheels?". In addition to the rims look more appealing than those of alloy steel, there are technical reasons why it tends to use them: reduced weight, starting and braking, rigidity, rapid cooling. Although it can produce sheet steel or cast alloy wheels profile is adopted depending on the specifics of the construction vehicles and the stress faced by their wheels. In this paper we studied the tensions that arise when a wheel is subjected to aerodynamic loading conditions, trying to play the best areas in which attention must be enhanced in order to prevent premature destruction. Using CATIA V5, we designed a concept of light and have undergone a finite element method using different forces and accelerations restrictions in areas where problems occur during use. Calculating the diagrams thus playing rim is observed when the material behavior is tensed and so we can correct the areas that present a danger of destruction. At the end of the method could draw the conclusion which shows the success of the concept, but also design new technologies for observation and verification of parts or assemblies. This approach is useful for any product development needs of Class A-surfacing. CATIA V5 users can implement and practice the same technique, without adding any costly hardware. As a personal opinion I add, as a matter of fact, over time, the need to design a new model of the rimin a short period of time can be achieved only with computers, specialized software specifically with these dedicated engineers today.

**NUMERICAL SIMULATION OF DYNAMIC SIDE IMPACT TEST FOR AN ALUMINIUM ALLOY WHEEL**

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A great number of wheel test are requited in designing and manufacturing of wheels to meet the safety requirements. The impact performance of wheel is a major concern of a new design. The test procedure has to comply with international standards, which establishes minimum mechanical requirements, evaluates axial curb and impact collision characteristics of wheels. Numerical implementation of impact test is essential to shorten the design time, enhance the mechanical performance and lower development cost. This study deals with the simulation of impact test for a cast aluminum alloy wheel by using 3–D explicit finite element methods. A numerical model of the wheel with its tire and striker were developed taking account of the nonlinearity material properties, large deformation and contact. Simulation was conducted to investigate the stress and displacement distributions during wheel impact test. The analyses results are presented as a function of time. The maximum value of the displacement and stress on the wheel and tire are shown. As a result, the use of explicit finite element method to predict the performance of new products design is replacing the use of physical test.

The dynamic response of a wheel–tire assembly during the impact test is a highly nonlinear phenomenon. In this paper, a numerical study of impact test of the wheel–tire assembly was the dynamic response of a wheel–tire assembly during the impact test is a highly nonlinear phenomenon. In this paper, a numerical study of impact test of the wheel–tire assembly was performed using explicit finite element code. 3–D finite element analysis with a reasonable mesh size and time step can reliably estimate the dynamic response. Such results will help to predict the locations, in which the failure may take place during impact test and improve the design of a wheel with required mechanical performance. The result showed that the maximum stress takes place in the lug region of the wheel. This is primarily due to the fact that the lug hole forms geometrical complexities and irregularities in this region. Moreover, the moment generated by the striker is highest with respect to an axis passing through lug region. As a result, nonlinear simulation can be very useful in the optimization phase in the design of the wheel.

## PROBLEM DESCRIPTION:

Previously steel wheels are used to manufacture wheels for the higher strength, but these alloy wheels are heavily due to its density and also giving trouble to manufacture because of its higher melting point and hard to forge it. Weight is also playing crucial role in mileage. After that aluminum took the place for the manufacturing of alloy wheel, but these alloy wheels are not giving good life due to its low compressive and yield strength. As above these aluminum wheels getting yield (bends) at the larger run and also these types of materials are not permitting heavy loads. So here we are going to analyze the models using radial and bending loads and find out the best suited

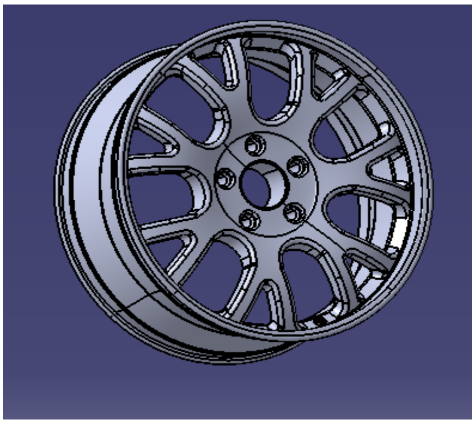
## METHEDOLOGY:

- As observed above problem and literature survey new type of alloy wheels are not permitting heavy loads and also getting yield (bend) during bumps and pits in long run.
- Hence in this project geometric optimization and material optimization used to solve the above said problems.
- Here we are going to analyze the product by verifying the radial and bending endurance and obtain the result.

## DESIGN

### ORIGINAL MODEL

### MODIFIED MODEL

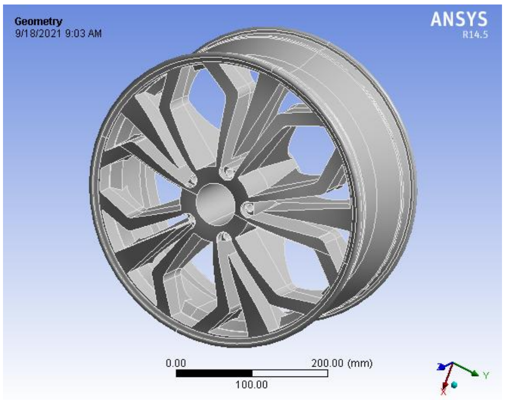


## BENDING ENDURANCE

### ORIGINAL MODEL

### STRUCTURAL ANALYSIS OF AN AUTOMOBILE WHEEL HAVING BENDING ENDURANCE BY USING AL 7075

### GEOMETRY



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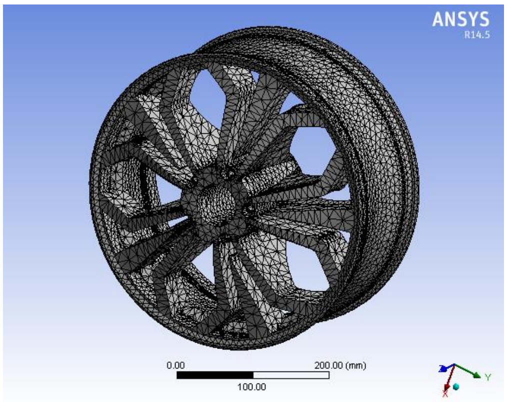
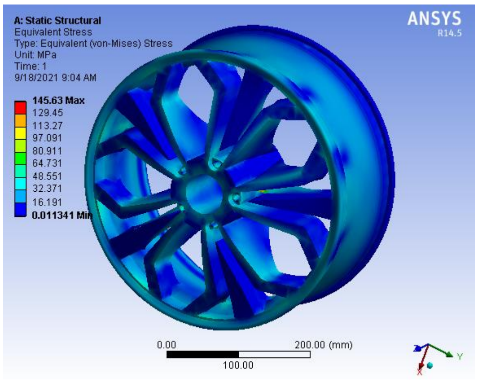
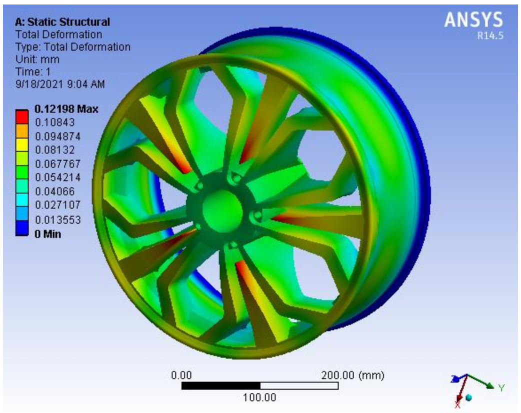
**MESH**




**STRESS**



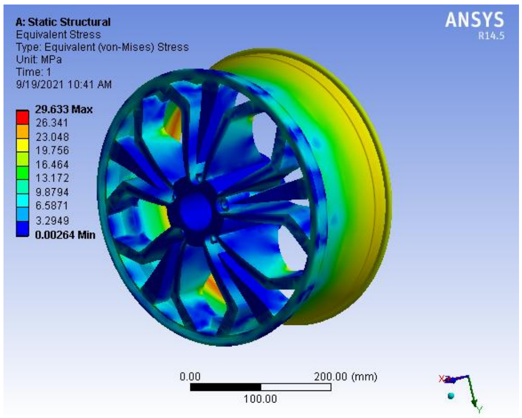

**TOTAL DEFORMATION**




**RADIAL ENDURANCE**

**STRUCTURAL ANALYSIS OF AN AUTOMOBILE WHEEL HAVING RADIAL ENDURANCE BY USING AL 7075**

**STRESS**

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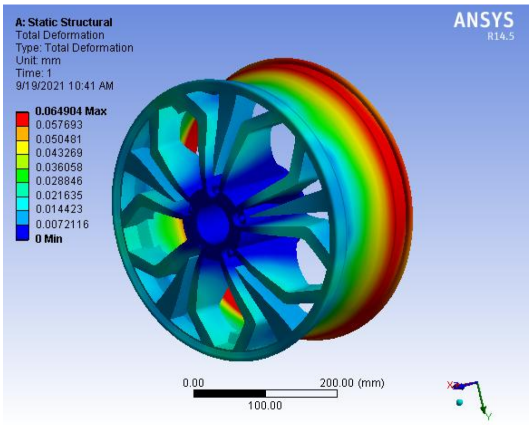
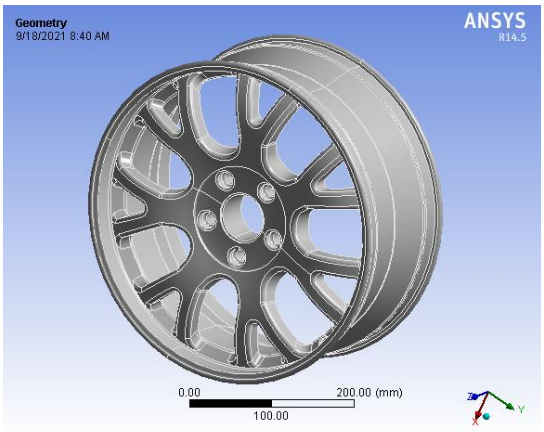



**BENDING ENDURANCE**

**MODIFIED MODEL**

**STRUCTURAL ANALYSIS OF AN AUTOMOBILE WHEEL HAVING BENDING ENDURANCE BY USING MAGNESIUM ALLOY**

**GEOMETRY**



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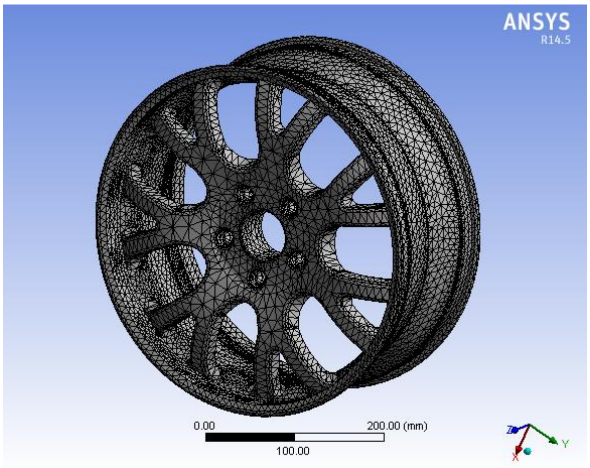
## MESH

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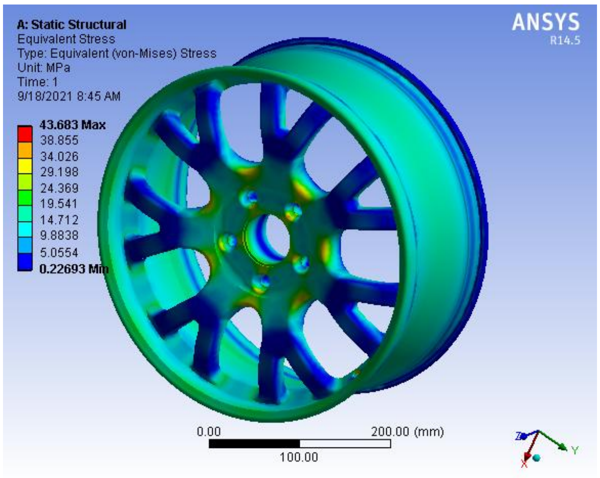


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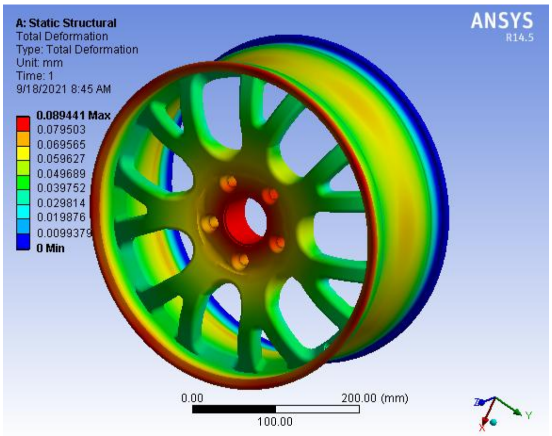
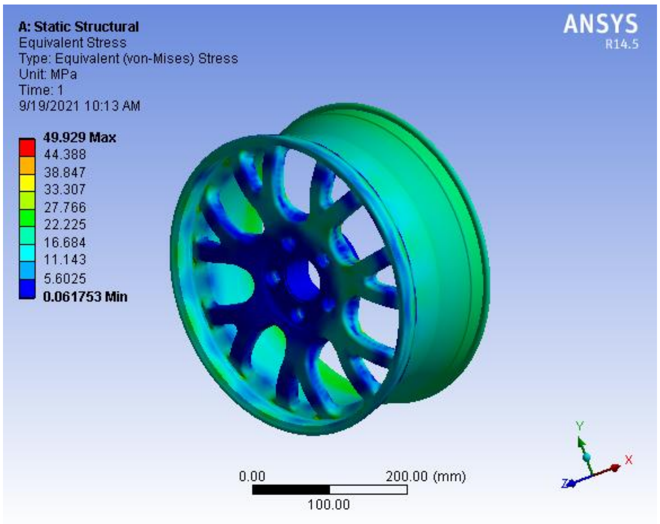



## RADIAL ENDURANCE STRUCTURAL ANALYSIS OF AN AUTOMOBILE WHEEL HAVING RADIAL ENDURANCE BY USING MAGNESIUM ALLOY

## STRESS

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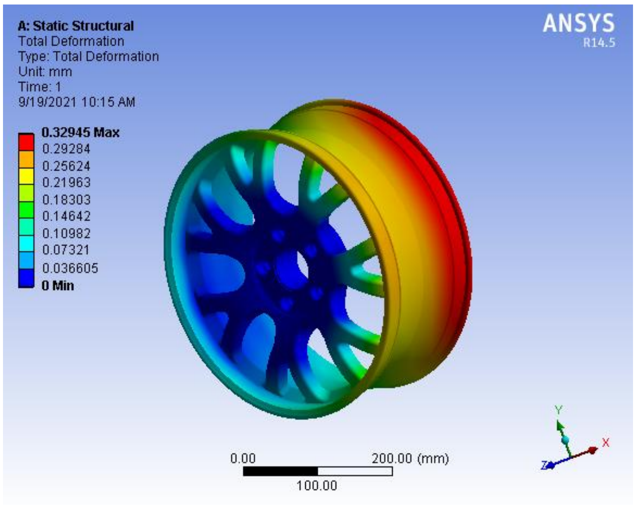

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## TABULAR RESULTS

## BENDING ENDURANCE

| MODEL | MATERIAL | STRESS (Mpa) | STRAIN (mm/mm) | TOTAL DEFORMATION (mm) | DIRECTIONAL DEFORMATION (mm) |
|---|---|---|---|---|---|
| ORIGINAL MODEL | Al 7075 | 145.63 | 0.0020734 | 0.12198 | 0.088885 |
| | Magnesium alloy | 95.286 | 0.0021611 | 0.12768 | 0.092916 |
| | Carbon steels | 405.7 | 0.0020717 | 0.12128 | 0.088441 |
| | Chrome steel alloy | 404.73 | 0.0020166 | 0.11825 | 0.0861 |
| MODIFIED MODEL | Al 7075 | 67.746 | 0.00095469 | 0.081961 | 0.078659 |
| | Magnesium alloy | 43.683 | 0.0009809 | 0.089441 | 0.081965 |
| | Carbon steels | 191.98 | 0.00096978 | 0.081563 | 0.078631 |
| | Chrome steel alloy | 191.53 | 0.00094384 | 0.079413 | 0.076633 |

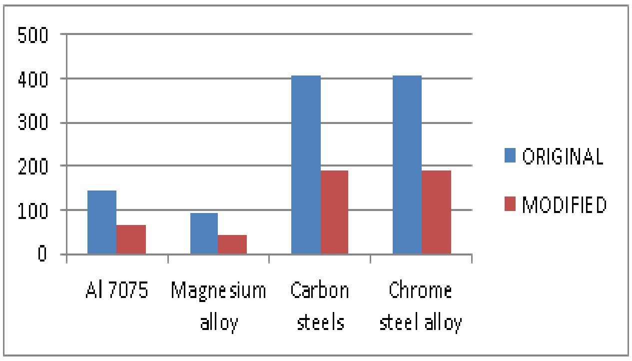
## RADIAL ENDURANCE

| MODEL | MATERIAL | STRESS (Mpa) | STRAIN (mm/mm) | TOTAL DEFORMATION (mm) | DIRECTIONAL DEFORMATION (mm) |
|---|---|---|---|---|---|
| ORIGINAL MODEL | Al 7075 | 29.633 | 0.00043197 | 0.064904 | 0.062435 |
| | Magnesium alloy | 29.161 | 0.00067815 | 0.10356 | 0.099424 |
| | Carbon steels | 30.331 | 0.00015823 | 0.023218 | 0.022399 |
| | Chrome steel alloy | 30.56 | 0.00015544 | 0.022636 | 0.021857 |
| MODIFIED MODEL | Al 7075 | 50.377 | 0.00074233 | 0.20695 | 0.059505 |
| | Magnesium alloy | 49.929 | 0.0011722 | 0.32945 | 0.094451 |
| | Carbon steels | 51.143 | 0.0002701 | 0.074254 | 0.021446 |
| | Chrome steel alloy | 51.42 | 0.00026492 | 0.072455 | 0.020958 |

## GRAPHS

## BENDING ENDURANCE

## STRESS

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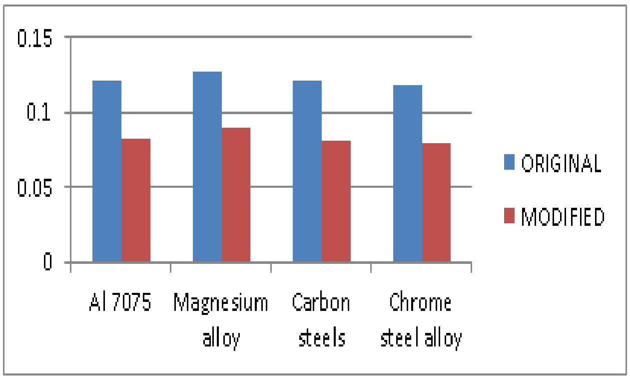
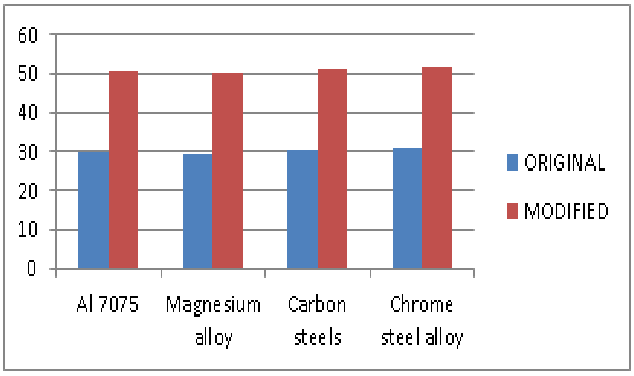



## RADIAL ENDURANCE

## STRESS

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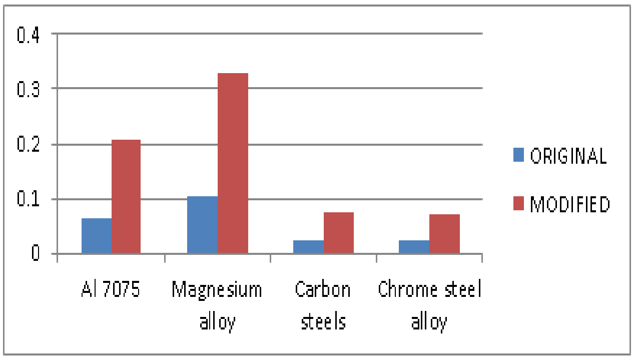


## CONCLUSION

Here we are going to consider four different materials namely magnesium alloy, aluminum alloy, chrome steel alloy and carbon steel, the stress and strain performances of each material will be obtained. Through evaluating and analyzing model in the results of the equivalent stress and deformation were compared. This research predicts the reliability of the structural design, some valuable references are provided for the design and development of alloy wheel.

Here we analyzed with 2 different alloy wheel models and used 4 different materials for the optimization. As if we verify here we have verified with different analysis models i.e. at the bending endurance and at the radial endurance.

As if we verify the results of the bending endurance models here the stress is very less for the model 2 when compared with the model 1 and even the stresses very less for the magnesium alloy. As if we compare the results obtained for the total deformation here the model 2 using chrome steel alloy has obtained the best result, but there is no much difference for the deformation values for all the materials for the similar models.so by observing all the obtained results we can conclude that the model 2 using magnesium alloy has got the stability for the bending endurance limits.
As if we verify the results of the radial endurance models here the stress is very less for the model 1 when compared with the model 2 and even the stresses very less for the magnesium alloy. As if we compare the results obtained for the total deformation here the model 1 using chrome steel alloy has obtained the best result, but there is no much difference for the stress and deformation values for all the materials for the similar models. As if we clearly verify the obtained results in radial here the stress has a variation in increase for the modified model, but the deformation is very low and negligible when compared with the model 1, So by observing all the obtained results we can conclude that the model 2 using magnesium alloy has got the stability for the radial endurance limits.

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