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RESEARCH ARTICLE

ASSESSMENT AND COMPARISON OF DIFFERENT MATERIALS FOR ALLOY WHEELS USING ANSYS

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ABSTRACT

Alloy wheels are automobile wheels which are made from an alloy of aluminium or magnesium metals or sometimes a mixture of both. Alloy wheels differ from normal steel wheels because of their lighter weight, which improves the steering and the speed of the car. Alloy wheels will reduce the unstrung weight of a vehicle compared to one fitted with standard steel wheels. The aim of the project is to suggest a new composite material Magnesium AZ91E-2%Al_2O_3 to the alloy wheels and evaluate its performance by performing the static & fatigue analysis and the results were compared with aluminiumA356 and magnesiumAM60A alloy materials. In this project three different parametric models are designed for Alloy wheel used in four-wheeler by collecting data from reverse engineering process from existing model. Alloy wheel models are designed in Autodesk Inventor14.0 software, then converted into IGES format and imported into ANSYS Workbench for analysis. The analysis was carried on three models to find the best one. Static analysis was carried out for finding the deformation and stress/strain results, Fatigue analysis under radial load was carried out and generating the S-N curves, by using S-N curve we predict the life of alloy wheel and factor of safety.

INTRODUCTION

Wheel: A wheel is a circular device that is 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 (Vikranth Deepak, 2012). Road wheel is an important structural member of the vehicle suspension system that supports the static & dynamic load encountered during vehicle operation (Ravi Kumar, 2013). A wheel, together with an axle overcomes friction by facilitating motion by rolling. In order for wheels to rotate, a moment needs to be applied to the wheel about its axis, either by way of gravity, or by application of another external force (Emmanuel, 2015) More generally the term is also used for other circular objects that rotate or turn, such as a ship's wheel, steering wheel and flywheel. Style, weight, manufacturability and performance are the four major issues related to the design of a new wheel (Muhammet cerit, 2014)

Alloy wheel: Alloy wheels are automobile (car, motorcycle and truck) wheels which are made from an alloy of aluminium or magnesium metals (or sometimes a mixture of both) (Sourav Das, 2014). Alloy wheels differ from steel wheels in a number of ways:

- Typically lighter weight for the same strength
- Better conductors of heat
- Improved cosmetic appearance (Anusha srikanta, 2012).

Lighter wheels can improve handling by reducing unsprung mass, allowing suspension to follow the terrain more closely and thus provide more grip, however it's not always true that alloy wheels are lighter than the equivalent size steel wheel (Saran Theja, 2015). Reduction in overall vehicle mass can also help to reduce fuel consumption. Better heat conduction can help dissipate heat from the brakes, which improves braking performance in more demanding driving conditions and reduces the chance of brake failure due to overheating (Prabha and Pendyala Veera Raju, 2012).

Problem Description and Methodology

Problem Description

Previously steel wheels are used to manufacture wheels for the higher strength, but these wheels are heavy due to its density and also giving trouble to manufacture because of its higher melting point and hard to do casting it (Praveen, 2014). Weight is also playing crucial role in mileage. After that aluminium and magnesium took the place for the manufacturing of alloy wheel, but these alloy wheels are not giving good life at the larger run.

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METHODOLOGY

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 best model and material optimization used to solve the above said problems. New type of composite Magnesium AZ91E-2% Al_2O_3 (Sameer Kumar, 2015), is implemented in this thesis (Anusha Srikanta, 2012).

MODELLING OF ALLOY WHEEL USING AUTODESK INVENTOR

The wheel design has done by using AUTODESK INVENTOR 2014 software. In this design created by using the sketch features are including extrude, extrude cut, revolving, holes, chamfer, roundness, shell, drafting, etc (Sasank Shekhar Panda, 2011). Design data was collected from reverse engineering process from existing model (Yadav, 2012). The dimensions of the wheel is shown in the below table.

Table 1. Specifications of alloy wheel

Wheel Specifications	
Rim Diameter	14"
Rim width	5.5"
Offset	43mm
PCD	4×100
Centre Bore	54.1mm

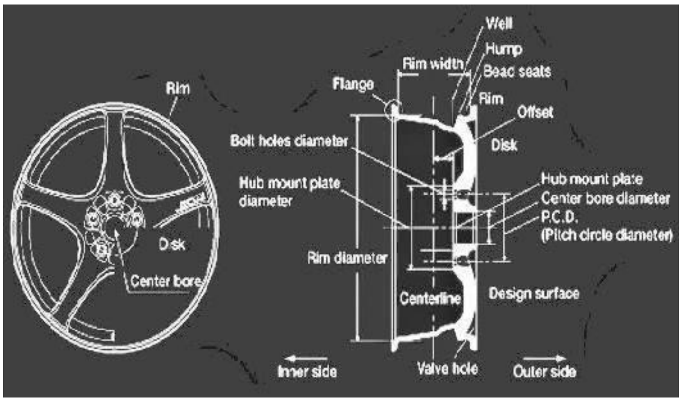

Fig. 1. Wheel Specification

Three different designs of alloy wheel 3D models

Fig 2. 6 Spokes Wheel

Fig. 3. 5 Spokes Wheel

Fig. 4. 4 Spokes Wheel

ANALYSIS OF ALLOY WHEEL

Static Analysis: Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects (Sivakrishna, 2014), such as those caused by time-varying loads. 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 (Prem, 2016).

Fatigue Analysis: Fatigue is an important consideration for components and structures subjected to repeated loads is one of the most difficult design issues to resolve. Experience has shown that large percentage of structural failure are attributed to fatigue and as a result, it is an area which has been and will continue to be the focus of both fundamental and applied research (Satyanarayana, 2012). Fatigue analysis is used to determine the life, safety and damage of any component. The present work involves the determination of the life, safety factor and damage of alloy wheel of three different models with three different materials (Liangmo Wang, 2010).

Procedure for doing the analysis in ANSYS Workbench

Modelling: The 3-diemensional modal of the wheel was created in Autodesk Inventor Professional2014 and the file was exported in the IGES (international graphics exchange specification) format into ANSYS Workbench.

Meshing: The process of dividing the object in to different elements is called meshing. Meshing thus holds a very important place in the finite element analysis. The meshing was performed using the mesh generate option in the ANSYS Workbench.

Materials Used for the Analysis & its properties

- Mg AZ91E+2% of Al_2O_3
- Magnesium Alloy AM60A
- Aluminium Alloy A356
- *Material composition*

Magnesium composite AZ91E-Al_2O_3 :

- Base metal- Al 9% ZN 1% and remaining Mg (Sameer Kumar, 2016).
- Reinforcement - nano particles of Al_2o_3 2% (50µm).

Magnesium alloy Am60A

- 5.5-6.5% Al, 0.13% Mn min, 0.50% Si max, 0.35% Cu max, 0.22% Zn max, 0.03% Ni max, balance Mg (Kalyani Radha, 2015).

Aluminum alloy A356

- Aluminium alloy A356.0 consists of 7% Si, 0.3% Mg alloy with 0.2%Fe (max) and 0.10% Zn (max).

Table 2. Material Properties

Property	Mg AZ91E+2%Al_2O_3	Magnesium Alloy AM60A	Aluminium Alloy A356
Yield strength	146N/mm2	130 N/mm2	195N/mm2
Elastic modulus	49913N/mm2	45000 N/mm2	72000N/mm2
Mass density	1.85gm/CC	1.8 gm/CC	2.7 gm/CC
Poisson's ratio	0.35	0.35	0.33

Loading & boundary conditions

- **Fixed Supports:** The pitch circle holes are constrained in all degrees of freedom [19].
- **Pressure Load:** Consider 30 psi of air pressure load acting on the outer surface of the wheel [20]. Therefore 30 = 30x0.4535x9.81/(25.4) 2 = 0.207 N/mm2
- **Load:** the load of 3800N is applied throughout the inner surface of the hub diameter by taking one middle node.

Gross weight= kerb weight + passenger weight+ luggage weight

=1138+ (5x65) +85 =1548Kgs

Each wheel carries = 1568/4=387Kgs

Each wheel load = 387x9.81 = 3796.47 ≈ 3800 N.

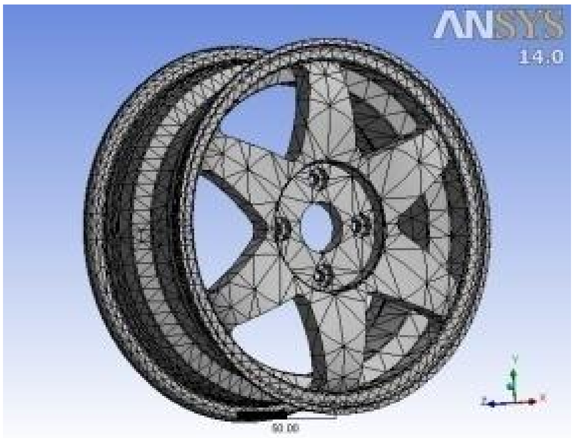

Fig 5. Meshed Model

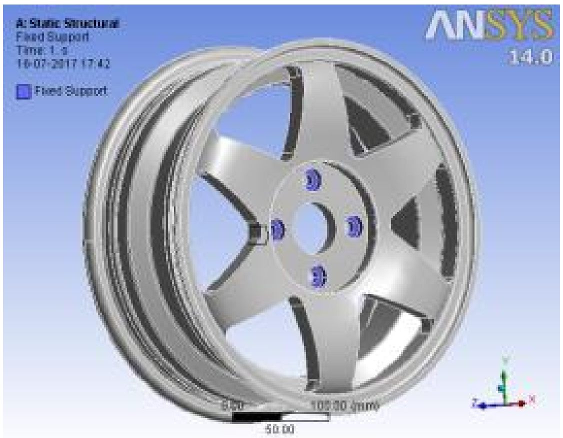

Fig. 6. Fixed Supports

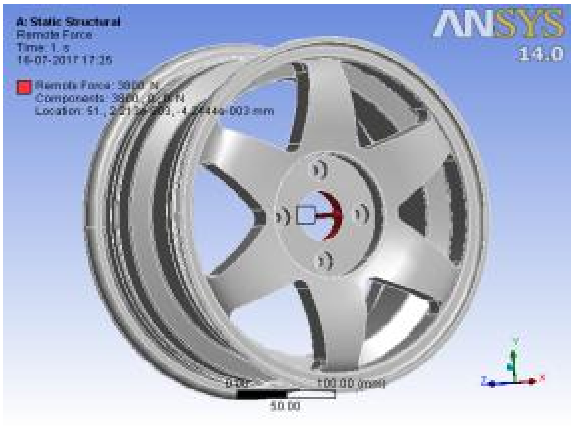

Fig 7. Remote Force

Fig 8. Pressure

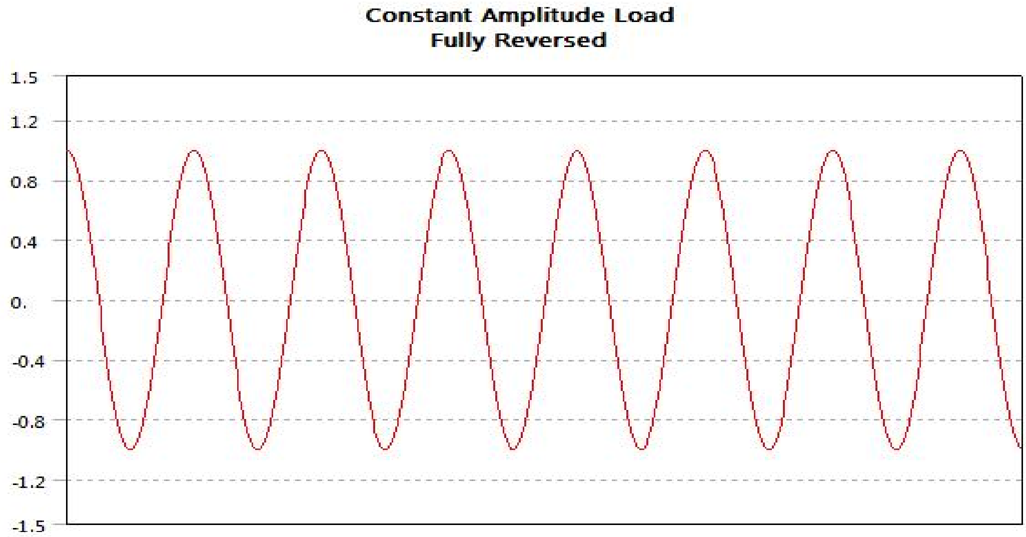

Fig. 9. Constant amplitude load fully reversed

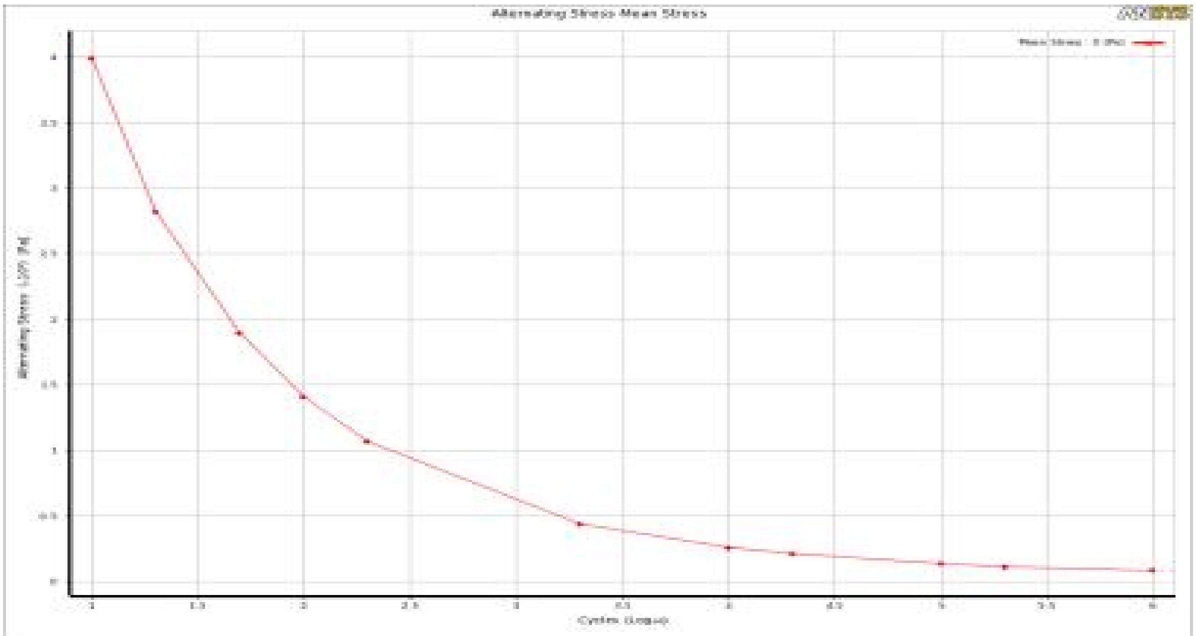

Fig. 10. Life & Load

RESULTS AND DISCUSSIONS

Static Analysis Results: Static Analysis Results for the material of Magnesium AZ91E-2% Al_2O_3.

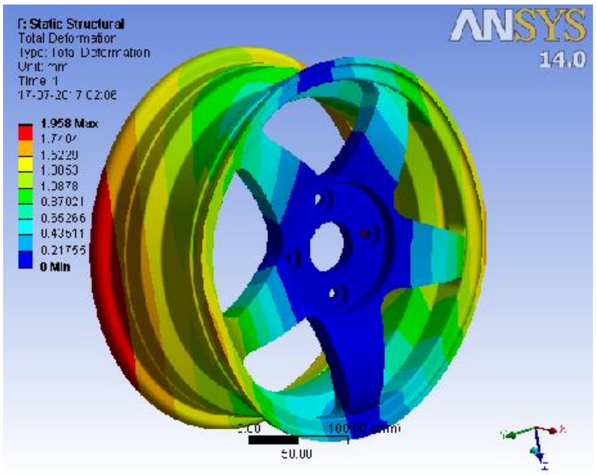

Fig. 11. Total Deformation (4spokes)

Total deformation of magnesium composite material for 4,5and 6 spokes alloy wheels are shown in above figures 11, 12 and 13 res. Total deformation was maximum at rim flanges and minimum at hub portion because hub area and bolts are fixed.

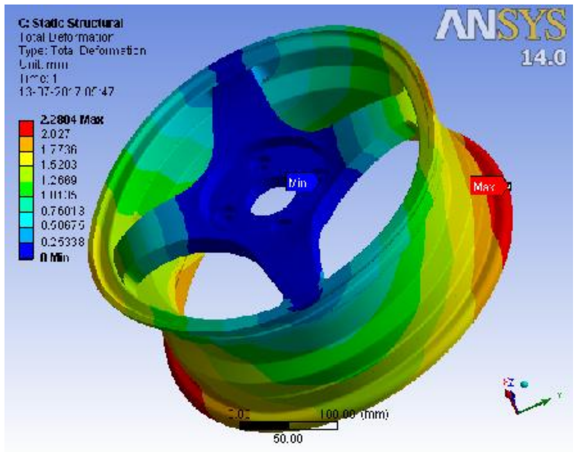

Fig. 12. Total Deformation (5spoke)

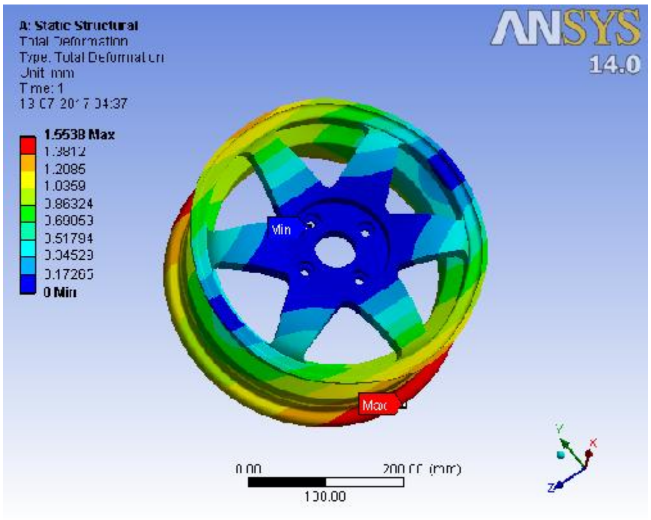

Fig. 13. Total Deformation (6spokes)

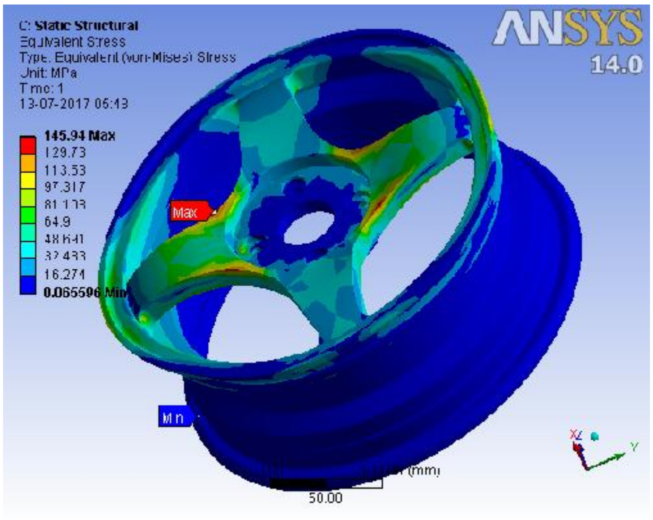

Fig. 14. Von-misses Stress (4spokes)

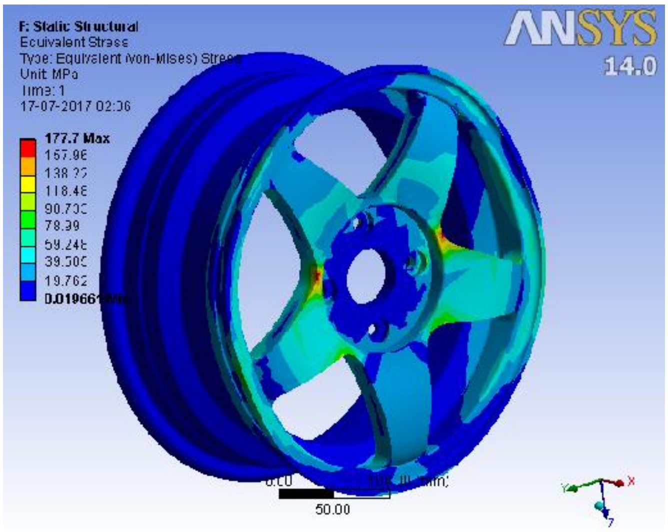

Fig. 15.Von-misses Stress (5spokes)

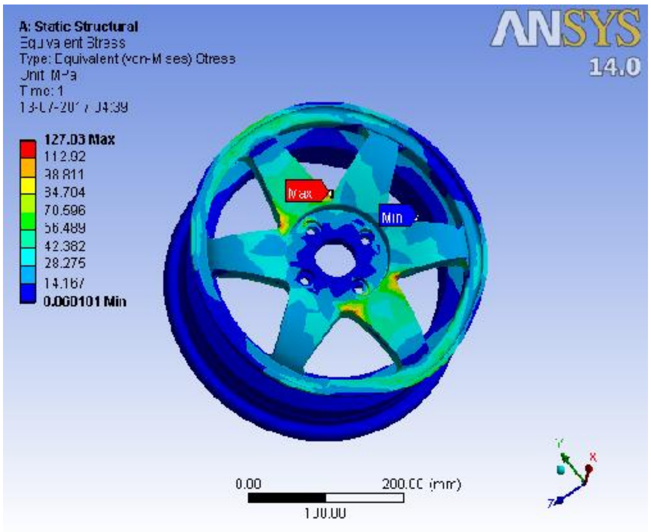

Fig.16. Von-misses Stress (6spokes)

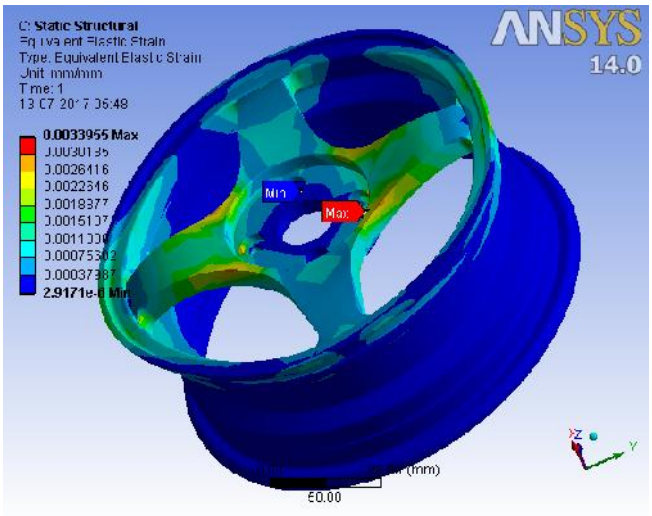

Fig. 17. Von-misses Strain (4spokes)

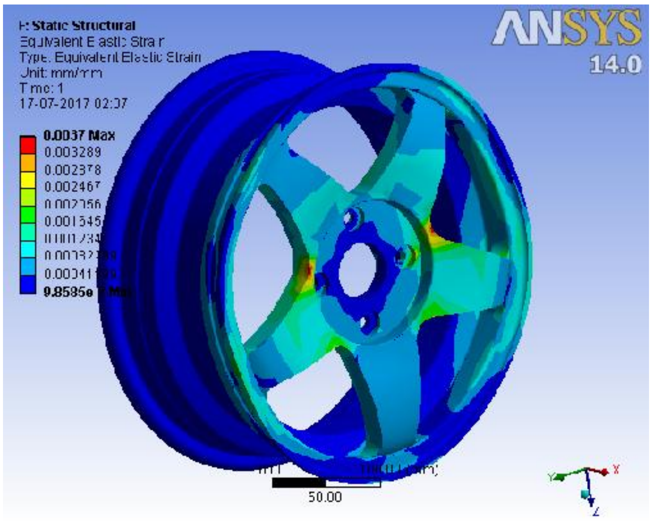

Fig. 18. Von-misses Strain (5spokes)

Minimum and maximum deformation shown in Fig.11. Among three alloy wheels minimum deformation obtained in 6spokes and maximum deformation obtained in 4 spokes alloy wheel. Von-misses stress for alloy wheels of 4spokes, 5spokes and 6spokes are shown in Fig. 14,15 &16 res, the minimum stress at wheel width and maximum stress at spokes intersection shown in above von-misses stress figures, among the three designs minimum stress obtained in 6spokes and minimum in 5spokes alloy wheel. Figures 17,18 & 19 shows the von-misses strain for the magnesium composite material of

4,5 &6spokes alloy wheels res. Minimum strain of 2.8885e-003 obtained at 6spokes and maximum strain of 3.7e-003 obtained at 5 spokes alloy wheel.

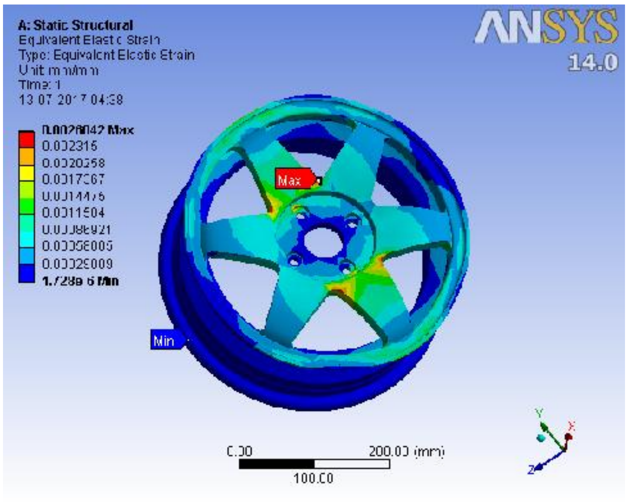

Fig. 19. Von-misses Strain (6spokes)

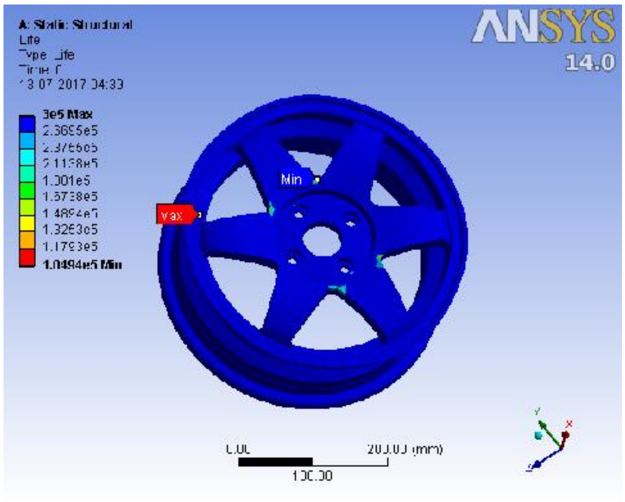

Fig. 20. Life

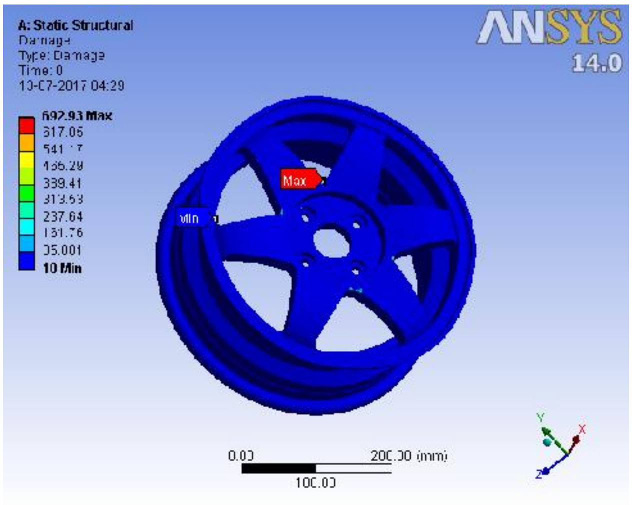

Fig. 21. Damage

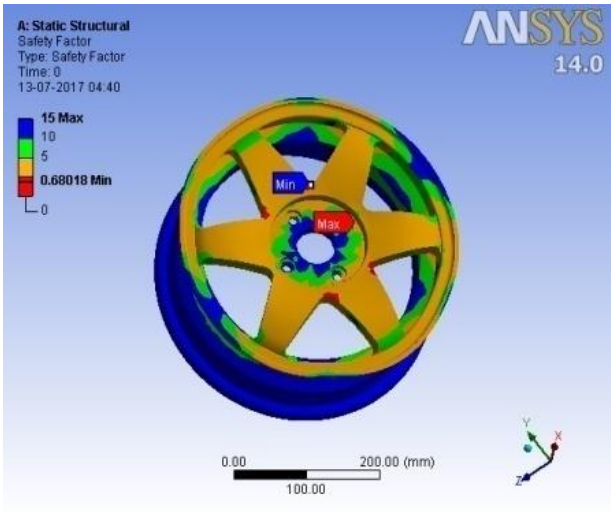

Fig. 22. Safety Factor

Table 3. Static Analysis results for Magnesium Composite material

MG AZ91E+2%AL2O3 Alloy wheel type		Total deformation (mm)	Equivalent (von-Misses)stress (MPa)	Equivalent elastic strain
4 spokes	Min	0	6.5596e-002	2.9171e-006
	Max	2.2804	145.94	3.3955e-003
5 spokes	Min	0	1.9661e-002	9.8585e-007
	Max	1.958	177.7	3.7e-003
6 spokes	Min	0	6.0101e-002	1.728e-006
	Max	1.5538	127.03	2.6042e-003

Minimum strain was obtained at hub area and rim width and maximum strain was obtained at spokes intersection.

Fatigue Analysis results: Fatigue Analysis Results for the material of Magnesium AZ91E-2% Al_2O_3

Results for magnesium alloy material shown in table.4 and it shows that maximum deformation of 2.5294mm in 4spokes and minimum deformation of 1.7235mm in 6spokes. Maximum stress of 179.25Mpa in 5spokes and minimum of 128.1Mpa in 6spokes alloy wheel. Maximum strain of 4.1145e-003 in 5spokes and minimum strain of 2.8885e-003 in 6spokes alloy wheel. Results for aluminium alloy material shown in table.5 and it shows that maximum deformation of 1.5848mm in 4spokes and minimum deformation of 1.0821mm in 6spokes. Maximum stress of 178.04Mpa in 5spokes and minimum of 126.78Mpa in 6spokes alloy wheel. Maximum strain of 2.5708e-003in 5spokes and minimum strain of 1.8031e-003 in 6spokes alloy wheel. Life, damage and safety factor for the magnesium alloy material are shown in table.7, among the three wheels minimum and maximum

Table 4. Static Analysis results for Magnesium Alloy

MG Alloy AM60A / Alloy Wheel Type		Total deformation (mm)	Equivalent (von-Misses)stress (MPa)	Equivalent elastic strain
4 spokes	Min	0	6.3895e-002	3.2355e-006
	Max	2.5294	147.45	3.7662e-003
5 spokes	Min	0	2.0315e-002	9.88e-007
	Max	2.1717	179.25	4.1145e-003
6 spokes	Min	0	6.2186e-006	1.9167e-006
	Max	1.7235	128.1	2.8885e-003

Table 5. Static Analysis results for Aluminium Alloy

Al Alloy A356 / Alloy wheel type		Total deformation (mm)	Equivalent (von-Misses) Stress (MPa)	Equivalent elastic strain
4 spokes	Min	0	5.9608e-002	2.2984e-006
	Max	1.5848	147.82	2.3671e-003
5 spokes	Min	0	2.0013e-002	9.3775e-007
	Max	1.3617	178.04	2.5708e-003
6 spokes	Min	0	5.9724e-002	1.1748e-006
	Max	1.0821	126.78	1.8031e-003

Table 6. Fatigue analysis for Magnesium Composite material

Mg AZ91E-2%Al2O3 / Alloy wheel type		Life (cycles)	Damage	Safety Factor
4 spokes	Min	4.8466e+005	10	0.59202
	Max	1e8	2063.3	15
5 spokes	Min	1.2868e+005	10	0.4862
	Max	1e8	7771.5	15
6 spokes	Min	1.4431e+006	10	0.68018
	Max	1e8	692.93	15

Table 7. Fatigue analysis for Magnesium Alloy

Mg alloy AM60A / Alloy wheel type		Life (cycles)	Damage	Safety Factor
4 spokes	Min	98630	3333.3	0.55974
	Max	3e5	10139	15
5 spokes	Min	96250	3333.3	0.46472
	Max	3e5	10390	15
6 spokes	Min	1.0494e+005	3333.3	0.65261
	Max	3e5	9528.9	15

Table 8. Fatigue analysis for Aluminium Alloy

Al alloy A356 / Alloy wheel type		Life (cycles)	Damage	Safety Factor
4 spokes	Min	84520	1000	0.59065
	Max	1e6	11832	15
5 spokes	Min	43137	23182	0.48508
	Max	1e6	1000	15
6 spokes	Min	1.3729e+005	1000	0.6786
	Max	1e6	7283.6	15

life and safety factor are obtained in 4 and 6spoke alloy wheel res. Fatigue analysis results for three models of aluminium alloy are shown in table.8. Life, damage and safety factor for the magnesium alloy material are shown in table.8, among the three wheels minimum and maximum life and safety factor are obtained in 4 and 6spoke alloy wheel res.

Results comparison: For magnesium composite material maximum deformation of 2.2804mm, 1.958 mm & 1.5538mm, maximum von-misses stress of 145.94 N/mm^2, 177.7 N/mm^2 & 127.03 N/mm^2 are obtained at 4spokes, 5spokes & 6spokes alloy wheels respectively. Maximum life of 1e8 cycles and maximum safety factor of 15 are obtained for all three alloy wheels. For magnesium alloy material maximum deformation of 2.5294mm, 2.1774mm & 1.7235 mm, and maximum von-misses stress of 147.45 N/mm^2, 179.25 N/mm^2 & 128.1 N/mm^2 are obtained at 4spokes, 5spokes & 6spokes alloy wheels respectively. Maximum life of 1e6 cycles and maximum safety factor of 15 are obtained for all three types of wheels. For aluminium alloy material maximum deformation of 1.5848 mm, 1.3617 mm & 1.0821 mm, and maximum von-misses stress of 147.82 N/mm^2, 178.04 N/mm^2 & 126.78 N/mm^2 are obtained at 4spokes, 5spokes &6spokes alloy wheels respectively. Maximum life of 3e5 cycles and maximum safety factor of 15 are obtained for all three types of wheels.

Conclusions

6spokes alloy wheel shows the better and with stand able results in both structural and fatigue analysis when compared to 4spokes and 5spkoes alloy wheels. In structural analysis minimum deformation of 1.0821mm and minimum von-misses stress of 126.78 N/mm^2 are obtained for aluminium alloy material with 6spokes alloy wheel than other materials, in fatigue analysis magnesium composite material gives better results than aluminium and magnesium alloy. For magnesium composite material min life of 1.4431e+006 cycles and maximum life of 1e8 cycles are obtained at 6spkoes alloy wheel. Even though aluminium gives less deformation and stress than magnesium composite material, the stresses obtained in magnesium composite are within the yield stress.

By considering the above results we can conclude that magnesium composite can be used as an alternative material for alloy wheels since it exhibits better fatigue properties.

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