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Design and Manufacturing of Automobile Alloy Wheel using Fused Deposition Modeling

M. Narasimha Reddy[1], B. Ramakrishna[2]

[1]PG Student, Department of Mechanical Engineering, Chiranjeevi Reddy institute of Engineering & Technology, Anantapur, India

[2]Assistant Professor, Department of Mechanical Engineering, Chiranjeevi Reddy Institute of Engineering & Technology, Anantapur, Andhra Pradesh, India

ABSTRACT

Alloy wheels are generally made up of aluminum or magnesium alloys. These alloy wheels are typically lighter in weight, good strength, provides better heat conduction and good corrosion resistance. In this paper design and development of alloy wheel pattern using Fused Deposition Modeling (FDM) process is carried out. FDM is a 3D printing process where material deposited layer by layer to get required shape and size. Generally - FDM is used for pattern making. It is useful in reducing the pattern making time and improving the surface finish. Pattern is made up of Acrylonitrile Butadiene Styrene (ABS) material on FDM machine. An automobile alloy wheel is modelled and analyzed to select the best material based on deformation, equivalent stress and life. Materials taken for analysis are Al6061 and LM25. A casting product is produced from the prepared pattern by selecting best material from Al6061 and LM25.

Keywords : Fused Deposition Modeling (FDM),Alloy Wheel,Al6061,LM25

I. INTRODUCTION

Alloys of aluminium or magnesium are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels. Although steel, the most common material used in wheel production, is an alloy of iron and carbon, the term "alloy wheel" is usually reserved for wheels made from nonferrous alloys.

The earliest light-alloy wheels were made of magnesium alloys. Although they lost favour on common vehicles, they remained popular through the 1960s, albeit in very limited numbers. In the mid-to-late 1960s, aluminium-casting refinements allowed the manufacture of safer wheels that were not as brittle. Until this time, most aluminium wheels suffered from low ductility, usually ranging from 2-3% elongation.

An aluminium alloy wheel designed to recall the crossed spokes of a wire wheel. Alloy wheels are also purchased for cosmetic purposes although the cheaper alloys used are usually not corrosion-resistant. Alloys allow the use of attractive bare-metal finishes, but these need to be sealed with paint or wheel covers. Even if so protected the wheels in use will eventually start to corrode after 3 to 5 years but refurbishment is now widely available at a cost.

Magnesium wheels were the first die-cast wheels produced, and were often referred to as simply "mag wheels." Magnesium wheels were originally used for racing, but their popularity during the 1960s led to the development of other die-cast wheels, particularly of aluminium alloys.

The alpha-numeric suffixes attached to alloys, such as 6061-T6, represent the temper, or degree of hardness. They also represent the method by which the hardness was obtained.

In the case of 6061-T6 aluminium alloy, the "T6" indicates that it was solution heat-treated and artificially aged. The suffixes may include additional numbers. For instance, -T6511 would indicate that the alloy was solution heat-treated, stress-relieved by stretching, and artificially aged to reduce the possibility of distortion in machined parts.

LM25 is a high purity aluminium alloy, which can be gravity die cast in permanent moulds or sand. It has excellent castability and good mechanical properties that can be varied by heat treatment. The alloy is mostly used for high specification castings in industries where shape and complex form is required and casting soundness is important. Its use is widespread in the automotive industries for alloy wheels, cylinder heads and blocks and in many other industries such as chemical, marine and electrical. Castings made from this alloy can be supplied in the as cast form or in one of three other heat treated conditions.

FDM begins with a software process which processes an STL file (Stereo Lithography file format), mathematically slicing and orienting the model for the build process. If required, support structures may be generated.

Metal casting process begins by creating a mold, which is the 'reverse' shape of the part we need. The mold is made from a refractory material, for example, sand. The metal is heated in an oven until it melts, and the molten metal is poured into the mould cavity. The liquid takes the shape of cavity, which is the shape of the part. It is cooled until it solidifies. Finally, the solidified metal part is removed from the mould.

II. LITERATURE REVIEW

Daniel Antony, prince Jerome Christopher 2016 A project on "design and analysis of two wheeler alloy wheel rim using composite materials" they have presented the original design of the wheel rim of a commercial vehicle HONDA CB SHINE.

The maximum values of stresses and displacements of aluminium alloy and different types of composite materials for various types of loads and pressures were analysed and tabulated. While comparing the results we concluded that aluminium alloy is suitable material for this commercial vehicle for the respective design.

Soumyabhardwaj, sushilsingh and Vishalverma2015 A project on "Design and optimization of alloy wheels for Dynamic loading conditions" has concluded that optimization of alloy wheel on design and material bases can serves better result among the Al6061 and Al6063-T6.

Sreenath and Srihari 2014 A project on "Structural analysis and comparative study of aluminium and magnesium alloy wheel" has concluded that structural analysis of wheels made of A356.2,AM60B and redesigned AM60B under same boundary conditions were carried out, revealing that the peak stress is reduced.

The peak stress in the redesigned magnesium alloy wheel is found to be less than that in aluminium alloy wheel, and improved fuel efficiency due to reduced weight.

D.Sameer Kumar and K.N.S.Suman 2014 investigated on multi attribute decision making (MADM) methods based on mathematical models provide a ranking to the different alternatives, there by the decision making become easier. This paper presents the selection of magnesium alloy material to use in automotive wheel applications using MADM methods.

Sourav Das 2014 discussed the design of aluminium alloy wheel for automobile application which is carried out paying special reference to optimization of the mass of the wheel. The Finite Element analysis it shows that the optimized mass of the wheel rim could be reduced to around 50% as compared to the existing solid disc type Al alloy wheel. The FE analysis shows that the stress generated in the optimized component is well below the actual yield stress of the Al alloy. The Fatigue life estimation by finite element analysis, under radial fatigue load condition, is carried out to analyse the stress distribution and resulted displacement in the alloy wheels. S-N curve of the component depicts that the endurance limit is 90 MPa which is well below the yield stress of the material and safe for the application. The FE analysis indicated that even after a fatigue cycle of 1020, the damage on the wheel is found only 0.2%.

Meghashyam, S.girivardhannaidu and N.sayed baba 2013 a project on "Design and Analysis of Wheel Rim using CATIA and ANSYS" has conclude that in the four wheeler automobile rim the amount of pressure 200kpa is applied along the circumference of the wheel rims made of both aluminium and forged steel and bolt circle of wheel rim is fixed.
Aluminium wheel rim is subjected to more stress compared to forged steel.

III. DESIGN AND MANUFACTURING OF ALLOY WHEEL

A. Modeling of alloy wheel

Modeling of a two wheeler alloy wheel is designed in the solidworks 14.0 with specified dimensions of HONDA CB SHINE.

B. Making Pattern Using Fused Deposition Modeling (FDM)

Fused Deposition Modeling (FDM) is an additive manufacturing (AM) or 3D printing technology commonly used for modeling, prototyping, and production applications. It is one of the techniques used for 3D printing. FDM receives and processes the STL file (Stereo Lithography file format) which produced from part model. The physical part is than produced by extruding small flattened strings of molten material to form layers as the material hardens immediately after extrusion from the nozzle and build the part along with support structure in three hours. The material used to build the part is Acrylonitrile Butadiene Styrene (ABS) material. The part can be used as pattern for manufacturing alloy wheel with real application material like aluminium or magnesium alloy which produced from casting process. The properties of ABS material are shown in table 1.

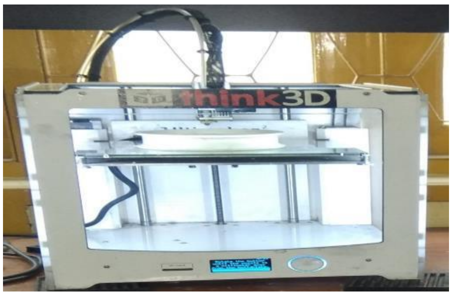

Fig 1. FDM Machine

Fig 2. Pattern made from FDM with ABS material

Table 1. Properties of ABS Material

Density	1.24 gm/cm^3
Specific gravity	1.04
Tensile strength	65MPa
Izod impact strength	2.46 J/cm
Elongation	40%
Yield strength	60.6GPa
Flexural modulus	103-112GPa
Deflection temperature	88ºc

IV. ANALYSIS AND RESULTS

Finite element analysis of alloy wheels is carried out in ANSYS 16.0 software.

A. ANALYSIS OF Al6061 ALLOY WHEEL

Table 2. Properties of Al6061

Tensile yield strength	240MPa
Tensile ultimate strength	280MPa
Young's modulus	75000MPa
Poisson's ratio	0.33
Young's modulus	73529MPa
Shear modulus	28125MPa

Table 3. Properties of LM25

Tensile yield strength	110MPa
Tensile ultimate strength	150MPa
Young's modulus	71000MPa
Poisson's ratio	0.32
Young's modulus	65741MPa
Shear modulus	26894MPa

B. THEORITICAL CALCULATIONS

LOADS AND BOUNDARY CONDITIONS

- ✓ Weight of the alloy wheel =3.725kg.
- ✓ Self-weight of the vehicle = 143kg
- ✓ Weight of the single rider = 75kg.
- ✓ Force acting with self-weight of the vehicle (load 0) = 143×9.81=1402N.
- ✓ Force acting with single rider (load 1)
  - o (143+75) ×9.81=2138.58N.
- ✓ Force acting with single rider (load 2)
  - o (143+75+75)×9.81=2874N.
- ✓ Force acting with triple rider (load 3) =(143+75+75+75)×9.81=3610.08N
- ✓ Circumferential pressure applied on the vehicle
  - o 0.2MPa.
- ✓ Speed of the wheel in clock wise direction
  - o 80kmph.
- ✓ Maximum force acting on the vehicle=8×(143+75+75+75)×9.8=28880N

Fig 4. Loads and Boundary Conditions

Circumferential pressure of 0.2MPa acting on the wheel with support at the hub of an alloy wheel as shown in Fig 4.

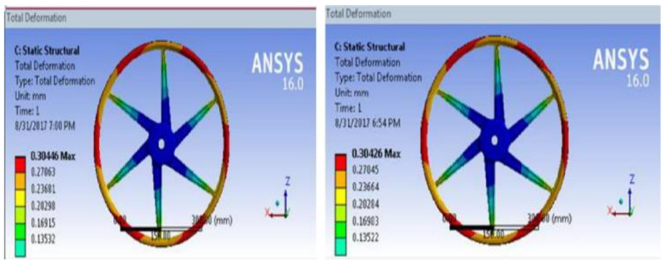

Fig. 5 Maximum Deformation of Al6061 & LM25

Fig 5 shows the maximum deformations of LM25 that is 0.037671mm at maximum load conditions.The maximum deformation occurs at joint of spoke and circumferential part of wheel.

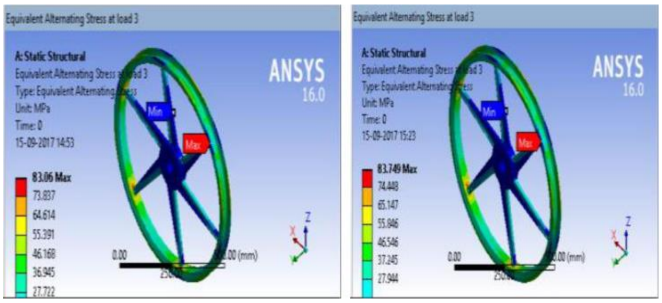

Fig. 6 Maximum Equivalent Stress of Al6061 & LM25

Maximum Equivalent Stress is occurred in LM25 that is 83.749MPa as shown in Fig 6 with respect to maximum load applied on the wheel.

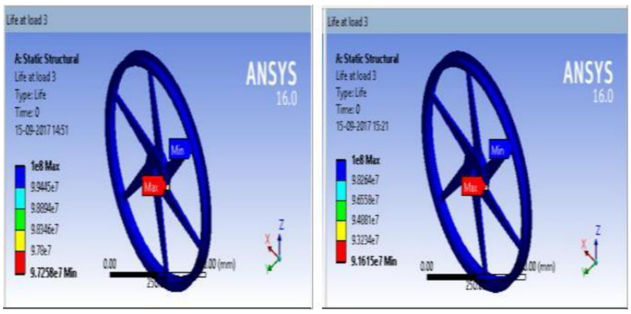

Fig. 7 Maximum life of Al6061 & LM25

Maximum life cycles is 9.725e7 noticed in Al6061 when compared to LM25 at maximum loading conditions.

Table. 4 Experimental Results of Al6061

FORCE(N)	DEFORMATION (mm)	EQUIVALENT STRESS (N/mm²)	LIFE (No. of Cycles)
1402	0.035365	83.048	9.7361e7
2138	0.035478	83.052	9.7326e7
2874	0.035591	83.056	9.729e7
3610	0.035619	83.06	9.725e7

Table 5. Experimental Results of LM25

FORCE(N)	DEFORMATION (mm)	EQUIVALENT STRESS (N/mm²)	LIFE (No. of Cycles)
1402	0.037332	83.738	9.1708e7
2138	0.037451	83.741	9.1677e7
2874	0.037569	83.745	9.1646e7
3610	0.037671	83.749	9.1615e7

From the above experimental results graphs were plotted for Force vs Deformation, Force vs Equivalent Stress and Force vs Life.

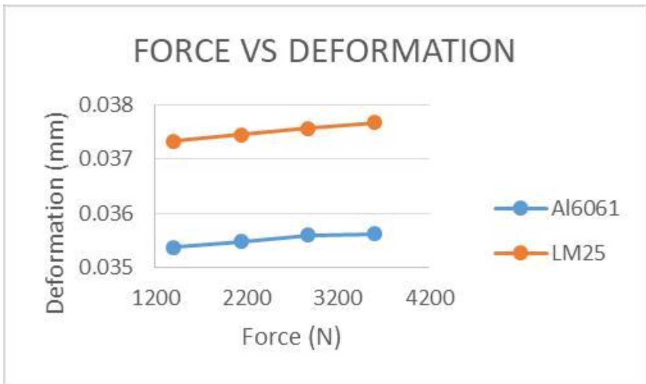

Fig. 8 Force vs Deformation.

Fig 8 shows that as the force increases the deformation also increases and here observed that the deformation of LM25 is more than the AL6061 alloy.

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Fig. 9 Force vs Equivalent stress.

Fig 9 shows that as the force increases the equivalent stress also increases and here observed that stress of LM25 is more than the AL6061 alloy.

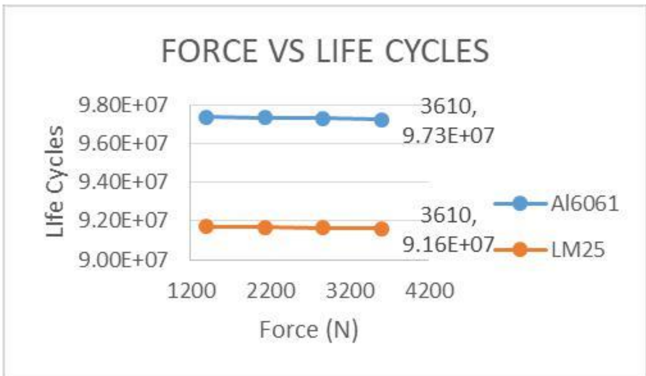

Fig.10 Force vs Life cycles.

Fig 10 shows that as the force increases the life cycles of alloy wheel decreases and here observed that life of LM25 is less than the Al6061 alloy.

PREPARATION OF PROTO TYPE OF ALLOY WHEEL

From the above results Al6061 alloy gives the better results when compare to LM25 in terms of deformation, equivalent stress and life of an alloy wheel. Therefore Proto type of Al6061 alloy wheel was prepared by Sand casting process.

Fig 11 Proto type of Al6061 Alloy Wheel

V. CONCLUSION

The present work aimed to produce pattern from FDM machine in order to reduce time of pattern making and improving the surface finish. An analysis carried out to select the best material from based on deformation, equivalent strength and life cycle. Up on the results of analysis the best material Al6061 is selected for producing casting product using the pattern.

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