

MODELLING AND ANALYSIS OF AN ALLOY WHEEL

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Abstract - This project concentrates on alloy wheels. The alloy is better than the conventional steel wheels in strength and durability. It has excellent wear resistance, anticorrosion properties, and longer service life as estimated by the stress frequency distribution. The alloy wheel is a significant structural member of the vehicular suspension system that supports the static and dynamic loads encountered during vehicle operation. As in the case of an automobile wheel maximum load is applied on the alloy wheel. Proper analysis of the alloy wheel plays a significant role in the safety of the passenger cars. The 3-dimensional models of the wheel are designed in modelling software SOLID WORKS, and further, it is imported to the ANSYS software. The static condition is chosen for the analysis alloy wheel.

Keywords: Solid works, Ansys, Alloy wheel

1. INTRODUCTION

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). Alloy wheels differ from steel wheels in a number of ways

- Lighter weight for the same strength.
- Better conductors of heat.
- Improved cosmetic appearance.

Lighter wheels can improve handling by reducing up sprung 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. 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.

1.1 Motivation:

A major concern in analysing practical mechanical structure is to reliably identify their dynamic characteristics such as their natural frequencies and vibration mode shapes. These vibration characteristics are needed in order to achieve effective design and control of the vibrations of structural components. Components that are manufactured from cast alloys have been widely used in the automotive industry because of its characteristic of high strength to weight ratio, low cost and better fuel consumption. The integrity of the structural

performance during the vehicle operations is determined through the strength of the spot welds in the body of vehicle structure. The metal cutting industry is driven by the increasing in number of consumers needs for quality metal cutting related products (more precise tolerances and better product surface roughness) thus causing them to continuously improve quality control of metal cutting processes. Optimization of milling is very useful to reduce cost and time for machining mould. Now, reduction in wheel weight is a major concern in wheel industry. The efficiency of machining operation especially milling process is determined by the material removal rate, tool wear and cycle time.

1.2 Types of Automotive wheels:

Various type of wheels which are used in today's automobiles

- Steel wheels
- Alloy wheels
- Forged and cast wheels
- Split rim wheels

1.3 Steel Wheel

Steel wheels have been standard on most low-cost vehicles for decades and dominated before alloy rims became cheaper to produce. Steel – an alloy of iron and carbon – is a harder metal than most other wheel materials, but this strength brings with it an increase in weight when compared to the likes of Aluminium. The basic way in which steel wheels are produced means that there is very little flexibility when it comes to design or any type of artistic flare. Different sections of a wheel are pressed out and then connected to form the entire wheel, ready to be used once the welds have been sufficiently ground down

1.4 History of an Alloy Wheel:

Alloy wheels are made from an alloy of Aluminium or magnesium. They were first introduced in the 1930s, but became more widespread in the 1960s. The main advantage of alloy wheels is that they are lighter and stronger than the steel wheels, which improves performance and handling. In addition, alloy wheels are more durable and less prone to corrosion. They are also available in a wider range of styles, which allows for greater customization of a vehicle's appearance. Alloy wheels are lighter and stronger than steel which makes alloy wheels more durable and better able to withstand the forces exerted on a vehicle while driving. The use of alloy wheels dates back to the early 1900s, but they did not

become widely popular until the 1960s and 1970s. Today, alloy wheels are standard on most new cars, and many drivers choose to upgrade their steel wheels to alloy wheels for the improved performance and appearance they offer.

1.5 Importance of an alloy wheel:

An alloy wheel is a type of wheel that is made from a mixture of metals, rather than just one type of metal. This makes the wheel stronger and more durable than a traditional steel wheel, and it also allows the wheel to be designed with a more aesthetically pleasing appearance. Alloy wheels are important because they are typically lighter and stronger than steel wheels, which can improve a vehicle’s performance, handling, and fuel efficiency. Additionally, alloy wheels are often more aesthetically pleasing and can improve the overall appearance of a vehicle.

1.6 Types of wheel rim material:

Steel and light alloy are the foremost materials used in a wheel rim however some composite materials together with glass-fibre are being used for special wheels. Various metals can be used for the rim. Commonly seen are alloy (magnesium and Aluminium), mag (magnesium), Aluminium, and chrome. Teflon coatings are sometimes also applied for an extra layer of protection.

1. Wire spoke wheel
2. Steel disc wheel
3. Light alloy wheel

1.7 Selection of material:

Alloy wheels are made of an alloy of Aluminium and magnesium, which makes them light and strong. Normal wheels are pressed from steel and may bend if it hits some undulation hard on the road. You can use tubeless tyres on mag alloy wheels, but on regular wheels you have to use tubed tyres. The Aluminium alloy wheel usually has better heat conductivity, anticorrosive properties and is much lighter than the steel wheel making it the best option for passenger vehicles. Aluminium alloy wheels are manufactured using casting and forging process. Less weight on the wheel creates less stress on the tire, and so a balance is created. Aluminium and alloy wheels are largely corrosion-resistant, but prone to galvanic corrosion. They are available in attractive bare-metal finishes because of their anti-corrosive properties which eliminates any need for paint. They also enhance performance by manipulating handling and suspension and add a brilliant appearance to the vehicle. In this project, A356 (A356.0) Aluminium alloy is a typical material for aircraft applications. Unlike wrought alloys, cast Aluminium has a different designation system. In this article, we’ll focus on A356 (A356.0) Aluminium alloy, explain what is A356 Aluminium, list its composition, properties, tempers, and uses, as well as 6061 vs A356. For superior quality A356 Aluminium casting parts, we’re capable of Aluminium die casting for a wide range of industries.

1.8 Comparison of materials:

A356(A356.0) Aluminium Properties – Physical and Mechanical Properties of A356 Aluminium. 14 The properties

of A356.0 Aluminium including 5 variations (tempers), they are A356.0-F, A356.0-T6, A356.0-T51, A356.0-T61, and A356.0-T71. T6 heat treatment of A356 Aluminium castings offers improved hardness and other mechanical properties. Here we create a chart that shows some properties of A356.0 Aluminium in the T51, T6, and T71 temper.

PROPERTIES	A356.0-T51	A356.0-T6
Yield strength	120Mpa	200Mpa
Ultimate tensile strength	180Mpa	270Mpa
Shear modulus	26Gpa	26Gpa
Fatigue strength	53Mpa	90Mpa
Elongation at break	3.0%	6.0%
Elastic modulus	70Gpa	70Gpa
Density	2600Kg/m^3	2600Kg/m^3
Thermal conductivity	150W/m-K	150W/m-K
Melting completion	610°C	610°C
Melting onset	570°C	570°C
Thermal expansion	21µm/m-k	21µm/m-k

1.9 Introduction to Solid works:

Solid works is one of the products of Solid works Corporation, which is powered by Dassault Systems 3D experience platform. Solid works mechanical design automation software is a feature-based, parametric solid modelling design tool that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. It takes advantage of the easy to learn Windows graphical user interface in which designers can use simple drag and drop (DD), copy paste functionality same as in the Windows. Many of the icons such as print, open, cut and save are also part of the Solid works application which is familiar with Windows functions. When designing a model using Solid works, you can visualize it in three dimensions, the way the model exists once it is manufactured. Solid works is structured in three basic types: part mode, assembly mode and drawing mode. Part mode is the basic building block in this software. For example, you must have to create a part before you create assembly.

Assembly mode contains parts or other assemblies, called subassemblies.

These three modes are discussed below one by one.



Figure: Sketching and revolving operation

1.10. Basic concepts of Solid works:

Parts are the basic building blocks in the SOLID WORKS software. Assemblies contain parts or other assemblies, called subassemblies. A SOLID WORKS model consists of 3D geometry that defines its edges, faces, and surfaces. The SOLID WORKS software lets you design models quickly and precisely. SOLID WORKS models are:

- Defined by 3D design 17
- Based on components

3D Design

SOLID WORKS uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies. When designing a model using SOLID WORKS, you can visualize it in three dimensions, the way the model exists once it is manufactured.

Component Based

One of the most powerful features in the SOLID WORKS application is that any change you make to a part is reflected in all associated drawings or assemblies.

1.11 Terminology of Solid works:

These terms appear throughout the SOLID WORKS software and documentation. Origin Appears as two blue arrows and represents the (0,0,0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0,0,0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin. 18 Plane Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, or a neutral plane in a draft feature, for example. Axis Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The SOLID WORKS application creates temporary axes implicitly for every conical or cylindrical face in a model. Face

Boundaries that help define the shape of a model or a surface. A face is a selectable area (planar or nonplanar) of a model or surface. For example, a rectangular solid has six faces. Edge Location where two or more faces intersect and are joined together. You can select edges for sketching and dimensioning, for example. Vertex Point at which two or more lines or edges intersect. You can select vertices for sketching and dimensioning, for example.

1.12 Introduction to Ansys Workbench:

The idea for Ansys was first conceived by John Swanson while working at the Westinghouse trinuclear Laboratory in the 1960s. At the time, engineers performed finite element analysis (FEA) by hand. Westinghouse rejected Swanson's idea to automate FEA by developing general purpose engineering software, so Swanson left the company in 1969 to develop the software on his own. He founded Ansys under the name Swanson Analysis Systems Inc. (SASI) the next year, working out of his farmhouse in Pittsburgh. Swanson developed the initial Ansys software on punch-cards and used a mainframe computer that was rented by the hour. Westinghouse hired Swanson as a consultant, under the condition that any code he developed for Westinghouse could also be included in the Ansys product line. Westinghouse also became the first Ansys user. Ansys develops and markets engineering simulation software for use across the product life cycle. Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analysing the strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

What is Ansys Mechanical:

ANSYS a product of SASI (System Analysis Simulation and Integrating). It is a world's leading software which run on CAE (computer aided engineering) and FEM (finite element methods). It is widely used by designers/analysis in industries such as aerospace, automotive, manufacturing, nuclear, electronics, biomedical, and much more. ANSYS provides simulation solution that enables designers to simulate design performance directly on the desktop. In this way, it provides fast efficient and cost-efficient product development from design concept stage to performance validation stage of product development cycle. In ANSYS, the basics of FEA concepts, modelling and the analysing of engineering problem using ANSYS workbench. In

addition, describe of importance tools and concepts given whenever required. this following simulation streams of ANSYS.

2. LITERATURE REVIEW:

[1] **Prasad SatisDivekar, Dr. ThippeswamyEkbotel:** In this research work the wheel modelling in CAD & analysed with Ansys software. In analysing different properties in 6 different materials (Al alloy, Mg alloy, titanium alloy, carbon/epoxy, E glass/epoxy, S glass/epoxy). Aluminium alloy has better sustainable properties when compared to other alloy materials, which has better deformation factors and stress now a days Aluminium alloy is widely used because it has good Equivalent Elastic Strain and deformation coefficient. But composite material has better advantage than aluminium alloy material because of its low weight, low deformation factor and high stress handling properties T. Siva Prasad et al. This study wheel rim is modelled by using modelling software Catia. Catia model is imported to Ansys for analysis work.

[2] **Sourav Das et al :** investigated the aluminium alloy by finite element method, emphasis on reduction of mass of wheel rim. There is approx. 50% mass reduction of aluminium alloy for existing alloy model. The finite element method used for optimizing the component by yield stress calculation. The test condition taken as radial fatigue condition, where fatigue life and stress distribution estimated. The yield stress of alloy material estimated up to 90 MPA for safe application.

[3] **B. LALUNAYAK et al:** In this study the Modelling of the different wheel rims (elliptical spokes shape, Hexagon shape) is generated in CATIA and this is imported to ANSYS (14.5) for processing work. Alloy wheel rim has been designed using Catia software, after that static and 31 modal analysis is done with different materials (Carbon Fibre, Mg Alloy, Al 6061) boundary conditions taking in ANSYS 14.5 Software. Taking boundary conditions on alloy wheel Radial load 3240N is applied along the circumference of the wheel rims Finally observed results of stress, total deformation, and shear stress on different wheel rims and materials and compared with each other. Thus, the best design and material can be selected for manufacturing of the alloy wheel. AL6061 with Elliptical spoke shape have subjected to more total deformation compared to Remaining materials 2 materials. Carbon fibre have less deformation.

[4] **M. Swamy, D Suresh Reddy:** in this study the modelling of alloy wheel is done is SOLID WORKS design software by using various structural analysis is carried out in ANSYS work branch at two different pressure with four different material such as aluminium alloy, Mg alloy, Peek material, Peek (20% carbon fibre) material.

[5] **J. Stearns:** The wheels of an automobile are usually made out of steel but due to the increased demand for peculiarity and enhanced outlook alloy materials are used for the wheels these days. Many researchers have been carried out

based on enhancing the geometry of the beam, like slightly curved beams could employ more behavioural changes and increased stiffness and 32 some have done research on the structure which concluded bi-directional fabrics could be more efficient and some changes can be made because of changes in cross section.

3. METHODOLOGY:

In this project we followed the methodology given in the below, first we collected all the related information about the different Aluminium alloys and then collecting some of the literature review.

- Problem identification.
- Selection of material.
- Creating a 3D model in SOLID WORKS.
- Analysing the model (Static structural analysis)
- Comparing the results.

1. **Problem identification:** The Aluminium alloy A356.0T51 used in production of alloy wheels. We done modelling of wheel using the other alloy to increase its properties.

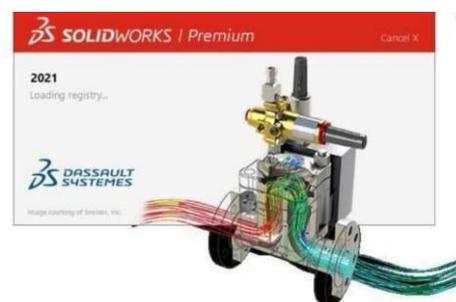
2. **Selection of material:** A356 Aluminium die casting alloy has good casting and machining performance. often used to manufacture intricate and complex Aluminium castings. It provides lightweight, pressure tightness and great mechanical properties.

3. **Creating a 3D model in SOLID WORKS:** A solid model an alloy wheel is modelled using the software Solid works using the different commands in Solid works. The design specifications are taken as per the our reference. 4. **Analysing:** the model The model created using Solid works is imported to the Ansys for the analysis. The static structural analysis of alloy wheel is done using the commands in Ansys.

5. **Comparing the results:** The properties of the alloy wheel A356.0-T6 has better properties when compared to the alloy A356.0-T51.

4. MODELLING:

4.1 Modelling of an alloy wheel



Feature based parametric bidirectional associative software It is a advanced designing software compared to Auto Cad, and in Auto Cad we can complete all the tasks in single window, but

in this we have different windows those windows here we call as modules, the main Modules in designing are

- 1 Part
- 2 Assembly
- 3 Drawing

Total 5 sub modules in part they are

- Sketcher, feature, sheet metal, surface and weld met. Open the Solid works by right clicking or double
- Clicking on the desk top. Select the file and select new then you will be getting the three modules
- Select the front plane. Sketch and draw the profile of the rim using the command functions like line, cantered line, use the smart dimension option for lines and to measure the angles. • Select exit sketch. And u will be entering into features. Here you can solidify it. Go to: Insert > surface > Extrude or click on the Extrude icon the surface-Extrude menu appears Direction 1 is set to blind. When you use the Blind feature, you'll get a solid extrude surface.
- Draw an axis and use revolve command
- Draw a line to extrude a disc for the inner side of the wheel.
- Adding a material for extrusion of the centre axle draw a line extrude it using extrude command.
- Fillet/Round creates a rounded internal or external face on the part. You can fillet all edges of a face, selected sets of faces, selected edges, or edge loops. • Click Modify > Fillet (or type Fillet).
- Filleting the centre line of rim inner side of the wheel rim.
- EXTRUDED BOSS/BASE: Adding of material normal to a sketch drawn in a plane. Go to Tools> Sketch Entities > Centre circular elongated slot a sketch which starts at the Origin. Select exit sketch. And u will be entering into features. Here you can solidify it. 39 Go to: Insert > Boss/Base > Extrude or click on the Extrude icon. The Boss-Extrude menu appears Direction 1 is set to blind. When you use the Blind feature, you'll get a solid extrude.
- Boss extrusion of wheel mounting surface using commands.
- FILLET: create a rounded corner between the wheel mounting surface and centre line of rim.
- Cut-Extrude: It is same as extrude. But it removes material from an existing solid in a cross section drawn. Draw a sketch then use extrudes in surface it. And draw a profile on the surface of the solid body. Select the cut with surface tool and remove the material.
- The material removed for making holes to for the wheel housing and bolts and nuts to fix it.
- The chamfer tool creates a bevelled feature on selected edges, faces, or a vertex. To create a chamfer: Click Chamfer (Features toolbar) or Insert > Features > Chamfer. Under Chamfer Parameters, select an item and set parameters.
- The outer side of the bolt holes are chamfered using chamfer command. This done to make the nuts fix without any irregularities.
- Cut-Extrude: It is same as extrude. But it removes material from an existing solid in a cross section drawn. Draw a sketch then use extrudes in surface it. And draw a profile on the surface of the solid body. Select the cut with surface tool and remove the material. • The operation is done to cut the

windows of the wheel. • Create extruded surfaces from models that include 2D or 3D faces and knit the extruded surfaces to surrounding features. • Click Insert > Surface > Extrude. Select a face: To extrude from a 3D face, select a 3D face. To extrude from a 2D face, press Alt + select the planar face.

- Thin layer is extruded to the windows of the wheel.
- Revolve cut step-by-step revolve features involve spinning a profile around a fixed point – the Axis of Revolution. This Axis can be a sketch line, an existing edge or a previously created axis feature. Often it makes sense to use a Construction Line, as this line will be ignored when revolving the actual profile. • The thin layer of the window of the wheel is cut-revolved.
- FILLET: create a rounded corner to the outer surface window and the disc of the wheel.
- Sketch and revolve to get tyre mounted on the rim.

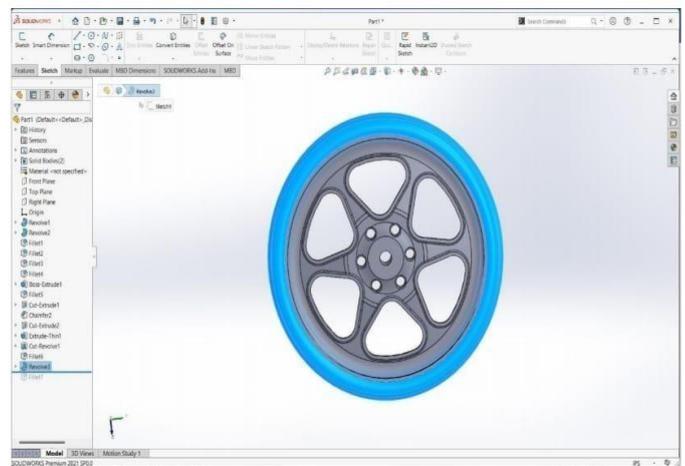


Figure: Sketching and revolving operation

5. STRUCTURAL ANALYSIS OF ALLOY WHEEL:

Static Analysis A static analysis calculates the effects of study loading conditions on a structure, which ignoring inertia and damping effects such as those caused by time varying loads. A static analysis can, however, includes study 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, strain, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Study loading and resonance conditions are assumed; that is, the loads and the structures response are assumed to vary slowly with respect to time.

To 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 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. Basic steps in this analysis are Importing an alloy wheel, Meshing the model by applying material properties, Applying the necessary loading and boundary conditions, Analysing the model analysis type as static.

5.1 ANALYSIS OF A356.0-T6 ALUMINIUM ALLOY

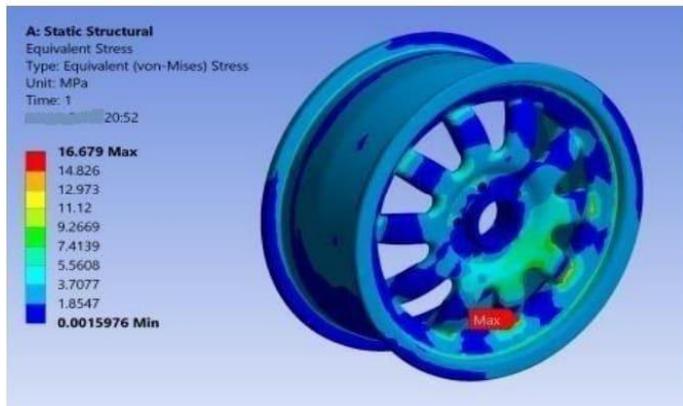
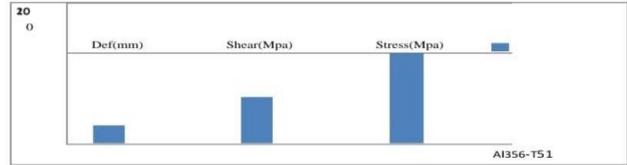


Figure: Equivalent Stress

6. Results And Discussion:



GRAPH1: A356.0-T51



GRAPH 2: A356.0-T6

7. CONCLUSION:

Model of the wheel rim is generated in SOLID WORKS and this is imported to ANSYS for processing work. In static loading, the different loads are applied along the circumference of the wheel rims for both Aluminium Alloy A356.0-T51 and Aluminium Alloy A356.0-T6 and hub circle of wheel rim is fixed.

Aluminium alloy A356.0-T51 wheel rim subjected to more deformation when compare to the aluminium alloy A356.0-T6. In both cases stress generated is less than the yield strength, hence design is safe. In both cases von-mises stress are less than ultimate strength. Aluminium alloy A356.0-T6 wheel rim has more life when compare to the aluminium alloy A356.0-T51. The alternating stress is more in aluminium alloy A356.0-T51 when compare to the aluminium alloy A356.0-T6. By comparing all result we are suggested that Aluminium alloy A356.0-T6 is better material than aluminium alloy A356.0-T51 for designing of alloy wheel.

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