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Design and Evolution of characteristic properties of automotive wheel spoke by using Aluminum alloy materials

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ABSTRACT
In Automobile parts one of the major important part is a wheel spoke because the load of the automobile parts is acted on the spokes. Due to the load vehicle parts, Should have high strength and good fatigue property spoke. In this project wheels are designed with five spokes and four spokes and comparison has done between the two models using aluminum alloy(LM 25) and Comparing properties of stress and displacement with Magnesium Alloy(AM 60A) and also the fillet radius is modified. The model is created using pro-e and analysis done in SOLIDWORKS software. Finally by comparison of two materials, aluminum composite material LM25 with the change in fillet radius has good fatigue life, low stress and high displacement.
Keywords: PRO-E, SOLIDWORKS, Fillet Radius, Aluminum composite material LM25.

INTRODUCTION
The wheel is a device that enables efficient movement of an object across a surface where there is a force pressing the object to the surface. Early wheels were simple wooden disks with a hole for the axle. Because of the structure of wood a horizontal slice of a trunk is not suitable, as it does not have the structural strength to support weight without collapsing; rounded pieces of longitudinal boards are required. The spoke wheel was invented more recently, and allowed the construction of lighter and swifter vehicles. Alloy wheels are automobile wheels which are made from an alloy of aluminum or magnesium metals [10] (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, however some alloy wheels are heavier than the equivalent size steel wheel. Alloy wheels are also better heat conductors than steel wheels, improving heat dissipation from the brakes, which reduces the chance of brake failure in more demanding driving conditions. Over the years, achieving success in mechanical design has been made possible only after years of experience coupled with rigorous field-testing. Recently the procedures have significantly improved with the emergence of innovative method on experimental and analytical analysis. Alloy wheels intended for normal use on passenger cars have to pass three tests before going into production the dynamic cornering fatigue test, the dynamic radial fatigue test, and the impact test. Many alloy wheels manufacturing company had done numerous amount of testing of their product but their method on simulation test on alloy wheel information often kept limited[13].

The composite materials wheel, is different from the light alloy wheel, and it (Generally, it is thermoplastic resin which contains the glass fiber reinforcement material) is developed mainly for low weight. However, this wheel has insufficient reliability against heat and for strength. Development is continuing [14].

Wheel Material:

Magnesium Alloy

Chemical Composition limits of AM60A

Element	**Al**	**Mn**	**Si**	**Zn**	**Fe**	**Cu**	**Ni**	**Other**	**Mg**
% of material	5.5 to 5.6	0.25	0.10	0.22	0.005	0.010	0.002	0.003	Remaining

Mechanical Properties
- Name :**Magnesium alloy AM60A**
- Yield strength : **130 N/mm²**
- Elastic modulus : **45000 N/mm²**
- Poisson's ratio : **0.35**
- Mass density : **1.8 gm/CC**

Aluminum Alloys

Chemical Composition limits of LM 25

Element	**Si**	**Mn**	**Mg**	**Zn**	**Fe**	**Cu**	**Ni**	**Other**	**Al**
% of material	6.5 to 7.5	0.3	0.20 to 0.60	0.22	0.5	0.1	0.1	0.45	Remaining

Mechanical Properties	**LM25**
Tensile Stress (N/mm2)*	130-150
Elongation (%)*	2
Modulas of Elasticity(GPa)	71
Poisson's ratio	0.33
Density (gm/cc)	2.685

Effects of Alloying Elements
The Aluminum Association's Designations and Chemical Composition Limits for Aluminum Alloys in the Form of Castings and Ingot lists for each alloy 10 specific alloying

elements and also has a column for “others”. Not all of the listed elements are major alloying ingredients in terms of an alloys intended uses; and some major elements in one alloy are not major elements in another. For example, can be very important to microstructure control and mechanical properties but are not specifically identified in the Aluminum Association document and are instead are merely included in the category “others”. For purposes of understanding their effects and importance, alloying elements for the majority of alloys are probably best classified as major, minor, microstructure modifiers or impurities; understanding, however, that impurity elements in some alloys might be major elements in others:

• **<u>Major elements</u>** typically include silicon (Si), copper (Cu) and magnesium (Mg)

• **<u>Minor elements</u>** include nickel (Ni) and tin (Sn) found largely in alloys that likely would not be used in high integrity die castings.

Necessity of using alloy wheels

Alloy wheels are automobile (car, motorcycle and trucks) wheels which are made from an alloy of aluminum or magnesium metals (or sometimes a mixture of both).

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

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. 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.

Alloy wheels are not only for improved driving performance; they are also for cosmetic purposes. The alloys used are largely corrosion-resistant, permitting an attractive bare-metal finish, with no need for paint or wheel covers, and the manufacturing processes allow intricate, bold designs. In contrast, steel wheels are usually pressed from sheet metal, and then welded together (often leaving unsightly bumps) and must be painted (as they corrode otherwise) and/or hidden with wheel covers / hub caps.

The earliest light alloy wheels made were made of magnesium alloys. Although they lost favor for common vehicles they remained popular through the 1960s albeit in very limited numbers. In the mid to late 1960s aluminum casting refinement finally started to allow manufacture of wheels that were safe. Until this time most aluminum wheels suffered from low ductility, usually ranging from 2-3% elongation. This meant these earlier aluminum alloy wheels were quite brittle, and as light alloy wheels at the time that were often made of magnesium and referred to as "mags" these early wheel failures were later attributed to magnesium's low ductility, when in many instances these wheels were poorly cast aluminum alloy wheels. Once these aluminum casting improvements were more widely adopted, the aluminum wheel took its rightful place as low cost high performance wheels for motorsports.

Most alloy wheels are cast into a mold, and the end result is a smoother ride and less tire stress than the traditional steel wheel and hubcaps. Most steel wheels are "cold rolled and welded," and usually have some movement - either high or low - in the welded seam area. They also tend to be heavier in the welded seamed areas and many have leaks, such as some of the Hyundai steel wheels.

But aluminum wheels are cast into a mold in a hot liquid state and cooled, which makes them more accurate in both the heavier and lighter areas. The end result is a balance that has less weight on the wheel and less stress on the tire.

Steel wheels are a great way to provide basic transportation for a basic car, but for those who want to extend the life of their tires and have a smoother ride, alloy wheels are the way to go. Aluminum wheels also provide a lighter weight for the racing enthusiast, and can be machined for a brilliant appearance.

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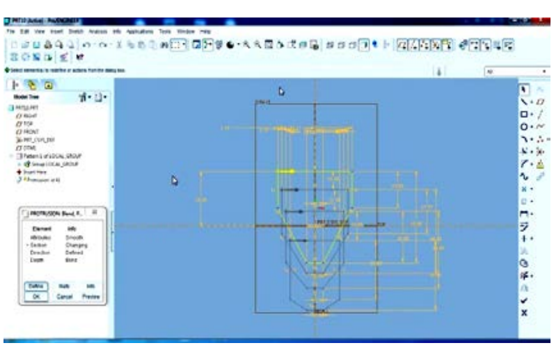
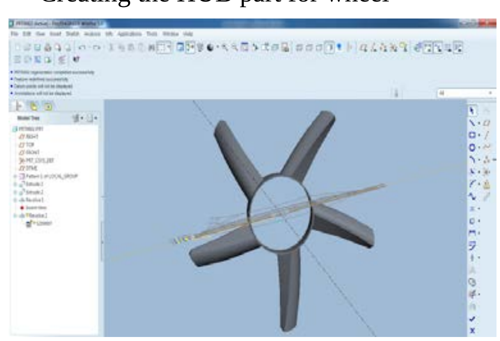
MODELING OF ALLOY WHEEL:

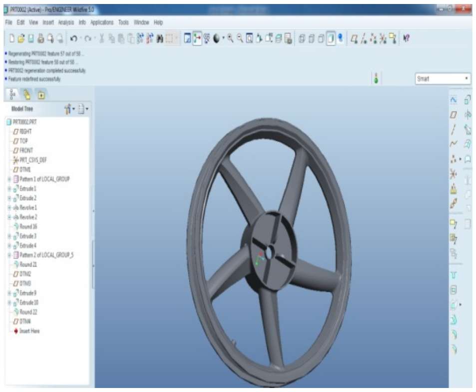
Sketcher mode of the Spoke



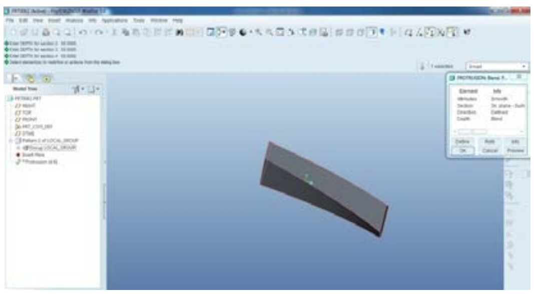
Creating the HUB part for wheel



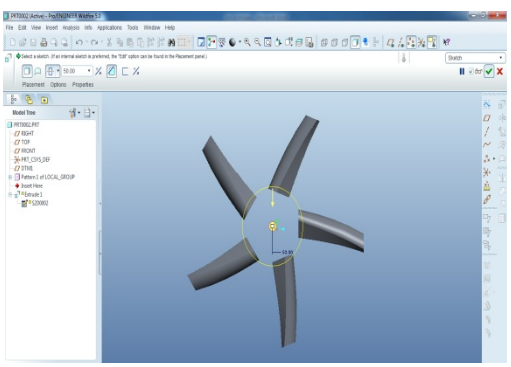
Creating the Rim Part of wheel

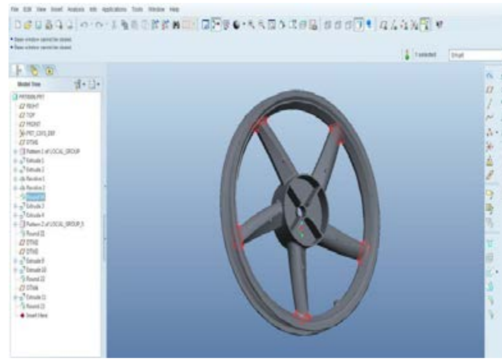


Creating the Spoke of the wheel



Creating Circular Pattern for Spoke





Creating the round edges at corners

INTRODUCTION TO SOLIDWORKS:

SolidWorks is a feature-rich control and configuration software for the Avitech line of products. It uses a GUI (graphical user interface) for configuring and editing complex Multiviewer systems. Preset configurations can be created, edited, are called. SolidWorks is designed to interface with third-party hardware such a routing switchers, production switchers, and Tally management systems allowing for dynamic label changes and Tally indicators on the display. SolidWorks will run on virtually any computer, running the windows operating system.

SolidWorks Simulation Xpress simulates the testing of your part's prototype in its working environment. It can help you answer questions like: how safe, efficient, and economical is your design. SolidWorks Simulation Xpress is used by students, designers, analysts, engineers, and other professionals to produce safe, efficient, and economical designs.

Solid-works Simulation

Types of analysis: Static Analysis and Fatigue Analysis.

Material Properties:

Name	:	Aluminum alloy LM 25	Magnesium alloy AM60A
Yield strength	:	235 N/mm^2	130 N/mm^2
Elastic modulus	:	71000 N/mm^2	45000 N/mm^2
Poisson's ratio	:	0.33	0.35
Mass density	:	2.685gm/CC	1.8 gm/CC

Applied Loads

Load1	:	weight of Bike (168 kg)
Load2	:	(168+50) kg
Load3	:	(168+100) kg
Load4	:	(168+150) kg

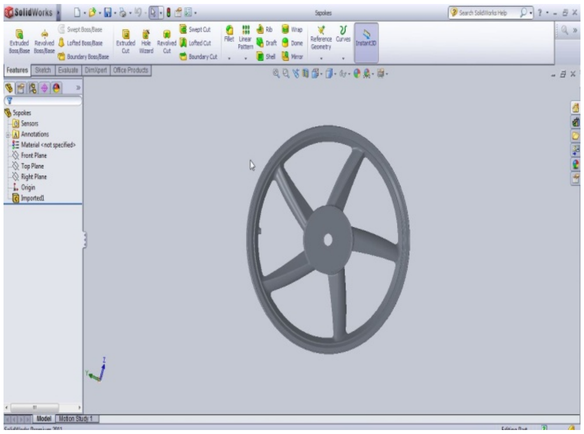
Importing of Alloy Wheel:

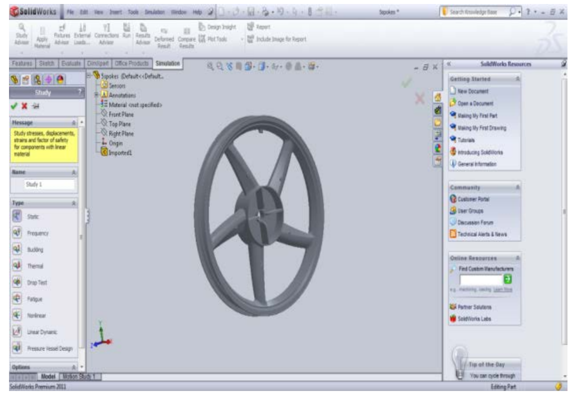
Steps to be followed for importing the model from Pro-E

- Open the Pro-Engineer in the computer, select the Pro-E model which has to be import into the SOLIDWORKS.
- Select File-> save a copy->select type as *.igs as shown in figure.

- Name the file something memorable, and click the ok check mark.
- Export the model into solid and shells, click on ok.
- Then the Pro-E part is saved in the *.igs format, which can be opened in the solid works for simulation.

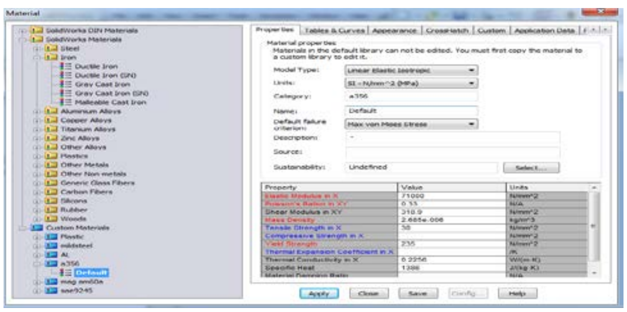
Imported model of alloy wheel spoke into solid works for simulation

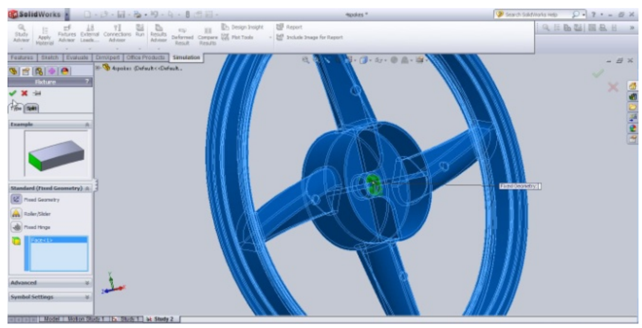




alloy wheel spoke into solid works

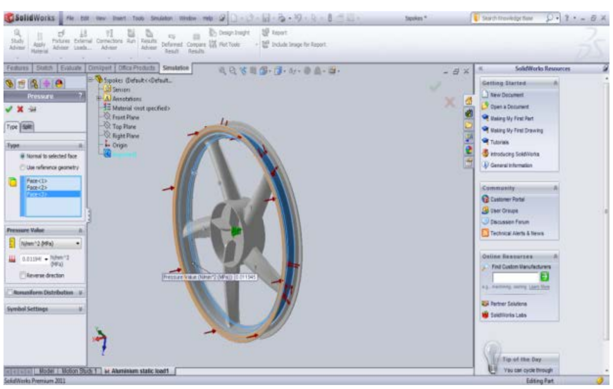
How to Assign the Fixtures





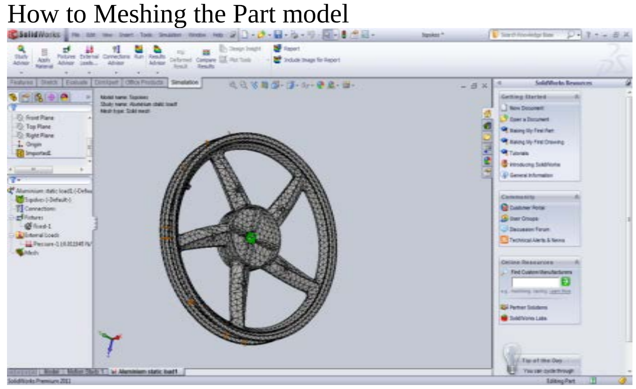
How to Assign the Material

How to Assign the Pressure



How to Assign the Fixtures

How to Meshing the Part model



RESULTS:

Stress analysis values for 5-Spokes Mg-alloy & Al-alloy

5-Spokes	Aluminum Alloys LM 25	Magnesium alloy AM60A
LOAD1	1.23366	1.24426
LOAD2	1.60394	1.61467
LOAD3	1.97349	1.98441
LOAD4	2.34163	2.35595

Stress analysis values for 4-Spokes Mg-alloy & Al-alloy

4-Spokes	Aluminum Alloys LM 25	Magnesium alloy AM60A
LOAD1	1.16996	1.18167
LOAD2	1.52037	1.53389
LOAD3	1.87069	1.88506
LOAD4	2.22184	2.23756

Fatigue Life values for 5-Spokes and 4-Spokes Mg-alloy & Al-alloy

5-Spokes and 4-Spokes	Magnesium alloy (AM60A)	Aluminum Alloys (LM 25)
LOAD1	1.0E8	1.2E7
LOAD2	1.0E8	1.2E7
LOAD3	1.0E8	1.2E7
LOAD4	1.0E8	1.2E7

Stress analysis values for 4-Spokes Mg-alloy(AM 60A) and Al-alloys(LM 25) with different Fillet radii.

4-Spokes	Aluminum alloy (LM 25)with Fillet 8 mm	Aluminum Alloy (LM 25) with Fillet 9mm
LOAD1	1.16881	1.16252
LOAD2	1.51887	1.51193
LOAD3	1.86912	1.86125
LOAD4	2.22029	2.21029

Aluminum Alloy (LM25) is utilized for the validation of this thesis from Deepak(2012)[25]. Analysis is done on the three different Al-alloys and also on an existing material of the Magnesium alloy (AM 60A).

The stresses obtained in the three different alloys are less as compared with the LM25, because if a material is heated to high temperature followed by quenching in hot water or rapid cooling,

- Larger grains will break into small grains.
- Hardness and Strength increases, due to Ionic bond between the molecules.

But the Stresses obtained in the Magnesium Alloy (AM 60A) is more as compare with all the three Aluminum Alloys, because an HCP structure exists in magnesium which makes magnesium more brittle because of their few active slip systems. Also magnesium is highly active in presence of Oxygen forming magnesium oxide and an improvement is needed in heat dissipation and micronization of Crystal grains of magnesium. Due to all these, the stresses obtained in Mg-alloy are more as compared with all Al-Alloys.

CONCLUSIONS:

An Al-Alloy Wheel was modeled using Pro-E of two Spokes i.e., 4 and 5with fillet radii (8mm and 9mm).These models were analyzed using SOLIDWORKS for five different materials,LM 25 and AM60A.

From the results obtained it may be concluded that

- The analysis results showed that the maximum stress area was located at Spoke-Rim contact. Stresses induced in 4-Spokes Aluminum Alloy (LM 25) are less as compared with Magnesium Alloy (AM 60A) and all the three Aluminum Alloys of 4 and 5 Spokes.
- Fatigue life cycle is estimated based on the Equivalent Stresses induced on Al-alloys and Mg-alloy material. Fatigue life cycle for the Mg-alloy is more as compared with all Al-

alloys material.

- Re-model of alloy wheel, from 5-Spokes to 4-Spokes, along with small change in Fillet radius from 8 mm to 9 mm, at Rim-Spoke contact. The Stresses induced in Aluminum alloy (LM 25) are further reduced as compared to all the three Al-alloys.

Thus, it is clear that by adding the material at fillet edges the stress concentration will be reduced which in turn increases the fatigue life of the material and material reduction can be done by reducing number of Spokes.

Even though, the Fatigue Life of Magnesium alloy is more, by considering all the properties of Aluminum alloy like easy availability, recyclable, good heat dissipation rate. Aluminum Alloy (LM 25) is the better material for alloy wheels.

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