# Analysis on Wheel Spoke With Aluminum Composite Materials

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**ABSTRACT**

Automobile parts one of the major important part is a wheel spoke because of all of the automobile parts carried by spokes. Heavy load carrying vehicles having high strength and good fatigue property spoke. In this work new spoke is designed and from five spokes to four spokes and comparing of these spokes by using new 4 aluminum composite materials LM 25, LM25TB7, LM 25TE, LM25TF. Comparing properties of stress and displacement with Magnesium Alloy (AM 60A). Model is developed in Unigraphics and analysis done in cosmos software. Finally absorbing in my project compare to all material what are the material using in this project the aluminum composite material LM25TF was good fatigue life, low stress and high displacement.

**Keywords :** LM 25, LM25TB7, LM 25TE, LM25TF

## I. 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 (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.
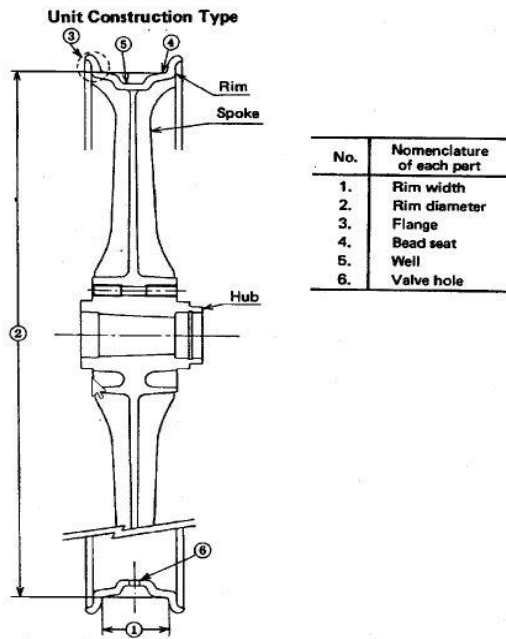
## Wheel Rim Nomenclature



**Fig 1.** Wheel Rim Nomenclature

**Hub:** This forms the interface between the hub of the vehicle's drive train and the wheel. This part will have the bolt holes to facilitate in the fastening of the wheel to the vehicle.

**Wheel disc or spokes:** This is the part of the wheel that transfers all of the loads.

**Rim flange or lips:** These lips retain the tire and also act as a strength-rib to protect the wheel against impact loads.

**Bead seat:** The tire bead will rest against this area.

**Humps:** These humps will ensure that the tire stays against the rim flange in the deflated condition.

**Rim well:** This area facilitates in the assembling and disassembling of the tire.

The rim of a wheel is the outer circular design of the metal on which the inside edge of the tyre is mounted on vehicles such as automobiles. For example, in a two wheeler the rim is a hoop attached to the outer ends of the spokes-arm of the wheel that holds the tyre and tube.

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.

Wheel rim is the part of automotive where it heavily undergoes both static loads as well as fatigue loads as wheel rim travels different road profile. It develops heavy stresses in rim so we have to find the critical stress point and we have to find for how many number cycle that the wheel rim is going to fail.

## Shape of Rim

Typical rim shape vehicles are made up of the following three types.
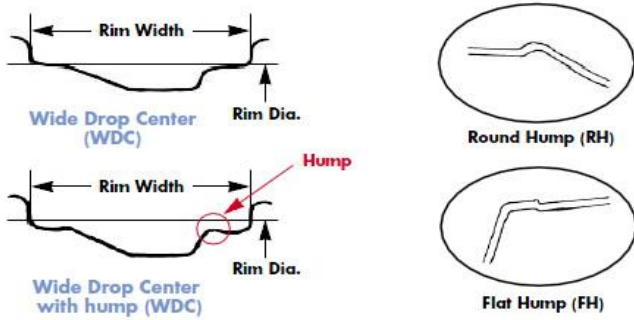
## Drop Center Rim (DC)

Drop Center Rim (DC Rim) is shaped so there is a well between the bead seat part which is located on both sides of the rim. This well is to make the mounting and dismounting of the tire easy. In most cases there is a taper of 5 degrees in the bead seat area.

## Wide Drop Center Rim (WDC)

Wide Drop Center Rim (WDC Rim) is basically the same as DC Rim. To expand the width of the rim, with a shallower well and a lower flange height, this rim is mainly applied to low aspect ratio tires. This design is currently applied to rims for tires of most passenger vehicles.

## Wide Drop Center Rim with hump (WDC)

In addition, this design has a bump, which is called a hump, on the beginning of the bead seat area. This hump is to prevent the bead slipping down and air leakage from the rim due to the horizontal force applied to the tire when a vehicle tubeless tires turns at high speed.

**Fid 2.** Shapes of Wide Drop Center Rim, with Hump

## Wheel Material:

### Magnesium Alloy

### Chemical Composition limits of AM60A [9]

| 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 [18]

| Element | Si | Mn | Mg | Zn | Fe | Cu | Ni | Other | Al |
|---------|----------|-----|-------------|------|-----|-----|------|-------|----------|
| % of material | 6.5 - 7.5 | 0.3 | 0.20-0.60 | 0.22 | 0.5 | 0.1 | 0.45 | 0.45 | remaining |

### Mechanical Properties

| | LM25-M | LM25-TE | LM25-TB7 | LM25-TF |
|---|--------|---------|----------|---------|
| Tensile Stress (N/mm2)* | 130-150 | 150-180 | 160 | 230-280 |
| Elongation (0%)* | 2 | 1 | 2.5 | 2.5 |
| Modulas of Elasticity(GPa) | 71 | 71 | 71 | 71 |
| Poisson's ratio | 0.33 | 0.33 | 0.33 | 0.33 |
| Density (gm/cc) | 2.685 | 2.685 | 2.685 | 2.685 |

## HEAT TREATMENT

- LM25-TE (Precipitation treated) - Heat for 8-12 hours at 155- 175°C and allow to cool in air
- LM25-TB7 (Solution treated and stabilized)-heat for 4-12 hours at 525-545°C and quench in hot water, followed by a stabilizing treatment at 250°C for 2-4 hours.
- LM25-TF (Fully heat treated)- heat for 4-12 hours at 525- 545°C and quench in hot water, followed by a precipitation treatment of 8-12 hours at 155-175°C.

## Effects of Alloying Elements[26]

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. Also, some elements, like Sr 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:

- **Major elements** typically include silicon (Si), copper (Cu) and magnesium (Mg)
- **Minor elements** include nickel (Ni) and tin (Sn) -- found largely in alloys that likely would not be used in high integrity die castings.

## Major Elements

**Silicon:** Silicon (Si) is unquestionably the most important single alloying ingredient in the vast majority of aluminum casting alloys. Silicon is primarily responsible for so-called "good castability"; i.e., the ability to readily fill dies and to solidify castings with no hot tearing or hot cracking issues.

Silicon's important role as an alloying ingredient is several-fold:

- Silicon's high heat of fusion contributes immensely to an alloy's "fluidity" or "fluid life".
- The fact that silicon has limited solid solubility (maximum 1.65%) and yet forms a eutectic with aluminum at a significantly high level (12%) means that alloys with more than a few percent silicon undergo a relatively large volume fraction of isothermal solidification, thus they gain significant strength while undergoing little or no thermal contraction - very important to avoiding hot tearing or hot cracking issues.
- The more silicon an alloy contains, the lower is its thermal expansion coefficient.
- Silicon is a very hard phase, thus it contributes significantly to an alloys wear resistance.
- Silicon combines with other elements to improve an alloy's strength and to make alloys heat treatable.
- Silicon can cause a permanent increase in a casting's dimensions (termed "growth") if the part is not thermally stabilized before being put into elevated temperature service.

**Copper:** Copper (Cu) has the single greatest impact of all alloying elements on the strength and hardness of aluminum casting alloys, both heat-treated and not heat-treated and at both ambient and elevated service temperatures. Copper also improves the machinability of alloys by increasing matrix hardness, making it easier to generate small cutting chips and fine machined finishes.On the downside, copper generally reduces the corrosion resistance of aluminum; and, in certain alloys and tempers, it increases stress corrosion susceptibility.

Aluminum-copper alloys that do not also contain at least moderate amounts of silicon have relatively poor fluidity and resistance to hot tearing during solidification. Although alloys with up to 10% copper were popular in the very early years of the aluminum foundry industry, they have now been replaced by silicon containing alloys, with the exception of the very-high-strength alloy 206 that is described later.

**Magnesium:** Magnesium's (Mg) role is also to strengthen and harden aluminum castings. As mentioned earlier in this section, silicon combines with magnesium to form the hardening phase, $Mg_2Si$ that provides the strengthening and heat treatment basis for the popular 356 family of alloys. Magnesium is also the strengthening ingredient in the high magnesium 5XX alloys that contain very little silicon; those alloys too depend on $Mg_2Si$, but gain additionally from other magnesium-bearing phase.

## Minor Elements

**Nickel:** Nickel (Ni) enhances the elevated temperature service strength and hardness of 2XX alloys. It is employed for the same purpose in some 3XX alloys, but its effectiveness in the silicon-containing alloys is less dramatic.

**Tin:** Tin (Sn) in 8XX aluminum casting alloys is for the purpose of reducing friction in bearing and bushing applications. The tin phase in those alloys melts at a very low temperature (227.7 C). Tin can exudes under emergency conditions to provide short-term liquid lubrication to rubbing surfaces if such bearings/bushings severely overheat in service. The 8XX series alloys are not generally applicable to die casting or its variations and thus are not shown among the alloys suitable for high integrity die casting.

## Tests conducted on Wheel[22]

Wheels are part of a vehicle and as such subjected to a high load. The durability of the wheel is important

for the safe operation of the vehicle. Therefore, it is necessary to examine a wheel for both strength and fatigue resistance.

a.  *Endurance Test in Direction of Radius of Rim*

The tire on the test rim is rotated under high pressure condition on steel drum and the durability of the rim is examined. Sometimes, test is done giving camber angle and adding a side force.

b.  *Test of Disc*

The rim flange is tested by applying a load from an arm mounted to the hub. A bending moment is applied while the rim rotates.

c.  *Impact Test*

The case where the wheel collides with curb of the road or a large obstacle is assumed and the fall impact examination is done.

d.  *Others*

The test for welding between rim and disc and the nut seat tightening etc. are provided in the vehicle test standard. Moreover, nondestructive testing such as X ray and color check, etc. are adopted to the light alloy wheel to detect the defects in the casting process. Bead Unseating Test, provided in the tire safety standards, for a mounted tire and the rim is also applied. In addition tests are carried out in the field with the assembly mounted on a vehicle under various road surfaces.

## Limiting period of Wheel

Though we think it is possible to permanently use a wheel until it rusts away there is a limit to a wheels useful life. If a rim is used in severe operations such as racing or rallying hidden damage is caused. This may result in an accident or sudden rim failure whilst damage is caused. This may result in an accident or sudden rim failure whilst the vehicle is in service. The life of a rim is varied according to using conditions. A rim normally lasts longer than a tire so at time of a tire change a rim should be checked for

damage or sign of failure. If any are found the rim should be scrapped. In the case of steel wheel, cracks and corrosions by rust at the joint parts of rim and disc, nut seats, between decoration holes of the rim or the flange is bent, you should scrap the rim.

## Maintaining rims

Very necessary but often overlooked, it is vitally important to inspect your motorcycle rims and clean them on a regular basis to help prevent spoke failure or corrosion weak points. You can definitely suffer flat tires if a few spokes fail on your motorcycle rims. This can happen under ordinary everyday conditions. The broken spoke pushes into the wheel and punctures the tube. So always keep your wheels clean and check them for signs of corrosion or other damage. It may only take one bad spoke to ruin your ride. The aluminum motorcycle rims are usually coated. Some chemicals used for bike maintenance of other systems (like brake fluid) can damage that coating. Once the bare aluminum on the motorcycle rim is exposed to air it can begin to corrode. Wheels can come under a lot of stress and even small areas of corrosion can become a point of failure.

Rim locks are used on wheels to prevent your tire from slipping around your motorcycle rims. This can occur if you are running your tires at very low pressures. They are quite common when bikers take to riding off road. If your tire turns on the rim it can pull the valve stem through the wheel or tear it off completely leaving you with a flat. They are fairly simple to install but it requires removal of the tires and tubes and this can be more work than the rim lock installation. The rear is the more critical of the motorcycle rims to lock as it is subjected to the forces of driving the bike forward. Install them opposite the valve stem to minimize the affect they will have on wheel balance.

## Failure of a Wheel rim
## Motorcycle Rim Problems

If we have been in an accident or purchased a bike with unknown history it is possible that your motorcycle wheel could be out of true. The wheel might seem to oscillate laterally (side to side) or appear to move up and down (out of round). Motorcycle rims can be casually inspected by supporting the bike on the centre stand or other stand and spinning them while viewing side on or edgewise. A really bad wobble will be obvious even to someone like us. We can secure a sharp pencil to the fork or swing arm to help measure smaller variations. If the wheel is badly out of true, especially if the cause is from an accident, we may want to let a professional motorcycle rims shop or dealer do the repair. Sometimes the cause is just from lazy spoke maintenance. The wheel can slowly drift out of true over time. This kind of thing can be repaired ourself if we are up to it.

## New Tire, new wobble

If you have just had new tires installed and you feel or see a wobble it is more likely that the tire is the cause not bent rims. What can happen when mounting a new tire is the installer fails to get the new tire fully seated on the motorcycle rims. It may be close and because the tire has a tube in it there will be no leak to give it away. What you need to do is this.

- Examine the sidewall of the tire where it meets the rim to see if there is any indication that the tire is not fully seated. This might show up as a slight variation in the measurement between a mould line on the tire and the rims. This is best done on a centre stand if you have one.
- Have the installer correct any problem you find. Sometimes stock rims can be difficult to seat properly (or unseat for that matter).
- Sometimes what the tire installer will do to correct the problem is overinflate the tire to force the tire to seat. I am not suggesting you try this yourself, it can be very dangerous.
- Also make sure the tire is installed correctly, arrow pointing in the direction of travel.

## II.  INTRODUCTION SOFTWARES

### INTRODUCTION OF CAD/CAM

Engineering drawings have been in use for more than 2000 years. However, the use of orthographic projections was formally introduced by the French mathematician Gaspard Monge in the eighteenth century.

Since visual objects transcend languages, engineering drawings have evolved and become popular over the years. While earlier engineering drawings were handmade, studies have shown that engineering designs are quite complicated. A solution to many engineering problems requires a combination of organization, analysis, problem solving principles and a graphical representation of the problem. Objects in engineering are represented by a technical drawing (also called as drafting) that represents designs and specifications of the physical object and data relationships. Since a technical drawing is precise and communicates all information of the object clearly, it has to be precise. This is where CAD comes to the fore. When it was introduced first, CAD was not exactly an economic proposition because the machines at those times were very costly. The increasing computer power in the later part of the twentieth century, with the arrival of minicomputer and subsequently the microprocessor, has allowed engineers to use CAD files that are an accurate representation of the dimensions / properties of the object.

### UNIGRAPHICS

NX is one of the world's most advanced and tightly integrated CAD/CAM/CAE product development solutions. Spanning the entire range of product

development, NX delivers immense value to enterprises of all sizes. It simplifies complex product designs, thus speeding up the process of introducing products to the market.

The NX software integrates knowledge based principles, industrial design, geometric modeling, advanced analysis, graphic simulation, and concurrent engineering. The software has powerful hybrid modeling capabilities by integrating constraint based feature modeling and explicit geometric modeling. In addition to modeling standard geometry parts, it allows the user to design complex free form shapes such as airfoils and manifolds. It also merges solid and surface modeling techniques into one powerful tool set.

NX design tools are superior in power, versatility and productivity. You can work faster and more efficiently in the full range of design tasks, from 2D layout through 3D modeling, assembly design, drafting and documentation. Work Seamlessly with Data from Other CAD Systems · With synchronous technology, NX allows you to directly use models created with other CAD systems. You can import and modify CAD geometry from any source with speed, ease and efficiency. NX is the solution of choice for multi-CAD, collaborative design.

### III. MODELING OF ALLOY WHEEL

### Entering In to Modelling :

Steps to be considered for Modelling of Alloy wheel :

- Selection of Datum Plane
- Selection of Curves
- Procedure of Revolve
- Extruding procedure
- Combing of features in to a single entity
- Procedure of hole
- Blend Process
- Drafting

### First Start up procedure of Unigraphics

- ➢ To start Unigraphics, Go to Windows Button and select the nx9.0 icon.
- ➢ Then the User Window will open.
- ➢ Select the model filter to draw the 3d model.
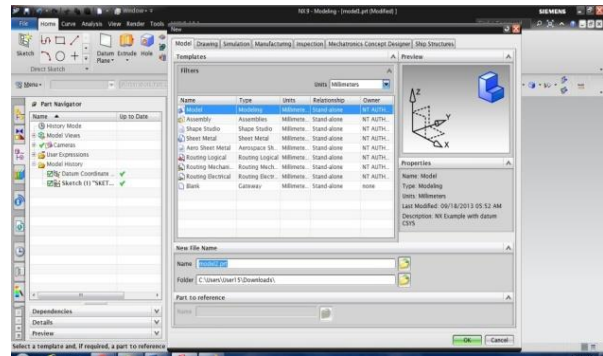


### Selection of datum plane

- ➢ After entering into the model.
- ➢ Select the datum plane from draw group with respective datum co ordinate system
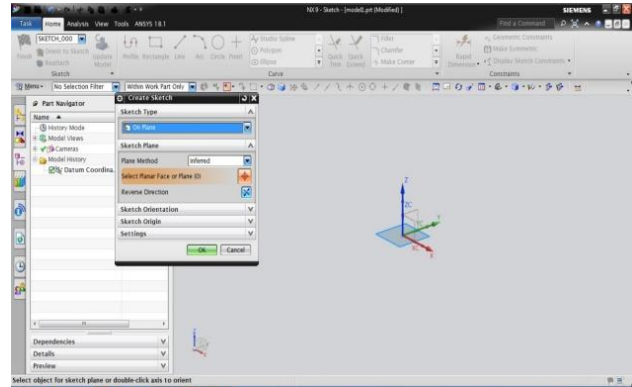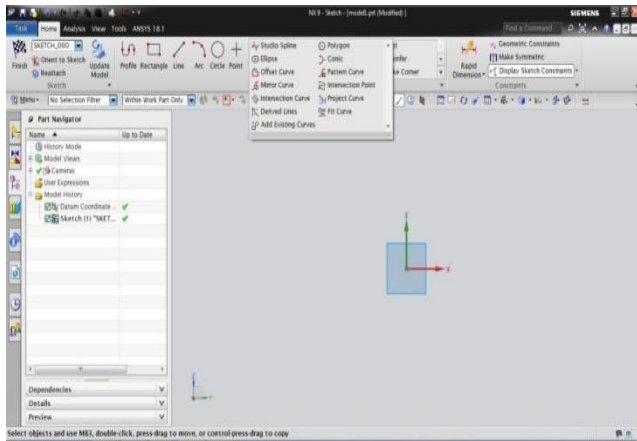


### Sketch Environment:

- ➢ To Draw a Sketch, we need to select the environment.
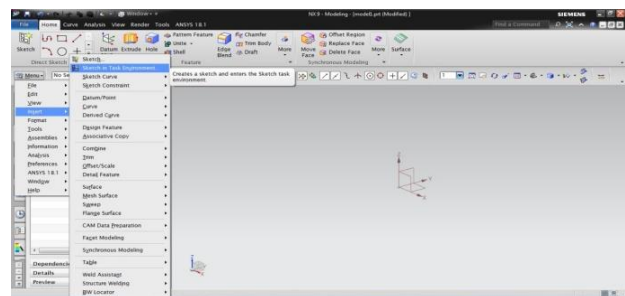
➢ By selecting the environment we will enter into the drawing plane which was in 2d

**Selection of Curves:**

➢ To draw a curve, select the required curve from the draw group.



➢ Draw a circle and fully constrained it with the help of Geometrical and dimensional Constraints .

**EXTRUDE Process :**

➢ To Extrude a Sketch we need to select the sketch.
➢ Then Click on the Extrude Command
➢ New Window will appears
➢ It will contain some required processes we have to fill the requirements.
➢ Make sure the direction is in our required position.
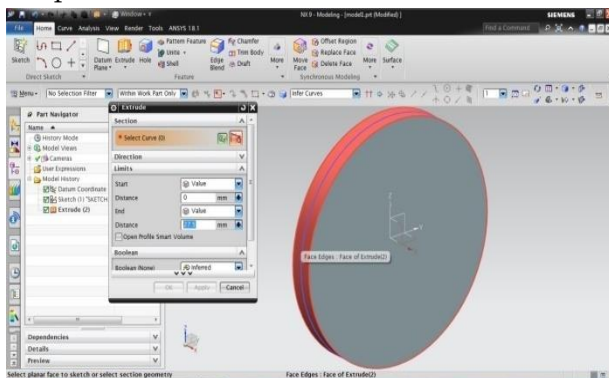


**Revolve Process:**

➢ After Extrusion process. We have to draw a revolving feature which supports the tire.
➢ To that process we have to draw a sketch.

➢ For revolving a Sketch we need to set the vector and plane direction.
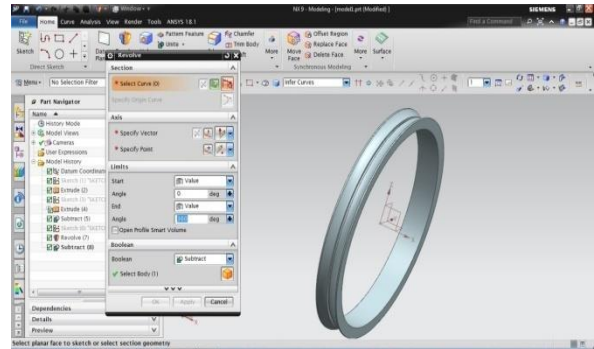


➢ While Revolving the feature dimensions need to be checked clearly

**Color Assigning:**

➢ For my better Appearance I used black color. Changing procedure is
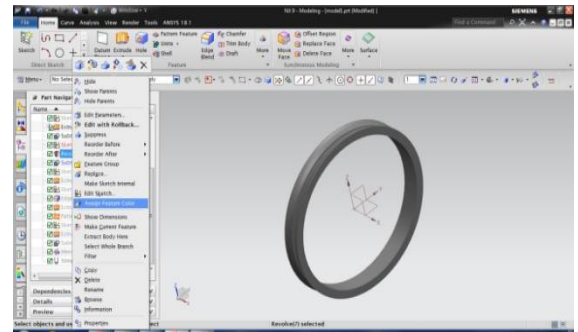


➢ Select the feature and go to menu > insert > assign color
➢ Select the required color.

**Sketching Alloy Spoke :**
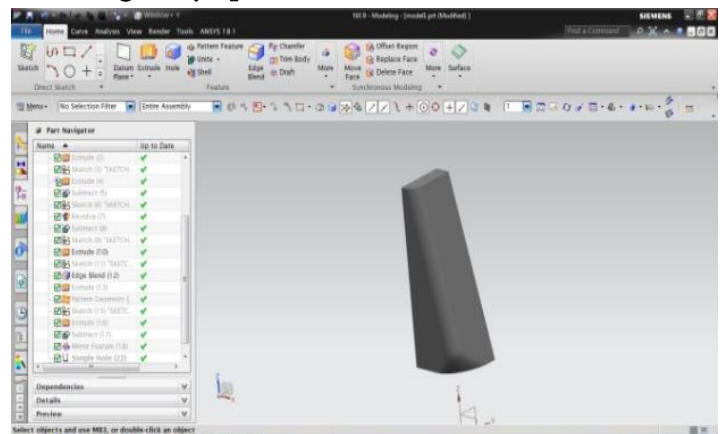


➢ For Alloy Spoke we have to use extra command
➢ Blend Command is used for spoke
➢ Procedure: Draw sketch with dimensionally

Extrude the sketch

Apply blend on edges

Variational blends are used in this spoke

**Pattern Geometry :**

- ➢ Pattern Geometry is used to place the copied features in a circular manner.
- ➢ Procedure: Select the feature

Go to > Insert > Associate copy>pattern geometry

Axis has to be selected

Number of entities

Angle of entities has to be mentioned
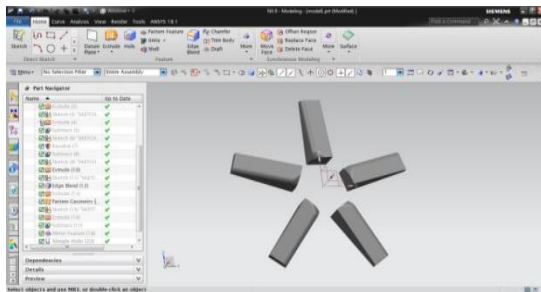


**Combining of Features:**

- ➢ For Combining, We use Unite Command.
- ➢ Procedure :

  Go to > Modify Command > Unite

  Select the target body

  Select the base body

  Both the features will combine.
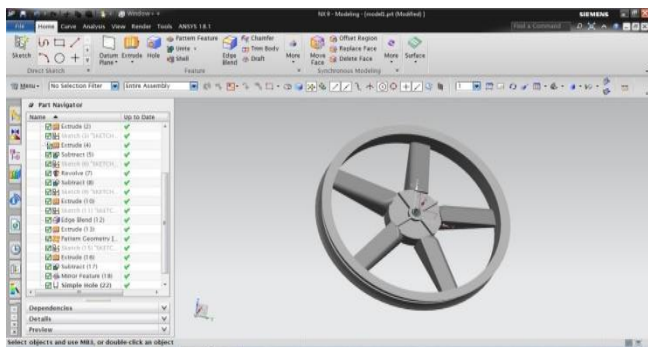


**Procedure for hole :**

- ➢ Select the face of the entity
- ➢ Select the center of the circular object
- ➢ Go to > Operations group > hole
- ➢ Select the type of hole
- ➢ Place the dimensions

- ➢ Diameter and depth should be given
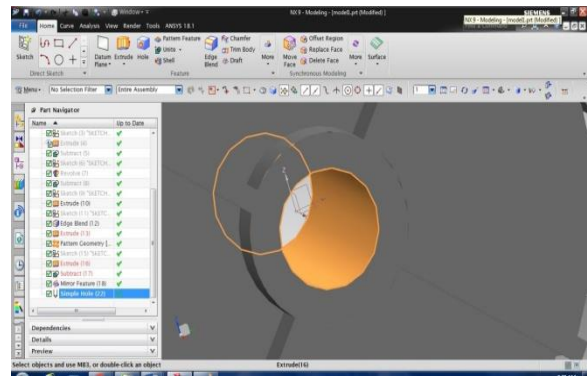


**Same procedure for 4 wheel alloy also**
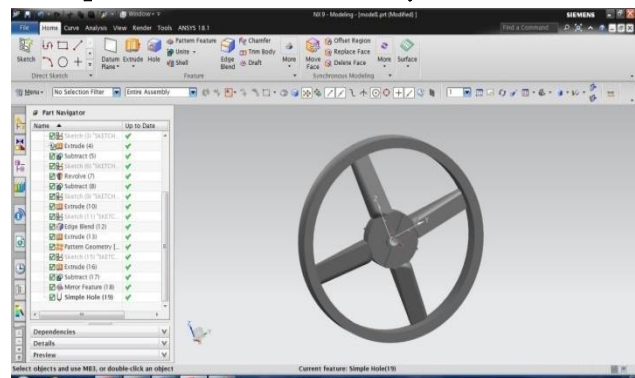


**Drafting :**

The Drafting Model is a part of a complex information model describing product definition data, their applications and their representations. The definition of the information model is a central component of the development of STEP, a future international standard for the exchange of product defamation data. Here the Drafting Model particularly encloses descriptions for the representations of organizational drawing data, tolerances, dimensions and surface attributes such as surface finish symbols (a survey of the whole content is shown in the figure above).
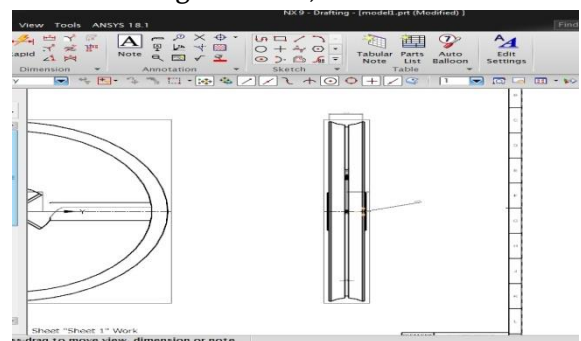


**Introduction to COSMOS**

## Using the COSMOS Program

Cosmos 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. Cosmos 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. The program contains a built-in alarm and fault reporting. When Cosmos is combined with the AviNet SNMP option the result is an extremely power control solution. Cosmos will run on virtually any computer, running the windows operating system.

SolidWorks Simulation Xpress is design analysis software that is fully integrated in SolidWorks.
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.

## Feature

- Add modules or groups while the system is online.
- Assign audio monitoring on any source.
- Change any window to full screen view with a single click of a but
- Configure Avitech's GPI interface. Control third-party routers, integration with multiple third-party router control systems.
- Create analog or digital clocks with ability to countdown/count up timer.

- Customize labels, borders, background colors, and fonts (color and
- Make changes to the entire border or for each individual window.

## System requirements for COSMOS

The following are the system requirements to ensure smooth running of COSMOS SOFTWARE.

**System unit:** An inlet® core™ i3-2600 CPU @ 3.40GHz based workstation running Microsoft 2009 corporation windows7 ultimate or home basic professional edition.

**Memory:** 12.0 GB of RAM is minimum recommended for all application.

**Disk drive:** 100 GB disk drive space (minimum recommended size)

**Internal /external drives:** A CD-ROM drive is required for program installation.

**Display:** A graphic colour display compatible with the selected platform – specific graphic adapter. The minimum recommended monitors size 17 inches. Graphics adapter: A graphics adapter with a 3D OpenGL accelerator is required with minimum resolution of $1024\times 768$ for Microsoft windows workstations and $1280\times 1024$ for UNIX workstations.

## Description of Commands used in COSMOS[30]

## Using the Interface

## Starting a Program

1 Click the Start button in the lower left corner of the window. The Start menu appears. The Start menu allows you to select the basic functions of the Microsoft Windows environment.

2 From the Start menu, click Programs, SolidWorks, SolidWorks as shown below.
The SolidWorks application program is now running.

## Exit the Program

To exit the application program, click File, Exit or click on the main SolidWorks window.

## SolidWorks Windows

SolidWorks windows have two panels. One panel provides non-graphic data. The other panel provides graphic representation of the part, assembly, or drawing. The leftmost panel of the window contains the FeatureManager® design tree, PropertyManager and ConfigurationManager.

1. Click each of the tabs at the top of the left panel and see how the contents of the window changes. The rightmost panel is the Graphics Area, where you create and manipulate the part, assembly, or drawing.

2. Look at the Graphics Area. See how the alloy wheel is represented. It appears shaded, in color and in an isometric view. These are some of the ways in which the model can be represented very realistically.

## Toolbars

Toolbar buttons are shortcuts for frequently used commands. You can set toolbar placement and visibility based on the document type (part, assembly, or drawing). SolidWorks remembers which toolbars to display and where to display them for each document type.

1. Click View, Toolbars.
A list of all toolbars displays. The toolbars with their icon depressed or a check mark beside them are visible; the toolbars whose icons are not depressed or without a check mark are hidden.

**2.** Turn several toolbars on and off to see the commands.

## Mouse Buttons

Mouse buttons operate in the following ways:
**Left** – Selects menu items, entities in the graphics area, and objects in the FeatureManager design tree.
**Right** – Displays the context-sensitive shortcut menus.
**Middle** – Rotates, pans, and zooms the view of a part or an assembly, and pans in a drawing.

## Stress Analysis:

SolidWorks Simulation Xpress offers an easy-to-use first pass stress analysis tool for SolidWorks users. SolidWorks Simulation Xpress can help you reduce cost and time-to market by testing your designs on the computer instead of expensive and time-consuming field tests. SolidWorks Simulation Xpress uses the same design analysis technology that SolidWorks Simulation users to perform stress analysis. The wizard interface of SolidWorks Simulation Xpress guides you through a five step process to specify material, restraints, loads, run the analysis, and view the results.

## Study on Static Stress Analysis

To create a static study, click the Simulation tab in the upper-left. There should be a button labeled "Study Advisor." Click the arrow just beneath it and choose "New Study," as in Figure. Here you can see all the types of studies available in Simulation. Click "Static," name the study something memorable, and click the green check mark.

Apply the material, as from the material library given. To set up the fixtures on the model, either right-click "Fixtures" in the static study pane or click the arrow beneath "Fixtures Advisor" in the Simulation tab. Choose "Fixed Geometry" as the fixture type for this study.

With the pressures and fixtures specified, we can run a finite element analysis now! SolidWorks needs to break the model into small triangular units, which together are called a *mesh*. Smaller meshes (as in meshes with smaller individual units) produce more precise results but require additional computing time. Large meshes run quickly but may produce wildly inaccurate results, especially around sharp edges. It is common to use a mesh with varying element sizes: smaller units around the areas of interest in a model, such as potential failure points, and larger units where precise results are less valuable.

In the static study pane, right-click "Mesh" and choose "Create Mesh." Accept the default mesh size and check OK. This will create a uniformly sized mesh over your entire model, which should look something like Figure shown. If you ever need a non-uniform mesh, you can do so by right-clicking "Mesh" and choosing "Apply Mesh Control" instead.

Begin the static study by clicking "Run" in the Simulation tab. You will see that even this simple problem consumes significant memory and time. If all goes well, a folder named "Results" will appear in the static study pane. Right-click the folder and choose "Define Stress Plot," then accept the default settings that appear.

Create a new result plot to show displacement. Right-click "Results" again and choose "Define Displacement Plot." In the settings pane that appears, set "Deformed Shape" to True Scale and check OK. By default the displacement is measured in URES ("resultant displacement"—U is commonly used to abbreviate displacement), which is a simple measure of displacement magnitude. Measuring displacement along the X, Y, or Z axes is also an option here, though we will stick with URES, like in Figure.

## Fatigue Analysis

During design validation, a structure is exposed to both static strength tests and fatigue tests. However, once a structure is deployed, it spends the vast majority of its lifetime being subjected to smaller repeated forces that can cause cumulative damage over time. For this reason, testing the durability of a structure makes up a larger proportion of the tests that are run. Durability is one of the most important attributes that structures can posses.

Fatigue testing measures durability and is defined as the repeated mechanical loading of a structure to determine failure points. It requires complex analysis using the field of fracture mechanics, which is the

analysis of material flaws to discover those that are safe and those that are liable to propagate as cracks and cause failure.

To create a fatigue study, click the Simulation tab in the bottom-left. There should be a Pop-up menu labeled as "New simulation study." Click on it and choose "Fatigue" as in Figure. Here you can see all the types of studies available in Simulation. Name the study something memorable, and click the green check mark.

Add an event as constant amplitude for a required number of cycles, with zero based condition. Then define S-N curve for the applied material, as log-log graph. The Stress-Life (S-N) or Total Fatigue Life method is widely used for HCF applications. During HCF testing, a material spends the majority of life in a state where the cracks are very small, the growth is controlled, and the structure integrity is retained. As noted earlier, the applied stress stays within the elastic range of the material. Total Life is determined by running multiple specimen tests at a number of different stresses. The objective is to identify the highest stress that produces a fatigue life beyond 10 million cycles. This stress is also known as the material's endurance limit.

Begin the fatigue study by clicking "Run" in the Simulation tab. You will see that even this simple problem consumes significant memory and time. If all goes well, a folder named "Results" will appear in the fatigue study pane. Right-click the folder and choose "Define life Plot," then accept the default settings that appear.

## 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/mm² 130 N/mm²

Elastic modulus : 71000 N/mm² 45000 N/mm²

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

## Analysis for strength needed[28]

Mass of Bike, Dead Weight of Bike =148 Kg

Other Loads= 20 Kg

Total Gross Weight= 148 + 20 = 168 Kg

 168 * 9.81 = 1648.08 N

Tires and Suspension system reduced by 30% of Loads

$W_{net}$ = 1648.08 * 0.7 = 1153.656 N

Reaction Forces On Bike= $F_T$ = 1153.656 N

Number of Wheels: 2

Reaction Force on Each Wheel $F_T$ =576.828 N

Number of spokes, N = 5

Stress on the each Rim = $\frac{F_T}{Area}$ = 0.011945 N/mm²

Area of rim at stressed parts = 48287.08 mm²

 Stress on the each rim for load1= 0.011945 N/mm²

## For Different Loads Stress on Each Rim are:

 With Load2 on Bike (168+50)Kgs

Total Gross Weight = 218 * 9.81 = 2138.58 N

Tires and Suspension system reduced by 30% of Loads

$W_{net}$ = 2138.58 * 0.7 = 1498.006 N

Reaction Forces On Bike: $F_T$ = 1498.006 N

Number of Wheels= 2

Reaction Force on Each Wheel $F_T$ =748.503 N

Number of spokes, N = 5

Stress on the each Rim = $\frac{F_T}{Area}$ = 0.015501 N/mm²

Area of rim at stressed parts = 48287.08 mm²

Stress on the each rim for load2= 0.015501 N/mm²

 With Load3 on Bike (168+100)Kg

Total Gross Weight = 268 * 9.81 = 2629.08 N

Tires and Suspension system reduced by 30% of Loads

$W_{net}$ = 2629.08 * 0.7 = 1840.356 N

Reaction Forces On Bike: $F_T$ = 1840.356 N

Number of Wheels= 2

Reaction Force on Each Wheel $F_T$ = 920.178 N

Number of spokes, N = 5

Stress on the each Rim = $\frac{F_T}{Area}$ = 0.019050 N/mm²

Area of rim at stressed parts = 48287.08 mm²

 Stress on the each rim for load3 = 0.019050 N/mm²

Similarly Load4 Stresses induced on each Rim is

 Stress on the rim for load4= 0.022611 N/mm²

## Importing of Alloy Wheel

## Steps to be followed for importing the model from Unigraphics

1. Open the Unigraphics in the computer, select the Unigraphics model which has to be import into the COSMOS.
2. Select File-> save a copy->select type as *.igs as shown in figure.
3. Name the file something memorable, and click the ok check mark.
4. Export the model into solid and shells, click on ok.
5. Then the Unigraphics part is saved in the *.igs format, which can be opened in the solid works for simulation.

## Analysis is carried out in COSMOS

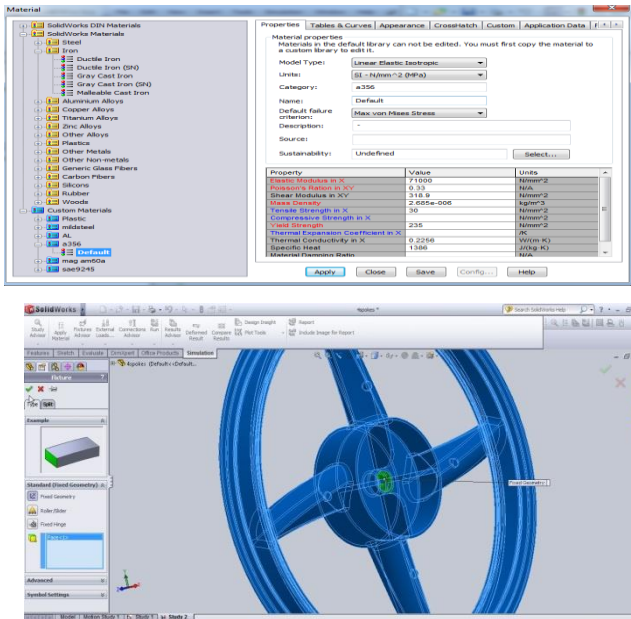## Step 1: Creating a Static Study

The first step in performing analysis is to create a study.

1. Click Simulation, Study in the main SolidWorks menu on the top of the screen. The Study Property Manager appears.

2       Under Name, type Alloy wheel.

3       Under Type, select Static.

4       Click .

## Step 2: Assigning Material

## Assign Alloy of aluminium

Ilustrates how to Assign the Material





1. In the SolidWorks Simulation Manager tree, right-click the Alloy wheel folder and click Apply Material to All Bodies. The Material dialog box appears.

2. Do the following:

a) Expand the SolidWorks Materials library folder.

b) Expand the Steel category.

c) Select Alloy of Aluminium required.

3 Click on Apply and Close.

### Step 3: Applying Fixtures

You apply fixtures to prevent the out of plane rotations and free body motions.

1. Press spacebar and select Trimetric in the Orientation menu. The model orientation is as shown in the figure.

2. In the Simulation study tree, right-click the Fixtures folder and click Fixed goemetry. The Fixture PropertyManager appears. click the green check mark. The fixtures are applied and their symbols appear on the selected edges.

### Step 4: Applying Pressure

Apply, 0.011945MPa pressure normal to the faces as shown in the figure.

1. In the SolidWorks Simulation Manager tree, right-click the External Loads folder and click Pressure. The Pressure PropertyManager appears.

2. Under Type, select Normal to selected face.

3. In the graphics area, select the faces as shown in the figure. Face<1> through Face<3> appear in the Faces for Pressure list box.

4. Make sure that Units is set to N/mm^2 (MPa).

5. In the Pressure value box , type 0.011945.

6. Click the green check mark.

SolidWorks Simulation applies the normal pressure to the selected faces and Pressure-1 icon appears in the External Loads folder.
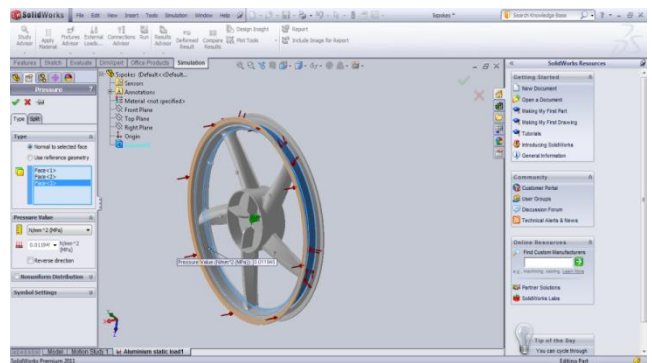


Ilustrates how to Assign the Pressure

### Step 5: Meshing the Model and Running the Study

Meshing divides your model into smaller pieces called elements. Based on the geometrical dimensions of the model SolidWorks Simulation suggests a default element size which can be changed as needed.

1. In the SolidWorks Simulation Manager tree, right-click the Mesh icon and select Create Mesh. The Mesh Property Manager appears.

2. Expand Mesh Parameters by selecting the check box. Make sure that standard based mesh is selected.

3. Check Run (solve) the analysis under Options and click.
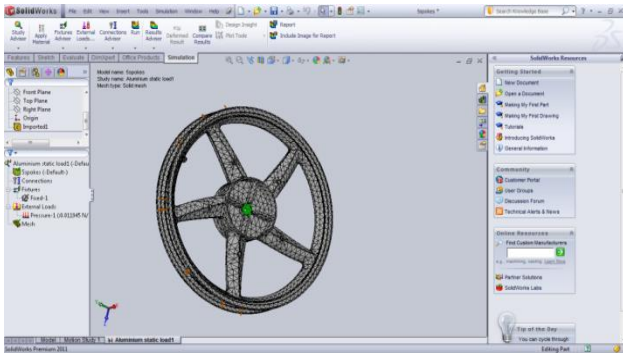
Ilustrates how to Meshing the Part model

## Step 6: Creating a Fatigue Study

The next step in performing analysis is to create a fatigue study.

1. Click on Alloy wheel option on bottom-left, a pop-up menu will generate, choose New Simulation Study in the SolidWorks menu on the screen. The Study PropertyManager appears.

2. Under Name, type Alloy wheel fatigue.

3. Under Type, select Fatigue.

4. Click the green check mark.

## Step 7: Assigning Event

1. In the SolidWorks Simulation Manager tree, right-click the Loading icon and select Add Event option. The Add Event PropertyManager appears.

2. Apply load, as per required number of cycles, with option zero based condition as shown in the figure.

3. Define the S-N Curve, as user defined that exists in the library.

## Step 8: Run the Fatigue Study

1. In the SolidWorks Simulation Manager tree, right-click the Alloy wheel fatigue icon and select Run (or)

2. Begin the fatigue study by clicking "Run" in the Simulation tab. You will see that even this simple problem consumes significant memory and time. If all goes well, a folder named "Results" will appear in the fatigue study pane.

## IV. RESULTS
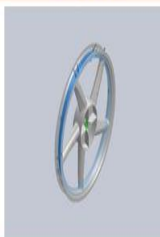
### Static and Fatigue analysis for 5-spokes Aluminium alloy wheel

**Material Properties**

| Model Reference | Properties | Components |
|---|---|---|
|  | Name: Aluminium Alloy wheel<br>Model type: Linear Elastic Isotropic<br>Default failure criterion: Max von Mises Stress<br>Yield strength: 2.35e+008 N/m^2<br>Tensile strength: 3e+007 N/m^2<br>Elastic modulus: 7.1e+010 N/m^2<br>Poisson's ratio: 0.33<br>Mass density: 2.685e-006 kg/m^3<br>Shear modulus: 3.189e+008 N/m^2 | SolidBody 1(Imported1)(5spokes) |

**Loads and Fixtures**

| Fixture name | Fixture Image | Fixture Details |
|---|---|---|
| Fixed-1 |  | Entities: 1 face(s)<br>Type: Fixed Geometry |

| Load name | Load Image | Load Details |
|---|---|---|
| Pressure-1 |  | Entities: 3 face(s)<br>Type: Normal to selected face<br>Value: 0.011945<br>Units: N/mm^2 (MPa) |

## Mesh report

Mesh information for Aluminium Alloy wheel-5 spokes
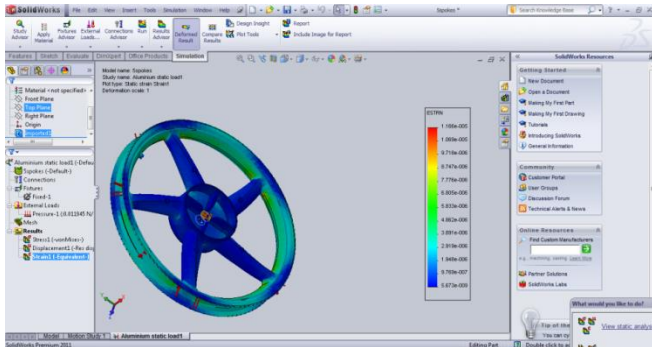
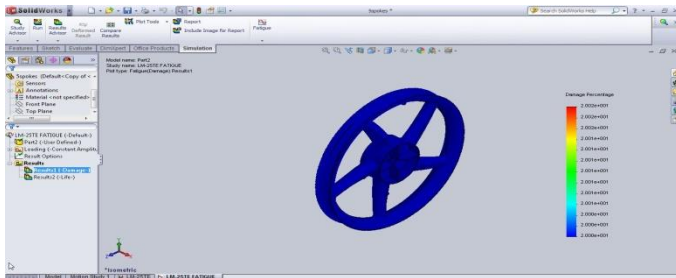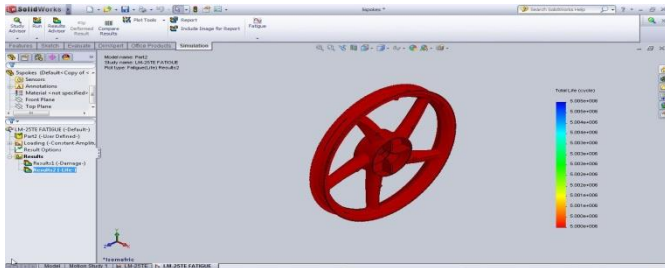| | |
|---|---|
| Total Nodes | 41528 |
| Total Elements | 21498 |
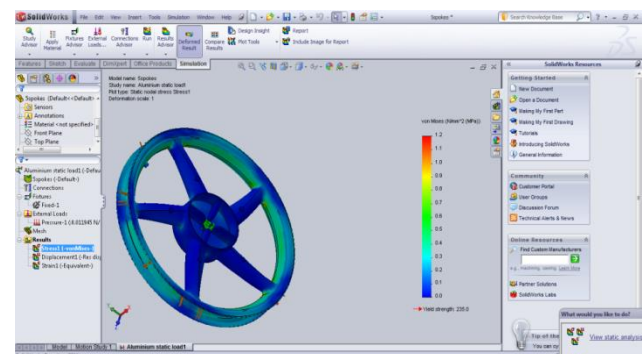


Stress results for 5-spokes Aluminium alloy wheel
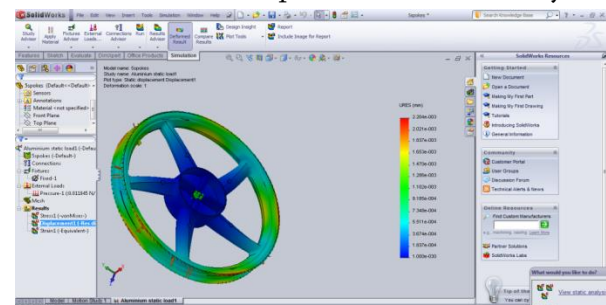
Displacement results for 5-spokes Aluminium Alloy Wheel



Strain result for 5-spokesAluminium Alloy Wheel



Damage percentage result for 5-spokes Aluminium Alloy wheel



Total Life (cycle) result for 5-spokes Aluminium Alloy wheel

Fig Shows the max stress 0.000968639 N/mm^2 and mini stress 2.35433N/mm^2 that are induced in 5-Spokes Aluminum Alloy(LM 25 TF).

Fig 5.2, Shows the max displacement 0.00417283 mm and mini displacement 0 mm that are induced in 5-Spokes Aluminum Alloy(LM 25 TF).

Fig 5.3, Shows the mini strain 1.07886e-008 and max strain 2.20737e-005 that are induced in 5-Spokes Aluminum Alloy(LM 25 TF).

Fig Shows the max fatigue life and mini fatigue 1e+007 cycle that are induced in 5-Spokes Aluminum Alloy(LM 25 TF).

Shows the max damage and mini damage % is 10 that are induced in 5-Spokes Aluminum Alloy(LM 25 TF).
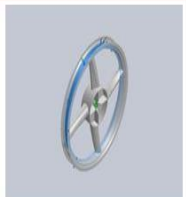
## Static and Fatigue analysis for 4-spokes Magnesium alloy wheel

**Material Properties**

| Model Reference | Properties | Components |
|---|---|---|
|  | Name: Magnesium aloy wheel<br>Model type: Linear Elastic Isotropic<br>Default failure criterion: Max von Mises Stress<br>Yield strength: 1.3e+008 N/m^2<br>Tensile strength: 3e+007 N/m^2<br>Elastic modulus: 4.5e+010 N/m^2<br>Poisson's ratio: 0.35<br>Mass density: 1.8e-006 kg/m^3<br>Shear modulus: 3.189e+008 N/m^2 | SolidBody<br>1 (Imported1)(4spokes) |

**Loads and Fixtures**

| Fixture name | Fixture Image | Fixture Details |
|---|---|---|
| Fixed-1 |  | Entities: 1 face(s)<br>Type: Fixed Geometry |

| Load name | Load Image | Load Details |
|---|---|---|
| Pressure-1 |  | Entities: 3 face(s)<br>Type: Normal to selected face<br>Value: 0.011945<br>Units: N/mm^2 (MPa) |

## Mesh report

Mesh information for Magnesium Alloy wheel 4-spokes

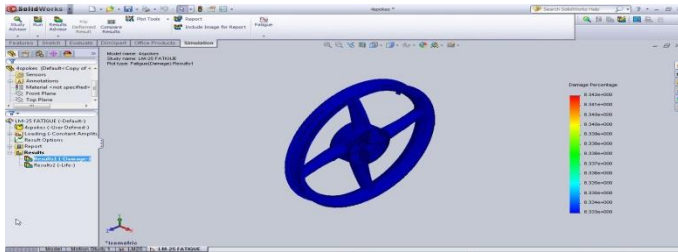| | |
|---|---|
| Total Nodes | 39450 |
| Total Elements | 20063 |
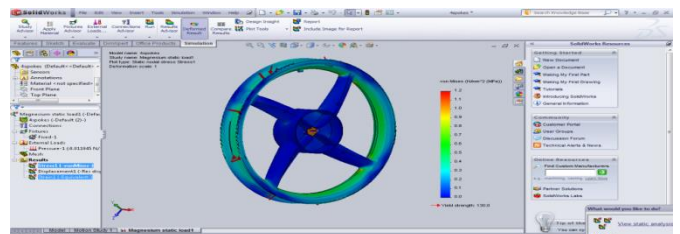


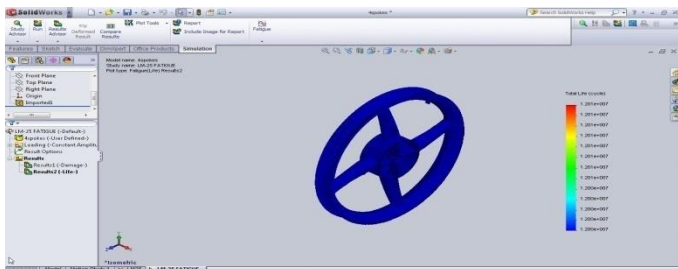Stress results for 4-spokes Magnesium Alloy Wheel
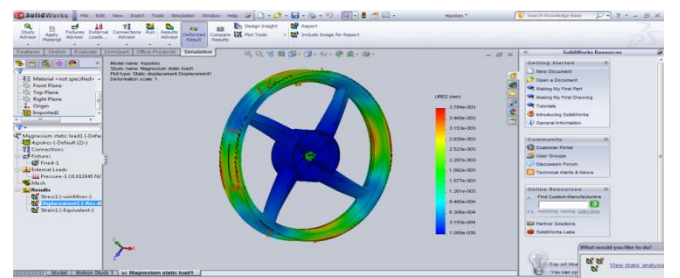
Displacement results for 4-spokes Magnesium Alloy Wheel

Strain results for 4-spokes Magnesium Alloy Wheel



Damage percentage results for 4-spokes Magnesium Alloy Wheel



Total Life(cycles) results for 4-spokes Magnesium Alloy Wheel

Fig Shows the max stress 0.000775803 N/mm^2 and mini stress 2.23756 N/mm^2 that are induced in 4-Spokes Magnesium Alloy(AM 60A).

Fig Shows the max displacement 0.00714043 mm and mini displacement 0 mm that are induced in 4-Spokes Magnesium Alloy(AM 60A).

Fig Shows the max strain 3.5419e-005 and mini strain 1.40248e-008 that are
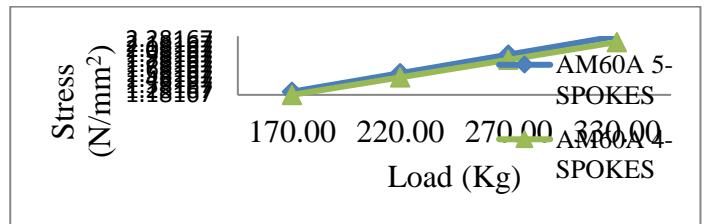
induced in 4-Spokes Magnesium Alloy(AM 60A).

Fig 5.9, Shows the max fatigue life and mini fatigue 1e+008 cycle that are induced in 4-

Spokes Magnesium Alloy(AM 60A).

Fig 5.10, Shows the max damage and mini damage % is 1 that are induced in 4-Spokes
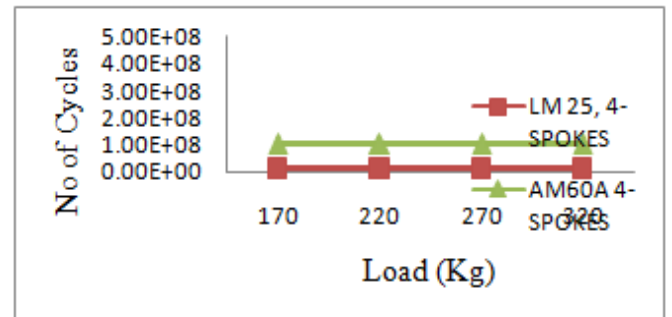
Magnesium Alloy(AM 60A).
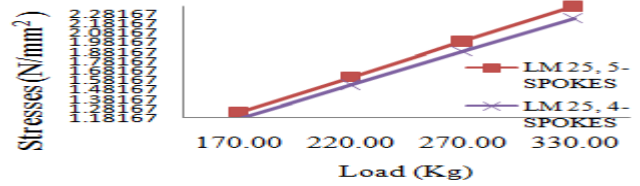


Stress Comparsion between 5-Spokes and 4-Spokes alloy wheel of Aluminum Alloy (LM 25).

Fig indicates Stresses induced in the 4-Spokes alloy wheel as less as compared with the Stress induced in the 5-Spokes alloy wheel, for the same Aluminum Alloy material (LM 25TF- U.K Standards) by 0.05%.



Stress Comparsion between 5-Spokes and 4-Spokes alloy wheel of Magnesium material (AM 60A).

Figure indicates that, Stresses induced in the 4-Spokes alloy wheel as less as compared with the Stress induced in the 5-Spokes alloy wheel, for Magnesium Alloy (AM 60A – ASTM Standards) by 0.05%.



Illustrates, the Fatigue Life Cycle of 4-Spokes alloy wheel of Magnesium and Aluminum material.
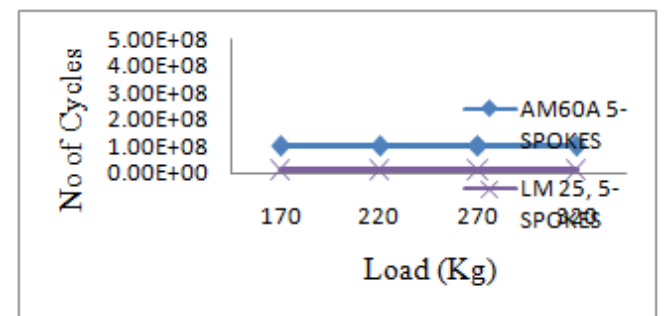
Illustrates, the Fatigue Life Cycle of 5-Spokes alloy wheel of Magnesium and Aluminum material.

The above two graphs indicates that, Fatigue life cycle of Magnesium alloy wheel is more as compared

VALIDATION

Stress analysis values for 5-Spokes Mg-alloy and Al-alloys (LM 25, LM 25TB7, LM 25TE, LM 25TF).

| 5-Spokes | Aluminum Alloys | | | | Magnesium alloy (AM60A) |
|---|---|---|---|---|---|
| | LM 25 | LM 25TB7 | LM 25TE | LM 25TF | |
| LOAD1 | 1.23366 | 1.23324 | 1.23282 | 1.23250 | 1.24426 |
| LOAD2 | 1.60394 | 1.60349 | 1.60290 | 1.60234 | 1.61467 |
| LOAD3 | 1.97349 | 1.97290 | 1.97236 | 1.97177 | 1.98441 |
| LOAD4 | 2.34366 | 2.34296 | 2.34238 | 2.34163 | 2.35595 |

The Stresses induced in the 5-Spokes Aluminum Alloy wheel (LM 25TF) 2.34163MPa is less as compared with the Stresses induced in the 5-Spokes Magnesium alloy (AM60A), Al-alloys (LM 25, LM 25TB7, LM25TE) wheels.

**Table 5.2:** Stress analysis values for 4-Spokes Mg-alloy and Al-alloys(LM 25, LM 25TB7, LM 25TE, LM 25TF).

| 4-Spokes | Aluminum Alloys | | | | Magnesium alloy (AM60A) |
|---|---|---|---|---|---|
| | LM 25 | LM 25TB7 | LM 25TE | LM 25TF | |
| LOAD1 | 1.16996 | 1.16961 | 1.16923 | 1.16881 | 1.18167 |
| LOAD2 | 1.52037 | 1.51989 | 1.51938 | 1.51887 | 1.53389 |
| LOAD3 | 1.87069 | 1.87016 | 1.86966 | 1.86912 | 1.88506 |
| LOAD4 | 2.22184 | 2.22134 | 2.22802 | 2.22029 | 2.23756 |

The Stresses induced in the 5-Spokes Aluminum Alloy wheel (LM 25TF) 2.22029 MPa is less as compared with the Stresses induced in the 5-Spokes Magnesium alloy (AM60A), Al-alloys (LM 25, LM 25TB7, LM25TE) wheels.

**Table 5.3:** Fatigue Life values for 5-Spokes and 4-Spokes Mg-alloy and Al-alloys(LM 25, LM 25TB7, LM 25TE, LM 25TF).

| 5-Spokes and 4-Spokes | Magnesium alloy (AM60A) | Aluminum Alloys | | | |
|---|---|---|---|---|---|
| | | LM 25 | LM 25TB7 | LM 25TE | LM 25TF |
| LOAD1 | 1.0E8 | 1.2E7 | 5.0E6 | 5.0E6 | 1.0E7 |
| LOAD2 | 1.0E8 | 1.2E7 | 5.0E6 | 5.0E6 | 1.0E7 |
| LOAD3 | 1.0E8 | 1.2E7 | 5.0E6 | 5.0E6 | 1.0E7 |
| LOAD4 | 1.0E8 | 1.2E7 | 5.0E6 | 5.0E6 | 1.0E7 |

Due to High Strength and Hardness of Mg-Alloy, Fatigue life is more compared with all Al-Alloys.

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

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

with the Fatigue life cycle of Aluminum alloy wheel. Due to High Strength of Mg-Alloy, Fatigue life is more compared with all Al-Alloys.

The Stresses induced in the 4-Spokes Aluminum Alloy wheel (LM 25TF) 2.21029 MPa is less as compared with the Stresses induced in the 4-Spokes Aluminum Alloy (LM25TF) wheels.

Aluminum Alloy (LM25) is utilized for the validation of this thesis from Deepak (2012)[25]. Due to different Heat Treatment conditions, Aluminum Alloys obtained are LM 25TB7, LM 25TE and LM 25TF. 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,

1.      Larger grains will break into small grains.
2.      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.

## IV. CONCLUSION

An Al-Alloy Wheel was modeled using Unigraphics of two Spokes i.e., 4 and 5 with  fillet radii (8mm and 9mm). These models were analyzed using COSMOS for five different materials, LM 25, LM25TB7, LM 25TE, LM25TF and AM60A.

From the results obtained it may be concluded that

1.  The analysis results showed that the maximum stress area was located at Spoke-

Rim contact. Stresses induced in 4-Spokes Aluminum Alloy (LM 25TF) are less as compared with Magnesium Alloy (AM 60A) and all the three Aluminum Alloys of 4 and 5 Spokes.

2.  Fatigue life cycle is estimated based on the Equivalent Stresses induced on Al-alloys and Mg-alloy materials. Fatigue life cycle for the Mg-alloy is more as compared with all Al-alloys materials.

3.  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 25TF) 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 25TF) is the better material for alloy wheels.

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