DESIGN AND ANALYSIS OF WAVE SPRING

FOR TWO WHEELER VEHICLE

A project report submitted

in partial fullfilment of the requirement for the ward of the degree of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

by

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ABSTRACT

The Springs are very important part in automobile suspension system. In springs the are many types but most commonly used spring was Helical spring. These springs are used as Rear suspension in two wheeler vehicle. Many research founded that Helical spring good effective as shock absorbers. Later we found that Helical spring can be replaced with Wave spring. Wave springs are very beneficial when compared to helical springs . It occupies half of the space when compared to other type of springs meanwhile it carry huge loads also .

For two wheeler vehicle rear suspension system wave spring is designed with similar dimensions of helical spring. Helical spring was designed in both theoretically and numerically. In the same way, we designed the wave spring. We consider Copper Alloy was the material which is machine ability best material for wave spring.
Copper Alloy is good at corrosion resistance, heat conductivity etc... In designing process we use equation curve to generate the wave spring by using SOLIDWORKS software and ANSYS15.0 software was used for analysis of wave spring.

KEYWORDS: composite of wave spring, Rear suspension system, Design of wave spring, wave spring analysis.

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CHAPTER 1

INTRODUCTION

1.1 Introduction:

A Mechanical Spring is a device that can also be defined as an elastic or resilient member, whose main function is to deflect under the action of load and recovers its original shape when the load is removed. It also used for storing energy.

When a conventional spring, without stiffness variability features, is compressed or stretched from its resting position, it exerts an opposing force approximately proportional to its change in length (this approximation breaks down for larger deflections).The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. That is, it is the gradient of the force versus deflection curve. An extension or compression spring's rate is expressed in units of force divided by distance, for example or N/m or lb f/in. A torsion spring is a spring that works by twisting; when it is twisted about its axis by an angle, it produces a torque proportional to the angle.

A torsion spring's rate is in units of torque divided by angle, such as N·m /rad or ft·lbf/degree. The inverse of spring rate is compliance, that if a spring has a rate of 10 N/mm, it has a compliance of 0.1 mm/N. The stiffness (or rate) of springs in parallel is additive, as is the compliance of springs in series. Springs are made from a variety of elastic materials, the most common being spring steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication.

Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance).

1.2 HISTORY:

Simple non-coiled springs were used throughout human history e.g., the bow (and arrow). In the Bronze Age more sophisticated spring devices were used, as shown by the spread of tweezers in many cultures.

Ctesibius of Alexandria developed a method for making bronze with spring-like characteristics by producing an alloy of bronze with an increased proportion of tin, and then hardening it by hammering after it is cast.

Coiled springs appeared early in the 15th century, in door locks. The first spring powered-clocks appeared in that century and evolved into the first large watches by the16th century.In 1676 British physicist Robert Hooke discovered the principle behind springs' action, that the force it exerts is proportional to its extension, now called Hooke's law.

1.3 Types of Mechanical Springs

Mechanical Springs can be classified into various types; here in this section I am going to mention some of the most widely used mechanical springs. So here is our list:

1. Helical Spring
2. Conical and volute Spring
3. Torsion Spring
4. Laminated or leaf Spring
5. Disc or Belleville Spring
6. Special Purpose Spring
7. Wave spring

1.3.1 Helical Spring:

Helical spring is one type of torsion spring which is made of wire coiled, form as a helix shape. It is one of the most used mechanical spring. The cross-section of the wire by which Helical Spring is made can be circular, rectangle or square in shape. In this type of spring, the spring can store the energy when it is pressed and released the store energy later on, as well as it can withstand the pulling force between two objects. This type of spring can also resist or absorb sudden jerk or impact.In practice, if you see the suspension of a motorcycle or a high-end railway coach; there you can see helical springs are used. Other than this, helical springs are used for carrying, pulling or compressing of any loads.

Helical Spring can be categorized as:

a. Closed Coil Helical Spring

b. Open Coil Helical Spring

a. Closed Coil Helical Spring

In closed coil helical spring, the distance between each turn or coil is pretty less, or you can say the pitch distance is too small. The angle of the helix of closed coil helical spring is less than 10 degree. This type of spring is used to resist the elongation or twisting. The stiffness of closed coil helical spring is generally higher than any other spring, for this reason, it is used in heavy-duty applications.

b. Open Coil Helical Spring:

As the name denotes open coil, that means the distance between two consecutive turns is more (Helix angle is greater than 10 degree). These springs are used to resist compression. Generally, open-coil helical springs are used in Automobile, Motorcycles and even V/Vs assembly of IC Engine.

Fig.1.1 Open helical spring

1.3.2 Conical and Volute Spring:

This is generally one type of compression spring, conical in shape. When the compression load applies to the spring, then the coils are slide over each other, make it short length and compact in shape than other helical springs. This type of springs is used in electrical or electronics equipment, garden secateurs etc. In practical life, you can see this type of spring in the remote or clock’s battery section. This type of spring is also known as tapered spring.

Fig.1.2 Conical and Volute spring

1.3.3 Torsion Springs

Torsion spring is one kind of close coil helical spring. In this type of spring, when twisting occurs then the spring stored the energy inside it, and when the twisting force lifted it push back to its actual position. When it is twisted than a torque generated at the opposite direction of the twisting force, which helps the spring to back its actual shape. According to one clear choice garage doors, a torsion spring can have a life cycle of 7-9 years, assuming 10,000 cycles at 4 cycles a day. Torsion springs are widely used in the garage door, clips, mouse catcher, torsion bar suspension, etc.

Fig.1.3 Torsion spring

1.3.4 Leaf springs:

It is an arc-shaped spring, made of metal strips one after another and held together by using nut and bolt or clamp. It is widely used as a suspension system of commercial vehicle such as bus, truck, etc. This spring is capable to withstand large forces in small areas. It is generally made of Steel, Graphite epoxy, Carbon epoxy.

Fig.1.4 Leaf spring

1.3.5 Disc Springs:

Disc or Belleville spring is a conical shape washers held together by bolt or tube which has the characteristic of spring. It is non-flat, conical shell spring which generally loads axially. This type of spring can exert constant pressure throughout the object and also provides a high load in small areas. It can be used where thermal expansion or contraction happens rapidly.

Fig.1.5 Disc spring

1.3.6 Special Purpose Springs:

Air spring, gas spring, extension Spring, grater spring, etc. falls under the category of Special Purpose Springs. As the name denotes "Special Purpose" that means these springs are not widely used, but still in some cases like, vice-grip pliers, carburettors, trampolines, washing devices, even in toys we use extension spring. Nowadays we use air spring, where the air is used to pump the bladder which helps us to absorb the shock and vibration completely. So these types of springs are falls under the category of special-purpose springs.

Fig.1.6 Special purpose spring

MOLDED SPRING

Plastic or composite springs are commonly found in corrosive environments, such as food production, medical, and marine applications. Due to creep, they should only be used in intermittent cycles. Compared to metal springs, they are relative newcomers to the space, and supply is not as abundant.

1.3.7 Wave spring: A wave spring, also known as coiled wave spring or scro wave spring, is a spring made up of pre-hardened flat wire in a process called on-edge coiling (also known as edge-winding). During this process, waves are added to give it a spring effect.The number of turns and waves can be easily adjusted to accommodate stronger force or meet specific requirements.

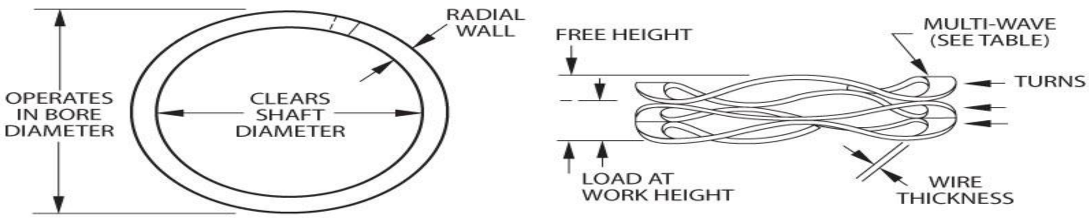

Fig.1.7 Wave spring

a. Single-turn wave spring: Single-turns are best for applications with short deflection and low to medium forces. The number of waves and material thickness can be changed to accommodate stronger forces. It is used for bearing pre-load.

Fig.1.8 Single wave spring

b.Multi turn wave spring: A multi-turn wave spring can decrease the needed axial space. It is suited for applications with large deflection and a small spring rate. A wide range of forces can be accommodated.

Fig.1.9 Multi turn wave spring

c.Nested wave spring

Eliminates the need to stack springs to accommodate higher loads. It produces high force while maintaining the precision of a circular-grain wave spring. It replaces a stack of belleville washers where a high but accurate force is needed.

Fig.1.10 Nested wave spring

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE REVIEW

P.N.L.Pavania, et al. [1] has analysis on wave springs has been done by structural mechanics approach and results were validated compared with the coil spring of the shock absorber. By performing static analysis comparison of wave spring with coil spring is done. Results shows that Wave springs possess less deformation and more stresses when compared with coil springs.

ChandraantChavan, et al. [2] has carried out work on the Fatigue life analysis of the suspension coil spring using a FEA technique interface would offer credible design inputs which can be used concurrently while designing the spring. The modified design based upon the analysis should further be subjected to analysis to check the new outcome. This process of iteration yields an optimized design which fits the function and helps the Design Engineer to validation his design over the virtual interface followed by physical test further to validation for improvement of fatigue life.

Dr P. Ravinder Reddy, et al. [3] has analysis on wave spring has been done by structural mechanics approach and results were validated and compared with the coil spring of the shock absorber. The deflection induced in the wave spring is average 25.88% less than the coil spring. The equivalent stress of wave spring is an average 58.32% less than coil spring. The strain energy of wave spring is an average 21.3% greater than coil spring.

C.Madan Mohan Reddy et al. [4] has carried out work on modeling, analysis and testing of suspension spring is to replace the existed steel helical spring used in popular two wheeler vehicle. The stress and deflections of the helical spring is going to be reduced by using the new material. The comparative study is carried out between existed spring and new material spring. In this the finite element analysis values are compared to the experimental values. A typical two wheeler suspension spring is chosen for study. The modeling of spring is developed on pro/E 5.0 analysis is carried out on ANSYS 14.

Dr P. Ravinder Reddy et al. [5] has present work on the structural analysis of wave and coil spring by modeling the structural behavior of these springs using three dimensional finite elements (FE) software. The design of spring in suspension system is very important. In this work a wave type of spring is designed and a 3D model is created using CREO software. The model is also varied by changing the length of the spring. Structural analysis has been conducted on the wave spring by varying thickness and number of turns. For the analysis, loads are bike weight with single and two persons. The buckling load is then estimated for both Wave spring and coil spring with the same parameters. Analysis on wave spring has been done by structural mechanics approach and results were validated and compared with the coil spring of the shock absorber.

Mr. J. J. Pharne et al. [6] has proposed a finite element model for helical compression springs subjected to cyclic loads is developed for fatigue stress analysis. In the design modification of this kind of spring both the elastic characteristics and the fatigue strength have to be considered as significant aspects. A typical helical compression spring used for two wheeler horn is chosen for study under fatigue loading condition. Fatigue analysis is done in ANSYS 14.0 software. The results developed have been compared with the experimental observations.

S. Abdullah et al. [7] has carried out on the study of a fatigue damage and relationship with I-kaz coefficient. The data collected from the coil spring of an automobile which was driven over highway, country road and damage road surface were used as the subject of this study. This comparative study shows that fatigue damage was proportionally related to the I-kaz coefficient. The reason behind this statement is fatigue damage has relationship with kurtosis and I-kaz coefficient was obviously based on kurtosis and standard deviation. This result shows that, fatigue damage determination can be evaluated either using strain-life approach or I-kaz method.

Krzyszto Michalczyk [8] has carried out analyzes the effectiveness of damping resonance vibrations of a spring using a new method of local coatings made of highly-damping material covering its last coils, as well as the influence of these coatings on the maximum values of dynamic stresses and the values of natural vibration frequencies of springs. It is shown that while an elastomeric coating applied on the whole length of spring wire always causes a decrease in the First natural frequency of the spring, application of the same amount of damping material only on its end-coils may lead to an increase in this frequency. The mathematical model derived in the paper allows users to calculate the effectiveness of dynamic stress reduction both in the spring and the coating itself, for arbitrary geometrical and material properties of coatings.

Rajkumar V. Patil [9] has proposed an analytical buckling equation with its experimental verification and used it along with the existing theories to locate the phase of compression of conical spring at which buckling occurs. Subsequently, a comparison between cylindrical and conical springs has been made at the point of buckling of cylindrical spring in respect of their load and deflection. This helps to decide the suitability of conical springs against buckling failure of cylindrical springs under the given operating conditions.

P.R. Jadhav et, al [10] has carried out work study presents the stress analysis of mono suspension spring. Here, stresses and deflections are calculated with changing speed and validated with FEA. From the finite element analyses, the following findings are reported. Though, the results are elaborated in earlier chapter, the brief discussion and conclusion is presented as follows.

Pinjarla.Poornamohan1, et al. [11] has carried out work on a suspension system or shock absorber is a mechanical device. In this project a shock absorber is designed and a 3D model is created using Pro/Engineer. The model is also changed by changing the thickness of the spring. Structural analysis and modal analysis are done on the shock absorber by varying material for spring, Spring Steel and Beryllium.

CHAPTER 3

EXPERIMENTAL METHODOLOGY

AND

ANALYSIS

EXPERIMENTAL METHODOLOGY AND ANALYSIS

3.1 MECHANICAL PROPERTIES OF COPPER ALLOY:

Table 3.1: Material composite properties

MECHANICAL PROPERTIES	WAVE SPRING	HELICAL SPRING
Compressive Yield Strength MPa	280	280
Tensile Ultimate Strength MPa	430	430
Young's Modulus MPa	1.1e+005	1.1e+005
Poisson's Ratio	0.34	0.34
Bulk Modulus MPa	1.1458e+005	1.1458e+005
Shear Modulus MPa	41045	41045

3.2 Calculation of dimension of Helical spring and Wave spring

In this work, According to the review of different author's work various parameters of helical and wave springs can be calculated:

Helical spring:

- Mean Diameter of coil (D)
- Wire diameter (d)
- Number of active coils (N)
- Coil free height (h)
- Pitch (P)
- Spring index (C)

- Modulus of Rigidity (G)
- Spring Index (C) =D/d
- Shear Stress factor (k) =$\frac{4c-1}{4c-4}+\frac{0.615}{c}$
- Maximum shear stress (τ) = $\frac{k8wd}{\pi d^3}$
- Deflection (δ) = $\frac{8NPD^3}{Gd^4}$

Wave Spring:

- Load (P)
- Length of a wave (L)
- Radial wall (width) (b)
- Thickness of material (t)
- Modulus of elasticity (E)
- Single wave deflection (f) = $\frac{PL^3}{4Ebt^3}$
- Deflection of wave spring f=$\frac{PKD_m^3}{Ebt^3N^4}\times\frac{ID}{OD}$

Table 3.2: Theoretical calculation:

Parameters	Helical spring	Wave spring
Deflection	12.2M Pa	79.4MPa

3.2 SOLIDWORK, a solid modeling computer-aided design and computer-aided engineering program, is one of the most popular software options for mechatronics engineers.

SOLID WORKS was developed by MIT graduate Jon Hirschtick and was bought by Dassault Systems in 1997.

The software now encompasses a number of programs that can be used for both 2D and 3D design.

SOLIDWORKS is used to develop mechatronics systems from beginning to end. At the initial stage, the software is used for planning, visual ideation, modeling, feasibility assessment, prototyping, and project management.

The software is then used for design and building of mechanical, electrical, and software elements.

Finally, the software can be used for management, including device management, analytics, data automation, and cloud services.

A sample of the products that are a part of SOLIDWORKS, as described on their website, include:

- CircuitWorks: an electronic CAD/ECAD translator that enables engineers to create accurate 3D models of circuit boards.

- CAM: an add-on to all versions of SOLIDWORKS CAD that lets you prepare your designs for manufacturability earlier in the development cycle.

- Electrical 3D: enables you to place electrical components and use SOLIDWORKS routing technology to automatically interconnect electrical design elements within a 3D model.

- 2D schematics and 3D models are synchronized bi-directionally in real time so any changes are automatically updated.

- Simulation: uses Finite Element Analysis (FEA) to predict a product's real-world physical behavior by virtually testing CAD models.

- Visualize: leverage your 3D CAD data to create photo-quality content in the fastest and easiest way you can–from images to animations, interactive web content, and immersive Virtual Reality.

Step 01

To get started, click the Part button. This will open a new part document, and the rest of the user interface will be revealed.

If you do not see the welcome screen, or are using an earlier version of SOLIDWORKS, Click the new button on the standard toolbar at the top-left corner of the screen to open the new SOLIDWORKS document dialog. From here, click the Part option and select OK. If the dialog that appears does not look like the one shown below, click the Novice button at the bottom-left of the dialog.

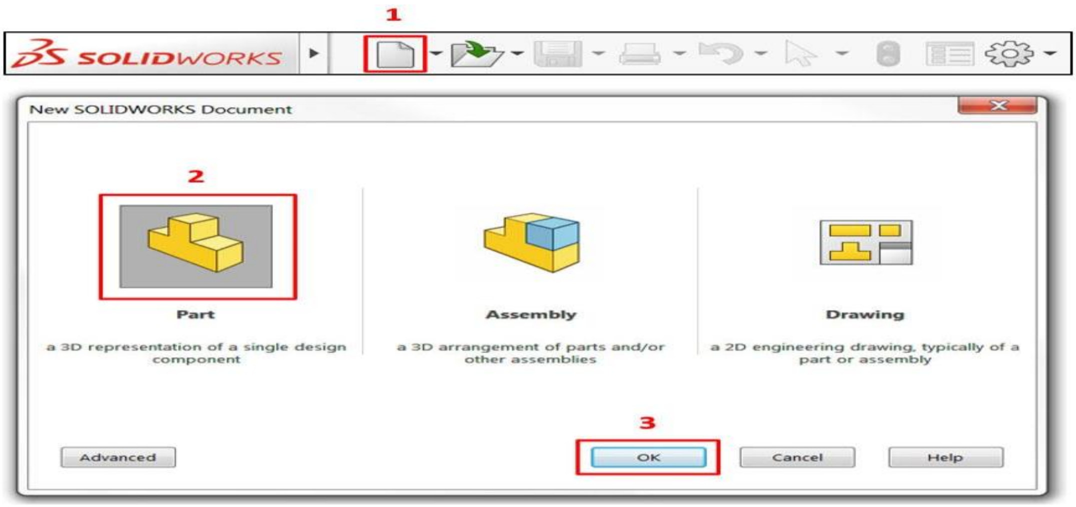

Fig.3.1 Part Selection

Step 02

Once the new part document has been opened, the interface will look like the figure shown below. There are six unique areas of the user interface which every new user should be familiar with, and we have labeled them in the image for convenience.

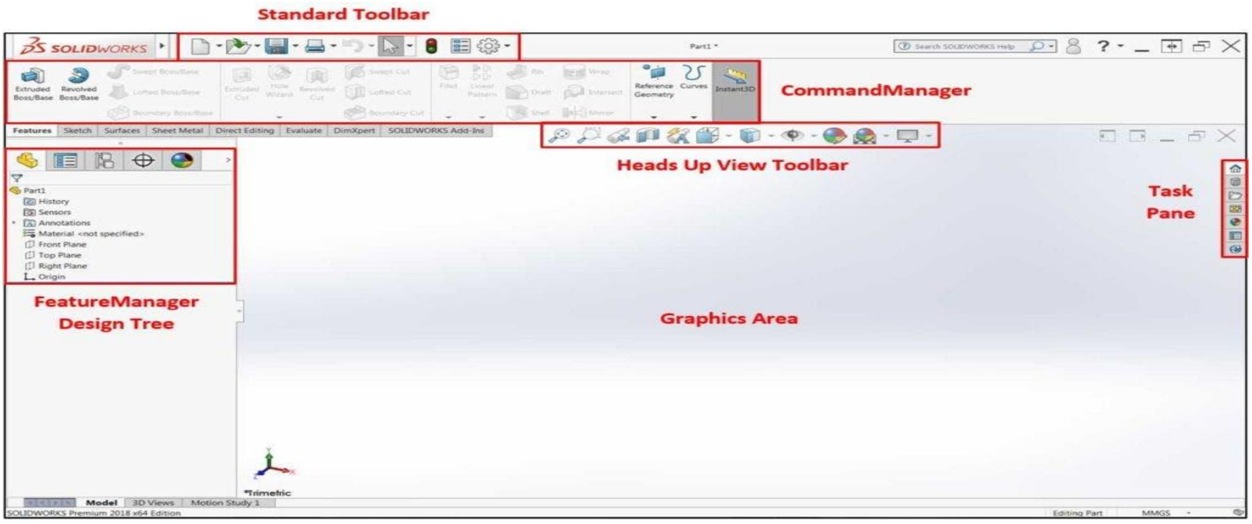

Fig.3.2 Display Interface

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Step 03

Standard Toolbar

Fig.3.3 Standard Toolbar

The Standard Toolbar contains basic commands including New Document, Open Document and Save Document.

Additionally, at the right end of this toolbar, a gear icon is available which will open a

System Options dialog, where a variety of settings can be changed.

Haveing the cursor over the SOLIDWORKS icon will reveal several drops down menus that contain all available commands, including a Help drop down menu where tutorials may be accessed.

Step 04

Command Manager :

The Command Manager is a context-sensitive toolbar that provides different sets of commands based on the tab that is selected directly below it (Features, Sketch, etc.). This is the primary area where users begin commands to create sketches, add/remove material, or evaluate models, among many others. In many cases, SOLIDWORKS will automatically switch to the appropriate Command Manager tab when changing modes, however, it may be necessary to manually switch between tabs by clicking on them.

Not all available tabs are shown under the Command Manager by default. If working in Sheet Metal or Weldments, for example, right click an existing tab and select the desired tab from the list. This will add the tab permanently.

Additionally, not all commands are available in the Command Manager tabs by default. To customize your Command Manager with extra commands, consider taking a look at this Command Manager tutorial. Otherwise, all commands can be accessed through the file drop down windows.

To reveal these drop down windows, however the cursor over the SOLID WORKS badge at the top-left of the screen. In these menus, you will find all the commands and options available in SOLID WORKS. These menus can also be made permanently visible by clicking the pushpin icon just to the right of the Help drop down.

Finally, it is possible to search for commands, provided you know the name of the command. At the top-right of the interface exists a search bar, which by default allows the SOLIDWORKS help file to be searched.

Click the down arrow on the right of the search bar and select Commands to enable command search. Search results can be clicked to execute the command, or the eyeball icon can be selected to automatically show the command's location in the user interface. Additionally, commands can be dragged and dropped directly onto the Command Manager from the results list.

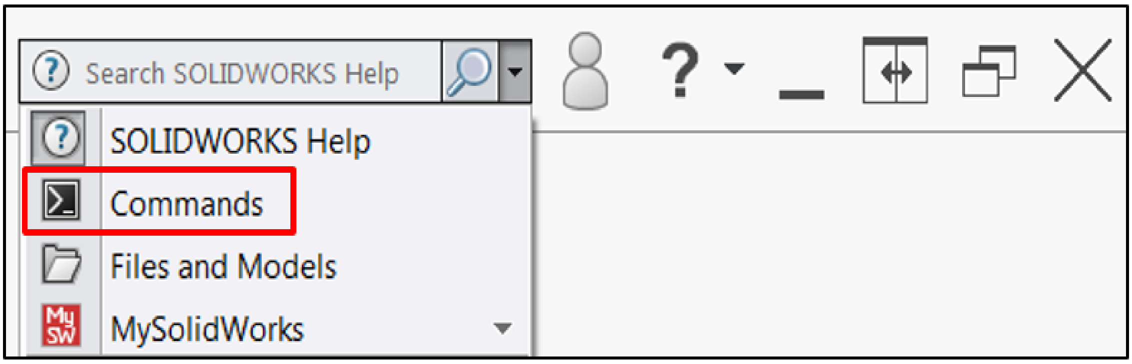


Fig.3.4 Command Manger

Step 05

Feature Manager Design Tree

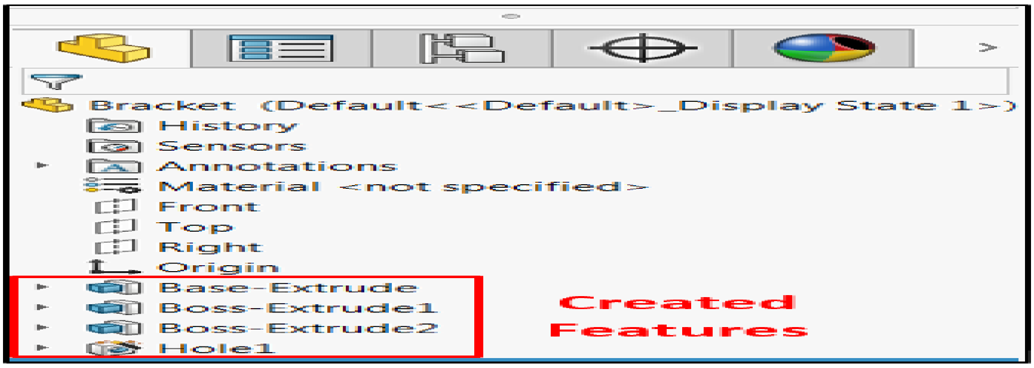


Fig.3.5 Feature Manger Design Tree

The Feature Manager Design Tree is a chronological hierarchy of all the sketches and features that have been created or applied to the model, appearing just after the Origin. This section of the interface is exceptionally important, as it is where many editing operations originate. Here, you will also find three default planes, which act as the base geometry for (at a minimum) your first feature.

This area of the user interface will temporarily change to a Property Manager when creating a new feature or during various other operations. This is the default behavior of SOLIDWORKS, and the Feature Manager Design Tree will return once the feature has been completed.

The tabs at the top of the Design Tree are used to navigate to other interfaces that use the same space; if another interface is accidentally shown, simply click the first tab to return to the Design Tree.

If the interface is completely hidden, be on the lookout for a small tab on the left side of the screen. Click this small tab to return the Design Tree to view.

Step 06

Heads Up View Toolbar

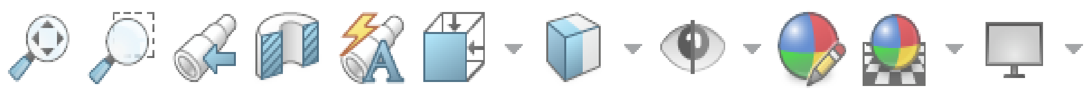


Fig.3.6 Toolbar

This transparent toolbar at the top of the graphics area provides a number of controls for manipulating the colors and appearances of your designs as well as your perspective of them. You may also here this toolbar referred to as the Heads up Display Toolbar.

Commonly used functions here include fitting the model to the screen, changing view orientation, changing the display style (shaded with edges, wireframe, etc.) and applying colors/appearances to designs.

Remember, overing the cursor over any of these commands will display a tool tip explaining it!

Step 07

Task Pane

Fig.3.7 Task Pane

The Task Pane contains several tabs that all serve different purposes.

Depending on other applications you may have installed in addition to SOLID WORKS, you may have a greater or lesser number of tabs than are shown here.

3.3 ANALYSIS

ANSYS WorkbenchR15.0

Introduction:

ANSYS Workbench combines the strength of our core simulation tools with the tools necessary to manage projects. The work is carried out in ANSYS Workbench project on the main project workspace, called the Project tab. The project is driven by a schematic workflow, represented visually on a flow chart like diagram called the Project Schematic. To build an analysis, building blocks are added called systems to the Project Schematic; each system is a block of one or more components called cells, which represent the sequential steps necessary for the specific type of analysis. Once you have added your systems, you can link them together to share and/or transfer data between systems.

Working through a System:

ANSYS Workbench provides you with a fairly straightforward workflow for creating and working through a system. First, you select a system from the Toolbox and add it to the Project Schematic. Then you work through the cells in the system, generally from top-to-bottom, until you have completed all the required steps for your analysis. In most cases, data flows from top to-bottom through the system, as well. For example, in a Mechanical system, the geometry must be defined before you can define the model; the Model cell uses the geometry defined in the Geometry cell as its input.

The ANSYS Workbench platform is the frame work upon the industries broad cast and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex metaphysics analysis with drag and drop simplicity, with bi-directional CAD connectivity, powerful highly automated meshing, a project level update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS .Workbench platform delivers unprecedented productivity, enabling simulation. The Workbench environment allows you to solve much more complex analysis, including (as of ANSYS 15.0)

1. Multi-part assemblies.
2. 3-D solid elements, shell elements and shell solid assemblies.
3. Non- linear contact with or without friction.
4. Small and large displacements static analysis.
5. Modal, harmonic, Eigen value and buckling analysis.
6. Steady state thermal analysis, including temperature dependent material properties. and thermal contacts. 5.3.3Step by step procedure for any.

Step 01

ANSYS Workbench is opened. The interface of the ANSYS appears as shown in the figure.

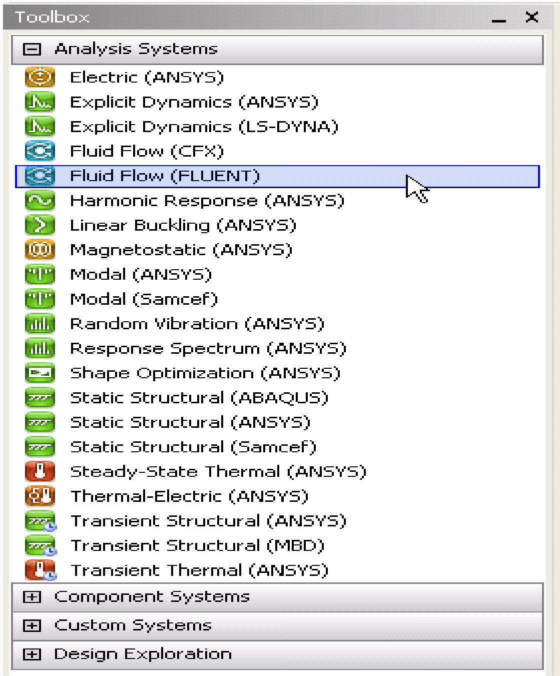


Fig.3.8 Workbench toolbox

Step 02: Creation of analysis system:

To create an analysis system, expand the Standard Analyses folder in the Toolbox and drag an analysis type object 'template'' onto the Project Schematic as shown in the figure. The analysis system is displayed as a vertical array of cells (schematic) where each cell represents a component of the analysis system. Address each cell by right clicking on the cell and choosing an editing option

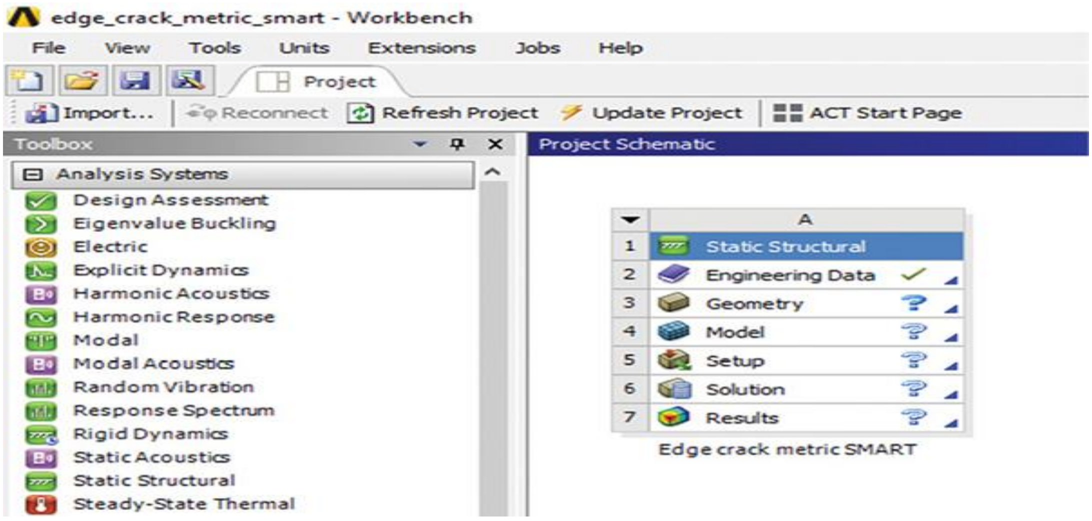


Fig.3.9 Analysis interface

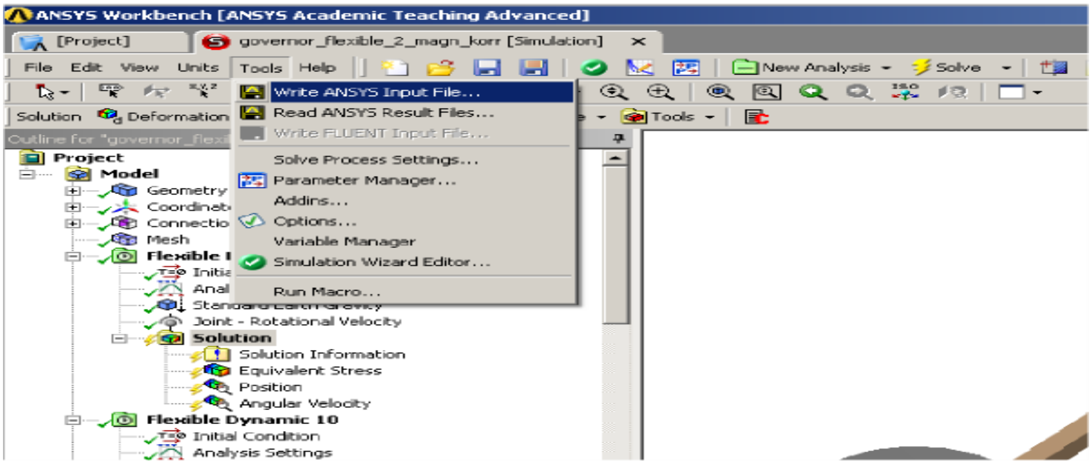


Fig.3.10 engineering data and Geometry

Step 03: Engineering data:

The engineering data option is selected. A window appears where the mechanical properties of the material of the leaf spring can be given as shown in the figure.

Step 04: Apply geometry:

Attach geometry to the system or build a new geometry in Design Modeler. Right-click the Geometry cell and select Import Geometry to attach an existing model or select New Geometry to launch Design Modeler. For an existing model, the geometry is imported in IGES format as shown in the figure.

Step 05: Apply Mesh Controls and Preview Mesh:

Meshing is the process in which the geometry is spatially discretized into elements and nodes. This mesh along with material properties is used to mathematically represent the stiffness and mass distribution of the structure. The default element size is determined based on a number of factors including the overall model size, the proximity of other topologies, body curvature, and the complexity of the feature. If necessary, the fineness of the mesh is adjusted up to four times (eight times for an assembly) to achieve a successful mesh. The option mesh is selected and fine meshing is selected. Helical spring is divided fine elements as shown in the figure.

Step 06: Apply Loads and Supports:

For a static structural analysis applicable loads are all inertial, structural, imported, interaction loads, and applicable supports are all structural supports. Fixed support is applied to the bottom face while force is applied on the top face of the helical spring. The load is acting in the downwards direction. So load is applied in the negative y- direction as shown in the figure

CHAPTER 4

DESIGN OF MATERIAL

AND

ANALYSIS PROCESS

Design of material and analysis process:

4.1 Design process:

SOLIDWORKS is a design automation software. In SolidWorks , we can sketch ideas and experiment with different designs to create 3D models and it is one of the powerful tool in designing and assembling of components.

The interface of the Solid Works is shown in figure:

Basically solid works model is made up of three modules of PART, ASSEMBLY and DRAWING .

select PART from the dialog box shown and select OK. the first part of the drawing can be made.

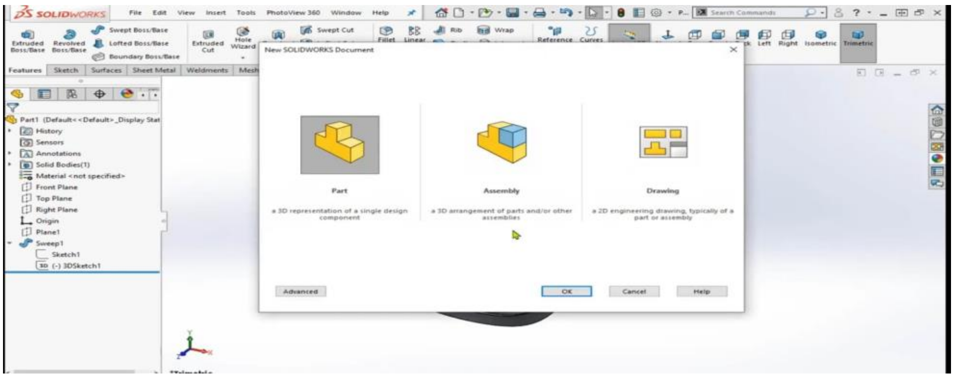


Fig.4.1 A Part Selection

4.2 Design of Helical spring:

Using solidworks helical spring was designed. SOLIDWORKS is a design automation software. In SolidWorks , we can sketch ideas and experiment with different designs to create 3D models and it is one of the powerful tool in designing and assembling of components.

The interface of the Solid Works is shown in figure:

Basically solid works model is made up of three modules of PART, ASSEMBLY and DRAWING .

select PART from the dialog box shown and select OK. the first part of the drawing can be made.

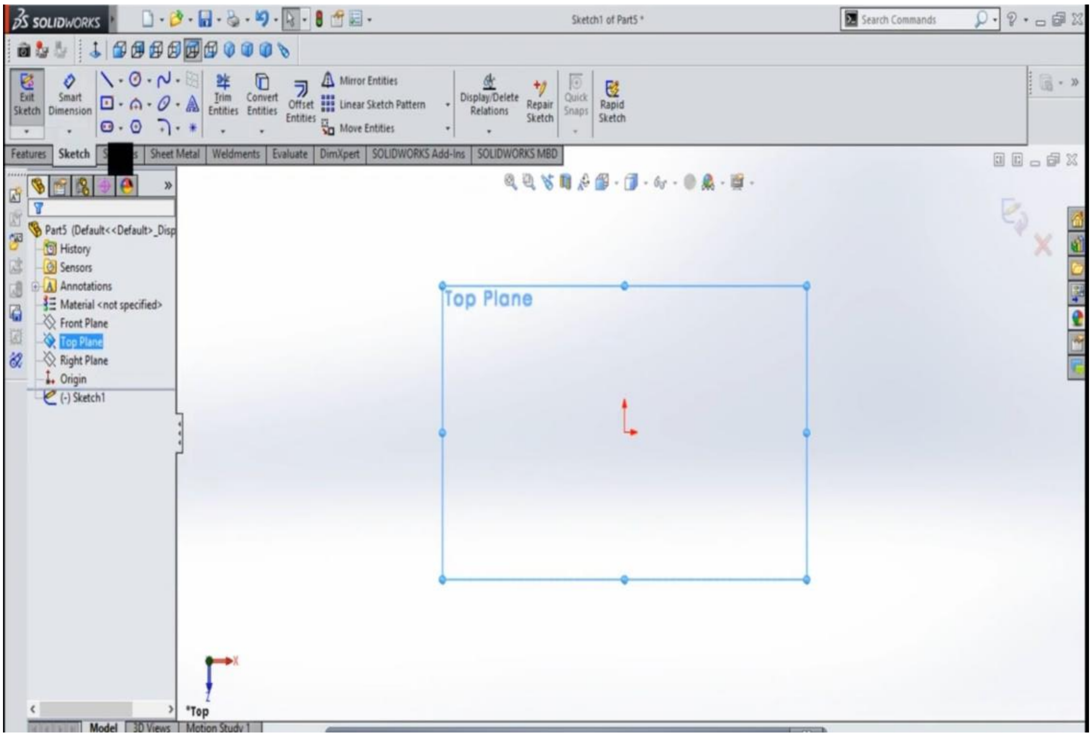


Fig.4.2 Select on Top Plane

Drawan axis along the horizontal direction with the length of 80mm. Draw cirle with diameter of 5mm near to the axis. Select the sweep boss options by choosing both the aixs and cirlce and click Ok..fig 4.3&4.4.

.

Fig:4.3   Selected Comand to draw cricle

Fig:4.4 Helical spring sweep extruded

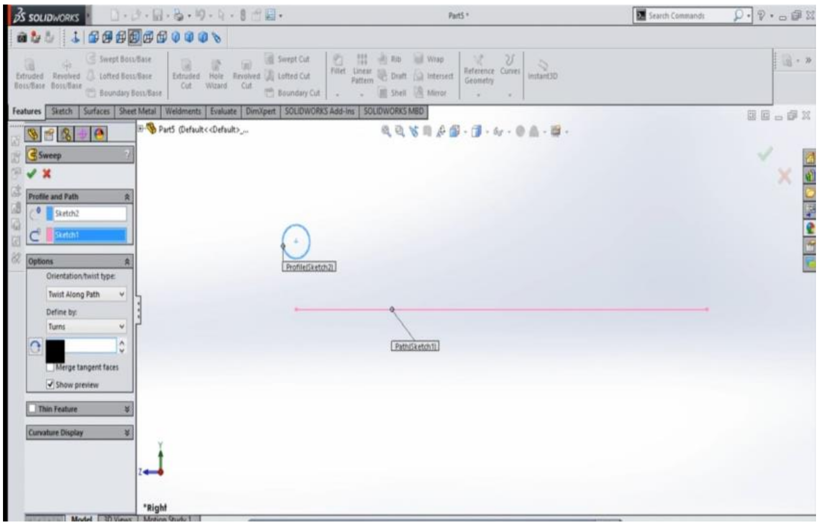
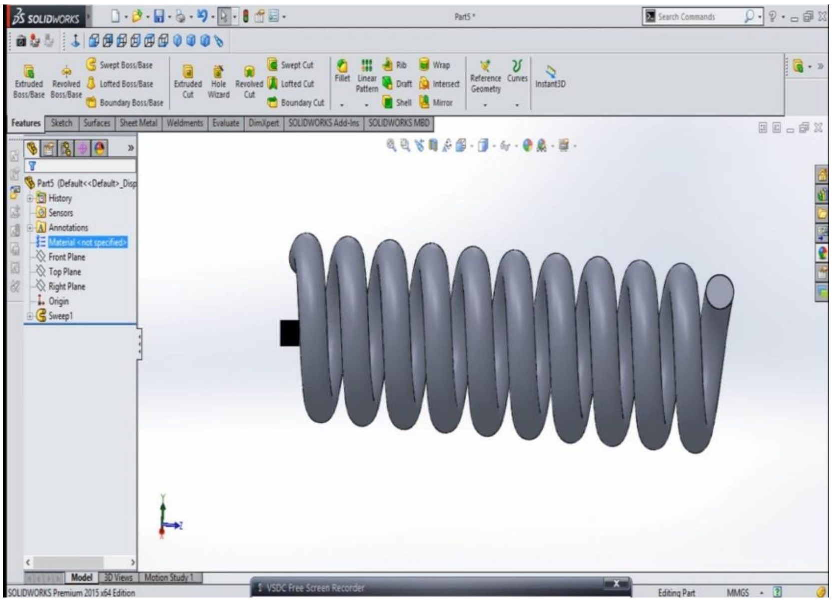


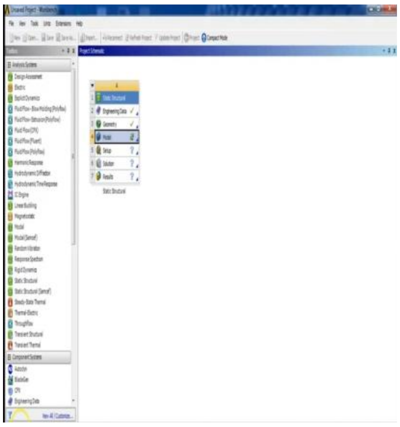
Fig 4.3

Fig 4.4



4.3 Ansys :

Helical spring



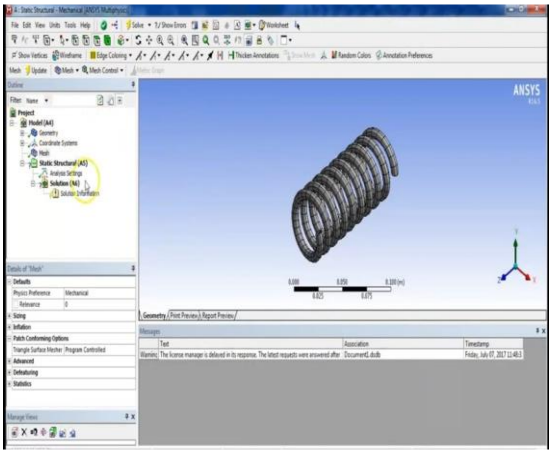


Fig 4.5 Analysis toolbox and mesh

Ansys15.0 version was use for analysis process. First, we choose static structural frature and then click Ok. We get the tool box as shown in the frist figure. Select the geometry data and then import the modelby selecting the model , import option.Using the geomery model we select the mesh tool to generate the meshing object as shown in figure2. Later apply the loads on the model.

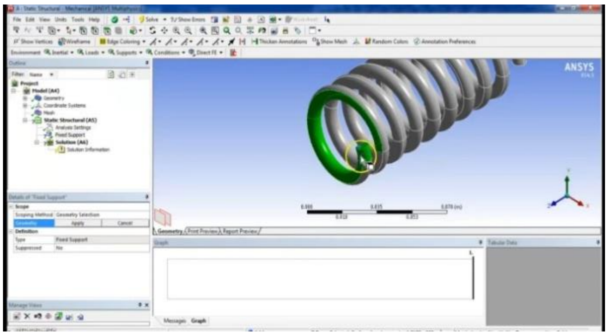


Fig 4.6 Loads on spring

4.4 WAVE SPRING

Step by Step process:

A plane has to be selected to start the sketch. According to the requirement of the drawing, select the plane (as shown in the figure) in which the part must be drawn.

First choose the top plane and draw a circle with outer diameter of45mm and inner diameter of 39mm.

Right click one equation driven curves in feature tab and then given the required value in equation and choose the reference planes accordingly.

X=A*Sin(t)

Y=A*Cos(t)

Z=B*Sin*(t)+D*(t)
where A = Radius ,

B= Amplitude/ pitch,

C = Curves in one revolution,

D = Spacing between spring

➢Finally, wave spring is generated with the specified dimensions and as shown in the figure.

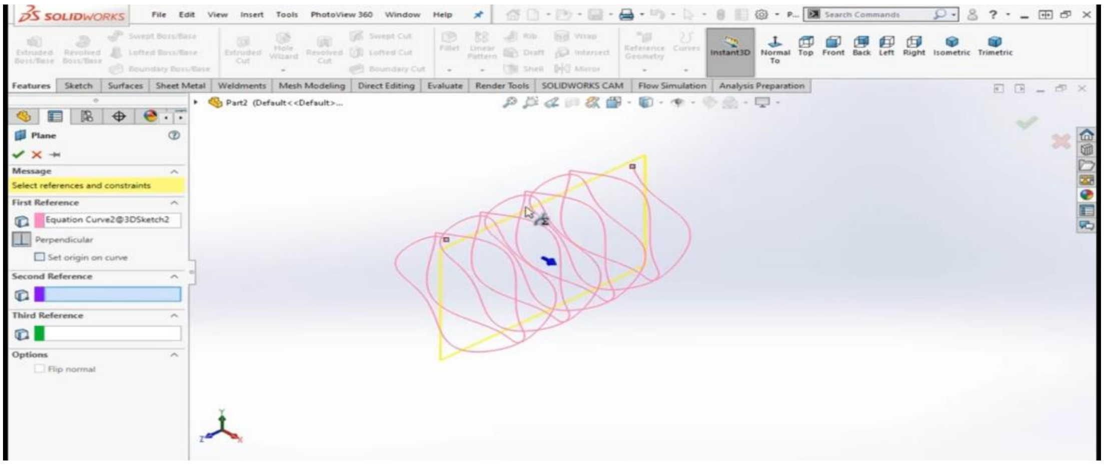


Fig.4.7 Command of curves lines path

Later, select the one end of the spring to generate an rectangle by choosing the center rectangle.

Using Smart dimensions tool, we generate the rectangle.

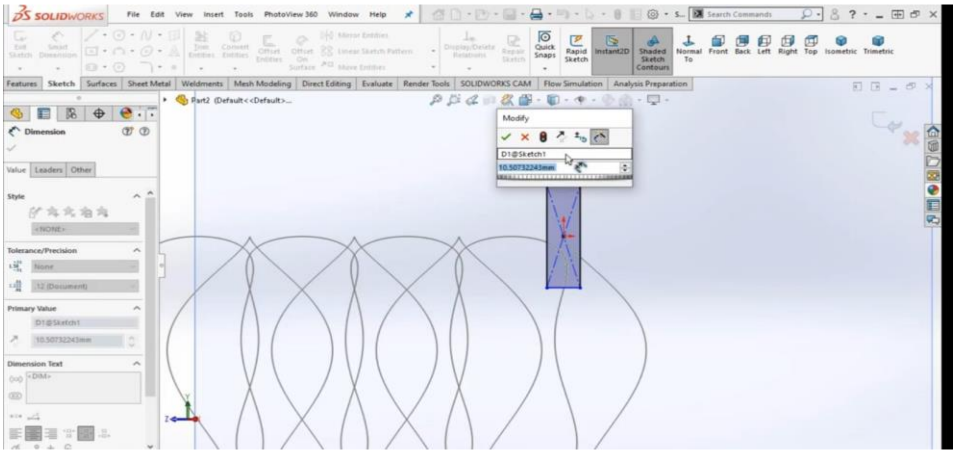


Fig.4.8 Smart Dimensions

From top of the left corner, we select the sweep Boss and click on it ok and then select the sketch planes to extrude using extrude option in features tab to generate the 3D object as shown in the figure

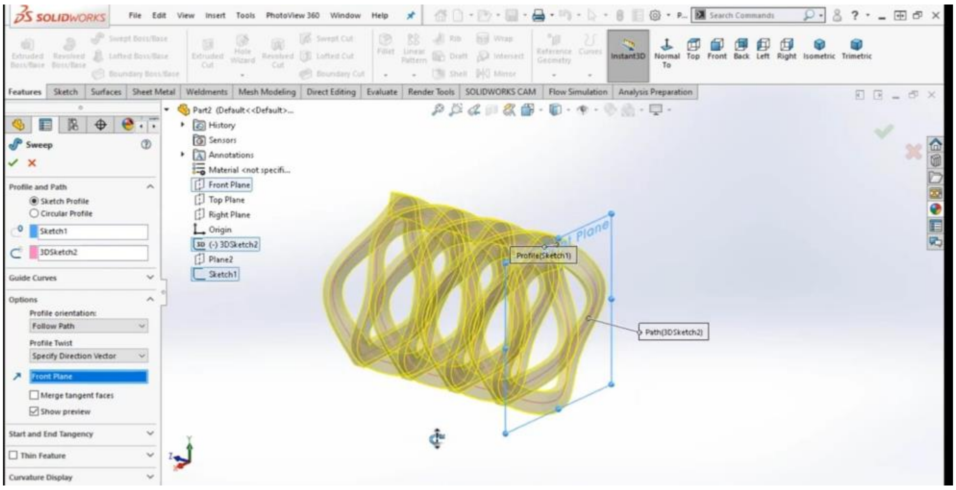


Fig.4.9 Solid Extruded design

Finally, the Wave spring is generated with the specified dimensions and as shown in the figure

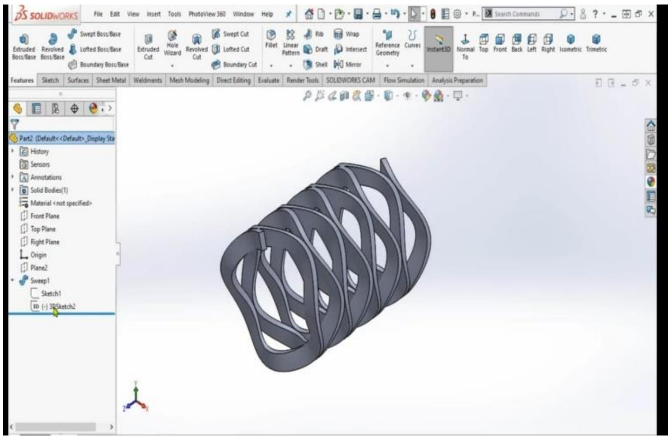
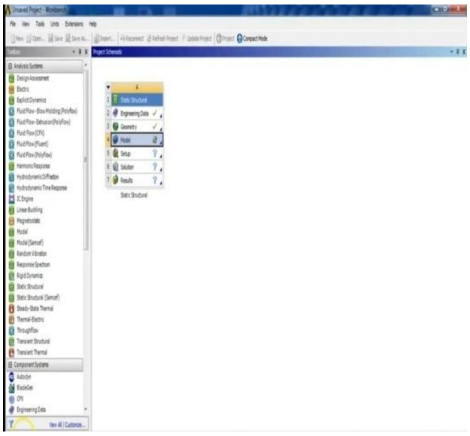


Fig 4.10 Wave Spring design

4.5 Analysis of wave spring

Analysis of wave spring was done by using ANSYS15.0. In figure1,it explains the Ansys model of wave spring where the geometry was import. From figur2 is the meshing process of wave spring model and meanwhile loads are applied on the model in figure3.



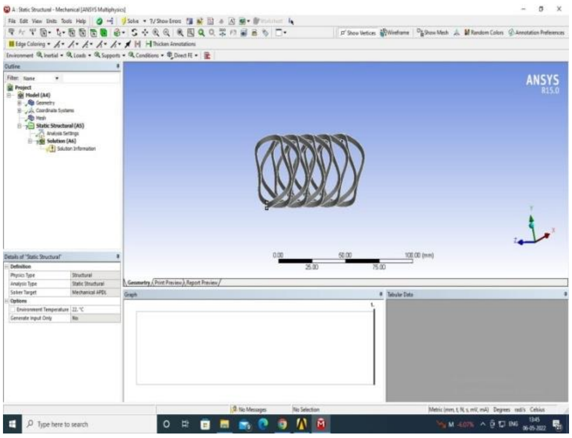


Fig 4.11 Analysis Toolbox

Fig 4.12 Geometry of Wave spring

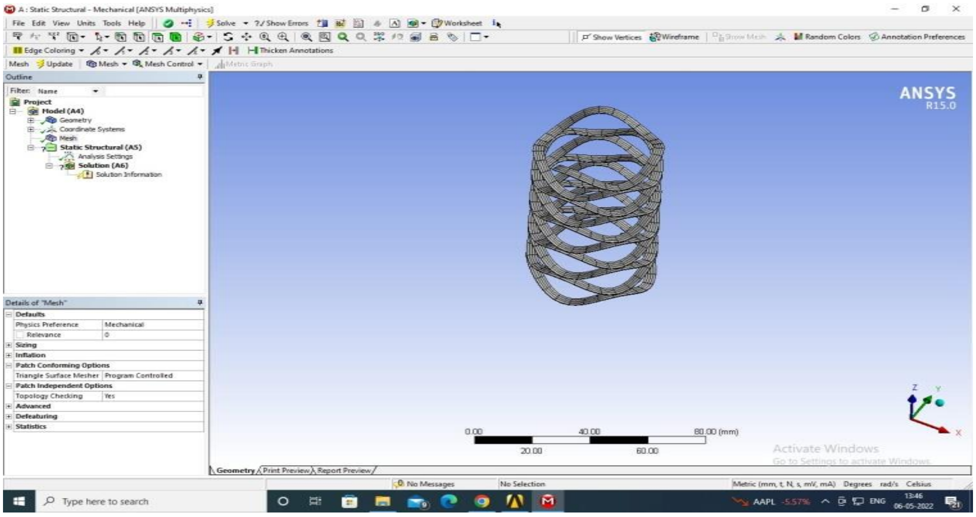


Fig 4.13 Mesh design of Wave spring

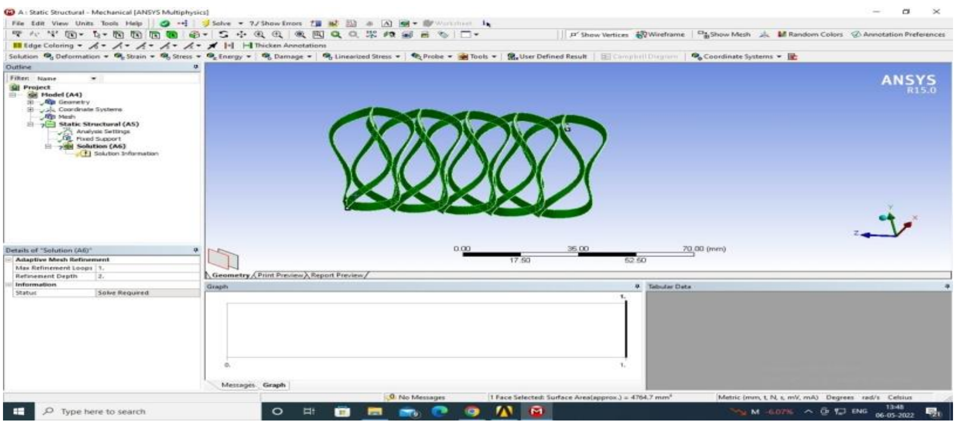


Fig 4.14 Loads on Wave spring

4.6 ANALYSIS OF HELICAL AND WAVE SPRING

4.6.1 Analysis of Shear Stress

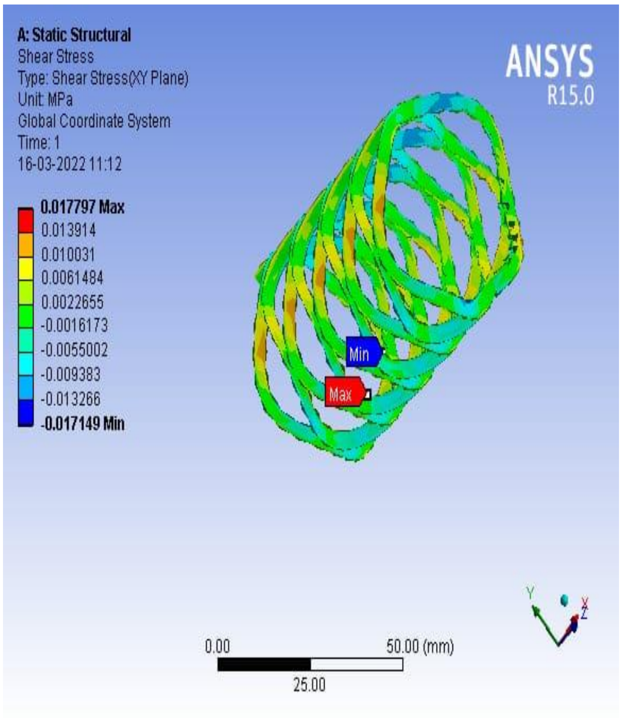
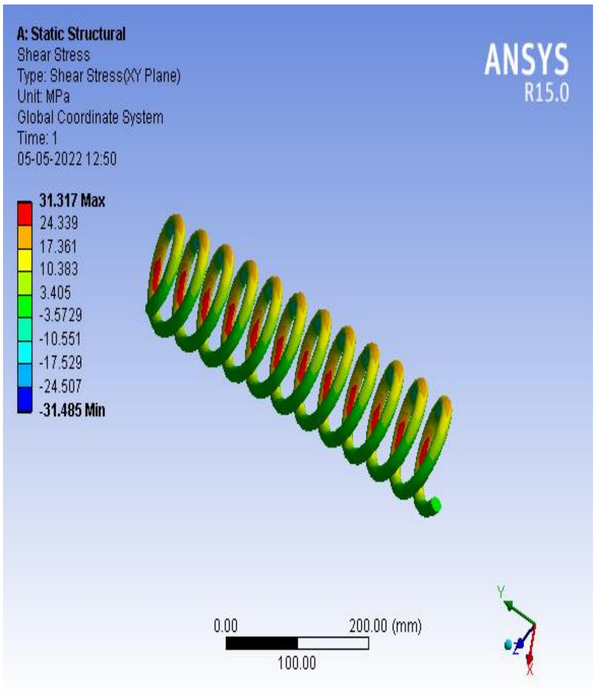


Fig 4.15 Shear stress of wave spring



4.16 Shear stress of helical spring

Table 4.1: Shear Stress of Helical spring and Wave spring

Object Name	Wave Shear Stress	Object Name	Helical Shear Stress
Minimum	-0.017149MPa	Minimum	-31.485 MPa
Maximum	0.017797 MPa	Maximum	31.317MPa

4.6.2 Analysis of Strain Energy

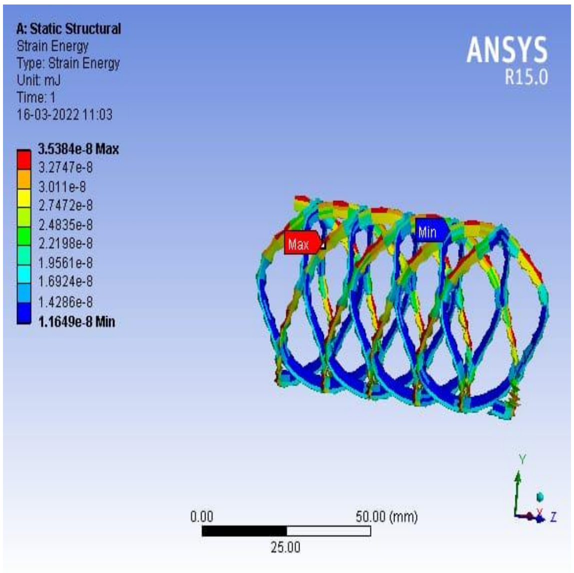


Fig 4.17 Strain energy of wave spring

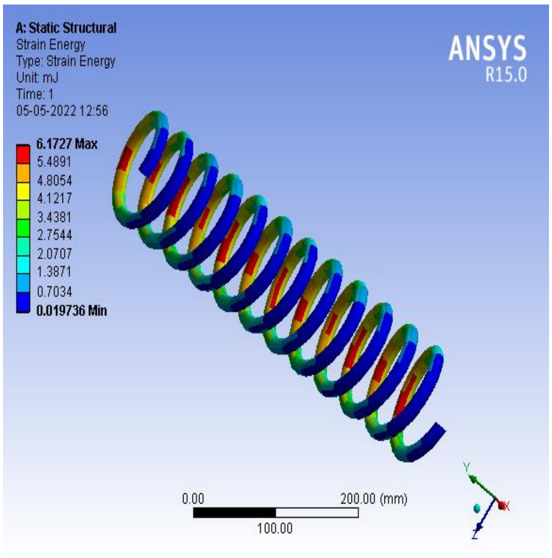


Fig 4.18 Strain energy of helical spring

Table 4.2: Strain Energy of Helical spring and Wave spring

Object Name	Strain Energy	Object Name	Strain Energy
Minimum	1.1649e-008mJ	Minimum	0.019736 MJ
Maximum	3.5384e-008 mJ	Maximum	6.1727 MJ

4.6.3 Analysis of Maximum Shear Stress

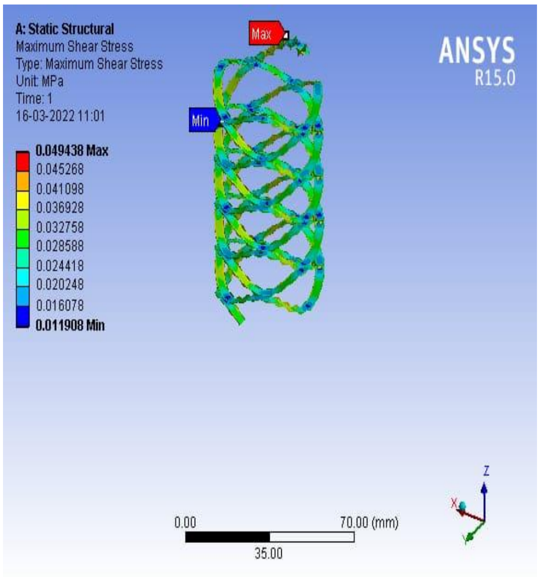


Fig 4.19 Max Shear stress of wave spring

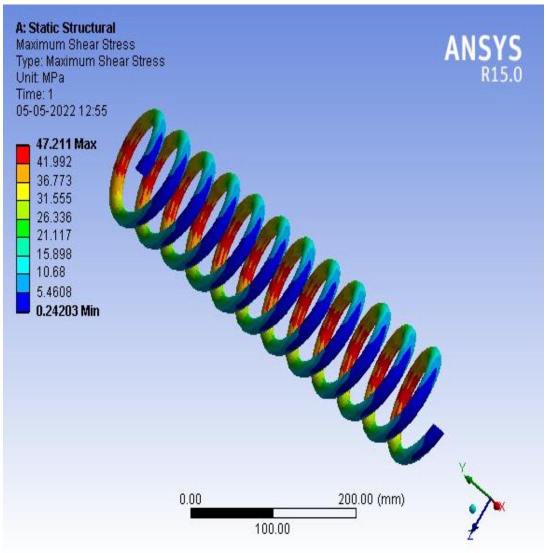


Fig 4.20 Max Shear stress of helical spring

Table 4.3 Max Shear Stress of Helical spring and Wave spring

Object Name	Maximum Shear Stress	Object Name	Maximum Shear Stress
Minimum	1.1908e-002 MPa	Minimum	0.24203 MPa
Maximum	4.9438e-002 MPa	Maximum	47.211 MPa

4.6.4 Analysis of Total Deformation

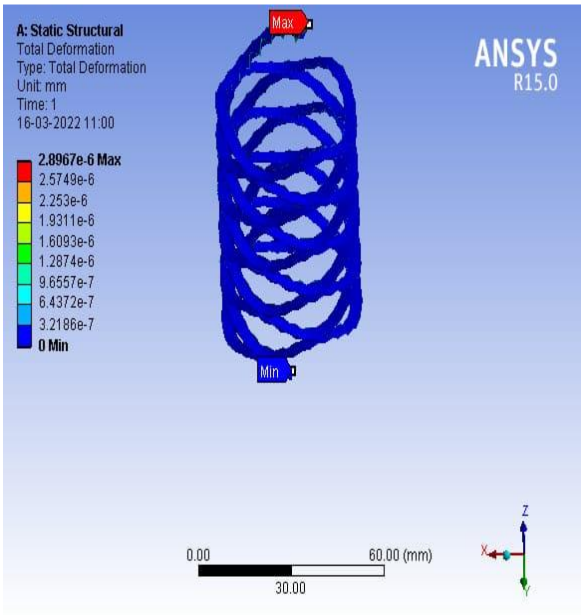


Fig4.21 Total deformation of wave spring

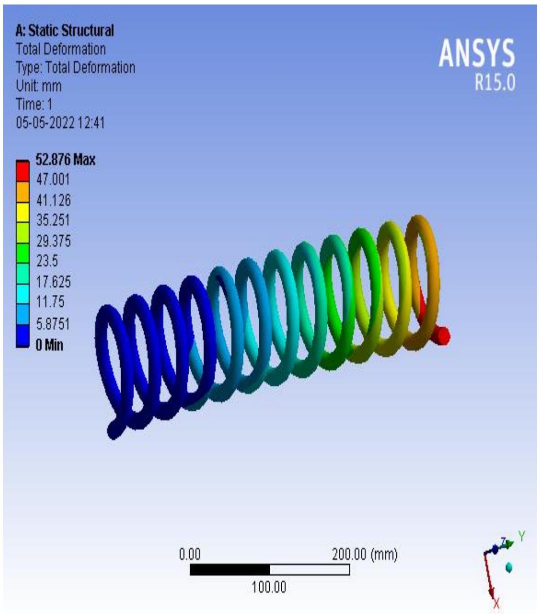
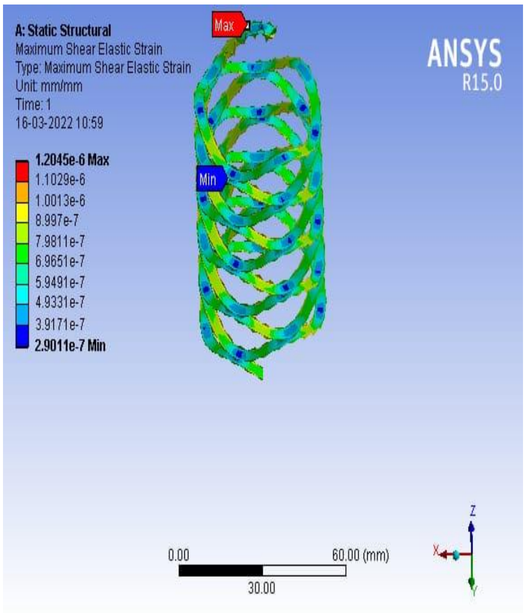


Fig4.22 Total deformation of helical spring

Table 4.4 Total Deformation of Helical spring and Wave spring

Object Name	Total Deformation	Object Name	Total Deformation
Minimum	0 mm	Minimum	0. mm
Maximum	2.8967e-006 mm	Maximum	52.876 mm

4.6.5 Analysis of Maximum Shear Elastic Strain



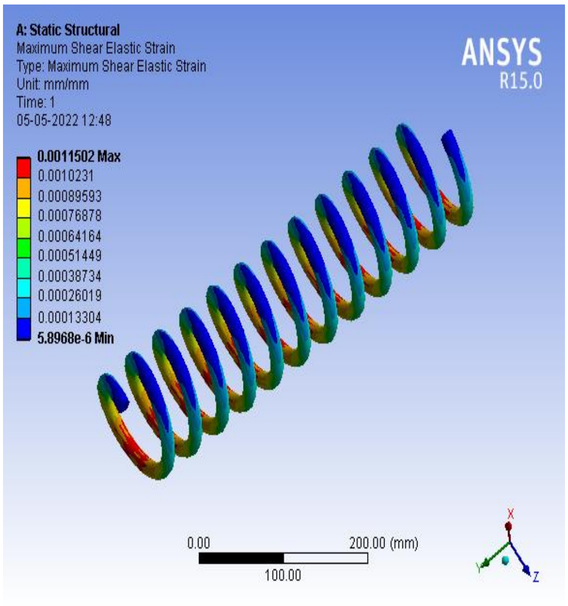


Fig 4.23 Max Shear Elastic Strain of wave spring

Fig 4.24 Max Shear Elastic Strain of helical spring

Table 4.5 Max shear elastic Strain Helical spring and Wave spring

Object Name	Maximum Shear Elastic Strain	Object Name	Maximum Shear Elastic Strain
Minimum	2.9011e-007 mm/mm	Minimum	5.8968e-006 mm/mm
Maximum	1.2045e-006 mm/mm	Maximum	1.1502e-003 mm/mm

CHAPTER 5

RESULT AND DISCUSION

RESULT AND DISCUSION

A brief study of Wave spring was done using ANSYS Workbench software. The results of stress and deflection for copper alloy material are discussed below:

From the above shown fig, it is observed that for two types of springs, as the stiffness of the spring material increases, total deformation decreases and corresponding stresses will increase. When the deformation decreases the spring back effect is less and the use of dashpot can be eliminated and the spring alone can be used as suspension system. Detailed analysis was made on two wheeler vehicle shock absorber coil spring and wave spring of half e height with same dimensions. From the above analysis it was concluded that as wave springs undergoes less deflection than that of coil springs. But wave spring show deflection result due to its spring wave design and helical show good result as compare wave spring.It was also observed from the results that Helical spring is preferable to two wheeler vehicle.

CHAPTER 6

CONCLUSIONS

CONCLUSIONS

The objective of the work is to study the behavior of Wave springs adopted for automobile suspension system under load conditions and design modifications. For this analysis copper alloy materials was used and the following conclusions are drawn from this work.

1. The modeling was done in SOLIDWORKS and analysis in ANSYS 15.0 and it is observed that copper alloy is the best material of construction for Wave spring from analysis.

2. The values of shear stress and deformation of various spring materials for circular cross-sections as well as square cross-sections are compared.

3. It is observed that the shear stress is maximum at 4.9438e-002 MPa and minimum at 1.1908e-002 MPa in Copper Alloy.

4. The Total deformation is maximum at 2.8967e-006 mm which was observed in copper alloy at the specified loading condition.

5. Copper alloy material was almost near to that of Stainless steel and more advantageous than others.

CHAPTER 7

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REFERENCES

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