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Research article

Static Structural Analysis of Suspension System

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ABSTRACT

Coil spring suspension systems are widely used in various applications, including automotive, industrial, and aerospace engineering. The spring, bearing, piston rod, seal block, rebound adjuster, and hydraulic oil make up the suspension system. The suspension system's main purposes include increasing the amount of contact time between the tyres and the road. It supports the vehicle's weight evenly and offers stable steering and good handling. The principle of force dissipation, which involves converting force into heat and thereby eliminating the impact that force would have made, underlies how a suspension operates. The energy will be stored by a spring and transformed into heat by a damper. By applying a theoretical method to determine the deflection of coil spring suspension system in this paper. Here mainly focus on the basic coil spring model which is the main part of suspension system. It also aids in the bike and rider's ability to absorb significant shocks when executing jumps. For designing of coil spring suspension system 3D software Solid works is used. For analysis of the model ANSYS workbench is implemented. Using standard theoretical data, analytical & simulation results are compared & mesh convergence graph study is also done in this paper.

1. INTRODUCTION

When riding on unpaved surfaces, shocks are absorbed mechanically by a suspension system or shock absorber. Shock absorbers are used in vehicles to improve ride comfort. Rides without shock absorbers are bouncy. The vehicle will vibrate at a frequency equal to that of rough terrain [1]. The main purpose of a two-wheeler suspension system is to cushion the rider and vehicle body from shocks caused by road irregularities. A good suspension system should have a minimal amount of deflection upon application of load, be inexpensive, light in weight, require little in the way of operating or maintenance expenses, and operate with the least amount of tyre wear possible.

A motorcycle wheel can move independently from the chassis due to a coil spring. The spring's movement is governed and managed by a hydraulic damper setup. The main purpose of motorcycle suspension is to shield the rider and chassis from the imperfections of the road. The vibration caused by potholes, bumps, corners, and acceleration or deceleration forces can be reduced with an effective suspension system. In contrast, when a motorbike encounters a bump in the road, its tyres would lose traction. Additionally, the suspension system offers both the rider and passenger a comfortable riding experience [2].

Newton's laws of motion state that every force has a magnitude and a direction. The wheel oscillates up and down perpendicular to the road when there is a bump in the road. Of course, the size will differ depending on whether the wheel is hitting a huge bump or a small speck. In either case, the car wheel accelerates vertically as it crosses an imperfection. Without a supporting structure, the frame receives all of the vertical energy from the wheel and moves in the same direction. The wheels may completely lose contact with the ground in this scenario [3]. The wheels may then crash back into the road due to gravity's downward force. The purpose of a car's suspension is to increase the amount of contact between the tyres and the road, provide good handling and steering stability, and ensure the comfort of the passengers. Spring-based safeguards regularly use loop springs or leaf springs; however, suspension bars can be utilized in tensional stuns also. Perfect springs alone, be that as it may, are not safeguards as springs just store and don't scatter or retain vitality. Vehicles normally utilize springs and suspension bars just as pressure driven safeguards. In this blend, "safeguard" is held explicitly for the water driven cylinder that ingests and disperses vibration [4].

The failure of a freight locomotive's helical spring was caused by redesigning it to increase durability and ride index. The composite suspension system can support loads under normal operating conditions and maintain ride index, but the failure happens during cornering and hunting speeds. To prevent this, the study of a composite spring's dynamic behaviour is examined. For the static analysis of the primary suspension system, they used Pro/E to model helical springs and ANSYS to analyse primary suspension springs made of two materials. Chrome The traditional steel helical spring made of 60Si2MnA steel, which is a new material compared to vanadium, is shown to be the best material for helical springs by a decrease in diversion and by high pressure [5]. Different suspension and steering systems serve a dual purpose by helping the vehicle hold, handle, and brake for good active safety and driving enjoyment and by keeping passengers in the vehicle comfortable and reasonably well isolated from road noise, bumps, and vibrations, etc [6, 7].

N. Lavanya looked into the ideal design and analysis of a suspension spring for a car that was put through a static helical spring analysis. The study demonstrates how spring behaviour will be observed under recommended or anticipated loads, and it also improves helical spring cyclic exhaustion. Low carbon basic steel has lower initiated pressure and strain values than chrome vanadium material [8, 9].

Composite helical springs with a hollow circular section were created by Gobbi and Mastinue. The method allows defining the spring geometrical and mechanical parameters in order to get the best compromise between spring performances (minimum mass, maximum strength), with constraints on local and global stability and on resonance frequency. In their study, the technical specifications, such as stiffness, maximum deflection, were provided [10].

A helical spring suspension system's main parts are as follows:

- Coil Springs: The suspension system's primary components are the coil springs. They are typically helical in shape and made of steel. The coil springs store and release energy when they are compressed or extended, giving the suspension system the support and flexibility, it needs.
- Suspension Struts/Shock Absorbers: Helical spring suspensions frequently include suspension struts or shock absorbers in addition to coil springs. These parts reduce oscillations and stop excessive bouncing or rebounding, which aids in controlling the suspension system's motion. They enhance the vehicle's control, stability, and handling.

- Control Arms: Helicoidal spring suspensions frequently use control arms, also referred to as A-arms, to join the suspension parts to the chassis. They give the coil springs the necessary points of attachment, enabling them to move and articulate as the suspension moves.
- Stabilizer Bars: Helicopter suspensions with helical springs sometimes include stabilizer bars, also known as sway bars. By transferring forces between the wheels, these bars, which join the left and right sides of the suspension system, assist in reducing body roll while cornering.

The following are some benefits of helical spring suspensions:

- Improved Handling: Helical spring suspensions improve handling and stability, enabling better maneuverability and control, by controlling suspension movement and maintaining tyre contact with the road surface.
- Comfortable Ride: The coil springs effectively absorb and dampen road vibrations, giving the passengers of the vehicle a smoother and more comfortable ride.
- Helical springs are strong and have a long service life, making them durable. They are capable of supporting heavy loads and are dependable for the duration of the vehicle's life.
- Cost-Effectiveness: Helical spring suspensions are generally more affordable to manufacture and maintain than other suspension types, making them a popular option for a variety of vehicles.

In this paper by taking the theoretical values the analytic solution calculated. Then the model is prepared by using solid works. For simulation of the model Ansys Workbench is used. The mesh size is placed an important role in the simulation. Here tetrahedral meshing is used with the mesh size varying 5 mm to 2.5 mm. Reduction in mesh size is giving more accurate results to the analytical value. Then mesh converging study is performed in it.

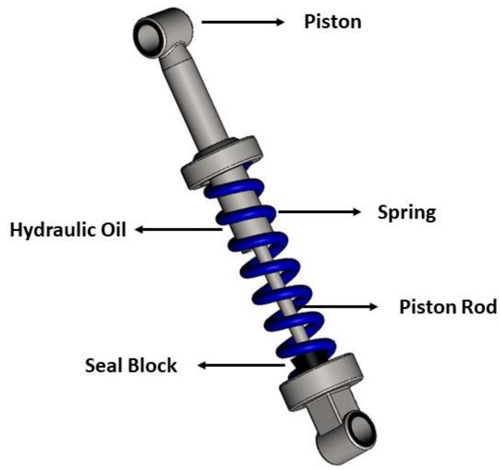

Fig. 1. 3D view of suspension system.

2. MATERIAL SELECTION AND INPUT PARAMETERS

Nomenclature of the symbols:

- D = Mean coil diameter
- Di = Inside diameter
- Do= Outside diameter
- d = Wire Diameter
- δ = Deflection
- N= Number of coils
- G = Shear modulus of elasticity (Structural steel)
- θ = Angle of twist
- Mt = Torsional moment
- J= Moment of inertia
- W= Load

Deflection:

$$\delta = \frac{8\,W\,N\,D^3}{G\,d^4}$$

2.1. Analytical solution for deflection

Table.1. Values & symbols of analytical solutions.

Serial No	Symbol	Value
1	W	1000 N
2	D	50 mm
3	N	10
4	G	$76900\,\frac{N}{mm^2}$
5	d	10 mm

The material properties used for calculations are structural steel.

$$\delta = \frac{8\,W\,N\,D^3}{G\,d^4}$$

$$\delta = \frac{8*1000*10*50^3}{76900*10^4}$$

$$\delta = \frac{10^{10}}{76900*10^4}$$

δ = 13 mm (Analytical solution value)

3. GEOMETRY & CONNECTIONS

3.1. Suspension model

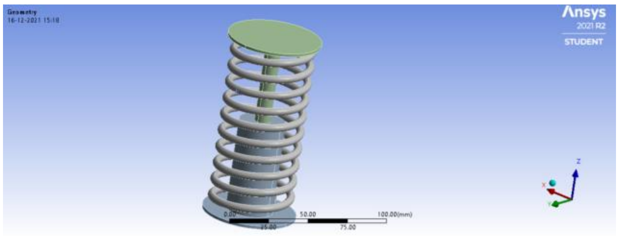

Fig.2. Geometry of suspension systems.

3.2. Connections

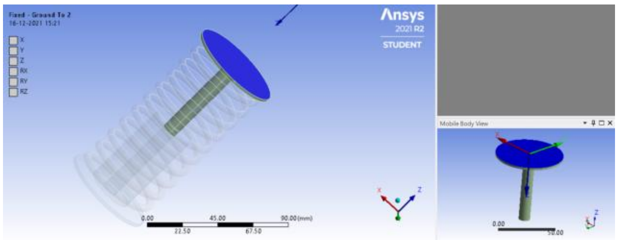

Fig.3. Connections of suspension systems.

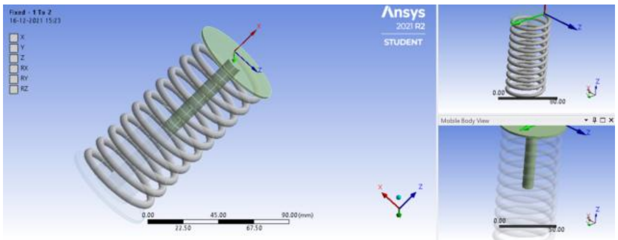

Fig.4. Connections of suspension systems.

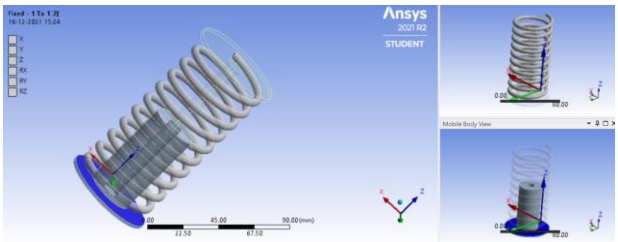

Fig.5. Connections of suspension systems.

4. MESHING

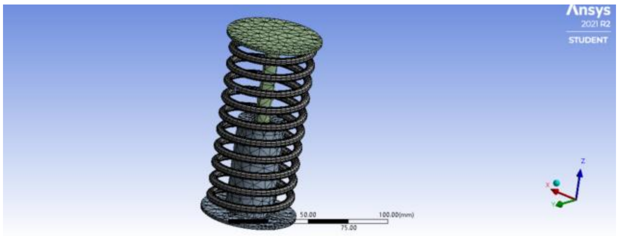

Fig.6. Meshing of suspension systems.

In a FEA, meshing is the process of breaking up a continuous domain into more manageable discrete elements in an effort to simulate the behaviour of the system under study. The goal of meshing is to discretize the governing equations into a set of algebraic equations that can be solved numerically while also representing the geometry and material characteristics of the structure or component under study. Meshing is a crucial step in the FEA procedure because it has a direct impact on the analysis's accuracy and effectiveness. The mesh's quality, which includes the element's type, size, and shape, is a key factor in determining how accurate the results are.

The following are some crucial FEA meshing components:

- Element types: Tetrahedra, hexahedra, triangles, quadrilaterals, and other element types are frequently supported by FEA software. The choice of element type is influenced by the geometry and kind of analysis being done. Every element type has unique benefits and restrictions.
- Element size: The accuracy and computational effectiveness of the analysis are impacted by the size of the mesh's elements. Although they cost more to compute, smaller elements give a more accurate representation of the geometry. Larger elements are less expensive to compute, but accuracy may suffer. To strike a balance between accuracy and computational efficiency, the element size should be chosen carefully.
- Element shape: The mesh's elements should ideally have the same shape as the geometry being studied. Errors in the analysis can be introduced by irregular or distorted elements. To ensure that the mesh has good element shape quality, take precautions to avoid using highly distorted or extremely small-angle elements.

- Mesh density: The quantity of elements used to discretize the geometry is referred to as the mesh density. It may be necessary to use a denser mesh to accurately capture the behaviour in certain areas of interest, such as those with high stress gradients or regions where significant deformation is anticipated. A coarser mesh can be used to cut down on computation costs in less crucial areas.
- Mesh generation techniques: Mesh generation can be done in a number of ways, including with structured or unstructured meshing. Unstructured meshing allows for greater element placement flexibility while structured meshing involves dividing the domain into a regular grid of elements. In order to generate meshes based on the input geometry, automatic mesh generation algorithms are frequently used in FEA software.
- Mesh refinement: Local mesh refinement might be necessary in some circumstances to accurately capture particular features or phenomena. When certain criteria, such as gradients in stress, displacement, or error estimates are present in an area of interest, adaptive meshing techniques can be used to automatically refine the mesh in that area.

In this model hexahedral meshing is implemented on the spring & tetrahedral meshing is used for other connection parts. In general, if oval or critical shape models are there, then tetrahedral & hexahedral meshing both are carried out. The size of the meshing is varying from 5 mm to 2.5 mm.

5. ANSYS DEFLECTION ANALYSIS USING BOUNDARY CONDITIONS

The boundary conditions for the simulations are:

- Fixed Support: This boundary condition forbids translation and rotation at a particular point or region in all directions. It is modelled by fully fixed constraints, so rotation and displacement are not permitted. The fixed support in this simulation is the upper part of the suspension.
- Applied Loads: Static structural analysis necessitates applying loads to the structure in addition to the aforementioned boundary conditions. Depending on the specific analysis being done, these can be point loads, distributed loads, pressure loads, or thermal loads. The load of 1000N is acting from down side to compress the suspension.
- Symmetry Conditions: When only a portion of a symmetric structure is being examined, symmetry boundary conditions are used. It is assumed that the symmetry planes or axes have no rotation or displacement. By only analyzing a portion of the entire structure, it helps to reduce the computational effort.

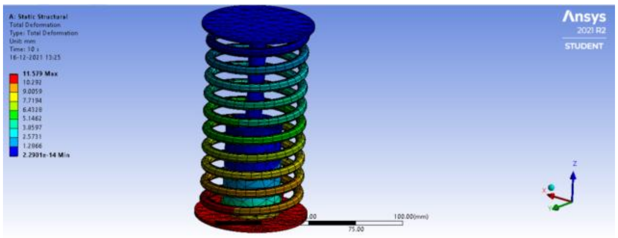

Fig. 7. Deflection of meshing size 5 mm.

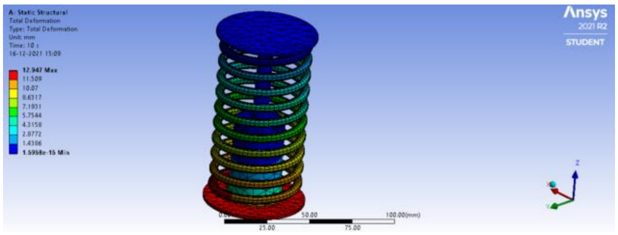

Fig. 8. Deflection of meshing size 2.5 mm.

6. RESULTS & DISCUSSIONS

Table.2. Shows Deflection values of both ansys & analytical solutions.

Serial No	Element size (mm)	Displacement (Ansys solution in mm)	Displacement (Analytic solution in mm)
1	5	11.579	13
2	4	12.105	13
3	3	12.632	13
4	2.8	12.842	13
5	2.5	12.947	13

When the size of a mesh is reduced, the vertices, edges, or faces that make up the mesh typically get smaller as a result. This leads to an increase in resolution, enabling the mesh to represent details more precisely. For instance, reducing the size of a mesh in computer graphics can produce smoother surfaces or intricate geometric shapes. A mesh's size can be reduced while still having an impact on how much computing power is needed

to render or process the mesh. Because there are more of the smaller elements to process, more memory and processing power may be needed. This may have an impact on simulations, real-time applications, or any other system that needs to effectively manage mesh data.
From the above table.2, the reduction in meshing size, the more accurate value is obtained from Ansys solutions. This value is converging more towards the analytical solution if the size of the meshing is reduced.

7. CONVERGING GRAPH

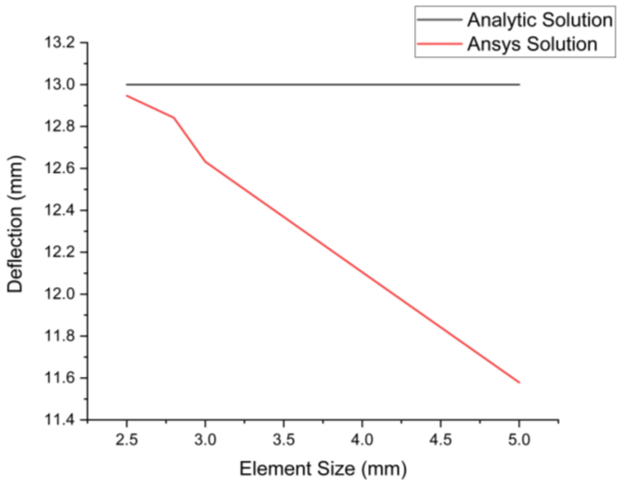

Fig. 9. Ansys vs Analytical deflection convergence graph.

In numerical simulations, convergence is crucial because it guarantees the accuracy and dependability of the results. When a simulation converges, it means that further mesh refinement has little to no impact on the outcomes. In other words, a stable state independent of mesh resolution has been reached for the solution. The process of fine-tuning a numerical mesh used in finite element analysis (FEA) simulations until the desired level of accuracy or convergence is attained is referred to as convergence in meshing. A computational domain is divided into smaller, finite-sized elements through the process of meshing, which aims to approximate the geometry and physics of the problem under consideration. A crucial component of numerical simulations is convergence in meshing, which ensures accurate and trustworthy results by fine-tuning the mesh until the solution stabilizes and becomes independent of further mesh-finetuning. From the above graph figure.9. the reduction in size is converging more towards the analytical solution.

8. CONCLUSION

The analytical solution is correct and takes into account all the important variables, the results from Ansys are fairly close to it. In this instance, the analytical solution can be regarded as trustworthy and provide a quicker and more affordable solution for problems of a similar nature. Although analytical solutions can still offer insightful information for simpler issues or serve as a jumping off point for more thorough simulations, Ansys is generally regarded as a more reliable and versatile tool for complex engineering analyses. The size of the mesh & the quality of meshing plays a crucial role in this project. The outcomes of both the solutions are giving the exact deformation of the suspension system with the same boundary conditions. The mesh convergence graph shows the exact result where the ansys solution is converging toward the analytical solution. The reduction in mesh size is a time-consuming process for getting the output solutions. Up to certain limit of reduction in mesh size is possible in Ansys workbench student version.

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