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# Structural Analysis of an Off-Road Vehicle Suspension System Using CATIA and ANSYS

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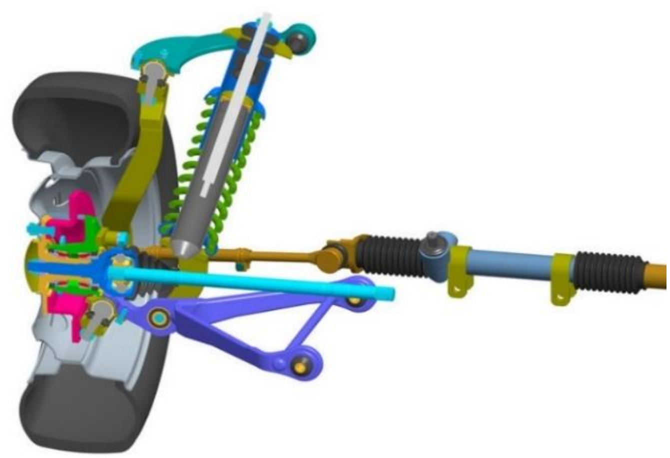
**ABSTRACT:** This project delves into the structural analysis of an off-road vehicle suspension system, employing cutting-edge software tools such as CATIA and ANSYS. Off-road vehicles necessitate robust suspension systems capable of withstanding harsh terrain conditions while ensuring vehicle stability, manoeuvrability, and passenger comfort. The study focuses on evaluating the structural integrity, performance, and behaviour of the suspension system under diverse load conditions and terrain scenarios. This project focuses on conducting a comprehensive structural analysis of an off-road vehicle suspension system using advanced engineering software tools, specifically CATIA and ANSYS. CATIA is a powerful computer-aided design (CAD) software known for its capabilities in creating detailed 3D models, while ANSYS is a leading finite element analysis (FEA) software used for simulating structural behaviour and analyzing mechanical systems.

**Keywords: suspension system, CATIA v5, ANSYS, iterations, FEA.**

## 1. INTRODUCTION

Off-road vehicles are designed to navigate challenging terrains, ranging from rocky mountainsides to muddy trails, requiring robust suspension systems to ensure vehicle stability, maneuverability, and passenger comfort. The suspension system plays a crucial role in absorbing shocks, maintaining tire contact with the ground, and providing sufficient ground clearance. As such, the structural integrity and performance of these systems are of paramount importance in off-road vehicle design and engineering.

The primary objective of this project is to evaluate the structural integrity, performance, and behaviour of the suspension system under various load conditions and terrain scenarios. By utilizing CATIA, a detailed 3D model of the suspension system will be developed, encompassing all critical components such as suspension arms, shock absorbers, springs, Subsequently, the CAD model will be imported into ANSYS, where finite element modeling techniques will be employed to discretize the complex geometry of the suspension system into finite elements. This will enable the simulation of stress, strain, deformation, and other mechanical responses under different operating conditions



Suspension system

The structural analysis will encompass static loads, dynamic loads, and off-road terrain simulations. Static analyses will evaluate the system's response to gravitational forces, vehicle weight, and external loads to ensure compliance with safety and performance standards. Dynamic analyses will investigate the system's behaviour during acceleration, braking, cornering, and off-road maneuvers, considering factors such as vibration, shock absorption, and stability.

### 1.2 Off-Road Suspension Working

Off-Road Suspension is made for off-road vehicles. It provides an adjustable ride height, and it can be adjusted from inside the cabin. This type of suspension can be found on many heavy-duty vehicles, and it also provides a smoother ride for the passengers.

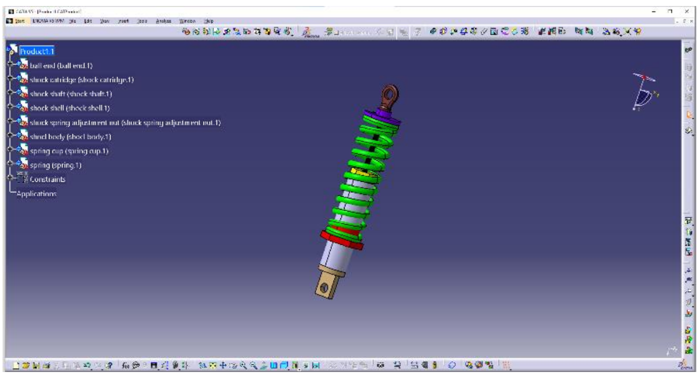
The basic idea behind how off-road suspension works is to make the suspension behave in a way that is more suitable for off-road driving. The suspension system on an off-road vehicle is designed to be stiffer than one on a typical car, and it's also designed to absorb more of the bumps, dips, and shocks of driving on unpaved surfaces.

Off-road suspensions are used in various types of vehicles. The system is made up of springs, dampers, and shock absorbers. The suspension has to be able to absorb the vertical motion so that the vehicle does not bounce around on uneven terrain

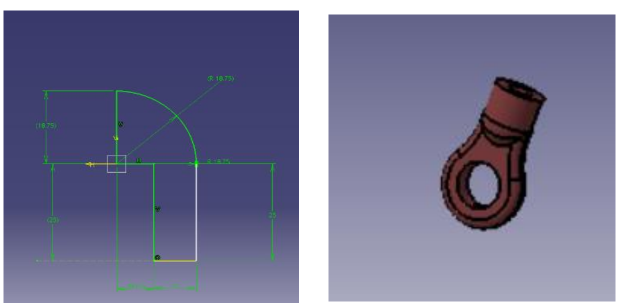
## 2. METHODOLOGY

### 1.1 CAD modeling

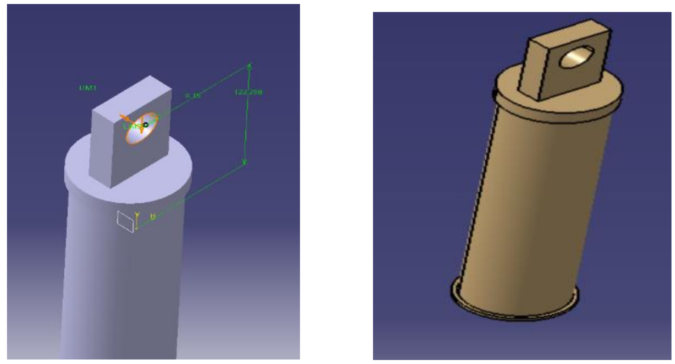
The design of entire Off-Road Vehicle Suspension System is carried out using CATIA V5 R20 software.



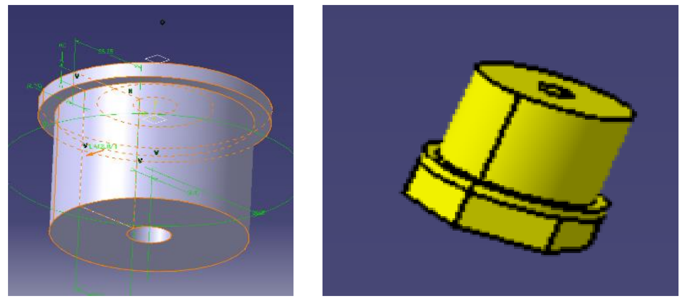
Individual parts designed in CATIA V5



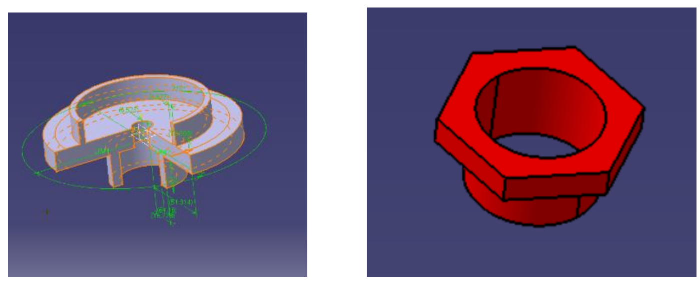
**Ball End**



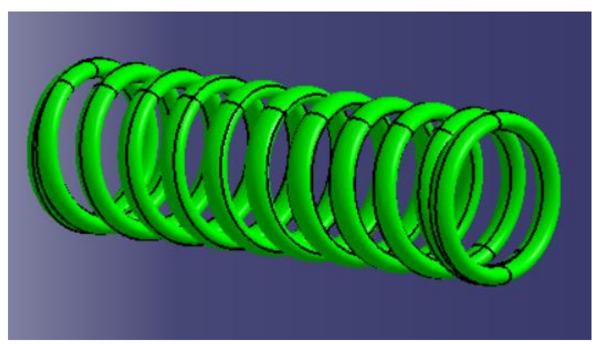
**Shock shell**



**Shock Catridge**



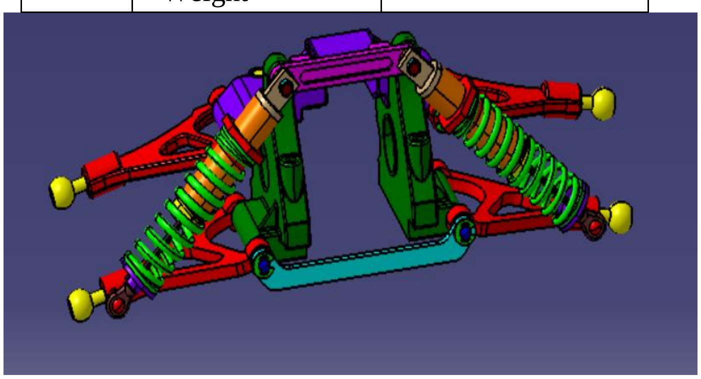
**Shock adjustment nut**



**Spring**

Table 1: Parameters of spring:

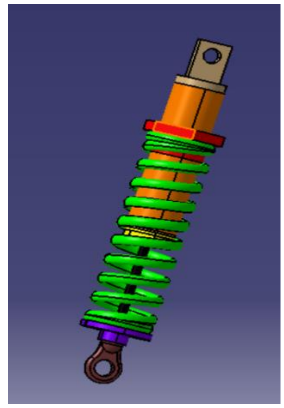
| SI NO. | Parameter | Dimensions in mm |
|---|---|---|
| 1 | Total number of coils, *N* | 9 |
| 2 | Total number of active coils, *n* | 6 |
| 3 | Mean diameter, *D* | 95 |
| 4 | Wire Diameter, *d* | 11 |
| 5 | Inner Diameter, $D_i$ | 84 |
| 6 | Outer Diameter, $D_o$ | 106 |
| 7 | Vehicle Curb Weight | 1255.09 kg |
| 8 | Vehicle Gross Weight | 1739.98 kg |



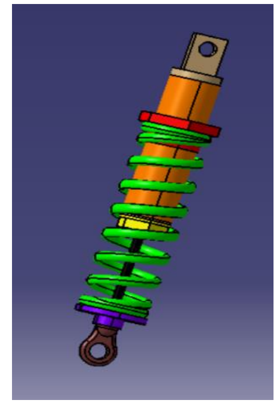
**Full assembly of off road suspension system**

**Design Calculation**

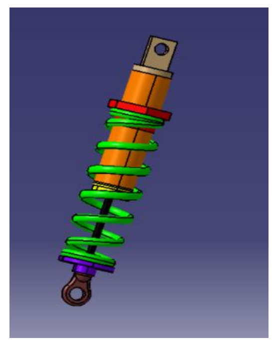
The lightweight vehicle whose suspension was modelled was Toyota corolla 2013 model. The parameters of the suspension coil spring of the Toyota corolla are as presented. The suspension coil spring of vehicles is of varied sizes between the front and the rear. The load transfer between these two axles has the ratio (40:60). Meaning 40% of the weight of the vehicle moves to the front axle while the remaining 60% of the load goes to the rear axle. The suspension coil spring of Toyota corolla has the following dimensions.



Pitch 20 MM



Pitch 25MM



Pitch 30MM

Free length,

$$L_f = N \times d + \delta_{max} + 0.15\delta_{max} = 340 \text{ mm}$$

Spring index,

$$C = D/d = 95/11 = 8.64$$

Unspring weight/ vehicle weight=0.15

The unspring mass or weight of the vehicle m1=curb weight×0.15=1255.09×0.15=188.26 kg

The sprung mass or weight m2=gross weight−unspring weight=1739.98−188.26=1551.72 kg full load

Empty load=1255.09−188.26=1066.83 kg

Therefore,

Un sprung weight or mass on each of there are wheels=**188.26×0.6/2=56.478 kg**

Sprung mass or weight one ach of there are wheels=**1739.98/2=521.994 kg**

## 3. ANALYSIS:

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software Implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

**ANSYS finite element analysis software enables engineers to perform the following tasks:**

1) Build computer models or transfer CAD models of structures, products, and components systems.
2) Apply operating loads or other design performance conditions.
3) Study physical responses such as, stress levels, temperature distributions or the impact of electromagnetic fields.
4) Optimize a design early in the development process to reduce production costs.
5) Do prototype testing in environments where it otherwise would be undesirable or impossible.

**Steps in Finite Element Analysis:**

- **STEP 1:** First the domain is represented as finite elements. This is called discretization of domain. Mesh generation programs called processors, help in dividing the structure.
- **STEP 2:** Formulate the properties of each element in stress analysis. It means determining the nodal loads associated with all element deformation stress that is allowed.
- **STEP 3:** Assemble elements to obtain the finite element model of the structure.

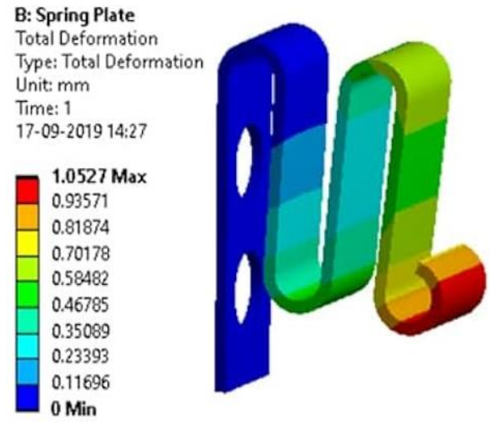



*Fig 5.2*

- **STEP 4:** Apply the known loads, nodal forces in stress analysis. In stress analysis the support of the structure has to be specified.
- **STEP 5:** Solve simultaneous line algebraic equations to determine nodal displacements in the stress analysis.
- **STEP 6:** Postprocessors help the user to sort the output and display in the graphical output form. A typical finite element model is comprised of nodes, degrees of freedom, elements material properties, externally applied loads and analysis type. The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide range of engineering problems.

**Material selection**

The material selected is AISI 1018. The properties of AISI 1018 are as follows:

**Table 2:** mechanical properties of AISI 1018

| Properties | Value |
|---|---|
| Modulus of elasticity | 205GPa |
| Bulk modulus | 140GPa |
| Shear modulus | 80Mpa |
| Poison's Ratio | 0.29 |

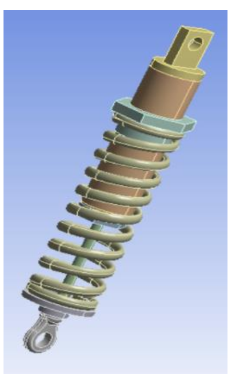
| | |
|---|---|
| Density | 7.87 g/cc |
| Yield strength | 370MPa |
| Ultimate tensile strength | 440MPa |

**Finite Element Analysis**

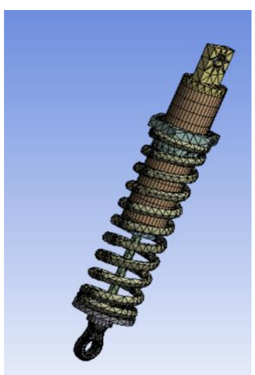
The wire frame designed in CATIA v5 is exported to ANSYS and tubular member dimensions are specified via ANSYS Design Modeler. Such analysis is called 1D analysis where one dimension is very much larger than other two. So, the larger dimension is software specified (dim. Specified in CATIA v5) while other two are user specified.

**Meshing**

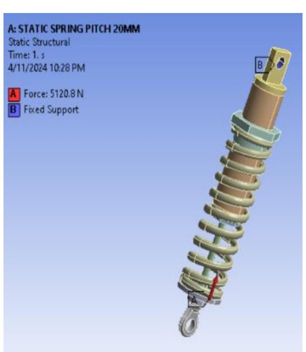
Meshing is the process of disintegrating a continuous body of infinite D.O.F and the nodes into finite no. of infinitesimally elements having finite D.O.F and nodes. It is the most important step in analysis. If meshing is not done correctly then the results also varies. Meshing converts a non-uniform body to a finite no. of uniform elements. Meshing in 1D analysis takes very less time.



Model in ANSYS



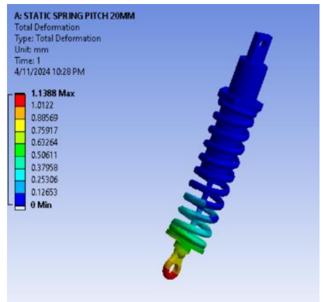
Mesh model in ANSYS



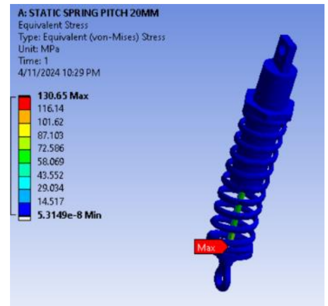

Load and Boundary conditions

**Pitch 20MM:**

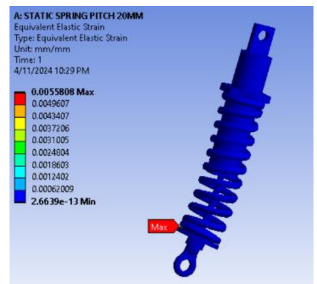
**Structural Analysis:**




Deformation

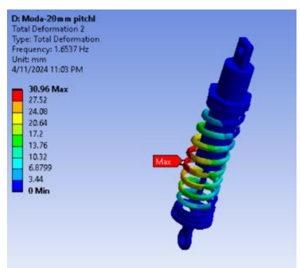



Von mieses stress

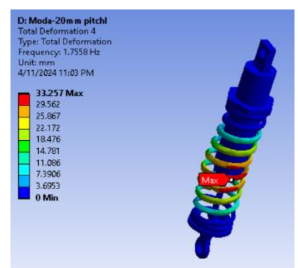



Von mieses strain

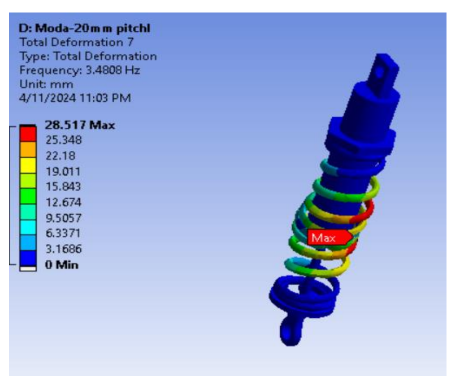
**Dynamic Analysis:**



Mode 1



Mode 2




Mode 3

**Pitch 30MM:**

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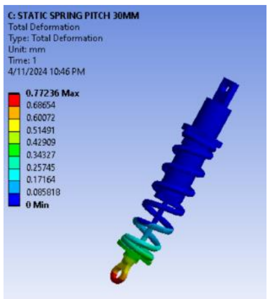
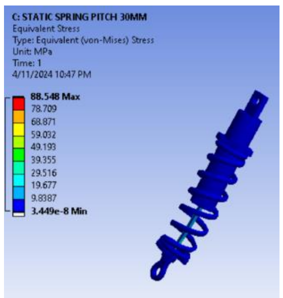
| S no | DETAILS | DEFORMATION (MM) | STRESS (MPA) | STRAIN (MM/MM) |
|---|---|---|---|---|
| 1 | 20MM PITCH | 1.13 | 130.65 | 5.50E-03 |
| 2 | 25MM PITCH | 0.91 | 105.08 | 4.20E-03 |
| 3 | 30MM PITCH | 0.77 | 88.54 | 4.50E-03 |

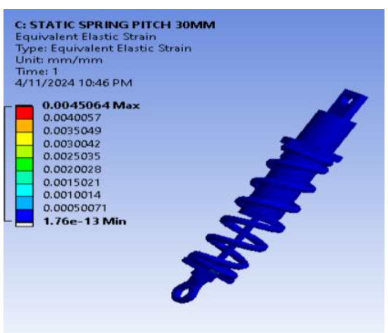
**Structural Analysis:**



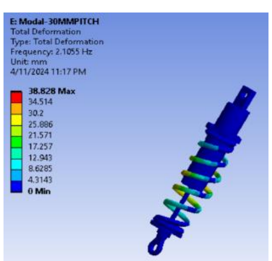


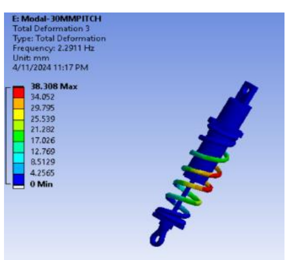
Deformation Von mieses

stress

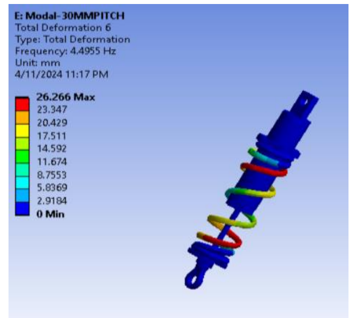



Von miese strain



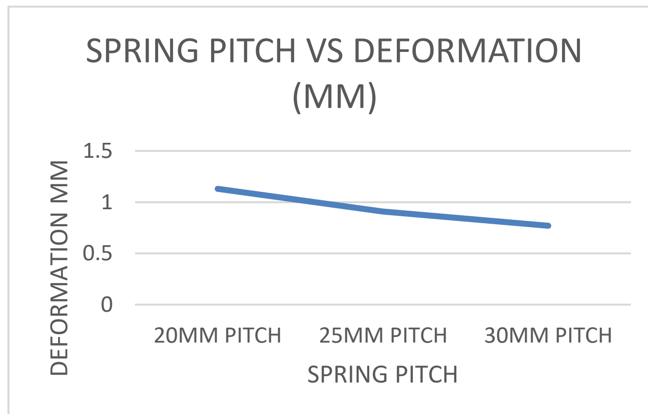


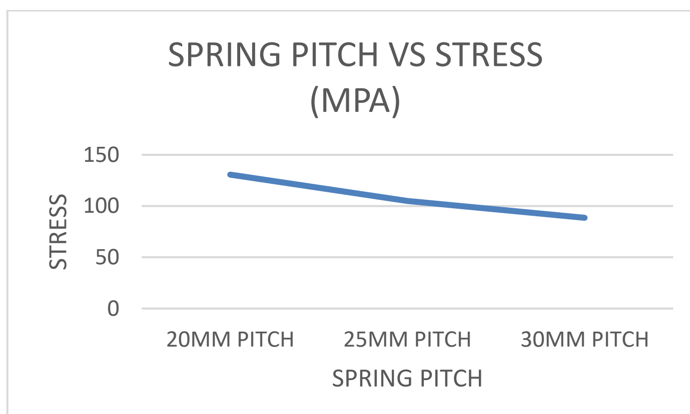
Mode 1 Mode 2



Mode 3

Table 3: Structural Analysis Results



| MODEL ANALYSIS | | | |
|---|---|---|---|
| | 20MM PITCH | 25MM PITCH | 30MM PITCH |
| 1 | 1.6537 | 1.8634 | 2.1055 |
| 2 | 1.6856 | 1.933 | 2.2265 |
| 3 | 1.7558 | 1.9669 | 2.2911 |
| 4 | 1.8013 | 2.1151 | 2.3843 |
| 5 | 3.2823 | 3.6933 | 4.1212 |
| 6 | 3.4808 | 3.9318 | 4.4955 |

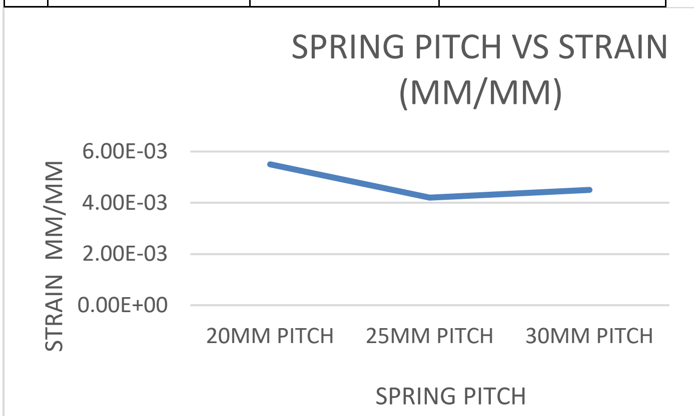
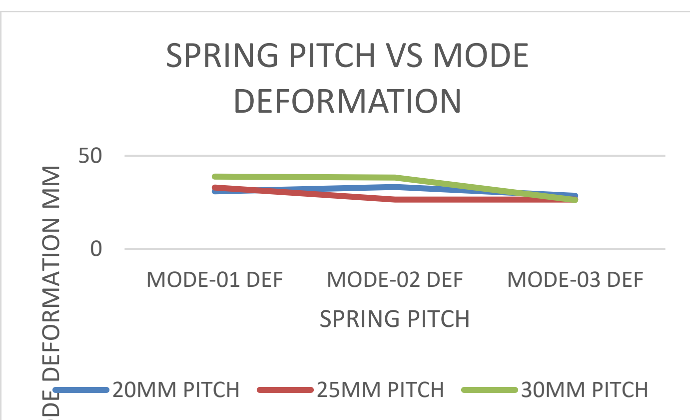
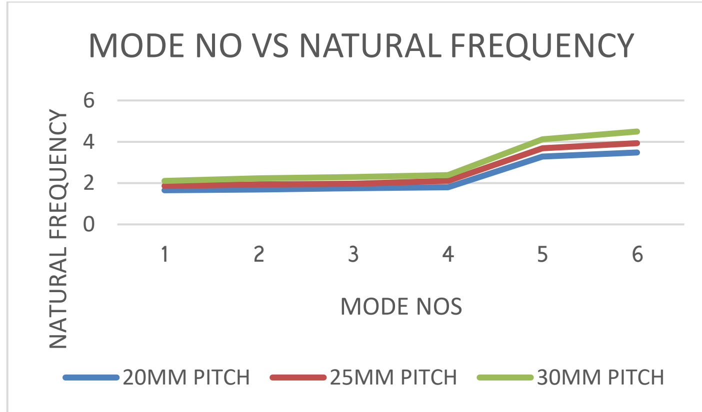



Table 4: Dynamic Analysis Results

| SNO | DETAILS | MODE-01 DEF | MODE-02 DEF | MODE-03 DEF |
|---|---|---|---|---|
| 1 | 20MM PITCH | 30.96 | 33.25 | 28.51 |
| 2 | 25MM PITCH | 32.94 | 26.49 | 26.49 |
| 3 | 30MM PITCH | 38.82 | 38.3 | 26.26 |




**CONCLUSION**

This Project examined two methods of analysis: static structural analysis and dynamic analysis. Under the static structural analysis, the following parameters were considered for three suspension coil springs made from different pitch 20mm, 25mm and 30mm coil, high carbon steel and structural steel body: total deformation, equivalent Von Mises stress, max and equivalent Von Mises strain. The suspension coil spring is designed to withstand shocks from irregular road surfaces and various road conditions, necessitating the use of robust materials. Typically, suspension coil springs are constructed from materials like high carbon steel and Structural steel. The primary objective of this study was to assess the suitability of structural steel for designing suspension coil springs in lightweight vehicles.

These suspension coil springs were modeled using CATIA v5 and then exported to Ansys for further analysis. In the Ansys software, a static load of 51,20.8 N was applied to all suspension coil springs made of high carbon steel, and structural steel. The study compared the specified parameters across all three suspension coil springs constructed from these different pitchs. This study concludes that, except for deformation, structural steel, the chosen material, exhibits superior properties in all the parameters compared to high carbon steel. For Pitch value 30mm has design safe than other pitch values.

Therefore, studies on suspension coil spring design should consider not only the design and manufacturing of the suspension coil spring but also conducting further tests by installing a prototype suspension coil spring in a real vehicle to identify any design-related issues. Modal analysis should also be conducted to assess any oscillatory frequency concerns with the suspension coil spring's design.

## FUTURE WORK

"Structural Analysis of an Off-Road Vehicle Suspension System Using CATIA and ANSYS," several avenues can be explored to better understand and optimize the suspension system's structural performance. Firstly, the parametric modelling in CATIA can be expanded to capture more intricate geometries and variations of suspension components such as arms, linkages, and mounts. Secondly, a comprehensive investigation into material properties and their impact on structural behaviour can be conducted to select the most suitable materials for components based on factors like weight, strength, and cost. Additionally, dynamic analysis using CATIA and ANSYS can simulate real-world off-road conditions to assess the system's response to dynamic forces and vibrations, ensuring optimal performance and durability. Furthermore, fatigue analysis can evaluate long-term durability under repeated loading cycles, guiding design modifications to enhance fatigue resistance. Optimization techniques like topology and shape optimization can be implemented to refine component geometry and material distribution for improved structural performance. Integration with vehicle dynamics simulation allows for a holistic evaluation of handling, stability, and ride comfort, optimizing overall performance. Validation through physical testing and field trials ensures reliability and performance consistency of the optimized suspension design. Finally, utilizing multi-body dynamics simulation software alongside CATIA and ANSYS enables a detailed analysis of interconnected motion and dynamics, further refining design parameters to enhance performance under various driving scenarios. These avenues collectively contribute to advancing the understanding and optimization of off-road vehicle suspension systems for improved performance and reliability.

## REFERENCES:

[1] Adams, Alan T. "Mechanical Design Handbook: Measurement, Analysis and Control of Dynamic Systems." McGraw Hill Professional, 2001.
[2] Cook, Robert D., David S. Malkus, and Michael E. Plesha. "Concepts and Applications of Finite Element Analysis." John Wiley & Sons, 1989.
[3] El-Wardany, Taher, and Fares Howari. "Finite Element Analysis of Automotive Suspension Systems." SAE Technical Paper, 2003-01-3671, 2003.
[4] Patil, Yogesh, and Santosh Bhosale. "Structural Analysis of a Suspension System of an Off-Road Vehicle." International Journal of Advanced Engineering Research and Science, vol. 3, no. 3, 2016, pp. 155-160.
[5] Design and CFD Analysis of Drone Thrust with Duct
KSS Gurudatta, V Harikiran, M Raju, B Rama Krishna… - International Conference on Machine Learning and Big …, 2022