iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** V **Month of publication:** May 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Analysis of Helical Spring of Two-Wheeler Suspension System Using Ansys Workbench 16.2

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Abstract: a helical spring is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock, or to maintain a force between contracting surface. They are made of an elastic material formed into the shape of a helix which returns to its natural length when unloaded. The purpose of this project is to modeling and analysis of helical spring and to increase the stiffness of it by using the new materials to reduce the vehicle problem happens while driving on bumping road condition. The comparative study is carried out between existed spring and new material spring. Static analysis determines the stress and deflection of the helical compression spring in finite element analysis (fea).the model is used to analyze the spring on the ansys 16.2 under different materials conditions. Finite element analysis methods (fea) are the methods of finding approximate solutions to a physical problem defined in a finite region or domain. Fea (workbench) is a mathematical tool for solving engineering problems. 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 solidworks and analysis is carried out on ansys 16.2.

I. INTRODUCTION

The suspension system allows the wheels to bounce up and down on rough roads while the rest of the remains fairly steady. It also allows the vehicle to corner with minimum roll or tendency to loose traction between the tyres and the road surface. The basic elements of a suspension system are springs and shock absorbers. This project is mainly based on spring. A spring is an elastic element which deflects under the action of the load and returns to its original shape when the load is removed.

A. Types of springs

1) Helical springs
2) Volute springs]
3) Laminated or leaf springs
4) Disc or Belleville springs

B. N.Lavanya et al

Generally for light vehicles, coil springs are used as suspension system. A spring is an elastic object used to store mechanical energy and it can be twist, pulled (or) stretched by some force and can return to their original shape when the forced is released. The present work attempts to analyze the shape load of the light vehicle suspension spring with different materials. This investigation includes comparison of modelling and analyses of primarily suspension spring made of low carbon-structural steel and chrome vanadium steel and suggested the suitability for optimum design. The result shows the reduction in overall stress and deflection of spring for chosen materials. [1]

C. Rahul Tekade et al

Shock absorbers are devices that smooth out an impulse experienced by a vehicle, and appropriately dissipate or absorb the kinetic energy. Almost all suspension systems consist of springs and dampers, which tend to limit the performance of a system due to their physical constraints. Suspension systems, comprising of springs and dampers, are usually designed for passengers' safety and do little to improve passenger comfort. To meet the current demands of high speed and safety we must designed and developed such a shock absorber which can sustain more and more vibrations and also improve the safety. [2]

D. P.R.Jadhav et al

Explained that, most commonly used element in suspension system is helical spring which is used to maintain a force between contacting surface. Forces are also measured with help of spring. Mono suspension is being analyzed by using finite element analysis (FEA). [3]

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E. Mehdi et al

In this paper author used helical spring is the most common used in car suspension system, steel helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element analysis has been compared with analytical solution and steel spring has been replaced by three different composite helical springs including E-glass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy. Numerical results have been compared with theoretical results and found to be in good agreement. [4]

F. Mulla et al

Presented the static stress analysis using finite element method has been done in order to find out the detailed stress distribution of spring. [5]

G. Madan et al

Carried out on modeling and analysis 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 new material. The comparative study is carried out between existed spring and new material spring. Static analysis determines the stress and deflections of helical compression spring in finite element analysis. [6]

H. James M. Meagher et al.

The author presented the theoretical model for predicting stress from bending agreed with the stiffness and finite element model within the precision of convergence for the finite element analysis. The equation was calculated by principal stresses and von misses stress and it was useful for fatigue studies. A three-dimensional finite element model was used for two coil of different wire model, one was MP35N tube with a 25% silver core and other a solid MP35N wire material helical conductor and the result was compared with the proposed strength of material model for flexural loading.[7]

I. Aurel P. Stoicescu et al

In his work presents the optimal design method of the helical springs of the automobile suspensions according to the criterion of the minimum mass. For this purpose, at a given spring rate, the torsional stress corresponding to the maximum force applied to the spring, the fatigue stress, the buckling stability condition and the constraints relating to the spring index and to the outer coil diameter are considered. Expressing analytically the coefficients that are necessary to calculate certain helical spring stresses of an automobile suspension they have elaborated a nonlinear programming model with constraints for the optimal design of an automobile spring suspension according to the criterion of the minimum mass. The reduction of the spring mass by optimal design may be of 16%. [8]

J. Mohamed Taktak et al

In their work a numerical method to model the dynamic behavior of an isotropic helical spring is coupled with optimization algorithms to construct a dynamic optimization method based not only on mechanical and geometrical objective functions and constraints; but also on dynamic ones. In the proposed dynamic optimization problem, four geometric parameters are chosen as design variables (wire diameter, middle helix diameter, active coils numbers and spring pitch). The result of simulation shows that by these algorithms the helical spring mass can be greatly reduced and the design quality is improved by moving away the helical spring first natural frequency from working zone. [9]

K. Priyanka Ghate et al.

In the present investigation, it was found that the existing primary suspensions with composite spring assembly could sustain loads in normal operating conditions and maintain the required ride index, however, during cornering and hunting speeds failure of outer spring of primary suspension was observed. In the present work, an attempt was made to analyze in detail the reason for failure and a single nonlinear spring had been suggested to improve durability of the primary suspension and in the meantime the required ride index. [10]

L. Kaiser et al.

In this paper, the author presents a long-term fatigue tests up to a number of 109 cycles on shot peened helical compression springs with two basic dimensions, made of three different spring materials. The test springs were manufactured of oil hardened and tempered of SiCr and SiCrV- alloyed valve spring steel wires and of a stainless-steel wire with diameters of 1.6 mm and 3.0 mm

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with shot peened. A lot of research paper are studied and found that there are used many type of new composite materials to reduce the many type of problems in two-wheeler suspension system. But there are some materials (Hastelloy, Elgiloy, and Inconel) are also available which are not used till now in any research papers. By using these materials (Hastelloy, Elgiloy, Inconel) the problem in suspension system can be also reduced. [11]

II. ANALYSIS ON HELICAL SPRINGS

The helical spring are made up of a wire coiled in the form of a helix and is primarily intended for compressive or tensile load. The cross-section of the wire from which the spring is made may be circular, square or rectangular.
Helical springs are two types-
Compression helical spring and tensile helical spring.
Spring constant dependencies
For the spring in this discussion, HOOK'S law is typically assume to hold,

$$F = k\Delta$$

We can expand the spring constant k as a function of the material properties of the spring. Doing so and solving for the spring displacement gives,

$$\Delta = \frac{F}{k} = \frac{8FD^3N}{Gd^4}$$

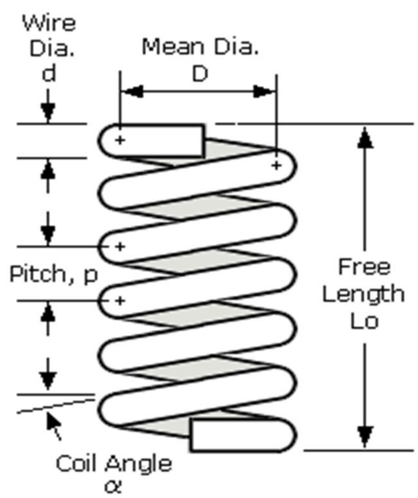

Figure-1

Where G is the material shear modulus
N is the number of active coil
D is the mean dia. Of coil
d is the wire dia.

Number of active coils = total number of coils – the number of end coils

$$N = N_t - N^*$$

The value of N^* depends on the ends of spring.
Deflection in the spring
The spring index C, can be used to express the deflection,

$$C = \frac{D}{d}$$

$$\Delta = \frac{8FC^3N}{Gd} = \frac{F}{k}$$

The useful range for C is about 4 to 12, with an optimum value of approximately 9. The wire dia. d should conform to a standard size if at all possible.

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The active wire length L can also be used to form an expression for the deflection,

$$L = \pi DN$$

$$\Delta = \frac{8FD^2L}{\pi G d^4}$$

Shear stress in the spring

The maximum shear stress τ_{max} in a helical spring occurs on the inner face of the spring coils and is equal to,

$$\tau_{max} = \frac{8FCW}{\pi d^2} = \frac{8FDW}{\pi d^3}$$

Where W is the Wahl Correction Factor which accounts for shear stress resulting from spring curvature,

$$W = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

Stiffness of the spring

The stiffness of the spring is given by

$$k = \frac{F}{\Delta}$$

Table: 2.1 Result by analytical method

Sr.No.	Materials	Deflection (mm)	Stiffness (N/mm)
1.	High Carbon Steel	81.787	33.624
2.	Elgiloy	76.116	36.129
3.	Hastelloy (C-276)	77.406	35.527
4.	Inconel X750	76.116	36.129

A. *Properties of materials*

Table: 2.2

Material properties (Taken from "Machinery's Handbook, 29th Edition)

Spring material	Materials specification	Density (lb/in^3)	Minimum tensile strength (psi×10^6)	Modulus rigidity(G) (psi×10^6)	Modulus elasticity(E) (psi×10^6)	Maximum operating temperature (°F)
High carbon steel	AISI 1065	.284				
Elgiloy	AMS 5833	0.3	270-330	12.0	32.0	250
Hastelloy (C276)	ASTM B574	0.321	100-200	11.8	30.7	700
Inconel X750	**AMS 5698/5699**	**0.298**	**230**	**12.0**	**31.0**	**750-1100**

High Carbon Steel:

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Table: 2.3 Material composition

ELEMENT	Content (%)
Iron, Fe	98.31-98.8
Manganese, Mn	0.60-0.90
Carbon, C	0.60-0.70
Silicon, Si	0.15-0.30
Sulphur, S	0.05
Phosphorous	0.04

Table: 2.4 Physical Properties

Properties	Metric	Imperial
Density	7.85 g/cm^3	.284 lb/in^3
Thermal Conductivity	49.8 W/mK	346 BTU in/hr.ft2.F

Table: 2.5 Mechanical Properties

Properties	Metric	Imperial
Tensile Strength, Ultimate	635 MPa	92100 psi
Tensile Strength, Yield	490 MPa	71100 psi
Modulus of elasticity	0.27-0.30	0.27-0.30
Bulk modulus (typical for steel)	140 GPa	20300 Psi
Shear modulus (typical for steel)	80 GPa	11600 Psi
Poisson's (typical for steel)	0.27-0.30	0.27-0.30
Elongation at break (in 50mm)	10%	10%

Elgiloy

Table: 2.6 Composition

Element	Content (%)
Cobalt	39-41
Chromium	19-21
Nickel	14-16
Iron	11.25-20.5
Molybdenum	6-8
Manganese	1.5-2.5
Carbon	$\leq$ 0.15
Beryllium	$\leq$ 0.10

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Table: 2.7 Physical Properties

Properties	Metric	Imperial
Density	8.30 g/cm^3	0.300 lb/in^3
Melting Point	1427 ℃	2601 °F

Table: 2.8 Mechanical Properties

Properties	Metric	Imperial
Tensile strength	970 MPa	141000 psi
Yield strength	480 MPa	69600 psi
Poisson's ratio	0.226	0.226
Elastic modulus	189.6 GPa	32×10^6 psi
Shear modulus	82.74 GPa	12×10^6 psi
Hardness,Brinell	224	224

Hastelloy (C-276)

Table: 2.9 Composition

Element	Content (%)
Nickel	57
Molybdenum	15-17
Chromium	14.5-16.5
Iron	4.0-7.0
Tungsten	3.0-4.5
Cobalt	2.5
Manganese	1.0
Vanadium	0.35
Silicon	0.08
Phosphorus	0.025
Carbon	0.010
Sulphur	0.010

Table: 2.10 Physical Properties

Properties	Metric	Imperial
Density	8.89 g/cm^3	0.321 lb/in^3
Melting point	1371 ℃	2500 °F

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Table: 2.11Mechanical Properties

Properties	Metric	Imperial
Minimum tensile strength		(100-200)x10^6 psi
Modulus of elasticity		30.7x10^6 psi
Modulus of rigidity		11.8x10^6 psi

Inconel(X750)

Table: 2.12 Composition

Element	Content (%)
Nickel-Cobalt	70
Chromium	14-17
Iron	5-9
Titanium	2.5-2.75
Aluminum	0.40-1.00
Niobium-Tantalum	0.70-1.20
Manganese	1.00
Silicon	0.50
Sulphur	0.01
Copper	0.50
Carbon	0.08
Cobalt	1.00

Table: 2.13 Physical properties

Properties	Metric	Imperial
Density	8.28 g/cm^3	0.299 lb/in^3
Melting point	1393-1427 °C	2540-2600 °F

Table: 2.14 Mechanical properties

Properties	Metric	Imperial
Minimum tensile strength		(190-230)x10^6 psi
Modulus of elasticity		31x10^6 psi
Modulus of rigidity		12x10^6 psi

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B. Comparison of material

1) Density Comparison

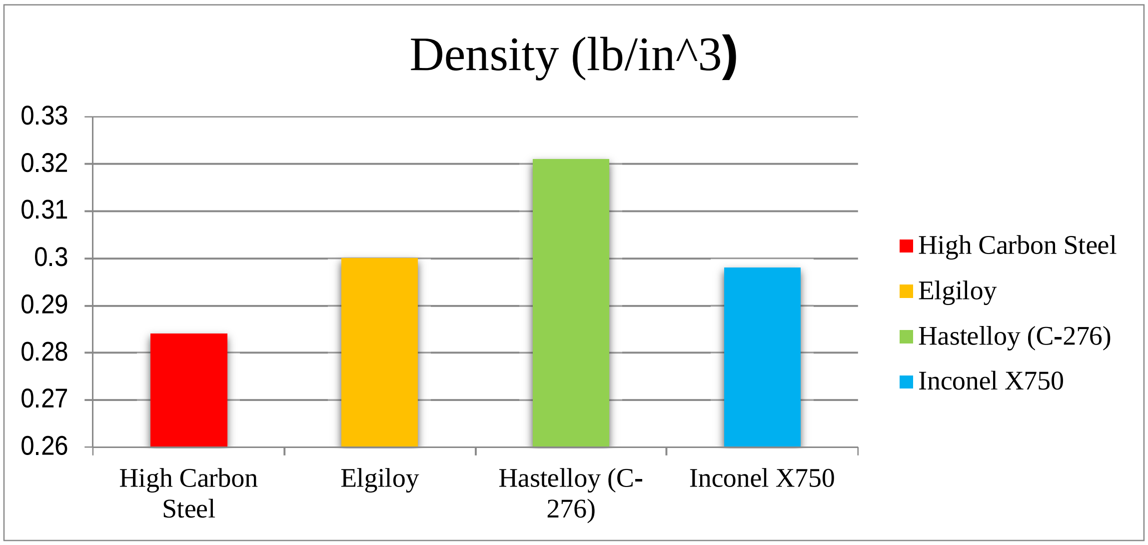

Figure-2

III. METHODOLOGY

A. Solid Works is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systems.

1) Modeling Technology: SolidWorks is a solid modeler, and utilizes a parametric feature-based approach to create models and assemblies. The software is written on Para solid-kernel. Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of Solid Works means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

2) Solid works home page:

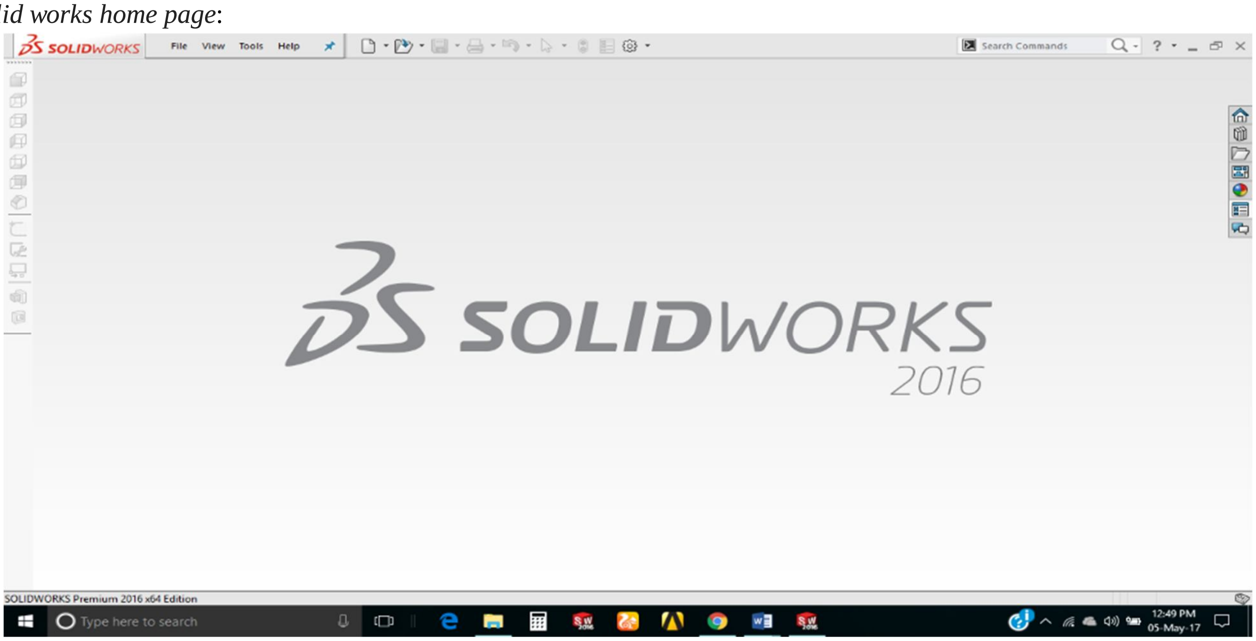

Figure.3 Home page

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3) Design of spring Select Top plane for creating sketch

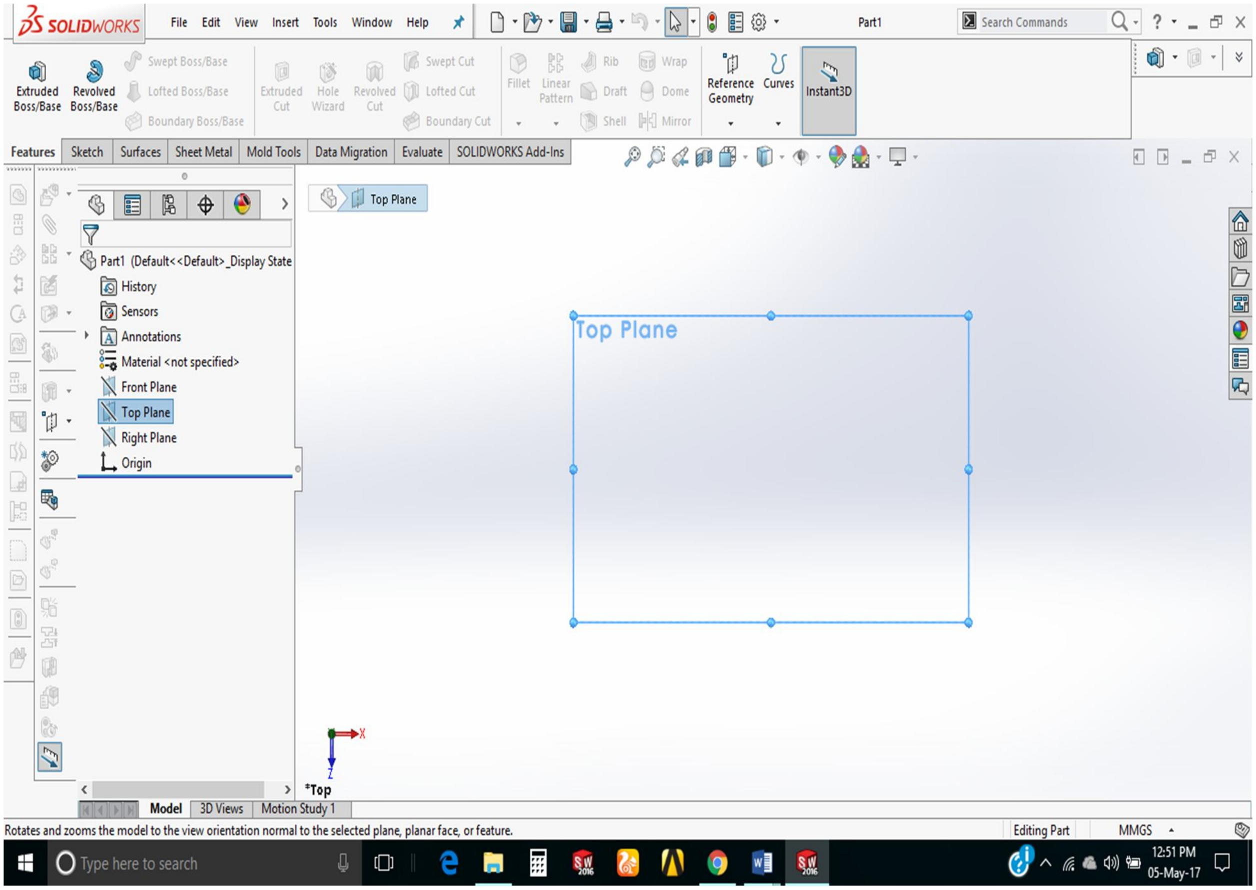

Figure.4

4) Prepare 2D sketch of helical spring

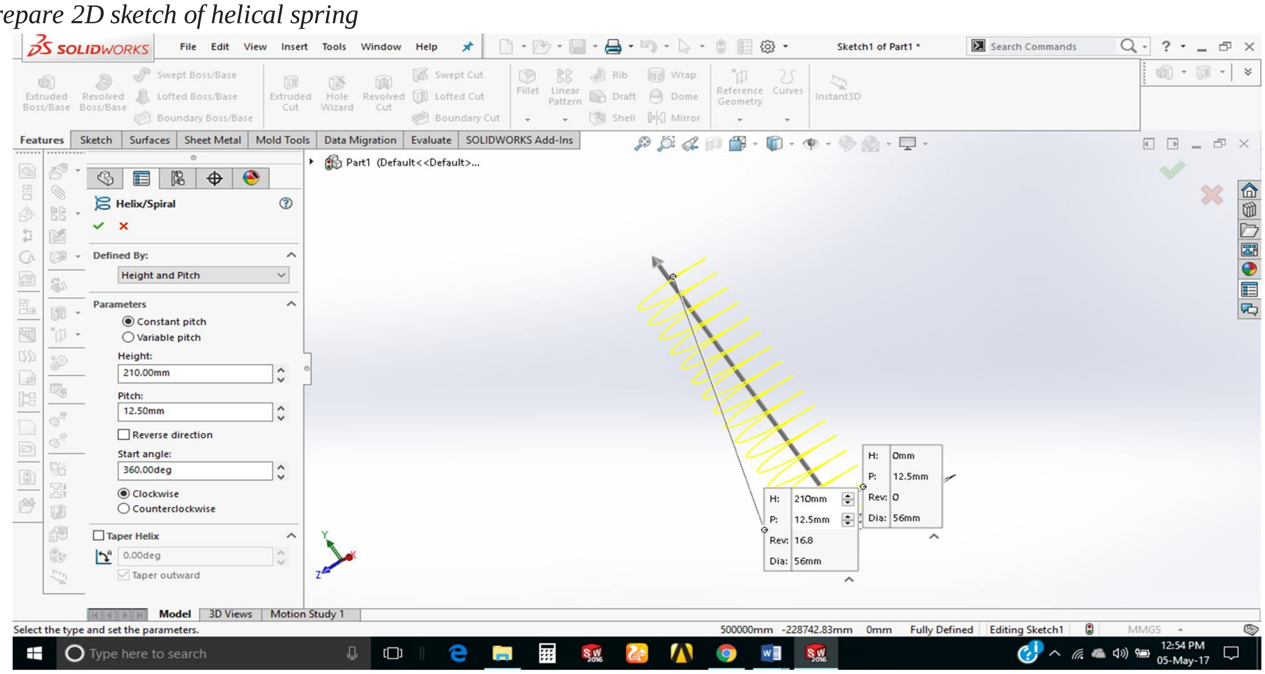

Figure.5

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5) Complete 3D helical spring

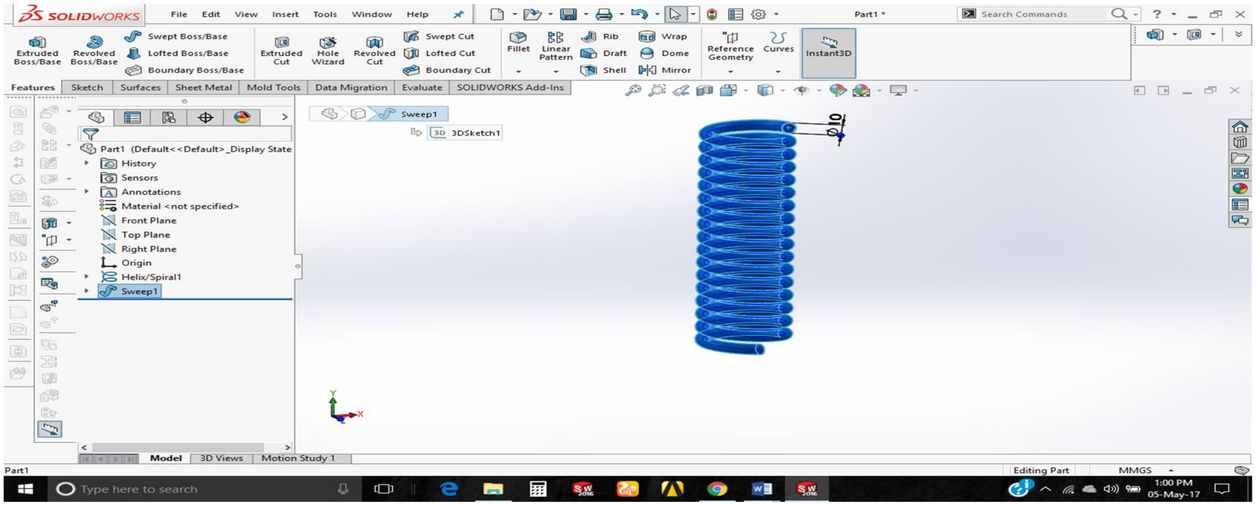

Figure.6

6) Design specification of Helical Spring

Outer diameter of spring = 66mm

Mean diameter of spring (D) = 56mm

Wire diameter (d) = 10mm

Coil free height (h) = 210mm

Pitch of spring (p) = 12.5mm

7) Complete Helical Spring

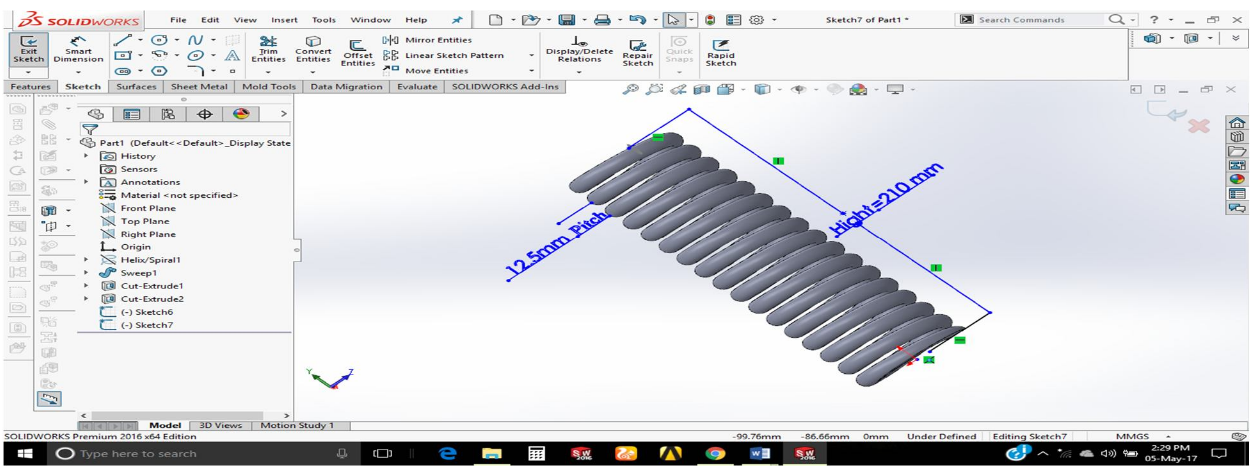

Figure.7

B. Analysis of deformation of helical spring at Ansys workbench 16.2

1) *Introduction to Ansys:* Ansys is an analyzing software. It is used to check design feasibility of the design almost in all aspect. Ansys as a software is made to be user-friendly and simplified as much as possible with lots of interface options to keep the user as much as possible from the hectic side of programming and debugging process. A glimpse of Ansys workbench is shown below

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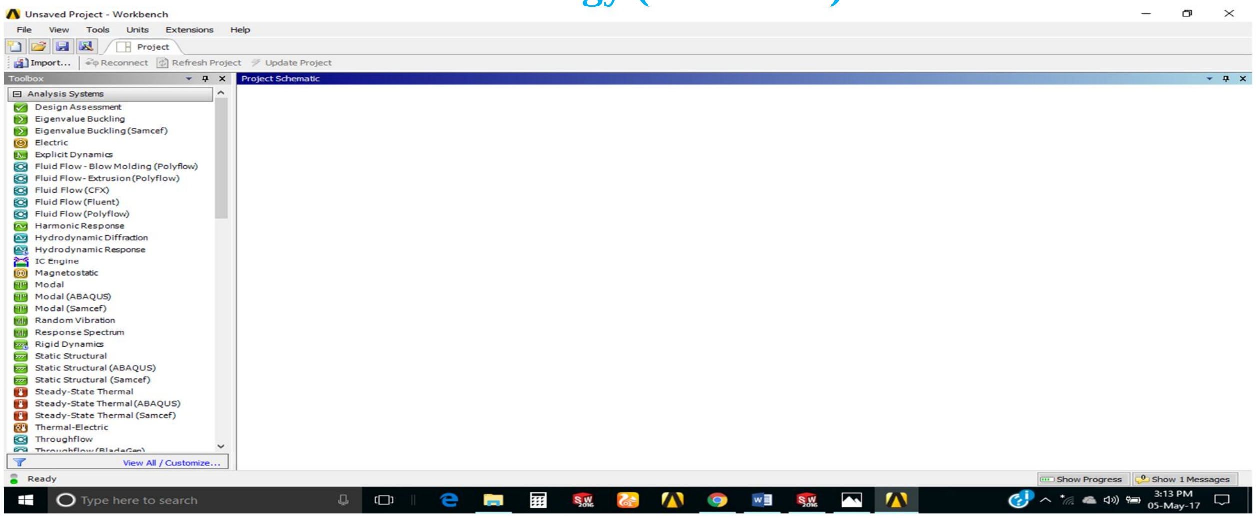

Figure.8 Ansys workbench 16.2

2) *Create Analysis System:* Take one of the readymade stencil from the tool box according to the need of the project. In this project we took static structural as analysis system for the analysis of connecting rod. To analyzing connecting rod using different material at Ansys workbench 16.2 following step have been followed

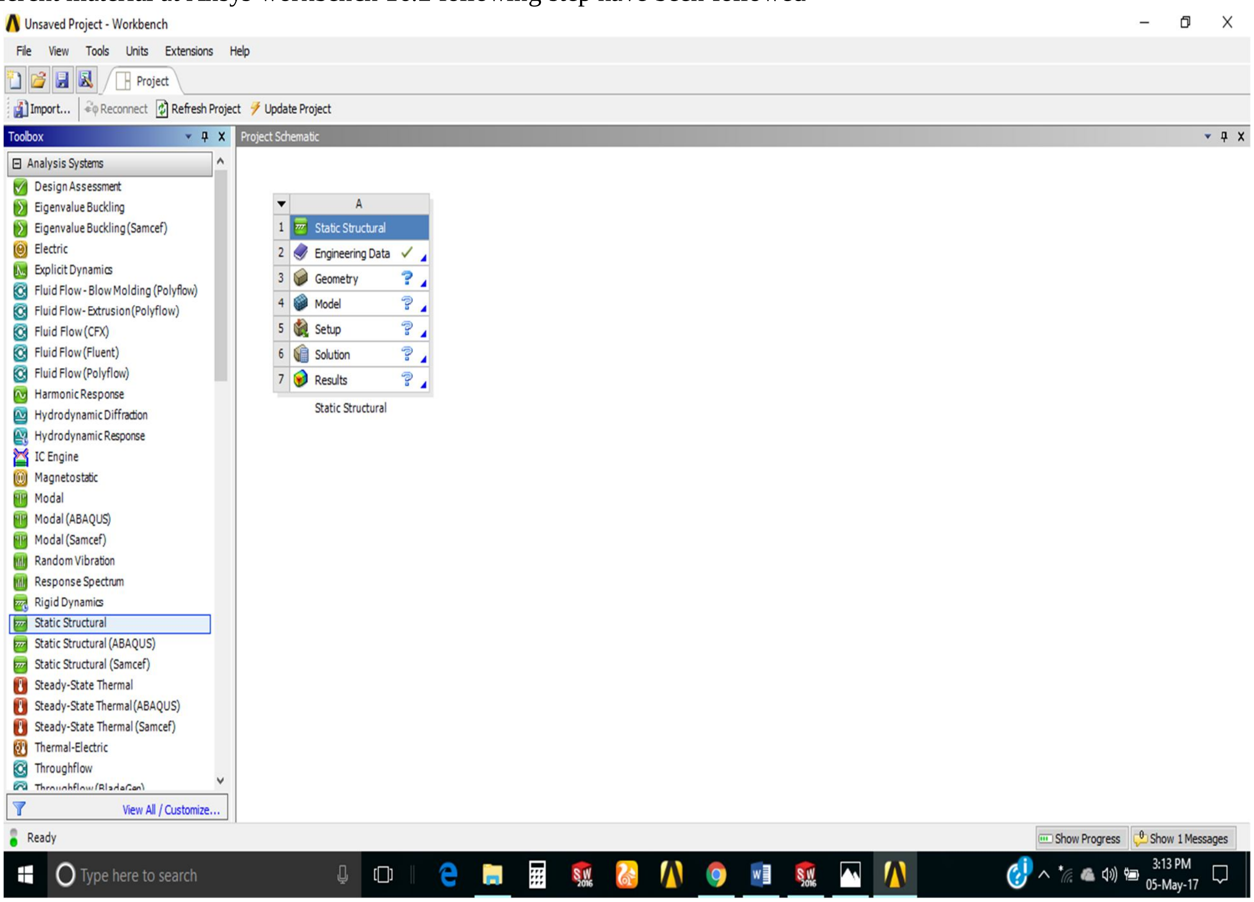

Figure.9 Static structural analysis system

3) *Define Engineering Data:* In this section material for the current project is assigned. In Ansys by default structural steel is selectedTo assign new material turn on the engineering data source

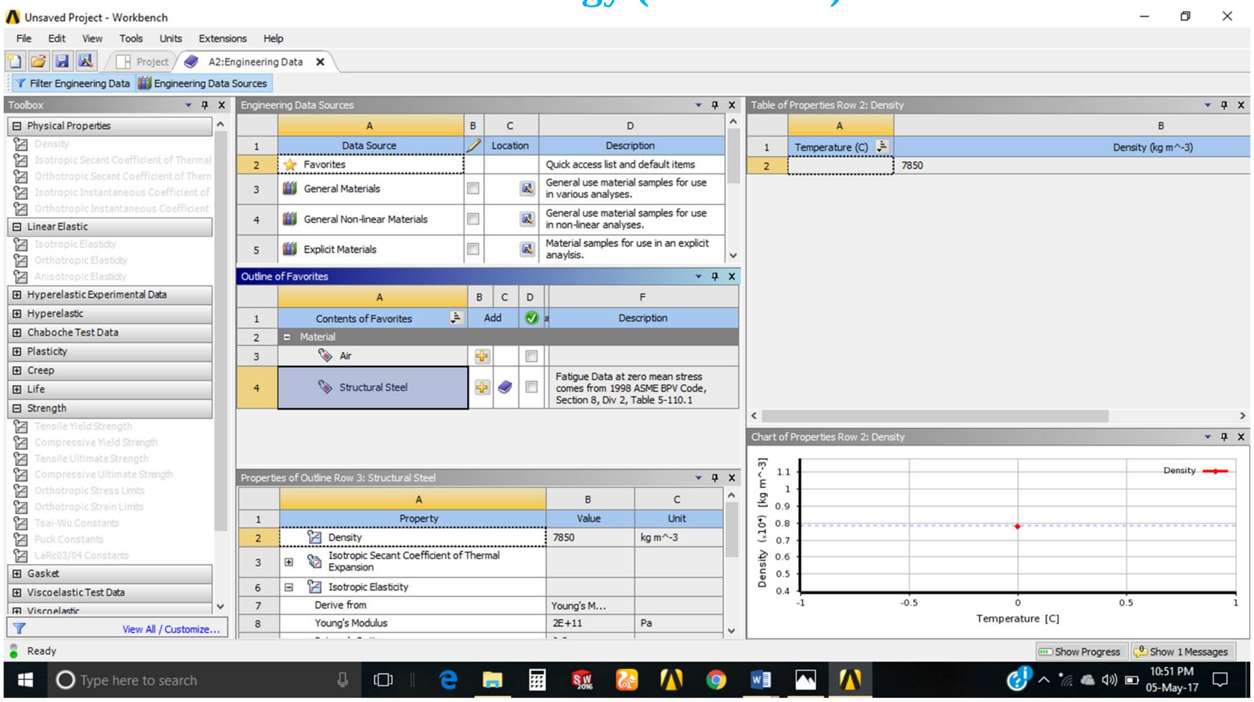

Figure.10 On mode of engineering data source

Generate new library for connecting rod.
Make a tick mark on the new generated library named helical spring to convert it into edit mode.
Add different four material which is kept under study as shown in figure below.
After giving all required properties for helical spring save them into the Library.
In the same way save the information about all consideration.
Add all the four materials in the content by clicking on the plus sign as shown below-

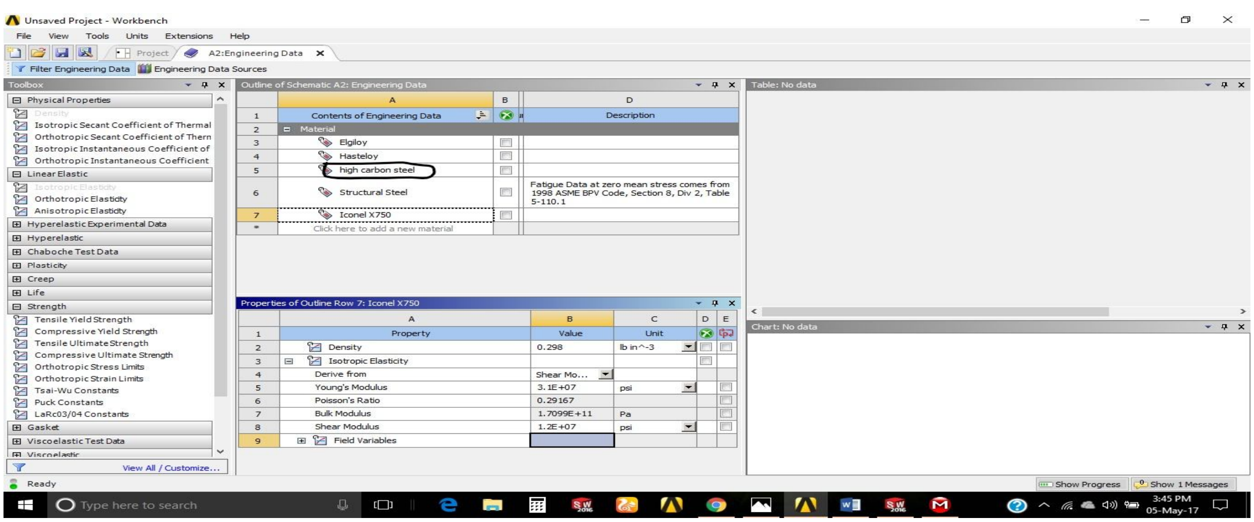

Figure.11 List of spring materials in new library

4) *Description of spring materials:* A spring material which have high stiffness, low deflection and low shear stress. Desirable properties of helical spring material are as follow: -

a) The material of helical compression spring must have high stiffness.
b) It must have high modulus of rigidity.
c) It must have high shear strength.

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d) It should have high corrosion resistance.

List of materials and their properties which is kept under consideration: -

Table: 3.1

Material properties (taking from engineering EDGE machinery's hand book)

Material Properties	High carbon steel	Elgiloy	Hastelloy (C276)	Inconel (X750)
Density (lb/in^3)	0.2817	0.3	0.321	0.298
Young modulus (psi×10^6)	29.887	32.0	30.7	31.0
Shear modulus (psi×10^6)	11.23	12.0	11.8	12.0
Poisson ratio	.33	.33	.30	.29

e) *Importing External Geometry*

As design of Helical Spring is done on SOLIDWORKS is imported as shown below

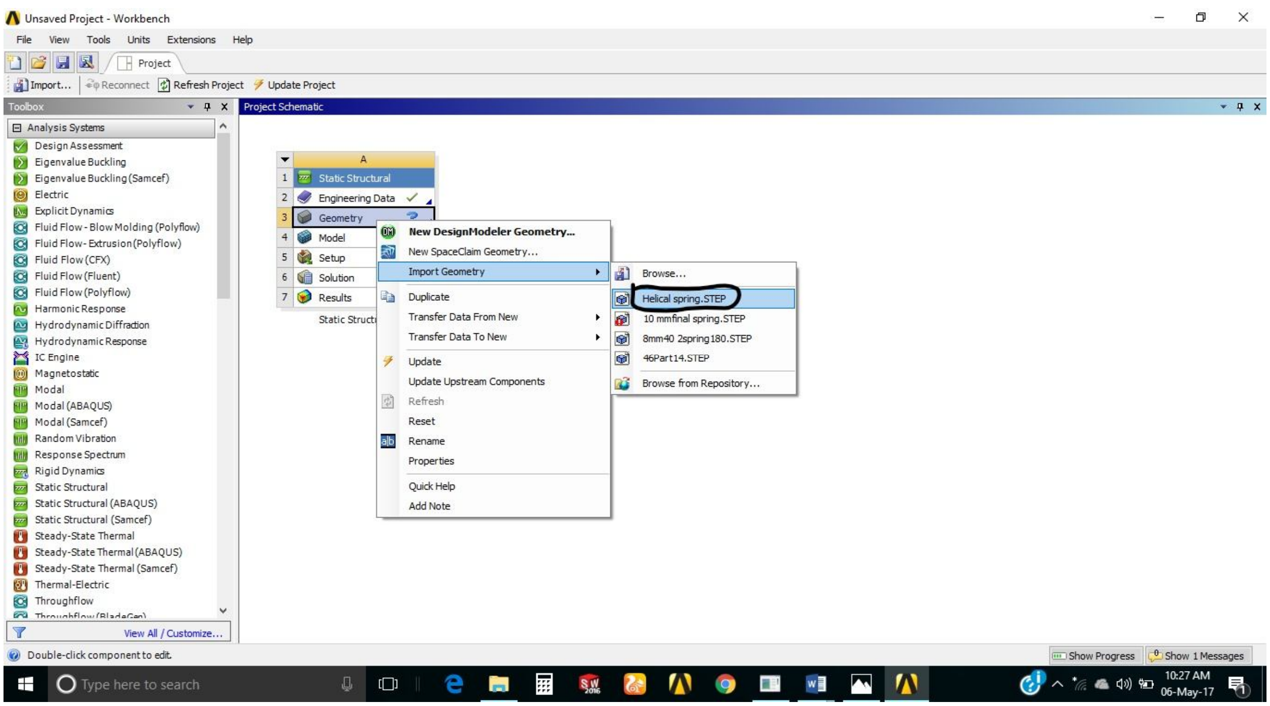

Figure.12 importing of geometry

5) Working on Model: After choosing geometry file click on the MODEL and then follow the following step

Check the geometry as assembled geometry comprises three component as shown below.

Choose global coordinate as coordinate system.

Connection is already defined during its design at SOLIDWORKS as contact 1 and contact 2 as shown in the given figure below.

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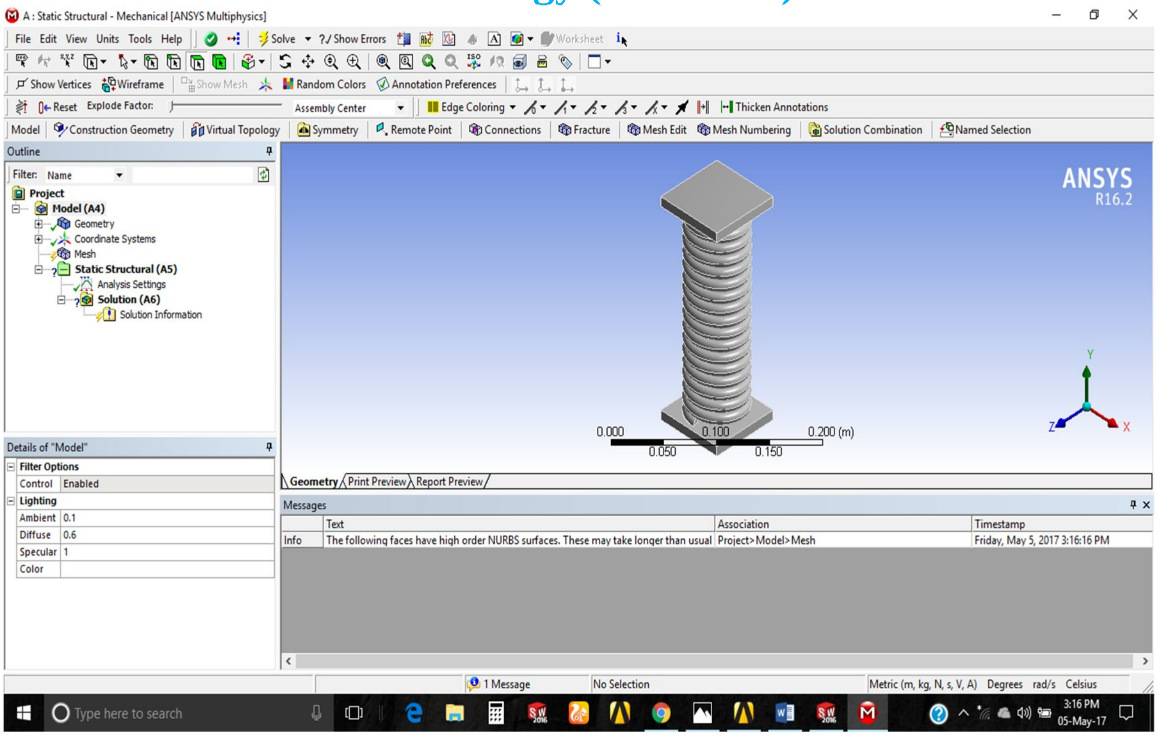

Figure.13 Model at ANSYS workbench 16.2

6) *After importing the geometry, click on material assign option.*

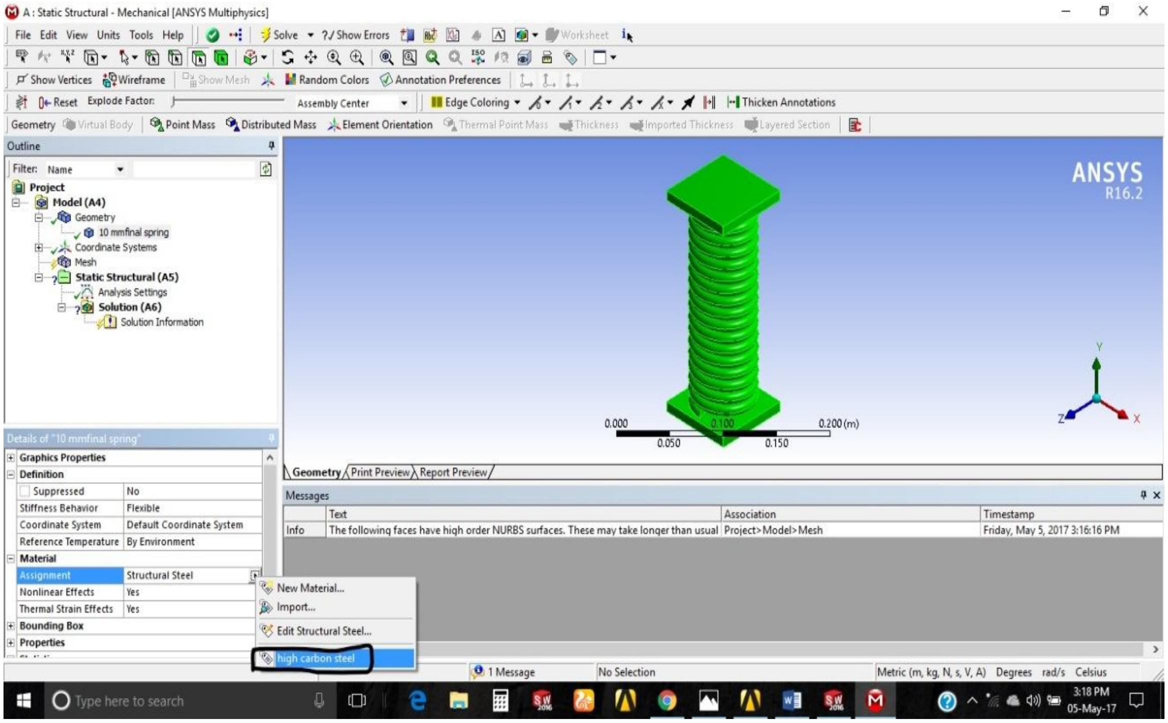

Figure.14Assigning material

Click at the mesh option set the element size as 5mm and run update to create meshing at the default setting. Meshing is shown below

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7) *Meshing*

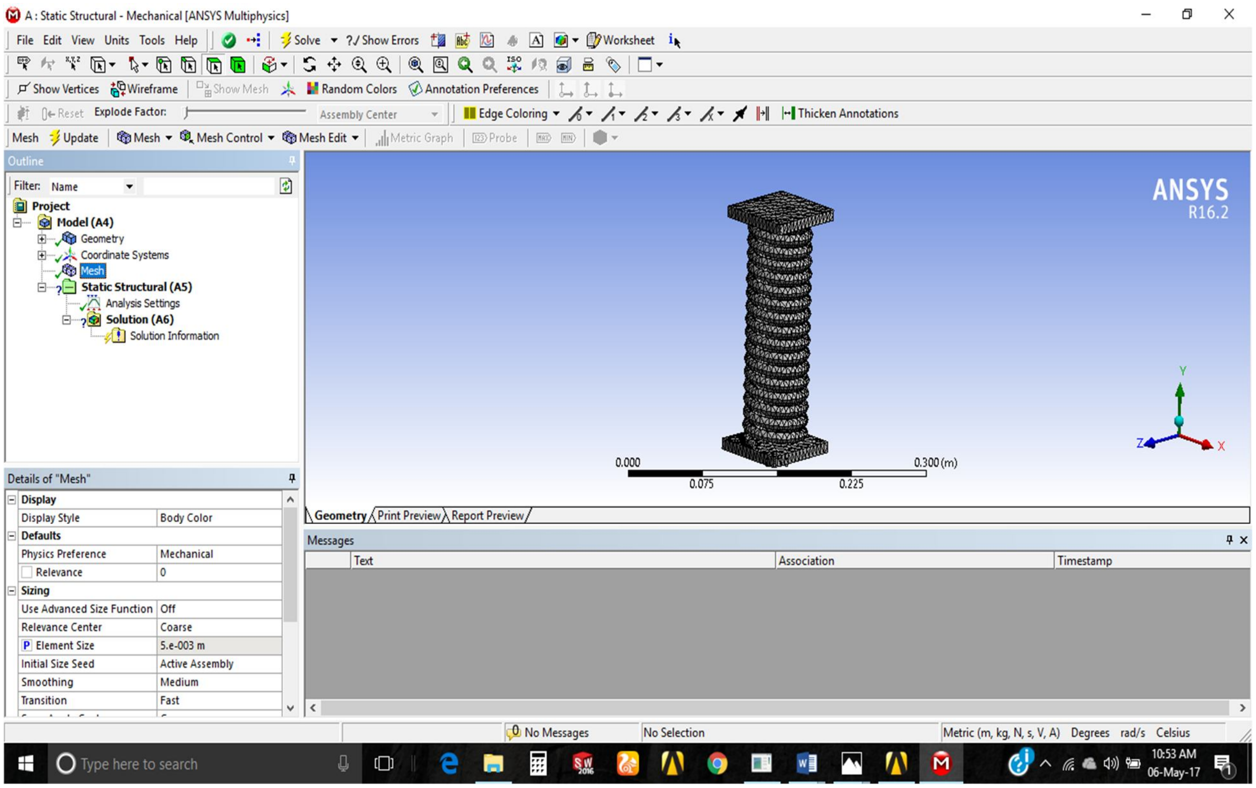

Figure.15 Meshing

Apply working environment

Following working condition will be apply on the geometry: -

8) *Fixed Support:* Fixed support is applied at one side of the spring component. To apply fixed support right click on static structural (A5) and insert fixed support as shown in figure below:

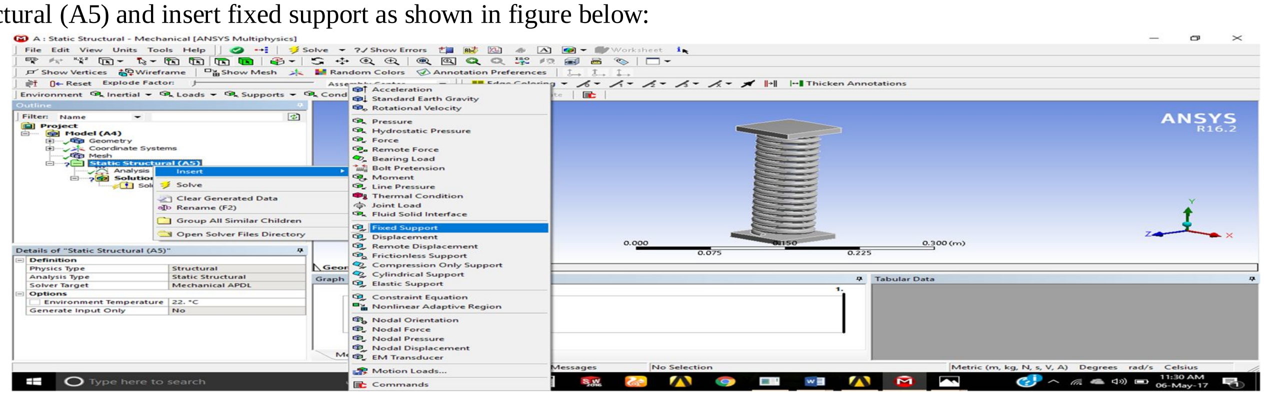

Figure.16

Fixed support at one of the face (say component 1) using face selection tool.

9) *Apply force:* Force is applied at one of the face of spring (say component 2).Generally spring absorb energy when applied force and release it when remove force.

10) *Solution setting of helical spring on Ansys Analysis setting:* In analysis setting we have to define the terms which we want get from the software. In this project we need to analyze the stress and deformation due to application of the axial force.

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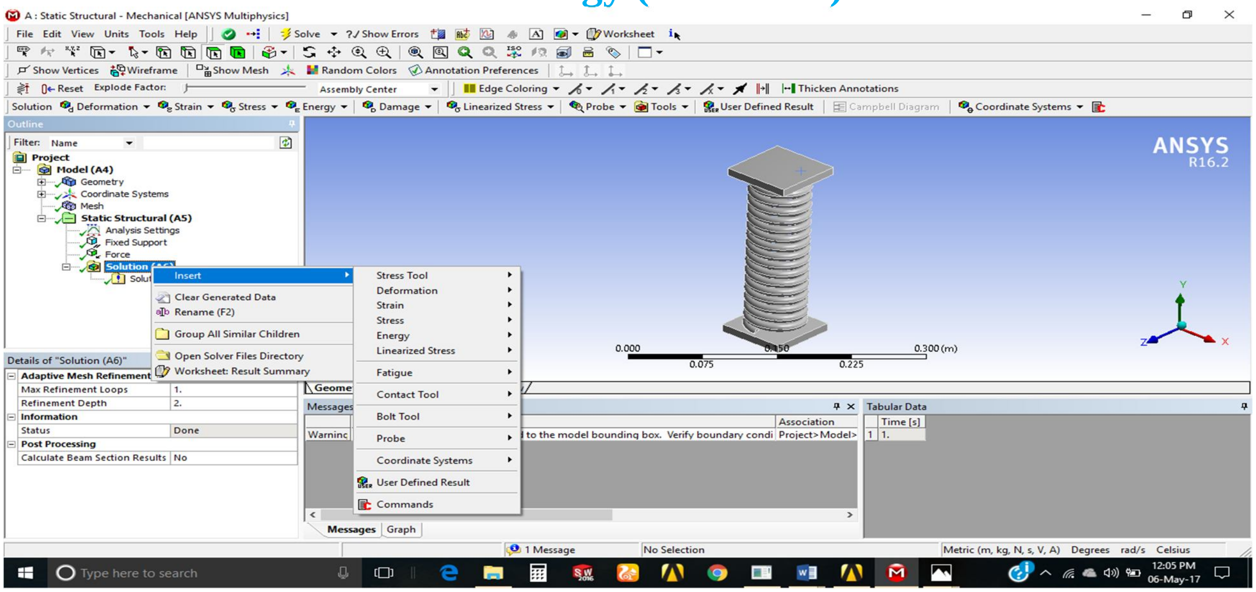

Figure.16 Analysis setting

11) *Definition of stress:* To define stress various theories have been already assigned in the Ansys like von mises, maximum principal etc. In this project, maximum shear stress is use as stress theory.

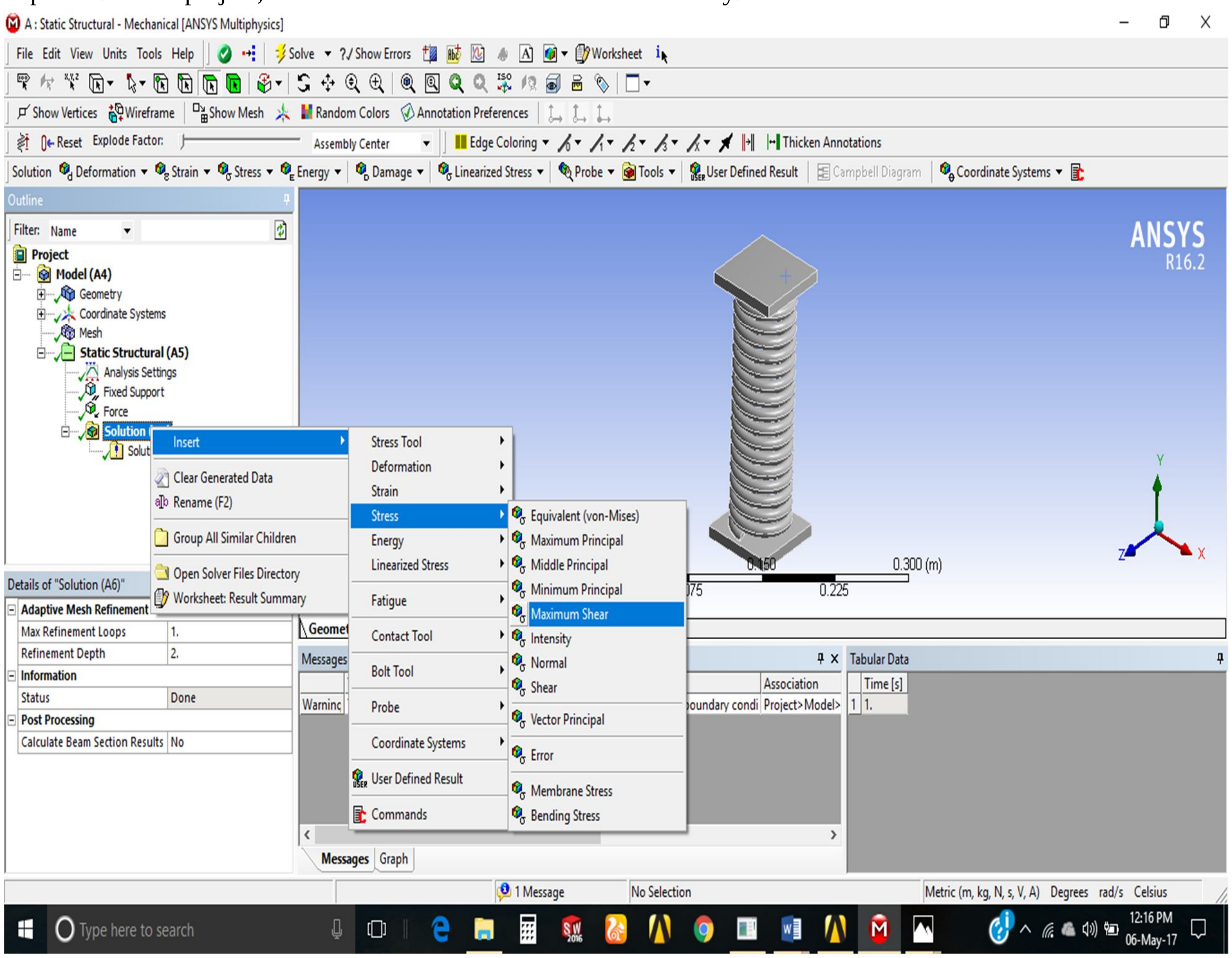

Figure.17 Definition of stress on workbench.

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12) Definition of deformation

Two type of deformation is given by the Ansys

Total deformation

Directional deformation

5.10.1 Total deformation

Total deformation is volumetric deformation of the geometry.

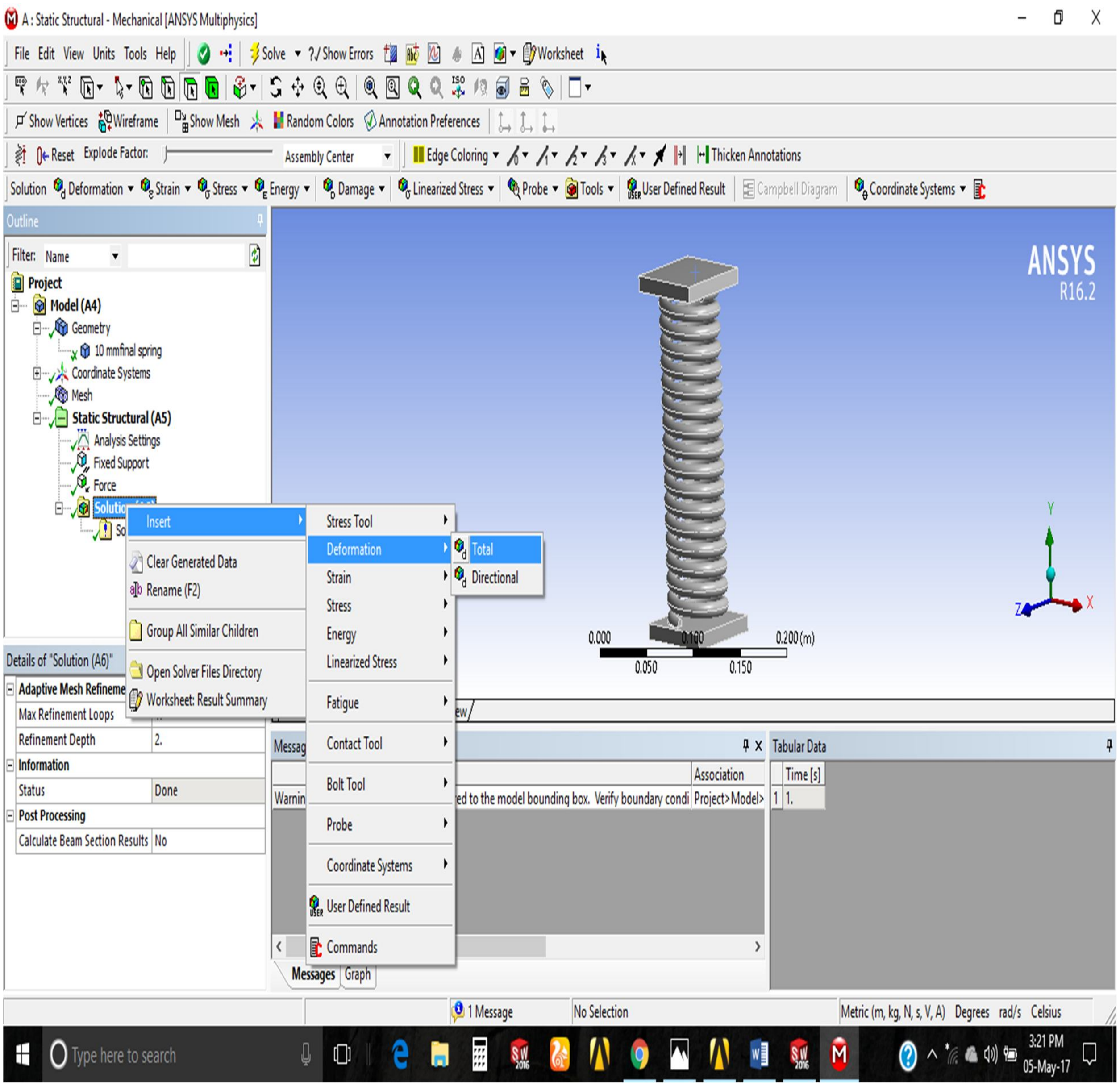

Figure.18 Total deformation

C. Structural Analysis Of Spring Material At Ansys

1) High Carbon Steel

Give

Poison ratio (μ) = .33

Density = .2817 lb/in^3

Young's modulus = 29.887 $\times 10^6$ psi

Shear modulus = 11.23×10^6 psi
Force applied = 2750 N

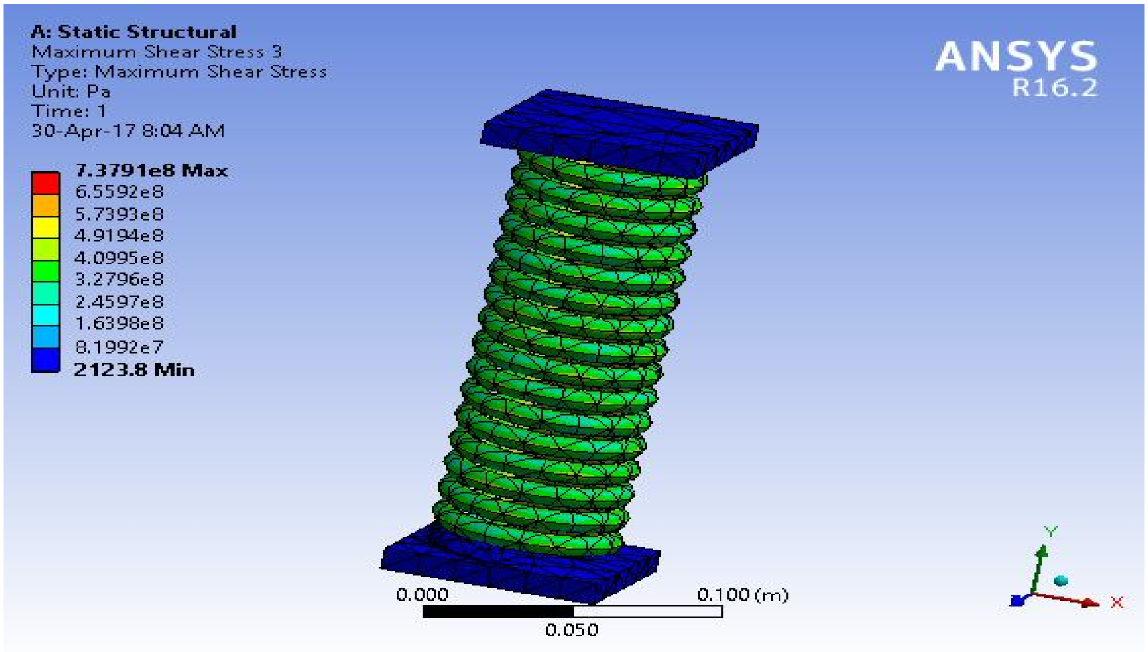

Figure.19 Equivalent stress

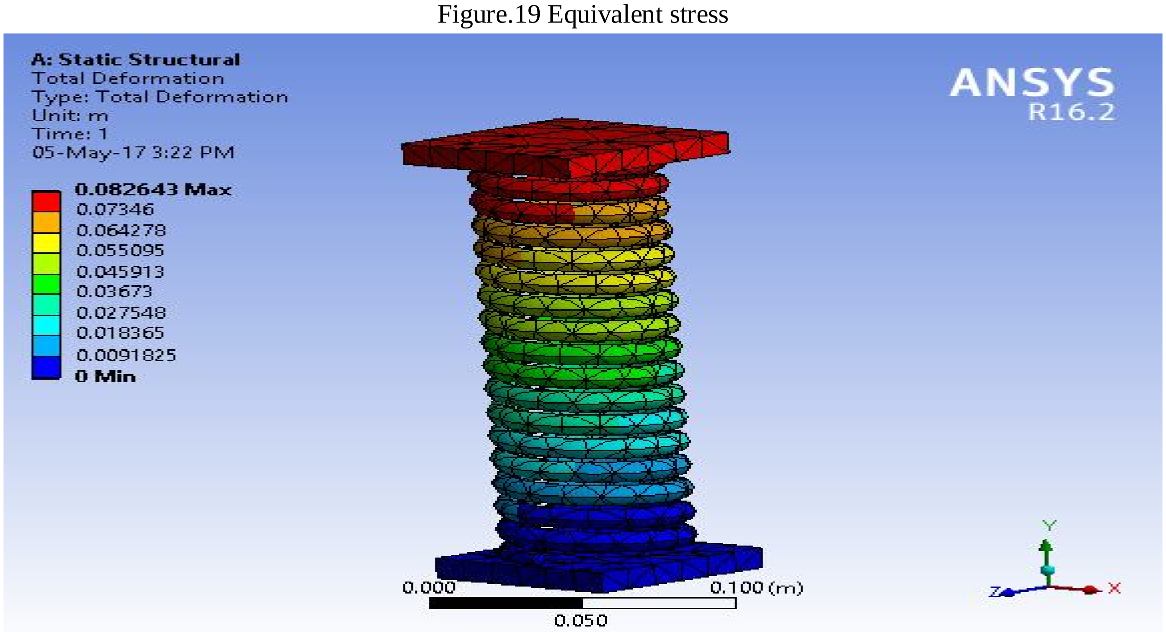

Figure.20 Total deformation

$$\text{Stiffness} = \frac{Applied\ force}{total\ deformation} = \frac{2750}{82.643} = 33.276\ N/mm$$

2) Elgiloy

Given

Poison ratio (**μ**) = .33

Density = .3 lb/in^3

Young's modulus = 32×10^6 psi

Shear modulus = 12×10^6 psi
Force applied = 2750 N

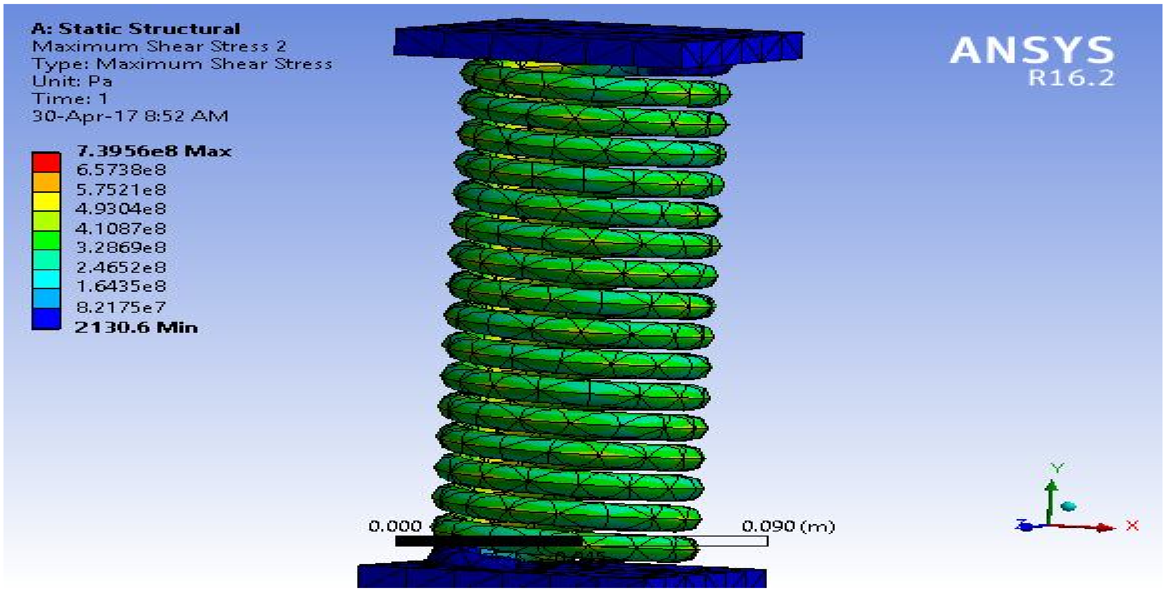

Figure.21 Equivalent stress

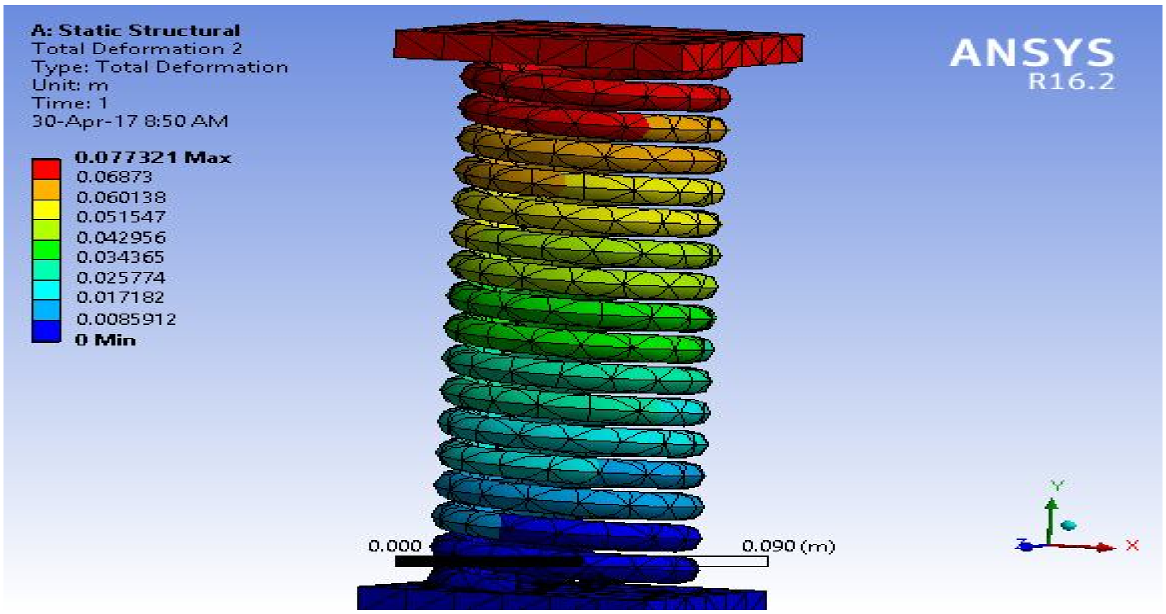

Figure.22 Total deformation

Stiffness $=\frac{2750}{77.231} = 35.566 N/mm$

3) Hastelloy (C-276)

Given
Poison ratio (**μ**) = .3
Density = .321 lb/in^3
Young's modulus = 30.7 $\times10^6$ psi
Shear modulus = 11.8×10^6 psi
Force applied = 2750 N

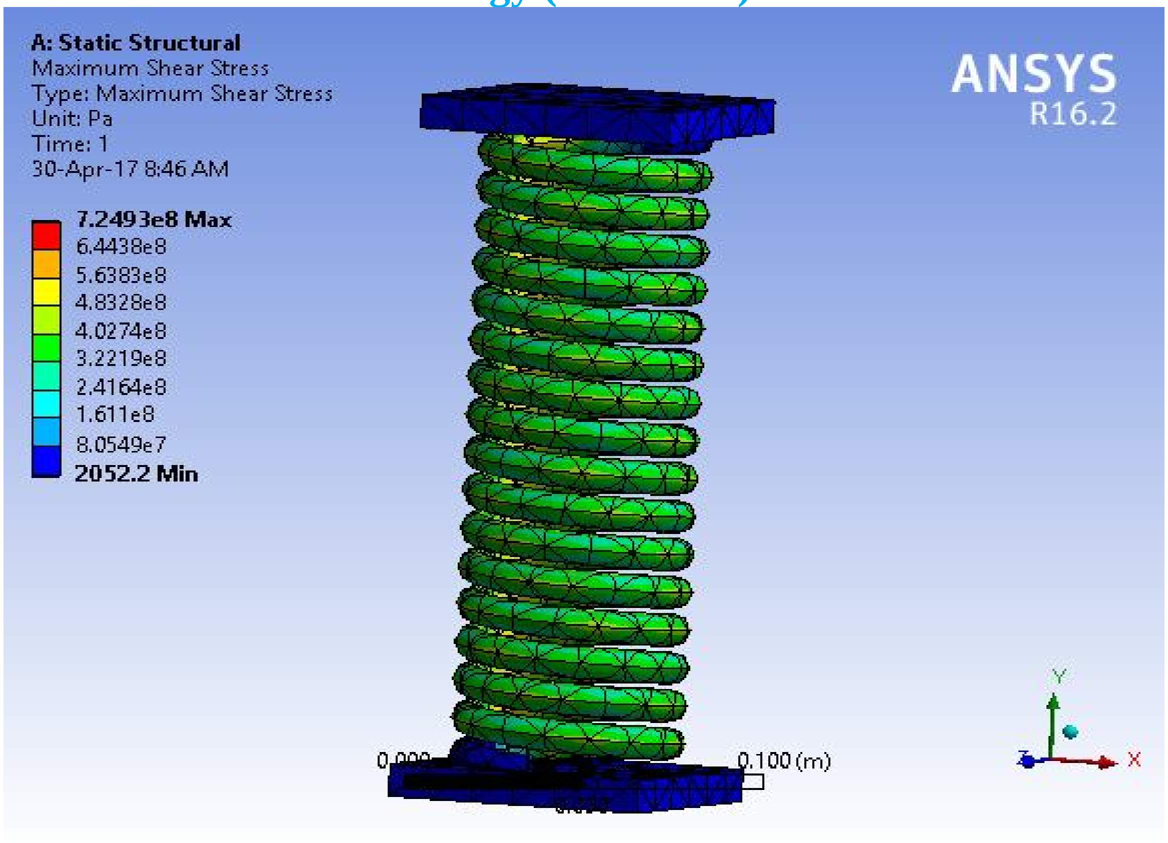

Figure.23 Equivalent stress

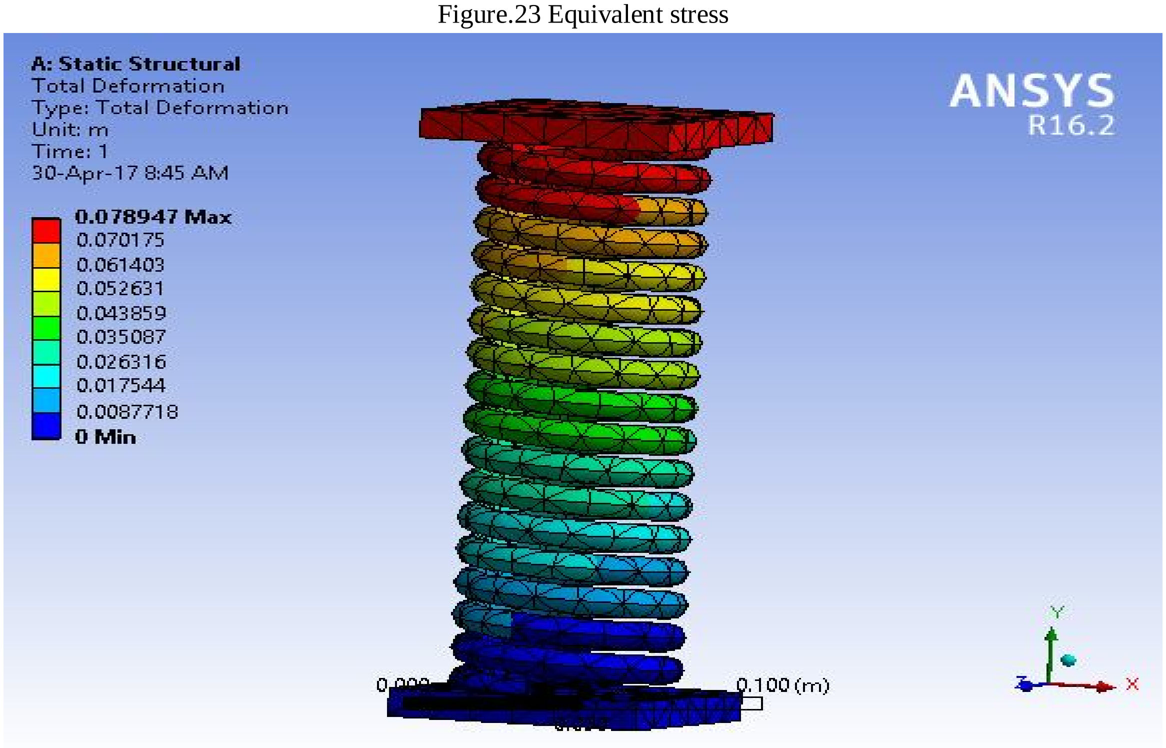

Figure.24 Total deformation

$$\text{Stiffness} = \frac{2750}{78.947} = 34.833 N/mm$$

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4) Inconel(X-750)

Given

Poison ratio (**μ**) = .29

Density = .298 lb/in^3

Young's modulus = 31 $\times 10^6$ psi

Shear modulus = 12×10^6 psi

Force applied = 2750 N

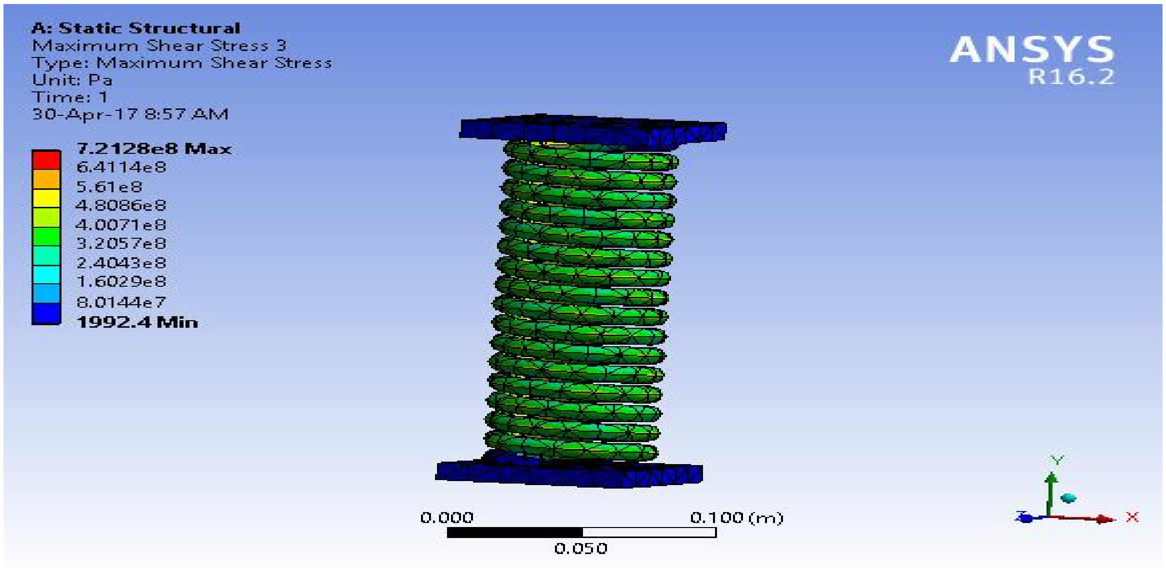

Figure.25 Equivalent stress

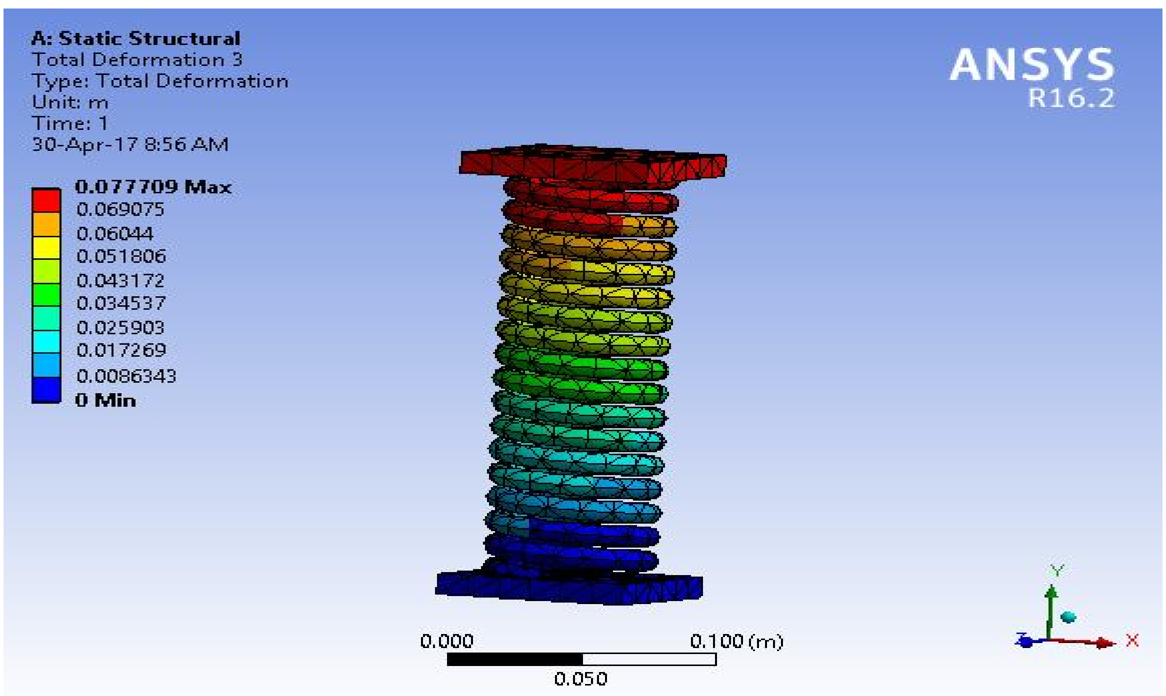

Figure.26 Total deformation

Stiffness = $\frac{2750}{77.709}$ = 35.388N/mm

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ISSN: 2321-9653
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IV. RESULT AND DISCUSSION

Table-4.1 Result table

S.No.	Materials	Deflection(mm)	Maximum shear stress(Mpa)	Load (N)	Stiffness (N/mm)
1	High carbon steel	82.643	737.91	2750	33.276
2	Elgiloy	77.321	739.56	2750	35.566
3	Hastelloy(C-276)	78.947	724.93	2750	34.833
4	Inconel(X-750)	77.709	721.28	2750	35.388

By comparison between stress and stiffness of above materials, we find Inconel is the best material for designing helical spring.

A. Graphs b/w Materials and Their Max. Shear Stress

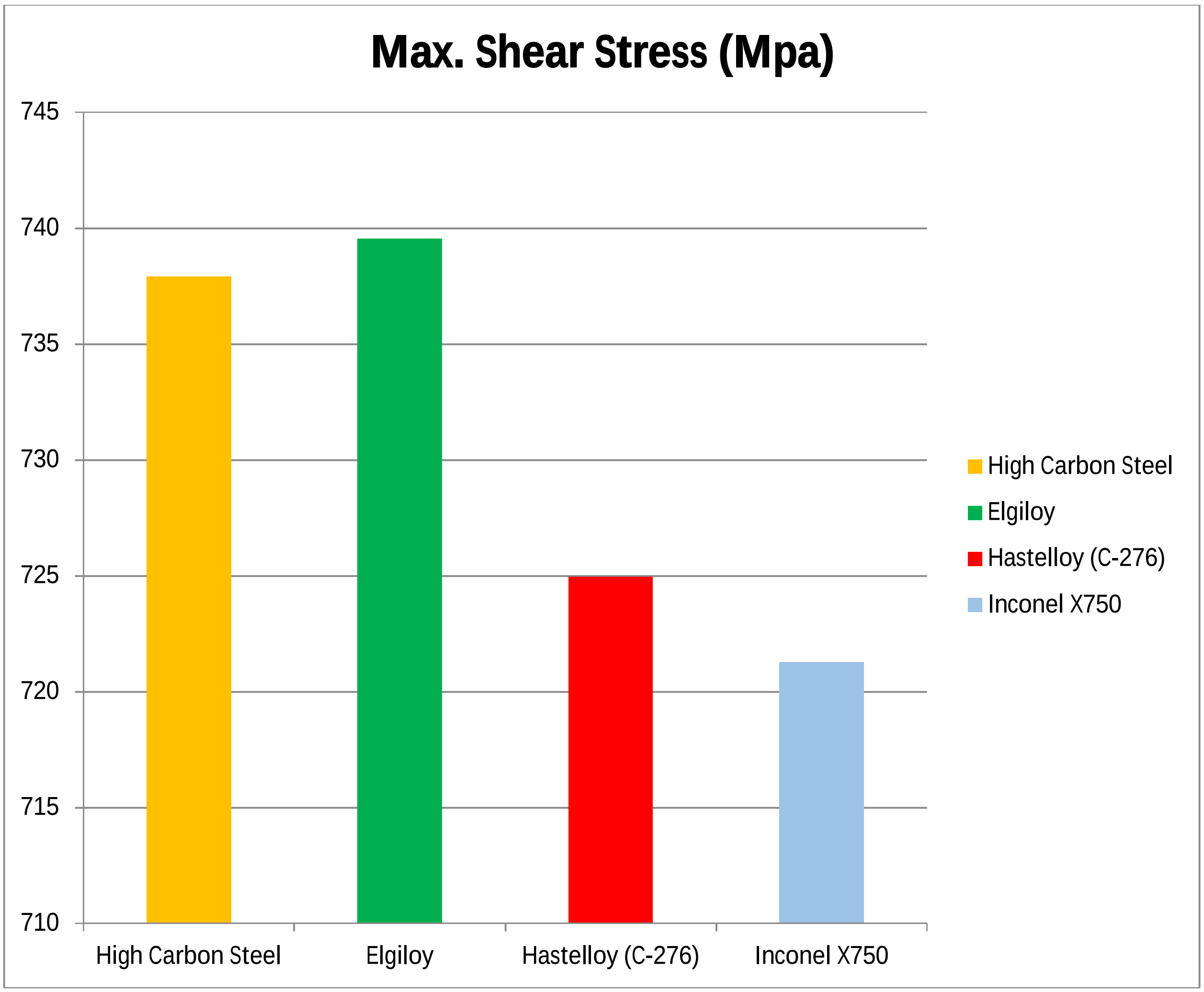

Figure.27

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B. Graph b/w Materials and Their Deflection

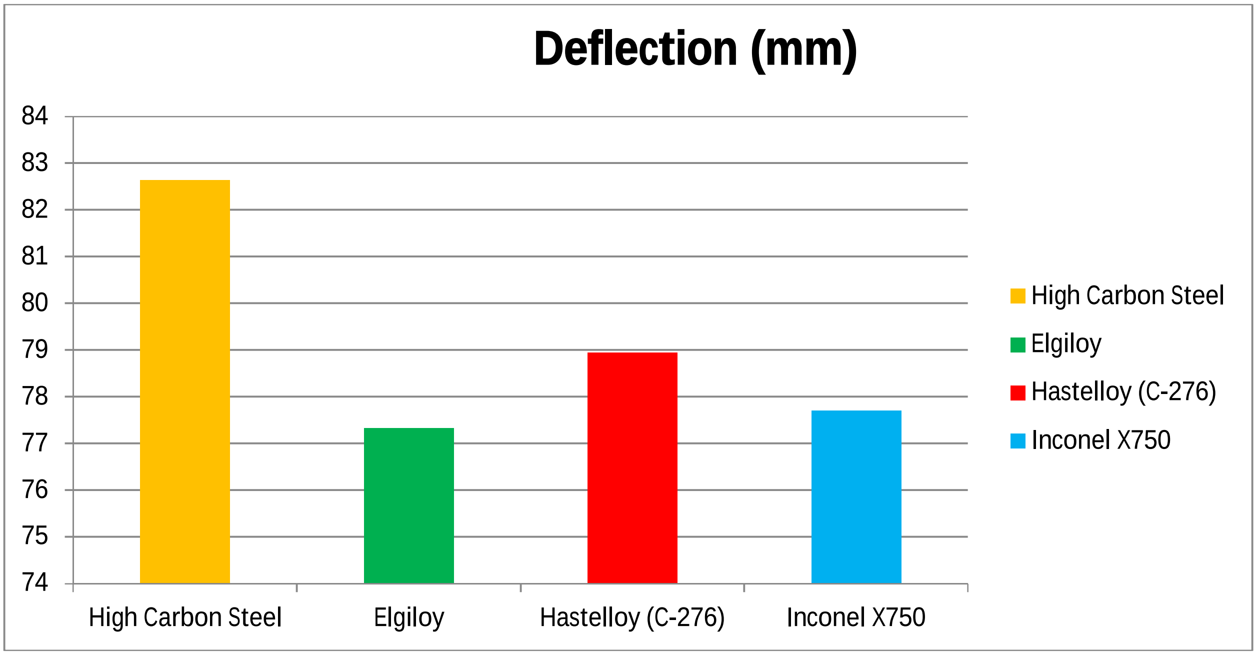

Figure.28

C. Column Chart b/w Materials and Their Stiffness

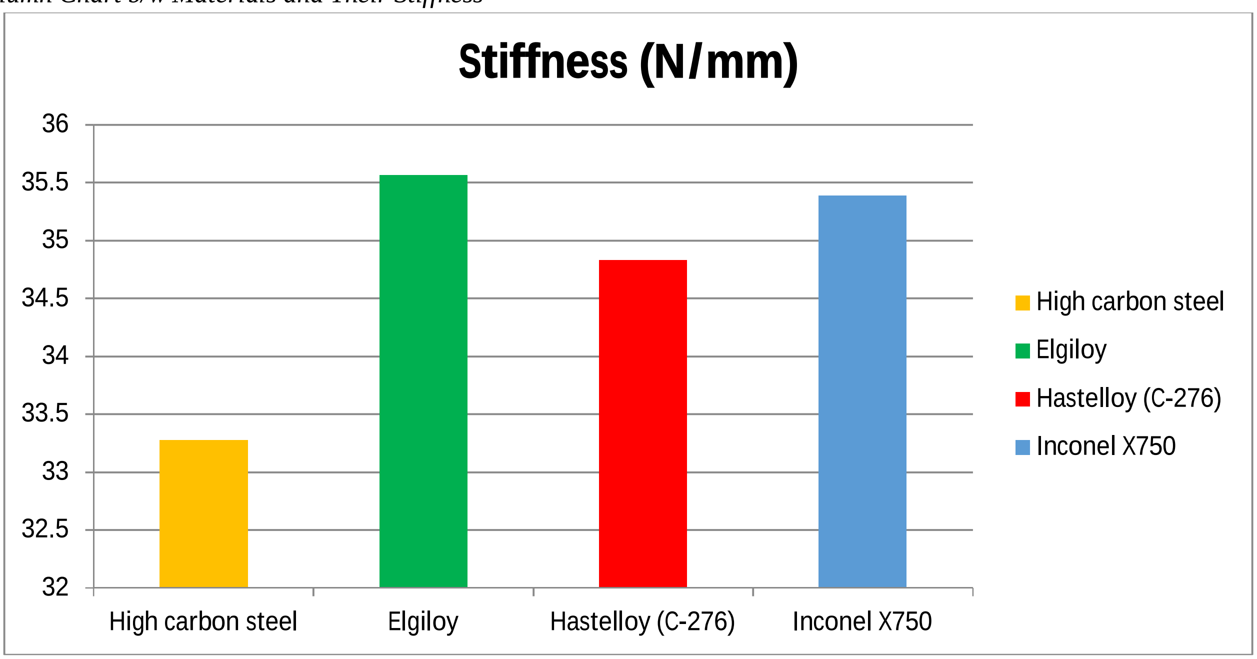

Figure.29

V. CONCLUSION

As per the graphs, plots and the reading given above Inconel X750 is the best material for spring design.

About Inconel X750

Inconel alloy X750 is a precipitation hardenable Ni-Cr alloy used for its corrosion and oxidation resistance and high strength at temperature up to 1300°F.

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Inconel X750 offers excellent resistance to relaxation and as a result it is widely used for spring's operation at elevated temperature.

VI. FUTURE ASPECT

A. Analysis of different spring either for heavy duty vehicle or light duty vehicle can also be analyzed.
B. Vibrational analysis can be done at Ansys for minimize the fatigue failure.
C. This material can work on even high industrial temperature that is up to 1100°F.
D. Dynamic analysis of spring can also be performed on Ansys to get better analysis.
E. Torsional analysis can be done due to presence of small amount of torsional moment in spring wire.
F. Design modification can be done to minimize the weight of helical spring and the inertia force.

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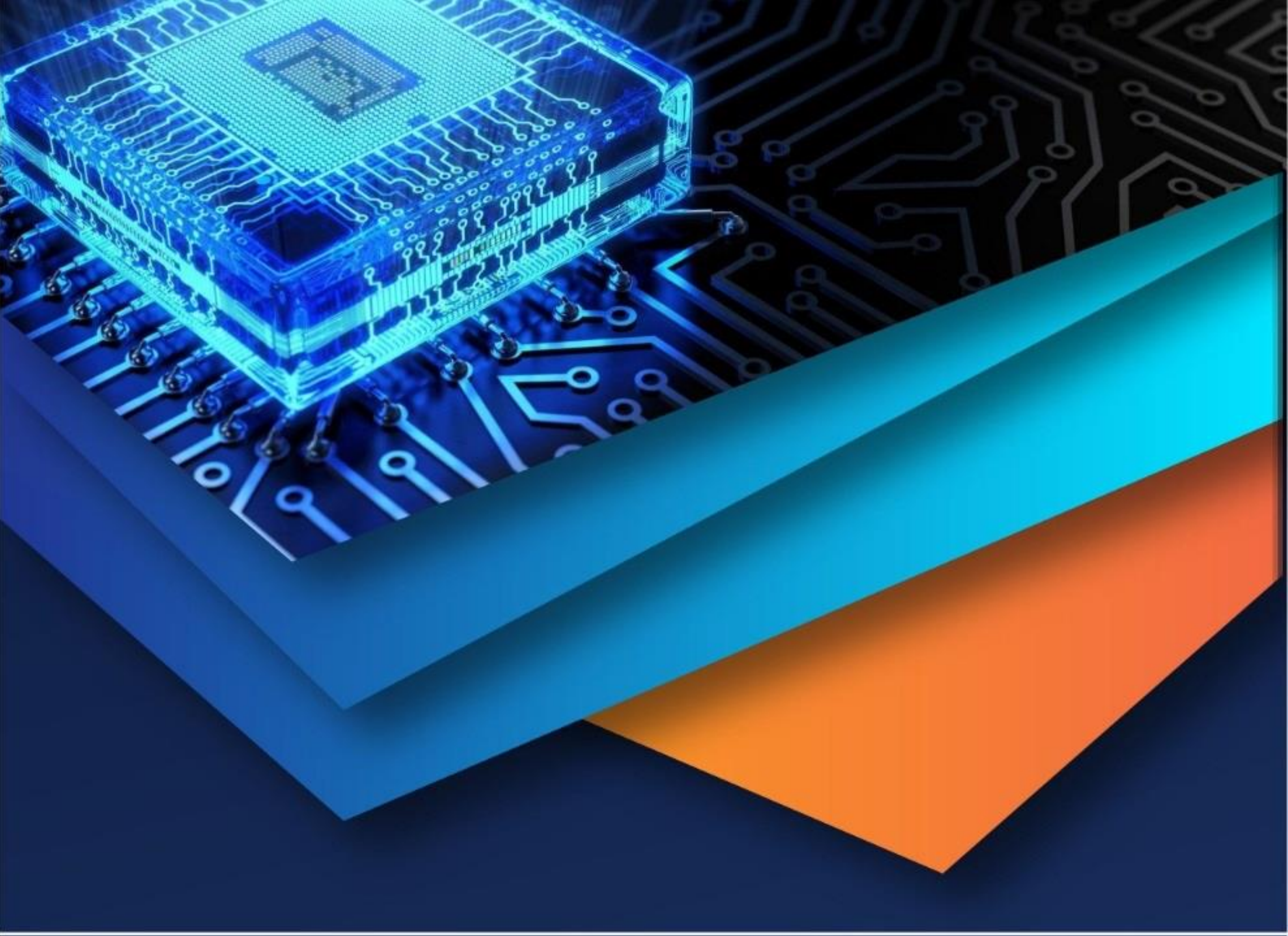

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