Comparative study and Analysis of Coil compression Springs with Composite materials

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Abstract: Helical springs are usually made from a metal wire of circular cross-section. The definition of many design variables required in order to get both the desired technical specifications and best compromise among spring objective functions. In other words, given the technical specifications like stiffness, maximum deflection, maximum acting load, strength to weight ratio etc, the designer is challenged to find the spring geometrical and mechanical parameters like diameter of the helical coil, number of coils etc, in order to gain the best compromise among the many different spring objective functions (minimum mass, minimum production cost, etc). For the static structural analysis, taking the dimensions of wire (diameter) is taken as 10mm and 13 mm respectively. Materials used in this research work are Carbon steel AISI 1065, Stainless Steel 302, Aluminum Alloy 6061 and Nitinol. Design of the suspension spring is created by using CATIA software and Static Analysis is performed by using ANSYS software. It was found that Nitinol and Al-6061 is best suitable for manufacturing the springs as the deflections are very less at different loads when compared to other springs and posses greater mechanical properties.

KEYWORDS: Stiffness, Maximum deflection, Carbon steel AISI 1065, Stainless Steel 302, Aluminum Alloy 6061 and Nitinol

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INTRODUCTION:

Spring is a piece of curved or bent metal that can be pressed into a smaller space but then returns its usual shape when the load is removed. Spring has a multiple area of applications, with different types. They are normally used in different purposes. The different types are springs are Helical spring, Conical or volute spring, Disc spring and Leaf spring. Among all these types of springs, Helical springs and Leaf springs are mostly used in automobile suspension system. The suspension system is the main part of the vehicle, where the shock absorber is designed mechanically to handle shock impulse and dissipate kinetic energy. In a vehicle, shock absorbers reduce the effect of travelling over rough ground, leading to improve ride quality and vehicle handling. While shock absorbers serve the purpose of limiting excessive suspension movement, their intended sole purpose is to damp spring oscillations. Hysteresis is the tendency for springs otherwise elastic materials makes them to rebound with less force than that of its required deformation. So modeling of the coil spring is made by using CATIA. Later the model is imported to ANSYS for the analysis work.

2. LITERATURE SURVEY

M. Muralidharan, R. Aravinth et.al have compared the design of Helical spring and wave spring with structural steel of a base metal. The standard dimensions of coil springs used is the Suspension System of Hero Honda Splender motorcycle. The design of spring is modelled in CREO Parametric 4.0 and Analysis in 18.0. The load applied on both Helical and wave springs are 10-100MPa respectively. Equivalent stress analysis and equivalent Von-mises strain of Helical springs for both Helical and wave Springs have applied of the Analysis Part. In the result it was concluded that as the load increases, equivalent strain decreases, stiffness will increase. Finally, it was concluded that wave spring 4% lesser deformation than the helical spring in Natural condition.

S.N. Gundre., P.A. wankhade has proposed in their research work & described that for a three wheeled electrical vehicle, the suspension System is designed in Catia V5 R20 Software. The spring leafs are modelled in analysis and contact of leaf spring withsurface is rigidly fixed. The spring is meshed, analysed with different elements with a constant load of 650kg. It was concluded that the relative errors on maximum shear stress was ranging from 1.5 to 4%.

Harshad B. Pawar et.al has done some research work about the design of helical spring by reducing the spring weight without changing the remaining system. A numerical and finite element analysis was used to suggest the alternate number of coils and to reduce the weight of the existing coil spring

Composition of materials and its properties

To ensure that we are having a good result and doing things correctly we came across few materials and did analysis on them, by designing spring of the same. To carry on with the good one within them. Following of them are

1. AISI 1065 – Carbon Steel
2. Stainless Steel 302
3. Nitinol (Nickel Titanium)
4. Aluminium Alloy – 6061

Composition of AISI 1065

Iron,(Fe)	98.31-98.8%
Carbon, (C)	0.9-1.0%
Manganese, (Mn)	0.3-0.5%
Sulphur, (S)	0-0.050%
Phosphorus, (P)	0.040%

Properties of AISI-1065

Density	7850 Kg/m^3
Elastic Modulus	200 GPa
Poisson's Ratio	0.3

Composition Of Stainless Steel 302

Chromium, (Cr)	17-19%
Nickel, (Ni)	8-10%
Manganese,(Mn)	2%
Silicon, (Si)	1%
Carbon, (C)	0.15%
Sulphur, (S)	0.03%
Phosphorous, (P)	0.045%

Properties of Stainless 302

Density	8027 Kg/m^3
Elastic Modulus	193 GPa
Poisson's Ratio	0.3

Composition of Nitinol

Nickel,(Ni)	49-51%
Titanium, (Ti)	49-51%

Properties of Nitinol

Density	6450 Kg/m^3
Elastic Modulus	83 GPa
Poisson's Ratio	0.33

Composition of Aluminium Alloy-6061

Aluminium,(Al)	97.9
Silicon,(Si)	1
Copper, (Cu)	0.60
Magnesium, (Mg)	0.28
Chromium,(Cr)	0.20

Properties of Aluminium Alloy-6061

Density	2700 Kg/m^3
Elastic Modulus	68.9 GPa
Poisson's Ratio	0.33

3.METHODOLOGY

3.1 Design Procedure

Spring Specifications

Spring wire diameter (d) =10 mm,
Coil mean diameter (D) =50 mm,
Total number of turns (n) =09,
No of active turns (n) = 09,
Free length (L_f) = 220 mm
Where n = no of active turns
d = diameter of the spring wire
D = Mean Diameter of Spring

End Connections for Compression Helical Spring having following four conditions

- Plain ends.
- Ground ends.
- Square ends.
- Plain and Grounded ends.

For this design of spring, Plain and Grounded ends condition were taken.

3.2 Theoretical Calculations

Let the weight of the bike = 130 kg,
Let the weight of the person = 80 kg,

Taking Rear Suspensions as 65%, then

- 65% of total bike weight, W_1 = 84.5 kg
- 65% of total bike weight + Single person on Spring, W_2 =136.5 Kg
- 65% of total bike weight + two persons on Spring, W_3 =188.5 Kg

By Taking Dynamic Load Factor as 1.5, Resultant Weights on Springs as follows

W1 = 84.5x1.5x9.81 = 1243.4175 N
W2 = 2008.59 N
W3 = 2773.77 N

For single shock absorber the load will be W/2

W1 = 621.7 N
W2= 1004.29 N
W3= 1386.88 N

Calculations,

Spring Index ©= $\frac{D}{d} = \frac{50}{10} = 5$

Wahl's Stress Factor (k) = $\frac{4C-1}{4C-4} + (\frac{0.615}{C})$= 1.3

- Maximum Shear Stress (τ) = $\frac{8kWD}{\pi d^3}$

For W_1 = 621.71 N, Then

$\tau_1 = \frac{8*1.31*621.71*50}{\pi*10^3}$ = 103.696 Mpa

For W_2 = 1004.29 N, τ_2= 167.5 Mpa

For W_3 = 13386.88 N, τ_3= 231.32 Mpa

- Deflection (◎) = $\frac{8*W*D^3*n}{Gd^4}$

Table 3.1: Theoretical Deflection

Material	**Force, W (N)**	**Deflection,✟ (mm)**
AISI 1065 (G = 80 Gpa)	621.71	6.99
	1004.29	11.298
	1386.885	15.6
Stainless Steel 302 (G = 153.17 Gpa)	621.71	7.46
	1004.29	12.05
	1386.885	16.64
Nitinol (G = 29 Gpa)	621.71	19.27
	1004.29	31.13
	1386.885	42.99
Aluminium Alloy 6061 (G = 26 GPa)	621.71	21.5
	1004.29	34.75
	1386.885	47.98

3.3 Modelling and Analysis

Create a 3D- Model of Helical Spring according design parameters with respect to the working conditions. Using Mechanical design and Shape Design of creating the spring. In this process, we are using the tools like Sketcher , Helix , Rib and finally Extrude Operations.

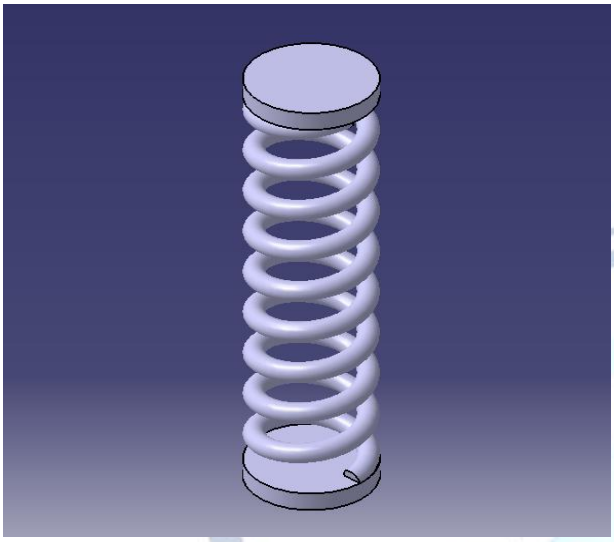

Fig-3.1: Helical Spring Design in Catia V5R20

3.3.1 Procedure for Analysis:

Name the file as "Helical Spring Analysis" in **Ansys R21** software tool. Create a "**Static Structure**". Edit the "**Engineering Data**", Create all necessary material properties from data source or External Source. Upload the Created 3D model of Helical Spring in Catia V5 to the "**Geomentry**" section. Generate the Fine Mesh for good results than Coarse Mesh. Add the boundary conditions (Force W, Fixed Support) to Spring in "**Static Structural**" section. Insert the Total Deformation and Shear Stress in the "**Solution**". Finally solve the Problem and note down the obtained results.

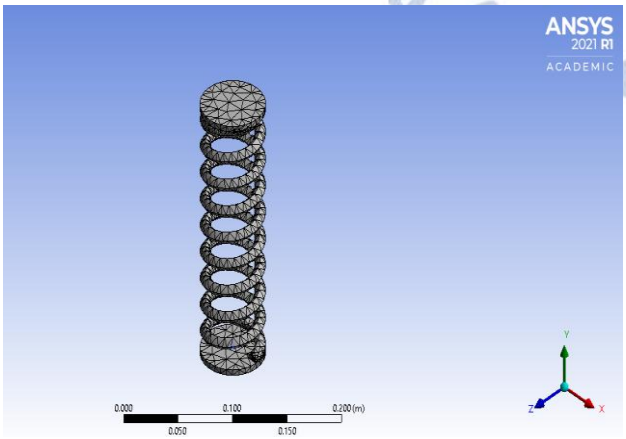

Fig-3.2: Meshing of Helical Spring in Ansys 21

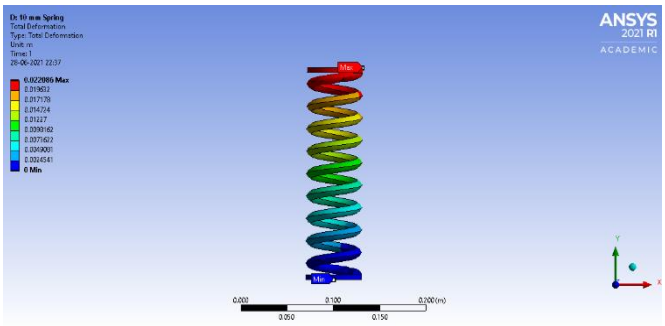

Fig-3.3: Deformation of AISI 1065 at W = 1386.885 N

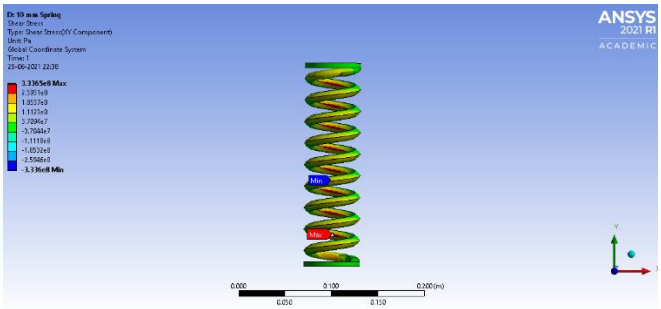

Fig-3.4: Shear Stress of AISI 1065 at W = 1386.885 N

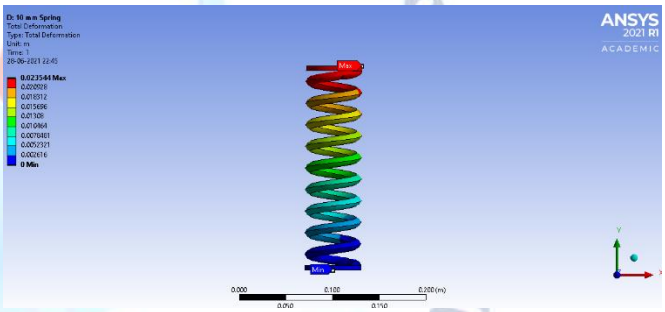

Fig-3.5: Deformation of SS-302 at W = 1386.885 N

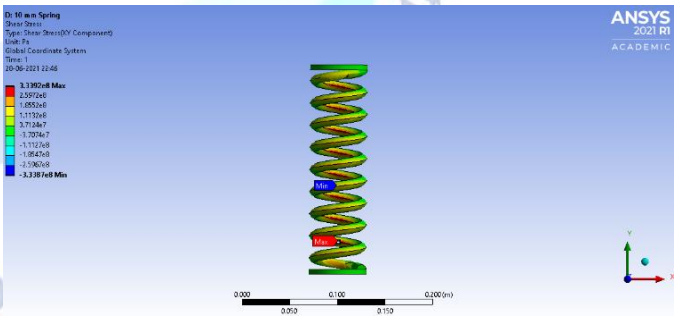

Fig-3.6: Shear Stress of SS-302 at W = 1386.885

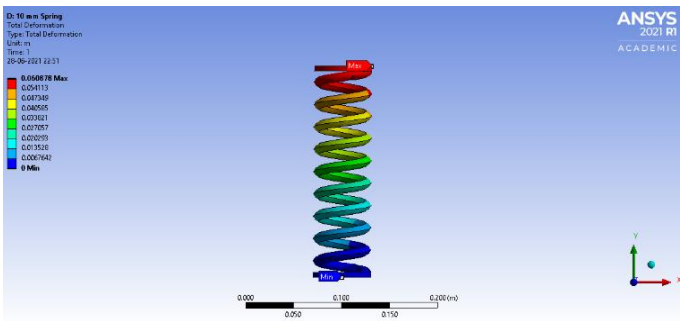

Fig-3.7: Deformation of Nitinol at W = 1386.885 N

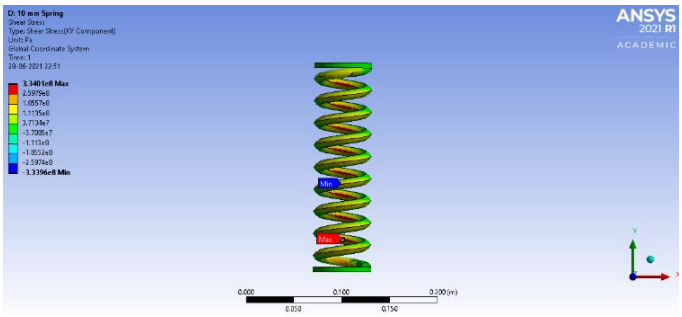

Fig-3.8: Shear Stress of Nitinol at W = 1386.885 N

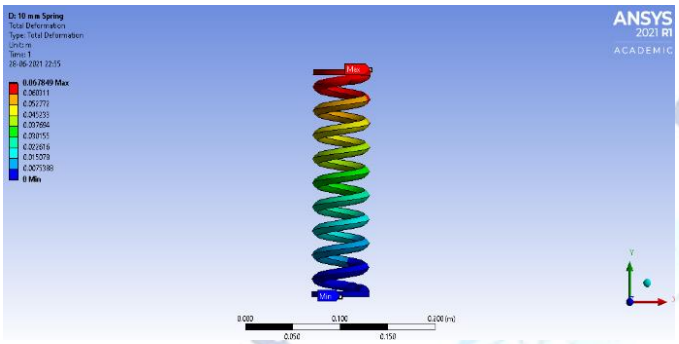

Fig-3.9: Deformation of Aluminium Alloy 6061 at W = 1386.885 N

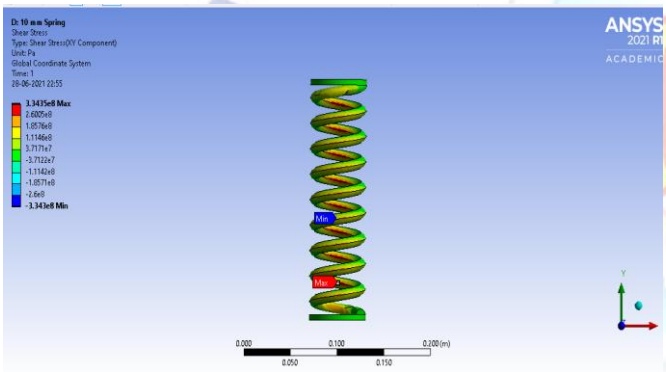

Fig-3.10: Shear Stress of Aluminium alloy 6061 at W = 1386.885 N

Table-3.2: Analytic Values

Material	**Force, W (N)**	**Deflection,✱ (Mm)**	**Max Shear,τ (Mpa)**
AISI 1065 (G = 80 GPa)	621.71	9.9	149.57
	1004.29	15.99	241.61
	1386.885	22.088	333.65
Stainless Steel 302 (G = 153.17 GPa)	621.71	10.55	149.69
	1004.29	17.049	241.8
	1386.885	23.54	333.9
Nitinol (G = 29 GPa)	621.71	24.29	149.73
	1004.29	44.08	241.87
	1386.885	60.87	334.01
Aluminium Alloy 6061 (G = 26 GPa)	621.71	30.41	149.88
	1004.29	49.13	242.11
	1386.885	67.849	334.35

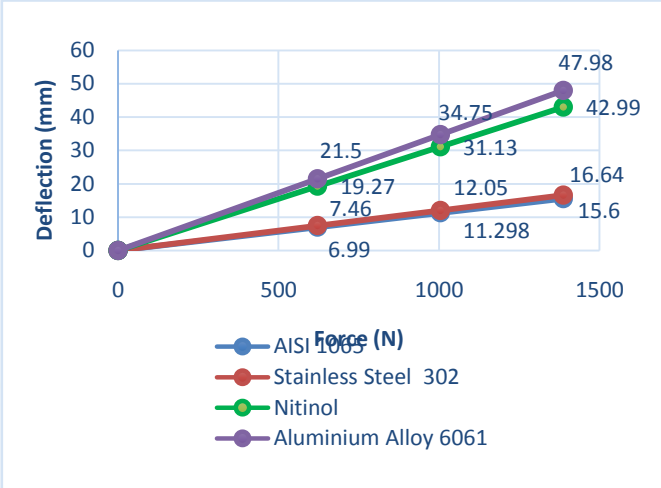

Fig-3.11: Force vs deflection(Analytical)

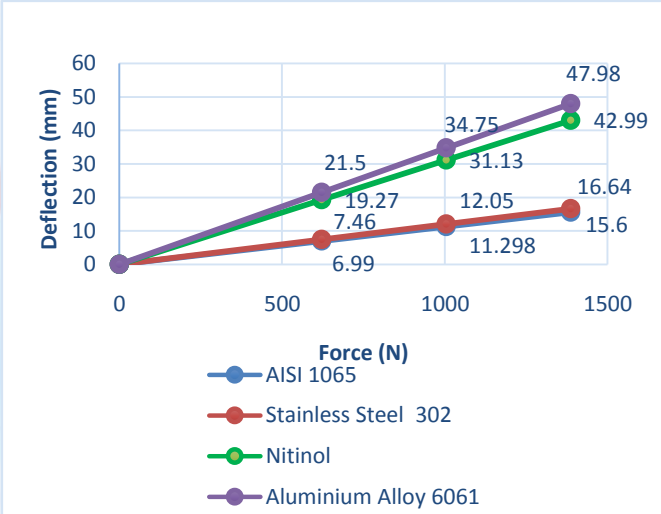

Fig-3.12: Force Vs Deflection(Theoretical)

3.3.2 Modification in Wire diameter:

Change in structure is to be carried out for reduction in stress, Due to stress is depend on structure. Change in dimensions (Wire diameter or Mean Diameter) can effects the stress.Here we are changing wire diameter as shear stress is inversely proportional to fourth power of wire diameter. Change in wire diameter means increase or decrease in wire diameter from its original size, here for reducing stress increase in wire diameter is required as shear stress is inversely proportional to fourth power of wire diameter.As per standard dimension, the first preference is 13mm after 10mm which is been selected here for further analysis.

The new dimension of spring will be,

Free Length (Lfree) = 220 mm

Mean diameter (D) = 50 mm
Wire diameter (d) = 13 mm
Pitch (p) = 23 mm
Number of active turns (n) = 9
Spring index C = D/d = 3.85

Based on the new dimension the analytical result for different forces on Spring made with above materials in Ansys and result obtained as shown in following figures.

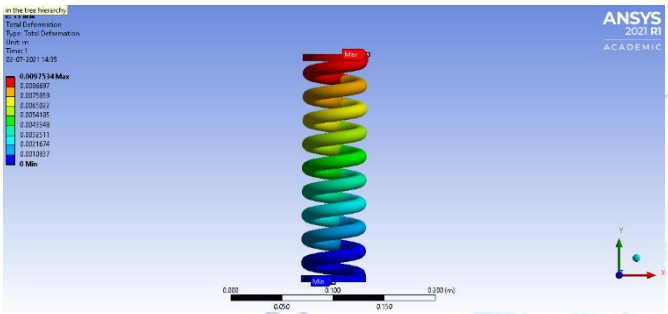

Fig-3.13: Deformation of AISI 1065 at W=1386.8 N with 13 mm diameter

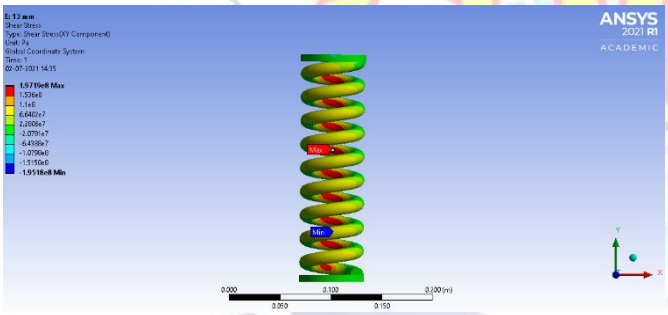

Fig-3.14: Shear Stress of AISI 1065 on at W=1386.8 N with 13 mm diameter

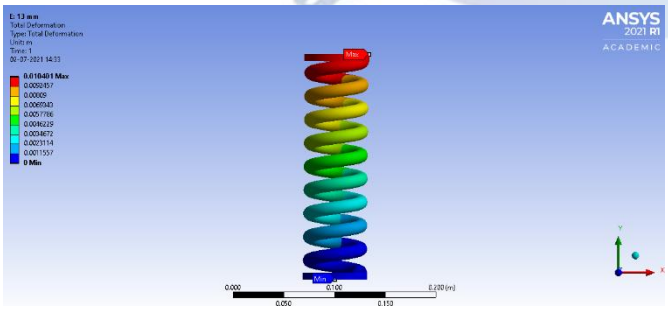

Fig-3.15: Deformation of Stainless Steel at W=1386.8 N with 13mm diameter

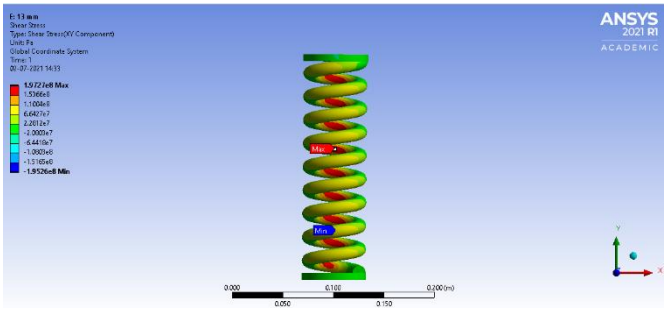

Fig-3.16: Shear Stress of Stainless steel at W=1386.8 N with 13 mm diameter

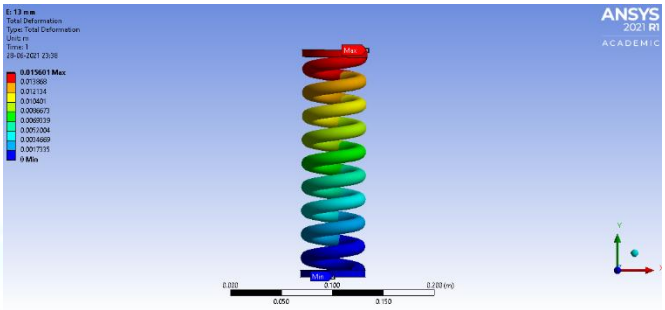

Fig-3.17: Deformation of Nitinol at W=1386.8N with 13 mm diameter

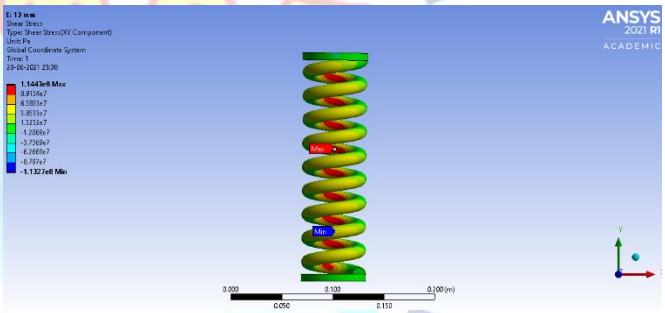

Fig-3.18: Shear Stress of Nitinol at W = 1386.8N with 13 mm diameter

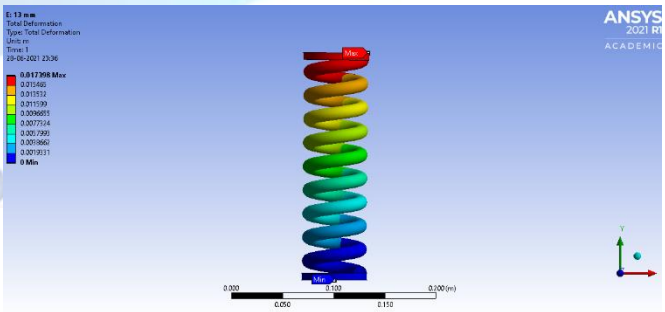

Fig-3.19: Deformation of Aluminium Alloy-6061at W =1386.8N at 13 mm diameter

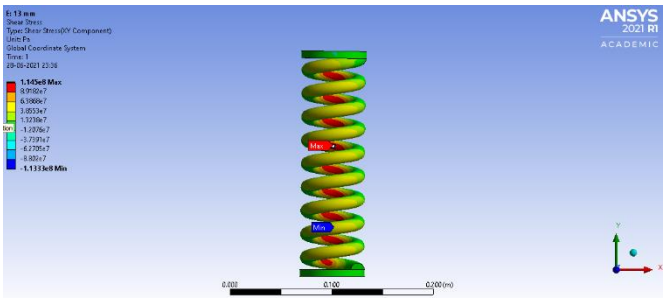

Fig-3.20: Shear Stress of Aluminium Alloy-6061 at W = 1386.8N with 13 mm diameter

Table-2.3: Analytical Values on 13mm at W=1386.8N

Materials	**Deformation,⊛ (mm)**	**Max Shear Stress,τ (Mpa)**
AISI-1065	9.75	197.19
Stainless steel-302	10.4	197.27
Nitinol	15.6	114.43
Aluminium Alloy 6061	17.39	114.5

Theoretical Results

Wahl's factor (k)= $\left(\frac{4\times3.846-1}{4\times3.846-4}\right) + \left(\frac{0.615}{3.846}\right)$

= 1.423

- Maximum shear stress $(\tau) = \frac{k.8WD}{\pi(13)^3}$

1. For W_1 = 621.71 N, τ_1 = 65 MPa
2. For W_2 = 1004.29 N, τ_2= 82.82 MPa
3. For W_3 = 1386.882 N, τ_3 = 114.37 MPa

- Deflection (⊛) $=\left(\frac{8\times W\times c^3 n}{Gd}\right)$

1. For AISI 1065 (G=80 GPa)

⊛$_1$ = 2.44 mm

⊛$_2$ = 3.95mm

⊛$_3$ = 5.46mm

2. For Stainless Steel 302 (G=153 GPa)

⊛$_1$ = 1.28mm

⊛$_2$ = 2.068mm

⊛$_3$ = 2.86mm

3. For nitinol (G=29 Gpa),

⊛$_1$= 6.754 mm

⊛$_2$ =10.91 mm

⊛$_3$ =15.6 mm

4. For Aluminium Alloy-6061 (G= 26 GPa),

⊛$_1$= 7.534 mm

⊛$_2$ = 12 mm

⊛$_3$ = 16 mm

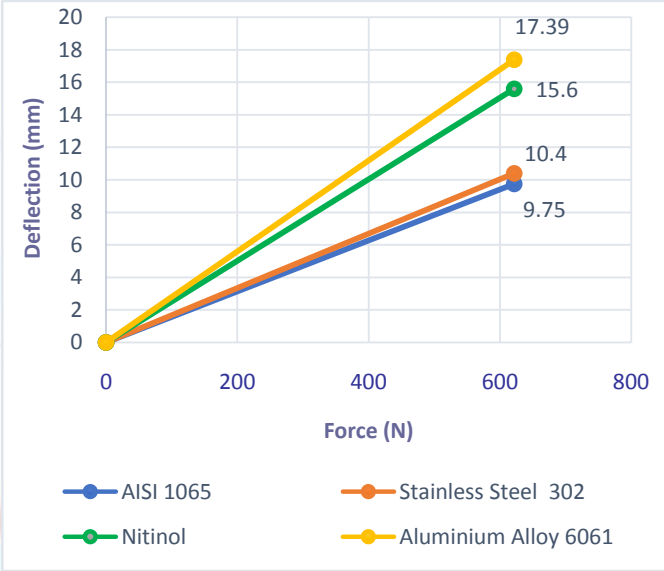

Fig-3.21: Force vs Deformation (Analytical)

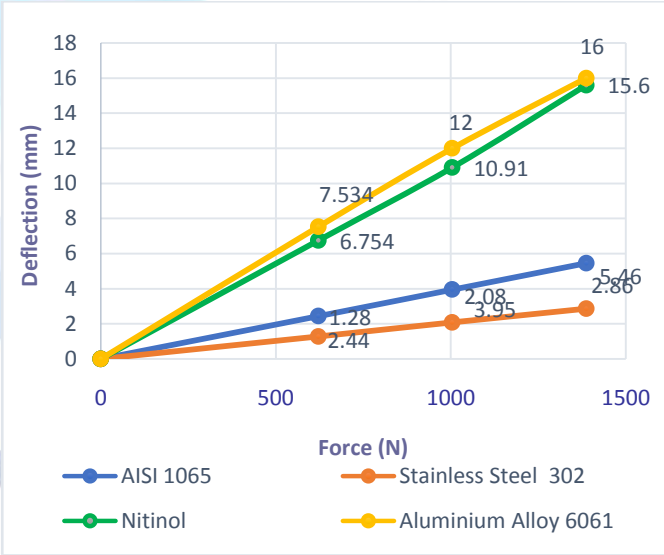

Fig-3.22: Force vs Deformation (theoretical)

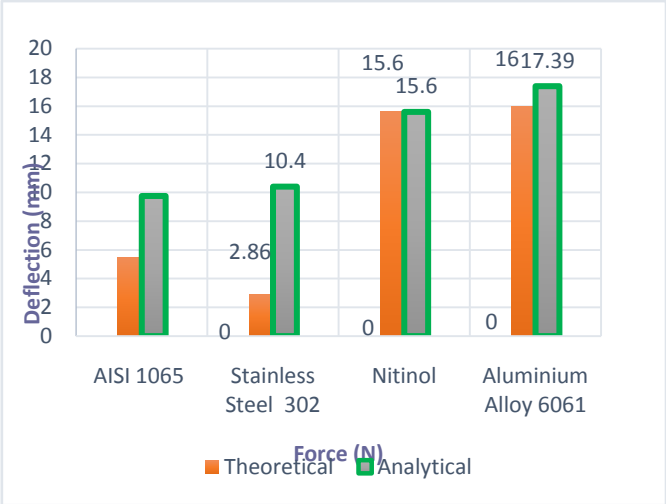

Fig-3.23: Comparison of Theoritical and Analytic Deformations

4.RESULT AND DISCUSSION

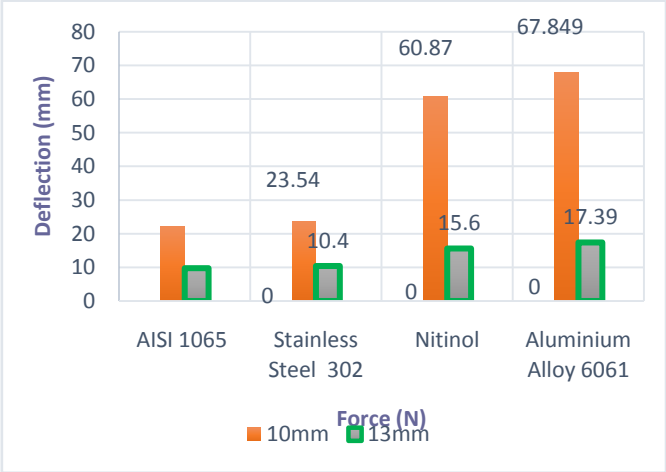

Fig:4.1- Comparison of deformation with original spring(10mm) and modified spring(13mm)

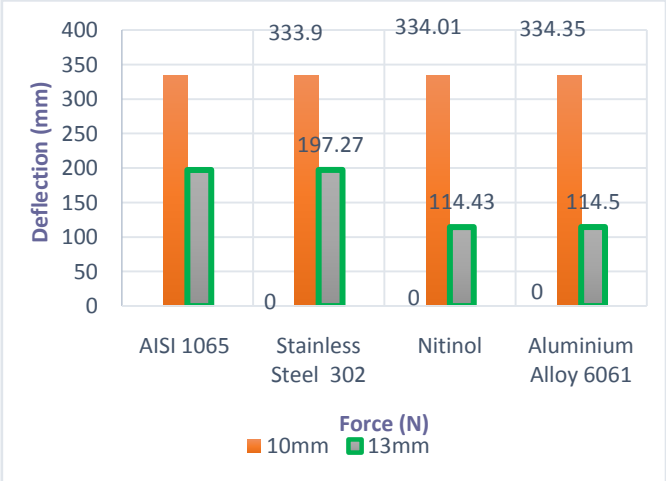

Fig: 4.2- Comparison of Maximum stress withoriginal spring(10mm)and modified spring(13mm)

The above figures show the comparison between AISI 1065, Stainless Steel 302, Nitinol and Aluminium alloy 6061 on 10mm wire diameter of Spring. The comparison is carried out at different loads 621.71 N, 1004.2 N & 1386.88 N. It was observed that maximum deflection for Carbon steel AISI 1065, Stainless Steel 302, Nitinol and Aluminium alloy 6061 are 22.088mm, 23.54mm, 60.87mm and 67.848mm respectively. Whereas, in the analysis on 13mm wire diameter, the maximum deformation results for AISI 1065, Stainless Steel 302, Nitinol, Aluminium Alloy-6061 are 9.75mm, 10.4mm, 15.6mm and 17.39mm respectively. Hence it is proved that Carbon Steel AISI 1065 and Stainless Steel 302 have minimum deflection and also minimum shear stress along other materials in both cases of 10mm and 13mm diameter of wire.

5. CONCLUSION

Considering the above 4 materials, Nitinol and Aluminium Alloy 6061 are having the good corrosion resistivity and induced stress also compare to AISI 1065, Stainless Steel 302. Nitinol and Aluminimum 6061 also have more strength to weight ratio. From the obtained results of Ansys 21.0, we can conclude that for 13mm wire diameter coil spring of Nitinol and Aluminium alloy 6061 are better materals than 10mm wire diameter of AISI 1065 & Stainless steel 302 which are generally used. Nitinol and Aluminium 6061 both have high restivity against corrosion but Nitinol shows less deflection and also the indused stress is compare to the Aluminium alloy 6061. Thus, Nitinol is the better one among the four materials that were analysed.

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