Structural Analysis of Material Behavior on Helical Spring with Defect (Notch)

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ABSTRACT

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The main of this work has to analysis the capacity of helical spring by using two different materials i.e. aluminium alloy and copper alloy and comparing the nature quality of spring (stiffness of spring, durability, reliability). There are many types defects present in the helical spring like Thermal Expansion, Vibration, Metal fatigue, Metal creep, Corrosion, Friction, Brittle fracture, Notch and so on. In which we have choosen a defect called Notch. We applied some load into the spring and checkout the deformations by regulating the position of notch from 1st layer to the last layer in all the three springs. In this we used two types of software i.e., CATIA V5 and ANSYS 2021 R1. We did analysis of all the layers of every spring and we calculate the total deformation in every layer of all the spring
Keywords : ANSYS, Thermal Expansion, Vibration, Metal fatigue, Metal creep, Corrosion, Friction, Brittle fracture, Notch

I. INTRODUCTION

A spring is an elastic object that stores mechanical energy. Springs are typically made of spring steel. There are many spring designs. In everyday use, the term often refers to coil springs. In classical physics, a spring can be seen as a device that stores potential energy, specifically elastic potential energy, by straining the bonds between the atoms of an elastic material. Hooke's law of elasticity states that the extension of an elastic rod (its distended length minus its relaxed length) is linearly proportional to its tension, the force used to stretch it. Similarly, the contraction (negative extension) is proportional to the compression (negative tension).This law actually holds only approximately, and only when the deformation (extension or contraction) is small compared to the rod's overall length. For deformations beyond the elastic limit, atomic bonds get broken or rearranged, and a spring may snap, buckle, or permanently deform. Many materials have no clearly defined elastic limit, and Hooke's law can not be meaningfully applied to these materials. Moreover, for the superelastic materials, the linear relationship between force and displacement is appropriate only in the low-strain region.

Hooke's law is a mathematical consequence of the fact that the potential energy of the rod is a minimum when it has its relaxed length. Any smooth function of one variable approximates a quadratic function when examined near enough to its minimum point as can be seen by examining the Taylor series. Therefore, the force—which is the derivative of energy with respect to displacement—approximates a linear function.

Force of fully compressed spring

$$F_{\max} = \frac{Ed^4(L - nd)}{16(1 + v)(D - d)^3 n}$$

E – Young's modulus
d – spring wire diameter
L – free length of spring
n – number of active windings
v – Poisson ratio
D – spring outer diameter

History of Helical Spring: R. Tradwell filed a British patent, number 792, for the first coiled spring back in 1763. The word coil meant to wind cylindrically or spirally. This new patent was considered a step up from the leaf spring which had to be separated and lubricated often or it was very squeaky. The new coiled spring didn't have to be spread apart.In the year 1857, the steel coil spring was officially invented and was often used in the construction of chair seats.Ever since the inventions of these coil springs, springs have been used in everything from shoes to trampolines. They helped make the car industry what it is today. Springs are used in every type of machinery and they really do help make the world go around.

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A coil 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 contacting surfaces. They are made of an elastic material formed into shape of helix which returns to its natural length when unloaded.

Fig.1.2.1 Spring

A coil spring may also be used as a torsion spring in this case the spring as a whole is subjected to torsion about its helical axis. The material of the spring is thereby subjected to a bending moment, either reducing or increasing the helical radius. In this mode, it is Young's Modulus of the material that determines the spring characteristics.

Defect on Helical Spring: Raw materials defects, surface imperfections, improper heat treatment, corrosion, surface conditions and decarburisation act as stress raiser and lead to failure of spring usually at the inner surface of an active coil of the helical spring.

Incorrect material Selection: There are various spring materials, and each of them has different characteristics that give it an advantage over others. These characteristics determine if they are more suitable in a particular application than another. Also, a spring material should be selected based on the features that are required in the application. Some of these features include water resistance, strength, corrosion resistance, temperature resistance, amongst others. To that effect, spring problems can be avoided if the right spring material for an application is selected.

Types of Spring Materials:

Titanium, Alloy Steel, Carbon Steel, Cobalt-Nickel, Stainless Steel, Nickel Base Alloy, Copper Base Alloy

Wrong Finoish selection: Spring problems can occur if these springs are susceptible to harsh conditions. However, springs finishes or coatings are used for cosmetic reasons since they prevent rusting. These coatings increase the spring's level of resistance to harsh elements. Much more, some springs are still made of stainless steel, which makes it necessary to use coatings on them – the use of coatings and finishes adds certain characteristics to these springs. Nonetheless, it is more important to consider the application the spring will be put into even before selecting the correct finish.

Spring Overstress due to Improper Design: Overstress in the spring is evident when its force is extended from what it was designed to handle. What causes this in the first place? You may wonder. But its a flaw in design! As a result, more stress or force being applied to the spring than what it can handle can cause it to break down. It's, however, worth noting that spring overstress can be curbed by specific preventative adjustments.

Spring Back due to Design: A stretched spring attempts to return to its original position after it has been released, and this is known as spring back. In a spring's design, its spring back must be taken into consideration in order to determine its proper bending angle. Here, the bends are not be made too close to an edge if not, the material that is on either side might get damaged. When that happens, it could tamper with the spring's integrity.

Wrong end Types: A spring's end type can affect its solid height, pitch, free length, number of active and total coils, and seating characteristics of the spring. That being the case, the end type should be selected after gaining an understanding of the various spring end options and their functions. The correct end type can also be selected after an understanding of the spring application demands.

II. Spring Dimensions

Spring Height :	120 mm
Spring Pitch :	15 mm
Diameter of Spring :	50 mm
Width of Spring :	5 mm
Revolution :	8
Load :	50 N
Spring Height :	120 mm
Spring Pitch :	15 mm

Table 2.1: Diamentions of Spring

III. Structural Analysis

Geometric modeling of Helical Spring: The relationship of the specific strain energy can be expressed as it is well known that springs, are designed to absorb and store energy and then release it slowly. Ability to store and absorb more amount of strain energy ensures the comfortable suspension sy

Fig.3.1.1 Design of Helical Spring in 3D

Fig.3.1.2 Design of Helical Spring with Notch

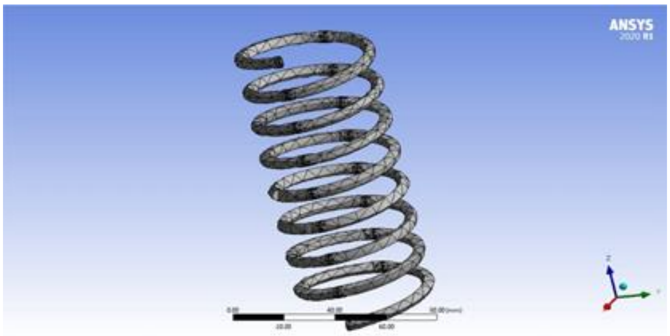


Fig.3.1.3 Mesh model of Helical spring

Notch Dimensions

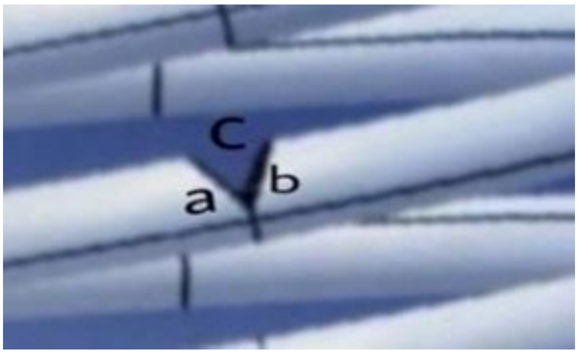
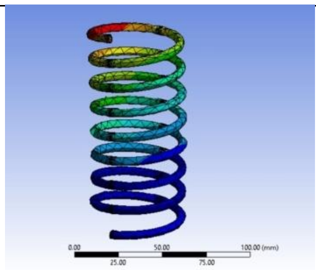


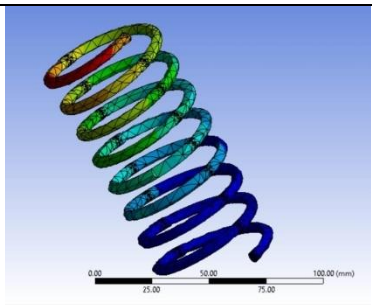
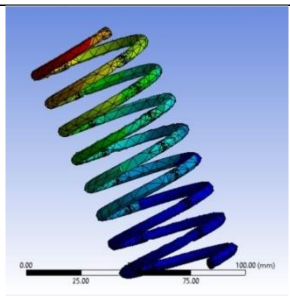
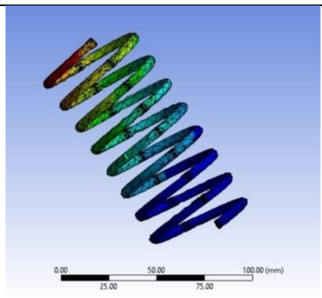
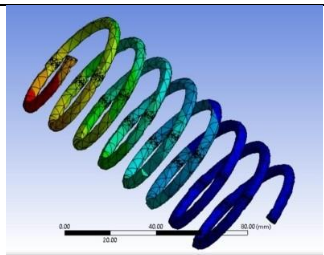
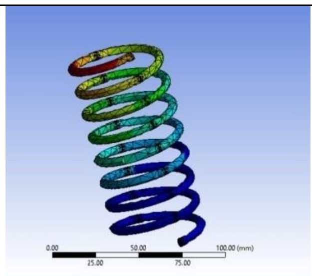
Fig.3.1.4 Notch of Spring

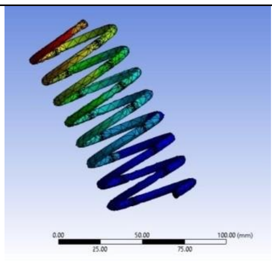
	Sides of Notch in mm		
	a	b	c
Notch 1	2.382	1.976	3.475
Notch 2	2.528	2.179	2.407
Notch 3	2.771	2.699	2.718
Notch 4	3.027	2.955	3.155
Notch 5	2.816	2.081	3.006
Notch 6	2.39	2.487	2.3449
Notch 7	2.029	1.928	2.249

Structural Analysis of Helical Spring:

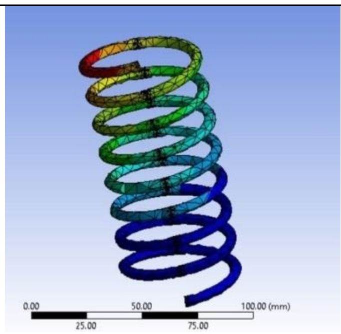
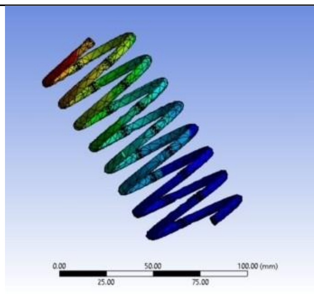
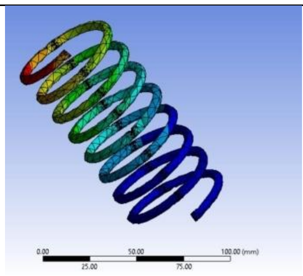
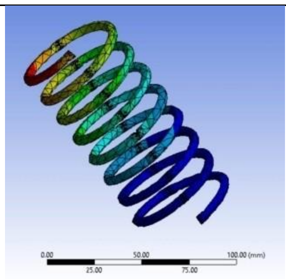
Structural Analysis of Aluminium Alloy Spring:

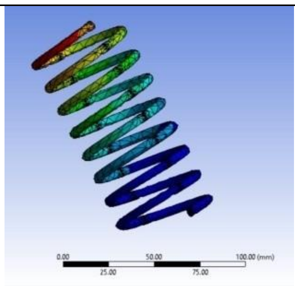
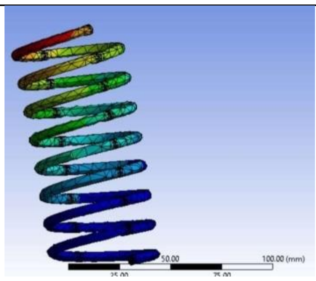
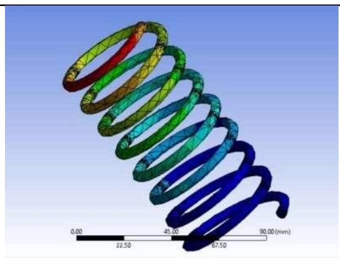
Aluminium alloy Springwith Notch (1st layer) x,y = (0,106.568)		Maximum Deformationd = 496.08mm

Aluminium Alloy Spring with Notch (2nd layer) x,y = (0,91.303)		Maximum Deformationd = 492.42mm
Aluminium Alloy Springwith Notch (3rd layer) x,y = (0,75.773)		Maximum Deformationd = 497.42mm
Aluminium Alloy Springwith Notch (4th layer) x,y = (0,60.518)		Maximum Deformationd = 499.39mm
Aluminium Alloy Springwith Notch (5th layer) x,y = (0,45.923)		Maximum Deformationd = 474.44mm
Aluminium Alloy Springwith Notch (6th layer) x,y = (0,30.977)		Maximum Deformationd = 490.43mm

Aluminium Alloy Springwith Notch (7th layer) x,y = (0,16.253)		Maximum Deformationd = 494.73mm

Structural Analysis of Copper Alloy Spring:

Copper alloy Spring with Notch (1st layer) x,y = (0,106.568)		Maximum Deformation d = 321.61mm
Copper Alloy Spring with Notch (2nd layer) x,y = (0,91.303)		Maximum Deformation d = 319.24mm
Copper Alloy Spring with Notch (3rd layer) x,y = (0,75.773)		Maximum Deformation d = 322.47mm
Copper Alloy Spring with Notch (4th layer) x,y = (0,60.518)		Maximum Deformation d = 328.74mm

Copper Alloy Spring with Notch (5th layer) x,y = (0,45.923)		Maximum Deformation d = 307.58mm
Copper Alloy Spring with Notch (6th layer) x,y = (0,30.977)		Maximum Deformationd = 317.19mm
Copper Alloy Spring with Notch (7th layer) x,y = (0,16.253)		Maximum Deformationd = 320.72mm

IV. RESULT DISCUSSION

Aluminium Alloy Spring: In analysis of structural steel we saw that the layer 4 with notch location xy (0,60.518) has the maximum the deformation value 499.39 mm among all the layer. The layer 5 with notch location xy (0,45.923) shows the minimum deformation 474.44 mm among all the layer. The other layer's i.e. layer 2 with notch location xy (0,91.303), layer 3 with notch location xy (0,75.773) , layer 1 with notch location xy(0,106.568), layer 6 with notch location xy(0,30.977) and layer 7 with notch location xy (0,16.253) shows the average deformation of aluminium alloy.

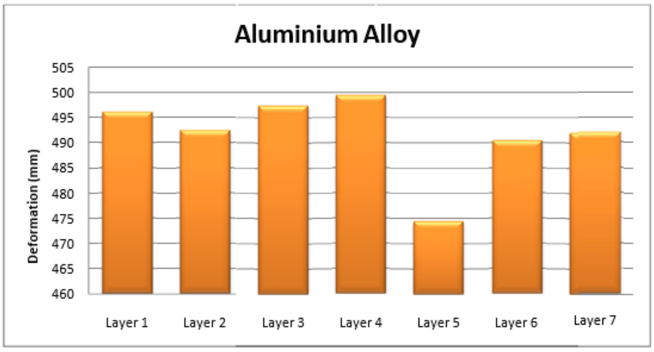


Fig.4.1.1 Maximum Deformation at Notch location (AL alloy)

4.2 Copper Alloy spring: In analysis of structural steel we saw that the layer 4 with notch location xy (0,60.518) has the maximum the deformation value 328.74 mm among all the layer. The layer 5 with notch location xy (0,45.923) shows the minimum deformation 307.58 mm among all the layer. The other layer's i.e. layer 2 with notchsteelocation xy (0,91.303), layer 3 with notch location xy (0,75.773) , layer 1 with notch location xy(0,106.568), layer 6 with notch location xy(0,30.977) and layer 7 with notch location xy (0,16.253) shows the average deformation of copper alloy.

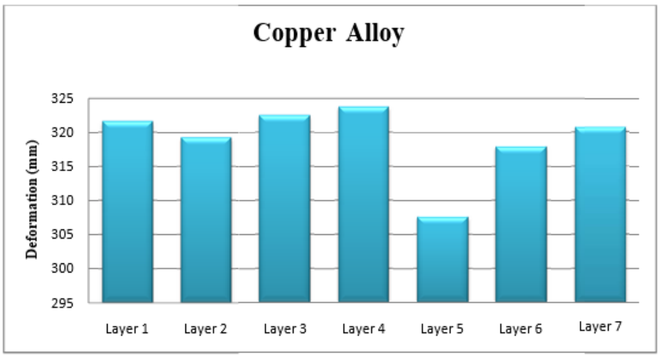


Fig.4.1.2 Maximum Deformation at Notch location (cu alloy)

V. CONCLUSION

In aluminium alloy the maximum deformation value is 499.39 mm in the layer 4. In copper alloy the maximum deformation value is 328.74 mm in the layer 4. Over all we saw that in the layer 4 of aluminum alloy has the maximum deformation value as compare to all the 3 type of material we used. Also aluminum and copper shows the same behavior.

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