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Studying the Effect of Electroless Nickel Coating on Helical Compression Springs by Finite Element Analysis

Arka Roychoudhury [1]
[1]UG Student, Mechanical Engineering,
KIIT University, Bhubaneswar, India

Ayan Banerjee [2], Saurav Dutt [3], Sibasish Sinha [4]
[2,3,4] UG Student, Mechanical Engineering,
KIIT University, Bhubaneswar, India.

Abstract **– Suspension systems serve to keep the car wheels in contact with the road, while also providing comfort for the driver and passengers. An important part of some suspension systems are helical springs that compress and elongate to support the vehicles movement. Like any other part of the car wear and tear is common in springs as well and it reduces service life and often causes spring failure. This paper studies the effect of providing an electroless nickel coating on helical springs by comparison of coated and uncoated springs through CAD modelling and static stress analysis using FEA. The results show reduction in overall stress values for coated spring.**

Keywords- Helical Springs, Suspension system, Coating, Finite Element Analysis, CAD modelling.

I. INTRODUCTION

Helical compression springs are widely used in auto industry as one of the principal member of the suspension systems. They connect the wheel to the body elastically and store the energy to absorb and smooth out shocks that are received by the wheel from road irregularities and transmitted to the body**.** Such a condition causes the fatigue failure of the suspension spring in a number of ways. Corrosion, surface irregularities, defects in war materials, improper heat treatment and decarburization an are generally recognized as main causes of fatigue failure of suspension spring. In service, the stress on the inner surface of an active coil of the helical spring is the position of maximum stress and the coil surface itself is vulnerable to imperfections in materials and surface integrity that serve as stress concentration points bringing about fatigue crack initiation. [1, 2]

Mechanical properties of the suspension spring alongside the geometric configurations like the wire diameter, number of turns, solid and free length, pitch etc. affect spring performance. Simulations employing Finite element approach might offer insight into the nature of the certain response parameters like magnitude and concentration of stresses, deflection etc. responsible for the spring performance.[3]

N.K.Mukhopadhyay, Ravi Kumar and D.K Bhattacharya (2006), investigated on the premature failure of suspension coil spring of a passenger car that failed during the service within few months and provided the reasons for the failure. This investigation included micro structural analysis, SEM analysis, hardness testing, and chemical analysis. The results showed deficient processing along with inherent defects led to the failure of the spring.[4]

Mehdi and Majid Bakhshesh(2012) worked on design of 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. This spring has been replaced by three different composite helical springs which are made of Eglass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy. The optimum design based on the parameters of weight, maximum stress and deflection have been compared with steel helical springs. It has been shown that spring optimization by material changing causes reduction in maximum stress considerably.[5]

N.Lavanya, Sampath Rao and Pramod Reddy (2014) worked on the design and analysis of helical springs for automotive vehicles made of low carbon Structural Steel and Chromium vanadium steel and concluded that Structural Steel is more suited in making Helical Compression Springs than Chromium vanadium steel.[6]

Electroless nickel plating has several advantages over electroplating. Free from flux-density and power supply issues, it provides an even deposit regardless of workpiece geometry. It can deposit on non-conductive surfaces as well, provided with the proper pre-plate catalyst.

Electroless nickel deposits have very uniform thickness and very low porosity. Porosity decreases with increase in thickness and any tendency towards the formation of porous coatings is greatly reduced in deposits containing over 10% phosphorus. The amorphous nature of the high phosphorus deposits is beneficial in corrosive environments for mainly two reasons. Firstly, unlike polycrystalline materials, amorphous alloys have no grain boundaries at which corrosion sites can be initiated. Secondly, they form passive, glassy surface films, which provide added protection. Electroless Nickel coatings are also cost efficient.[7]

For many years now, automotive companies have been focussing on performance, quality, efficiency and extended warranties. Consequently electroless nickel properties such as corrosion resistance, wear resistance, lubricity and uniform deposit thickness have been used to great advantage in this industry. The performance of steel and aluminium components has been enhanced by the use of electroless nickel and typical applications are on heat sinks, pistons, engine bearings, hose couplings, gear assemblies, carburettor parts, fuel injectors, shock absorbers and exhaust system components. Automotive companies have recognized the benefits of electroless nickel in all these and other applications and have their own specifications for its use.[8]

Although the hardness, wear resistance and lubricity of electroless nickel are inherently good, these properties can also be enhanced by the co-deposition of particulate matter with the nickel. Generally these particles are made of ceramic materials. For instance, silicon carbide particles are reported to increase hardness and silicon nitride or boron nitride to improve self-lubricating properties. These results have been used successfully in improving engine performance by electrodeposition of nickel phosphorus/silicon carbide composites on pistons and cylinder bores but electroless nickel/silicon carbide deposits have not produced similar results. Other very important composites have been used successfully in many applications involving various types of wear are electroless nickel with Polytetrafluoroethylene (PTFE) or fluorinated carbon (CFX). Both provide an excellent non-stick, low friction, dry lubricant surface with the latter having the advantage of superior temperature resistance. These composites have been used on carburettor and clutch parts, engine valves, bearings and gears. [9]

Project Objective

The main aim of this study is to study the effect of Electroless Nickel coating on helical compression springs. We will be analysing the suspension spring for passenger car using Finite Element Analysis for both coated spring and uncoated springs. Results will be verified by referring to other journals on the strength of helical springs. Finally a comparison will made to reach conclusion.

For analysing the helical spring we are using Finite Element approach. FEM approach allows us to generate a simulation of any design concept and determine is behaviour in any real world environment imaginable. It saves the cost and time of carrying out experiments with prototype and is used as the first step to determine the feasibility of any design. FEA is widely used nowadays and there are a multitude of companies that have created some well-known FEA software.

II. METHODOLOGY

For this particular project we have considered a constant pitch helical compression spring. The spring material is taken as AISI 1055 Carbon Steel while the coating considered Electroless Nickel Coating (having 10%-12% of Phosphorus). High percentage of Phosphorus in Electroless Nickel offers superior corrosion resistance. Most springs are made of hardened carbon steels and chromo vanadium steels. Electroless Nickel coating can be easily achieved over complex geometry giving a uniform deposition. It can be applied over a variety of substrates including stainless steel, aluminium, copper, brass and many proprietary alloys.

2.1 Specifications of helical spring and Material data

Specifications of Spring:

Table:1

PARAMETERS	VALUES	UNITS
Outer Diameter, D_o	111.87	mm
Inner Diameter, D_I	100.13	mm
Mean coil diameter, D	106	mm
Wire diameter, d	11.75	mm
Pitch, p	18.95	mm
No. of Active coils, N	9	
Total no. of coils, N_t	10	
Free Length, $L_O = p \times N_t$	189.5	mm
Solid Length, $L_s = d \times N$	105.75	mm
Spring Index, C=D/d	9.213	

Material Property:

AISI 1055 Carbon Steel:

Table 2

PARAMETERS	VALUES	UNITS
Density	7.85	g/cm^3
Young's Modulus	200	GPa
Poisson's Ratio	0.28	
Ultimate Yield Strength	660	MPa
Tensile Yield Strength	550	MPa

Electroless Nickel Coating (8-10% phosphorus):

Table 3

PARAMETERS	VALUES	UNITS
Density	7.9	g/cm^3
Young's Modulus	65	GPa
Poisson's Ratio	.31	
Tensile Yield Strength	800	MPa

2.2 Modelling of Helical Coil Spring

The coil spring is designed using SolidWorks as per the above specifications and all analysis is done using ANSYS 14.0 software. The modelling is done by first creating a circle that serves as the mean diameter in any plane that is then modelled into a helix by providing the no of turns and pitch. Then a circle of wire diameter is drawn on a normal plane and Sweep function is used to give the spring its structure. Solid model of our designed helical spring is shown in Fig1.

Fig1 : Uncoated Spring Model

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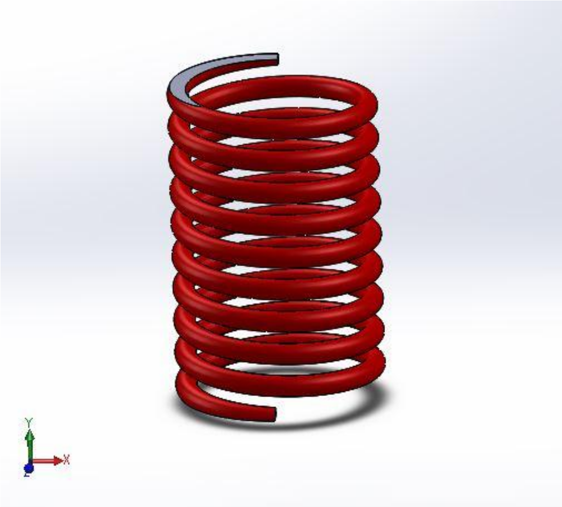

Fig2: Coated Spring Model

2.3 Analysis of Modelled Helical Coil Spring Meshing

The model that was created in SolidWorks is then imported to ANSYS for analysis. ANSYS breaks the model down into polygonal or polyhedral mesh that approximates some geometric domain. Meshing is used to subdivide the model to make it solvable using Finite Element approach. Accuracy is dependent on mesh size. However smaller mesh sizes have longer computation time. In our project we have used a mesh size of 5mm.

MESH DETAILS:

Table 4

DETAILS	UNCOATED	COATED
MESH SIZE	5mm	5mm
NO. OF NODES	24755	73787
NO. OF ELEMENTS	11385	44698
TRANSITION RATIO	0.272	0.272
MIN EDGE LENGTH	8.03290 mm	8.03290 mm
GROWTH RATE	1.2	1.2

Fig 3: Mesh Model

Load Definition

For Calculation of forces for the spring

We are considering a simple passenger car suspension for our research. The spring is part of the rear wheel suspension of considered vehicle. Specifications are as follows-

- Kerb Weight (W_k): 800kgs.
- Seating Capacity: 4
- Passenger Weight (W_P): 70kg each.
- Luggage Weight (W_L): 20kg.
- Weight Distribution Ratio: 49:51

Gross Weight (W_g) = $W_k + W_P \times 4 + W_L$

=800 + 280 + 20 = 1100kg.

As weight distribution ratio is taken as 49:51 the mass per wheel on the rear end-

(W_R)= (0.51*1100)÷2= 280.5kg

Therefore Load per wheel (Static Loading)-

$P_s = W_R \times g$

= 288.15*9.81=2751.70N

Generally it is seen that loads in dynamic loading condition do not exceed 2 times the load in static condition. So, Dynamic Load = 2751.7×2= 5503.4N.

Static Analysis of Coated and Uncoated Spring

Static analysis is carried out by first assigning the material properties to our solid model and then defining the boundary conditions and loads. The displacements in x- direction, y-direction, z-direction and displacement vector sum values for stress and strain are shown. This analysis also shows Von misses stress, Von misses strain and stress intensity.

III. RESULTS & DISCUSSION

The static analysis of the springs is completed in ANSYS and the results are collected for analysis. The maximum and minimum values of deformation, equivalent stress and elastic strain obtained are shown in Table: 5.

RESULTS	UNCOATED	ELECTROLESS NI COATED
Max Deformation(mm)	52.469	33.072
Min Deformation(mm)	0	0
Max Equivalent Stress(MPa)	328.27	267.19
Min Equivalent Stress(MPa)	$1.8235e^{-5}$	9.4159e-5
Max Elastic Strain	0.0016626	0.0030456
Min Elastic Strain	9.1175e-11	7.1558e-10

We see a significant difference in the values obtained for Uncoated and Coated spring. We see a deflection in a particular direction in both the springs. This is because the load applied was not uniform across the entire coil but is applied on the flat region of an inactive coil. In actual conditions however the spring is kept between two platforms or mounts that ensure uniform load distribution over the entire upper inactive coil.

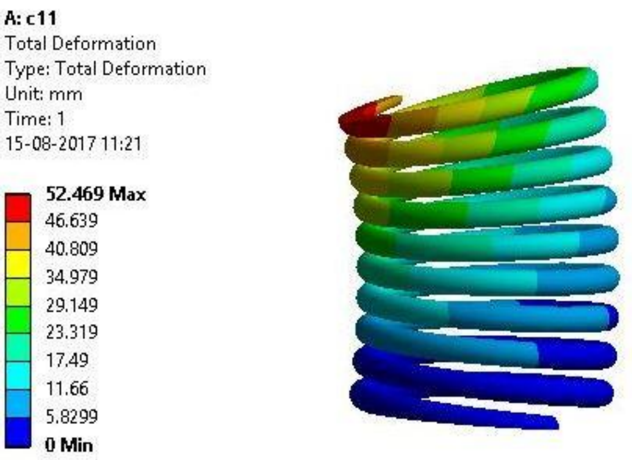

Fig:4 Deformation(Uncoated spring)

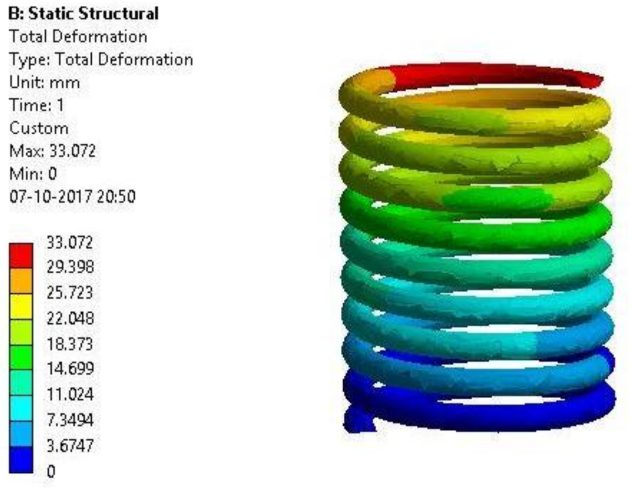

Fig:4 Deformation(Coated spring)

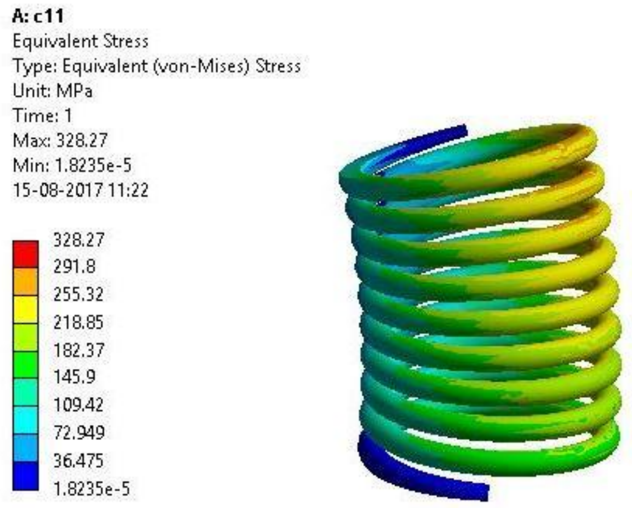

Fig6: Eq Stress(Uncoated spring)

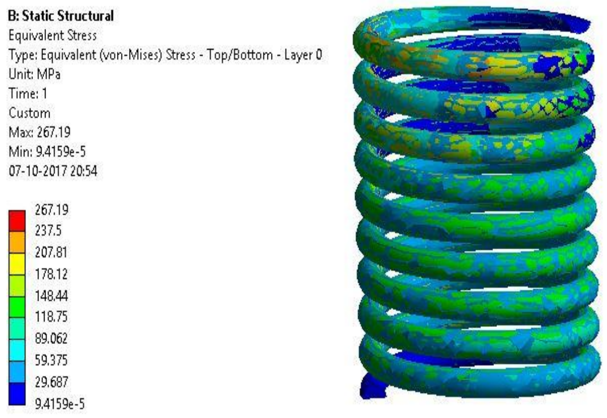

Fig7: Eq Stress(Coated spring)

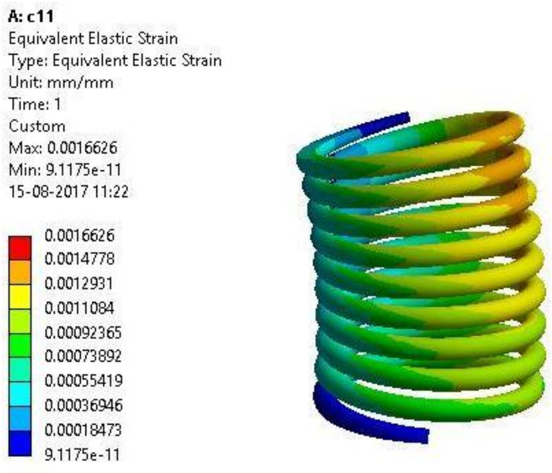

Fig8:Eq Strain(Uncoated spring)

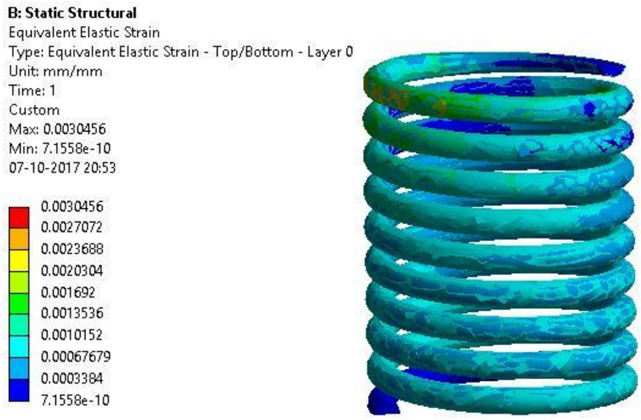

Fig7: Eq Stress(Coated spring)

The values of deformation and equivalent stress are much less in coated spring than in the uncoated spring. We also see that the stress concentration in the coated spring is also much less than in uncoated spring. Cyclic springs are flexed repeatedly and are expected to exhibit a higher failure rate due to fatigue. Decrease in the stress concentration and stress intensity will improve the spring's service life. Another principle reason of spring failure is corrosion. Electroless Nickel coating provides excellent protection against corrosion and rust.

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IV. CONCLUSION

The effects and advantages of using electroless Nickel Plating on helical compression springs have been discussed in this paper. The work shows the stress and strain responses of the spring under static loading. The advantages of using electroless Nickel coating was clearly visible as lower values stress and strain was developed in the coated spring. The stress concentration was also lower in the base material due to effect of the coating. Higher service life is obtained from coated springs for this reason. The differences in values of axial deflection theoretically and by software is significant because we see that in out ANSYS model deflection is more towards one side owing to constraints in uniform axial loading. If loading is done perfectly then the error is in the region of 3-5%.

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