Investigation on Reduction in Premature Failure of Locomotive Coil Springs

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Abstract **: The suspension system used in locomotives is to observe the shocks and stores the mechanical energy. It is made up of elastic materials such that it can twist, pulled or stretched by the application of force and regain its original shape when the force is released due to this the stress are produced along the length of the locomotive coil spring. On account of this stresses locomotives coil springs have been undergone the failure prematurely before its service life. The present work is investigation on to reduce the premature failure and improve the service life of helical compression spring. The life of spring is improved by optimum design and analysis by variation of wire diameter. Results indicate the von miss stresses are decreased for increased values of wire diameter of coil spring. Due to this, deflection of spring is reduced and spring rate is increased hence reduction of the premature failure of locomotive coil spring is attained.**

Keywords: locomotives, chromium vanadium steel, helical compression spring, modeling with design parameters, and analysis in ANSYS.

1. INTRODUCTION

Springs are used as mechanical equipment with moving parts, to absorb loads, which may be continuously, or abrupt varying. The springs are used in wide applications like automobile locomotives railway coaches, aircrafts with primary function of absorption of the loads in the form of elastic energy. The springs are made from the different steel materials and the heat treatment given to posses the inherent damping capacity. The spring fails in service due to faulty design and manufacturing defects. Coil springs are manufactured from rods which are coiled in the form of a helix. The design parameters of a coil spring are the rod diameter, spring diameter and the number of coil turns per unit length. Normally, springs fail due to high cycle fatigue in which the applied stress remains below the yield strength level and the loading cycle is more than 10^5 cycles/sec. The causes of failures are mainly related to deficient microstructure and/or presence of stress concentration raisers. M.Sudhakar Reddy[1] et al. study the dynamic behavior of the springs, 3D solid model of helical springs are modeled with PRO/E. Static and Dynamic stress analysis are carried out using ANSYS to understand the Structural and Dynamic response of the springs. Spring behavior will be observed under prescribed or expected loads. Based on the results design modifications will be suggested for better life without failure in service.

Manish Dakhore[2] et al. discussed about locomotive suspension coil springs, their fundamental stress distribution, materials characteristic, manufacturing and common failures. Investigation on the premature failure of suspension coil spring of a locomotive, which failed within few months after being put into service, has been carried out analytically and using FEA software. Kotaro watanabe[3] et al. investigated a new type rectangular wire helical spring is used in suspension springs for rally cars and the stress was checked by FEM analysis theory on the twisting part. The spring characteristic of the suspension helper spring in a body is clarified. Manufacturing equipment for this spring is proposed. Chang-Hsuan Chiu[4] et al. which present, four different types of helical cmposite springs were made of structures including unidirectional laminates (AU), rubber core unidirectional laminates (UR), unidirectional laminates with a braided outer layer (BU), and rubber core unidirectional laminates with a braided outer layer (BUR), respectively. It aims to investigate the effects of rubber core and braided outer layer on the mechanical properties of the helical springs. According to the experimental results, the helical composite spring with a rubber core can increase its failure load in compression. Therefore, based on this work the shock absorbers with high performance might be expected to come soon. Mehdi Bakhshesh[6] et al. discussed the helical spring 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.

Investigation on the premature failure of suspension coil spring of a locomotive which is failed before the service period to improve the service life varying pitch coli spring preferred previously ,but also with constant pitch helical spring the service life of helical coil spring is improved by increasing the wire diameter of coil spring in this the present work . The solid spring model is done by using

Pro/E Wildfire 5.0 software. This work describes static analysis, modal analysis, harmonic analysis of the locomotive suspension system is performed by using ANSYS, the behavior of helical spring will be observed under the prescribed loads due to which the stress is distributed along the spring at various nodes based on this summary of analysis results further design recommendations are done to reduce the premature failure of helical compression spring

2. METHODOLOGY

2.1 Spring Specifications and Material data

Wire Diameter =33.5mm,

Outer Diameter=242mm,

Inner Diameter =175mm,

No. of coils = 6.75,

Free Height = 360mm,

Pitch=53.33mm

Materials**:** Chromium Vanadium Steel - 52Cr4Mo2V

Properties**:**

Young's Modulus = 2.068E+11 Pa,

Density = 7833.4 kg/m^3,

Stress Concentration factor =k = 1.264, Deflection under 1000 kg =y = 21.22 mm,

Shear Stress = 832kg/cm^2,

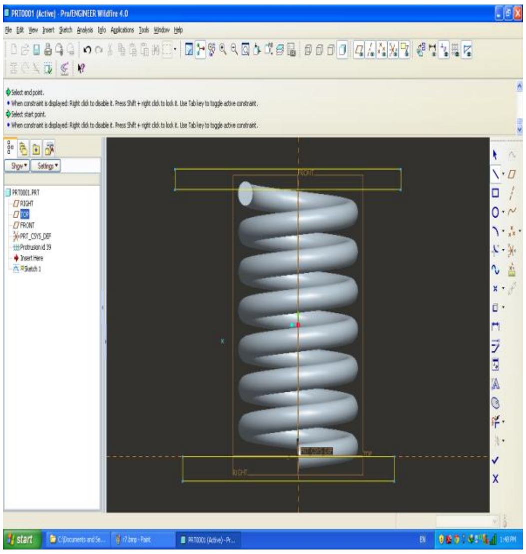
Home stress = 7465 kg/cm^2,

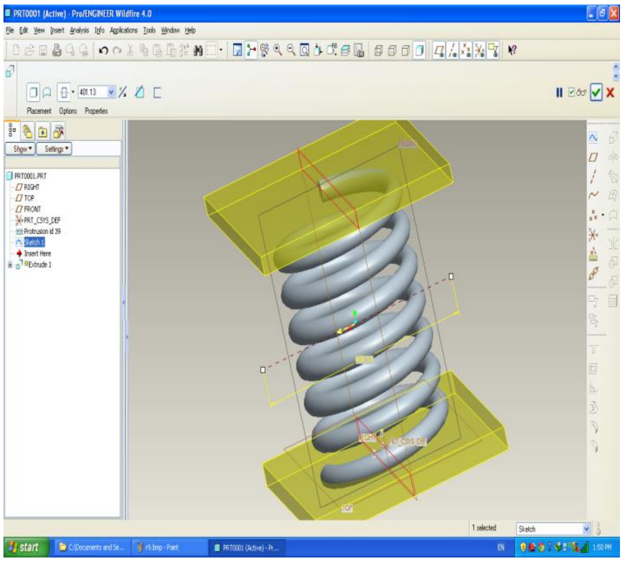
Modulus of rigidity G = 8155 kg/mm2

Load**:** 2 MT (metric ton)/19.62 KN is applied on top of the spring

2.2 Modeling of helical spring

This work involved creating a solid model of the helical spring using Pro/ENGINEER software with the given specifications and analyzing the same model using ANSYS software. Here the spring behavior will be observed under prescribed loads with variation of wire diameter to find Von miss stresses. Based on this analysis, design recommendations will be made to improve its service life. The steps involved in creating a model of the spring. A model of the spring will be first created design using Pro/Engineer software. For modeling of helical spring different steps are followed and begin by drawing a line of 360 mm length. This is the free height of the spring. The line is at a distance of 122 mm from the vertical axis. Next enter the pitch of the spring. The pitch is calculated as free height of the spring divided by the number of turns. In this case, it is 360/6.75 = 53.33mm, create the circle of wire diameter 33.5mm of spring and generate spring. The solid model of coil spring end steps as shown in fig.1





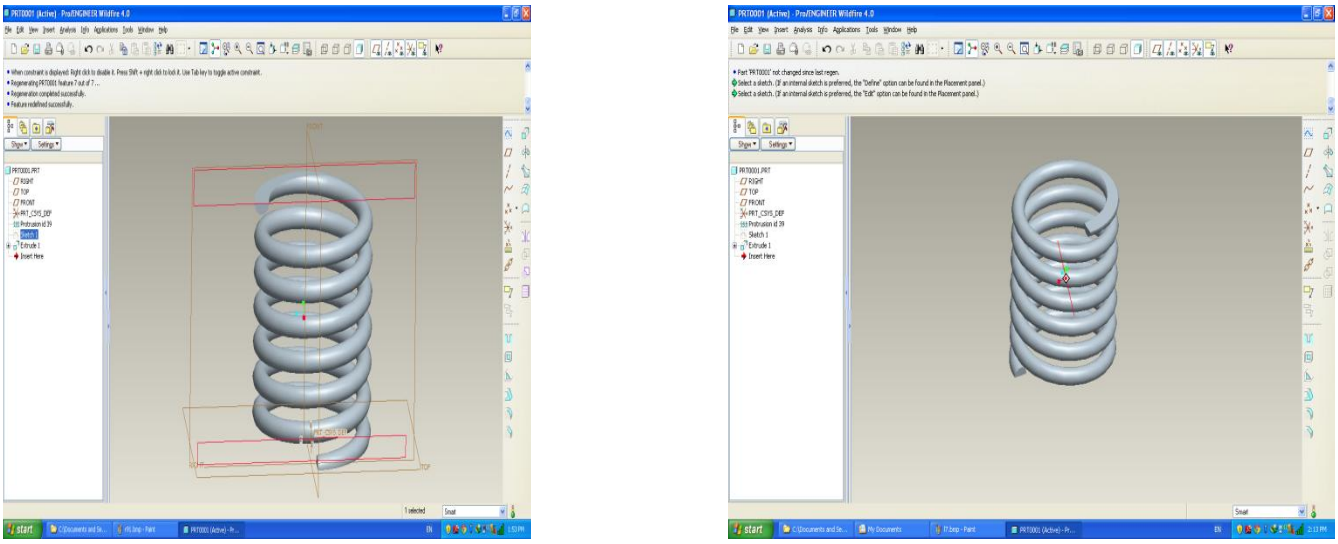


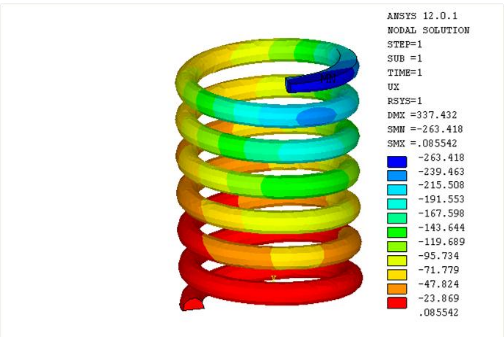
Fig.1: Solid model of helical spring

2.3 Analysis of modeled helical coil spring product

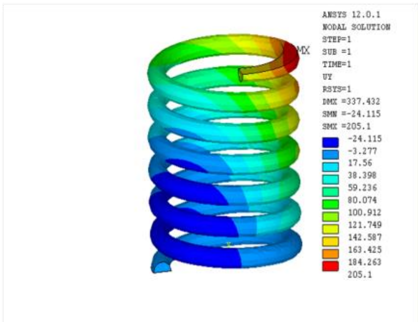
A model of the helical spring was created using Pro/Engineer software. Then the model will be imported to analysis using FEA in this connection ANSYS software is used. ANSYS to complete static and dynamic structural analysis. The structural analysis are different types but this work includes static and harmonic analysis at variation of spring wire diameter and estimated displacement and Von misses stresses for open end helical spring.

2.3.1 Static Analysis of the Open End Spring:

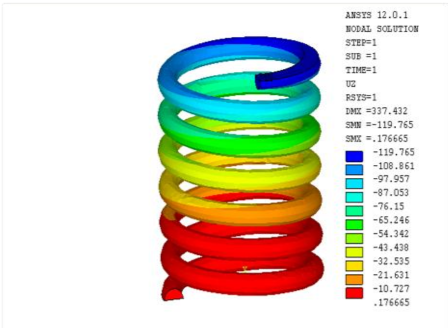
The Static Analysis is carried out for given Loading and Boundary Conditions, the results are shown below. The displacement in X direction, Z direction and resultant displacement as shown in fig.2.This analysis also shows Von misses stress 1284MPa which is more than Yield strength of the material as shown in fig.3.



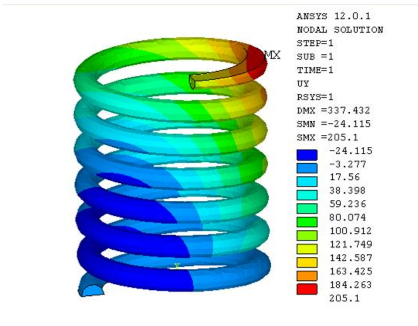
Displacement in X-direction



Displacement in Y-direction



Displacement in X-direction



Displacement in Y-direction

Fig.2: Displacement of open end coil spring under given load conditions

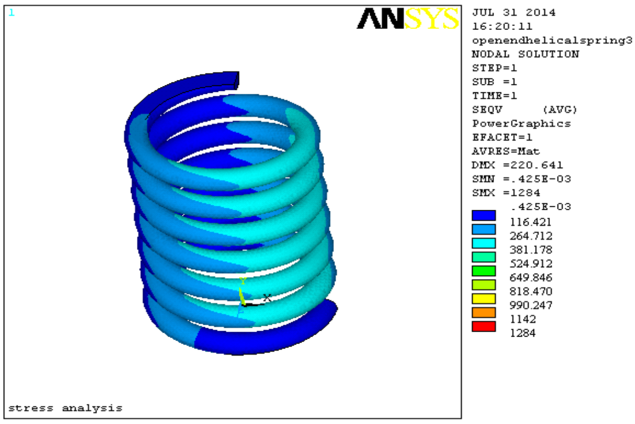
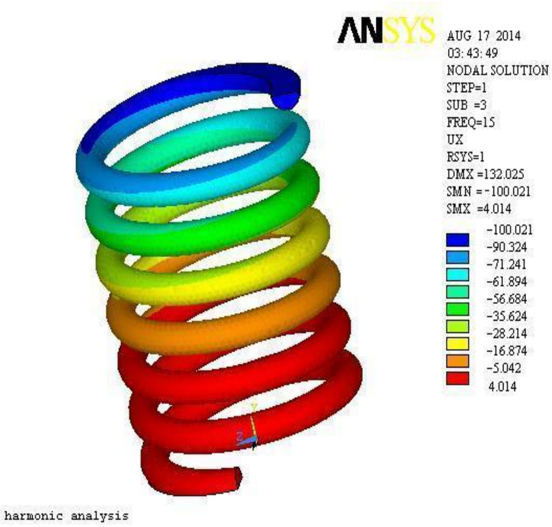


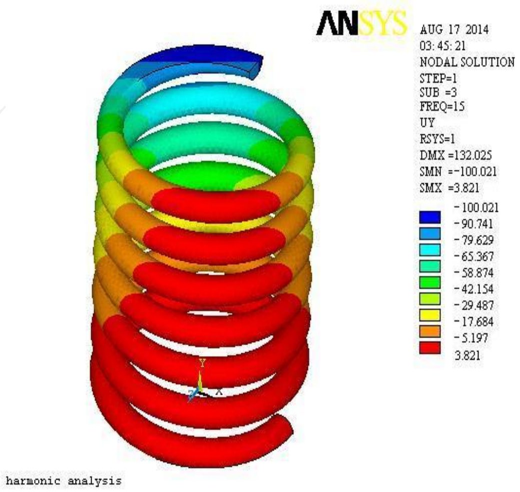
Fig.3: Von misses Stress of the Open End Spring

2.3.2 Harmonic Analysis of the Open End Spring:

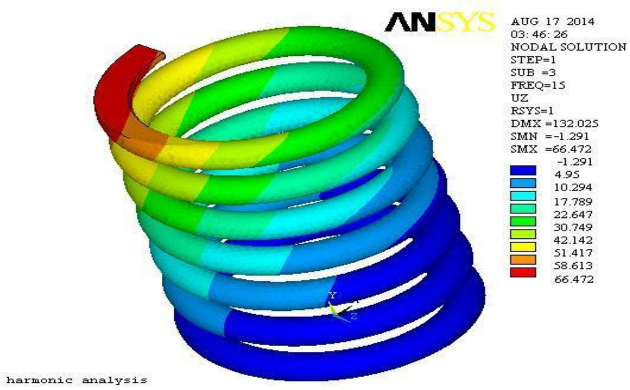
The Harmonic Analysis is carried to study dynamic behavior of the spring for the given operating Conditions 0 to 60 Hz. If the spring natural frequency is matches with the operating condition than it amplitudes shoots up and it will be under resonating conditions. The Von misses stresses are presented at spring diameters of 34mm,35mm,and 36mm for example at 34mm analysis is as shown in fig.4



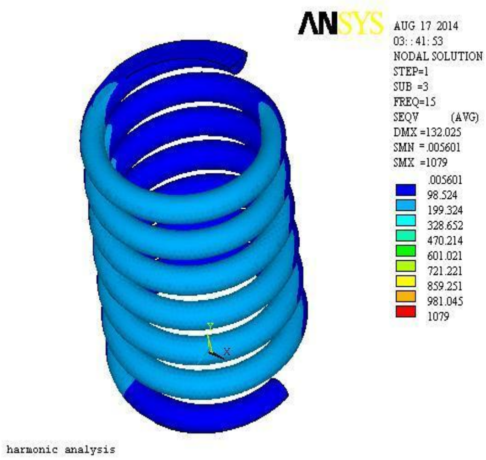
Displacement in X-direction



Displacement in Y-direction



Displacement in Z-direction



Von misses stress

Fig.4: Harmonic Analysis- Displacement and Von misses stresses

3. RESULTS AND DISCUSSION

The analysis of open end spring is simulated by using ANSYS. This analysis includes static analysis, modal analysis and harmonic analysis in terms of displacements, Von mises stresses and frequencies with varying wire diameter. These results are presented in the following tables

TABLE.1: DISPLACEMENTS OF OPEN END HELICAL SPRING WITH VARYING WIRE DIAMETER

Diameter in mm	Static analysis				Harmonic analysis			
	X Displacement (mm)	Y Displacement (mm)	Z Displacement (mm)	Displacement vector sum(mm)	X Displacement (mm)	Y Displacement (mm)	Z Displacement (mm)	Displacement vector sum(mm)
34mm	1.136	0.13889	0.19011	281.778	4.014	3.821	66.472	132.025
35mm	1.054	0.12301	0.16971	248.921	3.771	3.326	62.624	129.321
36mm	0.9792	0.10773	0.15120	220.641	3.041	2.987	60.014	123.478

Table.2 : Von mises stress and deflections of open end helical spring with varying wire diameter

Diameter (mm)	Static analysis	Harmonic analysis	Deflections are calculated mathematically
34mm	1326	1079	124.75
35mm	1304	1052	118
36mm	1284	1025	111.25

Table.3: Open end helical spring modal analysis frequencies

Frequencies of 34 mm wire diameter

SET,LIST Command
File

***** INDEX OF DATA SETS ON RESULTS FILE *****

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	11.283	1	1	1
2	12.516	1	2	2
3	13.845	1	3	3
4	15.298	1	4	4
5	16.639	1	5	5
6	18.301	1	6	6
7	19.647	1	7	7
8	21.510	1	8	8
9	22.858	1	9	9
10	24.915	1	10	10

Frequencies of 35 mm wire diameter

SET,LIST Command
File

***** INDEX OF DATA SETS ON RESULTS FILE *****

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	11.389	1	1	1
2	11.926	1	2	2
3	13.924	1	3	3
4	14.507	1	4	4
5	16.673	1	5	5
6	17.309	1	6	6
7	19.619	1	7	7
8	20.314	1	8	8
9	22.751	1	9	9
10	23.513	1	10	10

Frequencies of 36 mm wire diameter

SET,LIST Command

File

***** INDEX OF DATA SETS ON RESULTS FILE *****

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	10.656	1	1	1
2	12.055	1	2	2
3	13.358	1	3	3
4	14.778	1	4	4
5	16.310	1	5	5
6	17.745	1	6	6
7	19.494	1	7	7
8	20.936	1	8	8
9	22.894	1	9	9
10	24.339	1	10	10

The springs are failure due to high cycle fatigue in which the applied stress remains below the yield strength and the loading cycle is more than 10^5 cycles/sec. The present work is on the investigation of reduction in premature failure of coil spring, in this connection open end spring is modeled and analysis with a varying wire diameter. The modeling of open end helical coil spring as shown in fig.1 The model is imported to analysis software and carried out the simulation in ANSYS with a expected loads hence the static and dynamic behavior of the spring is observed for increased wire diameter and the displacements of a open end coil spring are presented in table.1,vonmises stress are shown in table.2 and modal analysis frequencies are shown in table.3 The results shows that the Vonmises stress and deflection of spring is reduced to a greater extent with varying the wire diameter of spring.

4. CONCLUSION

The present work is investigation on Reduction in Premature Failure of Locomotive Coil Springs subjected to static and dynamic loading conditions. The works shows the dynamic behavior and solid model of helical spring with Pro/E. Static and dynamic stress analysis are carried out using ANSYS to understand the Structural and Dynamic response of the springs. Spring behavior will be observed under prescribed or expected loads. Based on the results design modifications will be suggested for better life without failure in service. The following points are observed.

i. The displacement of spring for static analysis at 34 mm wire diameter is 281.778 mm, at 35 mm wire diameter is 248.921mm and at 36mm wire diameter is 220.641mm and for harmonic analysis at 34 mm wire diameter is 132.025 mm, at 35 mm wire diameter is 129.321mm and at 36mm wire diameter is 123.478 mm under same loading conditions. This predicts the increase in service life of the spring.

ii. The deflections calculated numerically of spring at 34 mm wire diameter is 124.75 mm, at 35mm wire diameter is 118 mm and at 36mm wire diameter is 111.25mm under same loading conditions. This predicts the increase in stiffness which intern improves the service life of the spring.

iii. The vonmises stress of spring for static analysis at 34 mm wire diameter is 1327 MPa, at 35 mm wire diameter is 1304MPa and at 36 mm wire diameter is 1284 MPa and for harmonic analysis at 34 mm wire diameter is 1079 MPa, at 35 mm wire diameter is 1052 MPa and at 36 mm wire diameter is 1025 MPa under same loading conditions. This predict the increase in service life of the spring.

iv. The frequencies of spring at 34 mm wire diameter is 11Hz,at 35 mm wire diameter is 11Hz and at 36 mm wire diameter is 10Hz under same loading conditions, if it won't fall near to the operating frequency hence spring will be safe under dynamic Conditions.

Finally conclude that spring strength effected by varying diameter of spring coil and at maximum diameter spring expected to loss the elastic property and unsuitable for the service.

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