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FAILURE ANALYSIS OF CYLINDER HEAD VALVE SPRING IN LOCOMOTIVES

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ABSTRACT - *The main objective of the project is Analyzing the failure of spring in the cylinder head valve spring in the locomotive. 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 ANSYS software. Statistical process control chart was used as the main tool in the analysis. Failure of the composite spring assembly was analyzed by applying the forces obtained from dynamic analysis. The dynamic analysis was performed using rail at four different velocities and three different track conditions.*

Key words: Quality assessment, process capability, helical coil locomotive cylinder head value springs.

1. INTRODUCTION

Coil springs are used on the front suspension of most modern light vehicles. Then the spring act as an elastic object used to store mechanical energy. They can twist, pulled (or) stretched by some force and can return to their original shape when the force is released. A coil spring is made from a single length of special wire, which is heated and wound on a former, to produce the required shape. The load carrying ability of the spring depends on the diameter of the wire, the overall diameter of the spring, its shape, and the spacing of the coils. Normally, helical spring failures occur due to high cycle fatigue in which the induced stress should remain below the yield strength level and also with poor material properties. Tensile stress at the surface promotes fatigue failure, and compressive stress, improve the fatigue behavior. The effect of adverse residual stresses on the surface can be reduced either by proper stress relief treatment or by giving a shot peening operation, which imparts compressive stress on the surface.

2. LITERATURE REVIEW

A spring is an elastic object used to store mechanical energy. They can twist, pulled or stretched by some force and can return to their original shape when the force is released. Static analysis determines the safe stress and corresponding pay load of the helical compression spring [1]. Springs that can reserve high level of potential energy, have an undeniable role in industries. Helical spring is the most common element that has been used in car suspension system [2]. Its spread, from the manufacturing to the service sector and on to public services. What is TQM? In simple terms, it is the mutual cooperation of everyone in an organization and associated business processes to produce value-for-money products and services which meet and, hopefully, exceed the needs and expectations of customers [3]. The analysis of life quality assessment of helical coil springs. The types of springs considered are: outer spring, inner spring and stabilizers spring. Statistical process control chart was used as the main tool in the analysis [4]. Total Quality Management (TQM) is to evolve organizations' traditional Quality Control to Quality Management, which is far more than shifting the responsibility of detection of problems from the customer to the manufacturer. TQM is an approach to improving the competitiveness, strength and flexibility of a whole organization [5].

The cause-and-effect diagram for the helix and stabilizer spring deflection dysfunction

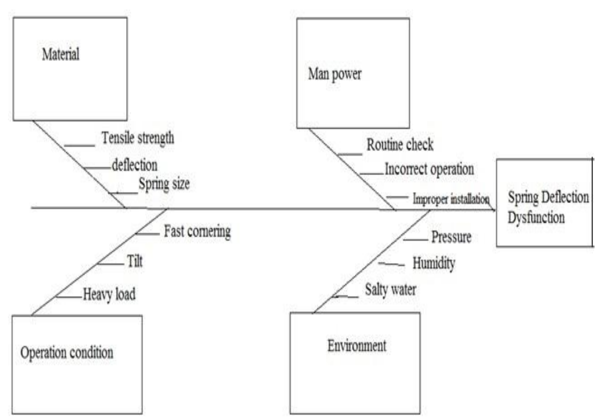

Fig – 1: Cause-and-effect diagram

Routine Check gives the operators the clues of the springs' state. If the maintenance officers are not keen the worn out and imposition of the spring shortens the lifespan of the opposite or immediate ones. Incorrect operation leads to failure of the springs before the stipulated time of guarantee. Heavy load on wagons affect the spring suspension characteristic by load force due to maximization of the customer to reduce the cost of shipping. Tilt affects the sides of the load flow force due to uneven rail-line. Fast cornering operations harm the springs' function results from the train drivers' no adhering to the rules and regulations for short time scheduling to make out the day-to-day trip. The tensile strength of the material used inherent the deflection deficiency of the springs due to manufacturing property. Deflection characteristic of the springs itself, not accommodating the purpose of absorbing shock or unevenness of the rail-line. Spring size in the contour of the height and diameter variation (the inner, outer and coil bar diameters) brings forth the effect of inconsistency of suspension function.

3. METHODOLOGY

In this project modelling and analysis has been borne out on different materials for helical spring. The materials chosen are chromium, vanadium steel material, low carbon structural steel material; the specifications, modelling and analysis is as follows. While entering the industry, analyses of failures have been taken place. Coil spring got more number of failures in the industry. While passing through the case file, the analysis of spring failures, load, heat and manufacturing defects has been founded. The result in failure has overcome through founding the machine to test the spring quality. Better check of the spring will result the quality of better spring and no more failure will be occurring in the spring. Heat should be applied to the spring has been found by using ANSYS software.

3.1 SPRING ANALYSES

The weight management mechanism assists to transmit the TE and BE effectively to the locomotive. During locomotive start axle loading occurs to the end axles and middle axles get unloaded because of this DWM mechanism. As soon as the locomotive goes to normal operating condition load get distributed equally. The mechanism fitted at the middle axle. The TE and BE are transmitted by end axles only when the mechanism is fitted. In view to sustain with such dynamic loadings, end axle's primary suspension of each bogie is arranged with composite spring assembly. The composite spring assembly comprises of concentric outer and inner springs. Outer spring is supported at journal box and inner spring is supported and guided by holding rod. Holding rod pivots at the bottom by nut and bolt.

3.1.1 Modelling of the coil spring

A coil spring is designed by using PRO-E as per the specifications and analyzed by ANSYS 12.0 software. In this the spring behavior will be observed by applying different material loads, to optimum stresses and the result shows best material. Model of the spring will be first created by using PRO-E. Start by drawing a line of 100.79 mm length and it is the free height of spring. The vertical axis and it is the outer diameter of the coil. Next, enter the pitch of spring. Pitch is calculated by free height of coil the spring divided by the number of turns. In this 100.79/10= 10.079 mm. Create the circle of wire diameter 9.49mm of spring and create.

3.1.2 Analysis of modelled helical coil spring

A model of the helical spring was created using Pro/Engineer software. Then the model will be imported to analysis using FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. This model includes static analysis with different materials to optimize the stresses.

3.1.3 Static analysis

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in it.

3.1.4 Static analysis of chrome vanadium material

The static analysis is carried out in a given material properties and loading boundary conditions as mentioned in material specifications. The displacements in x-direction, y-direction, z-direction and displacement vector sum values for stress and strain are shown in figure2. This analysis also shows Von misses stress, strain, stress intensity and total mechanical strains.

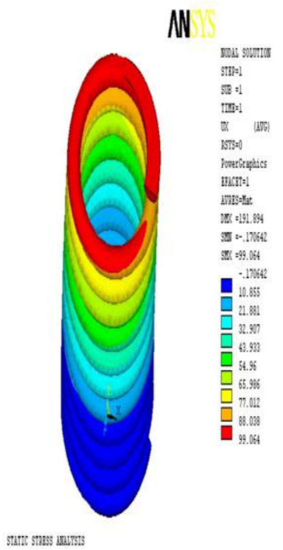

Fig – 2: Displacement in x-direction

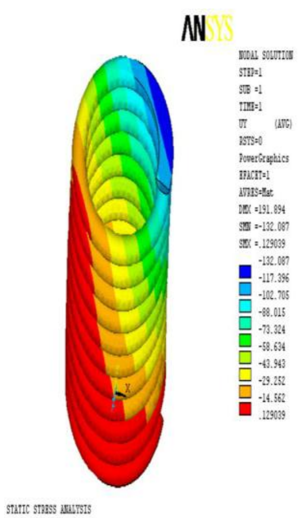

Fig – 3: Displacement in y-direction

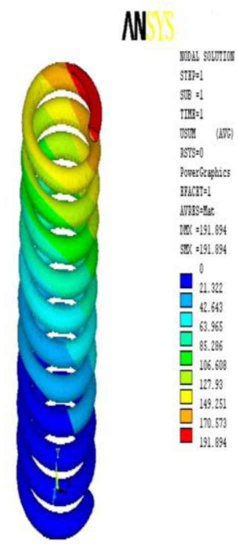

Fig – 4: Displacement z-direction

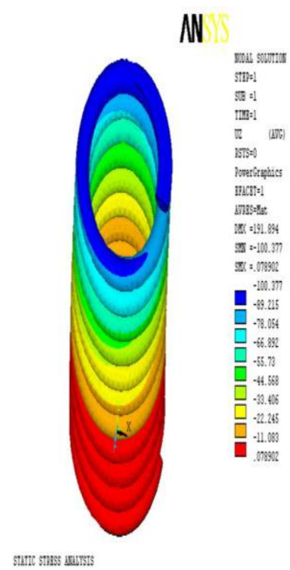

Fig – 5: Displacement of vector sum

4. LOAD TESTING MACHINE LAYOUT DIAGRAM

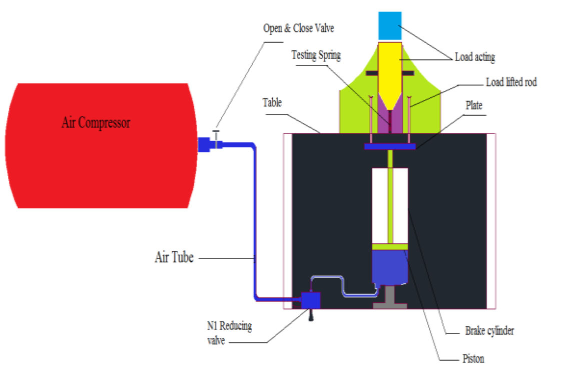

Fig – 6: Load testing Machine Layout Diagram

4.1 WORKING PRINCIPLE OF LOAD TESTING MACHINE

It's consists of brake cylinder, air compressor, N-1 reducing valve, air brake, testing spring (two stroke), load stand, etc. The air to come from the compressor then the air meet to N-1 reducing valve. The N-1 reducing valve takes air from the connecting tube. Then the press the pedal manually. Then the pressurized air meets to the bottom of the brake cylinder from the N-1 reducing valve by the helping tube. The air kept inside the cylinder, then the piston and plates move upper function altogether because the piston rod connected with the plate. The two lifted rod fixed on the plate. So the lifted rod also moves upper function. The load moved upward by the lifted rod. That time the testing spring is fixed under the load. The spring sheet is fixed under the spring, is to avoid the vibration of the spring. Then the pedal is released the piston is moved downward. And the same time plate, lifting rod, and load. These things come to down spring. So the spring becomes compressed. The 32.54 mm compress is the safest spring, after testing it can be used for the working process.

5. SPRING REDESIGN

In view to avoid failure, the difference spring arrangement concept generated considering various factors like the packaging requirement, number of components, positioning of the components, manufacturability and supplier availability. The trade-off study assisted to predict to the non-linear coil spring concept to be taken ahead as a solution to avoid the spring failure. This concept eliminates the innerspring and holding rod arrangement. Hence, number of Components get reduced. The supplier's availability and manufacture ability are also the important factors to proceed ahead to non-linear spring design.

5.1 NEW SPRING DESIGN

The final concept of non-linear coil spring studied for various types of nonlinear springs and trade off study performed to decide the type nonlinear coil spring detail design to be carried ahead. The tradeoff study assisted to finalize the variable pitch nonlinear coil spring details design. The analytical approach used to carry out the detail design of the variable pitch two stage nonlinear coil spring.

5.1.1 CAD DIAGRAM OF THE SPRINGS

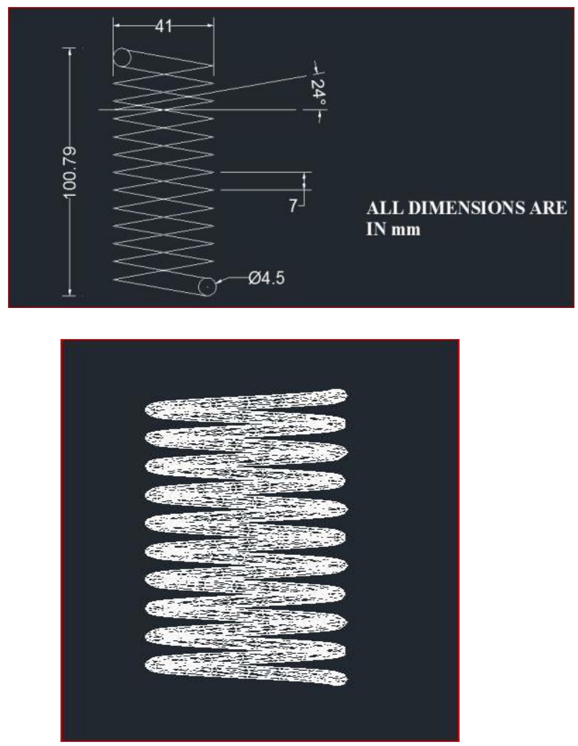

Fig – 7: Spring design for cad

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5.1.2 MODEL OF THE SPRINGS

Before Testing Machine

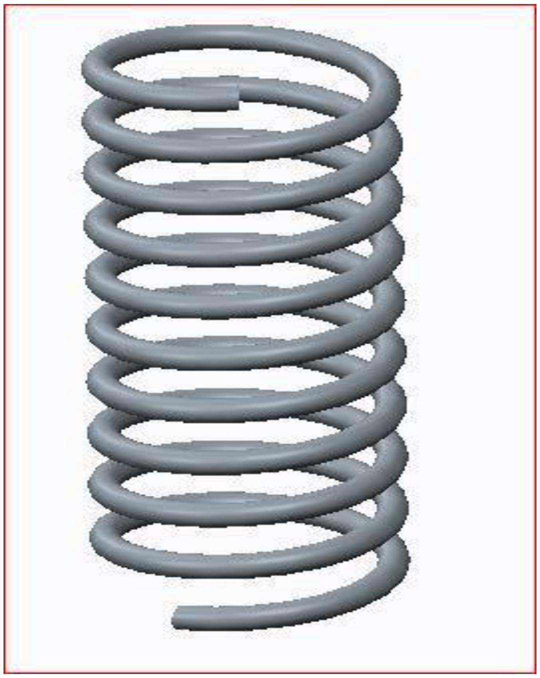

Fig – 8: Spring Model for before compress

After Testing Machine

Fig – 9: Spring Model for after compress

6. SPECIFICATIONS OF HELICAL SPRING AND MATERIAL DATA

Specification of spring:

Wire diameter =4.5 mm, Coil outer diameter =41 mm, Coil inner diameter =31mm, Coil free height =100.79 mm, No. Of active turns =10, Pitch =7 mm, and test load on each spring =1750 N, Material property in Chromium vanadium steel material properties are, Young's modulus =207000MPa, Poisson ratio =0.27, Density =7860kg/m3, For low carbon structural steel material properties are Young's modulus =198000MPa, Poisson ratio =0.37, Density =7700 kg/m3

7. DESIGN CALCULATIONS

7.1 SHEAR STRESS

Shear Stress (τ) = Ks * 8PDπd³

= Ks * 8∗ (79.37∗ 9.81) ∗ (41−31) π∗ (31)²

Ks= 4C – 14C−4 + 0.615c

Spring Index

Spring Index (C) = Dd

= 4131

Spring Index (C) = 1.3225

Wahl Stress Factor

Wahl Stress Factor (Ks) = $\frac{(4*1.3225)-1}{(4*1.3225)-4} + \frac{0.615}{1.3225}$

= 4.291.29

Wahl Stress Factor (Ks) = 3.3255 Say 4

Shear Stress (τ) = 4 ∗8 ∗784.8 ∗ 10 π ∗ (31)3

Shear Stress (τ) = 245.5929 N/mm²

7.2 DEFLECTION

Deflection (y) = 8PC3nGd

Where,

G = Modulus of Rigidity = 84 * 103 N/mm², it is a constant term

n = Number of coils

d = Wire Diameter

= 8 ∗ 784.8 ∗ (1.3225)3 ∗ 1084 ∗ 103 ∗ 4.5

Deflection (y) = 53.59 mm

7.3 HELIX ANGLE

Helix Angle of the coil (α) = tan−1PπD

= tan−1784.8π ∗ 41

= tan−16.0929

Helix Angle of the coil (α) = 24°

7.4 STIFFNESS

Stiffness (q) = P y

= 784.853.59

Stiffness (q) = 14.6445 N/mm

7.5 PITCH COIL

Pitch coil (P) = $\frac{Lf-Ls}{n}$ + d

Where,

Ls = Solid length of the spring

Lf = Free length of the spring

Solid length of the spring

Ls = (d * n) + (2d)

= (4.5 * 10) + (2 * 4.5)

= 45 + 9

Ls = 54 mm

Free length of the spring

Lf = Ls + y

= 54 + 53.59

Lf = 107.59 mm

Pitch coil (P) = $\frac{107.59-54}{10}$ + 4.5

= 5.359 + 4.5

Pitch coil (P) = 9.859

8. RESEARCH OBJECTIVES

8.1 To assess the lifespan of helical springs

During the manufacturing process the springs design and evaluation are considered alongside with the protective coatings against corrosion and friction hardening. Damage to the surface of the spring occurs as a result of friction against surrounding components (Axle).Friction and chafing marks. The hardness values of the spring cater for the friction action upon the Axle. The severe friction action leaves chafing marks to the springs and the spring plank. Hence causes the variability in the springs' characteristics which results to shortening of the spring's lifespan (Service life).

8.2 To establish the root cause of spring fracture in service

The factors that contribute to the spring fracture in service are as follows: improper positioning of the springs during maintenance action, the stiffness of the spring itself against the exerted force, manufacturers' faulty (for the case of impurities inbuilt to coils) and the service action upon uneven rail-lines(lose position) and overloading.

8.3 To quantify the springs' quality variability after service

The specifications of the helical coil springs are given by the designer/ Manufacturer of the helical coil springs and the stabilizer springs. Hence, the reference of the amount variation is established by comparing the measurement system of the springs' quality variability after service with the precision scale from the designer/ Manufacturer.

8.4 To define the parameters used to clarify the range and Standard deviation

The overall standard deviations calculated stipulate the measures for the variability of the whole data set. The data set collection upon the measured values of the different variable of the springing components gives the actual measures after-service of the parameters. The helical coil springs and the stabilizer springs are measured in terms of: coil free height, load at test height, additional deflection, free height after static test, coil/bar diameter, ground edge thickness, outer and inner diameter parameters.

9. RESULTS

Thus, our project reduces the failure occurred in spring testing. Thereby the life of the spring can be increased and then the load bearing capacity can also be increased. Since the thermal stresses induced in the spring can also be reduced. This project helps to determine the times at which the spring fails.

10. CONCLUSIONS

This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while making this project work. We feel that the project work is a good solution to bridge the gates between institution and industries.

We are proud that we have completed the work with the limited time successfully. The failure analysis of cylinder head valve spring in locomotives is working with satisfactory conditions. We are able to understand the difficulties in maintaining the tolerances and also quality. We have done with our ability and skill, making maximum use of available facilities.

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