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Failure Analysis of Helical Spring: A Review

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Abstract- This report explores about a review of general failure occurred in the helical spring. The helical spring plays vital role in automobile for absorbing shocks due to uneven jerks and so that it is very important to analyzed its performance irrespective further development. An in depth discussion is carried on the parameters influencing the quality of coil springs is also presented. Factors affecting strength of coil spring, like its stress distribution, buckling is studied by the approaches of F.E.A. Reduction in weight is a need of automobile industry. Thus the springs are to be designed for higher stresses with small dimensions. This requires critical design of coil springs. This leads to critical material and manufacturing processes.

Index Terms- Decarburization1, Inclusion2, Delayed quench crack3, Coil spring4, Stress distribution5.

1. INTRODUCTION

The automobile chassis is mounted on axles, not direct but through some form of spring this done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in automobile frame and body. All the parts which perform the function of isolating the automobile from the road shocks are collectively called the suspension system. The energy of road shocks causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper, which is more commonly called a shock absorber.

Suspension system prevents the road shocks from being transmitted to the vehicle components and to safeguard the occupants. It also prevents the stability of vehicle in pitching or rolling, while in motion.

1.1. GENERAL FAILURE IN HELICAL SPRINGS

Springs are placed between the road wheels and the body. When the wheel comes across a bump on the road, it rises and deflects the spring, thereby storing energy therein. On releasing, due to the elasticity of the spring material, it rebounds thereby expending the stored energy. In this way the spring starts vibrating, of course, with amplitude decreasing gradually on account of internal friction of spring material and friction of the suspension joints, till vibrations die down.

Generally it is noted that the helical spring gate brakes due to uneven loading or high impact jerks. This spring brakes due to uneven distribution of stresses and it will break in two parts. Also it is observed that spring get failed due to manufacturing defect and over flexible suspension system may dislocate position of spring result in to break down of spring due surging.

Fig.1.1 Broken Helical Coil Spring

1.2. CAUSES OF FAILURE IN HELICAL SPRINGS

1.2.1. VERTICAL LOADING

When the road wheel comes across a bump or pit on the road, it is subjected to vertical forces, tensile or compressive, depending upon the nature of the road irregularity. These are absorbed by the elastic compression, shear, bending or twisting of the spring. The mode of spring resistance depends upon the type and material of the spring used.

1.2.2. ROLLING

The centre of gravity of the vehicles is considerably above the ground. Due to this reason, while taking the turns, the centrifugal force acts outwards on the C.G.

of vehicle, while the road resistance acts inward, at the wheels. This gives rise to a couple turning the vehicle about a longitudinal axis. This is called rolling. The manner in which the vehicle is sprung determines the axis about which the vehicle will roll. The tendency of roll is checked by means of a stabilizer.

1.2.3. BRAKE DIP

On braking, the noise of the vehicle has a tendency to be lowered or to dip. This depends upon the position of centre of gravity to the ground, the wheelbase, and other suspension characteristics. In the same way, torque loads during acceleration tend the front of the vehicle to be lifted. These forces on account of braking and driving are carried directly by deflecting the spring, by wishbone arms or by radius rods.

1.2.4. UNSPRUNG WEIGHT

Unsprung weight is the weight of vehicle components between the suspension and the road surface. This includes rear axle assembly, steering knuckle, and front axle in case of rear drive rigid axle suspension, wheels, tyres and brakes. The sprung weight, i.e., the weight supported by the vehicle suspension system, includes the frame, body, engine and the entire transmission system.

2. REVIEW OF LITERATURE

Manish Dakhore [1] has studied value of stress found to be more at the critical section of the spring as indicated by red colour. Hence possibility of failure is more at that section compared to other section of spring. This paper is a discussed about locomotive suspension coil springs, their fundamental stress distribution and materials characteristic. The analysis of loco spring is carried out by considering cases, when the loco moving at the straight path, curved path and on uphill. This paper also discusses the Experimental analysis of a helical suspension spring by using strain gauge. The stress analysis for the forces obtained and for modal and harmonic response has been carried out by FEA using ANSYS.

Md. Mustak [2] studied the used of E-poxy glass materials for the design of helical suspension spring. The metal coils of helix spring are replaced by e-poxy carbon. In this works finite element analysis of helical spring is analyzed by using ANSYS, and in out the values of all parameters.

Aamir A. Waghade [3] have carried out the works on harmonic analysis of helical suspension spring. In this paper they have introduced the method for rectangular cross section helical spring. This paper discusses the Experimental analysis of ahelical suspension spring by using strain gauge. The stress analysis for the forces obtained and for modal and harmonic response has been carried out by FEA analysis.

Achyut P. Banginwar [4] carried out work on the design and analysis of shock absorber using finite element analysis in this paper; he discussed about shock absorbing system by using 3D Pro/Engineering Software and validates the design, he is done structural analysis, model analysis on the shock absorber system.

Mehdi Bakhshesh [5] have studied result found by comparing steel spring with composite helical spring has been found to have lesser stress and has the most value when fiber position has been considered to be in direction of loading. Weight of spring has been reduced and has been shown that changing percentage of fiber, especially at Carbon/Epoxy composite, does not affect spring weight.

3. CONCEPT OF SPRING DESIGN

The design of a new spring involves the following considerations:

- Space into which the spring must fit and operate.
- Values of working forces and deflections.
- Accuracy and reliability needed.
- Tolerances and permissible variations in specifications.
- Environmental conditions such as temperature, presence of a corrosive atmosphere Cost and qualities needed.

The designers use these factors to select a material and specify suitable values for the wire size, the number of turns, the coil diameter and the free length, type of ends and the spring rate needed to satisfy working force deflection requirements. The primary design constraints are that the wire size should be commercially available and that the stress at the solid length be no longer greater than the torsional yield strength. Further functioning of the spring should be stable.

3.1. STABILITY OF THE SPRING (BUCKLING)

Buckling of column is a familiar phenomenon. Buckling of column is a familiar phenomenon. We have noted earlier that a slender member or column subjected to compressive loading will buckle when the load exceeds a critical value. Similarly compression coil springs will buckle when the free length of the spring is larger and the end conditions are not proper to evenly distribute the load all along the circumference of the coil. The coil compression

springs will have a tendency to buckle when the deflection (for a given free length) becomes too large. Buckling can be prevented by limiting the deflection of the spring or the free length of the spring.
The behavior can be characterized by using two dimensionless parameters, critical length and critical deflection. Critical deflection can be defined as the ratio of deflection (y) to the free length (Lf) of the spring. The critical length is the ratio of free length (Lf) to mean coil diameter (D).The critical deflection is a function of critical length and has to be below a certain limit. As could be noticed from the figure absolute stability can be ensured if the critical length can be limited below a limit. For reducing the buckling effect following condition must be satisfied.

$Lf < 4D$ ….1.1

The crippling load can be given by

$Wcr = K \times KB \times Lf$ ….1.2

Where, K = spring rate KB= buckling factor.

3.2. SPRING SURGE AND CRITICAL FREQUENCY

If one end of a compression spring is held against a flat surface and the other end is disturbed, a compression wave is created that travels back and forth from one end to the other exactly like the swimming pool wave. Under certain conditions, a resonance may occur resulting in a very violent motion, with the spring actually jumping out of contact with the end plates, often resulting in damaging stresses. This is quite true if the internal damping of the spring material is quite low. This phenomenon is called spring surge or merely surging. When helical springs are used in applications requiring a rapid reciprocating motion, the designer must be certain that the physical dimensions of the spring are not such as to create a natural vibratory frequency close to the frequency of the applied force.

3.3. FATIGUE LOADING

The springs have to sustain millions of cycles of operation without failure, so it must be designed for infinite life. Helical springs are never used as both compression and extension springs. They are usually assembled with a preload so that the working load is additional. Thus, their stress-time diagram is of fluctuating nature. Now, for design we define,

$Fa = (Fmax - Fmin)/2$

$Fa = (Fmax + Fmin)/2$

Certain applications like the valve spring of an automotive engine, the springs have to sustain millions of cycles of operation without failure, so it must be designed for infinite life. Unlike other elements like shafts, helical springs are never used as both compression and extension springs. In fact they are usually assembled with a preload so that the working load is additional. Thus, their stress-time diagram is of fluctuating nature.

- Twisting moment
  $\mathbf{Fs1} = \mathbf{Kc}(\mathbf{8PD}/\mathbf{\Pi d^3})$
- Direct shear stress
  $\mathbf{Fs2} = \mathbf{W}/[(\mathbf{\Pi/4})\mathbf{d^2}]$
- Max shear stress
  $Fs = \mathbf{8KWD}/(\mathbf{\Pi d^3})$

4. MAJOR IMPERFECTIONS IN COIL MANUFACTURING

Raw material selection is always the most important decision in obtaining the best quality of any product, including coil springs. The selection of the raw material usually includes the enforcement of cleanliness, microstructure, and decarburization inspection. Figure 4.1 shows a typical raw material defect in the form of an inclusion; also shown is a microstructure matrix defect (b) and decarburization (c). Other sources of defects include improper heating prior to coiling. The control of the prior-austenite grain size is an important step in coil manufacturing. Figure 4.2 shows the difference between a small grain size and a large grain size. This example was taken from identical materials processed with different parameters. Although not reflected by other mechanical properties, larger prior-austenite grain size has proved to be less advantageous, to fatigue life than that of a small size.

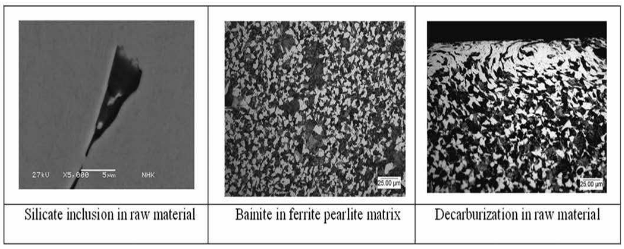

Fig.4.1 Typical defects in raw materials: inclusion (a), inappropriate microstructure (b), decarburization (c).

Some argue that this is due to the fewer number of the grain boundaries passed during crack propagation. Once the raw material is heated properly, the coil is then formed. Physical defects due to coiling sometimes cause the coil to fail early. Following coil formation, a heat treatment process of quenching and tempering is performed. Heat treatment–related defects are another major cause of a coil failing early. These defects include, but are not limited to, quench cracking, insufficient tempering and over-tempering. After tempering, the coil spring is shortened. The shot penning process is beneficial for two reasons: it cleans the surface of defects and scale caused by quenching, and introduces compressive residual stresses at the surface. A typical residual stress distribution formed by shot penning. When a load is applied to a coil spring, the net stress is the superposition of the beneficial residual stress due to shot penning and the applied stress. Shot penning is followed by setting, which usually does not have a detrimental effect on the coil. Coating is typically the last step of coil-making. The process of coating consists of two major steps: pre-treatment and coating application. The main ingredient in a pre-treatment is usually zinc, which works as a sacrificial anode to protect the steel. After pre-treatment, either a powder coat with spray.

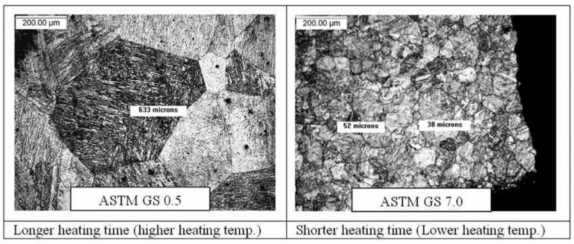

Fig.4.2 Identical raw materials heated with different heating conditions.

5. FEA APPROACH FOR ANALYSIS OF SPRING DESIGN

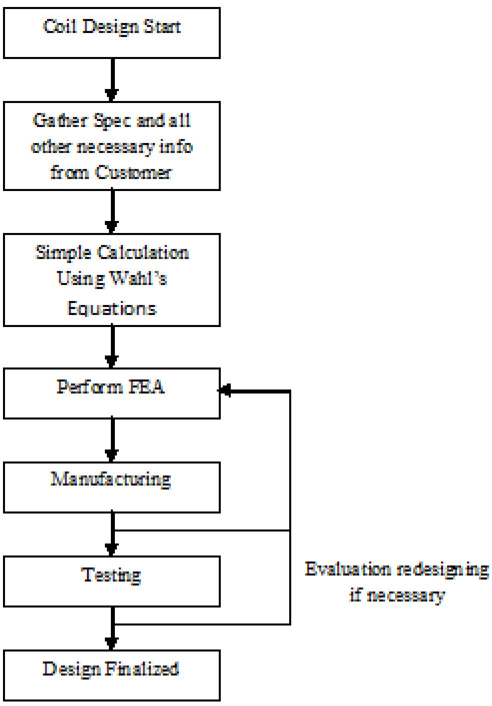

Fig.5 Flow chart of coil spring design

6. CONCLUSION

Paper concluded about a short study about failure of helical spring. Also it's include the various imperfection occurred during the manufacturing process.

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