Testing of helical spring using composite materials

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Abstract

The influence of corrosion combined with mechanically generated surface flaws on the durability of vehicle springs. In the course of this project, different spring production technologies and surface coating systems were associated for a generic spring type in order to control the best manufacturing and corrosion protection practices that would ensure a long fatigue life as well as to derive the necessary measurements and parameters for reliable testing. This comprehensive testing program involved several vehicle and spring manufacturers. The following pages offer a first-time qualitative evaluation of the results. An effective countermeasure is to recover surface protection. The effects and advantages of consuming ceramic coating on helical compression springs have been developed. The work shows the deflection responses of the spring under static loading. The advantages of using ceramic coating was clearly visible as lower values deflection was settled 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 compression test is substantial because we see that in out 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%.

1. INTRODUCTION

The durability of vehicle springs is subject to numerous influencing factors. Besides the mechanical stress resulting from axle kinematics, mounting and application profile, a spring's fatigue life mainly depends on material, manufacturing and environmental conditions. Vehicle springs are made of (ultra) high-tensile and heat-treated steel, subjected to high static and cyclical loads and sensitive to superficial defects that can be caused by mechanical and corrosive action during production or operation. To reduce the risk of fracture, manufacturers use different types of surface coatings that provide protection against both corrosion and mechanical damage by grit or other abrasives. A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. It is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance). When a spring is compressed or stretched, the force it exerts is proportional to its change in length.

1.1 Types of springs

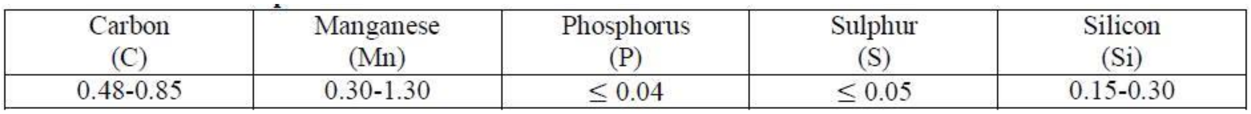
Though there are many types of sprigs, these are the main springs which we can see often.

1. Helical springs.
2. Conical and volute springs.
3. Torsion springs.
4. Laminated or leaf springs.
5. Disc or Belleville springs.

1.2 HELICAL SPRINGS The helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile loads. The cross-section of the wire from which the spring is made be circular, square or rectangular.

1.2.1 HARD-DRAWN SPRING STEEL High-carbon spring steels are the most commonly used of all springs materials. These materials is preferred to others because they are least expensive, readily available, easily worked, and most popular. These materials are not satisfactory for high or low temperatures or for shock or impact loading. Also this is the general purpose spring steels and should only be used where life accuracy and deflection are not too important.

Nominal Chemical Properties



Carbon (C)	Manganese (Mn)	Phosphorus (P)	Sulphur (S)	Silicon (Si)
0.48-0.85	0.30-1.30	≤ 0.04	≤ 0.05	0.15-0.30

1.3 CERAMIC COATING

Nanomaterials are defined as those materials whose length scale lies within the nanometric range, i.e. from one to a hundred nanometers. Within this length scale, the properties of matter are considerably different from the individual atoms, molecules and bulk materials. The physical, chemical, electrical and optical properties of these materials are size and shape dependent and they often exhibit important differences from the bulk properties. These unique properties are related to the large number of surface or interface atoms. Nanostructured ceramic materials have good refractory properties, good chemical resistance, good mechanical resistance and hardness both at normal and high temperatures; they are especially amenable to sintering and reactions with different oxides. The materials at nano scale have attracted many researchers in various fields from material science to biotechnology and genetics. The interest for nanostructured ceramic materials which are synthesized in dimensions smaller than 100 nm has been growing in the last decades. The interest has been stimulated by the large variety of applications in industries such as fabrication of dense ceramics, sensors, batteries, capacitors, corrosion-resistant coatings, thermal barrier coatings, solid electrolytes for fuel cells, catalysts, cosmetics, health, automotive, bioengineering, optoelectronics, Computers and electronics etc. Currently, the importance of nanomaterials in the field of luminescence has increased, especially, as they exhibit enhanced optical, electronic and structural properties. Many new physical and chemical methods of preparations have also been developed in the last two decades. Nanoparticles and nanorods of several ceramic materials have been produced. More recent studies have revealed that optical, luminescence and other properties get modified by its shape and size, incorporation of impurity at different site and also due to the presence or absence of certain defects.

2. LITERATURE REVIEW:

Bai-yan He et al have studied the cause of a passenger car's damper spring tower early failure. Inspection of the road surface, tire inflation pressure, suspension, and service load are done first in order to determine the further test procedures and analysis methods. The static stress of the spring tower caused by the body weight is calculated by finite element model. Public road tests with an equipped car are carried out to simulate the real usage by the customers. With the measured strain signals of different test conditions and local strain-life *method, fatigue Wfe prediction is made.* The *calcuiated fatigue iife coincides with* the actual failure mileage, and it turns out that the broken spring damper causes the early failure of the spring tower. It is suggested that more emphasis should be taken on the durability design and test of the spring damper.

R. Rivera, A et al determined the premature rupture of a spring from an elevator door control mechanism. The study is based on the general methodology applicable to failure analysis. The results obtained in the experimental analysis and the analytical calculations lead to the conclusion that the failure of the spring was caused by a mechanical fatigue mechanism whose origin is related to the presence of the periphery of the material of inclusions and superficial folds (stress concentrators), probably abbreviated by the tensional state derived from the lack of alignment in the application of the load on the spring with respect to its axial axis.

Howard S. Kliger has taken a patent on Carbon Fiber Reinforced Composite Coil Spring. A carbon fiber reinforced composite coil spring is provided which is made from a braid formed of carbon fibers oriented at a preferred angle to the braid axis of approximately + 45° and impregnated with a resin which serves as a substantially continuous matrix phase. Longitudinal reinforcing fiber may be incorporated into the braid to prevent it from straightening under longitudinal tension. The carbon fiber reinforced composite coil spring is formed by wrapping the braid, impregnated with a non-solidified resin, within a groove which extends helically along the surface of a helical mandrel and solidifying the resinous matrix material, and then removing the solid composite coil spring from the helical mandrel.

Kenji Hashimoto has taken a patent on manufacturing of fiber-Reinforced Resin Coil Spring. A fiber-reinforced resin coil springs impregnated with thermosetting resin which comprises a resin-impregnated and twisted rod-shaped fiber bundle formed by binding a plurality of fiber wire blanks made of glass or carbon, immersing the fiber bundle and twisting the rod-shaped fiber bundle in a thermosetting resin, and forming coiled twisted rod-shaped fiber bundle from the resin-immersed and rod-shaped fiber bundle. Thus, the resin coil spring incorporates large elastic energy and high load withstanding capability due to the twisting of the fiber bundle. Glass fiber hollow springs were fabricated. Method used for the production was variation of resin transfer moulding (RTM) process.

J.C. Hendry et al have developed carbon Fiber coil springs, for the rear suspension of a Rover Saloon for the replacement. Carbon fiber/Epoxy material was selected. Fibers were oriented at + 45° circumferentially on the spring stock. The method of manufacturing selected spring was braiding. Material used is carbon fiber. Springs were tested in a mechanical spring testing machine and they fail to meet the required stiffness. Fatigue tests were also conducted on these springs.

Kenji Ukal et al have taken a patent on synthetic resin-coated spring and method for making the coated spring.The synthetic resin coating layer contains an olefin polymer modified with an unsaturated carboxylic acid or a derivative thereof. A method for making the coated spring is also described. This invention relates to synthetic resin-coated springs which have a good selfsilencing property or damping effect and a good corrosion resistance.

William G. Roeseler has taken a patent on composite coil spring. A helical torsion spring composed of unidirectional graphite fibers encased in an epoxy resin
matrix of rectangular cross section. The graphite fibers are longitudinally oriented relative to the core of the coil spring and can be located adjacent to the inner and outer surface of each of the coils. The present invention relates to counterbalance springs, and more particularly, to helical torsion springs.

3. DESIGN OF HELICAL COIL SPRING FOR LIGHT VEHICLE

Compression springs may be cylindrical, conical, tapered, concave or convex in shape and are curled in a helix usually out of round wire. The largest working length of the spring should be appreciably less than the free length to elude all possibility of contact being lost between spring and structure member, with resulting shock when contact is reinstate. As the spring approaches solidity, small pitch differences between coils will tip to progressive coil- to- coil contact rather than to sudden contact between all coils simultaneously. Any contact tips to impact and surface deterioration and to an increase in stiffness.The performance of a spring is characterized by the relationship between the loads (P) applied to it and the deflections (δ) which result, deflections of a compression spring being considered from the unloaded free length. The P-δ characteristic is approximately linear provided the spring is close coiled and the material elastic. The slope of the characteristic is known as the stiffness of the spring

k = P/δ

The designing of spring in a suspension system is very crucial. The analysis is done by considering mass, loads acting on the spring. Comparison is done by varying the wire diameter of the coil spring to verify the best dimension for the spring.

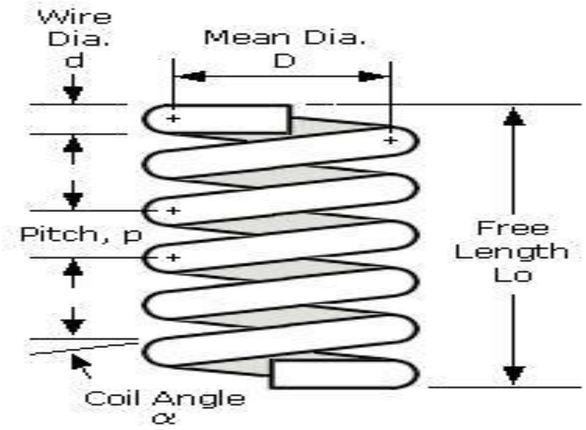


Fig.3.1 Diagram of a Helical Spring

Dimension of helical spring

Upper outer diameter: 45mm

Lower outer diameter: 60mm

Height of the spring: 240mm

Diameter of spring wire: 6mm

Pitch at start: 8mm

Pitch at end: 16mm

Pitch at the quarter middle: 13mm

Table: 1 nominal chemical property. Nominal Mechanical Properties

Young's Modulus: 206000 MPa.

Modulus of Rigidity: 85000 MPa.

Density: 7800 kg/m3

Poisons Ratio: 0.33

3.1 PLASMA SPRAY COATING

The metallic and ceramic coatings are both applied by a plasma spray process. The plasma spray process uses a spray gun, Figure 4 to melt the coating material and spray it onto the substrate. The coating process works as follows: The plasma gun utilizes a chamber with one or more cathodes (electrodes) and an anode (nozzle). With process gases flowing through the chamber, direct current power is applied to the cathode, which arcs to the anode. The powerful arc strips the gas molecules of their electrons to form a plasma plume. As the unstable plasma ions recombine back to the gaseous state, a tremendous level of thermal energy is released. The feedstock material is injected into the hot gas plume, where it is melted and propelled towards the target substrate to form the coating. The plasma spray coating process produces a layer of individual particle “splats” on the substrate. The “splats” are the result of the liquid particle impacting the surface and rapidly solidifying. Undesirable coating constituents include unmelted coating particles, oxides, and voids. Unmelted particles can be reduced by controlling the gun parameters, stand-off distance, and particle size. Oxides can be minimized by coating in a vacuum or low pressure environment and are only a concern for metallic coatings; ceramic coatings do not react with oxygen.

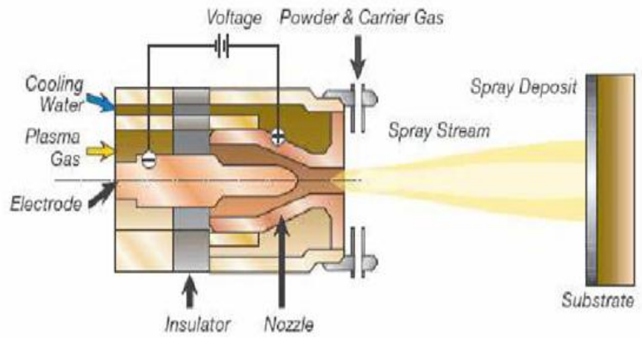


Fig.3 (a) Plasma spray gun cross section.

The coating thickness ranges between 90 and 120 micrometer. Example of these measurements are in micrograph. It was observed as a general trend through the spring, that the thicker layer of the coating was located on the inner section of the core spring wire. The thinnest coating was on the upper section of the spring wire sample. Examples of the coating measurements are in Figure and visual representations of these locations are in Figure

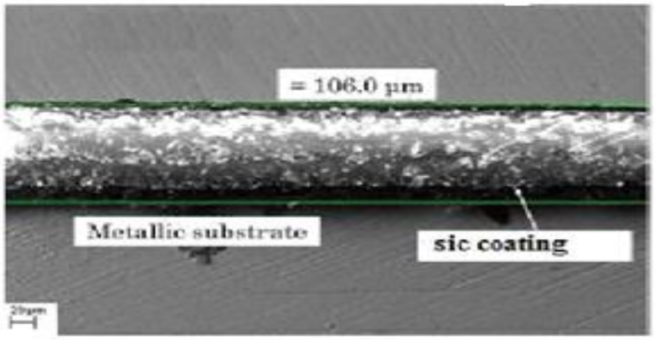


Fig 3 (b) Plasma Spray gun coating

4. RESULTS AND DISCUSSIONS:

4.1 EFFECT OF SILICON CARBIDE COATING ON COMPRESSIVE STRENGTH

COATED SPRING SAMPLE

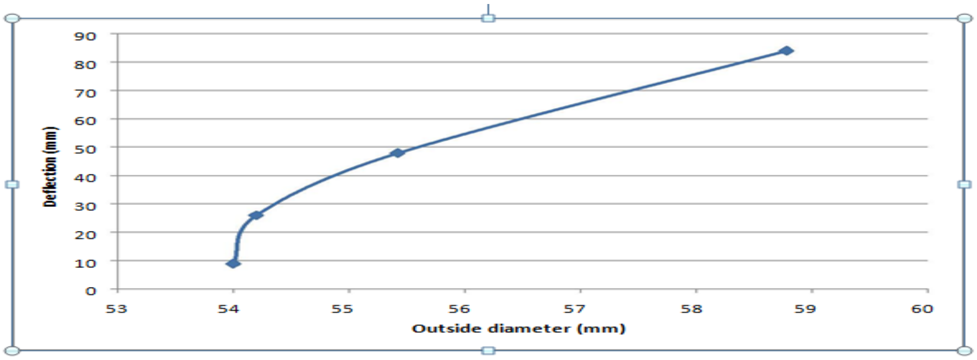


FIG 4.1 Deflection vs Outside diameter

Compressive strength is of the most important attributes of suspension spring. Ductility of the material causes it to bulge or swell but helps to prevent fracture, the lack of compressive strength in brittle materials cause fracturing. Cemented carbide has high compressive strength that tends to increase with decrease in binder content and grain size.

4.2 NON-COATED SPRING SAMPLE

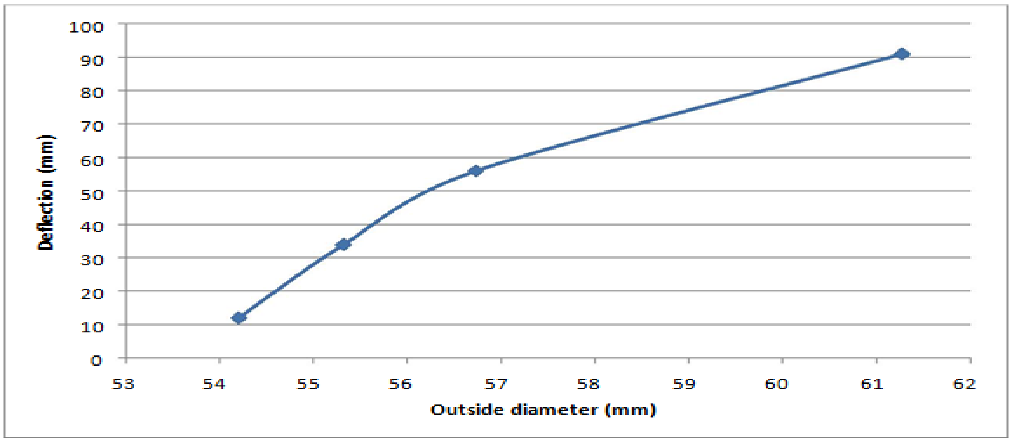


FIG 4.2 Deflection vs Outside diameter

Compressive strength is essential to eliminate thermal cracking and fracturing. The results are shown in a graphical form and the characteristics of each deflection with varying spring diameter contents are compared to find the stronger spring. The result clearly suggests that the non-coated spring, which has lower compressive strength and higher deflection for minimum load. The non-coated compression spring has poor compressive strength and is less effective against thermal cracking and fracturing thereby poor spring life compare with coated spring.

4.3 COMPARISON OF COATED Vs NON COATED

Fig.4.3 Comparison of Coated Vs Non Coated

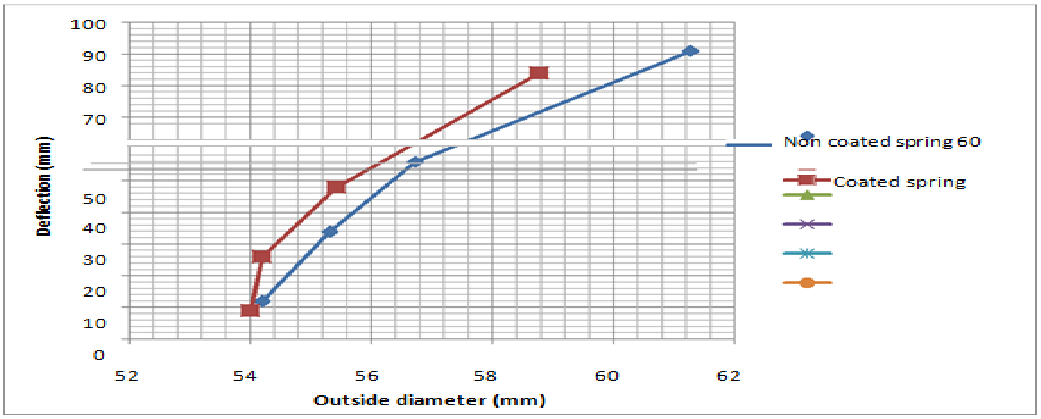
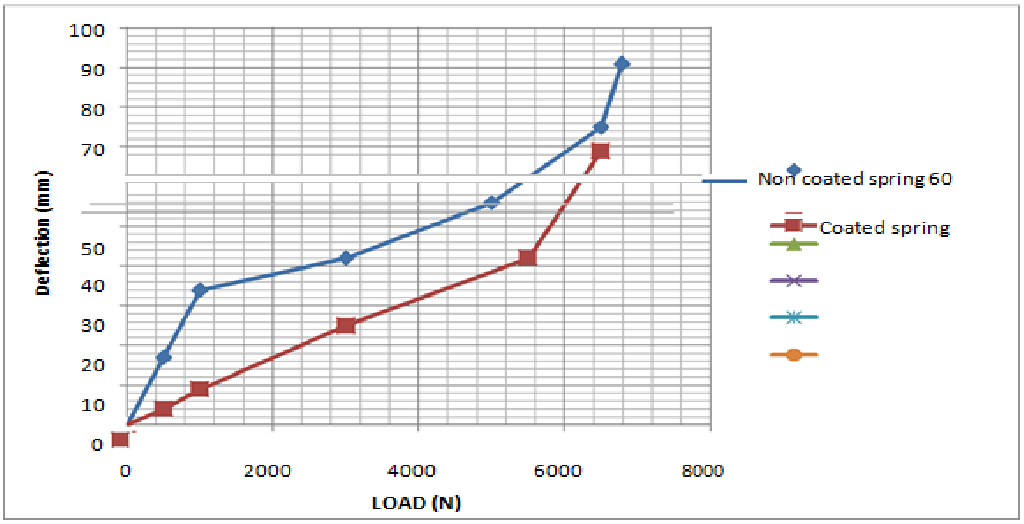


Figure 4.3 shows the micrographs of coated and non coated . The reinforcement (SiC) particles were uniformly distributed within the matrix alloy, thereby showing that PS could be used for the production of Spring with improved properties and reduced particle clusters. The dark regions shown in Fig.4.4 represent sic particles or the pores formed upon polishing the surface. The SIC particles are solid lubricant particles that are abraded easily during polishing of the and increase the Compressive strength

and elastic properties.

4.4COMPARISON OF COATED Vs NON COATED (Load Vs Deflection)

Fig.4.4 Comparison Of Coated Vs Non Coated (Load Vs Deflection)



The optical micrographs indicated a flake-like structure for the sic particles in the spring surface, whereas the SiC particles appeared like cubes (Fig. 4). The SiC particles were uniformly dispersed within the spring stell matrix. The micrographs also indicated perfect bonding between different components of sic and absence of cracks.

These results indicated the presence of silicon carbide and particles in the minor peaks. A number of studies have been carried out for developing sic reinforced with compression Spring, it was increasing more ductility and durability. In sic phase it was increasing hardness then non coated spring, in figure (load vs deflection) clearly indicates the load gradually increased with deflection but coated spring was withstand maximum load for minimum deflection.

CHAPTER 5

CONCLUSION

For the purpose of systematically strength of coated suspension springs under realistic environmental conditions, reproducible parameters for premature damage and durability tests were determined and then compared with uncoated spring results. Comprehensive durability tests on generic springs manufactured with different technologies and coatings enabled the verification and quantification of the dominant influence of advance mechanical damage by grit impact and abrasion on the fatigue strength under loading conditions. An effective countermeasure is to improve surface protection. The effects and advantages of using ceramic coating on helical compression springs have been developed. The work shows the deflection responses of the spring under static loading. The advantages of using ceramic coating was clearly visible as lower values deflection 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 compression test is significant because we see that in out 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%.

CHAPTER 6
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