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Analysis and Comparison of helical springs used in tractor seat application

#1 VikramVakte ,#2 L S Dhamande

[1]vikramvakte@gmail.com
[2]lsdhamande@rediffmail.com

#12 SRES College Of Engineering, Kopargaon, Maharashtra, India

ABSTRACT

Helical springs plays a significant role in minimizing the vibration of Tractor seat. Most of the tractor seat helical springs are used in tension rather than compression but because of the repetitive stress acting on tension spring gives rise to early fatigue failure. This paper focuses on the experimental and finite element analysis of helical spring. The new model has proposed for reducing vibration of tractor seat which used in compression state instead of tension. The accelerated fatigue test has been carried out on helical spring sample and the results are compared with finite element analysis model and results shows compression helical spring gives higher life.

Keywords- **Fatique analysis, compression spring, finite element analysis.**

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I. INTRODUCTION

Most of the component used in heavy vehicle automobiles are subjected to high stress loading and they are designed to withstand the structural as well as fatique failure analysis. The Tractor seat failure has been out to be due to fatique failure, so designers and engineers are concerned about the very high cycle fatique. Failure of any mechanical component is depend upon the loading condition, material, component design and its manufacturing. To improve the life of the component the material used is very high strength steels and standard manufacturing process is followed which gives the fatique failure of mechanical component is depends on loading conditions. Most of the tractor seat are failed due fatique stress acting on because of recitative load due vibration of automobile.

There has been a lot research has been carried out to find optimized solution for helical spring depending on the application. The jinhee Lee has proposed a Pseudo spectral method which was applied to the free vibration analysis of cylindrical helical springs. The displacements and the rotations are approximated by the series expansions of Chebyshev polynomials and the governing equations was collocated [1]. A.M. Yu , Y. Hao has done analytical study on the free vibration analysis of cylindrical helical springs with noncircular cross-sections. They have formulated explicit analytical expressions of the vibrating mode shapes of cylindrical helical springs with noncircular cross-sections and the end conditions clamped–clamped and clamped–free, using the symbolic computing package MATHEMATICA [2]. L.E. Becker et al. linearized disturbance equations governing the resonant frequencies of a helical spring subjected to a static axial compressive load are solved numerically using the transfer matrix method for clamped ends and circular cross-section to produce frequency design charts[3]. The scope of K.MIchalczykwork includes the determination of the stress amplitudes in the spring for the given parameters of elastomeric coating, at the consecutive resonance frequencies[4]. Mohamed Taktak has proposed a numerical method to model the dynamic behavior of an isotropic helical spring[5]. The analytical and numerical models describing wave propagation, of gradual excitations in time has been investigated by AiminYu,et al.[6]. Suraj Kumar et al have purposed air spring which is to restrict the vibration at a desirable level as per requirements. Anis Hamza et al has studied the vibrations of a coil, excited axially, in helical compression springs such as tamping rammers are discussed. He has developed a mathematical formulation which was comprised of a system of four partial differential equations of first-order hyperbolic type, as the unknown variables are angular and axial deformations and velocities. The numerical resolution was performed by the conservative finite difference scheme of Lax–Wendroff. Youl Zhu et al.[7] has Shown that a variety of factors may cause fatigue failure of helical compression springs in engineering applications.

In this paper, we conducted a structural and fatique analysis of tractor seat spring. We have proposed new arrangement of spring on a tractor seat which will improve the performance of the spring.

I. MATERIAL

Springs are resilient structures designed to undergo large deflections within their elastic range. It follows that the materials used in springs must have an extensive elastic range.

Some materials are well known as spring materials. Although they are not specifically designed alloys, they do have the elastic range required. In steels, the medium-and high-carbon grades are suitable for springs. Beryllium copper and phosphor bronze are used when a copper-base alloy is required. The high-nickel alloys are used when high strength must be maintained in an elevated-temperature environment.

The selection of material is always a cost-benefit decision. Some factors to be considered are costs, availability, formability, fatigue strength, corrosion resistance, stress relaxation, and electric conductivity. The right selection is usually a compromise among these factors.

A. Commonly Used Spring Materials

One of the important considerations in spring design is the choice of the spring material. Some of the common spring materials are given below.

Hard-drawn wire.

This is cold drawn, cheapest spring steel. Normally used for low stress and static load. The material is not suitable at subzero temperatures or at temperatures above 1200C.

Oil-tempered wire.

It is a cold drawn, quenched, tempered, and general purpose spring steel. It is not suitable for fatigue or sudden loads, at subzero temperatures and at temperatures above 1800C.

Chrome Vanadium.

This alloy spring steel is used for high stress conditions and at high temperature up to 2200C. It is good for fatigue resistance and long endurance for shock and impact loads.

Chrome Silicon.

This material can be used for highly stressed springs. It offers excellent service for long life, shock loading and for temperature up to 250^{0}C.

Music wire.

This spring material is most widely used for small springs. It is the toughest and has highest tensile strength and can withstand repeated loading at high stresses. It cannot be used at subzero temperatures or at temperatures above 120^{0}C.

Stainless steel.

Widely used alloy spring materials.

Phosphor Bronze / Spring Brass.

It has good corrosion resistance and electrical conductivity. it is commonly used for contacts in electrical switches. Spring brass can be used at subzero temperatures.

On the basis of this particular study we have selected material as 55 Si 2 Mn 90

TABLE 1.
MATERIAL CONFIGURATION

% C	**% Si**	**%Mn** % Si
0.5-0.6	1.5-2	0.8-1.0

% N

II. FINITE ELEMENT FORMULATION

Two CAD models has prepared for this particular research depend on the position of helical spring by using Pro-E Platform. The Models are prepared in such way that, It will take all real boundary conditions. Fig. 1 shows the CAD Model

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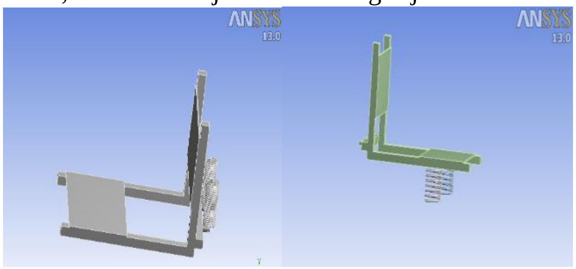


Fig 1 CAD Model of Tractor Seat

a) Helical Tension
b) Helical Compression

A. Helical Tension spring model

The Structural analysis of Helical Tension spring tractor seat model has been carried out in ANSYS Workbench. The boundary condition are as follows, 1) spring is fixed on the top edge and other edge is connected to the Tractor seat. 2) The Force of 1000 N is applied on the seat.

The tetra-hyadral element is used for meshing of the model which is having 28402 nodes and 11200 Element

B. Helical compression spring model

The Structural analysis of helical compression spring tractor seat model has been carried out in ANSYS Workbench. The boundary condition are as follows, 1) spring is fixed on the bottom edge and other edge is connected to the Tractor seat. 2) The Force of 1000 N is applied on the seat.

The tetra-hyadral element is used for meshing of the model which is having 28402 nodes and 11200 Element

Similarly a fatique model has been added to the each analysis which is used to find out the life of total component.

III. FATIQUE MODEL

Fatigue life is defined as the number of stress cycles of specified character that a specimen sustains before the first evidence of failure. In case of Tractor seat road irregularities and engine will cause a vibration which ultimately will gives the fatique in the helical spring. Here for this research we have considered a vibration to be in completely reversed manner. So, for the fatigue life calculation we have to consider the fully reversed cycle.

Mean stress value ( ) = 0

Stress amplitude (σa) = 200 MPa

Endurance limit of mechanical a component (Se)

Se = Ka×Kb×Kc×Kd×Ke×Se'

Where,

Ka = Surface finish factor: - The surface finish factor is depends on modes of surface finish operation. Due to complex geometry of Tractor seat, polishing is the best way for finishing of crankcase. For polishing operation value of surface finish factor is one.

Kb = Size factor: - The size factor depends upon the size of cross-section of the component. As the size of the component increases, the surface area also increases, resulting in a greater number of surface defects. Ford> 50, its value is 0.75.

Kc = reliability factor: - The reliability factor depends on the reliability that is considered in the design of component. The reliability of the fatigue test is 50 %. At 50 % reliability the value of reliability factor is one.

Kd = Temperature factor: - Temperature factor depends on the temperature of component. Due to increase in temperature endurance strength of component decreases. Its value for temperature 550 ºC is 0.67.

Ke = Modified factor for stress concentration = 1

Se' = Endurance limit

= 0.45×Sut

Sut = 2×Syt

Se = 0.750 ×1 ×1 × 0.67× 1 ×2 Se’

Fatigue strength (Sf) = Nf×σa

From S-N diagram as shown in Fig 2

CF/FB = AE/EB

$$\frac{\log(Sf) - \log(Se)}{6 - \log(N)} = \frac{\log(0.9\ Sut) - \log(Se)}{6 - 3}$$

From above formula we can find out the life cycle of our models.

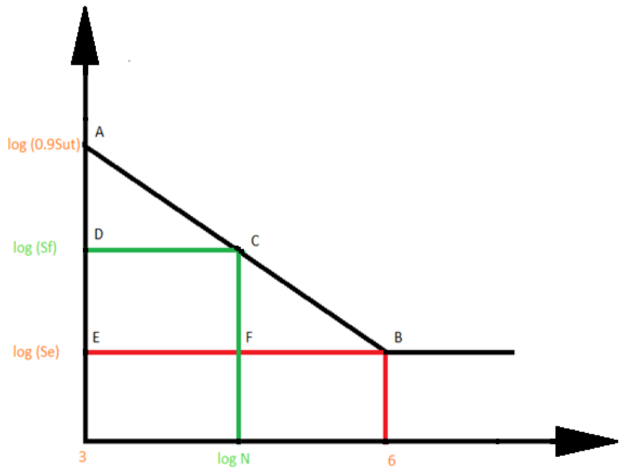


Fig. 2 S- N Diagram

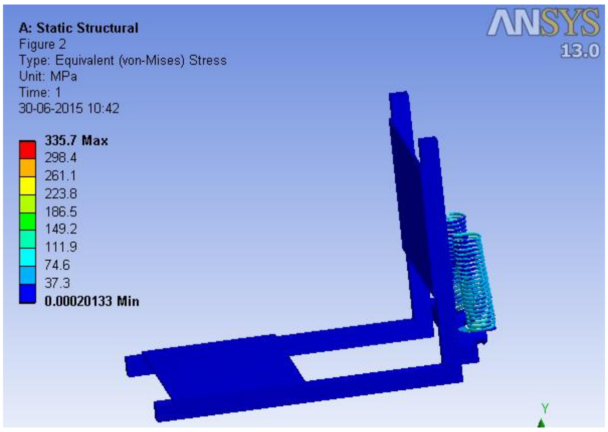
IV. Experimental Setup

Experimental testing has been carried out in specially manufactured Lab set-up to get completely reversed stress.

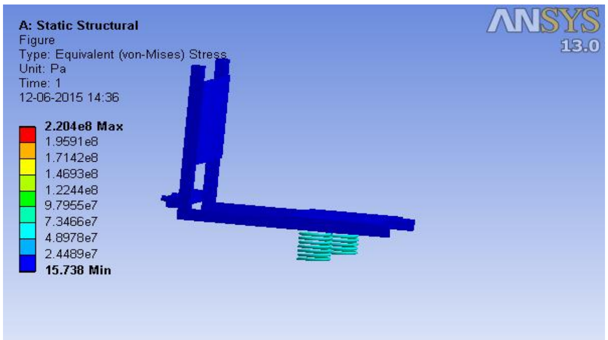
The experimental set-up of helical tension spring model is as shown in Fig 3

V. Result And Discussion

The maximum Von misses stress of both models are shown in Fig. 4 .Fig 4 (a) Shows that equivalent von misses stress for helical tension spring. Fig 3 (b) Shows that equivalent von misses stress for helical compression spring model.



a) Helical tension spring



b) Helical compression spring model.

Fig 4 Equivalent Von Misses Stress

Fatique Failure analysis of the both models shows the higher life cycle in a compression spring helical model than tension helical spring also von misses stress of helical tension is higher than compression model.

TABLE 2.

FATIQUE AND STRUCTURAL ANALYSIS RESULTS

	Helical Tension	Helical Compression
Life (Cycle)	32303	49201
Von Misses Stress	335 MPa	220 MPa

Experimental testing of 3 compression spring and 3 tension spring has been carried out on experimental set up .experimental reading has measure according to the time required to fail each reading and average cycle has been calculated .The following Table 3 shows the comparative analysis of experimental and FEA results of number of cycles to fail of each spring

TABLE 3

COMPARATIVE ANALYSIS

		Helical Tension	Helical Compression
Life (Cycle)	FEA	32303	49201
	Experimental	36307	57609

VI. CONCLUSIONS

The tractor seat helical compression spring will last longer than the helical tension spring and also the stresses obtained in helical tension spring are much higher than the compression spring model.

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