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Design and Fabrication of Digital Spring Testing Machine

Prof. A. D. Kachare
Assistant Professor
Department of Mechanical Engineering
Dr. V. V. P College of Engineering, (ViladGhat), Ahmednagar, Maharashtra, India
Corresponding author's email id: *kachareamit977@gmail.com*

Abstract

Digital Spring Testing Machine is designed for conducting load-deflection test on spring or other material in compression. Digital Spring Testing Machine is a hand wheel operated machine which uses a strain gauge based load cell with microcontroller based digital load indicator with peak hold features for highly stable and accurate force measurement system. The displacement is measured using standard accurate scale. The spring testing machine is useful instrument for testing of compression or tension springs at low affordable price. By using hand wheel we can apply desired load or deflection.

Keywords: *Spring, Stiffness, Microcontroller, Strain Gauge, Load Cell.*

INTRODUCTION

Springs are mainly used in the industry as members absorbing shock energy as well as for restoring the initial position of a part upon displacement for initiating a given function. Compression springs are coil springs that resist a compressive force applied axially. Compression springs may be cylindrical, conical, tapered, concave or convex in shape. Coil compression springs are wound in a helix usually out of round wire. It has been reported by the warranty/ maintenance department that frequent complaints are being received over the failures of these springs well within their intended life span. The springs must be designed for reliability. The springs must be designed to withstand the cyclic loading during operation. Therefore in this dissertation work it is proposed to carry out the designed fatigue analysis of compression spring so as to have better performance in terms of longer life. For automotive springs, the most relevant

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performance characteristic is stiffness or "springiness" For automotive springs, the most relevant performance characteristic is stiffness or "springiness" under load. On the coil line, assembly operators conduct performance testing on each spring at the end of the manufacturing process. These springs move through stages from raw steel into their final shape, with experienced assembler/operators monitoring all phrases of production and at the end of the line, every string undergoes a performance test on mechanical testing machine. For coil spring, a typical performance test include applying a series of variable loads to each spring, literally bouncing it up and down for a specified period of time at high rate of speed to determine its stiffness quality. The results are collected via a gauge and compared to an established performance design standard. Due to a spring coil design, it generates side loads and moments in addition to axial loads. The most important part of maintaining an accurate load tester is the calibration and verification of the spring. When springs are used in a moving mechanism, their dynamic behavior has to be analyzed. However, the machine might not be able to test the stiffness for all forms of spring available on the automobile or equipment but to test only compressive spring.

A spring is basically an elastic body whose purpose is to detect or distort under loading conditions and consequently store energy and release it slowly or rapidly depending on the particular application. In 1932, Lucien Lacoste invented the zero-length spring. A zero length spring has a physical length equal to its stretched length. Its force is proportional to its entire length, not just the stretched length and is therefore constant over the range of flexures in which the spring is elastic. Springs are usually made from alloys of steel. Hooke's law of elasticity is an approximation which state that the amount by which a material body is deformed (strain) is linearly related to the force causing the deformation (stress). The materials for which Hooke's law is a useful approximation are known as linear-elastic or "Hookean" materials. For systems that obey Hooke's law, the extension, x produced is proportional to the load, F. When this holds, we say that the spring is a "Linear spring". There are three basic principles in spring design: The heavier the wire, the stronger the spring, the smaller the coil, the stronger the spring and the more active the coils, the less load you will have to apply in order to get it to move a certain distance.

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The most common method for checking the performance of shock absorbers is for the owner or mechanic to jump up and down on the car bumper and observe whether or not the car motion appears to be adequately damped. When the shocks are completely worn out, it is clear that the damping is inadequate, however by the time the wear is readily observable, the car owner has been driving for an extended period of time with bad shocks. By then the owner has learned to hate his vehicle, the tyres have been abnormally worn, and the road ability has deteriorated to the point that he or she has been driving dangerously all over the road. Main reason for replacement of shock absorber (spring) is physical damage. Spring stiffness must be checked before replacement. This test rig will give the force applied on spring. With the help of force and deflection produced, we can calculate stiffness of spring. By varying the force, we can obtain corresponding deflections. We are going to study the suspension characteristics of spring by graphical method.

Extension and compression springs are literally on opposite sides of the spring spectrum. Extension springs are used primarily to hold two components together, while compression springs are best for keeping components from meeting one another. Both employ a coil design for elasticity and strength, but they work under two different principles of elastic potential energy. Torsion spring provides torque around the axis of the helix, rather than a force in line with the axis of the helix, as in compression and extension springs. The ends of the torsion spring are attached to other components that rotate around the middle of the spring. Springs are used to absorb and reduce shock, support moving masses or isolated vibration and apply definite force or torque. Few examples of application of springs are in control valve, safety valve, torque converter, clutch manual transmission, brake system, damper, stamping machine etc. Spring rolling is a large and growing industry. There are many special purpose machines used in industry today. The proper section of the machines depends upon the type of the work under taken by the particular industry. Digital Spring testing machine finds huge application in all spring manufacturing industry.

LITERATURE REVIEW

Olugboji Oluwafemi Ayodeji, Mathew Sunday Abolarin, Jiya Jonathan Yisa, Alaya Garba Muftau and Ajani Clement Kehinde states that a spring stiffness testing machine was produced which

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differentiates a good spring from bad one using hydraulic principle and locally sourced materials were used to produce at relative low cost and high efficiency. It also categories each spring by stiffness into one of several distinct categories based on its performance under test. This is to ensure that in the final assembly process, springs with similar performance characteristics are mated to ensure a better ride, more précised handling and improved overall vehicle or equipment performance. The construction of the machine involves basically the fabrication process which includes such operation as cutting, benching, welding, grinding, drilling, machining, casting and screw fastening. Taken into consideration under test, were types of compression springs with varying spring loading and their different displacement recorded at different pressures to compare their stiffness. [1]

Z.Hamedon1,M.Nafis.O.Z ,Ghazalli3, M.M.Noor and K.Azha told that A new harvesting pole, specifically designed for palms trees, was designed, developed and tested. It comprises three sections, the locking, extension and spring sickle, which were joined through an aluminum pole. The pole can be adjusted to certain length to reach different height of tree. It is built using standard circular rod with cross section diameters of 50 mm. This newly invented spring sickle pole called "ZappIt®" has been designed based on the ordinary sickle widely used in Malaysia palm estates. Zapp It introduced new mechanism concept of spring compression as a source of mechanical force to cut the frond and fruit bunch. The locking system was designed and located at the bottom of the pole for manual hand operated.While the threaded steel used to link the locking systems and spring sickle system.[2]

G.S.Jagushte, S.S.Joshi, S.S.Jangali, D.S.Joshi and S.M.More told that Springs isolate the driver from road imperfections by allowing the tyre to move over a bump without drastically disturbing the chassis. If the chassis remains fairly steady then the tyres are better able to follow road contours automatically. While springs do an excellent job of smoothing over bumps, they will keep bouncing once started. In other words, the chassis continues swaying and the tyres keep hopping long after the vehicle strikes a bump. Left uncontrolled, springs give an uncomfortable ride with very poor tyre to road contact. To control this undesirable behavior, a shock absorber keeps the spring from over reacting to every bump or dips and not only prevents but also balances excess movement of the tyre and chassis. Springs are durable items

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and are easily inspected. If the ride height of a vehicle has decreased excessively or a coil/leaf has broken it is advisable to replace the springs in axle sets. Consumers also often change springs to alter their vehicle's ride and handling characteristics. Spring problems are generally easy to identify.[3]

Avdhut.R.Jadhav,Gajendra.J.Pol and Amit.A.Desai told that Industries they purchase the springs for their hydraulic valves but they are facing the problem of checking the spring stiffness. After understanding the Industries problems for spring testing we designed and developed hydraulic spring stiffness testing machine. Only considering the two parameters load and deflection) we can calculate spring stiffness. The machine is based on the requirement of the company which manufacture different valve. So according to the requirement of company, hydraulic spring testing machine is developed. An engineer is always focused towards challenges of bringing ideas and concepts to life. Therefore, sophisticated machines and modern techniques have to be constantly developed and implemented for economical manufacturing of products. At the same time, quality and accuracy factor is considered. A spring is defined as an elastic machine element, which deflect under the action off the load and returns to its original shape when the load is removed.[4]

PROBLEM STATEMENT

Many companies manufacture valves and they required the springs for installing in their products (valves). Depending upon the valve size there is variations in sizes and shapes of springs, hence company are facing problem of checking stiffness of spring. In industry many problem are created like high testing cost, more time required, leakage problem, less accuracy. Understanding the Industry problems, we are designed and developed a digital spring stiffness testing machine.

DESIGN AND SELECTION OF COMPONENT-

Design of Lead Screw:-

Selection of Material: Design Data Book

We have selected material from data book, pp. 1.12

C45	Tensile Strength N/mm^2	Yeild Strength N/mm^2
Tubes, Cold Drawn and tempered	700	600

Factor of Safety = 1.5

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Consider Load = 25×10^3 N

$$\sigma_c = \frac{S_{yc}}{N_f} = \frac{600}{1.5} = 400 \text{ N/mm}^2$$

$$\sigma_c = \frac{W}{\frac{\pi}{4} d_c^2}$$

d_c = 8.92 mm ≈ 10 mm

From data table choose dc = 17 mm

d_c = 17 mm , d=22 mm, p=5mm

$d_m = d - \frac{P}{2}$ = 19.5 mm

d_c = 17 mm

d_m = 19.5 mm

d= 22 mm

p = 5 mm

$\lambda = \tan^{-1}(\frac{P}{\pi d_m})$

$\lambda = 4.66^0$

Consider $\mu = 0.15$

$$\emptyset = \tan^{-1}(0.15) = 8.53^0$$

$T_t = \frac{Wdm}{2} \tan(\emptyset + \lambda)$

T_t = 57110.62 N-mm.

$R_o = 0.875\ d$ = 19.25 mm

$R_i = \frac{Ro}{4}$ = 4.82 ≈ 5 mm

$T_c = \frac{2}{3} \mu c\ W\ (\frac{Ro^3 - Ri^3}{Ro^2 - Ri^2})$

T_c = 54031.4 N-mm

$T = T_t + T_c$

T = 111142.01 N.mm

Stresses in screw:

1) $\sigma_c = \frac{W}{\frac{\pi}{4} d_c^2}$

σ_c = 110.14 N/mm^2

2) M = P*H

H= Max lift, P= Force applied

M = 90*10^3 N-mm

$\sigma_b = \frac{32M}{\pi d_c^3}$ = 186.05 N/mm^2

$\sigma = \sigma_c + \sigma_b$

σ = 296.7 N/mm^2

3) $\tau = \frac{16\ T_t}{\pi d_c^3}$

τ = 59.2 N/mm^2

$\tau = \sqrt{(\frac{\sigma}{2})^2 + \tau^2}$

τ_{max} = 159.74 N/mm^2

Permissible shear stress for screw material,

$\frac{S_{ys}}{N_f}$ = 200

$\therefore\ \tau_{max} < \frac{S_{ys}}{N_f}$

∴ Design is safe

Screw Dimension: d = 22 mm , p = 5 mm

Design of Nut:

1) Bearing pressure between threads :-

$P_b = \frac{W}{\frac{\pi}{4}(d^2 - d_c^2)z}$

Z = 10.20

Z = 10 threads

h = Z*P

h = 50 mm.

Shear stress induced in nut threads,

$\tau_n = \frac{W}{\pi\ dtz} = \frac{W}{\pi * d * \frac{p}{2} * z}$

τ_n = 14.468 N/mm^2

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Permissible shear stress for material

$\frac{S_{y(nut)}}{N_f} = \frac{90}{1.5} = 60$ N/mm^2

Material for Nut: Phosphor Bronze

Tensile yield = 110 N/mm^2

Compressive yield = 130 N/mm^2

Yield strength = 90 N/mm^2

$\tau_n < \frac{S_{yt}}{N_f}$

∴ Design is safe

Shear stress induced in screw threads:-

$\tau_s = \frac{W}{\pi\, d_c t\, z}$

$\tau s = 18.72$ N/mm^2

$\tau_s < \frac{S_{yt}}{N_f}$

Design is safe

Dimension of Nut:-

Considering the tensile failure of nut,

$\sigma_{t(nut)} = \frac{W}{\frac{\pi}{4}(D_1^2 - d^2)}$

$\frac{S_{yt(nut)}}{N_f} = \frac{W}{\frac{\pi}{4}(D_1^2 - d^2)}$

$D_1 = 30.29$ mm

D_1 = Outer dia of Nut = 32 mm

Considering the crushing of nut collar:-

$\sigma_{c(nut)} = \frac{25 * 10^3}{\frac{\pi}{4}(D_2^2 - D_1^2)}$

$\frac{S_{yc(nut)}}{N_f} = \frac{W}{\frac{\pi}{4}(D_2^2 - D_1^2)}$

$D_2 = 38$ mm

Considering the shearing of nut collar:-

$\tau_{nut} = \frac{W}{\pi\, t_1\, D_1}$

$\frac{S_{ys(nut)}}{N_f} = \frac{W}{\pi\, D_1\, t_1}$

$t_1 = 4.14 \approx 5$ mm

Design of Handle:-

Find length of handle (L_H):-

T = M = 111142.01 N.mm

Effective length :-

$L_E = 0.55$ m

= 555 mm

Length Of Handle:-

$L_H = L_E$ + Gripping Length

$L_H = 605$ mm

Find the diameter of handle:-

$\sigma_{bh} = \frac{32\, M}{\pi d_h^3}$

$\frac{S_{y(handle)}}{N_f} = \frac{32M}{\pi d_h^3}$

$d_h = 16.14 \approx 18$ mm

Height of screw Head (H) :-

$H_1 = 2\, d_h = 36$ mm

Design of Spring:

1) $S_{ys} = 0.45\, S_{ut}$ for oil hardened and tempered carbon steels & alloys steels.

$= 0.42 S_{ut}$ for cold drawn carbon steel.

$= 0.35 S_{ut}$ for stainless steel and non ferrous alloy

S_{ut} = Ultimate tensile strength, N/mm^2

S_{ys} = Yield strength in shear for spring material, N/mm^2.

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For helical compression and tension springs subjected to static loading, the FOS is taken as 1.5.

$$\tau_{all} = \frac{Sys}{Nf} = \frac{Sys}{1.5}$$

τ_{all} = 0.28 S_{ut} for cold drawn carbon steel

= 0.30 S_{ut} for oil hardened and tempered carbon steel and alloy steel.

= 0.24 S_{ut} for stainless steel and non ferrous alloy.

1. Spring index = Commonly used values of spring index 6 to 12.

2. Wire diameter-

τ_{all}= Allowable shear stress.

C= spring index

d= Wire diameter.

$$\tau = K_w \left[\frac{8FC}{\pi d^2}\right]$$

Stiffness consideration-

$$k = \frac{Gd}{8nc^3}$$

n=Number of active coils.

K = stiffness.

Material	Tensile Properties	
Carbon Steel Oil Tempered Wire	Ultimate Strength MN/mm^2.	Elastic Limit MN/mm^2.
	1070	820

$S_{ys} = 0.45 \times S_{ut} = 481.5\ N/mm^2$.

$$\tau_{all} = \frac{Sys}{Nf} = \frac{Sys}{1.5} = \frac{481.5}{1.5}$$

τ_{all} = 321 N/mm^2.

Spring index = Commonly used values of spring index 5 to 12

Consider C=6

By static loading,

$K_s = 1+\frac{0.5}{c} = 1+\frac{0.5}{6} = 1.08$

$\tau = K_s \left[\frac{8FC}{\pi d^2}\right]$

d = 4.5 mm

By Fatigue Loading,

$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{c}$

K_w = 1.2525

d = 4.87mm

By Static Loading,

$C = \frac{D}{d}$

D = 27≈28 mm

By Fatigue Loading,

D = 6*4.8 = 28.8≈30 mm

$T = \frac{FD}{2}$

T = 6000 N-mm (Fatigue)

$T = \frac{400*28}{2}$

T = 5600 N-mm

Torsional shear stress,

$\tau_t = \frac{16T}{\pi d^3} = \frac{8FD}{\pi d^3}$

τ_t = 276.31 N/mm^2

$\tau_t = \frac{8*400*28}{\pi*4.5^3}$

τ_t = 312.92 N/mm^2

Direct shear stress,

$\tau_t = \frac{4F}{\pi d^2}$

τ_t = 25.15 N/mm^2

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FABRICATION OF COMPONENTS-

I) Lead Screw and Guide Bar

Lead screw also known as a Power Screw or Translation Screw, is a screw used as a linkage in machine, to translate turning motion into linear motion. It has large load carrying capability. It is compact, simple in design, easy to manufacture; no specialized machinery is required, large mechanical advantages. It has low maintenance. Guide bar is used for support the machine& to avoid unbalance problems and for easy to moving of plate.



Figure:-1 Lead Screw

II) PLATES:

Three types of Mild Steel plates is used in this machine. One is sliding plate and Two are fixed plate. Moving plate is move or press by using hand wheel lead screw arrangement.



Figure:- 2 Plates

ASSEMBLY OF COMPONENTS-

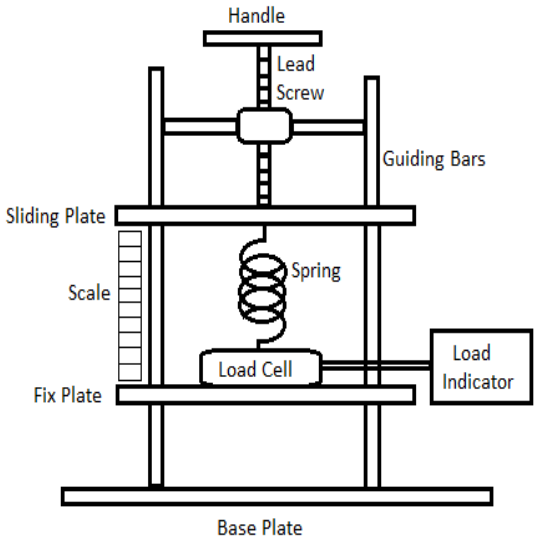


Figure:-3 Assembly

WORKING

The spring is the very important item as we have already explained in the Applications chapter. The machine what we have made is to check the load required to deflect the spring throughout its length step by step & at the final to convert the free length of the sprig in to the solid length.

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Initially the lead nut position is upward. The spring is placed on the base platform. The scale is fitted near the spring. The load cell & the load indicator unit supply are on. The handle is rotated with a moderate speed; the lead screw creates the force on the spring. Reduce the spring length by 5 mm initially. Measure it on the scale provided near the spring. Take the force in Kg. exerted by the lead screw on the spring. Do this procedure another 4 times reducing the spring length by 25 mm. take reading every time on the scale & on the load indicator also. Finally compress whole the spring & make it in to the solid length & take the reading of the force required to make the free length of the spring to the solid length.

Compare it to the manufacturers given spring rate. If the spring rate or the stiffness of the spring measured by our equipment & matching the mfg.rers. Reading then the spring supplied is the correct & its properties, material, chemical composition & heat treatment processes made on it is correct. If the readings are not matching one of the above mentioned is faulty. Hence it is very important to check the spring life as the part life where it used is depends on the spring life. And there is a big risk to use the faulty spring.

CONCLUSION

By using this Digital Spring testing Machine we can conduct Load and deflection test. Applied load and deflection produced in spring is measured by microprocessor and value of spring stiffness is displayed. This machine reduces the checking time and cost.

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APPENDIX

Notation	Description	Unit
C	Spring index	-
D	Nominal diameter of screw	mm
D	Wire diameter of spring	Mm
d_c	Core diameter of screw	Mm
d_h	Diameter of handle	mm
d_m	Mean diameter of screw	mm
D	Mean coil diameter of spring	Mm
D_1	Outer Diameter of the nut	mm
D_2	Outer Diameter of nut collar	mm
F	Axial force on the spring	N
H	Height of the nut	mm
H	Maximum lift	mm
H_1	Height of screw head	mm
K_s	Shear stress concentration factor	-
K_w	Wahl's correction factor	-
L	Lead	Mm
L_H	Length of handle	mm
M	Maximum bending moment	N-mm
N_f	Factor of safety	-
P	Pitch	Mm
P	Effort applied	N
P_b	Bearing pressure between threads	N/mm^2
R_i	Inner radius of collar	Mm
R_o	Radius of screw thread	Mm
S_{yc}	Compressive yield strength	N/mm^2
S_{ys}	Yield strength in shear	N/mm^2
S_{yt}	Tensile yield strength	N/mm^2

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S_{ut}	Ultimate tensile strength	N/mm^2
T_c	Torque required to overcome collar friction	N-mm
T_t	Torque required to overcome thread friction	N-mm
T	Total torque	N-mm
T	Thickness or width of thread at the root	Mm
t_1	Thickness of nut collar	Mm
W	Load	N
Z	Number of threads on nut	-
σ_b	Maximum bending stress	N/mm^2
σ_c	Direct compressive stress	N/mm^2
σ_{bh}	Bending stress induced in handle	N/mm^2
M	Coefficient of friction	-
μ_c	Coefficient of collar friction	-
$\emptyset$	Pressure angle	°
$\lambda \uparrow$	Lead angle	°
τ	Resultant shear stress	N/mm^2
τ_{max}	Maximum shear stress	N/mm^2
τ_d	Direct shear stress	N/mm^2
τ_n	Shear stress induced in the nut thread	N/mm^2
τ_s	Shear stress induced in the screw thread	N/mm^2
τ_t	Torsional shear stress	N/mm^2
τ_{all}	Allowable shear stress	N/mm^2

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