Design Of Mechanical Test Setup To Find The Endurance Limit Of Coil/Compression Spring Using Modified Slider-Crank Mechanism

Harshal Vispute, Akshay Kamane, Vardhan Patil, Suraj Shaha, Santosh Katkar

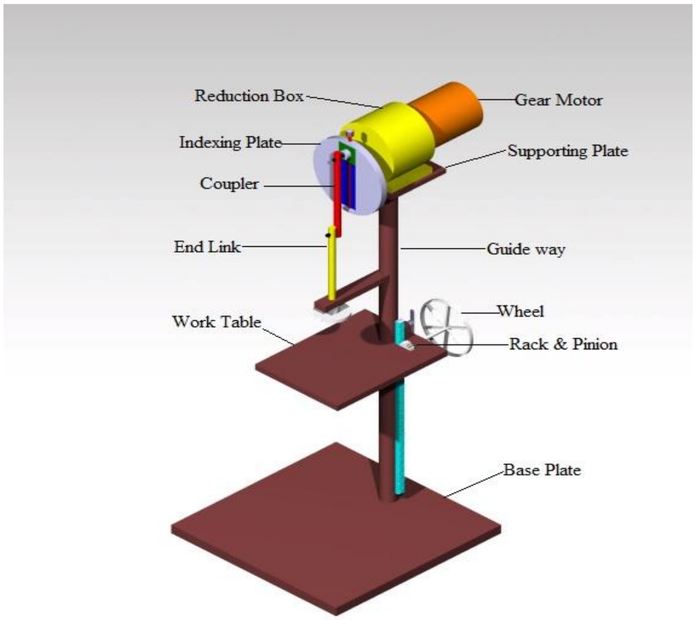
Abstract- A spring is an elastic or resilient body, whose function is to deflect or deform when a load is applied and recover its original shape when the load is removed. The important applications of springs are in application of a force (clutches, brakes etc.), measurement of a force (spring balance), storing energy (clock/toy springs) and absorbing shocks and vibrations (springs in vehicle suspension systems). Fatigue loads are generally cyclic and fluctuating in nature and are much less in magnitude than the yield strength of materials but they tend to have unpredictable behavior due to dissimilar and brutal fracture patterns. To avoid this, determining the endurance limit becomes inevitability. The present paper aims to test the endurance limit of a wide range of coiled/compression springs in the smallest possible time frame using a screw-based modified slider-crank mechanism in a mechanical system.

Keywords- Coiled/Compression Spring, Fatigue Load, Endurance Limit, Modified Slider Crank Mechanism.

1. INTRODUCTION

The springs manufactured have a wide range of applications and hence they have different specifications like coil diameter, wire diameter, spring stiffness, solid length, free length etc. Consequently it becomes necessary to have a testing device which will enable us to have a wide testing range to accommodate the fatigue testing of various particular springs. In order to achieve this, we have used a modified slider crank mechanism using an indexing plate. To have testing of a large variety of springs, we have used a rack and pinion mechanism to adjust the lower level of the springs and keep it fixed. We have taken into account very high cycle fatigue (VHCF) – over 10^8 cycles to failure as the main point of interest in this study. This mechanism has also been developed so as to get maximum number of cycles in the minimum possible time. So overall, it will be a good option for a variety of applications.

2. MODIFIED SLIDER-CRANK MECHANISM

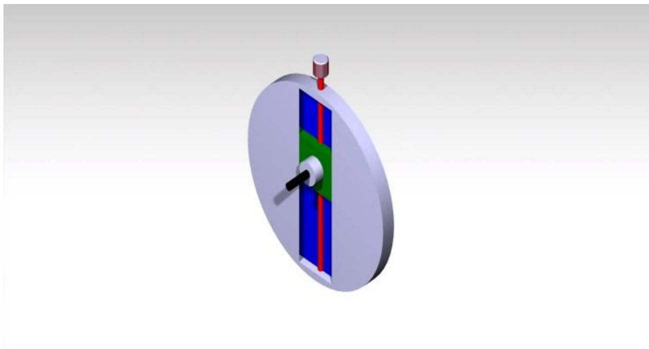


The slider-crank mechanism is modified using an indexing plate. This allows for getting different displacements for different springs. The drive and actuation is provided by an electric motor and a speed reduction box. The lower end of the spring is fixed on the work table and this can be adjusted for different free lengths of springs. The adjustment and locking is provided by means of a rack and pinion mechanism. The coupler is fixed onto the indexing plate according to the required deflection. This is then attached to the end link via a pin.

2.1 MODIFIED INDEXING PLATE

The indexing plate modification is shown in fig.

- *Harshal Vispute, (Former Student), Dept. of Mech. Engg. JSCOE, Pune visputeharsh123@gmail.com*
- *Akshay Kamane, (Former Student), Dept. of Mech. Engg. JSCOE, Pune kamanes7119@gmail.com*
- *Vardhan Patil, (Former Student), Dept. of Mech. Engg. JSCOE, Pune vardhan.4patil@gmail.com*
- *Suraj Shaha, (Former Student), Dept. of Mech. Engg. JSCOE, Pune suraj.shaha02@gmail.com*
- *Santosh Katkar, (Current Student), Dept. of Mech. Engg. JSCOE, Pune katkar.santosh440@gmail.com*



It uses a screw mechanism so as to adjust the required deflection for the testing. Deflection range from 6 mm to 200 mm can be achieved from the following mechanism. A scale is engraved on the plate. The indexing plate is fixed to the output shaft of the reduction gear-box via a key. The screw acts like a guide way for adjusting the scale which in turn helps in adjusting the deflection of the spring upon the application of force. The rotary motion of the screw is converted into vertical longitudinal motion along the guide way. The mechanism is self-locking.

3. LITERATURE REVIEW

- Purushottam Sarjerao Suryawanshi, Prof. T. S. Shikalgar, Swapnil S. Kulkarni, CAE analysis for fatigue failure for coiled spring life enhancement in press machine Stamping operation, Propose new Design and Validate the Design through trials and testing of the Compression Spring for fatigue failure.
- Mr. J. J. Pharne, Dr.R.G.Todkar, Dr.N.D.Sangle, Design, Analysis and Experimental Validation for Fatigue Behaviour of a Helical Compression Spring Used For a Two Wheeler Horn, The experimental results show that at the end of 3 lakh cycles, no cracks or breakages were found in any of the five modified springs under experimental investigation.
- V.Kazymyrovych, Very high cycle fatigue of engineering materials, This paper examines the development and present status of the Very High Cycle Fatigue (VHCF) phenomenon in engineering materials. The concept of ultrasonic fatigue testing is described in light of its historical appearance covering the main principles and equipment variations.
- K. K. Alaneme, Design of a Cantilever Type Rotating Bending Fatigue Testing Machine, This research was centred on the design of a low–cost cantilever type rotating bending fatigue testing machine. On completion and testing, it was observed that the machine has the potential of generating reliable bending stress-number of cycles' data.
- Supriya Burgul, Literature Review on Design, Analysis and Fatigue Life of a Mechanical Spring, Vol.2, July 2014, Long-term fatigue tests on shot peened helical compression springs were conducted by means of a special spring fatigue testing machine at 40 Hz. Test springs were made of three different spring materials – oil hardened and tempered SiCr- and SiCrV-alloyed valve spring steel and stainless steel.

  (With a special test strategy in a test run, up to 500 springs with a wire diameter of d = 3.0 mm or 900 springs with d = 1.6 mm were tested simultaneously at different stress levels. Based on fatigue investigations of springs with d = 3.0 mm up to a number of cycles N = 109 an analysis was done after the test was continued to N = 1.5 _ 109 and their results were compared. The influence of different shot peening conditions were investigated in springs with d = 1.6 mm. Fractured test springs were examined under optical microscope, scanning electron microscope (SEM) and by means of metallographic micro sections in order to analyse the fracture behaviour and the failure mechanisms. The paper includes a comparison of the results of the different spring sizes, materials, number of cycles and shot peening conditions and outlines further investigations in the VHCF-region.. For comparison the results for the springs with d = 1.6 mm and d = 3.0 mm and Ps = 98% are summarised in. Except for springs made of the stainless steel wire, the fatigue strength of springs with d = 3.0 mm is higher than for springs with d = 1.6 mm. The size effect would imply higher fatigue strength for smaller wire diameters.)
- T. Udomphol, Fatigue Testing, Mechanical Metallurgy Laboratory, The fatigue strength of engineering materials is in general lower than their tensile strength. A ratio of the fatigue strength to the tensile strength as described in equation 1 is called the fatigue ratio. It is normally observed that, in the case of steels, the fatigue strength increases in proportional to the tensile stress. Therefore, improving the tensile strength by hardening or other heat treatments normally increases the fatigue strength of the material.

4. DESIGN CALCULATIONS

4.1 For gear motor:

Horse power $= \frac{\textbf{Torqe X RPM}}{\textbf{5250}}$, where torque in lbft.

Torque = force * radius

= 60 * 9.81 * 0.1

=58.86Nm

=43.38 lbft

Considering motor with 1440 RPM with gear reduction 25

Speed of output shaft= 1440/25 = 57.6 rpm

HP=(43.38*57.6)/5250

HP=0.4759

Selecting motor of 0.5 HP with output torque 60 Nm and 55 rpm

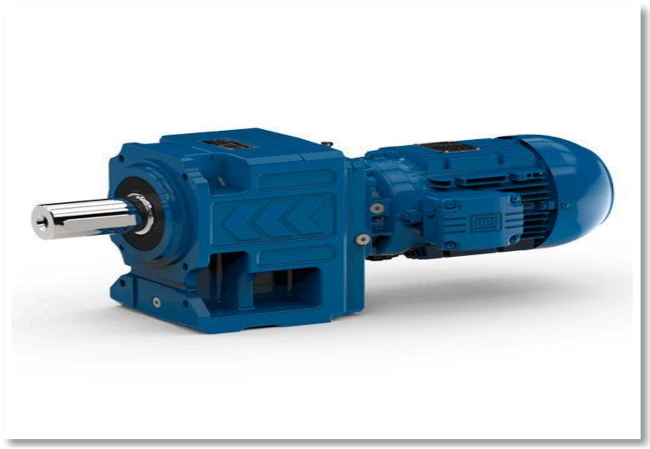


Fig. 4.1 *Gear motor*

4.2 Supporting Bar:

Material C25Mn75
General purpose: low stress component
S_{yt}= 274.68 N/mm^2
FOS=2
Using maximum shear stress theory:
τ = S_{yt}/2
=137.34 N/mm^2
σallowable = 137.34/2
=68.67 N/mm^2
Load on bar= 60Kg = 588.6N≈ 600N

σallowable= $\frac{P}{\frac{\pi X d^2}{4}}$

$$68.67 = \frac{600}{\frac{\pi X d^2}{4}}$$

d_1 = 3.33 mm

<u>***For Buckling:**</u>

Condition for Buckling: One end fixed and one end free

$$P_e = \frac{\pi^2 EI}{4l^2}$$

$$600 = \frac{\pi^2 * 210 * 10^9(\frac{\pi d^4}{64})}{4 * 1.1^2}$$

d_1= 0.013 m
d_1= 13 mm
Selecting d_1 = 50 mm.

4.3. Design of pin:

Material C10
Syt = 21 Kgf/mm^2
=206.01 N/mm^2

<u>***Causes of failure:**</u>

Shear stress:
Maximum force = 50 Kg =490.5 N

$$\tau_{max} = \frac{F_{max}}{\frac{\pi}{4} * d^2}$$

$\tau = \frac{0.5 * S_{yt}}{FOS}$= 57.50 N/mm^2

$$57.50 = \frac{490.5}{\frac{\pi}{4} * d^2}$$

dp = 3.4822 mm
Selecting dp = 10mm

4.4. Design of Coupler:

Material C10
Crushing failure:

$\sigma_c = \frac{F_{max}}{dp * t}$

$166.77 = \frac{490.5}{10 * tc}$

t_c = 3.4 mm

Tensile Failure:

$\sigma_t = \frac{F}{(t - dp) * t}$

$166.77 = \frac{490.5}{(tc - 10) * tc}$

t_c = 10.28 mm
Selecting t_c =15 mm

4.5. Design of End link:

Material C10
Crushing failure:

σc = $\frac{F_{max}}{d * d'}$

166.77= $\frac{490.5}{10 * d'}$

$$d' = 3.4mm$$

Tensile failure:

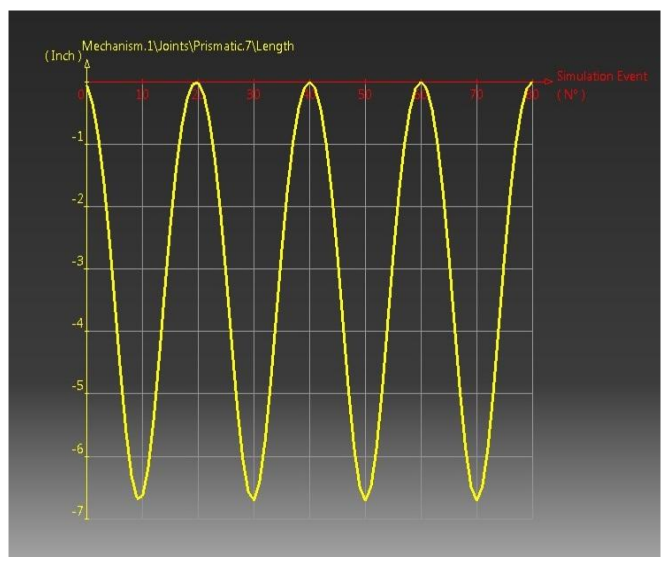
σt = $\frac{F_{max}}{\frac{\pi}{4} * d'^2 - d * d'}$

166.77 = $\frac{490.5}{\frac{\pi}{4} * d'^2 - 10 * d'}$

d'= 13.02 mm
Selecting d'= 20 mm

(MS plates/rods for all part other parts like all mounting and base plates, work table and supporting column.)

5. SIMULATION GRAPH (TO DETERMINE BEHAVIOUR OF TESTING MACHINE)



(Graph 1)

<u>**AXES:-**</u>
x= time (0-20 is 1 cycle and all further intervals are of 20);
y= deflection of spring (inches).

<u>**Explanation:-**</u>
The spring-testing-machine has been developed for the uniform deflection of springs (within a certain range). Before

proceeding to the manufacturing of such a machine however, it becomes imperative to check the simulations in order to determine the system behaviour. This has been done using a simulation interface in CATIA. It gives us a fair understanding of the system behaviour over the entire work-cycle for the testing of a particular spring. It will also help us in determining the system reliability at normal working conditions (which is beyond the scope of this paper).
The behaviour seen via the simulation shows almost equal deflection per cycle and hence encourages us to go through with this design and manufacture this set-up to test compression springs.

6. THE ACTUAL MECHANICAL TEST SET-UP (1:3 MODEL)

Construction:-
A working model (in a ratio of 1:3) of the mechanical testing machine set-up system was manufactured. A DC Motor with an output speed of 30 rpm was used. The indexing plate was manufactured for a diameter of 90 mm. The holes (for 2-way coupling) were done at 15mm, 20mm, 25mm, 30mm, 35mm and 40mm respectively and they gave displacement two times of the distances taken (since diameter=2*radius).The supporting bar was used with a diameter of 25 mm. The coupler was used at a height of 85 mm. and a thickness of 3 mm. The gear motor was mounted on the supporting plate. The diameter of the end link is 8 mm. while its height is 85 mm. The compression plate is used with a diameter of 25mm.

7. BOUGHT OUT PARTS (O.E.M.)

a. Motor:
Make- **Mica Sales and Engineering**
Type- **3 Phase, Gear motor**
Specifications- **0.5 HP, 3 Phase, 50 Hz, 55 RPM, 60Nm**
Cost- **Rs. 10,500.00**

b. Load Cell:
Make-
Type-
Specifications- **0 to 50Kg**
Cost- **Rs. 1,200.00**

c. Counter:
Make-
Type- **8 Digit Display**
Specifications- **0 to 9 Digit counting**
Cost- **Rs. 4,500.00**

8. COST ESTIMATION/ANALYSIS

Sr. No.	Description	Amount (Rs.)
1.	Bought out cost	24,851.00
2.	Process Cost	**8,800.00**
3.	Installation cost	**6,000.00**
4.	Miscellaneous cost	**5,000.00**
	Total cost	**44,651.00**

9. ACTUAL OBSERVATIONS

Parameters	Mechanical System
Cycles Time (Cycles/min)	55

Velocity (m/s)	0.38
Time Required for testing 1 spring (10 lakh cycles)	Days
Return of Investment	Days

10. CONCLUSION

In this manner, we have designed an optimized mechanical set-up using the modified slider-crank mechanism, to test the fatigue life of compression springs using CATIA software as a tool for design and simulations. All modes of failure for the design of key components have been taken into consideration, and the components have been drafted for both performance as well as safety (considering the high work cycles that they will undergo). Further, we have also put the cost estimation/analysis of the actual set-up based on the model that we have manufactured. In conclusion, we have tried to provide a good alternative for the fatigue testing of compression springs under uniform load cycles and over a large range of specifications.

11. FUTURE SCOPE

- This mechanism can be further modified to check the endurance limit of complex automobile suspension springs (non-uniform parameters and progressively increasing spring stiffness).
- Time can be reduced further by giving a more high-speed input of nearly uniform parameters.
- Locking of springs can be provided by a screw arrangement with lateral (radial) and longitudinal flexible conditional adjustments.

12. REFERENCES

[1] “Mechanical Spring”, Richard G. Budynas and J. Keith Nisbett, Shigley’s Mechanical Engineering Design, McGraw-Hill, Ninth Edition.

[2] “CAE Analysis for Fatigue Failure for Coiled Spring Life Enhancement in Press Machine Stamping Operation”, Purushottam Sarjerao Suryawanshi[1], Prof. T.S.Shikalgar[2], Swapnil S. Kulkarni[3], International Journal of advanced Engineering Research and Studies, April-June 2014 (61-63).

[3] “Fatigue”, ASM international Elements of Metallurgy and Engineering Alloys, 2008.

[4] “Design, Analysis and Experimental validation for fatigue behaviour of Helical Compression Spring used for Two Wheeler Horn ”, Mr. J.J.Pharne[1], Dr. R.G.Todkar[2], Dr. N.D.Sangle[3], IOSR Journal of Mechanical and Civil Engineering, Vol. 11, Issue 6 , Nov-Dec 2014 (05-11).

[5] “Literature Review on Design, Analysis and Fatigue Life of a Mechanical Spring”, Supriya Burgul, International Journal of Research in Aeronautical and Mechanical Engineering, Vol.2, July 2014.

[6] “Design Data Book”, PSG Edition, 1978.

[7] www.springer.com

[8] B. Pyttel , I. Brunner, B. Kaiser, C. Berger, M. Mahendran,” Fatigue behaviour of helical compression springs at a very high number of cycles– Investigation of various influences, International Journal of Fatigue, 2013.