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The Design and Fabrication of Spring Testing Apparatus

Adio M.A. and Chapi S.P.
Department of Mechanical Engineering, Federal Polytechnic, Ilaro, Ogun State.
Corresponding author: Adio M.A

Abstract: *A spring testing apparatus has a wide range of uses. Its application is mainly in academic and industriallaboratories. The need to test spring is essentially to determine spring characteristics likestiffness, shear stress twist angles on which other uses of spring are hinged. The apparatus is fabricated from mild steel and measures 750mm by 360mm in dimension. A rectangular hole measuring 600 mm by 90 mm,cut through the centre of the apparatus accommodates the load hanger which measures incremental load of the spring under investigation.Two steel rules, attached on each side of the rectangular hole enable the apparatus to measure the extension of the spring. A Mild Steel base is supported on four rubber bushings and these give the apparatus a firm stand and balance. The springs of different wire diameterswhich include 0.75, 0.73, 0.7 and 0.65 respectively, wereinvestigated.Findings showed that the spring with the highest diameter offered the highest resistance/stiffness to applied load. Also the computed shear stress showed that the spring with the lowest wire diameter offers the highest stress load. This improvised design is quite a useful apparatus in an academic lab in investigating a test spring and has huge industrial and economic values.*

Keywords: *Design, fabrication, spring, and testing*

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I. Introduction

The usual challenge focused on by an Engineer when designing a new machine for economic production, is how to convert new ideas and concepts and make them become reality. This being the case, complicated machines and new techniques have to be constantly re-engineered to make products economically viable for production. However, two key factors to be mindful of in any new designare quality and accuracy of product, Avdhut R. Jadhav et al (2014). Therefore, in designing a spring for any application, stiffness is a very crucial parameter to be considered, having in mind where such a spring is to be used. A spring by definition, is an elastic element of a machine and therefore, its design is considered being mindful of its application and the determination of the crucial element that determines its elasticity.Spring stiffness is a function of force per deflection, and therefore, designing an apparatus to determine this stiffness is therefore, the focus of this design. Furthermore, the method of loading and the removal of load must be crucially considered. Mechanical Spring, is one of the oldest technologies that has found applications in many areas where to and aft motion is required. Springs are used to perform simple and complex tasks such as push pen to suspension systems in automobiles. Therefore, designing and testing of spring for various applications, is key. After production, before installation, each spring must be tested. The stiffness value of each spring must be determined, and it must suit the purpose of usage. Spring is usually an elastic body which compresses if a compressive force or load is applied toit, or it stretches if a tensile load or force is applied. Basically, the purpose is to distort it under load and for it to absorb or release energy based on the conditions of application(Belapurkar and Jadhav, 2015).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 [4]. The focus of this design, first is to give the students hands-on experience in design and fabrication of mechanical equipment, and secondly, to match theory learnt in the classroom to real time practice for economic production.

II. Statement of problem

In the rural environment where the authors work, manufacturers of springs of different sizes and shapes have found it increasingly difficult to test the stiffness of their springs. This challengetherefore, culminated to a session of brainstorming by the authors which gave birth to this simple apparatus to address this challenge. Secondly, there is a synergy gap between the tertiary institutions and the industries in Nigeria, therefore, this breakthrough, will definitely close that gap.

III. Determination OF SPRING STIFFNESS

3.1 Theoretical background

Spring is an elastic machine element whose stiffness is a function of force per unit deflection. It requires application of load to cause this deflection. Therefore, the load required to produce a unit deflection in a spring is defined as:

Torsion of a circular shaft is given as, $\frac{T}{J} = \frac{c.\theta}{L}$

Where, $\theta = \frac{T.L}{J.c} = \frac{T}{J} = \frac{WR.2\pi Rn}{\frac{\pi}{32}\times d^4 c}$, and deflection (δ), is defined as:

$\delta = R.\theta = R\times \frac{64WR^2n}{cd^4}$

$\delta = \frac{64WR^3n}{cd^4}$

Similarly, energy stored in the spring, $u = \frac{1}{2}$ W.δ, and the stiffness of the spring (s), is defined as, $s = \frac{W}{\delta} = \frac{cd^4}{64R^3n}$ (Khurmi and Khurmi, 2008).

Where W= axial load in Newton

R= mean radius of spring coil

C= modulus of rigidity for the spring materials, and

δ= deflection of the spring as a result of axial load n = equals the number of coils, and θ, is the angle of twist in the spring wire, d, is the diameter of spring wire.

3.2 Spring deflection.

Spring deflection, also known as spring travel, depends on the force acting on it. This force could either be a compressive or tensile force, therefore,

Torsion in circular shaft, $\frac{T}{J} = \frac{c.\theta}{L}$

Where, $\theta = \frac{T.L}{J.c} = \frac{T}{J} = \frac{WR.2\pi Rn}{\frac{\pi}{32}\times d^4 c}$, and deflection is defined as,

$\delta = R.\theta = R\times \frac{64WR^2n}{cd^4}$

Therefore deflection of spring, $\delta = \frac{64WR^3n}{cd^4}$ (Khurmi and Khurmi, 2008).

IV. Fabrication Methodology

Springs are generally made from Mild Steel because of its versatility, availability, and low cost, therefore, Mild Steel was selected for the fabrication of the spring apparatus. The mild steel was marked using a scriber and was cut to required dimensions,751mm by 356 mm, using aGuillotine cutting machine. The sharp end was bended backward 10mm to avoid piercingoperator's hand. At the centre of the plate arectangular slotof 610 mm by 90mm was drilled to accommodate load hanger. When loads are placed on the hanger to initiate displacement.Two steel metre rules are each attached to each side of the rectangular slot cut through the centre of theapparatus to measure displacement of the spring upon load application. The vertical rectangular member of the apparatus containing the slot, is screwed to a mild steel base of dimension 360mm by 300mm and the base sits on four rubber bushings, togive the apparatus a firm stand and support.

Table 4.1: Design Analysis.

Part name	**Input**	**Analysis**	**Decision**
Weight of Apparatus	Mass, m= 6.6 kg	w = mg 6.3×9.81	W = 61.8N
Cross sectional area of the rectangular body	Height, h_1 = 750 Base, b_1 = 350	A_1 = h × b 750 × 350	A_1 = 262,500mm^2
$A_{2=}$ Area where metal is cut off	Height, h_2 = 600 Base, b_2 = 90	A_2 = h × b 600 × 90	A_2 = 54,000mm^2
Total Area	A = A_1 - A_2	A = 262,500 - 54,000	A = 208,500mm^2

V. Result

The following results were obtained from the test carried out on six springs of different dimensions and the results are as presented in Table 4 below.

5.1 Table of Values

Specimen dimension:Spring initial height h_1 = 19.94mm, Wire diameter (d) = 0.73mm, Coil diameter (D) = 16.03mm and Number of coils (n) = 28.

Table 5.1: Result obtained from spring sample A

S/N	Mass (g)	Force (N)	Initial height $H_{1(mm)}$	New height $H_{2(mm)}$	Extension $(h_2 - h_{1(mm)})$	Shear stress [τ] N/m^2	Angle of Twist [θ]	Spring stiffness [s]	Spring Deflection δ
1	100	981	19.9	67	47.1	2344	1849658.2	6.7×10^{-8}	1.4×10^{7}
2	200	1962	19.9	102	82.1	4688	3715453.3	6.9×10^{-8}	2.9×10^{7}
3	300	2943	19.9	139	1191	7032	5545004.3	7.5×10^{-8}	4.4×10^{7}
4	400	3924	19.9	177	157.1	9376	7430259.6	7.9×10^{-8}	5.9×10^{7}
5	500	4905	19.9	206	186.1	11720	9287824.5	8.5×10^{-8}	7.4×10^{7}
6	600	5886	19.9	247	227.1	14064	11145389.4	8.9×10^{-8}	8.9×10^{8}
7	700	6867	19.9	287	267.1	16409	13005039.7	9.2×10^{-8}	1.0×10^{8}

Specimen B dimensions:
Spring initial height h_1 = 84.20mm, Wire diameter (d) = 0.75mm, Coil diameter (D) = 9.36mm Number of coil (n) = 120

Table 5.2: Result obtained from spring sample B

S/N	Mass (g)	Force (N)	Initial height $H_{1(mm)}$	New height $H_{2(mm)}$	Extension $(h_2 - h_{1(mm)})$	Shear stress [τ] N/m^2	Angle of Twist [θ]	Spring stiffness [s]	Spring Deflection δ
1	100	981	84.2	86	1.8	2229.8	31772.8	5.0×10^{-8}	1.9×10^{7}
2	200	1962	84.2	95	10.8	4459.1	63545.5	2.5×10^{-8}	3.9×10^{7}
3	300	2943	84.2	147	62.8	6688.6	95300.3	1.6×10^{-8}	5.9×10^{7}
4	400	3924	84.2	180	95.8	8918.2	127067	1.2×10^{-8}	7.9×10^{7}
5	500	4905	84.2	210	125.8	11147.7	158833.5	1.0×10^{-8}	9.9×10^{7}
6	600	5886	84.2	241	156.8	13377.3	190600.5	8.3×10^{-9}	1.1×10^{8}
7	700	6867	84.2	273	188.8	15606.8	222367.3	7.1×10^{-9}	1.3×10^{8}

Specimen C dimension;
Spring initial height h_1 = 95mm, Wire diameter (d) = 0.50mm, Coil diameter (D) = 6.85mm Number of coil (N) = 180

Table 5.3: Result obtained from spring sample C

S/N	Mass (g)	Force (N)	Initial height $H_{1(mm)}$	New height $H_{2(mm)}$	Extension $(h_2 - h_{1(mm)})$	Shear stress [τ] N/m^2	Angle of Twist [θ]	Spring stiffness [s]	Spring Deflection δ
1	100	981	87.9	108	19.1	4618.6	11036778.80	$0.3\ 10^{-0}$	1.8×10^{7}
2	200	1962	87.9	141	54.1	9237.3	22073557.59	1.5×10^{-8}	3.7×10^{7}
3	300	2943	87.9	177	89.1	13855.9	33110336.39	3.0×10^{-8}	5.5×10^{7}
4	400	3924	87.9	211	123.1	18474.6	4414 7115.1	7.9×10^{-9}	7.4×10^{7}
5	500	4905	87.9	246	158.1	23093.2	39055570.2	6.3×10^{-9}	9.3×10^{7}
6	600	5886	87.9	281	193.1	27711.9	46866684.3	5.3×10^{-9}	1.1×10^{8}
7	700	6867	87.9	314	226.1	32330.5	54677798.3	7.6×10^{-9}	1.3×10^{8}

Specimen D dimension
Spring initial height h_1 = 87.94mm, Wire diameter (d) = 0.52mm, Coil diameter (D) = 5.67mmNumber of coil (N) = 171

Table 5.4: Result obtained from spring sample D

S/N	Mass (g)	Force (N)	Initial height $H_{1(mm)}$	New height $H_{2(mm)}$	Extension ($h_2 - h_{1(mm)}$)	Shear stress [τ] N/m^2	Angle of Twist [θ]	Spring stiffness [s]	Spring Deflection δ
1	100	981	95.0	149	54	1070.6	61650	9675.5	211151.1
2	200	1962	95.0	210	115	9994.9	123300	19351.1	422302.5
3	300	2943	95.0	273	178	14992.4	184950	29026.2	633453.8
4	400	3924	95.0	337	242	19989.8	246600	38702.1	844605.0
5	500	4905	95.0	400	305	24987.3	308250	48377.7	1055756.3
6	600	5886	95.0	469	374	29984.7	369900	58053.3	1266907.5
7	700	6867	95.0	523	428	34982.2	431550	67728.7	1478058.8

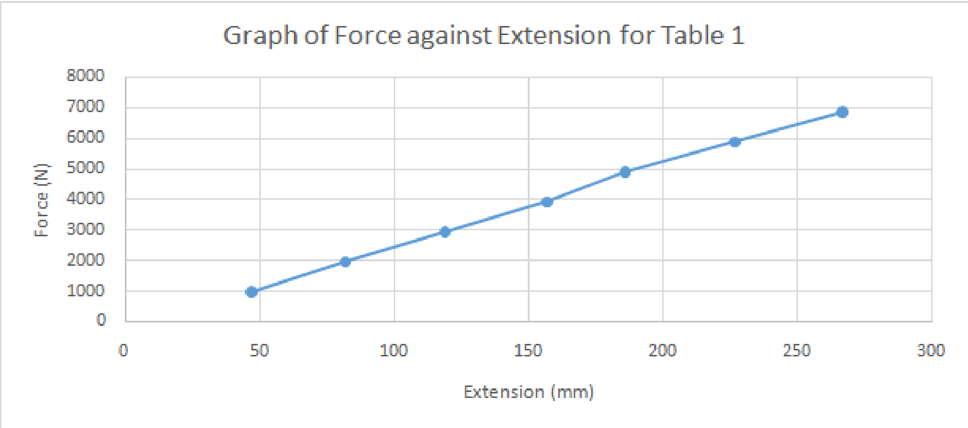

Fig 5.1: Graph of Force against Extension for Table 1

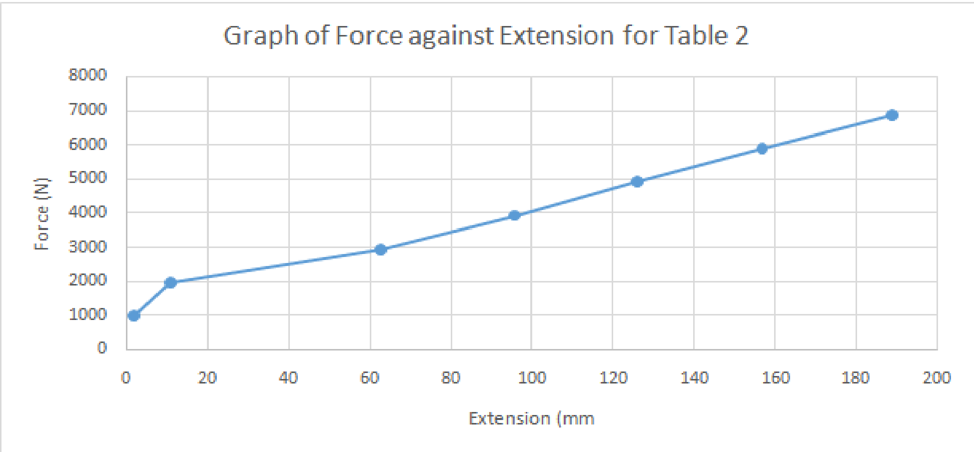

Fig 5.2: Graph of Force against Extension for table 2

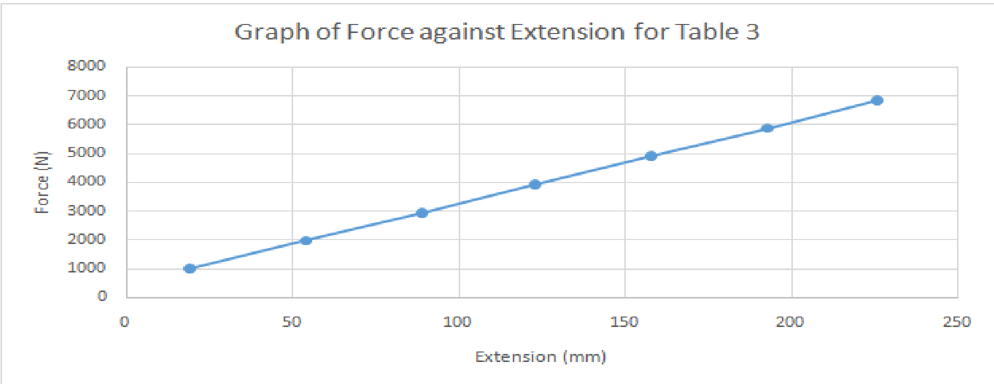

Fig 5.3: Graph of force against extension for table 3

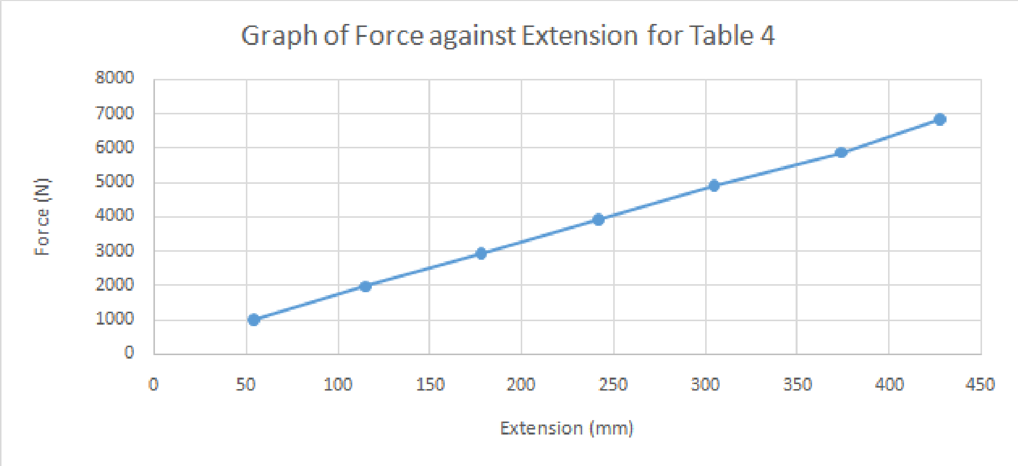

Fig 5.4: Graph of Force against Extension for table 4

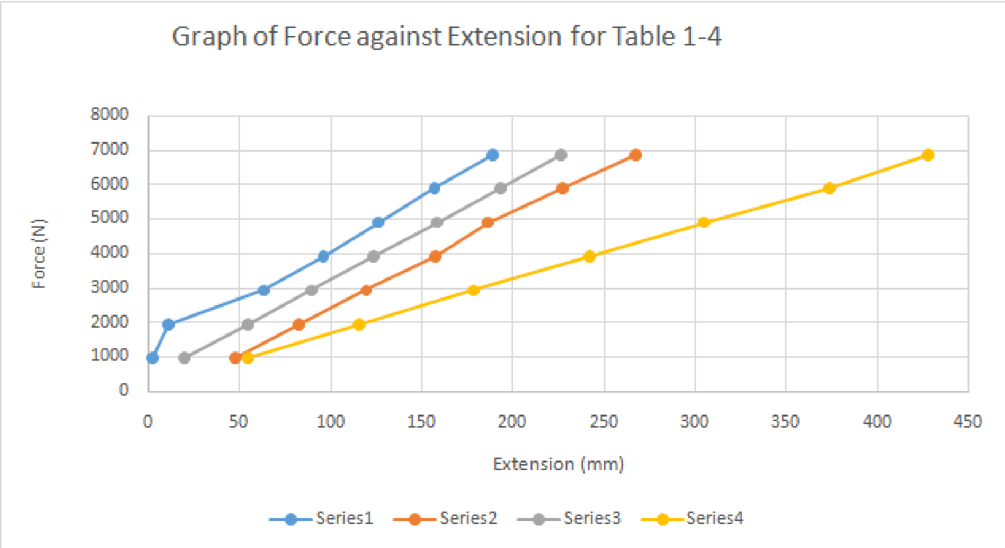

Fig 5.5: Graph of Force against Extension for Table 1-4

VI. Discussion

The spring apparatus was tested with different spring samples. The results were presented in the table 5.1-tables 5.4 above. From the test trials on each spring, an increment in load from 100- 700g produced an appreciable increase in length for each of the springstested. The spring with the highest wire diameter of 0.75mm,offers the highest resistance (spring stiffness) to applied load, as opposed to the spring with the lower wire diameters of 0.50mm, 0.52mm and 0.73mm respectively. This agrees with one of the principles of spring design, which states that 'the heavier the wire, the stronger the spring'.

The computed values of shear stresses for the four springs tested using the apparatus, indicated that since shear stress is a function of the ratio of applied load to area, therefore, it was observed that the higher the wire diameter (d) the lower the stress acting on the spring. At maximum load of 700g for the sample springs of wire diameters ranging between 0.50 mm and 0.75mm, the corresponding values obtained for shear stresses, also range between 32330.51N/m^2 and 15606.81N/m^2. From these values, it is clear that the spring with minimum or least value of wire diameter has the highest shear stress value i.e., the value of shear stress decreases as the wire diameter increases. This clearly shows that, the wire diameter affects the value of shear stress in springs.

Similarly, the computed valuesforan angle of twist for the four springs tested depends on the axial load, mean radius, number of coils and wire diameter. Since an incremental force applied on the four springs was of the same magnitude as an infinitesimal difference in wire diameter as well asmean diameter,the variations in the value of angle of twist is therefore as a result of thesignificant difference in the number of coils which is n= 28 for sample A, n=120 for sample B, n= 180 for sample C and n= 171 for sample D respectively. Also, the angle of twist provides us with an insight or gives us an idea of the expected value of deflection, by multiplying the value obtained for the angle of twist with the mean radius(Deflection = mean radius x angle of twist).

The computed value of spring deflection for the four spring tested using the apparatus indicates that since deflection is a function of spring distortion, therefore, all the springs were subjected to same load value,at maximum load of 700g for the spring tested. It was noted that the spring with the wire diameter and coil diameter of 0.52mm and 5.67mm has the highest deflection (spring travel) to load applied as opposed to the other springs of diameters 0.50mm; 6.85mm, 0.52mm; 5.67mm, and 0.73mm; 16.03mm respectively.

5.2Application

This apparatus is used to measure the stiffness of coil springs with different diameters. It can also be used by students in the strength of materials or materials testing lab to perform simple test on springs to deepen their knowledge of the course. It can as well be used by spring manufacturing companies to determine the strength of their springs. With this apparatus, comparison can be made of the stiffness of the test spring with the standard one.

5.3Advantages of the Spring Testing Apparatus

The following advantages can be derived from using this apparatus:

- It is very handy and can be moved to any location.
- Springs of different diameters can be tested using this apparatus.
- No assistance is required to use this apparatus i.e., one person can run test on this machine.
- This machine does not require any special skills or expertise to use.
- This machine can only test spring or wire diameters ranging between 0.75, 0.73, 0.70 and 0.65, respectively.

VII. Conclusion

The most significant performance characteristic of spring,is its stiffness, in any area of engineering where spring application is necessary. The results analysed in this research showed a trend which agrees with the principle of spring design, drawing inferences from tests run with the following spring diameters: 0.75, 0.73, 0.70 and 0.65, respectively. The larger thewire spring diameter, the stronger the spring. From the results of the various test- runs using this apparatus, it is clearly seen that to design a spring for any application for that matter, no assumptions should be made to either underestimate or overestimate this critical characteristic of spring- stiffness before selecting it for any typical use.

Plate 1: Spring Testing Apparatus

Plate 2: Spring Testing Apparatus

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