

Design and Development of Spring Stiffness Measuring Instrument

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Abstract - Springs are inevitable part in many mechanical systems. Currently spring stiffness measurement is carried out mostly using some mechanical devices with hydraulic systems and analog measuring instruments. But these systems are much more costly for smaller industries. This paper presents a work of designing and fabrication of a small scale spring stiffness measuring machine. Here load application is done by conventional method, i.e. using hydraulic system. Use of sound sensors instead of scales and gauges makes it more compact and less expensive than any other apparatus. Additionally, using electronic components make this system flexible for more add-ons and gives better user interface. All the components used for this system are available in low cost. At the end, the results of measurement of stiffness by using machine and by theoretical method are compared.

Keywords: Spring, Stiffness, Sound Sensor, Load Cell

I. INTRODUCTION

A spring is an elastic machine element, which deflects under the action of the load and returns to its original shape when the load is removed. Spring can take any shape and form depending upon the application [6]. Before using any spring for different applications it is required to measure stiffness of that spring. The machines available to measure the stiffness are costlier as well as time consuming. So they are not suitable for small scale industries. So it was required to design instrument which can measure stiffness of spring with low cost.

II. LITERATURE REVIEW

Generally spring stiffness is measured on Universal testing Machine. But for large scale that method is not appropriate. Few machines attempt to measure the spring stiffness by hydraulic means. It consists of a lever operated hydraulic piston cylinder arrangement. Deflection is measured manually using scale. Spring is compressed by hydraulically operated piston by pressing it against a rigid support [5].

In some machines, attempts have made to measure the spring stiffness by combining two hydraulic piston cylinder systems. The setup is horizontal. It consists of a large cylinder, small cylinder, load gauge, scale, frame etc. Large cylinder applies force through piston on the spring mounted between small and large pistons. Spring is placed inside the cylindrical support. The force applied by large cylinder is measured by the load gauge fitted at smaller cylinder and deflection is observed on scale provided near the spring.

Load gauge reading and scale reading are used to find stiffness of the spring manually [4].

In some recent attempts, efforts are taken to make an automated spring stiffness testing machine. Hydraulic jack, Load cell, LVDT, along with LCD display is provided. But due to LVDT, structure became big in size. So it was suggested to use microcontroller to make it simpler [3].

III. METHODOLOGY

Spring stiffness measuring instrument is mainly consist of following elements

1. Hydraulic Jack
2. Arduino
3. Load Cell
4. Ultrasonic Sensor
5. HX – 711 bridge

Force required to produce deflection in spring is generated by using hydraulic jack. Circular platform is attached to rod of hydraulic jack, on which spring rest. As load is applied, spring start to deflect. Function of load cell is to measure applied load. It is firmly mounted on rod of hydraulic jack. According to Newton's third law, every action has equal and opposite reaction. Thus, as piston rod moves up, compresses spring with some force, reactive force acts on load cell which measures the magnitude of applied force. Ultrasonic sensor is used to measure deflection of spring. It is fixed to steel platform mounted on load cell. HX - 711 Module is the 24 – bit analog to digital converter (ADC) for weigh scales and industrial control applications to interface directly with a Module sensor.

At the end, inputs of load cell and ultrasonic sensor are supplied to Arduino. Arduino is microcontroller which performs arithmetic operations on inputs supplied to it and output is directly displayed on display.

IV. MANUFACTURING

A. Fabrication

At the beginning frame is manufactured. Then plate is attached to jack. Then mounting of load cell to hydraulic jack is done. Since most of springs height lies between ranges of 15 cm to 25 cm, a stand is prepared which will accommodate a spring of height between 25 cm to 30 cm.

A rectangular plate of size 20 mm * 15mm is welded to support stand. Before that 2 holes are drilled in it. And jack is bolted to that plate.

It is necessary to bolt load cell to rod with the help of allen nuts. For this hole of diameter 10 mm is drilled in rod, to which small rectangular chip is bolted. Before bolting plate, 3 holes are drilled in chip. To this chip, 3 holes are rimmed to which load cell is mounted. At other end of load cell, platform (circular disc of diameter 20 cm) is attached.



Fig. 1 Mounting of load cell to hydraulic jack

B. Circuits

It is required to integrate both sensors, so microcontroller can receive data and process them in such a way that the value of require result will be displayed on circuit without error. Breadboard has been given a VCC and GND supply initially. Common connections for both the sensors and display are +5V dc supply and ground terminal which are provided efficiently with the help of Breadboard.

The wiring for circuit is as shown in picture below.

1. Load Cell: The output from load cell is in form of four wires which are connected to the input pins on the ADC (HX711) and the ADC is further gives two way output as Clock and Digital Signal from pins SCK and DT which further connected to microcontroller.
2. Ultrasonic Sensor: Ultrasonic sensor connected with microcontroller with two terminals as Trigger pin and Echo pin and two another pins for supply and ground.
3. Display: Display is connected to Arduino with total 7 wires and a terminal each four of them are data transmission lines and remaining are data handling instruction lines (RS, RW, E). Display is also connected with a variable resistance in order to obtain clear output.

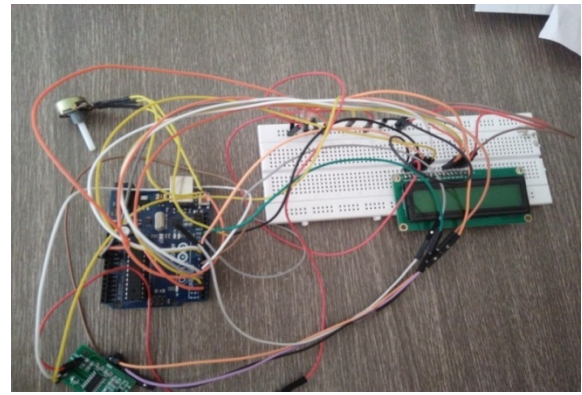


Fig. 2 Electronic Circuit

V. TESTING AND RESULT

A. Experimental Spring Stiffness

Once all setup get ready then 2 helical springs from industry brought for testing purpose. Those springs further mounted on the setup using jack in such a way that initial displacement must be zero at the start. By application of strokes further displacement of the base platform directly sensed by the ultrasonic sensor and thus value for stiffness is directly displayed on the display.



Fig. 3 Stiffness Value: Spring I



Fig. 4 Stiffness Value: Spring II

B. Theoretical Spring Stiffness Calculations

1. Deflection:

$$\delta = \frac{8PD^3N}{Gd^4}$$

Where,

P = applied load in “N”

D = Mean coil diameter in “mm”

d = spring coil diameter or wire diameter in “mm”

G = modulus of rigidity in “N/mm²”

N = Number of active turns

2. Stiffness:

$$\text{stiffness} = \frac{\text{load}}{\text{deflection}}$$

Stiffness of spring is calculated by using these two formulae.

Spring I:

D = 50mm

d = 7.5mm

N = 13

$$\delta = \frac{8PD^3N}{Gd^4}$$

$$\delta = \frac{8 * 1000 * 50^3 * 13}{87500 * 7.5^4}$$

$$\delta = 46.95 \text{ mm}$$

$$\text{Stiffness} = \frac{\text{Load}}{\text{deflection}} = \frac{1000}{46.95} = 21.29 \text{ N/mm}$$

Spring II:

D = 25mm

d = 4.5mm

N = 17

$$\delta = \frac{8PD^3N}{Gd^4}$$

$$\delta = \frac{8 * 1000 * 25^3 * 17}{87500 * 4.5^4}$$

$$\delta = 59.22 \text{ mm}$$

$$\text{Stiffness} = \frac{\text{Load}}{\text{deflection}} = \frac{1000}{59.22} = 16.88 \text{ N/mm}$$

TABLE I COMPARISON OF EXPERIMENTAL AND THEORETICAL STIFFNESS VALUE

Stiffness	Spring I N/mm	Spring II N/mm
Experimental	20.34	16.23
Theoretical	21.29	16.88

VI. DISCUSSION ON RESULT

Observing the results, it is found that, only 4.46% error in spring I and 3.85 % error in spring II occurred. So, it is clear that the error in stiffness measurement is very less and can be accepted.

The slight fluctuation in values of force and displacement are due to higher sensitivity of the sensors and high sampling rate per unit time which is necessary for accuracy point of view. Also Arduino have some processing limitation causing some minor error.

VII. CONCLUSION

Purpose of this work is to make a low cost instrument which must be capable of calculating stiffness of spring well satisfied keeping the accuracy. Combination of mechanical plus electronic component makes it easy to operate, compact mainly faster and accurate. Both input and output modules are easily integrated with microcontroller (Arduino) which forms complete system. A display is provisioned so that real time values of influence parameters (displacement, force) and result as stiffness is displayed which makes it user friendly. The compactness and accuracy makes it suitable for industrial use. With some more work on it can make it ready for commercial use.

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