Modern Hydraulic Operated Spring Stiffness Testing Machine

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Abstract—In many engineering machines and mechanisms spring is an essential component used for proper functioning of that machine for maximum efficiency, there are many applications of springs in automobile suspension system, IC engine valves, two wheeler horns, brakes, clutches, measurements of weights, for storing energy such as in spring type accumulator, in shock absorber, in hydraulic components such as hydraulic cylinders, pressure relief valves, flow control valves etc. But according to the our market survey and observations sometimes spring used in above applications having a many defects such as manufacturing defects, processing defects like defects occurs at the time of hardening sometimes this causes the more hardened spring which has more stiffness value and sometimes causes a less stiffness value of spring, hence this creates a problems on the applications of the springs for proper uses and creates a problems in working of that machine components. So by considering the above problems we manufactured a spring as well as material testing machine, so the purpose of this machine is to measure the stiffness of (spring constant) of helical compression springs as well as tension springs and also of leaf springs. And also this machine is manufactured according to the actual problems arises to the users of springs for checking their spring for stiffness values and also we can get the compression test for material on this machine.

Keywords—Compression test, Deflection, Load, Material Testing, Spring, Stiffness.

I. INTRODUCTION

The design, manufacture and use of springs can be traced back in time to the Bronze Age. Spring design is a science based on complex arithmetic calculations combined with material science. Springs are used in everyday consumer devices including cellular phones and computers they are used widely in industrial applications including automotive and aerospace they are used in precision medical devices where a spring, having a diameter of 0.0036 inch (about equal to the size of a human hair), is used in catheters and endoscopic instruments.

While the wheel is often considered one of the most important inventions ever, the spring is arguably as equally important and with spring design constantly evolving and requiring more advanced testing and tolerance. Helical compression springs and tensions springs are used widely all over the world and they are primary machine elements of suspension system of vehicles, measurements system such as in weighing machine, IC engine valves, different hydraulic valves etc. But spring used in in above applications have different configuration such as different diameters of coil, solid length, free length, stiffness values, etc. So it must be necessary that to manufacture a testing rig. This can have wide range of testing of spring and material for testing variety of spring we can avail the facility for adjusting the height of spring for different spring for different height. Spring and material testing rig.is a machine in which compression springs are compressed and tension springs are stretched for measuring the load and deflection. When springs are compressed or get stretched by exerting force on it then length of spring get increased in case of tension spring and decrease in case of compression spring proportional to the force applied on it. The ratio of the load and deflection of spring is termed as stiffness.

According to the latest and today’s world technology advances goes on beyond the expectations of simple technical person thinks, so it is difficult to stay upgrade according to changes. Mechanical system are changes to mechatronics system, hence more precision and accuracy is needed from mechatronics system so according to the requirements of market we can decided and manufactured the spring testing machine with high precision and accuracy by using good design of machine. Hence the purpose of this machine determining a spring’s characteristics and validating a spring’s performance is critical to ensuring that the spring will perform to its specification over its intended life-cycle for its intended application and calculating the stiffness of spring(Spring Constant).
II. PROBLEM DEFINITION

In today’s growing market there are many companies which uses the springs and spring are the main components in their products/machines components in which they installed the springs but one major problem arises reference to the checking the stiffness of the spring because spring uses for installation have different diameters, different height and different shapes and also for checking the stiffness of spring more time is required and also initial investment hence ultimately the cost of testing more. And also testing machine has high maintenance and operational cost and also time is very important factor which affects the productivity of industries and it is important to achieve precision and accuracy hence we manufactured this machine to optimize everything with new methods.

III. OBJECTIVES OF SPRING STIFFNESS TESTING MACHINE

1. Main objectives of this machine/ test rig are to checking the stiffness of spring with higher accuracy and precision.
2. Designing and constructing a spring stiffness test rig that is capable of testing a various types of springs of different height, diameters and of materials and also it is capable to taking a compression test on it.
3. To reduce the time required for testing and increase the profit of industries and also to reduce inventory and investment cost and to avoid fatigue to workers.

IV. WORKING PRINCIPLE

Working principle of this machine is based on the hooks law and Pascal’s law, because for the application of load on the spring i.e. to compress the spring hydraulic jack is used. Hydraulic jack has a lever on it and force is applied by that lever and this force is also multiplied by many times and hence it requires less effort. Due to this multiplied force plunger compresses the liquid i.e. oil and also this pressurized fluid will goes between the plunger and piston. And this pressurized fluid forces the piston, and due to the forces coming on the piston and piston rod which is much larger than the forces acting on the plunger with the help of lever; piston rod moves outwards and applies the forces on spring and then spring get compresses. When we open the pressure relief valve pressurized fluid get release into the reservoir and spring gets its original position due to the springing action and piston of hydraulic jack is come at its initial position i.e.at no load condition.

One of the basic principles of a spring is to withstand a force while having the ability to compress or extend and then return to its original position or shape.

Robert Hooke, a 17th century British physicist, determined that that the extension of a spring is in direct proportion with the load applied to it. Hooke’s Law, named after Robert Hooke, and is often used in spring design. The most commonly form of Hooke’s law is probably the spring equation, which relates the force exerted by a spring to the distance it is stretched or compressed by a spring constant, $k$, measured in force per length. And also hooks law are applicable to helical compression spring.

![Figure 1: Working Principal](image)

Equation:

$$ F = -kx \quad (1) $$

Where

- $x$ - Displacement of the spring’s end from its equilibrium position
- $F$ - Restoring force exerted by the spring on that end
- $k$ - Constant called the rate or spring constant (STIFFNESS).

Forces coming on the spring are measures with the help of the load cell which is connected in the machine setup. And it is used to calculate the stiffness of spring.
V. CONSTRUCTION

Above figure 2 shows the detail construction of the spring stiffness testing rig. And this machine has many components such as Frame, Height Adjuster Plate, Load cell, Hydraulic Jack, LM Guide, Digital Scale, etc. Details of each are as follows.

A. FRAME-

In this test rig two frames are used one is outer frame and other is inner frame, details of that are as follows.

1) Outer Frame

In this setup outer frame consist of the ‘base plate’ for the foundation, support and for mounting of hydraulic jack, and on the base plate two vertical of channel are provided because for fitting the ‘lm guide’ as well as channel has more rigidity and toughness and on the application of load it does not deflect very easily, material used for the base plate is hot rolled steel plate.

Dimensions of the base plate are 400*210*20 mm and also vertical column are made up of the structural steel material. And dimensions of the vertical columns of channels used are 70*40*5 mm. And on the vertical columns there are some holes are provided for the adjusting the height for the moving plate. And holes of 12 mm diameter are provided with difference of 50 mm from each other on the both column and also 6 mm holes are provided on the both vertical column for the fitting of ‘LM guide’.

2) Inner Frame

Figure 4 shows the CAD model of ‘Inner Frame’, Inner frame used in this setup has a vertical rectangular type of shape, steel strip is used for the fabrication of the frame for vertical edges and channels are used at the top edge and at bottom edge.
On the inner frame at the bottom, base is provided for the placing the spring for testing with the help of the channels and steel plate. And also at the top of the frame one hook is provided for the placing the tension spring for tension testing. And also at the bottom of the frame load cell are attached to calculate the load.

B. Height Adjuster (Moving Plate)

Figure 5 shows CAD model of moving plate moving plate, it is provided in this set up for the adjusting the different type of spring of different height for testing purpose on which base is provided for support the helical compression spring from bottom side. Hook is provided at the top side for the testing of tension spring. It is made up from channel and structural steel material is used.

C. Load Cell

Figure 6: Load cell

The heart of any weighing system is the load cell and figure 6 shows the load cell, whilst they are not exciting to watch, load cells is highly accurate transducer which provides the user with information not generally obtainable by other technology due to commercial factors. Load cells are designed to sense force or weight under a wide range of adverse condition; they are not only the most essential part of an electronic weighing system, but also the most vulnerable.

In today’s world accuracy and precision is must be necessary for better results and for improving the system effectively hence to calculate the load applied or exerted by spring accurately and precisely we provided load cell. Load cell used in this setup has a capacity of 500 kg. I.e. 4905 n of force and it gives quick response to change in load magnitude, and load cell used in this setup is cantilever type, and load cell is also attached to the electronic circuit and display which is well calibrated and which shows the correct reading of the load at any instant. Load cell has a very good least count for load i.e. 10 gm.

D. Hydraulic Jack

Figure 7 shows Hydraulic jack. Hydraulic jack used in this setup is single acting type of cylinder and it has a capacity to exert 2 tons of force i.e. 2000 kg.
Force, at the time of loading of spring load is applied with the help of the hydraulic jack. Hydraulic jack used in this setup is lever operated which required only 200N of force for lever operation. Maximum stroke length of hydraulic cylinder is 150mm.

With this features, linear guide ways can greatly enhance moving accuracy, it is true when accompanied with precision ball screws.

A linear guide ways allows a type of linear motion that utilizes rolling balls. By using circulating balls between the rail and the block, a linear guide ways can achieve high precision linear motion. Compare to a traditional slide, the coefficient of friction for a linear guide way is only a 1/50th. Because of the restraint effect between the rail and the blocks, linear guide ways can take a load in both the up and down and the left and right direction.

Figure 8 shows LM Guide, In this setup ‘LM guide’ is very important because it eliminate all that conventional method of guide and bushes because guide and bushes has a more friction when compared with the ‘LM guide’. Lm guide has a two parts i.e. ‘LM block’ and ‘LM rail’.

In this setup ‘LM guide’ connects the outer frame and inner frame hence there is no effects on the reading of load exerted by spring because ‘lm guide’ eliminate the friction between the ‘lm rail’ and ‘LM block’. Since inner frame and outer frame moves freely upward and downward relative to each other with it’s self-weight.

F. Linear Transducer (Digital Scale-Magnetic scale)

Figure 9 shows the Digital Scale, it is very precise and accurate for the giving its output corresponding to its input and its fluctuations, the linear encoder is based on the magneto resistive sensing principle. The read head detects the magnetic signature of the magnetised scale as it moves over it. The analogue signals are then processed to produce a range of digital resolutions to 1 μm. The system is suitable for linear and partial arc applications.
VI. METHODOLOGY

1. Firstly take the spring which is to be checked for determining its stiffness value.
2. Check whether it is tension spring or compression spring.
3. Adjust the height adjuster plate/ moving plate according to the height of spring with minimum clearance possible between spring end and moving plate for accurate result of displacement of spring.
4. Close the pressure relief valve and then give some load up to 10 to 20 gm. To ensure the contact of spring ends with its supports.
5. Then set load at zero by using tare button provided on load cell display panel.
6. Then by using lever apply the load gradually on the spring and compress to it and then take the reading of load and displacement of spring.

Use the following formulae to calculate the stiffness of spring.

\[ \text{Stiffness} = \frac{\text{load}}{\text{deflection}} \]

7. Follow the above procedure more than one time and take the reading at different loads and deflections to calculate the stiffness of spring more accurately and precisely.

VII. ADVANTAGES

1. On this machine non-destructive type of testing of spring is possible because we can check the spring without damaging to the spring.
2. We can check the springs of different diameters and of different heights and materials.
3. Time required for the testing of spring is very less ultimately it reduces the testing cost and increases the testing rate.
4. This machine requires only one person for handling and testing.
5. Lm (linear motion) guide is used in this setup which is self-lubricant hence this machine system is self-lubricating.
6. There is no any rotating parts, no more friction between parts hence the system is always noiseless.
7. This machine is also easy to handle hence the semiskilled or unskilled person can get test on spring very easily.
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8. This machine has a compact size and weight of machine is very less hence it is portable in nature and mobile anywhere easily.

VIII. DISADVANTAGES
1. External power supply (electrical supply) is required to calculate the load applied on the spring, because the load cell is used to shows the load on display.
2. As in this setup hydraulic jack is used there may be a chances of hydraulic leakages hence the periodic inspection, maintenance and refilling of oil is necessary.
3. Proper reading of load and displacement is necessary.

IX. CONCLUSION
In this machine setup we have designed and also optimizes the conventional type of setup to modern type of setup by using the LM guide which reduces the friction and also helps to gives to accurate results hence by using LM guide performance of this machine is improved and this machine reduces the time of testing and ultimately it supports to reduces the cost of the testing. We can test the spring of minimum height of 50 mm also. This machine is very accurate and precise in nature.

X. FUTURE SCOPE
In future this machine will be very useful, by using the microprocessor and controllers we can make full automation for the testing of spring and also in future this machine will use for materials testing as well as fatigue testing of aluminum tubes by using suitable fixture.

REFERENCES