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DESIGN OF A SPRING TEST DEVICE FOR URBAN TRAINS APPLICATION

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Abstract. The objective of this work is to design a spring compression test device for the preventive maintenance of urban trains, but can later be adapted for any application within the industrial and transport areas. In order to achieve this purpose, a series of calculations were initially performed for the sizing of the fundamental parts of the device. For the mechanical parts, 1020 steel crown screws and 1020 steel bases were selected, as well as a CS type load cell. In the acquisition system, we selected encoders, strain gage and Motorola MC68HC908QY4 microcontroller. Thus, we conclude that it is possible to design a reliable and concise test device for urban train suspension springs, enabling real savings on maintenance costs within the urban train transport system.

Keywords: Mechanical tests, springs, urban trains.

1. INTRODUCTION

Scheduled mechanical maintenance is a fundamental part of engineering. It is divided into preventive maintenance and corrective maintenance (Fogliatto, 2009). The most efficient way to avoid potential problems in any system is to pay proper attention and care to preventive maintenance, which is generally less costly and less aggressive to the system.

In addition to this, testing devices are widely used for material evaluation. Stolz et al. (2016), for example, developed and validated a device for testing shear bond strength in mortar coatings, while Silva Filho (2017) developed a biaxial traction device for mechanical testing of materials from the solutions presented in the literature, finally Morais et al. (2018) developed a universal hole testing device for destructive mechanical testing

Besides that, city trains have a spring system in their suspension, these devices usually have a replacement routine due to programmed wear, which is strictly adhered to, but in some cases the replacement of the part is done without the apparent real need. because they do not have a testing routine to measure their replacement requirements.

With this in mind, the aim of this paper is to design a spring testing device for the preventive maintenance of city trains, but can later be adapted for any application in the industrial and transport areas, allowing real savings in relation to maintenance costs. within the urban train transport system.

2. THEORETICAL REFERENCES

2.1. Mechanical springs

In general, springs are classified as wire springs, flat springs, or specially shaped springs, and there are variations within these divisions. Wire springs include both round wire and square wire coil springs, both of which are designed to resist and deflect under tensile, compressive or twisting loads. Flat springs include swing and semi-elliptical types.

Coil or coil springs, used in most suspension systems of Brazilian city trains, are devices made by wrapping a metal wire around a cylinder, are types of torsion springs, because the wire itself is twisted when the spring is compressed or stretched.

For springs used in Brazilian urban train suspensions we have numerous variables to consider when it comes to maintenance, as the nature of the function is extremely risky and should be inspected with great caution. The variables that we will take into account for the system calculation base were, according to Budynas and Keith Nisbett (2016), described below.

2.1.1. Tensions in coil springs

Figure 1 shows a round-wire helical compression spring carried by axial force F. We denote D as the average diameter turns and d as wire diameter, we can also see the cut spring with representation of the forces in the spring. This cut portion would contain a shear force and a torque given by:

$$T = \frac{FD}{2} \tag{1}$$

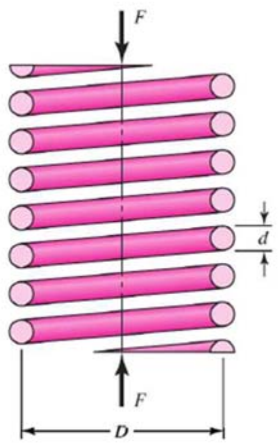

Figure 1. Spring cross section (Budynas and Keith Nisbett, 2016)

The maximum wire tension can be computed by overlapping the direct shear stress given by the equation below.

$$\tau = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2} \tag{2}$$

Now define the spring index as:

$$C = \frac{D}{d} \tag{3}$$

Which is a measure of the curvature of the loop. With respect to Eq. 2 it can be rearranged as:

$$\tau = K_s \frac{8FD}{\pi d^3} \tag{4}$$

Where Ks is a shear stress correction factor and is defined by the equation:

$$K_s = \frac{2C+1}{2C} \tag{5}$$

For most springs, C ranges from about 6 to 12. Eq. 5 is quite general and applies to both static and dynamic loads.

2.1.2. Curvature effect

The equations presented above are based on the round wire. however, the curvature of the wire increases the tension on the inner side of the spring, but decreases only slightly on the outer side. This bending stress is primarily important in fatigue because the loads are smaller and there is no opportunity for localized flow. For static loading, these stresses can usually be neglected because of strain hardening with the first load application.

Unfortunately, it is necessary to find the curvature factor in a circumloquial manner. The reason is that published equations also include the effect of direct shear stress. Suppose that K_s in equation 5 is replaced by another fact K which corrects for both curvature and direct shear. The factor is given by the equation, according to Budynas (2011):

$$K_b = \frac{4C+2}{4C-3} \tag{6}$$

The curvature correction factor can now be obtained by completely canceling the effect of direct shear. Therefore, the curvature correction factor is found to be:

$$K_r = \frac{K_b}{K_s} = \frac{2C(4C+2)}{(4C-3)(2C+1)} \tag{7}$$

Now Ks or Kb are simply voltage correction factors applied multiplicatively to Tr / J at the critical location to estimate a particular voltage. There is no stress concentration factor to predict the highest shear stress, according to Melconian (2000).

$$\tau = \frac{K_b 8FD}{\pi d^3} \tag{8}$$

3. MATERIALS AND METHODS

The proposed spring testing device (Figure 2) is composed of a mechanical drive from a 4-pole, 1750 rpm and 4 hp electric motor. Motor torque is transmitted to a crown worm-type screw, the worm-driven crown in turn transmits torque to the power screw which ultimately compresses or pulls the spring to be tested.

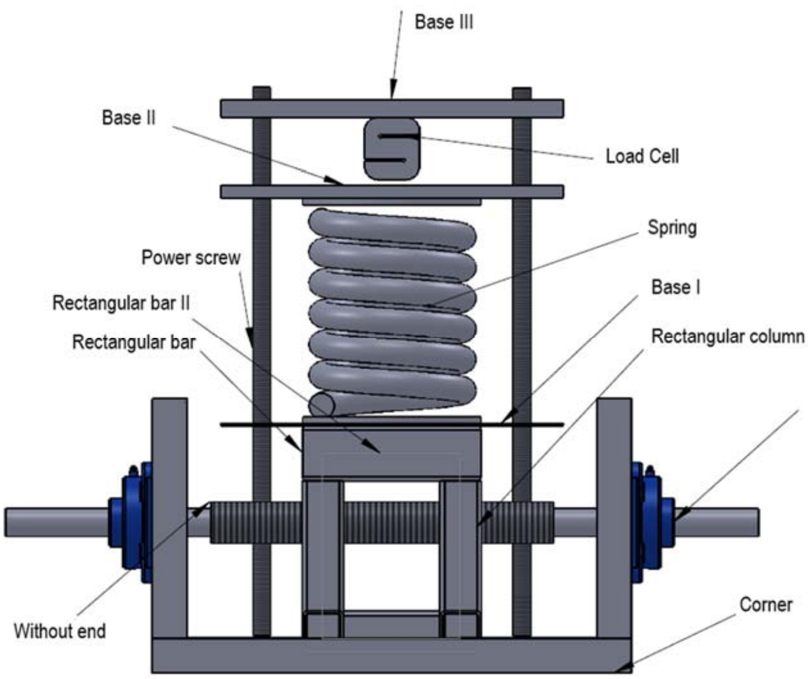

Figure 2. Spring Testing Device

The device has a load cell between bases II and III, which is responsible for measuring the force applied to the spring and an encoder that measures spring deformation. The encoder and load cell electrical signals are sent to a microcontroller, which then calculates the stiffness of the tested spring and sends it to an LCD display.

3.1. Size of constitute parts

The dimensioning of the pieces, so that they are functional, were calculated from the equations already presented or which will be presented below. Thus, they will have the required strength for the tests, plus the base to accommodate the acquisition system and, of course, the spring. The specific details for the main parts used follow in each subitem of this topic.

3.1.1. Bases

As the work beams are long straight elements that carry load perpendicular to their longitudinal axis, and all bending situations in the device occur in prismatic beams of homogeneous material and symmetrical cross section, the bending calculations were made according to the classification. of your support. In the designed device, the support base beams are simply supported, as are the bases I and III and the endless. Base II is supported with rocking end. Determination of their supports is necessary for the calculations of the bending diagrams. For this it was resorted to the concepts of material strength and general mechanics, summarized, according to Almeida (2017) and (Melconian, 2019) in the formula below, where σ corresponds to the maximum normal stress in the element, M resulting internal moment, and the perpendicular distance of the neutral axis to the furthest point from this axis on which σ acts, H the base length and h the cross-sectional length thereof.

$$\sigma = \sqrt{\frac{6Mc}{BH^3 - bh^3}} \tag{9}$$

The material chosen for the bases was 1020 steel, widely used for its proven strength characteristics, its basic characteristics are σ rupture of 420.507 Mpa, E of 200 Gpa and its yield limit of 351.571 Mpa, being the safety factor (FS) adopted the 2.

Thus, we can calculate the bending moment and the bending diagrams for each base. The base measurements follow in the figures below.

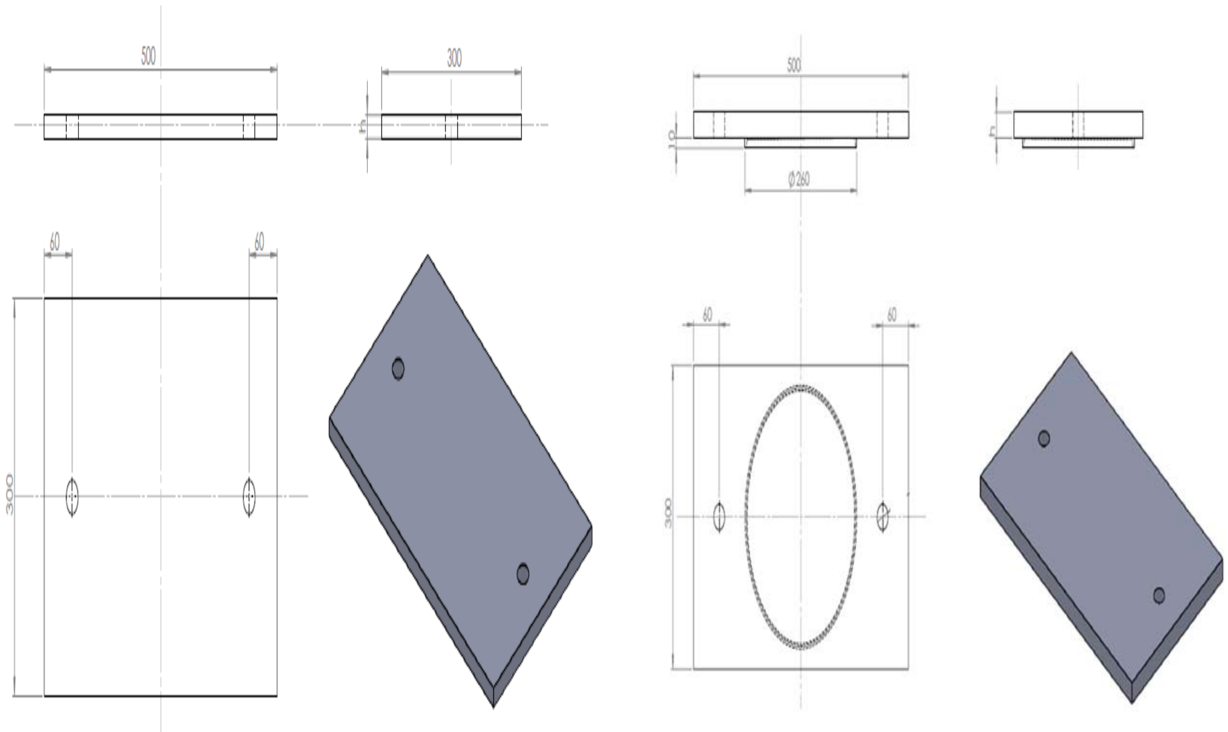

Figure 3. Bases III and II respectively.

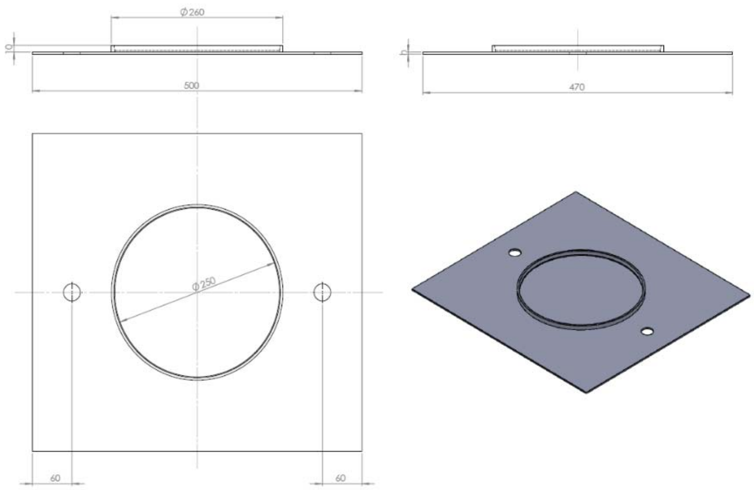

Figure 4. Base I

3.1.2. Power screws

The Power Bolt is a device used in machines to transform angular motion into linear motion and usually to transmit power. Familiar applications include lathe lead screws and vise, press and jack screws.

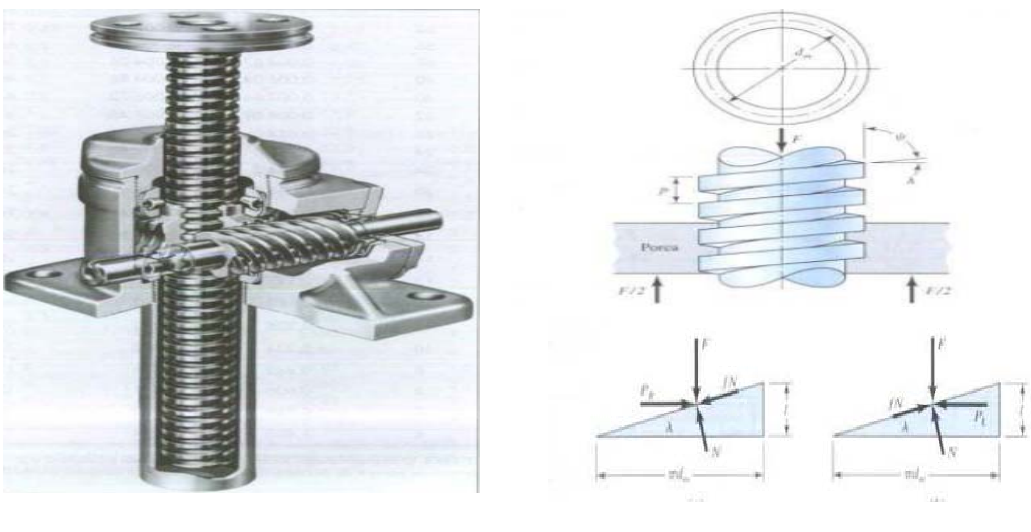

Figure 5. Endless power screw and power diagram
(Budynas and Keith Nisbett, 2016)

After flattening the thread, a thread edge will form the hypotenuse of a right-angled triangle whose base is the circumference of the medium-diameter circle of threads and whose height is the pitch. The angle λ in the figures above is the thread pitch angle. We represent the sum of all unit axial forces acting on the normal thread area by F. To lift the load, a normal force N, and acts to oppose the movement. The movement. The system is in equilibrium under the action of these forces, so to lift the load we have, according to Niemann (1971).

$$P_r = \frac{F[\left(\frac{1}{\pi dm}\right)+f]}{1-(\frac{fl}{\pi dm})} \tag{9}$$

$$P_l = \frac{F[f-\left(\frac{l}{\pi dm}\right)]}{1+(\frac{fl}{\pi dm})} \tag{10}$$

The torque required to raise and lower the load respectively is given by:

$$Tr = \frac{Fdm}{2}\left(\frac{1+\pi f dm}{\pi dm - fl}\right) \tag{11}$$

$$T_l = \frac{Fdm}{2}\left(\frac{\pi f dm - 1}{\pi dm + fl}\right) \tag{12}$$

With this, the worm and the crown can be designed for transmission between normal axes or at any angle, it can also be said to have the following characteristics:

- Materials:

Screw - Cemented Steel or Gray Cast Iron.

Crown - common bronze, phosphor bronze, lead bronze (high speeds), aluminum bronze, and silicon bronze (low speeds and high loads), gray cast iron (light duty).

3.1.3. Load cell

Load cell is an electromechanical device that measures the deformation or flexion of a body and transforms it into a voltage output. The signal in microvolts changes proportionally as we apply a load to its physical structure.

The cell is made up of one or more strain gauges, and a circuit called the Wheatstone Bridge. The type of cell application is the determining factor for choosing the amount of strain gauges and bridge circuit configuration. The CS type load cell was used in the work (Figure 3), as its shape and characteristics ensure that its proportionality relationship between the intensity of the acting force and the consequent strain of strain gauges is preserved in the initial weighing cycle. as in subsequent cycles, regardless of environmental conditions. The geometric shape, therefore, should lead to a "linearity" of the results.

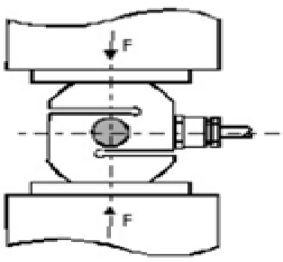

Figure 6. CS load cell

3.2. ACQUISITION SYSTEM

3.2.1. Strain gage

The strain gage is an electrical resistor composed of a metal grid over an insulating layer of polymer substrate. This is glued on a test structure in which it is sensitive to the variation of its resistance as a function of an applied load and can then be studied by measuring and verifying the behavior of its structure. These structures, in turn, present deformations that can be monitored in several ways, including: by comparator clock, electronic displacement detector, photo elasticity, fragile layer and strain gage, among others.

Strain gage is commonly used for its versatility. A force or pressure sensor, for example, is nothing more than a mechanical structure designed to deform within certain limits.

The extensometer performs the measurement in two directions. The main direction is the best choice to make because it has the highest sensitivity, as opposed to the secondary direction given by the Poisson's ratio (υ), as shown in Figure 7.

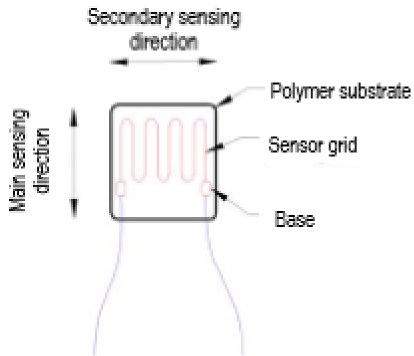

Figure 7 - Strain gage.

3.2.2. Encoder type sensors

Encoders are motion transducers capable of converting linear or angular motions into electrical information that can be transformed into binary information and worked by a program that converts past information into something that can be understood as distance, speed, etc. In other words, the encoder is a feedback unit that reports on current positions so that they can be compared to desired positions and their movements planned. Briefly they are devices that change their behavior under the action of a physical quantity, being able to provide directly or indirectly a signal that indicates this quantity. When they operate directly, converting a form of neutral energy, they are called transducers. Indirectly operating ones change their properties, such as resistance, capacitance or inductance, under the action of a quantity, more or less proportionally.

One option for monitoring spring displacement would be to use optical type linear encoders. There are other types of linear encoders, such as electric or magnetic, but due to their operating mode, optical linear encoders are simpler to implement. Regardless of the type, linear encoders work on the same principle. There is a tape, or a rail, with markings at specific positions. On this rail slides a sensor that “reads” the markings on the rail, thus indicating how far and where the sensor has moved.

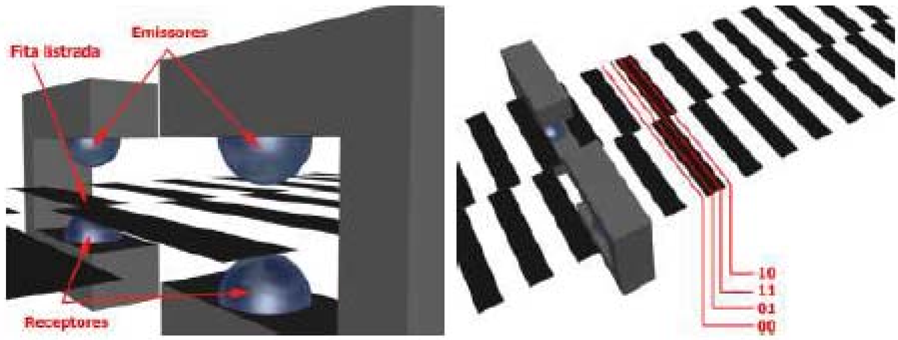

Figure 8. Linear Encoders

3.2.3. Microcontroller

Because the work requires electronic manipulation for both data acquisition such as load cell reading and encoding as well as for arithmetic and decision-making processes, the work uses a Motorola MC68HC908QY4 Microcontroller.

Microcontrollers are chips where we can store logical, arithmetic, and decision change instructions allowing it to work in many different ways depending on the instructions that were stored in its memory. It functions as the brain of the whole system, that is, it controls everything that is done by the microprocessor system. Low figure follows with short microcontroller system selected.

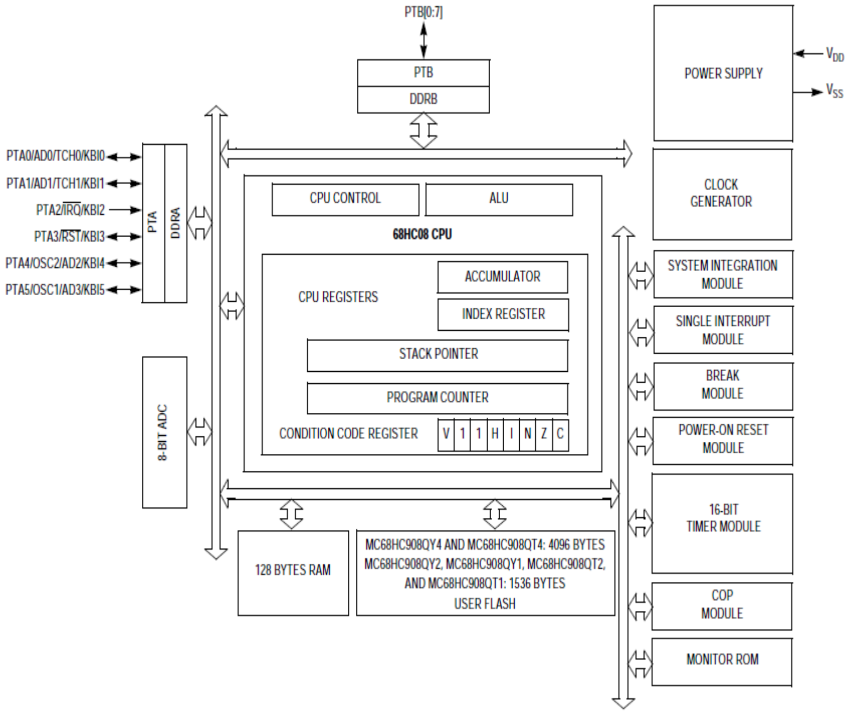

Figure 9. Motorola MC68HC908QY4 Microcontroller Block Diagram.

4. RESULTS

4.1. Flexion diagrams

From the presented in the methodology, we can present the flexural diagrams and the thickness of each constituent part.

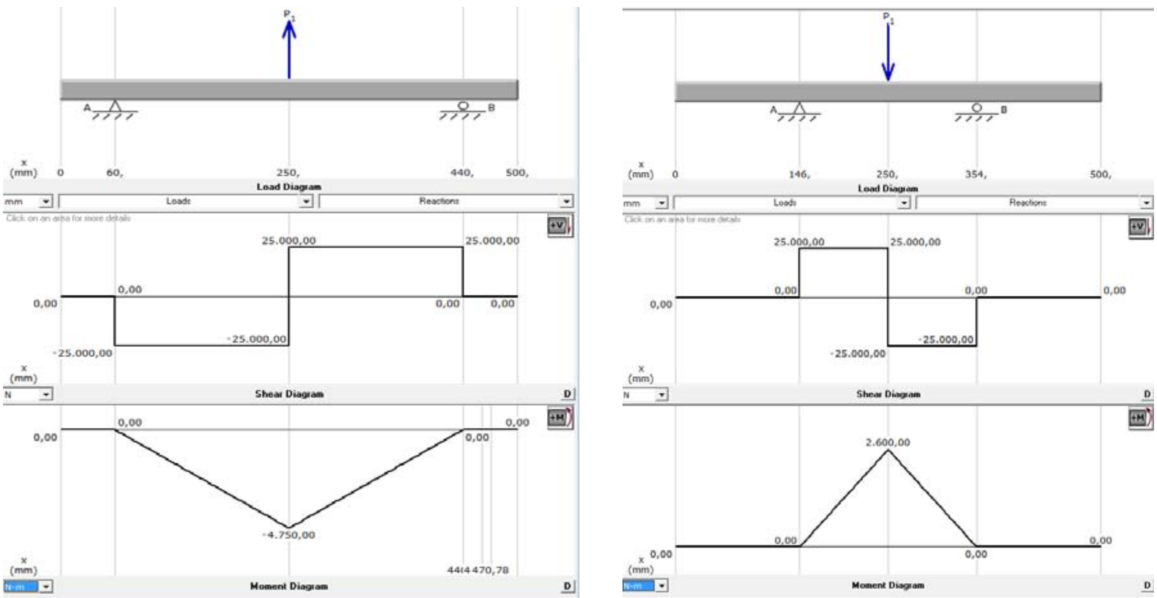

Figure 10. Basis flexion diagram III and II

Thus, the thickness of each piece was based on the diagrams and formulas presented: base III = 21.4 mm; base II = 15.73 mm; base I = 12.7 mm; Worm bolt radius = 30.5 mm.

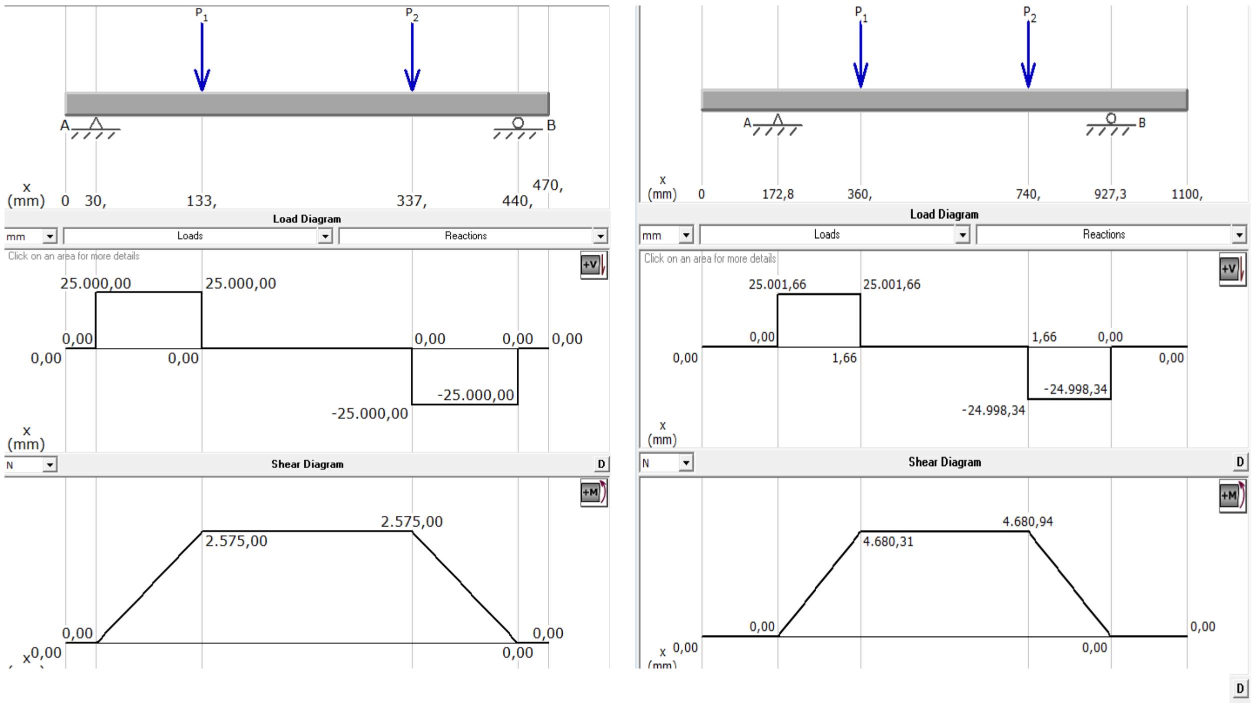

Figure 11. Phase III and worm screw diagram

From this information we come to the device design shown in the figure below:

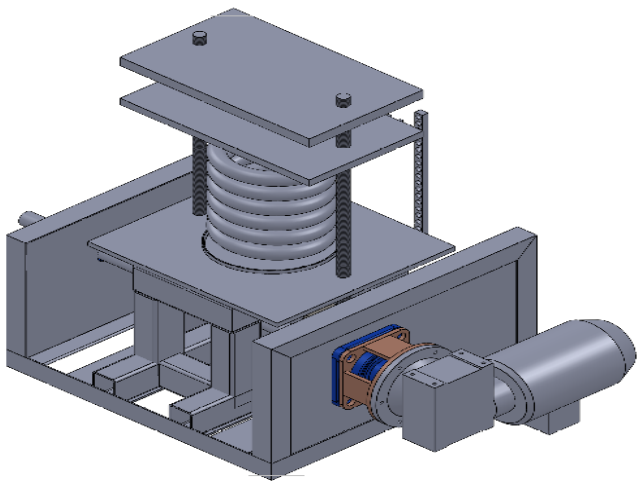

Figure 12. Final Testing Device

With this, the initially proposed design is efficiently presented. However, due to budget limitations, timely timing and even the limit imposed for the maximum length of this article, it was not possible to show more calculations needed to further specify the device, such as traction and flabbing.

5. CONCLUSION

It can be concluded first, that it is possible to design, and even build, a spring testing device for urban trains, or for any type of spring, thus contributing to greater efficiency within Brazilian industrial maintenance enabling real savings on maintenance costs within the city rail transport system.

We can also conclude the evident efficiency of the proposed device, which can be used in several areas of Brazilian industry.

Finally, as future work, it can be made clear the possibility of constructing the proposed device to finally run experimental tests on it to prove its practical use.

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7. RESPONSIBILITY NOTICE

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