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TESTING DEVICE FOR CHARACTERIZATION OF THE THERMOMECHANICAL PROPERTIES OF A SHAPE MEMORY ALLOY ACTUATOR

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Abstract. *The shape memory alloys (SMA) have the property to get back to its original shape, right after a deformation by an adequate thermal proceeding. Nowadays many applications using components made with this material are applied on determinate areas that come from medicine science to aerospace engineering, allowing the development of devices used as smart actuators. By this reason, the work shows the development of a device, monitored and controlled by the LabVIEW software, able to perform tests in order to correlate the applied force by the actuator (SMA) with its temperature. The tests consisted in many compression cycles of a spring that in each cycle the spring was compressed 5mm, using the temperature control. With support of the tools provided by LabVIEW software it was able to determine very quickly, accurately and effectively the thermomechanical properties of the alloys, as well as the temperatures of phase transformation and the relationship between actuator force and temperature.*

Keywords: *Shape Memory Alloys, LabVIEW, Low Coast.*

1. INTRODUCTION

Shape memory alloys (SMA) are metal alloys that exhibit well-defined phases transformations when subjected to a suitable heat cycle. This results in a single behavior, because when the material is deformed through a mechanical loading, the original form of the material is recovered when it is subjected to a specific heating. This behavior is not found in the materials most commonly used in the various sectors of engineering. Among the materials that exhibit these characteristics, the composed of Nickel and Titanium alloys (Ni-Ti), where the same can retrieve the form even after a deformation of up to 8%.

The recovery of form occurs when the alloy is subjected to certain temperatures, where during the heating process the crystalline structure of the League goes to the austenite phase and are subject to initial and final temperatures of austenite, and during the League phase passes cooling austenite to martensite phase and temperature martensite starting and ending are checked.

During the design of shape memory actuators the determination of phase transformation temperatures martensite to austenite and vice versa is important and this determination most often requires time and a considerable financial cost.

According to Lagoudas (2008), two parameters are important when selecting the actuator material: the energy density (production capacity of work per unit volume) and the range of working frequency of the material. The ideal would be to have an active material with a high energy density and a high frequency response.

The actuators of SMA has the recoverability of their shape when the temperature is increased, even under high loads applied, as well as absorb and dissipate mechanical energy when the reversible changes of shape, being considered as good when it comes to actuators dampen vibrations and absorb impacts (AQUINO, 2011).

However, the SMA have low frequencies of response relative to most other materials assets, thus reducing its use to situations where the frequency bands in question are low. For frequencies above 10 Hz (10-1000 Hz), is more feasible the use of LMF (LAGOUDAS, 2008).

Shape memory alloys have a completely different behavior of materials. The thermomechanical properties, however, depend on certain conditions as the initial phase (initial temperature), applied tensions, deformations and stabilization mechanisms (OLIVEIRA, 2009).

The Shape Memory Alloys are useful in various situations when they work as actuators, changing shape, stiffness, natural frequency, and other mechanical characteristics in response to temperature or electromagnetic fields. The potential of these leagues provided actuators has been expanded in several scientific areas, such as in electromechanical systems, vibration control, civil industry, aeronautics, medicine among others (AQUINO, 2011).

The present work has as its main objective to describe the developed low-cost device able to characterize the thermomechanical properties of shape memory Alloy (SMA) through LabVIEW software, allowing a detailed analysis of the process parameters, with fully automatic test sequence and instantly generated results from the data of strength, temperature and displacement.

2. MATERIALS AND METHODS

2.1 Manufactore of helical springs with shape memory

The rigidity of a helical spring depends on parameters such as geometry and the modulus of elasticity of the material involved in manufacturing. In the case of springs made of SMA, the modulus of elasticity, can vary with the temperature rise. According to Khajepour *et al.* (1998) the module of elasticity of the SMA depends on the fraction of martensite and austenite, and that in the case of coil springs the modulus of elasticity increases by approximately three times with increasing temperature (SRINIVASSAN, 2001).

For making the spring shape memory alloy used was of Ni-Ti (50%), identified by the manufacturer as being M alloy (Memory-Metalle GmbH©), presents 2.59 mm in diameter. Spring made is shown in Fig. 1.

Figure 1. Spring of SMA Ni-Ti

2.2 Tracks of transformation temperatures – Differential Scanning Calorimetry (DSC)

To obtain the transformation temperatures of shape memory alloys the method used was the differential scanning calorimetry. This technique is widely used to determine the transformation temperatures of the SMA with the advantage of using a small amount of the material. A sample of 0,05 g, Fig. 2 has been removed from SMA spring made.

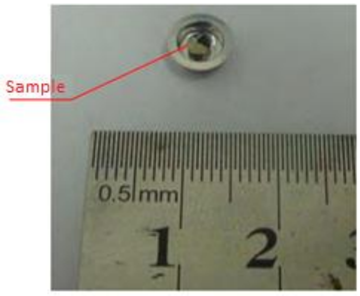

Figure 2. Sample of alloy Ni-Ti under test of DSC

This sample was subjected to a thermal heating and cooling cycle, which measures the amount of heat absorbed and released. The difference between the quantities of heat in each container of equipment, Fig. 3, reveals the heat absorbed or generated. During this measurement process are checked peak fluxes (during the cooling cycle) and endothermic (for inverse transform when heated) which allowed to determine the beginning and end of the transformations responsible, respectively, for the absorption or by the release of heat.

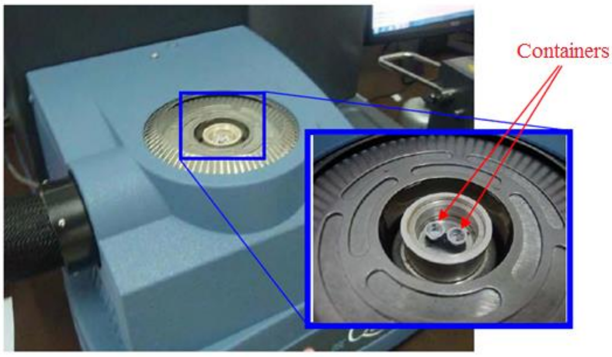

Figure 3. Sample under test of DSC

The Figure 4 shows the graph of DSC in function of temperature. For this graph appears that direct transformation temperatures are Ms = 22° C (temperature of the Martensitic transformation), Mp = 12° C (peak temperature of Martensitic transformation) and Mf = 2° C (temperature of end of Martensitic transformation) and the reverse transformation temperatures are the = 48 C (temperature of the reverse transformation), Ap = 57° C (peak temperature of reverse transformation) and Af = 63 C (temperature of end of reverse transformation). The temperatures of the beginning and end of the transformation were interpolated, and may present slight variations to out of range. Currently, it is usual to use peak processing temperatures that do not have errors of interpretation and, for these points, it can be observed that the Martensitic transformation hysteresis Ap-Mp is 45° C.

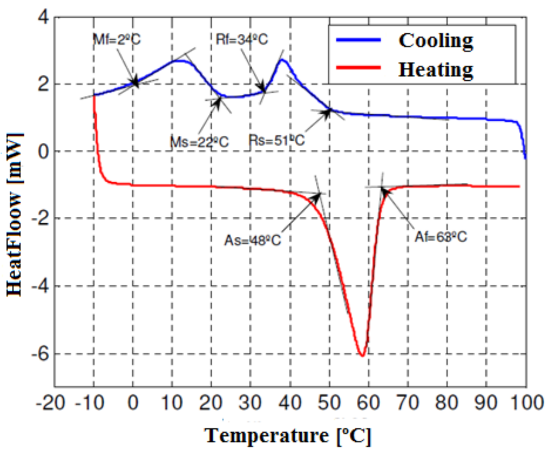

Figure 4. Transformation temperatures obtained by DSC

2.3 Description of test device

The developed device performs tests on actuators of shape memory alloy. For demonstration, was used as actuator of shape memory alloy a helical spring as can be noted in Fig. 1, composed of 10 active coils, wire and spring diameter respectively equal to 2.59 mm and 12 mm.

Basically the test accompanied the forces and offset spring compression. In spring compression was used a 2 mm pitch spindle turned by a DC motor with reduction. At one end of the spindle was installed an encoder, where each electrical pulse was converted into greatness "offset", Fig. 5.

As regards the collection of greatness "strength", was installed a load cell that recorded the compressive force of the spring. For each offset held, a compressive force was associated, thus creating the spring stiffness of shape memory alloy.

The testing device also has a system of on-off temperature control with current ticket relay for heating and cooling cooler. The spring during the test temperature ranges from room temperature (16° C) up to 72° C.

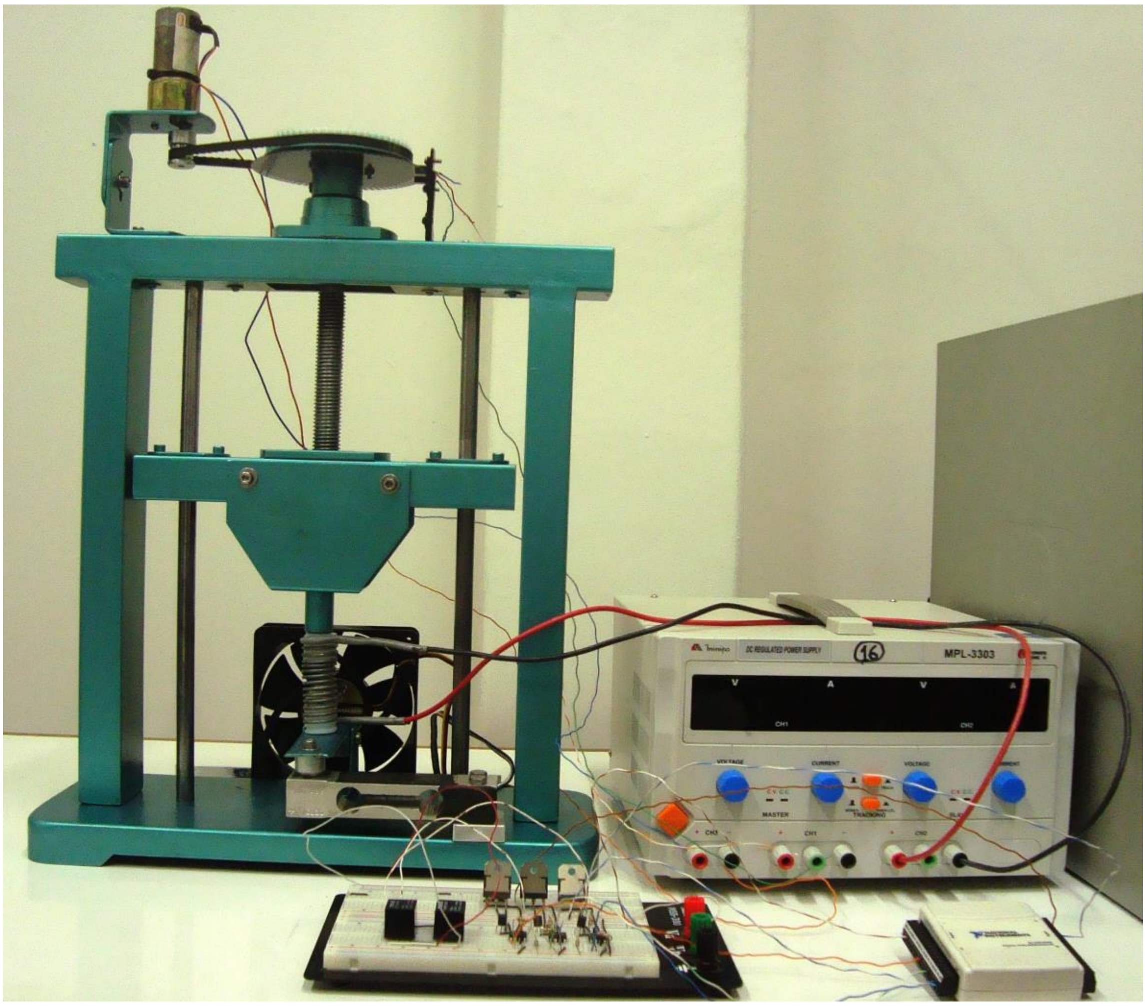

Figure 5. Developed device

2.4 Description of the operating environment

The Figure 6 shows the block diagram (done through LabVIEW software) used for operation of the device. It can be seen using the USB card 6009 collected and controlled some equipment actuators. It's worth pointing out that for data acquisition and control, electronic amplification boards were necessary.

In the collection of temperature, a plaque was added to the thermocouple voltage signals. It was verified that this numerical value of temperature corresponded to 100 times the voltage value collected.

In temperature control, worked with the difference between the temperature and the measured temperature.

Through this mistake, the motor temperature control the relay or the cooler. The relay allowed the passage of electric current through the spring, causing a heating. Already the cooler spring cooled by forced convection.

The offset values were obtained through the information of the encoder pulses and spindle pitch.

The spring stiffness resulted in the division between the strength provided by the load cell and the compression of the same displacement.

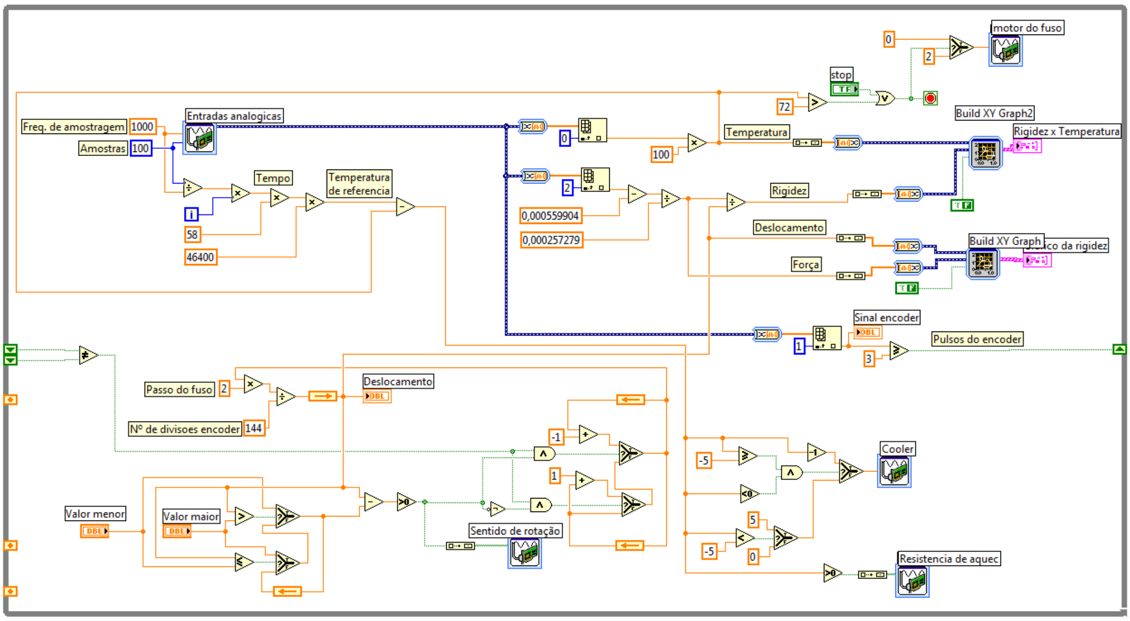

Figure 6. Block diagram of the system

3. RESULTS AND DISCUSSION

3.1 Registration and visualization of the results generated by the device developed

The procedure for data collection begins with the setting of previously selected temperatures having beginning in 16° C with intervals of 3° C, ending in 73° c. For each fixed temperature, there were 10 spring compression cycles in 5 mm. Was removed so an average of 10 stiffness values for each fixed temperature. The result of this procedure is shown in Fig. 7.

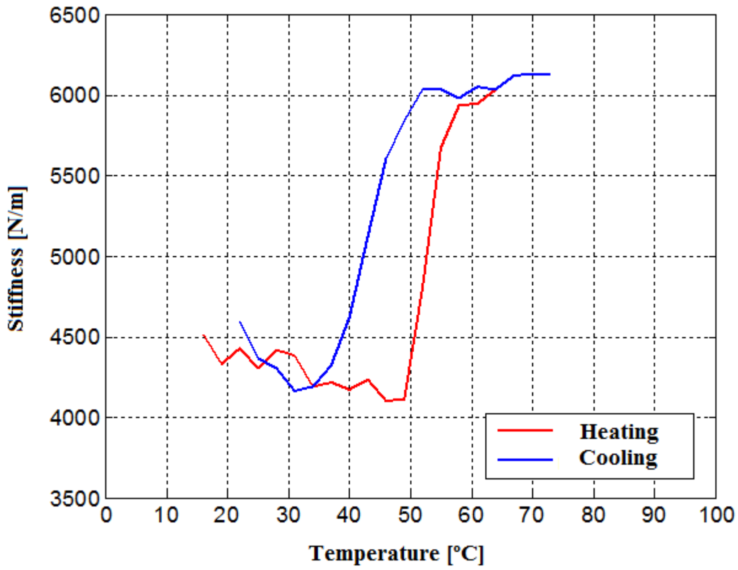

Figure 7. Stiffness spring of SMA Ni-Ti obtained from the device developed

During the heating stage is checked that stiffness has increased significantly around 50° C, is very close to the beginning of the austenitic phase. This large increase of stiffness lasts up to 58° C, and from this there is some stabilization in the values of rigidity. The result of the Fig. 4 shows the austenite region is around 63° C, which is demonstrated in Fig. 7 where a slight variation of the stiffness in these temperatures.

To obtain the hysteresis is considered the difference of temperatures where the value of the stiffness was 5116 N/m, average value between the minimum and maximum stiffness. To this average stiffness, the temperatures obtained were 43° C and 53° C, so 10° C hysteresis.

Basically the test accompanied the forces and offset spring compression. In spring compression was used a 2 mm pitch spindle turned by a DC motor with reduction. At one end of the spindle was installed an encoder, where each electrical pulse was converted into greatness "offset", Fig. 5.

The procedure for data collection begins with the setting of previously selected temperatures having beginning in 16° C with intervals of 3° C, ending in 73° c. For each fixed temperature, there were 10 spring compression cycles in 5 mm. Was removed so an average of 10 stiffness values for each fixed temperature. The result of this procedure is shown in Fig. 7.

The study used only a coil spring of SMA, composed of 10 active coils, diameter 2.59 mm wire diameter 12 mm spring. The result showed maximum and minimum variations of stiffness, respectively equal to 6129N/m and 4103N/m. The classical equation for determining the stiffness, depends on their geometry (spring, wire diameters and number of coils) and the material, represented in the equation for transverse modulus. Based on the data described also obtain maximum and minimum values for the module, with values of Gmax = 18 GPa e Gmin = 12, 6 GPa. Despite the literature vary up to 8 times between the extremes of transverse elasticity of shape memory alloys, the result does not invalidate the study, because these variations depend mainly on the percentage of the alloy elements and heat treatment which it has undergone.

4. FINAL CONSIDERATIONS

The tests consisted of several spring compressions, where every charging cycle the spring was compressed into 5 mm, with temperature control. With aid of the tools offered by LabVIEW software it was possible to determine very quickly, precision and effectiveness the thermomechanical properties of alloys, as well as the phase transformation temperatures and the relationship between the actuator force and temperature.

Through this work, it was possible to develop a low-cost device with high reliability and providing accurate results. Using the LabVIEW software was of paramount importance, contributing to the reduction of costs and time.

Comparing the device developed in this work with the methods already consolidated, one can observe a range of qualities that suggest that it may be used as a new technique for evaluation of thermomechanical properties of shape memory alloy.

5. AGRADECIMENTOS

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7. RESPONSIBILITY NOTICE

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