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Vertical positioning surveillance by magnetostrictive transducer

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Abstract. This work purpose is to create a positioning automated system of a tailstock to perform impact resistance tests on silicone mammary implants. This system is capable to measure and oversight the positioning through interrelation between three main components: programmable logic controller, human-machine interface and magnetostrictive transducer. Together, these components form an operational closed loop that ensures an appropriate positioning for the impact device. The paper describes how the closed loop works and also the algorithm implemented in the programmable logic controller which surveys the positioning. As a last topic, the paper presents the operator work on the machine's operation in conjunction with human-machine interface. The results were satisfactory and in accordance with the limits determined on ABNT NBR ISO 14607 for this method of tests.

1. Introduction

After resolution of the National Health Surveillance Agency (ANVISA), which establishes the minimum requirements for identity and quality for silicone mammary implants and imposes the requirement for certification of conformity of the product within the Brazilian System of Conformity Assessment (Sbac), laboratory analyses to verify the resistance of the prosthesis made itself necessary [1]. Hence it was designed a machine for testing the impact resistance of mammary implants based on the characteristics established in Annex E of [2].

There are some machines that perform impact resistance tests on silicone mammary implants in Brazilian laboratories, however none of them is as automated as the one shown in this paper. In order to build a machine that reduces operator's influence and so on enhances the repeatability of the test [3], it was developed the project of the Impact Resistance Test Machine.

The Impact Resistance Test Machine was fully developed by the Laboratory of Physical Metallurgy (LAMEF/UFRGS), from designing the project and its mechanisms until the automation system as a whole, including the positioning's algorithm. This part of the project consists in a closed-loop system that controls the position of the impact mass at the correct height, which is going to be detailed in the article body. The impact mass is equal to 4.4 kg and its diameter is equal to 250 mm, according to [1].

The operation center of this system is a programmable logic controller, through it occurs the surveillance position of the impact device and the control of all others devices. The measure of the position of the impact device is done by a magnetostrictive transducer [4]. The machine operator has to inform the prosthesis data and to enable the next stage after each concluded stage.



It is expected to obtain a reliable vertical positioning for the impact mass, guaranteeing the accuracy of the test as well as the correct operation of the test machine.

2. Methodology

The Impact Resistance Test Machine in mammary implants is largely automated, the operator controls all stages of the process through a human-machine interface (HMI), Delta Electronics™ - DOP-B. The machine operator needs to inform the height and mass of the prosthesis onto HMI. The programmable logic controller (PLC), Delta Electronics™ - DVP-SA2, uses this information to perform the calculation of the height from which the impact mass is to be released against the prosthesis, and then a stepper motor, Applied Motion Products™ - HT34-487, is triggered by just rotating the spindle which moves a tailstock fitted with an electromagnet. The tailstock goes down to find the mass, so the electromagnet gets attached with the mass, then the couple moves vertically to a certain point set by calculation.

Once the impact mass reaches the height calculated for the test, the operator is informed about this condition and it is requested the positioning of the prosthesis at the test platform. After this, the machine operator can release the impact mass by HMI again, so that the electromagnet is switched off and the impact between impact mass and prosthesis occurs. It is prompted for the operator to remove the prosthesis of the test site and the process is terminated.

An image of the machine can be observed in figure 1.

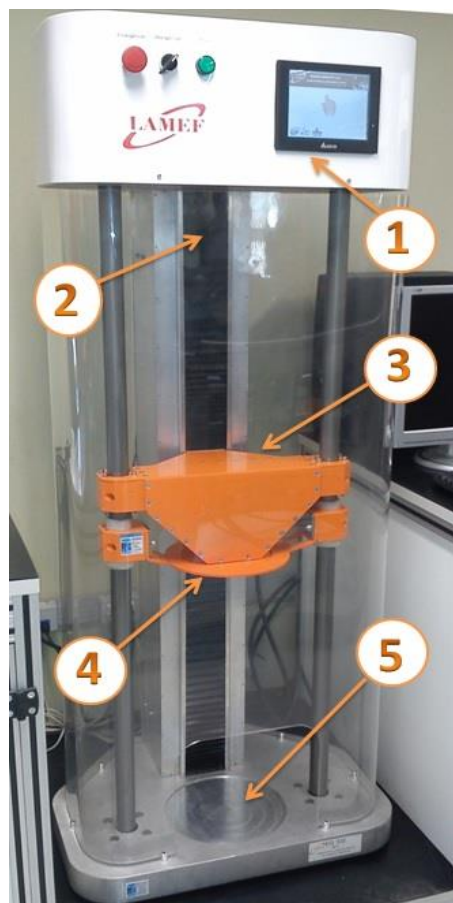


Figure 1. Impact Resistance Test Machine on mammary implants; 1. HMI; 2. spindle; 3. tailstock; 4. impact mass; 5. place of prosthesis (test platform).

2.1. Closed-loop system

Positioning's routine of the impact mass at the height, where the test must be performed, is made jointly by an A/D module, Delta Electronics™ - DVP06XA-S, a PLC, and a linear displacement magnetostrictive transducer, GEFTRAN™ – ONP1-A. These components form a closed loop system.

The transducer is positioned parallel to the spindle whereby the motor moves the tailstock. In this device there is a sensor which according with the position of the impact mass, returns a voltage level to the output of the transducer, acquired by A/D module. The PLC receives the signal already transformed into digital and compares this value with the value calculated according to equation (1).

Once the tailstock reaches the desired position, the PLC stops the stepper motor. Then, the machine operator is noticed that the test is ready to be performed.

In figure 2 it is shown a sketch of the closed loop representing this system.

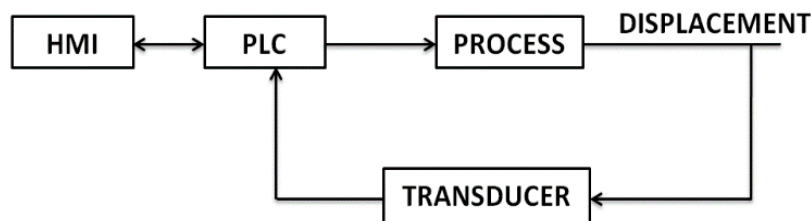


Figure 2. Closed-loop system

The sketch shows the loop feedback by the transducer. There is not a controller in the system, the PLC acts as a comparator, supervising when the impact device approximate the desired position. The PLC and HMI interrelation occurs with the exchanging of information by a serial communication. This way, the values inserted by the operator in HMI can be accessed by the PLC and the values calculated by the PLC can be accessed by the HMI.

2.2. Methodology of positioning the impact mass

The machine operator measures the mass of the prosthesis on a precision weighing-machine, BEL Engineering™ - MARK M 2202, and observes the prosthesis height provided by the manufacturer. This data is entered via an HMI and accessed by PLC. The calculation of the distance where the impact mass should be in relation to the test platform, before the resistance impact test, is given by equation (1).

$$H[mm] = m[g] \cdot 0,95[mm/g] + h[mm] + 144[mm] \quad (1)$$

Where $H[mm]$ is the distance between the test platform and the impact mass and $m[g]$ and $h[mm]$ are, respectively, the mass and height of the prosthesis.

With this calculated value, after the release of the operator, the PLC triggers three of its digital outputs: a pulsed signal in an input of the driver, Applied Motion Products™ - STR4/8, which drives the stepper motor, rotating the spindle in order to move the tailstock; another constant signal that drives the electromagnet in order to maintain fixed the impact mass to tailstock; and the last with a constant signal into another input of the driver, which defines the direction of motor rotation.

The driver that performs the communication between PLC and motor had its settings made under engine operation conditions. In this system the driver was configured with a ratio of 200:1 with microstep emulation, in which every 200 pulses received from the PLC on driver, representing a complete turn on the motor shaft. Thus, it ensures that the movement proceeds smoother [5], without compromising the structure of the machine.

2.3. PLC – transducer communication

The A/D module works with a resolution of 12 bits from -10 to +10V. The linear displacement magnetostrictive transducer returns in its output signal of 0.1 to +10.1V [6]. The use of these devices together provides a value to the PLC of 12 bits with sign bit.

In practice, the PLC quantizes this value received, from 0 to 2047, and transforms it into a value, in mm, indicating the distance between the impact mass and the test platform. The calculation performed by the PLC can be seen on equation (2).

$$H[mm] = -0,62[mm/bit] \cdot B[bit] + 1223,43[mm] \quad (2)$$

Where $H[mm]$ is the height of the impact mass and B is the number of bits received by module A/D from the displacement transducer. This transducer was calibrated by a laboratory certified by the Brazilian Network Calibration (RBC).

2.4. PLC's algorithm

The PLC program does the surveillance of the position of the tailstock with two conditions: if the tailstock is above or if it is below the desired position. The PLC uses the value obtained from equation (2) to compare with the value obtained from equation (1). The stepper motor stops when the value of equation (2) is in a range of ± 1 of value obtained by equation (1).

The PLC performs the comparison if the value arising from the transducer is above the calculated value, if it is positive, the stepper motor is triggered and spins the spindle making the tailstock going down. In case the result of the first comparison being negative, the PLC does a new comparison, this time to verify if the value arising from the transducer is below the calculated value, if it is positive, the stepper motor is triggered and spins the spindle moving the tailstock up. In case the result of the second comparison being negative, it means that the tailstock is already in reference position and then the positioning routine is finished.

A flowchart of routine process is shown in figure 3.

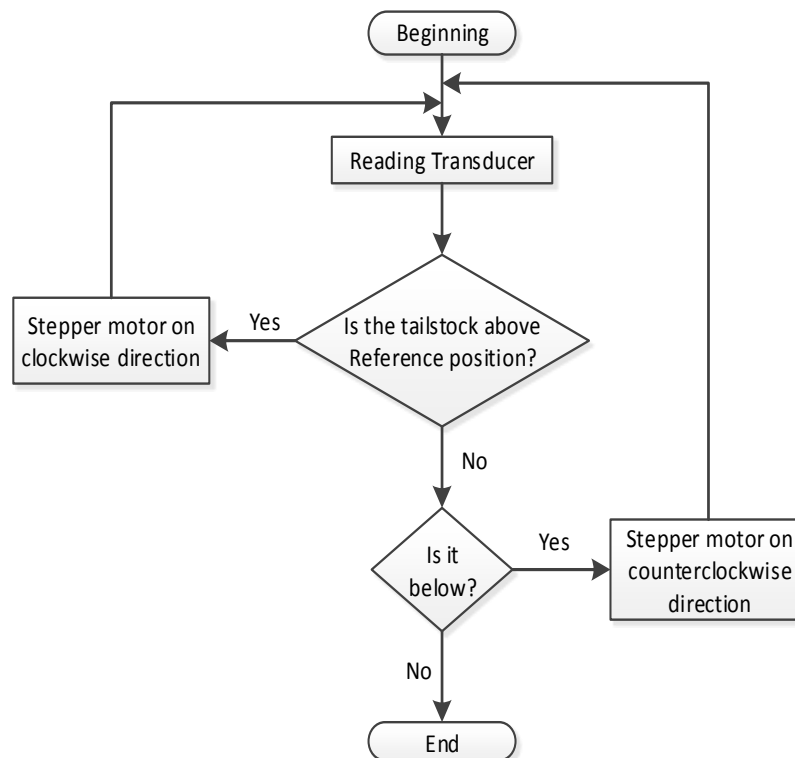


Figure 3. Routine process flowchart

2.5. HMI – machine operator communication

The operator's function in the Impact Resistance Test Machine on mammary implants is the insertion of data of the prosthesis, the enabling of every new stage and the placing and withdrawal of the prosthesis from the test platform. The communication between operator and machine is performed by a HMI. Through the HMI the operator can insert the mass and height of the prosthesis which are used in the calculation of the height that the impact mass is to be released in the test. It is from the HMI that the operator also can move onto a new stage of the process and can cancel the process at any time.

The operation of the machine is divided in some stages that demand the participation of the operator to occur:

In the first stage the operator enters the values of mass and height of the prosthesis to be tested in the HMI screen, as can be seen in figure 4, then he presses the 'OK' button to advance to the next stage. The values entered by the operator will be available to PLC use them in equation (1).



Figure 4. Inclusion of information screen

In the second stage occurs the positioning of the impact device through the closed loop system and algorithm already mentioned in the paper. The operator has the function to check if the data inserted is correct and print the screen to save the information about the test, as can be seen in figure 5. At the end of the positioning, the HMI informs to the operator that the stage was concluded and the 'OK' button is enabled to the operator, allowing him to move onto the next stages.

In the third stage of the process it is requested to the operator the placing of the prosthesis at the test platform. After the placement of the prosthesis, the operator must inform to HMI that the impact is ready to be performed by pressing the 'OK' button.

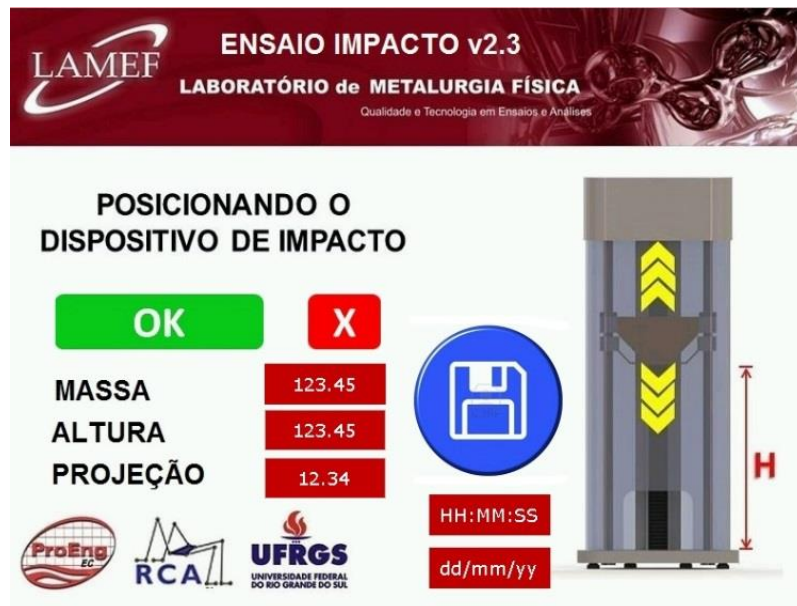


Figure 5. Positioning and assay's information screen

In the last stage occurs the impact between prosthesis and impact mass. After the impact, it is requested to the operator to remove the prosthesis from the test platform and the process is finished. Finishing the assay, the HMI returns to home screen, where a new assay can be started or the machine can be switched off.

3. Results

It was necessary to define a range of $\pm 1\text{mm}$ of the acceptable value for ending the displacement of the tailstock due to oscillations provided by transducer's signal. However, the closed-loop system behaves satisfactorily, showing a fast response to the procedures required in this project.

By setting the configuration of the stepper motor driver to a relation of 200 steps/rev resulted into a better positioning of the impact device. Thus, it was possible to decrease the range of the acceptable value, from 1.5mm to 1mm, around the desired position to the end of the displacement of the tailstock.

After the final results were obtained, the machine was evaluated and accredited by Inmetro to perform assays.

4. Conclusion

The closed-loop system's methodology applied to oversight the positioning of the impact mass provided the reduction of external disturbances and greater stability for the correct positioning.

The friendly interface of machine provided a simple operation, easy to understand and without requiring an elaborate training to authorize someone to operate the machine.

Through automation of the test it was possible to obtain a great repeatability on the impact device's positioning, with small oscillations of values.

From the values obtained in the positioning of the system, it was concluded that the system operates satisfactorily with the purposes of this project and is able to perform impact tests on mammary implants with accuracy and in accordance with the requirements in the standard.

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