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RETROFITTING A TENSILE TESTING MACHINE FOR TEACHING PURPOSES

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Abstract. *The retrofitting is the process of modernization of some equipment already considered outdated, intending to increment the lifespan by implementing more recent systems of hardware and software. In this work is described the process of retrofitting of a WP350 educational traction test machine. Electronics circuits and software were developed to allow better measurement and accompany during the tests. It was used a microcontroller AVR Atmel to collect all data provided by the auxiliary circuits and send to a personal computer. The results demonstrate a low error of 2.58 N and 0.026 mm considering an 8 mm stroke.*

Keywords: *Arduino, Teaching, Tensile Testing Machine, Retrofitting, WP350*

1. INTRODUCTION

According to Callister (2009), it is essential for engineers to be able to characterize the properties of materials and know how they are measured and what they represent. This measure can prevent unacceptable levels of deformation from occurring. Depending on the needs of the project, materials more ductile or more fragile, or with higher or lower rupture tensile stress, or with more or less linearity in the elastic phase, should be used. An educational traction test machine can be used to study these concepts with the students, as well as contribute with essential data needed to perform analyses of these materials. However, if the machine available for this purpose had its functional capacity reduced and no capability of reading data using electronic readers, it might lose a significant capacity to be used as a medium for the transmission of this knowledge. This work aims to present the methodology employed in the retrofitting of an educational traction test machine. This process involves the study and analyses of the sensors that were used, the formulation of an interface with didactic bases in order to facilitate the learning of the students, the analysis of the tensile test and elaboration of an electronic system for reading the data. Also, it is expected to obtain, using the available sensors, and through a low-cost electronic system, a system whose accuracy and robustness are sufficient for classroom use. The purpose of retrofitting is to incorporate new technologies into obsolete equipment, as defined by Plotegher (2012), so this project is characterized as a retrofitting.

As stated by Felder and Silverman (1988), due to discordance between the teaching style of professors and the learning style of students, students can get unsatisfactory grades in tests, lose focus and in some cases, even drop the school. Due this discordance, it is needed that the professor learn techniques to use also the others teaching styles. Felder and Silverman (1988) also recommended the use of demonstration to increase the efficiency of the sensing and visual learning style and the use of hands-on, when possible, to benefit the active learners. The use the traction machine in a didactic way can help these learning styles.

2. MATERIALS AND METHODS

The WP350 tensile testing machine (Fig. 1) aims to obtain the properties of the material during tests, in the course of the plastic regime and the elastic regime. The necessary data for this process are obtained from a displacement sensor and a load sensor.

The load sensor used consists of a displacement sensor PY2-C (Gefran, 2016) with ball point tip and return by spring (Fig. 2), and the dynamometric ring (Fig. 3). The main purpose of this machine is to be used for demonstrations in the classrooms.

The tensile testing machine, WP350, works by traction an "I" shaped tensile specimen (Fig. 4). The machine uses a
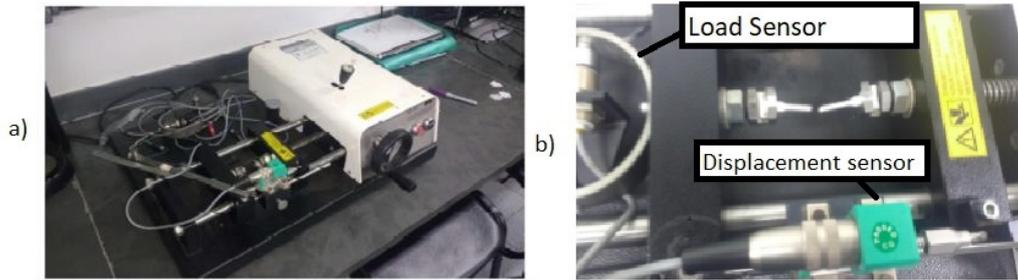
Figure 1. Tensile Testing Machine WP350 a. before the retrofitting b. used sensors. Source: Author

Figure 2. Displacement sensor. Source: Author

Figure 3. Load sensor. Source: Author

horizontal axle. Thus, it can work in manual or automatic mode (Fig. 5).

2.1 Electronic System

The electronic system (Fig. 6) was designed as a way of processing the signals. It was used a 16 bits analog to digital converter (ADS1115) (Texas Instruments, 2019) to read the sensors outputs thought two operational amplifiers. After the data acquisition, the microcontroller communicates to ADS1115 using an I2C communication protocol in order to process the acquired data and send to computer via serial protocol. The whole system is powered up via USB with 5 V, and the chosen microcontroller was Atmel328P (Microchip, 2019) boarded in a Arduino Uno board, due its ease of replacement. In order to supply 20 V to the load sensor, it was used a buck buster converter (XL6009), that outputs a 9 V power supply from a 5 V power supply using the Arduino Uno 5V power pins. Since that the load sensor outputs a signal strength of maximum 20 V, as opposite from displacement sensor that outputs a maximum 5 V, it's needed to use a voltage divider to keep the signal voltage ratings within the Arduino Uno analogical input port operating range.
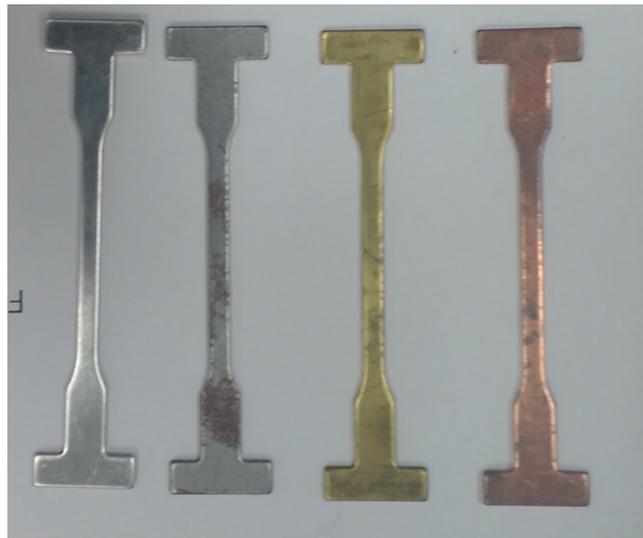
Figure 4. Tensile specimens that are sold with the machine by the manufacturer. Source: Author

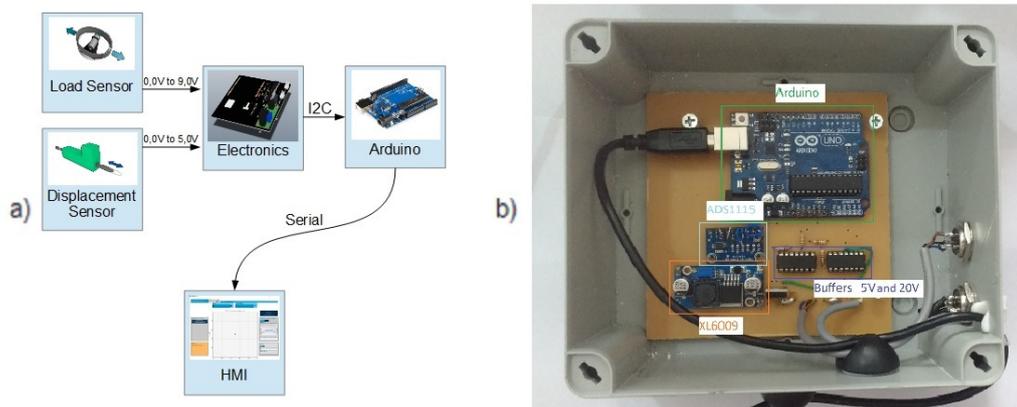Figure 5. The machine can be used in manual or automatic mode. Source: Author

Figure 6. a.Flowchart of signals b. Electronic system. Source: Author

The PCB design had made using the software Circuit Maker (Fig. 7), and was machined in CNC in order to archive a better precision in the fabrication process.

A 3-pin industrial connector and a USB connector were used to communicate with the sensors (Fig. 8).

To be able to create a communication between the microcontroller and the HMI (Human Machine Interface), a Serial protocol was used over USB.

2.2 Calibration

To improve the system accuracy, the sensors and the electronic system were calibrated together. From the data obtained from the calibration process, it was possible to use a linear equation to characterize the response of each sensor. For both
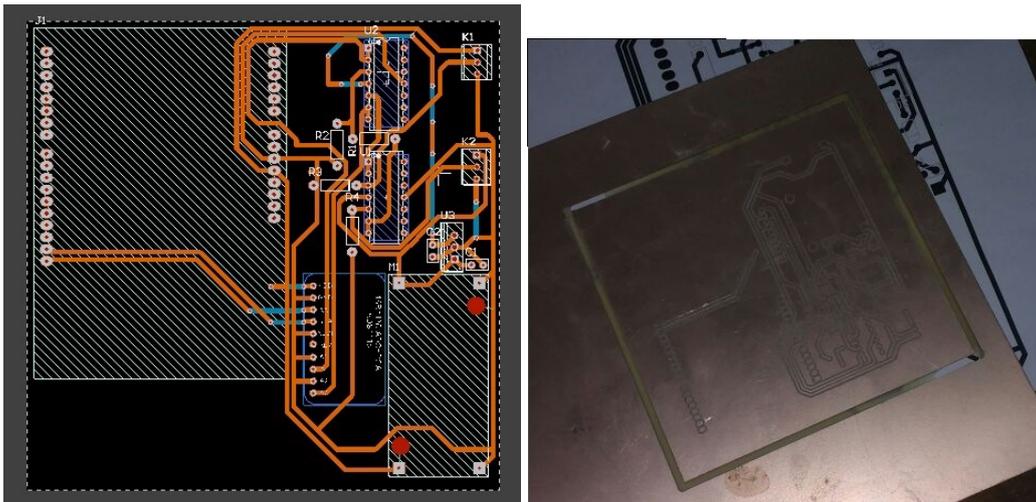
Figure 7. a.Printed circuit board design b. Machined printed circuit board. Source: Author

Figure 8. 3 way industrial connector. Source: Author

sensors, the maximum error value was considered to be the maximum absolute error, as recommended by Albertazzi (2008).

During the calibration the sensor values were recorded and those that were out of sensor range were discarded.

The load sensor was calibrated using a dynamometer manufactured by Albatroz Fishing, with 10 g of resolution. The displacement sensor was calibrated using a strain gauge calibrator manufactured by INSTRON, as shown in Fig. 9.

Figure 9. Position sensor calibration. Source: Author

2.3 Human Machine Interface

The interface used (Fig. 10) was programmed in the Processing program. It was created using a clean interface, and the buttons with similar actions were grouped in order to become more instinctive the use, as recommended by Jhonson (2010). In addition, contrasting colors were also used as suggested by Jhonson (2010) (Fig. 10). By using the created interface, it was possible to extract data through documents with .pdf extension, using graphics, and .txt extension, with numeric data.
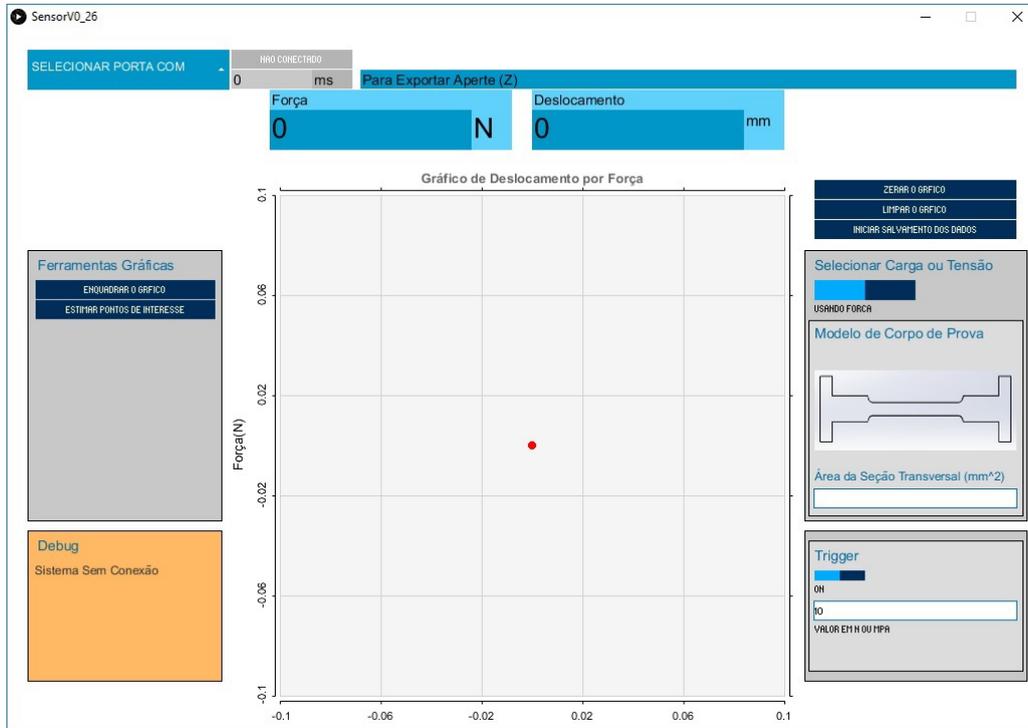

Figure 10. Human Machine Interface. Source: Author

3. RESULTS

The calibration method, as described in materials and methods, was followed, and the data obtained for each sensor are presented in Fig. 11. It can be analyzed that the measurement data is fairly linear. The initial displacement at 0 mV (Fig. 12) is due the sensor displacement limits.
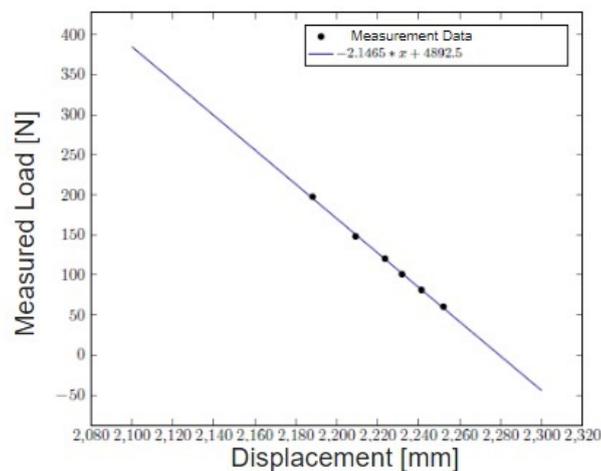

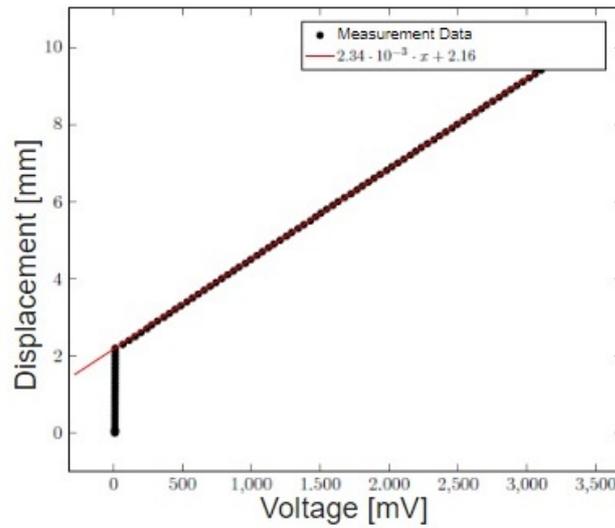Figure 11. Measurement data used for calibration and linearization of load sensor. Source: Author

Figure 12. Measurement data used for calibration and linearization of displacement sensor. Source: Author

As described previously, the maximum error was used as the constant error. The maximum error is the maximum difference between the linearized equation and a set of all points. Once the sensors were calibrated, it was possible to perform some tensile tests in samples that were produced by the machine manufacturer. The results are shown in Fig. 13, 14 and 15. The tensile test machine, with the electronics and HMI, is shown in Fig. 16.
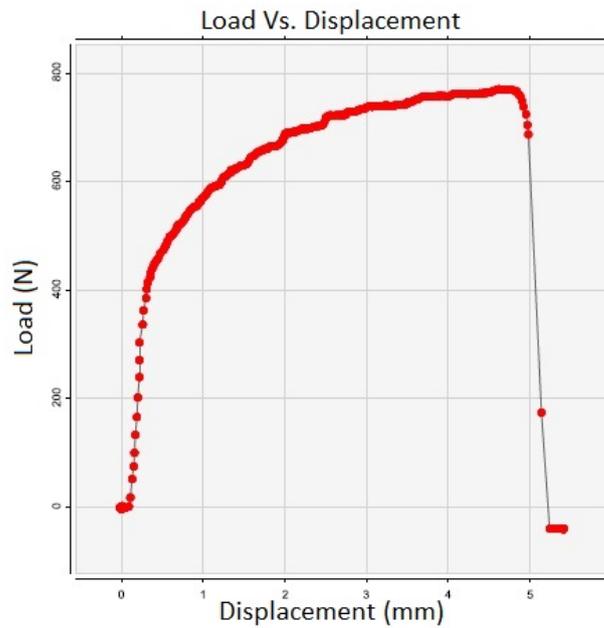

Figure 13. a. Representation of a tensile test on the WP350 traction machine with load test bodies [N] by displacement [mm] of AlMgSi0.5F22. Source: Author
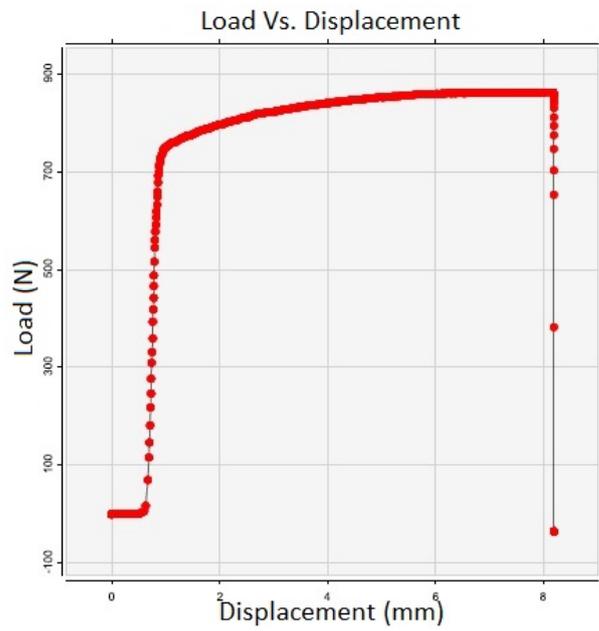
Figure 14. a. Representation of a tensile test on the WP350 traction machine with load test bodies [N] by displacement [mm] of Cooper. Source: Author
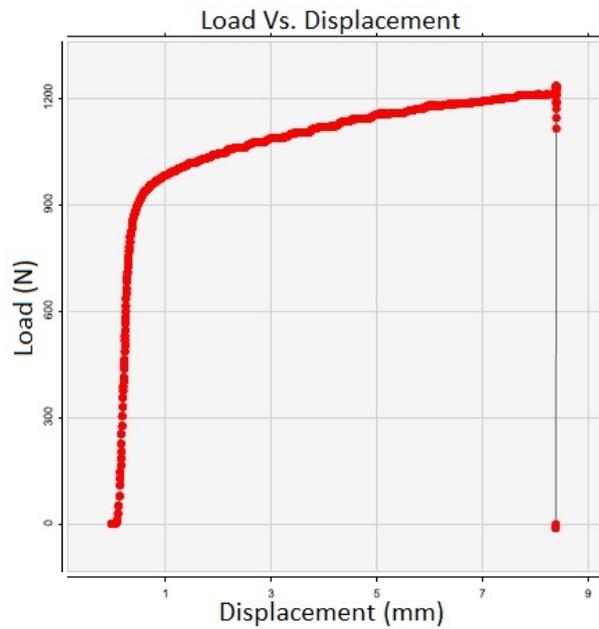

Figure 15. a. Representation of a tensile test on the WP350 traction machine with load test bodies [N] by displacement [mm] of CuZn39Pb3. Source: Author

Figure 16. Finished design of the Tensile Test Machine. Source: Author

4. CONCLUSION

By observing the results and discussions and comparing with the proposal of this work, it is concluded that the system presented a good response. The error obtained during the tests was of about 2.58 N and 0.026 mm so the test machine can be used for test samples with deformations up to approximately 8.0 mm. This is sufficient to assess the important points as the rupture point of various materials, however, for materials with a deformation occurring after this displacement, a larger stroke sensor should be used. Also, the possibility of exporting data as well as graphs makes it possible to use the data obtained for future analysis. It can also help in the didactic use, since the students will be able to obtain the data and analyze them later. The HMI feature, along with a cleaner, clearer and easier to use interface gives the user a better control in obtaining the data for analysis. This is important so that it can be used in a didactic way, as students should be able to discovery machine characteristics and run the machine quickly.

In addition, it is expected that the use of the machine may be included as a way to improve the quality of teaching, but further analysis is required to measure the benefits.

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6. RESPONSIBILITY NOTICE

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