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Virtual laboratory for measuring of elastic modulus with stress and strain for different metals

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Abstract. The Colombian ministry of information and communications technologies is leading a digital revolution to bring computer and internet equipment to rural areas, taking into account that in these areas there are educational establishments that do not have equipment and materials for the performance of laboratories or experimental demonstrations. Therefore, this project proposed the development of a virtual learning laboratory for the study of the elastic modulus, obtained from real tensile-compression tests. It is important to clarify that there is not theoretical procedure to obtain stress-strain curves out of their linear regime. The virtual laboratory was developed in python language. The simulation allows the students to manipulate tensile-compression test for different materials. Also, they can visualization of the procedure, the stress-strain curve, and the Young modulus, all with the aim of transferring the conceptual and procedural knowledge of the physical phenomenon to the student.

1. Introduction

Nowadays, information and communication technologies ICT have a leading role in the transformation of physics teaching [1]. ICT are powerful tools in order for students to increase their interest and immerse researching [2]. From the international framework, UNESCO proposes three standards with information and communications technologies ICT use to classify the teachers. Explorer, integrator, and innovator. In Colombia, the Colombian ministry of ICT is motivating the educational institutions and the main actors (students and teachers) to incorporate ICT into their teaching-learning environments. In addition, from our local framework, the Universidad Industrial de Santander has guidelines for the strengthening of the University ethos named institutional project. Here, strategic approaches take into account the pedagogical innovation mean innovate spaces that include ICT.

On the other hand, new teaching-learning strategies use ICT in the study of physics [3]. For example, the University of Colorado develops interactive simulations so that students can learn by exploring [4].

The culture of the modern student is based on applications use [5]. They like to download and proof new applications that simplify their lifestyle. We have turned it into an opportunity to mediate the teaching-learning process.

Since 2016, in the laboratories of physics at Universidad Industrial de Santander has using the technique Just in Time Teaching, and other elements of mediated learning through the Moodle platform [6].

Many students achieve physics understanding through experimentation. Then, the laboratory classes help them to connect with sensitive experiences and figure out physical phenomena a different way to the board cathedra [7,8].



The laboratory courses must be directed following a plan. They have an important role in the training of scientists and engineers since they offer students the possibility of questioning and confronting them with reality, growing their own knowledge and generating new experiences [9].

Although, is out discussion the importance of experimental procedures, sometimes arises troubles at the time to make science from schools. Many times, the equipment and materials at the laboratories are insufficient, even some schools don't have it because of laboratory equipment is usually expensive [10].

Then, for the aim to promote the teaching of the science of a didactic and interactive way a virtual laboratory was developed. The idea was getting experimental setups and data to match with theoretical models and bring both the virtual laboratory, once there the students can manipulate some metallic materials and bring them to tensile-compression essays to obtain Young's module.

2. Materials and methods

In order to find Young's modulus of metallic materials, each of these specimens (proof cylinders) was subjected the stress, which one was measured and can be obtained from Equation (1), and refers to the applied axial force over the cross section of the proof cylinders.

$$\sigma = \frac{\Delta \vec{F}}{\Delta S} \quad (1)$$

When a proof cylinder is subjected to stress, it changes in size and shape, it was deformed. The unit strain of the proof cylinder is found through Equation (2), where the change in length and the initial length of the specimen is required.

$$\varepsilon = \frac{\Delta L}{L_o} \quad (2)$$

With the stress and strain measured on proof cylinders are possible to get the Young modulus of the materials, this parameter shows the elastic performance of the materials and it is obtained from Equation (3).

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

In the traction essays, the limit zones are looked as follow [11,12].

- Proportional zone: here Hooke's law is fulfilled, i.e., the relationship stress against strain is linear.
- Elastic zone: in this zone, a discharge is made, which behaves elastically, i.e., we can see that the axial force is eliminated, therefore there is no permanent deformation in the specimen.
- Plastic zone: permanent deformation of the specimen is possible in this zone, even if the axial force is completely eliminated.
- Yield zone: in this zone, the deformation increases without a significant increase in tension.
- Ultimate tensile strength: in this zone, a significant decrease in the center of the specimen is observed, a bottleneck is formed to produce the rupture of the specimen.

It's important to know that the tensile and compression test should only be performed with specimens that are duly standardized, i.e., they must comply with the ASTM E8 and E9 standards [13].

It is important to mention that the success of this work is due to the real tests made for different test pieces. The materials needed to develop this project are described below: measuring tape, steel 1020, aluminum and brass test pieces, metal cutting machine for steel, scale, tensile-compression equipment: 810 material test system as shown in Figure 1, and station manager software used for data collection.



Figure 1. 810 material test system used for tensile essay.

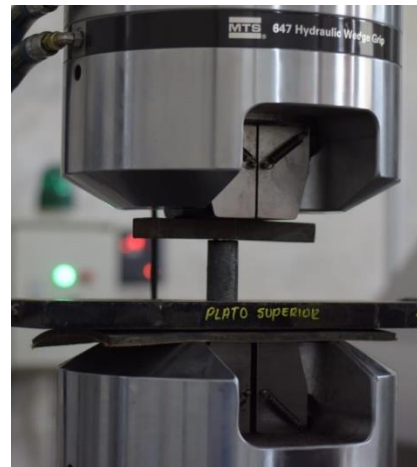


Figure 2. 810 material test system used for compression essay.

The experimental development will be described below: in the first phase, study of ASTM E8 and E9 standards was conducted [13]. In the second phase, it was necessary to use the cutting machine to adapt the size of the test pieces according to standard required. In the third phase, diameter, length and mass values were recorded for each specimen. In the fourth phase, the test pieces were coupled to the equipment and the tensile essay was carried out, followed by the compression essay; with data obtained through the software, the calculations and analysis were carried out to experimentally determinate Young modulus, stress and deformation for each material. Finally, the programming code was developed, and allowed the real data found to be taken to a virtual laboratory.

3. Results

3.1. Experimental results

Tensile and compression essays were performed to determinate Young modulus and graphs to visualize the proportional, elastic, plastic, yield and ultimate tensile strength zones, how was describe in the previous section. The results of Young modulus are now shown in Table 1.

Table 1. Young modulus for different materials.

Material	1020 Steel	Aluminium	Bronze
Stress (Pa) for tensile essay	49.08	13.96	28.32
Stress (Pa) for compression essay	52.57	5.08	20.70

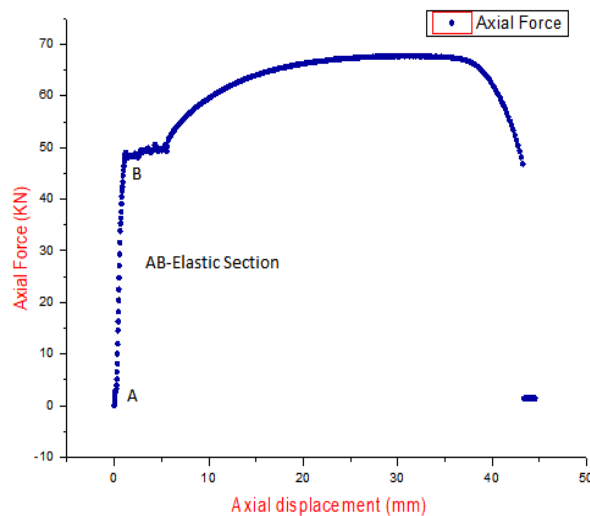


Figure 3. Stress vs strain curve for 1020 steel tensile essay.

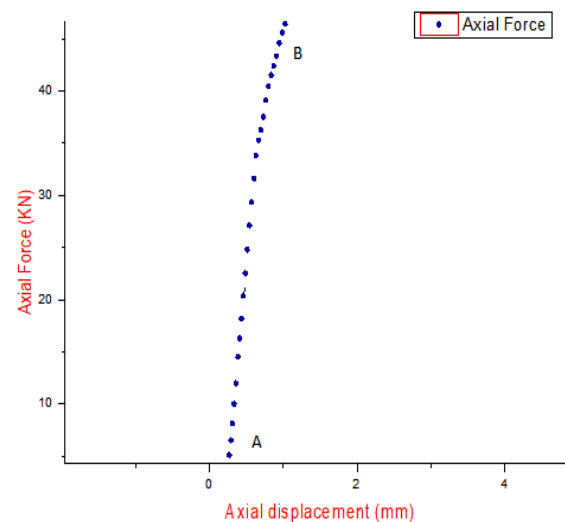


Figure 4. Elastic section of Stress vs strain curve for 1020 steel tensile essay.

The graphical results shown in Figure 3 and 4 will be used feeding the database of the virtual laboratory.

3.2. Virtual laboratory design

A virtual laboratory was developed considering the data and figures obtained in experimental results subsection. The code was structured for objects in two classes in python 2.7 language, one class is used to define virtual laboratory specimens and the other to create a graphical interface. The graphical interface was implemented with the tkinter library and the "canvas" widget, all the implementation of buttons or other objects was done with bitmaps or "sprites", which were also used for tensile and compression module animations while analyzing specimens and presenting results. The design of the bit maps was done in its entirety in inkscape. Due to this is a didactic software, it was designed for the user to interact just using the mouse. On the other hand, "bindings" or attachments to mouse click operations for each of the graphical interface buttons were defined. Also, the trawling operation of the specimens from a support table to the traction and compression module machine was implemented.

3.3. Code implementation

To develop the script described in the flowchart of Figure 5 python 2.7 was used. The code allows implementing any number of additional materials. A list inside the code was created to incorporated three materials (aluminum, bronze, and steel) with full graphical resources another developer that download the code could add additional materials you can use the examples contained in the "sprite" directory and modify the global list "self.materials" in the source code for the name of the additional material.

3.4. Use of graphical interface

It is important to consider the most representative icons into the virtual laboratory, described in Table 2. Also, Figures 6 and Figure 7 show graphical interface where user can select the tensile or compression test; after choosing the test, three test pieces of different material will be shown, each one can be moved to the tensile-compression machine, then press again the button of the chosen test and the animation will be displayed along with the actual results that were taken, including Young modulus and the stress vs strain graphic. In case that user wants to choose another test piece, he can press a reset button and return to the starting point.

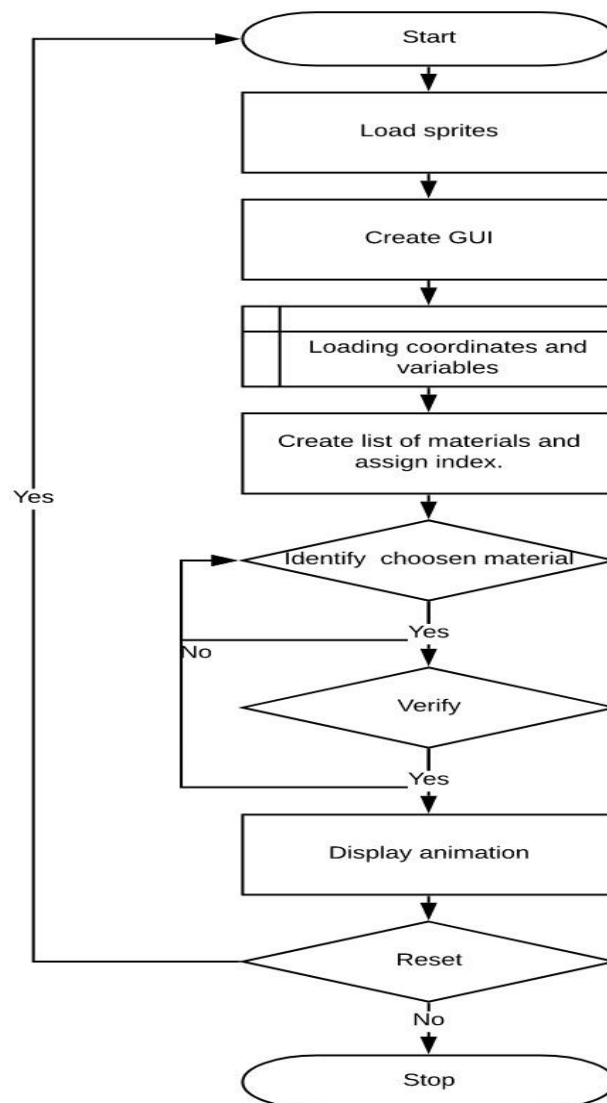


Figure 5. The flowchart describes step by step the animation process.

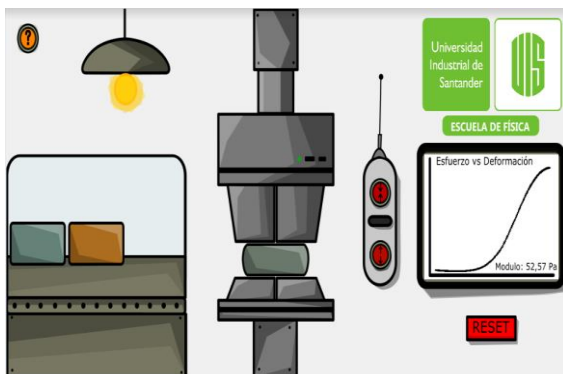


Figure 6. Graphical visualization a compression test.

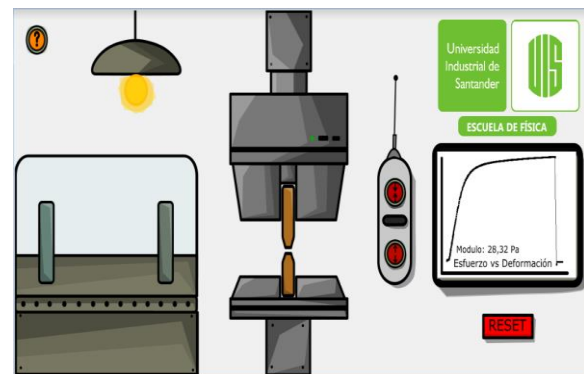


Figure 7. Graphical visualization a tensile test.

Table 2. Important objects for the operation of the virtual laboratory.

	Help button	This button allows the user to know how the virtual laboratory work, gives the instructions for the tensile and compression essays, as you wish.
	Compression button	This button allows to do the compression essay.
	Tensile button	This button allows to do the tensile essay.
	Reset button	The reset button allows the user to restart any essay

4. Conclusion

The virtual laboratory developed in this research allows students of basic secondary and universities with limited access to specialized equipment, to develop abilities in materials science without physically attending a laboratory. Through, an intuitive, and interactive simulation. The virtual laboratory can be used into academic communities without experience in python programming, we have compiled files to create an extension ".exe" for Windows 64 bits you can be found in the following link https://github.com/dantrica/Young_module. Also, you can find the source files if you want to work on the code.

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