Uniaxial Tensile Tester Team 2

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Activity Report

Abstract—Among the problems with the current tensiometer design are accuracy of the range sensor, friction between the track, weight limit of the load cell, elasticity of the cable for pulling, human error when pulling, and non-uniform force application. The problems described above need to be addressed because they add errors to the measurements, making it difficult to calculate Young's Modulus and Ultimate Tensile Strength accurately. The fixes for these problems include: Replacing the current range sensor with a laser optical range sensor for relatively accurate measurements of strain. Replacing the current load cell with a 20-kilogram load cell allows greater force application when stressing materials with large Young's Modulus. Replacing the current pulling track with a linear bearing track reduces measurement errors caused by resistance. Replacing current cable with non elastic metal cable reduces errors in measurements caused by rope elasticity. Adding a ratchet crank in order to apply force uniformly. Lastly, adding a LCD screen to prompt the users with basic instructions improves ease of use. These solutions will allow for the stress and strain to be measured with greater accuracy and consistency.

Index Terms—Uniaxial Tensiometer, System Analysis, Engineering Design

1 BACKGROUND

A tensiometer tests the strength and elasticity of a material by applying stress and observing how the material stretches, deforms, and eventually breaks. In order to accurately measure these variables both a load cell that measures the force applied, and a range sensor to find the amount the material stretches are necessary. It is essential that these sensors be calibrated and that the system allows for uniform and steady application of force. Any significant deviation of values will result in an inaccurate representation of material properties. The operation of this device should be relatively easy to learn and consistent in its performance regardless of the operator.

The current prototype [1] has several problem areas that have been identified. The range sensor is unreliable, it often produces inaccurate or even random values. There is significant friction between the track and shuttle which produces additional stress on the load sensor thereby inflating stress values. The weight limit of the load cell is fairly limited and will not allow for the testing of stronger materials. There is elasticity in the rope used to apply force and its own tensile properties could impact measurements. Testing has shown high potential for human error when applying force. The operator can easily unintentionally apply force at an uneven rate or even reduce force applied. The current system does not allow for a uniform increase in application of force. Lastly the code is cumbersome to use, especially for those unfamiliar with basic programming.

In order to improve upon the design several components will be replaced and some components will be added. The range sensor can be replaced with a laser range sensor rated for a higher degree of accuracy. The current track is a drawer slider and replacing it with a guide rail that uses bearings could reduce friction and weight of the shuttle. The load cell can be replaced with a 20kg load cell with the

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same dimensions. Instead of using a rope to apply stress, a metal cable's tensile properties would be negligible at these weights. To provide smoother application of force the cable will be run over a pulley to a ratchet crank. Including a LCD screen with instructions can ease use of the device and reduce human error.

None of these inclusions are expensive and their costs are comparable to the parts they replace. These modifications however have the potential to greatly increase the overall performance of the system by reducing the errors in measurement of Young's Modulus and Ultimate Tensile Strength of the material being tested. Making the system more accurate and reliable is essential for the desired functionality of the Stakeholder. The proposed modifications will also make the operation of the devices easier which ultimately helps in operation and consistency of results.

2 System Requirements & Constraints

In order to define requirements it is important to understand what the stakeholder wants. The first major requirement is that the measurement of Young's Modulus and Ultimate Tensile Strength is relatively equal to the theoretical value, and the system should be able to perform the task with consistency. The second major requirement is that the data collecting components of the system have the ability to be calibrated in order to get accurate and precise measurements for different materials. Calibration also assures similar reliable results across different devices.

2.1 Accuracy and Precision

The "Run Tensile Test" use case aligns with this requirement. The desired functionality of this requirement is to get accurate and precise measurement of stress applied to the material under observation and strain produced in the material due to the application of stress. In order to start, the user will upload the Arduino code and open Ardu Plotter tool from the tools tab. The Ardu Plotter will give the distance of the sensor from the base and the amount of force applied on the material being stretched. The user will use the crank to pull the material until the material breaks. The Ardu Plotter tool will upload the data to an excel sheet which the user will use to plot stress vs. strain curve.

Normal Flow

- **Step #1:** User Loads material to be tested into the clamps and increases tension until material is just taught, but not stressed.
- **Step #2:** User slowly cranks pulley when LCD displays "GO", straining the material.
- **Step #3:** System records displacement and force every 0.5 seconds.
- **Step #4:** User stops cranking the rope after the material fractures, can not be displaced further, or LCD displays "STOP".
- **Step #5:** Chemist analyzes the data. Stress is calculated by dividing force by cross-sectional area. Stress-strain curve is defined. Material properties are determined.

Alternative Flow

- **Step #1:** User slowly cranks pulley when LCD displays "GO", straining the material
- **Step #2:** Ultimate tensile strength of the material is beyond load cell limits. When load cell approaches 75 percent of maximum load, LEDs flash, and LCD displays warning message.
- **Step #3:** User stops cranking the rope after the material fractures, can not be displaced further, or LCD displays "STOP"

2.2 Calibration

The "Calibrate Instrument" use case aligns with this requirement. The desired functionality of this requirement is to calibrate the load cell and the range sensor to get accurate measurement of the force applied on the load cell due to pulling the rope and and strain produced in the material due to application of stress. In order to start the calibration, the user will upload the Arduino code which will prompt the user to put a known load on the load cell and prompt the user to type in raw value of load cell. The code will then generate a calibration value and calibrate the load cell to give an accurate measurement of the load.

Normal Flow

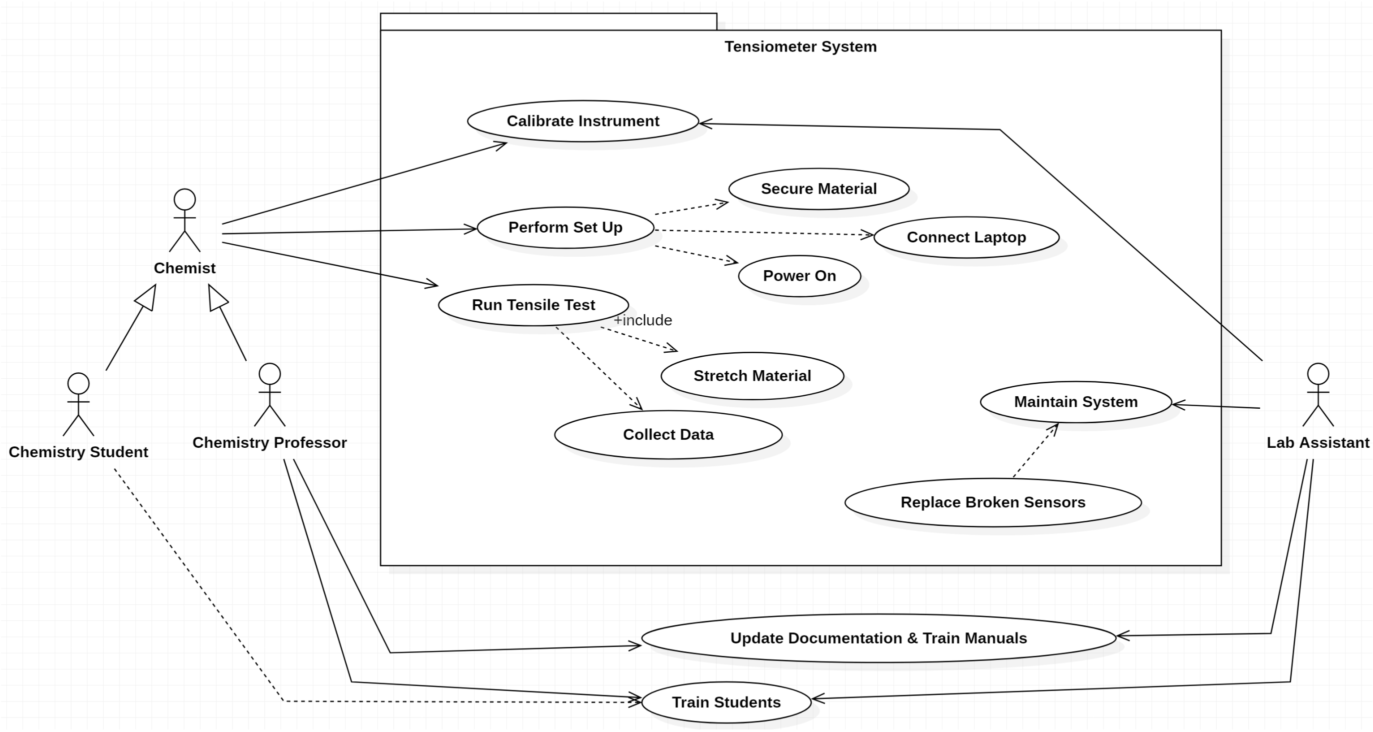

Figure 1. Use case model of the tensiometer system depicting system actors and the desire actions the system is required to support.

- **Step #1:** User will upload the Arduino Code.
- **Step #2:** Code will prompt the user to put a known load cell.
- **Step #3:** Code will prompt the user to write the mass of load.
- **Step #4:** The load cell gets calibrated and the user gets accurate and reliable measurement.

Alternative Flow

- **Step #1:** User will upload the code.
- **Step #2:** Code will prompt the user to put a known load cell.
- **Step #3:** If calibration fails LCD displays warning message.
- **Step #4:**User re-uploads the code and calibration runs again.

2.3 Constraints

System constraints include:

- **Time Constraint:** Completed and read to presentation/demonstrate by April 22nd
- **Budget:** Cost needs to be below $150. Going over budget will require strong justification as to the value added from the cost overrun.
- **Replication:** Relatively straight-forward process to replicate your work, such that we can build out a lab of identical tensiometers.
- **Accessibility of Parts:** Parts need to be readily accessible, ship quickly (not on back order) and available from common part suppliers (e.g., Digikey, Mouser, Adafruit, SparkFun, Amazon). Avoid parts that are difficult to source.
- **Safety:** System must be safe to operate without significant training or supervision

3 Logical Design

The proposed design is simplistic in nature and follows the designs constraints. Referencing the Figure 2, the system consists of sturdy wooden frame and uses two pulleys to efficiently transfer force from an adjacent crank to apply a vertical load. The lower clamp is attached to the base and the upper clamp is attached to the shuttle with the load cell. The material under observation will be placed between these

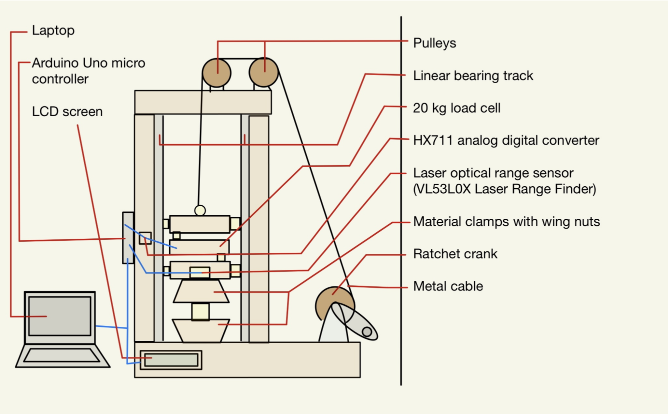

Figure 2. Uniaxial Tensile Tester Design

clamps. The laser sensor attached to the shuttle will measure the distance from the base as the rope is pulled through the pulley. The data will be read by both the load sensor and range sensor through micro-controller and processed accordingly. The LCD screen will display commands to help the calibration process and operation of the device. Commands can range from calibration instructions to operation instructions like ”Pull” or ”Stop”.

3.1 Design Justification

This design is better than potential alternatives because of its ability to increase the load uniformly, low friction linear bearing tracks, higher load capacity, useful LCD screen, and easy-to-use clamps. This design allows for intuitive operation and accurate values. The current system is cumbersome to use and does not provide accurate and precise measurements of stress and strain. These shortfalls will impede the users ability to find Young's Modulus and Ultimate Tensile Strength of the material under observation. The advancements stated above will increase the accuracy and precision of measurements by reducing systematic and human errors.

References

[1] J. H. Arrizabalaga, A. D. Simmons, and M. U. Nollert, "Fabrication of an economical arduino-based uniaxial tensile tester," *Journal of Chemical Education*, vol. 94, no. 4, pp. 530–533, 2017. [Online]. Available: https://doi.org/10.1021/acs.jchemed.6b00639