Logical Design Proposal Improved Tensile Tester Team 6

Mazin Chater, Youssef Jalwaj-Soubai, Jaden Pharoah

Activity Report

Abstract—A uni-axial tensile tester is a widely used system for gathering ultimate tensile strength and Young's Modulus of a given material. Generally, these systems can be expensive and sophisticated yet their value as an educational tool for chemistry students is significant. As such, a cheaper, student-friendly design is highly desirable. Provided a minimally functional base model with issues ranging from largely inaccurate and imprecise results, obscure functionality, and generally an unpleasant and non-intuitive user interface, a targeted solution must aim to re-envision and harmonize the old structure into a more refined prototype. What follows is an advanced design that rectifies a number of defects as well as markedly improves accuracy and reliability. Additional ease-of-use features are implemented with an emphasis towards student use. The new capabilities deliver a low-budget, discernibly innovative solution with supporting documentation that sum to provide an accessible educational tool for students.

Index Terms—Uniaxial Tensiometer, System Analysis, Engineering Design

1 Background

Tensile testers are instruments crucial in the study of materials science. A vast majority of those on the market, however, are thousands of dollars for a single unit and can be overly sophisticated beyond the scope of educational benefit. An alternative solution has been designed with these limitations in mind – one that is fundamentally simplistic with student use considered at its core [1]. The existing solution, nevertheless, has extensive flaws that hinder at the overall goals of reliability, accuracy, and accessibility. Most prominently, the accuracy of the system is only within an order of magnitude of accepted values which is due to a variety of factors including friction losses and unnecessary parts which add to erroneous load cell readings. Ease-of-use is also obstructed with the provided plastic clamps which are especially time-consuming and inconsistent when holding materials. Likewise, data transfer must be performed manually from an Arduino interface to a MATLAB file to generate a stress-strain curve, creating a troublesome barrier for prospective chemistry students. In the purest sense, the following design resolves these issues by bridging the gap between a thought experiment and a fully-functional system.

- *Mazin Chater,*
  E-mail: mchater3@albany.edu,
- *Youssef Jalwaj-Soubai,*
  E-mail: yjalwaj-soubai@albany.edu,
- *Jaden Pharoah,*
  E-mail: jpharoah@albany.edu,
  University at Albany.

2 System Requirements & Constraints

It's important to define functional requirements of the system as outlined by both stakeholders and end users. At the forefront of the design must be accuracy and reliability. Having accurate results is only as useful as their consistency and having precisely inaccurate results is similarly of little utility. The constructed design aims to minimize error as well as to maximize reproducible trials. Another key aspect lies in the accessibility of the system. A functional model is only worthwhile to those who are capable its operation; therefore, there is merit in recognizing that additional software requirements, a non-intuitive structure and an intimidating arrangement of circuitry among other things are undesirable features to be mitigated. The following requirements describe functionality from a user's perspective in ideal and alternative scenarios.

2.1 Accuracy and Precision

Accuracy is the characteristic that defines the adherence of a measure to a known value, whereas precision refers to the consistency of a measure across multiple iterations. Both qualities are integral to the stakeholder and a functional instrument must contain these attributes. Users engage with the apparatus to test a sample material. Interaction with the system must first consist of calibrating both the load and distance sensor. An LCD screen will guide the user through the process and prompt the participant to input appropriate values such as that of a sample mass or distance. Utilizing this data the sensors will be configured accordingly as to eliminate erroneous outputs. Furthermore, in order to ensure the quality of the load sensor data a more sophisticated load cell has been implemented to maximize the accuracy of measurements. In contrast, the current range sensor has proven to be dependable and is unlikely to be replaced.

Normal Flow

- **Step #1: Initiate calibration process via button press.**
- **Step #2: Enter sample mass or distance value when prompted.**
- **Step #3: Instate the sample condition.**
- **Step #4: Confirm step via button press.**
- **Step #5: Repeat steps 2-4 until confirmation message is displayed.**
- **Step #6: Proceed with experiment.**

Alternative Flow This describes what will happen under an error condition.

- **Step #1: Error message will display citing imprecise measurements.**
- **Step #2: User will be unable to proceed under erroneous conditions.**
- **Step #3: LCD Screen will prompt the user to initiate the calibration process once again.**

2.2 Accessibility

Having an accurate and reliable system is significant, but the system must be functional for its intended audience. To make the system accessible, design elements shall consider the stakeholders' experience and goals when interacting with the model and prioritize elements that maximize fluidity. An LCD screen in addition to its value as a calibration mechanism is also inherently user-friendly by providing simple options that hide the complex operations behind them. Users will merely select an option (i.e. start test, end test, send data, etc) and can disregard background intricacies. Modified clamps similarly serve to minimize setup time by dispensing with unnecessary screws and by implementing a simpler method whereby the clamps may open. Users will open each clamp with a single knob and firmly place the material in a matter of seconds, allowing for more tests to be conducted and minimizing hassle associated with the base model.

Normal Flow

- **Step #1: Place a sample firmly between both clamps.**
- **Step #2: Use the LCD screen to select the Start Test option.**
- **Step #3: Upon the sample tearing, select the End Test option.**
- **Step #4: Select the Send Data option.**
- **Step #5: Receive the data via network connection.**

Alternative Flow This describes what will happen under an error condition.

- **Step #1: Select the Refresh System option on the LCD screen.**
- **Step #2: Once reloaded, follow normal case steps.**
- **Step #3: If error persists, re-upload code using Arduino software as specified in the system documentation.**

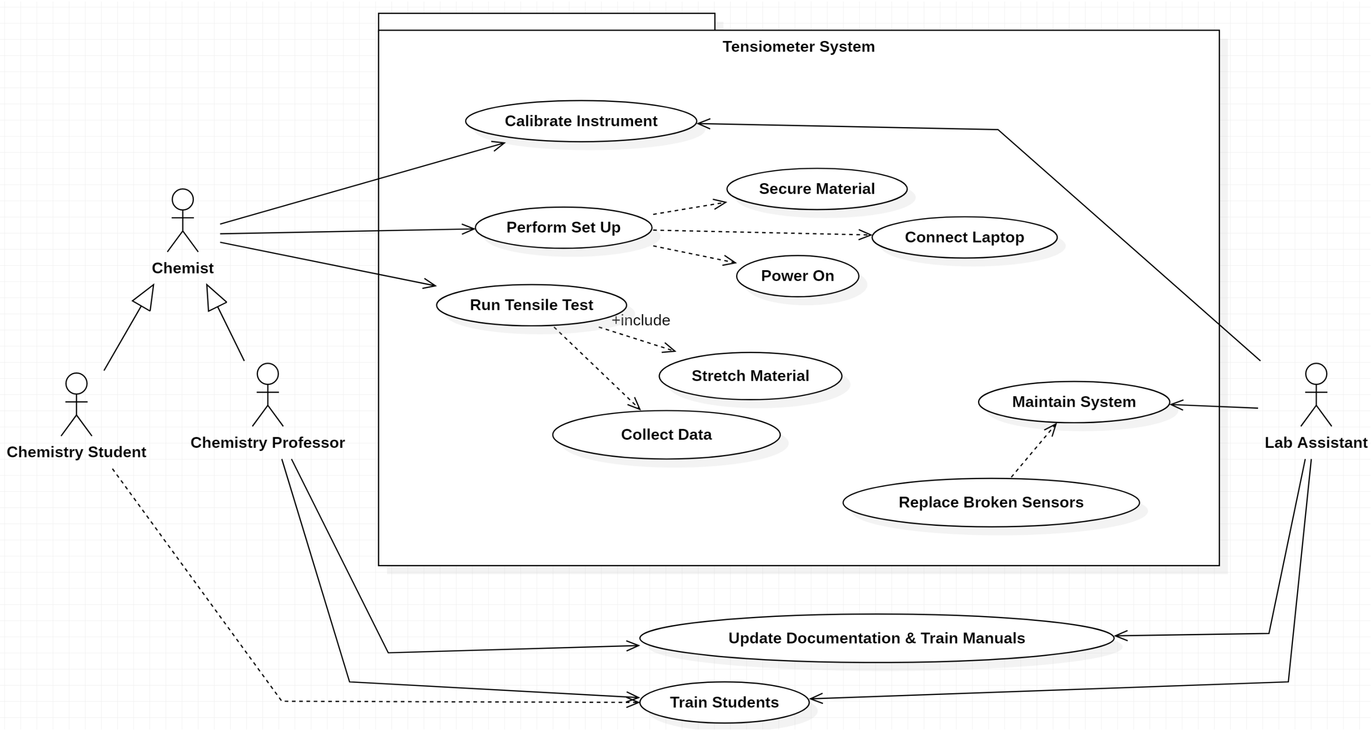

Figure 1. Use case model of the tensiometer system depicting system actors and the desired actions the system is required to support.

2.3 Constraints

The stakeholders have imposed certain restrictions upon the design process. System constraints are defined below and detail the conditions that the resulting testing apparatus must abide by.

- **Time Constraint:** Completed and ready to presentation/demonstrate by April 22nd
- **Budget:** Cost needs to be below $150. Exceeding the budget will require strong justification as to the value added from the cost overrun.
- **Replication:** Relatively straight-forward process to replicate project work, such that an individual 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). Parts that are difficult to source should be avoided.
- **Safety:** System must be safe to operate without significant training or supervision

3 Logical Design

The proposed design is simplistic in nature and abides by all given constraints. A visual depiction of the logical design is detailed within Figure 2. Referencing this image an individual first takes notice of the structural frame. A combination of wood and metal rods the testing apparatus lies upon a sturdy foundation. The drive system is comprised of a linear actuator that applies the necessary uni-axial force. The bottom clamp is attached to the end of the actuator, whereas the top clamp is fastened to the load cell. Our specimen of interest will be placed between these entities. Data will be collected from both the load cell and range finder. This information will be read by the micro-controller, processed accordingly and sent to the LCD display. Furthermore, if the user desires they may export the test data to their personal machine via network connection.

3.1 Design Justification

The proposed design is superior to potential alternatives due to a myriad of factors. Specifically, the selected design is an entirely stand

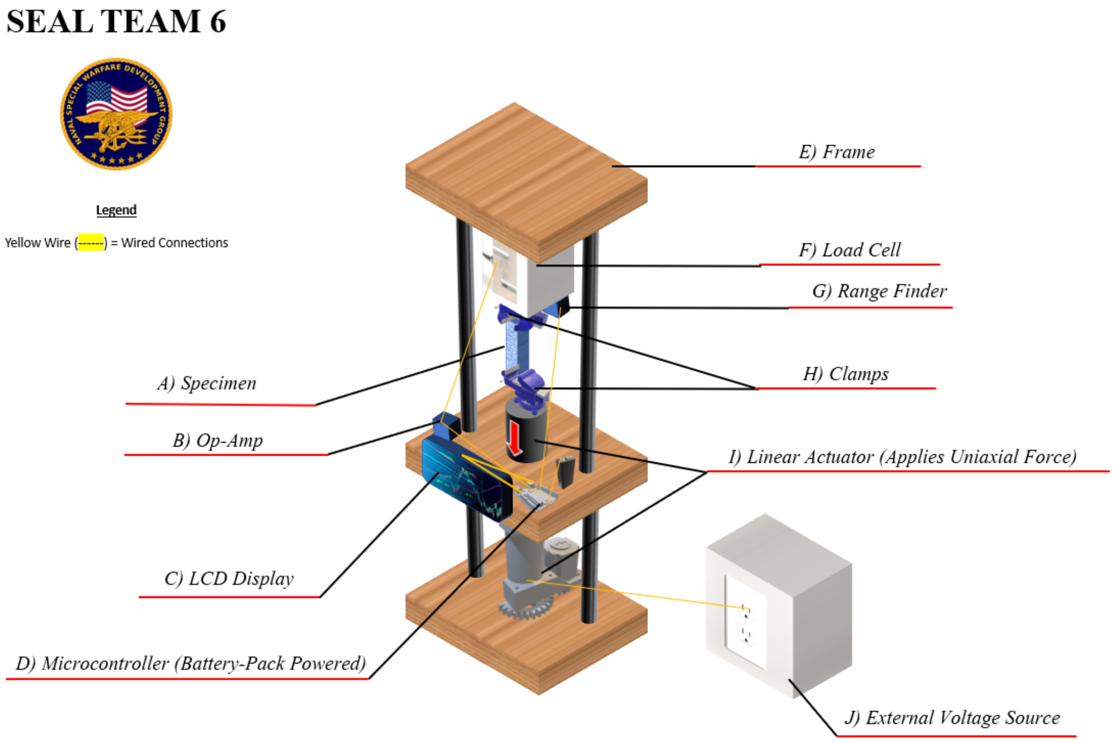

Figure 2. Logical prototype of the current system. Of key importance is the uni-directional movement of the clamps and addition of an interactive LCD screen as a user interface.

alone apparatus and does not require the user to own a laptop. Removing such dependencies denotes that all students will be able to participate within a lab regardless of preparation. Furthermore, the device is ergonomically sound, this denotes that even an individual with no prior experience may perform a successful tensile test. The entire process is iteratively walked through via clear instructions presented on the LCD screen. Moreover, the selected drive system allows for a constant and reliable form of force application. Utilizing the linear actuator a user will have far more consistent results compared to a manual system such as a hand-crank. The referenced implementations sum to unveil a working mechanism that satisfies client requirements quite comfortably.

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