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Fabrication of Automated Desktop Universal Tensile Testing Machine

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Abstract – Before we begin, we need to discuss terminology. We're amazed at the variety of terms in the industry that are used to refer to a UTM. Most common are "tensile tester", "compression tester" and "bend tester". Today, a UTM can perform all of these tests and more. A UTM is a great multi-purpose instrument for an R&D lab or QC department. Thus, keeping in view the diversified scope in the engineering field, we have opted to design a Universal Testing Machine and to comply with the reduction of physical effort, the testing mechanism is automated along with the inclusion of all necessary parameters and the movement of the members. The main ideas behind opting this project of designing a UTM is to provide a helping hand to the students and personnel associated with the Mechatronics Engineering field and to provide them the better understanding of the UTM machine of international standard. Secondly, provide Pakistan this machine, manufacturing it locally at a very reasonable cost with exceptional functionality and automated mechanism.

Keywords – Material Testing; Intelligent monitoring; Embedded system.

I. Introduction

Tensile Testing is an important tool for testing the purity of the material that how far an element can bear the cyclic loading on itself. Although the process requires extreme precision and control, the process is very demanding and requires extreme patience [1], [2].

An important feature of this device is the simplicity to exchange components according to the user requirements: the low cost, low machine compliance and the high resolution obtained. This machine can also be adapted for compression testing with appropriate samples and grips [3], [4].

Commercial testing machines with the required capabilities are available, however they are prohibitively costly. The tester will need to be assembled for a fraction of the cost of an off the shelf tester while retaining the same capabilities as commercially available systems [5].

The stated objective was to design and build a low-cost, compact prototype for conducting axial load testing, should also act as a platform for future expansion, incorporating a modular design and flexible fixture mounting points to allow for the addition of new capabilities as needed by the lab.

The universal testing machine must be able to apply 5 KN axis loading to the specimen being tested. The system must be designed to comply with interchangeable test fixtures needed for different types of testing. A MATLAB user interface is to be used to make the system user-friendly as well as effective for data collection and management, and to use the interface many of the intended users are familiar with. The tester must also be designed and built under a reasonable budget. To comply with this requirement, the team has made it a goal to build the testing platform within an optimum budget [6]–[8].

In order to keep the functionality of the project device similar to the current system the size of the device and the way it functioned would be based on the reference model. Multiple concepts were generated for each component, while keeping in mind the overall requirements of the system and the interface between all of the parts. By creating a design matrix and evaluating all of the possible system components, the team narrowed the project down to four essential system components:

- Design Analysis using CAD/Solidworks
- Material Selection and Mathematical Computations.
- Frame Fabrication
- Automation using electronics and control system.

This design allows the user to conduct the most common mechanical tests using commercially available and machinable-inhouse parts while maintaining high resolution. The chosen components and versatile frame allow for expansion of the system in the future for additional test capabilities without the need for re-designing the existing components.

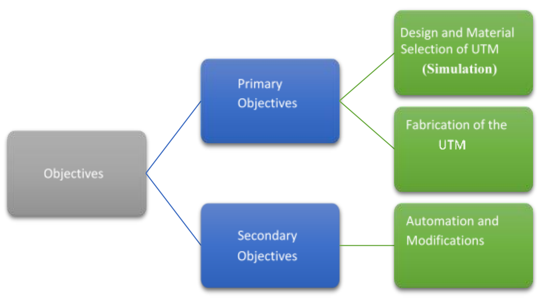


Fig. 1 Layout of project

Fig. 1 shows the basic layout and architecture of project. The cross-member slides through the cross-head by means of the guide rods. The procedure is quite straightforward.

The structural components of the testing system are used to subject material specimens to tensile or compressive forces from which we can derive very useful material-specific properties in the observations known as a stress strain plot. While the motion control and data acquisition is done through the computer. A servo motor provides the necessary torque to turn the master cylinder of the hydraulic actuator. The overall electrical system consists of a servo motor and driver circuit, an optical encoder, an amplifier, and a controller card [9], [10]. The function of the encoder is to measure the rotation of the servomotor. The controller and a PC-bus plug-in interface card connect the computer to the mechanical testing system. It is planned to connect Analog inputs such as load cell, displacement, and strain gauge to this card using the auxiliary channels for data acquisition. The CAD model of the system is shown in Fig. 2.

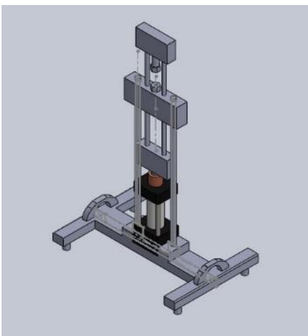


Fig. 2 Simulated Model (Solidworks)

The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the engineering strain, ε, using the following **Hata! Başvuru kaynağı bulunamadı.**

$$\varepsilon = \frac{\Delta L}{L_o} = \frac{L-L_o}{L_o} \tag{1}$$

Where, ΔL is the change in gauge length, L0 is the initial gauge length, and L is the final length. The force measurement is used to calculate the engineering stress, σ, using the following **Hata! Başvuru kaynağı bulunamadı.**.

$$\sigma = \frac{F_n}{A} \tag{2}$$

Where, F is the tensile force and A is the nominal cross-section of the specimen. The machine does these calculations as the force increases, so that the data points can be graphed into a stress–strain.

$$T_R = \frac{F d_m}{2}\left(\frac{l+\pi f d_m}{\pi d_m - f l}\right) \tag{3}$$

$$T_L = \frac{F d_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + f l}\right) \tag{4}$$

Following variables have been reviewed thoroughly and assumed known

- Friction coefficient μ = 0.1~0.3
- Total length = 500~600mm
- Lead length = 10~15mm
- Diameter dm = 15~35mm
- Efficiency h = 0.9 ~0.96
- Frictional resistance = 500N
- TR = 40Nm
- TL = 13.82Nm

II. Methodology

The working principle of our project includes the mechanism of rotating the screw jack mechanically using the handle provided with a key so that it remains fixed within. When the screwjack rotates, the pressure is exerted though a master cylinder, attached directly with the screw jack, and the force is transmitted through the cylinder to the crosshead. The force member (crosshead) moves in the upward direction exerting the force on the loadcell and ultimately exerting the tensile force on the specimen attached. The force is continuously exerted till the specimen breaks and fracture strength is achieved. This stepwise increment of the force and its effects on the specimen are recorded as a data set of values and computation is being simultaneously done on every data set using our created GUI. The set of observations are recorded in tabular form and a stress-strain curve is plotted with the help of these values using a GUI. The actual image of the system is shown in Fig. 3.

Fig. 3: Actual System

A. Load Cell

When the force member moves upwards and tensile force is applied on the specimen, as a result a force is also exerted on the loadcell. The loadcell produces a proportional voltage change in response to the exerted force and this voltage change is stepwise recorded.

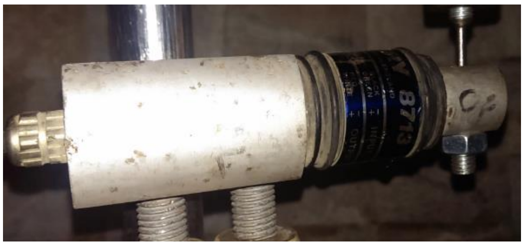


Fig. 4 Load cell

B. LVDT (Linear Variable Differential Transformer)

The LVDT is an analog sensor used primarily to measure the change in length of the specimen caused by the tensile force. In other words it is used to measure the strain developed in the specimen. It is connected with the force member and the specimen.

Fig. 5 LVDT

III. ANALYSIS

Before initiating the tensile test, user-defines important experiment parameters in relevant fields.

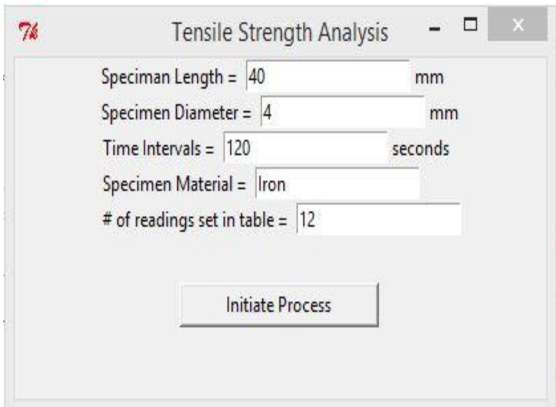


Fig. 6 GUI (Functional Parameters)

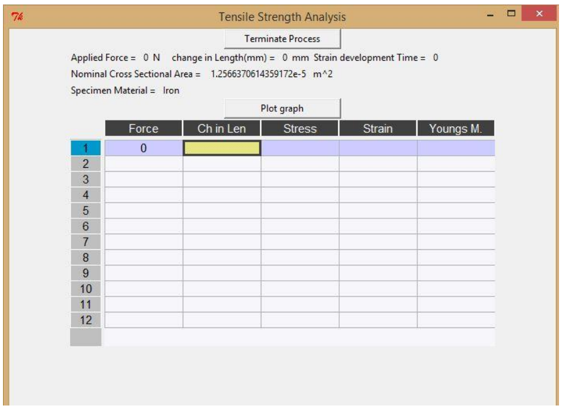


Fig. 7 GUI (Applied Force Displayed)

This prompts a new window tabulating the readings based on first screen. As we see initially, the fields are empty but they will populate after each time interval passes. These are processed readings gained from the loadcell and lvdt sensors. The Young's modulus is then calculated from the stress and strain values.

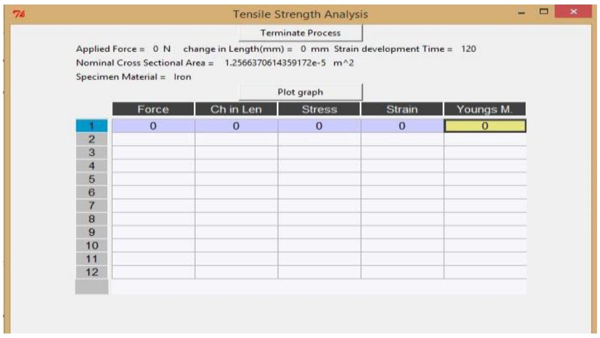


Fig. 8 GUI (Young's Modulus calculated)

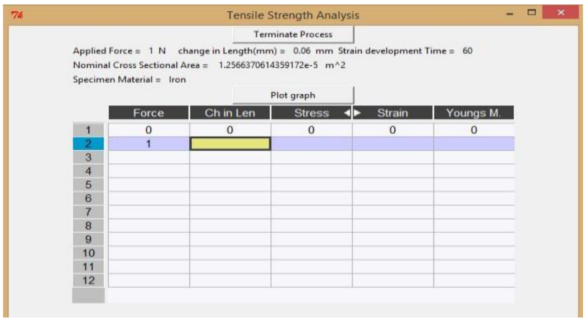


Fig. 9 GUI (2nd Iterative parametric formulation.

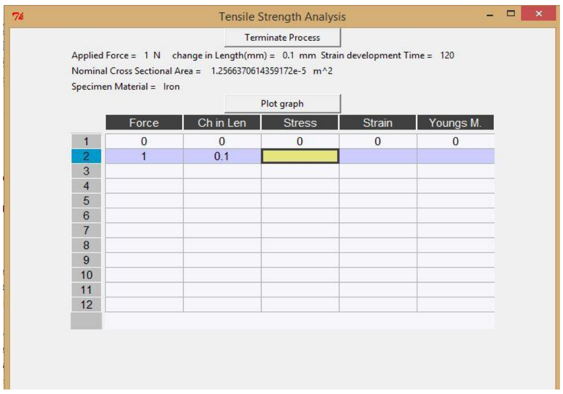
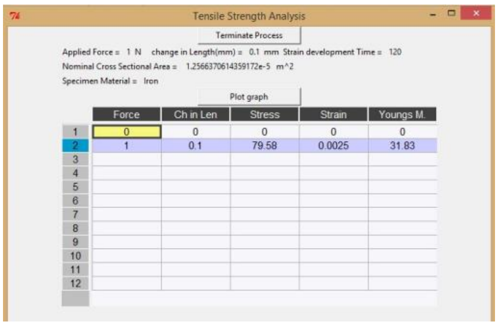
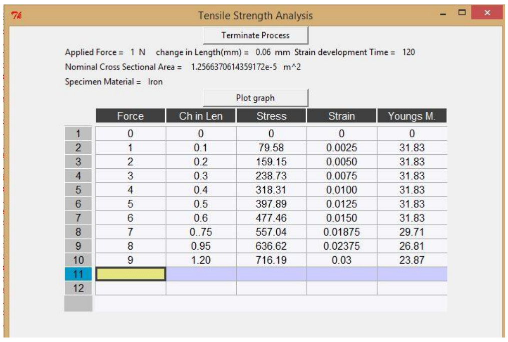


Fig. 10 Stress computation



	Force	Ch in Len	Stress	Strain	Youngs M.
1	0	0	0	0	0
2	1	0.1	79.58	0.0025	31.83
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Fig. 11 Young’s Modulus Formulation



	Force	Ch in Len	Stress	Strain	Youngs M.
1	0	0	0	0	0
2	1	0.1	79.58	0.0025	31.83
3	2	0.2	159.15	0.0050	31.83
4	3	0.3	238.73	0.0075	31.83
5	4	0.4	318.31	0.0100	31.83
6	5	0.5	397.89	0.0125	31.83
7	6	0.6	477.46	0.0150	31.83
8	7	0..75	557.04	0.01875	29.71
9	8	0.95	636.62	0.02375	26.81
10	9	1.20	716.19	0.03	23.87
11					
12					

Fig. 12 GUI (Stress Stain values set : iterative procedure)

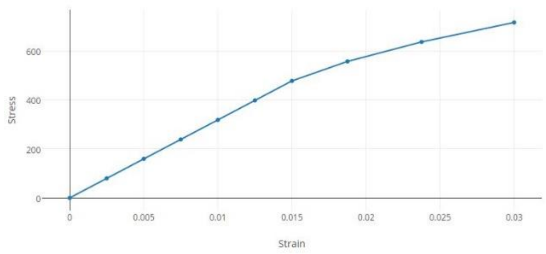


Fig. 13 Stress Strain Curve generated

The performance of this universal testing machine indicates that it is appropriate to obtain reliable mechanical properties of compliant materials in thin and soft materials. The testing phase was completed for elastic deformation of the steel specimen by the end of the project timeline. A table has been provided with actual values of typical engineering materials. Of these, Iron, Steel and Aluminum specimen were acquired. For a grade450 steel specimen, we can read off yield strength value as 450 Mpa. If we observe the graph generated by the machine (see 5.2) we see that nonlinearity occurs at approximately 480 Mpa.

Given the scale of our project, and the many components that have to be put together, the team had to place the rotary table development on hold during the midst of the semester. A temperature and humidity control chamber can simulate an environment that the specimen may encounter during normal circumstances, thus making the test results more convincing and useful. Other possible modules include electrochemical mechanical planarization capability, high precision loading tip, nano-indenter, and a movable sample platform. The above mentioned improvements would enable the machine to perform more advanced tests to a point where only customized modules can help further.

IV. CONCLUSION

This design allows the user to conduct the most common mechanical tests using commercially available and machinable-inhouse parts while maintaining high resolution. The chosen components and versatile frame allow for expansion of the system in the future for additional test capabilities without the need for re-designing the existing components.

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