International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 10 | October - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Development of Digital Measurement System for Analog Universal Testing Machine

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Abstract - Today, Older Analog universal testing machines are still in use. Often, the equipment remains functional decades after initial purchase, thereby returning the initial investment back to the owner. However, older machines should be upgraded to benefit from newer innovations and capabilities. The replacement costs for the older mechanical testing machines can be in the tens and hundreds of thousands of dollars. By retrofitting an older machine, the owner will gain a clear cost benefit over the purchase of a new system. The reason for this is, since the most expensive and durable part of a new system is the load frame, keeping that old load frame in place and merely adding digital controllers and windows-based software, one expands the functionality with minimum investment. Computerized universal testing machines available are so advanced with the capability of analysing and displaying multiple material properties on system. But these systems are expensive and with complex designs because of using different advance electronic equipment to computerize the system. So, by developing existing universal testing machine with low-cost equipment can resolve the problem of taking manual readings of different material properties testing.

This development is been done to provide developed low-cost universal testing machine which can measure different material properties by performing material tests giving relation between stress and strain data generated through Processing 3 software and pressure-displacement sensors which are interfaced by Arduino microcontroller. Data can be generated by preparing program in Arduino for interfacing sensors and Processing 3 for measurement readings of testing. Sensors gives accurate data if they are properly calibrated and assembled on respective existing machine instruments. Computerized universal testing machine works by applying gradual load on specimen of known geometry which is fixed within jaws of upper and middle crossheads or middle and lower crossheads operated by hydraulic actuation system and electric motors. The results stress strain data and mechanical material properties obtain from this system is simulated in real time by creating Graphical User Interface in Processing 3.

***Key Words*:** Material properties; Testing; Interfacing; Stress-Strain

1.INTRODUCTION

Tensile testing is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation, and percentage reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uni-axial tensile testing is mostly used for obtaining the mechanical characteristics of isotropic materials. For anisotropic materials, such as composite materials and textiles, biaxial tensile testing is required. Universal Testing Machine (UTM) is used to carry out tensile test, compression, shear, and bending test.

2. ANALOG UNIVERSAL TESTING MACHINE

2.1 Construction

It mainly consists of drive system with robust base. The main hydraulic cylinder is fitted in the center of the base and the piston slides in the cylinder. A motor is fitted to the left-hand side of the base. The chain and sprocket drive by the motor rotates two screwed columns mounted in the base with bearings. Loading unit has lower table which connected to the main piston through a ball and ball seat joint. This joint ensures axial loading. This lower table is rigidly connected to the upper crosshead by two straight columns. The lower table and upper crosshead assembly moves up and down with the

main piston. The jaws insert for the tensile test specimen along with the rack jaws slide in the lower and upper crossheads. The sliding motion of the rack jaws is achieved by rotating the helical toothed pinion by the operating hand wheel provided. Jaw locking handle is provided to lock the jaws of the lower crosshead after the specimen is clamped. This arrangement ensures firm clamping of the specimen and easy take out of the broken specimen. Different test attachments are provided to perform different tests. The space between the lower table and the lower cross head is used from compression, bend and shear tests, and the space between the lower and upper cross heads is used for tension test. Two compressions plates, upper and lower are provided for conducting compression test. Bending table bending Roller and bending pan are provided as an attachment for carrying out the bend test. Single and double shear test is performed by different die for respective specimen. Pendulum dynamometer permits selection of favorable hydraulic ratios producing relatively small frictional forces. Pressurized oil in the loading cylinder pushes up the measuring piston proportionally and actuates the special dynamometer system. Load measurements are indicating on circular scale with range selection knob. Different measuring ranges can be selected using range selection knob. An elongated scale is kept sliding on the scale rod which is fixed between the lower table and the upper crosshead. Autographic Continuous Roll Load-Elongation Recorder unit is of the pen and drum type recorder. The horizontal motion of the pen produces the load ordinate of the diagram and the drum rotation produces the extension ordinates.

2.2 Different Mechanical Material Properties Testing Using UTM

To determine different mechanical material properties of material to be use in application needs to perform different tests like tensile, compressive, shear, bending test to determine the behavior of material under different types of forces and by determining the following parameters: Percentage elongation in length, Percentage reduction in area, Working stress or permissible stress or safe stress, Young's modulus, Yield stress, Ultimate stress or Maximum tensile stress, Breaking stress or Failure stress , Proof of Resilience, Modulus of Resilience. Tensile/compression testing is used to find the behavior of the material when it is subjected to a slowly applied tensile/compression load up to when the material gets a fracture. In the single shear test, one side of the specimen will be clamped, and the other side will be subjected to vertical load. Double shear test, in which both sides of the specimen will be clamped and at the middle portion, the vertical load will be subjected. The Shear Strength of the specimen will be calculated as the amount of the force needed to make the shear over the given cross-sectional area. Flexural testing is used to determine the flex or bending properties of a material. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and initiating a load using a third point or with two points which are respectively call 3-Point Bend and 4-Point Bend testing.

3. METHODOLOGY

This study addressed problem by combining modern transducers, electronics, software, and full servo control with an older system. Modern control engineering practice includes the use of control design strategies for improving manufacturing processes and the efficiency of energy use. This enables users to conduct more sophisticated tests using better control of the testing machine and many others through reporting. This gives rise to the need to develop an optimum, effective, and inexpensive system that would completely perform the test by using electronic equipment.

3.1. Methodology

- Study existing hydraulic analog universal testing machine and understand its working and design principles to develop digital measurement system of universal testing machine and determine the mechanical material properties of material.
- Development of system for digital measurement by selecting the components to acquire the physical parameters from universal testing machine and convert them into digital signals.
- Calibration and testing of individual sensor by making electrical circuit connection and interfacing them with Arduino software to get the physical parameters in terms of digital form.
- Programming for measurement system Processing3 software to get the graphical representation of stress strain curve for tensile test and simulation of different mechanical material properties on front panel of Graphical User Interface in Processing3 software.
- Installation of whole setup on analog hydraulic universal testing machine and interfacing it with Arduino software for experimentation to get digital measurements from analog hydraulic universal testing machine.
- Experimental analysis by using developed digital measurement system in Processing3 software and verification of system by comparing the results with values taken by analog hydraulic universal testing machine.
- Incorporate the developed digital measurement system for other testing like compression, shear and flexure testing which are perform on analog hydraulic universal testing machine.

3.2. Component Selection for Measurement System

From the study of existing universal testing machine, principle and working, necessity of UTM to analyze mechanical properties and knowing about the basic requirements for development of UTM, there are few necessary components required, like sensors to acquire parameter like force, displacement, Arduino to acquire data. Pressure sensor is measuring instrument which sense fluid flow pressure in terms

of analog signal. The fluid flow pressure is directly proportional to load applied by crossheads of UTM machine on specimen. Load is major measuring factor in material properties testing. Todays developed UTM machines consist of expensive and complicated load measuring instruments like load cell, gauges etc. here we tried to use simple and economical sensor so that it can reduce cost of development. The pressure transmitters must be calibrated to convert the analog voltage signals into digital pressure signals in terms of Bar. Linear Potentiometer is used as displacement measurement sensor. As potentiometer is three terminal resistors having rotated and sliding contacts to create adjustable voltage divider which also when used with two terminal acts as variable resistor or rheostat. Potentiometers which are mostly used for controlling devices can also be used as position/displacement transducer as they can give large output signals. So instead of using expensive strain measuring gauges, DIC (Digital Image Correlation) cameras or any complicated sensors, we have used simple position encoding linear sliding potentiometer to measure the displacement or elongation of sample loaded in UTM. As linear potentiometer gives the analog output signal in terms of voltage it must be calibrated to convert volts to millimeters(mm) so that it can relate with load value acquired from Pressure sensor to calculate mechanical properties of material. Here, Arduino Uno is a data acquisition system which helps in acquiring data from sensors and transducer as shown in figure 4.6. Analog inputs of pressure and displacement sensors are given through analog pin 0 and 1 respectively. These analog signals are programmed with Arduino IDE software to display it on screen and further interfaced with other software's or systems for data acquisition.

3.3. Block Diagram of Digital Universal Testing Machine

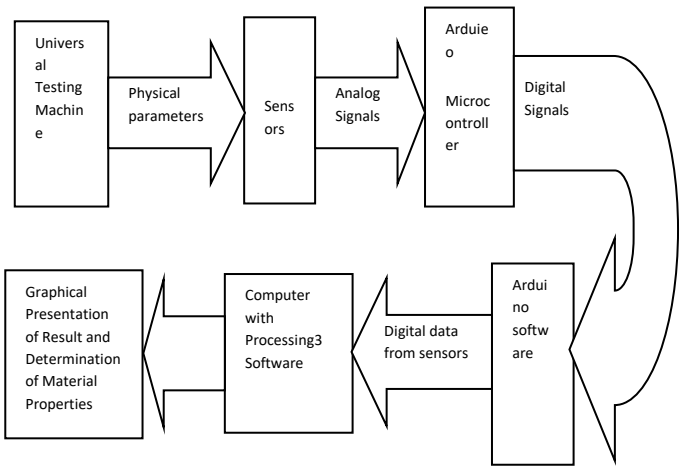

Fig- 1 Block Diagram of Digital Universal Testing Machine

Figure 1 shows block diagram of digital universal testing machine presents development of existing hydraulic universal testing machine. Digital universal testing machine mainly consist of hydraulic analog universal testing machine, sensors, Arduino microcontroller, computer with Processing3 software.

Hydraulic analog universal testing machine is used to determine mechanical material properties of different materials. Hydraulic analog universal testing machine shows the physical parameters force in terms of Newton on load dial and displacement in terms of millimeter on scale. Sensors are used to acquire physical parameters and convert them into analog signal. Pressure sensor is assembled on hydraulic system used to acquire applied load on specimen by crossheads. This physical parameter load is converted into analog signal by sensor. Linear potentiometer as Position or displacement sensor is used to acquire physical parameter displacement and convert it into analog signal. After getting analog signals, Arduino microcontroller is used to convert those signals into digital signals so that signals can be interface with Processing3 software.

Calibration of sensors is done individually by interfacing them with software. Programming in Arduino and processing3 software helps to represent the analog signals values into physical parameters with their respective units. Processing3 software also helps to represent those quantities in graph or other types of indicators which are useful to determine mechanical material properties of different materials.

4. DEVELOPMENT OF SYSTEM

Development of system includes the calibration and interfacing of individual sensor with Arduino and Processing3 software before assembling all sensors with universal testing machine. As individual interfacing of sensors is done, whole setup can be assembled. Development of system also involves the common electric circuit with Arduino Uno Board which will connect with universal testing machine to computer with operating system installed with Arduino IDE software. Graphical user interface created by programming in both Arduino IDE and Processing 3 software for development of system.

4.1. Assembly and connections

For the development of system, all the components are been tested and now it need to be interfaced with each other in order to relate the relation to obtain various parameters like stress, strain etc. By connecting pressure sensor, 9V supply transformer, Transformer circuit board, Linear Potentiometer, Arduino Uno Board. The system circuit is designed in such way that it requires 5volt DC power supply for linear potentiometer, 9V supply for Pressure sensor and window operating system with Arduino IDE and Processing3 software installed in it.

4.2. Arduino IDE and Processing 3 for digitalization

Data acquiring is a process to collect the data from sensors by making programming based on the signal flowing through different pins of sensors and finding that element in software known as Arduino IDE. The Arduino Integrated Development Environment or Arduino Software (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and hardware to upload programs and communicate with them. Here, pressure sensor and linear potentiometer are used to sense data from machine which are connected to Arduino Uno board. This hardware is connected to computer through USB-B port and cable to collect and display data on Arduino IDE software by programming.

The Processing 3 Environment includes a text editor, a compiler, and a display window. It enables the creation of software within a carefully designed set of constraints. Data obtain from Arduino is processed through programming to get stress-strain graph and other material properties values to be display.

5. Conclusion

The measurement system for the universal testing machine has been designed, developed and it successfully realized all functional testing machine system requirements. The computer software and programming test machine monitoring system has achieved the desired results. System is developed by using minimum costing components like pressure transducer, linear potentiometer and Arduino Uno.

The developed system had been applied in Universal testing Machine with good effect; it can reduce the difficulty of measurement.

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