International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 12 Dec. 2022, pp: 804-808 www.ijaem.net ISSN: 2395-5252

# Design and Fabrication of a Prototype Manually Operated Tensile Testing Machine

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Submitted: 18-12-2022 Accepted: 31-12-2022

**ABSTRACT**
In an attempt to find a solution to the problems of structural failures resulting from inadequate skill in materials selectionduring design and to alleviate the problems of poor maintenance culture, paucity of funds and high cost of equipment in most laboratories of our higher institutions, a simplified manually operated tensile testing machine was designed, constructed and tested using locally sourced materials. The aim is to facilitate the demonstration of tensile test to enable understanding of the mechanical properties of ductile material such as mild steel metal for proper selection in design. The principal parameters used in the design include the maximum load (20kN), the gage length and diameter of a standard tensile specimen of 50mm and 12.5mm respectively. The major components of the machine include 20-ton hydraulic jack, a locally made axial extensometerand load cell, a fixed and a movable frame. The machine was tested for performance using standard tensile test specimens. The data from the test was used as dummies to demonstrate how to compute the ultimate tensile strength, yield stress, fracture stress, % elongation and % reduction in area of the mild steel. The machine can be used to compliment the complex and expensive imported model which enable demonstration of tensile test in a simplermanner to enable students have a better skill in material selection of ductile materials such as mild steel metal for different engineering applications.
**Keywords:** Prototype, Tensile, demonstration, ductile metals, % elongation, % reduction in area.

## I. BACKGROUND OF THE PROJECT

The development of engineering over the years has been the study of finding ever more efficient and convenient means of load application using different engineering materials, either for pushing and pulling, rotating, thrusting and controlling load, ranging from a few kilograms to thousands of tons (Sumaila, 2002). In most applications metals are used for such services. The choice of the suitable material for various load applications requires an understanding of the behavior of the metal under different operating conditions. Understanding the behavior of the metal is carried out by conduct of a test on the material. Usually destructive tests are carried out where the metal is subjected to loads great enough to cause its failure as is usually the case that occurs when structures fail. Generally, failure of a structure occurs due to application of excessive load greater than that which the material can bear either in error or as result of unforeseen circumstances. In the tensile test, a force of tension is applied gradually which leads to the metal increasing in length with a consequent reduction in area depending on its ductility. The behavior of the metal as it undergoes failure is physically observed. Such tests are referred to as tensile test to destruction and are usually carried on a type of press known as the Universal tensile testing machine.

Presses are widely used to achieve this. Presses, as defined by Lange (1975), are pressure exerting machine tools. They can be classified into three principal categories as: hydraulic presses which operate on the principles of hydrostatic pressure, screw presses which use power screws to transmit power and mechanical presses which utilize kinematic linkage of elements to transmit power (Niebel,et al. 1989; Degarmo,et al. 1997; Sharma, 2005). In hydraulic press, the force generation, transmission and amplification are achieved using fluid under pressure. The liquid system exhibits the characteristics of a solid and provides a very positive and rigid medium of power transmission and amplification. In a simple application, a smaller piston transfers fluid under high pressure to a cylinder having a larger piston area, thus amplifying the force. There is easy transmissibility of large amount of energy with

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practically unlimited force amplification. It has also a very low inertia effect. The main advantages of hydraulic systems over other types of systems are that theyprovide a more positive response to changes in input pressure, the force and pressure canaccurately be controlled, and the entire magnitude of the force is available during theentire working stroke of the ram travel. Hydraulic systems are preferred when verylarge nominal force is required (Lange, 1975). The versatility of application of hydraulic systems finds application in many testing machinery and equipment used in workshops and laboratories especially for press fitting operations and forthe deformation of materials such as in metal forming processes and material testing forstrength. One of the important testing equipment in the laboratory for conduct of destructive test is the tensile testing machine. A look at the laboratories in our institutions in Nigeria reveals that all such machines are mostly imported into the country and are expensive and costly to maintain. The main thrust of the paper is to present the design, fabrication and testing of a prototype manually operated tensile testing machine for the demonstration of tensile test on a mild steel metal with the aim of simplifying the understanding of the test by engineering students in higher institutions of learning. The proposed machine is as shown in Appendix I.

## II. AIM AND OBJECTIVES OF THE FABRICATION PROJECT

The main aim of the fabricationproject is to design, fabricate a prototype tensile testing machine. The specific objectives of the study are to:

(i) design and fabricate a prototype hydraulic tensile testing machine,
(ii) demonstrate the conduct of tensile testing on a ductile material,
(iii) explore the use metallic scraps as a source of materials for local production of machinery to save cost.

## III. JUSTIFICATION OFFABRICATING THE MACHINE

Inadequate skill on selection of engineering materials in design resulting from the problems of high cost of laboratory equipment and poor maintenance culture in our higher institutions is affecting the quality of engineeringpractice in the country. This often leads to the production of engineering graduates without the adequate skill needed to be able to select the appropriate materials during design process. This situation has a devastating effect on the economy. Consequent upon that, collapse of building structures have continued to become a national problem leading to loss of lives and properties. Research has shown that so many reasons have been identified as the causes of structural collapse in the construction of buildings, bridges, dams, roads etc. A study on causes of building collapse in Nigeria using historical data from 1974 to 2006 shows thatpoor maintenance culture, design error, poor quality of materials and workmanship, natural phenomenon and excessive loading contributed to about 7%, 15%, 52%, 7% and 20% respectively of building collapse in Nigeria with most of them being private residential buildings executed by indigenous contractors (Oke, 2011). The result shows poor quality of materials and workmanship contributed the highest with alarming 52%. Metals constitute greater percentage of materials needed as reinforcement in the construction industry most especially buildings. Therefore, the importance of any research that will further improve the understanding of the behavior of materials in service and for metals in particular cannot be overemphasis.

Understanding the behavior of metals requires a test of their mechanical properties and the most common test needed is the tensile test using a tensile testing machine. The cost of the testing machine is exorbitant and therefore, not available in most of our institutions. In some institutions the available machines are no longer functional due to lack of skill in operating them and poor maintenance culture. The conduct of the tensile test is very simple hence its understanding will be much easier if the tensile testing machine is simplified to enable its affordability and ease of maintenance by our institutions. The simplified machine will enable our students conduct the test and understand the mechanical properties of a ductile metal under various loading conditions which will improve their skills in material selection for different engineering applications. Using locally sourced material enables its affordability for introductioneven in the curricula of primary and secondary schools across the Nigeria. This will ensure a sound skill on material selection and alleviate the problems of building collapse in the country as well as saving foreign reserve during the importation of the machine.

## IV. MATERIALS AND METHODS

The machine consists of a hydraulic jack whichis used to provide effort required for the application of a uni-axial tensile load on a standard mild steel specimen. The machine also has a fixed and a moving frame which held beams that carry the tensile specimen attached via gripping chucks, an extensometer to record amount of elongation of the specimen, a load cell to record the amount of force applied on the test specimen. The machine is as shown in Appendix I.

The principal parameters of the design are the maximum load (20kN), the distance the load resistance has to move (50 mm) and the gauge diameter 12.5mm. The critical components that require design included the fixed and moving frames, beams and the gripping chucks.

**4.1 Component Design**

**4.1.1 Frame design**

The frame provides mounting points and maintains proper relative positions of the unitsand parts mounted on it over the period of service under all specified working conditions.It also provides general rigidity of the machine (Acherkan, 1973). The design consideration isthat of direct tension imposed on the pillars. The frame members such as the beams are subjected to simple bending stresses.

**4.1.2 Beams**

The upper and lower beams provide point of direct contact with the specimen being pulled. Hence, they are subjected to pure bending stress due to an equal andopposite couple acting in the same longitudinal plane. The design consideration is essentiallyfor bending and consists primarily upon the determination of the largest value of thebending moment (M) and shear force (V) created in the beam. They would be computed using the procedure adopted fromBeer and Johnston (1992).

**4.1.3 Section modulus**

The values of V and M obtained facilitate the computation ofthe modulus of section of the beams. The minimum depth (thickness) dand width of the metal plate b required would be computed using:d = [(6M)/(δb)]1/2 (Kurmiand Gupta, 1997). The total deflections of the beams are such that they do not exceed the total elongation of the test specimen.

**4.1.4Hydraulic jack**

The initial parameter in the design is the force required to provide the maximum force needed to break the test specimen (6.1kN). The pumping action would be actuated by a leversystem. The length of the lever was calculated byassuming a maximum theoretical effort and taking moment about the fulcrum.A lever of 800mm length was used for actuating the force and was selected based on ergonomic consideration.

## V. DETAIL MANUFACTURING PROCEDURE

The axial extensometer and the load cells are the standard components that have to be ordered while all other components would be fabricated.After determining the main dimensions of the critical sections from the designs, channel steelsection would be purchased locally from the structural steelvendors in Muda Lawal market, Bauchi City, Nigeria.The components of the machine such as the frames, beams and base wereproduced by cuttingfrom the steel sections using power hacksaw and welded using the arc welding machineand assembled in the workshops of the Mechanical Engineering Department, Federal Polytechnic Bauchi.In the fabrication of the components, there are two major sub-assemblies. These are the fixed frame and the moving frame. The tensile test specimen is mounted at the lower end on the fixed frame while the upper end is mounted on the moving frame. The two ends of the tensile test specimen are gripped using locally fabricated chucks.

## VI. PERFORMANCE TEST RESULT

It is a normal practice to subject engineering products to test(s) after manufacture. This is a significant step in the manufacturing process. The machine was be tested using a standard specimen. Two set of values were recorded, the force applied using the hydraulic jack was measured using the load cell and the elongation of the specimen using the axial extensometer. The two readings were compared with standard mechanical property values. The result of the test are not expected to agree with the standard values which is quite obvious due lack of precision of the gripping chucks and the position of the extensometer. The values were recorded and were only used as dummies to demonstrate how to calculate the percentage elongation, percentage reduction in area.

## VII. BILL OF ENGINEERING MEASUREMENT AND EVALUATION

The Bill of Engineering Measurement and Evaluation (BEME)or cost estimate for the tensile testing machine comprises of material, labour, transportation and contingencies. The materials costs are of prices in Bauchi City, Nigeria at the time of fabrication of the machine.The breakdown is as presented in Table 1.

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Table 1: Bill of Engineering Measurement and Evaluation for the Manual Tensile Testing Machine

| S.No. | Description | Quantity | Unit cost (₦) | Total cost (₦) |
|---|---|---|---|---|
| 1 | 15mm mild steel plate | 1 | 25,000 | 25,000 |
| 2 | 25mm mild steel rod | 1 | 5,000 | 5,000 |
| 3 | M15 mild steel bolt | lot | - | 2,000 |
| 4 | M15 mild steel nut | lot | - | 2,000 |
| 5 | 20 tons hydraulic jack | 1 | 35,000 | 35,000 |
| 6 | Axial Extensometer | 1 | 25000 | 25000 |
| 7 | Hand grinder, Makita 7566CV 6 in. variable | 1 | 85,000 | 85,000 |
| 8 | Power drill, Dewalt 20V, DC, D996B | 1 | 170,000 | 170,000 |
| 9 | Steel Channel section, 150mm x 15mm | 2 | 35,000 | 70,000 |
| 10 | Load cell | 1 | 50,000 | 50,000 |
| 11 | G12 electrode | 3 | 1,000 | 3,000 |
| 12 | Grinding disc | 3 | 3,000 | 9,000 |
| 13 | 18tpi hacksaw blade | 6 | 500 | 3,000 |
| 14 | Hacksaw frame | 3 | 2,000 | 6,000 |
| 15 | Rough emery cloth | lot | - | 4,000 |
| 16 | Dial gauge | 2 | 9,000 | 18,000 |
| 17 | Workmanship | - | - | 100,000 |
| 18 | Miscellaneous | - | - | 200,000 |
| 19 | Oil Paint maroon | 3 | 2,000 | 6,000 |
| 20 | Bolts and nuts, M13 | lot | - | 2,000 |
| 21 | Jaw grip | 2 | 5,000 | 10,000 |
| 22 | Measuring scale, 50kg | 2 | 2,000 | 4,000 |
| **TOTAL** | | | | **₦834,000.00** |

## VIII. CONCLUSION

The20-ton prototype manually operated tensile testing machine is expected to contribute in great way to the understanding of the tensile test on ductile materials and in particular mild steel metal. The machine is inexpensive compared to the imported one, hence can be afforded by many institutions to facilitate demonstration of tensile tests for understanding of material behavior under different loading conditions. It is the understanding of the tensile test that will facilitate theselection of most suitable material for different engineering applications, which is expected to contribute to the reduction of structural failures as is recorded in many parts of Nigeria.

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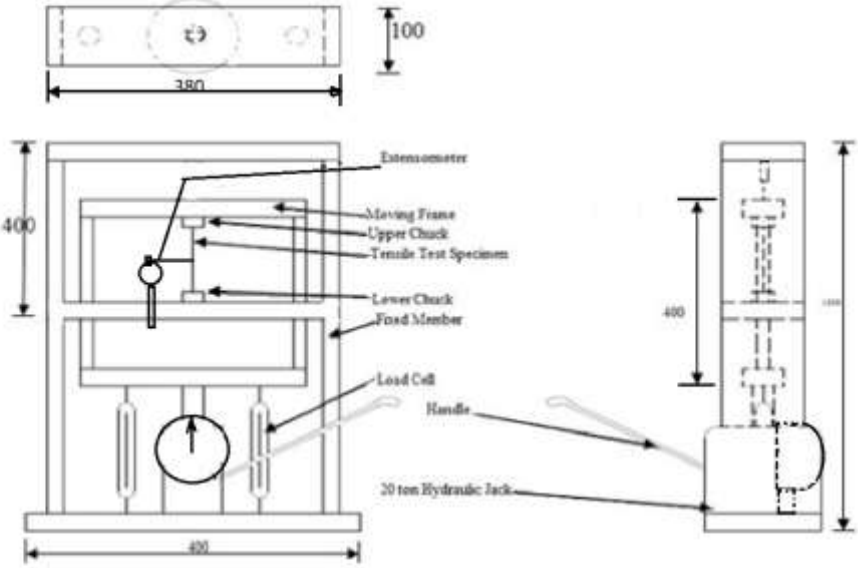


Figure 1: The prototype tensile testing machine assembly.

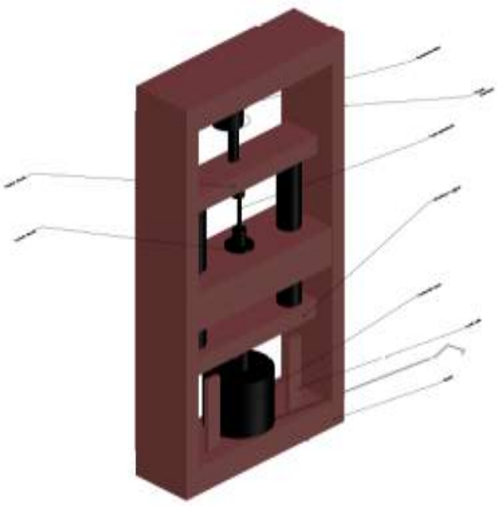

Plate1: Isometric view of the prototype tensile testing machine

Plate 2: Pictorial view of the prototype tensile testing machine