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The Design and Fabrication of Compression and Extension Testing Machine

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Abstract – **This study was carried out to design and fabricate a cost effective and efficient compression - extension machine to alleviate the problem of the dearth of equipment in our laboratories in most of our higher institutions. In carrying out the project work a thorough study of the foreign testers and the requirements of the Nigerian industrial standards, was done. Design drawings and calculations were established and the machine was fabricated with well selected materials and components all sourced locally. The performance of the fabricated machine was finally evaluated against a standard foreign machine employing a stress-strain diagram that enable the comparison of the mechanical properties of aluminum. Test results reveal absolute errors of measurement of 3.79%, 3.97% 2.17% and 2.53% for ultimate tensile strength, Young's modulus, yield strength and ductility. Performance characteristic in the various mechanical tests evaluated was found satisfactory. The machine provides a low cost solution for engineering and engineering technology programs that wish to expand their material testing capabilities but are not capable of funding the acquisition of commercially available compression and extension testing machines.**

Keywords: **Tensile Test, Ultimate Tensile Strength, Young Modulus, Absolute Error, Ductility**

I. Introduction

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction Hashemi(2006). It has been established that any given material has a number of interesting and useful mechanical properties, and that these properties are often interrelated, it follows that we need to be able to measure all of the them. It would be nice if one type of test could measure all of them but, unfortunately, no one test can do this. The tensile test, however, which can be used to measure a number of the most commonly used mechanical properties, is a very good place to start Meir (2004).

Compression testing is a method for assessing the ability of a material to withstand compressive loads. This test is commonly used as a simple measure of workability of material in service. Materials behave differently in compression than they do in tension so it may be important to perform mechanical tests which simulate the condition the material will experience in actual use (Hassan *et al* 2009). Because of difficulties in obtaining accurate information from a compression test on ductile material, very little compression testing is done on metal (Bukar 1992). Difficulty arises from two causes, namely compression instability and frictional restraint. The compression test finds greatest use in testing brittle materials such as mortar, concrete brick and ceramic products, whose tensile strengths are low compared with their compressive strengths and which are principally employed to resist compressive forces William(2007).

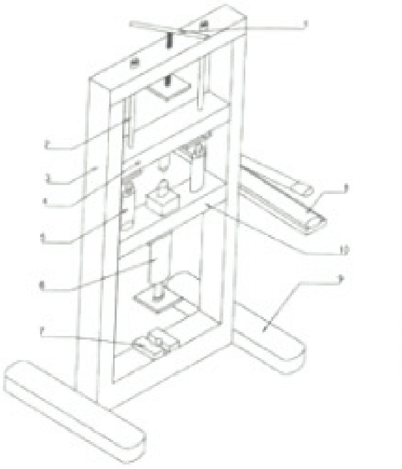
Testing machines are used to develop better information on known materials or to develop new materials and maintain the quality of the materials. There are two classes of testing machines, electromechanical and hydraulic. A hydraulic testing machine uses either a single- or dual-acting piston to move the crosshead up or down. In general, the electromechanical machine is capable of a wide range of test speeds and long crosshead displacements, whereas the hydraulic machine is a cost-effective solution for generating high forces and can be manually operated. Materials education is a key foundation for engineering education, especially mechanical engineering. A mandatory materials course with a laboratory component is included in almost all engineering or engineering technology programs. This may include demonstration, testing, and/or simulation of materials properties and behavior under various loading and environmental conditions. Limited time and credit hours may limit the number and variety of laboratory exercises. Often lack of testing apparatus adds to the problem. Understanding and testing for engineering materials characteristics under various loading condition is critical materials education. The hydraulic testing machine is an invaluable equipment in laboratories especially for material testing for strength. A look at the workshop in Nigeria reveals that all such machines are imported into the country. Therefore, it is intended here to design and fabricate a compression –extension machine, which is low cost and hydraulically operated using locally sourced materials. This enhance the level of our local technology in the exploitation of hydraulic fluid power transmission.

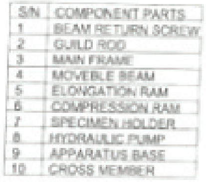
II. Design Concept and Operating Principles

The design concept adopted for the tensile and compression testing machine is indicated on the Fig(i) Isometric and orthographic views of the apparatus shown below. It consist of a mainframe 116cm x 52cm made of structural steel, a cross-member is positioned at the mid-point of the frame. Also a second arm is made moveable within the frame guided by two guide rods. Two hydraulic ram (jack) of about 16tonnes capacity are fixed on top of the cross-member such that they carry the moveable arm.

Below the cross-member is attached a third jack, a compression ram that acts downwards. Specimen holders in form of grip jaws are attached to the moveable arm, the cross-member, the compression ram and the apparatus base respectively.

The hydraulic pump is fixed by the side of the apparatus frame and can supply hydraulic fluids to the jack through the hoses, H_1 and H_2. Valves V_1 and V_2 and pressure gauges G_1 and G_2 are attached at convenient points along the hose lines.





S/N	COMPONENT PARTS
1	BEAM RETURN SCREW
2	GUILD ROD
3	MAIN FRAME
4	MOVEBLE BEAM
5	ELONGATION RAM
6	COMPRESSION RAM
7	SPECIMEN HOLDER
8	HYDRAULIC PUMP
9	APPARATUS BASE
10	CROSS MEMBER

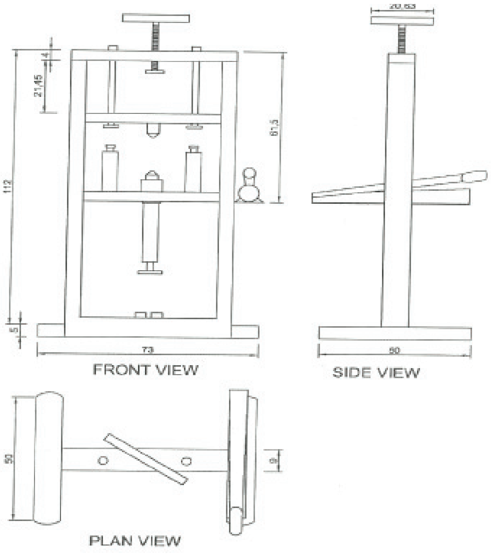


Fig.1 Isometric and orthographic view of compression –extension testing machine

III. Operating Principle

To carry out a tensile test, the sample material is firmly held between the specimen holder on the tensile section of the apparatus (i.e. on the moveable arm and the fixed member). The valve V_2 loading to the compression ram is shut, the pump is then operated, hydraulic fluid flows through the open valve V_1 into the hose H_2 loading to the extension rams with the specimen held between the jaws, the moveable arm is pushed up by the extending rams thereby exerting a tensile force on the specimen held between the moveable arm and the fixed cross-arm.

The magnitude of the pressure (force) exerted can be read from the pressure gauge attached along the hydraulic hose h_2.The extension produced is read from the digital vernier caliper attached to the system. After the experiment, the moveable arm and the hydraulic rams are pushed to their initial position with the beam return screw.

To perform a compressive test, the test sample is fixed between the specimen holders on the compression ram and the apparatus base, then the valve V_1 is closed so that the hydraulic fluid delivered by the pump only passes through hose H_1 into the compression ram. The specimen is thus compressed between the holders. Pressure gauges read the pressure exerted and the linear scale measures the compression of the sample.

Design Specification and Component List

The specification given for the design and construction of the tensile and compression testing machine include:

(i) Maximum applied load = 300,000N(30KN)

(ii) Structural material made of mild steel channel and sections

Table I Component List and Materials

S/n	Part	Quantity	Material
1	Hydraulic Press	3	
2	Main Frame		Channel iron(mild steel)
3	Cross beam		I-section(mild steel)
4	Specimen Holder		
5	Extensometer		Digital Venier Calliper
6	Hydraulic pump		
7	Guide rod	2	Stainless steel
8	Pressure gauge	2	
9	Hydraulic Hose		
10	Flow valves	3	
11	Pressure spring	2	Hardened steel

IV. Component Design

Dimensional Analysis

The overall dimension of the parts and full structure of the apparatus will be determined considering the specified maximum load to be applied.

Determination Of Total Height Of The Machine

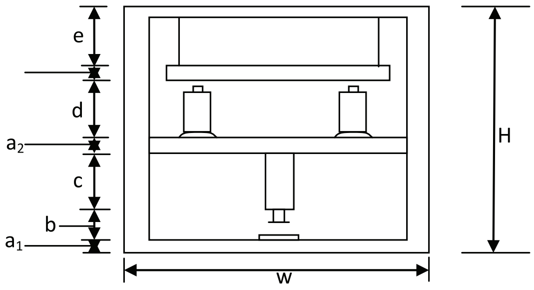


Fig.2. Diagram of frame of compression –extension testing machine

From the diagram of the frame above, For a specified load of 30KN, two 15.7KN hydraulic jacks of height (d) =22cm were selected;

Height of Apparatus (H) $= a_1 + b + c + a_2 + d + a_3 + e$ (1)

where a_1 = width of the structure member = 4.5cm b = Height of the compression tool holder and maximum length of specimen=15cm, c= Height of compression ram = 30cm, a_2 = Width of cross steel frame = 8cm, d = Height of extension jack = 22cm, a_3 = Width of movable member = 4.5cm, e = 20cm, Thus H= 104cm.

Determination of The Width (W) Of The Machine

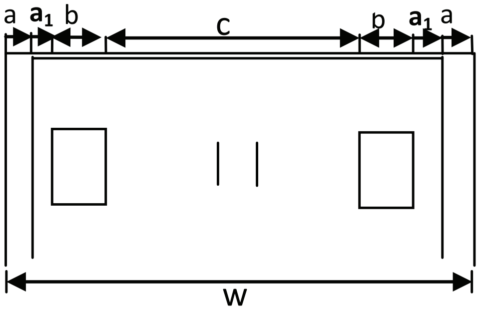


Fig.3 Schematic diagram of machine width

Considering the diagram above, the total width of the structure w is equal to

$$w = a + a_1 + b + c + b + a_1 + a \quad (2)$$

Where, a = width of the structure frame = 4cm, a_1 = fixed clearance between jack and frame = 2cm,

b = diameter of jack = 10cm, c = Minimum distance between jack = 20cm, Thus w = 52cm

Determination Of Optimum Length Of Moveable Member M_l

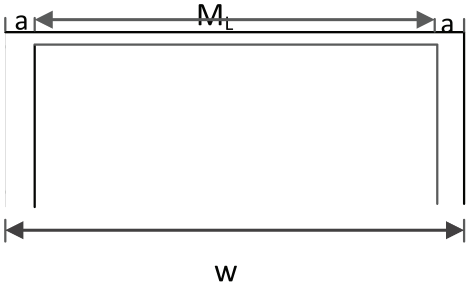


Fig.4 Schematic diagram of machine moveable member

$$M_L = (w-2a) \qquad (3)$$

Where w = overall width of the apparatus = 52cm, a = width of the frame = 4cm, hence M_L = 45cm

For easy sliding of the moveable beam within the main frame, a clearance of 3mm is given on both sides.

Thus, optimum length of moveable beam = 45 – 0.6 = 44.4cm.

V. Force Analysis

In analyzing the forces acting on the structural frame, we consider the free body diagram of the frame.

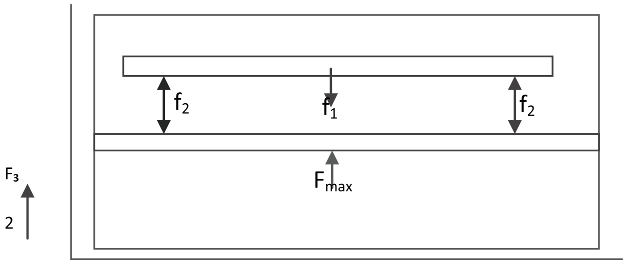


Fig.5 Free Body Diagram of Machine Main Frame

From the FBD, force F_{max} is acting on the cross member

F_2 F_1 are acting on the moveable member, while force F_3 acts on the vertical column as shown.

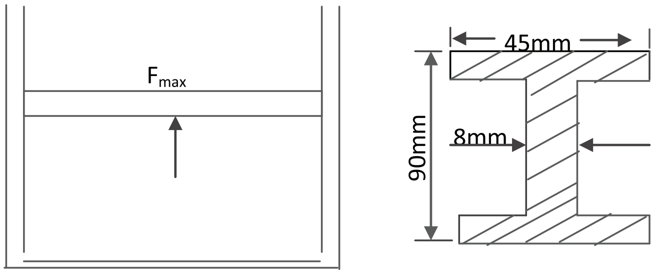
Thus the members under stress under the applied load include:

(i) The cross member

(ii) Moveable beam

(iii) Main Frame

The major effect of the stress (load) on the members is to cause shear, thus the system will be analysed for shear failure.



X-section of the member

Fig. 6 Free body Diagram and cross section of the machine

VI. Specification and Stress Analysis

Material – Carbon steel (070m20) – I section.

Allowable shear stress (F_A) = 270 N/mm (Ryder, 2005), Maximum force applied (F_{max}) = 294,000N.

The force F_{max} exerted by the lower ram presents the highest single force at the middle of the beam ,thus this will be used to analyse the beam , Considering the F.B.D for the equilibrium position ,the force F_{max} across the X-section of the member , thus shear stress is given as :

$$F_a = \frac{F_{max}}{A_x} \qquad (4)$$

Where, F_a = Allowable stress for the material, F_{max} = Maximum force applied = 294,000N, A_x = Cross sectional area of member.

For satisfactory application of the member, we must

have $F_a \geq \frac{F_{max}}{A_x}$

From fig3b above the X-sectional area is given as

A_x = Area A + Area B + Area C (5

Area A = 45 x 8 = 360 mm^2,Area B = 74 x 8 = 592mm^2, Area C = 45 x 8 = 360mm^2

X = 360 + 592 + 360 = 1312mm^2

$F_s = \frac{294{,}000}{1312}$ = 224N/mm^2, Given that F_a = 250N/mm^2 F_s = 224N/mm^2 then the cross member will withstand the maximum load.

VII. Fabrication

Following the analysis and design of the apparatus with the subsequent production of the working drawing for the fabrication of components and assembly, the fabrication of the apparatus was undertaken. The extension and compression testing machine was constructed making use of locally available and relatively cheap materials, since the bulk of the machine is structural iron, the equipment were mainly machine shop tools and equipments.

The fabrication was carry-out in the following sequence:

i. All materials were measured and marked out according to the design specification.
ii. All measured and marked material was then cut to shape.
iii. All members requiring drilled holes were drilled with the drilling machine.
iv. The members were then welded together to form the system.
v. The hydraulic unit was fixed in position.
vi. The entire system was painted before use.

The parts of the mainframe which were fabricated as a separate unit were coupled together using bolts and nuts. These parts including the base member, the mainframe, the pump base, the top member and the movable member. The hydraulic pump and rams were bolted in their respective positions, and all the connecting hoses and valves fixed. Accessories such as extensometer, pressure gauge, specimen holder, guide rods where attached to their respective position. With the unit completely assembled, the hydraulic lines were then tested for leakages by pumping hydraulic fluid through the system.

Total Production Cost

The cost estimate for the tensile and compression machine was N121,150 (US$320) at prices in Benin City, Nigeria as at the time of machine fabrication. However, the unit cost of a product in most cases is several times higher than for quantity based production (Dagwa and Ibhadode 2005). Hence, the items bought were as required for the machine fabrication. The cost of labor, transportation and contingencies were also included in the cost estimate. Total production cost = Material cost + Labour cost + Overhead cost + Design cost

i.e 80,200 + 22,200 + 6,720 + 12,030 Therefore total = ₦121,150

Performance Evaluation

Following the fabrication and complete assemblage of the machine, the machine was tested by carrying out tensile test on three different samples of aluminium. The tensile test is one of the tests that measure the mechanical properties of materials. The tensile test does measure these design criteria: tensile strength, yield strength and modulus of elasticity or Young modulus and ductility with the % elongation or %reduction in area.

The aluminium materials provided was first prepared or machined to the standard sample, size and shape recommended for tensile and compression testing.

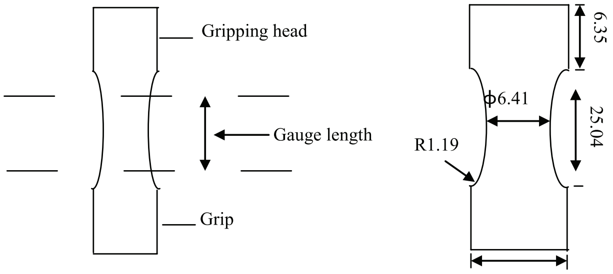


Fig.7 Standard Material Sample

Three samples were provided for the aluminium material. Testing procedure entails

(i) A measured length of the sample to be tested was fixed tightly on the specimen holder.
(ii) The pump was gradually actuated and the load applied to extend the sample was gradually applied.
(iii) As the load is gradually increased, the material stretches or elongates.

The load acting on the material was indicated and read from the pressure gauge, the subsequent elongation was indicated by the extensometer on the stem of the machine. The load was continuously increased and the specimen was elongated to its maximum limit to the point of breakage. Three separate tensile tests with aluminium sample were carried out for the aluminium sample.

VIII.TEST RESULT

Aluminium sample length (25.04mm) and sample diameter (6.6mm)

TABLE I STANDARD VALUES OF ALUMINIUM AS OBTAINED FROM A STANDARD MACHINE

Load(KN)	Extension(mm)	Stress(MPa)	Strain
0	0	0	0
32.01	0.626	131.00	0.025
52.22	0.751	213.74	0.03
63.17	1.052	258.55	0.042
65.65	0.931	268.70	0.0372
67.38	0.83	275.79	0.033
67.38	1.00	265.79	0.04
69.07	0.989	252.68	0.0395

TABLE II AVERAGE VALUES OF THE THREE SAMPLES OBTAINED FROM THE FABRICATED MACHINE

Load(KN)	Extension(mm)	Stress(MPa)	Strain
0.00	0.000	0.00	0.0000
31.98	0.626	130.87	0.0240
51.73	0.748	211.74	0.0290
61.88	0.815	253.28	0.0326
62.46	1.060	258.64	0.0420
64.82	0.932	265.33	0.0368
67.87	1.010	257.77	0.0410
68.59	0.985	250.72	0.0385

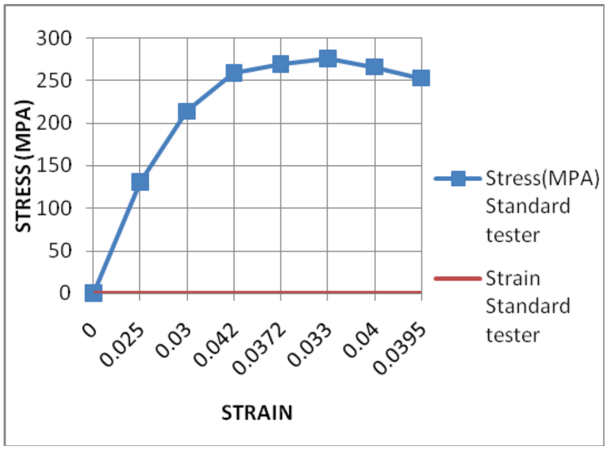


Fig.8. Aluminium stress-strain curve of standard tester

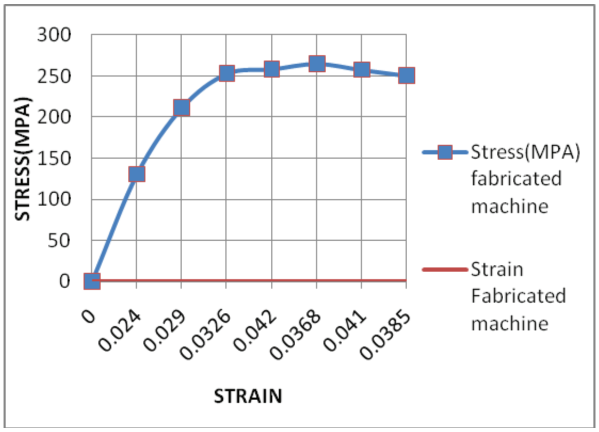


Fig.9.Aluminium stress-strain curve of fabricated machine

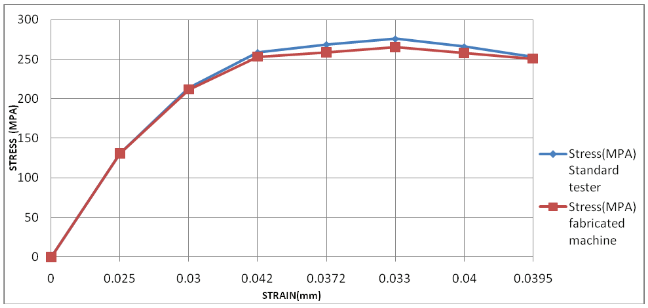


Fig.10. Engineering stress –strain curve for aluminium for standard and fabricated universal testing machine

IX. RESULTS AND DISCUSSION

The results obtained from figure(viii) for the standard testing machine shows that.

(i) Ultimate Tensile Strength= 275.79MPa at point 3 on the stress-strain plot.

(ii) Modulus of Elasticity= $\frac{131-30}{0.025-6.25X10^{-3}}$ =5.39GPA at point 1 on the stress-strain plot.

(iii) Offset yield strength = 230MPA at point 2 on the stress-strain plot.

(iii) Ductility= 3.95% at point 4 on the stress-strain plot.

The results obtained from figure (ix) for the fabricated machine reveals that:

(i) Ultimate Tensile Strength=265.33MPa at point 3 on the stress strain plot.

(ii) Modulus of Elasticity = $\frac{130.87-30}{0.024-6x10^{-3}}$ =5.60GPa at point 1on the stress –strain curve.

(iii) Offset yield strength=225MPA at point 2.

(iv) Ductility = 3.85% at point 4 on the stress- strain plot.

Hence, the absolute errors of the mechanical properties values obtained by the fabricated machine from the standard machine are evaluated thus:

1) Ultimate tensile strength: This is the highest stress on the stress-strain plot. Absolute error of measure of the fabricated machine from the standard machine reveal a value; Ultimate Tensile Strength = (275.79-265.33)/275.79 * 100 = 3.79%

2) Young's Modulus: A measure of a material's stiffness when deformed in tension. It is measured from the slope of the initial linear region on the stress-strain plot, thus the absolute error of the mechanical values obtained by the fabricated machine from the standard machine is Modulus of elasticity = (5.39 -5.6) / 5.39 * 100 = 3.97%

3) Yield Strength: The stress where deformation changes from being mostly elastic to mostly plastic. It is taken from the end of the linear (elastic) portion of the stress-strain plot. Aluminium having a FCC crystal structure does not show the definite yield point in comparison to those of the BCC structure materials, but shows a smooth engineering stress strain curve. The yield strength therefore has to be calculated from the load at 0.2% strain (Dieter 1988). Absolute error of offset yield strength =230-225/230 =2.17%

4) Ductility: There are two ways to represent this property but both are measures of the strain at fracture. One is the elongation at fracture and the other is the reduction of area in the necked region of the fractured specimen. The elongation to failure was used for determination of ductility in this work. Absolute error obtained for Ductility = 3.95-3.85/3.95 =2.53%

X. CONCLUSION

Tensile testing, also known as tension 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. A low cost device that produces a satisfactory extension test was designed and constructed. The device is easy to operate and maintain. Properties that are directly measured via a tensile test such as ultimate tensile strength, maximum elongation and reduction in area were evaluated in comparison with an imported standard tensile testing machine. From these measurements the following properties were determined: Young's modulus, yield strength, and ductility characteristics. Tested results reveal absolute errors of measurement of 3.79%, 3.97% 2.17% and 2.53% for ultimate tensile strength, Young's modulus, yield strength and ductility respectively. This may be attributable to accuracy of specimen production which affects the test quality, the measurement results and, accordingly, the measurement uncertainties.

REFERENCES

[1] Y. A. Bukar, "Benefits of Enhanced Product Quality for Industries like Aluminum, Steel, Auto Mobile and related Industries" been paper presented at the seminar on Strategy for Developing Local Raw Materials for Metallurgical and Building Industries, Lagos, June 1992.

[2] I.M. Dagwa, and A.O.A. Ibhadode, "Design and manufacture of automobile disk brake pad test rig", *Nigerian Journal of Engineering Research and Development,* Vol.4 No.3, pp.15-24, 2005

[3] G.E. Dieter, "Mechanical metallurgy", SI metric edition, McGraw-Hill, ISBN 0-07-100406-8, 1988

[4] A.B. Hassan and Y. A. Bukar, "Design and Fabrication of Compression Strength Testing Machine for Blocks and Clay Bricks", *Leonardo Electronic Journal of Practices and Technologies,* Vol.14, pp.142-153, 2009.

[5] S. Hashemi, Foundations of materials science and engineering, 4th ed, McGraw-Hill, ISBN 007-125690-3, 2006.

[6] Mike Meier, "Mechanical properties'' Department of Chemical Engineering and Materials Science University of California, Davis, September, 2004.

[7] A. Stanisław, B. Jerzy, and K. Czesław, "Stress and strain measurements in static tensile tests", *Metrology and Measurement systems,* Vol.19, No.3, pp.531-540, 2012

[8] D. C. William, Materials science and engineering-An Introduction, 7th ed. New York. John Wiley & Sons, Inc, 2007.