Journal of Engineering and Applied Sciences 3 (6): 491-495, 2008
ISSN: 1816-949X

Development of a Low Cost Mechanically Operated Tensile and Creep Testing Machine

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Abstract: A low cost, mechanically operated tensile and creep testing machine capable of determining the strength and deformation property of materials is developed. The design of the testing machine was motivated by having a mechanically operated tensile and creep testing machine to complement the existing Baldwin Hydraulic Universal Testing Machine used by the mechanical engineering students, providing an economical means of performing standard tensile and creep experiments. The experimental result is a more comprehensive understanding of the laboratory experience, as the technology behind the tensile and creep testing machine, the test methodology and the response of materials loaded in tension and creep are explored. The machine provides a low cost solution for mechanical engineering laboratories interested in material testing but is not capable of funding the acquisition of commercially available electromechanical and hydraulic tensile/creep testing machines. The machine is satisfactory since, it is always ready for operation at any given time, as it does not rely on electricity, pneumatic or hydraulic for its operation.

Key words: Tensile, creep, testing, machine, experiments, material

INTRODUCTION

Testing is an essential part of any engineering activity, it is necessary at any point in the engineering process. Iron, steel, aluminum, copper, lead and zinc and their alloys are metals that are mostly used for the production of appliances, devices, machines and buildings. The spectrum of their properties also determines the essential demands on testing machines. Materials testing machines are predominantly used for the determination of the strength and deformation behaviour of specimens and components. The primary use of the testing machine is to generate values for stress-strain diagram and creep-time diagram. Once the diagram is generated, a graph book, pencil and straight edge or computer algorithm can be used to calculate yield strength, Young's Modulus, Tensile strength (Gedney, 2005), elongation, creep rate, creep recovery or stress-relaxation.

Tensile testing is the slow straining of metal (specimen) with varying load. The yield stress, ultimate tensile stress and elastic or Young's modulus of a material can all be determined from the engineering stress-strain curve for that material.

Creep is a time-dependent deformation that happens when metals or other materials are subjected to stress over a period of time (Evans, 1984). In metals, creep usually occurs only at elevated temperatures. Creep at room temperature is more common in polymeric materials and is called cold flow or deformation under load. Soft metals (e.g. lead) creep at room temperature. Thus Andrade commenced studies of creep behaviour in 1910 using lead, since this metal exhibits creep at room temperature (Benham *et al*., 1996). It has been found that plastic deformation at both room and elevated temperatures prior to creep testing has either beneficial or detrimental effect on the materials, although the problem has been previously studied experimentally for several materials (Xia and Ellyin, 1993).

Materials such as components of power plant, steam generators or turbine rotors must operate at high temperature, under significant stress. For this reason, the components and structures need to be designed on the basis that excessive creep distortion or creep failure must not occur within the expected operating life of the plant (Evans and Wilshire, 1993). Knowledge of the creep behaviour of metals is therefore important.

Tensile and Creep tests were carried out on Aluminium and Lead test-piece, results obtained were in agreement with what is obtainable in practice. The Test Rig now provides additional testing facilities for engineering students to carry out properties and characteristic tests on Aluminium and lead in the Department of Mechanical Engineering laboratory.

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Design of the tensile/creep testing machine: There are certain features, which must exist in any material testing machine be it tensile or creep. These features are:

Load application system: This is a mechanism for applying a force/load to the test-piece and for carrying the force/load at a controlled rate.

Grips and fixtures: This is use for locating and holding the test-piece in a satisfactory position. Correct alignment of the grips and the specimen, when clamped in the grips is important; offsets in alignment will create bending stresses and lower tensile stress readings. It may even cause the specimen to fracture outside the gage length (Gedney, 2005).

The strain measuring system: This is use for the accurate measurement and recording of changes in test-piece dimensions.

The tensile/creep testing machine shown in Fig. 1 consist of four major parts, namely:

Main frame: The main frame rugged construction provides years of trouble-free and dependable test results for the system. The principal parts of the main frame are: Stand/Cross U-channel and Top and bottom plate.

Stand/cross U-channels: Is made of 6×3 in and 4×2 in U-channel mild steel cut to required sizes, bolted together to give proper rigidity and easy assembling.

Top and bottom plates: Are made of flat plate of 10 mm thick to withstand stress due to bending.

Load application system: This comprises of Lever, Load hanger, dead weight and Single strand roller chain with sprockets.

Strain measuring system: The main mechanism for accurate measurement and recording of change in test-piece dimensions is a dial gauge shown in Fig. 2. When a force is applied to the test-piece, strain occurs; relative movement between the gripping points is

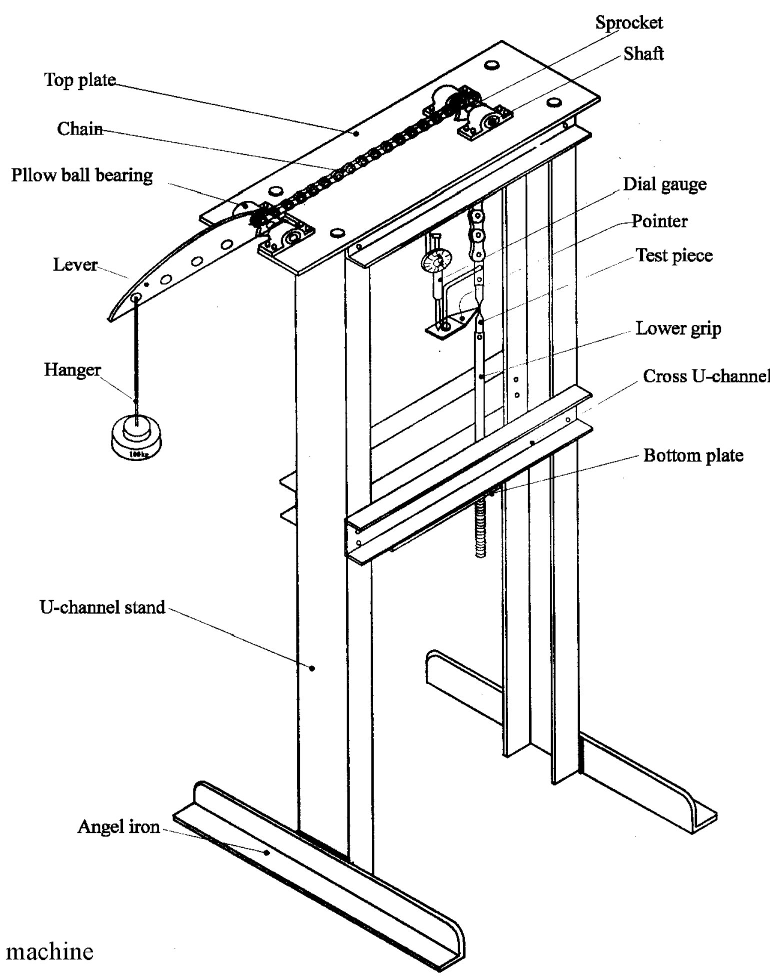

Fig. 1: Tensile/creep testing machine

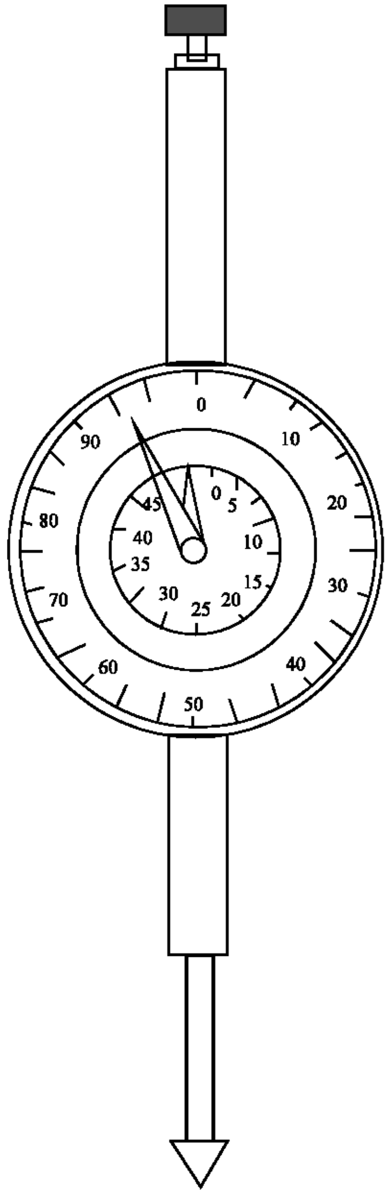

Fig. 2: Dial gauge

transmitted through the lever to the dial gauge. The dial gauge is calibrated in steps equivalent to an extension of 0.001 mm and the maximum amount of extension, which may, measured is 2.5 mm.

Test-piece grip: The force applied from the hanger through the lever to the chain is transmitted to the material through the upper test piece holder. The test piece grip is made out of a long steel shaft with hole drilled on it to accommodate 10 mm diameter test piece and a slot to accommodate flat specimen. To overcome slipping problem, provision were made for pin slot on the test piece.

Design consideration:
Design of frame:

For 6×2 U-channel
Area = A m^2
Height of frame = L m
Volume = V = A×L = 4.517×10^{-3} m^3
Density of steel = ρ kg m^{-3}
Weight (mass, m) = ρ×V = 35.69 kg
For 1 frame, m = 35.69 kg, For 2 frames, m = 2× 35.69 = 71.37 kg

Supporting channels (4 off):

For 5×1.75 channels
Volume = V = 0.001298 m^3
Weight of 1 supporting frame = 10.23 kg, 4 frames = 40.93 kg

Angle bar:

L angles bar (unequal legs) L$3^1/_2$×3
Weight of 2 angle bars = 19.43 kg
Top Plate, Weight = 22.28 kg
Bottom Plate, Weight = 8.295 kg
Total weight of the frame = Weight of 2 standing channels + weight of 4 supporting channels + weight of 2 angle bars + weight of top and bottom plates = 162.31 kg. Since, weight of the frame with other accessories is 162.31 kg, the applied load should not exceed 1592.26 ₦.

Maximum load applied to hanger: From Fig. 3, taking moment about the pivot

$$P = \frac{1592.26\times0.4}{0.533} = 1404.6 \text{ N}$$

The maximum allowable load for the hanger is 1404.6 ₦; any load applied beyond this value will topple the material test system.

Design of shaft: Shafting is usually subjected to torsion, bending and axial loads. In this shaft design, there is no axial loading and torsional load is negligible since the speed of rotation of the shaft is very small to be considered. The design of shaft is based on the permissible lateral deflection for proper bearing operation, accurate performance of the system, satisfactory sprocket teeth action and shaft alignment.

Weight of Sprocket = 10 ₦, Number of teeth = 16

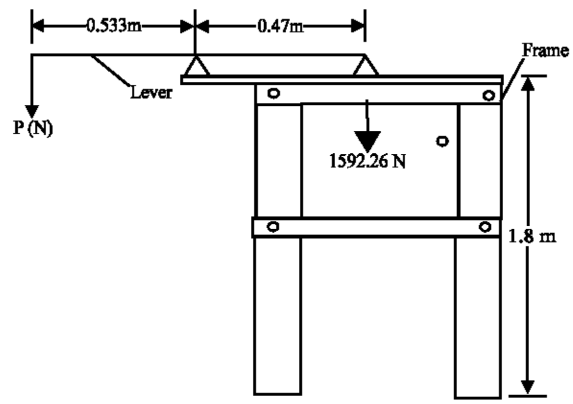

Fig. 3: Tensile/creep testing machine free body diagram

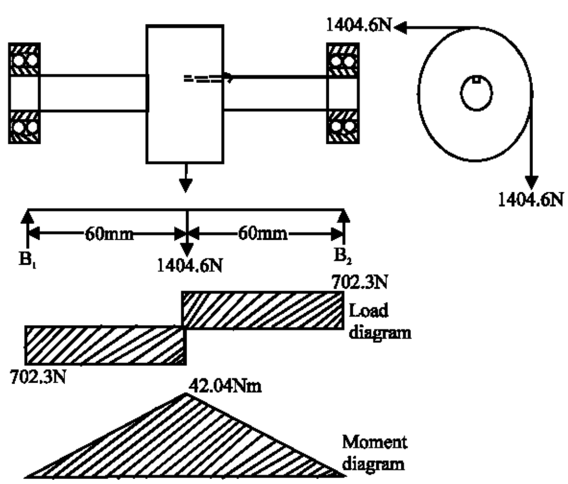

Fig. 4: Load and moment diagram

The maximum bending moment acting on the shaft as shown in Fig. 4 = $M_{b(max)}$ = 42.14 Nm.

Determination of the diameter of shaft:

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$(K_1 M_1)^2$ = 0; no torsional moment.

K_b = 1.5, for rotating shaft load gradually applied.

S_s = 40 MN m^{-2}, for shaft with keyways (Khurmi, 2005).

$$\therefore d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2} = 8.048\times10^{-6}$$

$$d = 0.02004 \text{ m} = 20.04 \text{ mm}$$

Determination of the shaft deflection

$$\frac{dy}{dx} = \delta = \frac{M_b}{EI}A$$

$$I = \frac{\pi d^4}{64} = 7.85\times10^{-9}$$

E = 200 GN m^{-2} for steel.

δ = 0.026 m.

XBearing selection: Two bearings were used on each shaft; they were selected based on the shaft diameter design, the closest bearing dimension to the shaft diameter is 20.00 mm. The Juvinall and Marshek (1991) design guides and specifications were used for bearing selection.

Cost: The cost of the purchased components used in the tensile testing machine was ₦ 32, 700.00. The bearings, chain and sprockets amounted to 60% of the total costs.

MATERIALS AND METHODS

The American Society for Testing and Materials (ASTM) has established a number of standards covering practically every aspect of tensile testing. For instance, there are separate standards dealing with the design of the specimens, certifying the testing machine, performing the test, analyzing the results and even comparing the results of tests where different specimen designs were used. These standards are invaluable. They help ensure that results from many different laboratories are consistent and reliable.

Tensile test procedure for the testing machine:

(i) Measure the diameter of the specimen d and mark out the gauge length (L_o).
(ii) Place the specimen between the lower and upper grips.
(iii) Connect the chain to the lever via the sprockets and place the hanger on the lever arm.
(iv) Fix the dial gauge holder and adjust the readings to zero deflection.
(v) Apply load gradually taking readings of the load increment and extension.
(vi) Increase the load gradually until the specimen extend with no increase in load, remove the load gradually from the hanger until the specimen fracture.
(vii) Remove the broken specimen from the machine and measure the diameter at the neck, then place the two pieces together and measure the final length L_F.

Creep test procedure for the testing machine: Creep test is conducted in the same manner as the tensile test.

- Follow the procedure (i)-(vi) for tensile.
- Take the ambient temperature.
- Apply a constant load and take extension reading at regular time interval.

RESULTS AND DISCUSSION

In order to benchmark the new Material Test system, several standard measurements and calibrations were made. Tensile tests carried out on a conventional tensile testing machine for 4 mm diameter Aluminium were

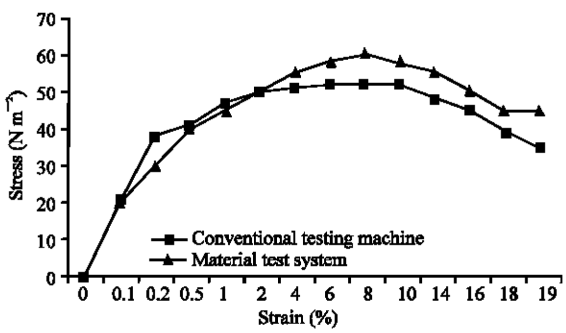

Fig. 5: Stress-strain curve for 4 mm diameter of aluminium

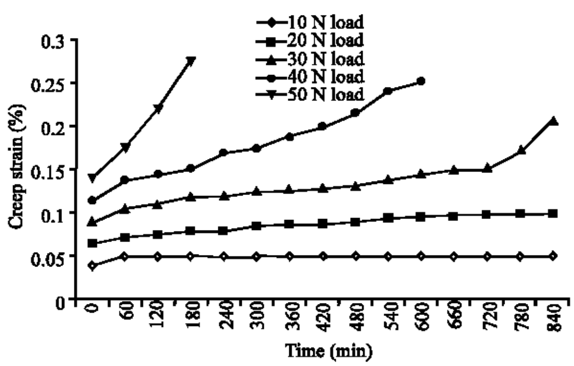

Fig. 6: Creep curve of 10 mm diameter lead at different load and room temperature

compared with results obtained from the Material Test system and also test on variation in Creep rate at room temperature with different loads were carried out using a 10 mm diameter lead test-piece. Figure 5 and 6 illustrate the results of the test performed on the machines, both showing good agreement.

CONCLUSION

The creep/Tensile testing machine developed in this work has proven to be satisfactory, cost effective and good alternative to Baldwin Hydraulic Universal Testing Machine for engineering students to carry out properties and characteristic tests on Aluminium and lead. This eliminates the rigor of the complexity that comes with the hydraulic type material testing machines and it is always ready for experimental operation at anytime, as it does not rely on electricity, pneumatic or hydraulic for its operation.

REFERENCES

Benham, P.P., R.J. Crawford and C.G. Armstrong, 1996. Mechanics of Engineering Materials. 2nd Edn. Longman Group, Singapore. ISBN, 0-582-25164-8.

Evans, H.E., 1984. Mechanisms of Creep Fracture. Elsevier Applied Science Publishers, New York, 1-22.

Evans, R.W. and B. Wilshire, 1993. Introduction to Creep. The Institute of Materials, London, 1-75.

Gedney, R., 2005. Tensile Testing Basics. Tips and Trends Quality Test and Inspection ADMET Inc Norwood., MA.

Khurmi, R.S. and J.K. Gupta, 2005. A Textbook of Machine Design. 1st Edn. Eurasia Publishing House, New Delhi, ISBN, 81-219-2537-1.

Juvinall, R.C. and K.M. Marshek, 1991. Fundamentals of Machine Component Design. John Wiley and Sons, New York.

Xia, Z. and F. Ellyin, 1993. An Experimental Study on the Effect of Prior Plastic Straining on Creep Behavior of 304 Stainless Steel. J. Eng. Mater. Technol., 115: 200-203.