Design analysis and Fabrication of a Tensile Creep Testing Machine

Abstract:- This work covers the design analysis and fabrication of a tensile creep test machine for determining the creep curve for thermoplastic materials (Teflon) and light metals (aluminum, lead) that creep easily. The apparatus consists of four primary systems which are the load application system, the heat generation and control system, the strain measuring system and then the frame and the Specimen grip. The insulating material for the heating chamber is clay and the maximum temperature the chamber can hold is 300^{0}C. The maximum amount of load that would not topple the machine is 2457N and the dial indicator measures a maximum extension of 10mm with an accuracy of 0.01mm. Any specimen to be used on the machine must be designed to have a cross sectional end diameter of 16mm, a gauge length of 65mm and an overall length of 145mm. Creep Tests were carried out using Teflon/Polytetrafluoroethylene as the test specimen at a constant load of 0.44MPa and at varying temperatures of 80^{0}C, 100^{0}C and 120^{0}C for a duration of two hours; the results show that at constant load and varying temperature, the elongation increases with time and also the creep rate decreases with time as temperature increases. Secondly, Creep tests were carried out on Teflon/Polytetrafluoroethylene test specimen at a constant temperature of 100^{0}C and at varying stresses of 1kg, 2kg and 3kg for duration of two hours. The results show that at constant temperature and at varying load, the extension and the creep rate increases with time as the load increases. These Creep curves show excellent agreement with experimentally determined data using stress relaxation.

Keywords: Aluminum, Creep Test, Design, Load, Machine, Material, Mild Steel, Teflon, Temperature, Tensile.

1. Introduction

Success in today's market place requires improvement in efficiency, quality and accuracy of testing facilities and testing equipment. Testing is an essential part of all engineering activity, it is necessary at any point in the engineering process [1]. 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. Recent developments associated with the innovative use of thermoplastics in structural applications demand accurate engineering data. More specifically, the assessment of structural performance requires data that spans appropriate range of stress, time, temperature, and strain rate [2]. The spectrum of their properties determines the essential demands on testing machines. Creep testing machines are predominantly used to measure how a given material will perform under load at a specific temperature. The primary use of the creep testing machine is to enable students generate values for creep-time curve.

Creep is the time-dependent deformation that happens when metals or other materials are subjected to a constant load at high temperature over a period of time. "High temperature" is a relative term that is dependent upon the materials involved. The temperature at which a material starts to creep depends on its melting point [3]. Creep is a time and temperature dependent phenomenon, occurring under load control. In creep, the material's temperature is a governing factor regarding what happens. However, some creep may occur even at low homologous temperatures, and they are not always negligible. Creep at room temperature is more common in polymeric materials and is called cold flow or deformation under load [4]. Plastics also creep at ambient temperatures but, compared to lead, they are able to sustain much greater extensions before failure, the creep curves are similar in shape to those for metals, but the mechanism of deformation is quite different because of the difference in structure of the material [4].

In materials science, creep is the tendency of a solid material to slowly move or deform permanently under the influence of stresses. It occurs as a result of long term exposure to high levels of stress that are below the yield strength of the material [5]. Creep is more severe in materials that are subjected to heat for long periods, and near melting point. Creep always increases with temperature. The rate of this deformation is a function of the material properties, exposure time, exposure temperature and the applied structural load. Depending on the magnitude of the applied stress and its duration, the deformation may become so large that a component can no longer perform its function for example creep of a turbine blade will cause the blade to contact the casing, resulting in the failure of the blade [5]. Creep is usually of concern to engineers and metallurgists when evaluating components that operate under high stresses or high temperatures. Creep is a deformation mechanism that may or may not constitute a failure mode. Creep deformation does not occur suddenly upon the application of stress. Instead, strain accumulates as a result of long-term stress [6].

The temperature range in which creep deformation may occur differs in various materials. For example, tungsten requires a temperature in the thousands of degrees before creep deformation can occur while ice will creep near 0^0C (32^0F). As a rule of thumb, the effects of creep deformation generally become noticeable at approximately 30% of the melting point (as measured on a thermodynamic temperature scale such as Kelvin) for metals and 40–50% of melting point for ceramics [7]. Virtually any material will creep upon approaching its melting temperature. Since the minimum temperature is relative to the melting point, creep can be seen at relatively low temperatures for some materials.

This work is aimed at designing and fabricating a tensile creep testing machine that would be used to perform creep tests on Polytetrafluoroethylene (Teflon). The relevance of this work is not restricted only to its application as a creep testing machine in the engineering laboratory but its significance in the allied and oil industries is also very important [1]. Knowledge of the creep behavior of any material is therefore important because many mechanical systems and components like steam boilers and reactors, 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 must not occur within the expected operating life of the plant. Knowledge of the creep behavior of any material is therefore important [8].

In architectural and building designs, a good number of polymer composite materials are currently used as structural and semi-structural components. Due to exposure to intermittent solar radiation, the creep behavior of these polymer based materials has also come under scrutiny [1]. It is thus imperative in materials design for high temperature applications, to account for creep behavior to safeguard against likely failure short of projected design life time.

It is evident that the creep testing machine is very important in the making of plastics, metals and other engineering materials and it is also very important in the industrial sector because with it, appropriate tests can be carried out on materials before they can be used to venture into production. It helps to detect when failure will occur. The creep testing machine is either at elevated temperature at constant load or it is at constant temperature at different load. The creep test machine that will be set up will be less space consuming; hence it can be used in small shops and also can be afforded by schools and other technical/engineering institutions to serve as a teaching aid in smaller foundry shops because the machine shop is cheap.

2. Methodology

2.1. Materials Selection

Table 1: Material Selection

MACHINE COMPONENTS	MATERIAL SELECTED	CRITERIA FOR SELECTION
Machine frame	Mild steel (76.2mm by 38.1mm by 1mm thick rectangular tubing and 38.1mm by 38.1mm by 2mm thick angle bar)	High strength, good machinability, good weldability, resistance to heat, low cost , ease of availability, Light weight

Rectangular top plate	Mild steel (3mm thick sheet metal)	
Load beam	Mild steel (3mm thick metal bar)	
Heating chamber	Mild steel (38.1mm by 1mm thick square tubing and 1mm thick sheet metal)	
Locking pin and locking slot	Mild steel (2mm thick metal bar and 9mm diameter metal pin)	
Test piece grip (upper and lower grip) and pillow box bearing connecting shaft	Mild steel (15mm and 20mm diameter shaft respectively)	High strength, good machinability, low notch sensitivity factor, good heat treatment properties, high wear resistant properties, light weight, ease of availability, low cost
Load hanger		Light weight
Load beam fulcrum	A pair of Pillow box bearing connected with a 20mm diameter mild steel shaft	Easy to mount and erect, cleanliness, suitable for an easy deflection of the load beam on load application, suitable for low speed rotation of the connecting shaft as a result of light load acting on the load beam.
Heating element	1900W – 240V heating element	Readily available and relatively cheap
Insulating (lagging) material	Moist clay	High refractory, resistance to heat, low thermal conductivity
Temperature measuring device	Thermocouple	High temperature sensitivity
Temperature controller	Digital Display	Easy temperature display, High sensitivity
Contactor	12 volt contactor	Optimum voltage specification for the temperature controller
Strain measuring device	Dial indicator	High sensitivity, High accuracy(0.001mm)
Load (Masses used)	1kg, 1.5kg, 2kg, and 3kg	Light weights below the maximum applied load
Pilot Lamp red and green		Red for indicating that the circuit is on while green for indicating that the heater is on
Control box		Light weight
Specimen	Teflon	Low melting temperature, low creep rate

2.2. Design Consideration and Analysis

2.2.1. Frame and Grips

Frame: The frame was made out of two standing rectangular tubing made of mild steel, four cross rectangular tubing, two angle bars and a rectangular top plate.

Table 2: Frame design dimensions

S/N	DIMENSIONS	VALUES	UNITS
1	Height of each standing rectangular tubing	700.0	mm

2	Breath of each standing rectangular tubing	38.1	mm
3	Length of each standing rectangular tubing	76.2	mm
4	Thickness of each standing rectangular tubing	1.0	mm
5	Mass of each standing rectangular tubing	0.794	kg
6	Weight of each standing rectangular tubing	7.8	N
7	Length of each crossed supporting rectangular tubing	500.0	mm
8	Height of each crossed supporting rectangular tubing	76.2	mm
9	Breath of each crossed supporting rectangular tubing	38.1	mm
10	Mass of each crossed supporting rectangular tubing	0.57	kg
11	Weight of each crossed supporting rectangular tubing	5.6	N
12	Height of each angle bar	38.1	mm
13	Breath of each angle bar	38.1	mm
14	Length of each angle bar	500	mm
15	Thickness of each angle bar	2	mm
16	Mass of each angle bar	0.9	kg
17	Weight of each angle bar	8.8	N
18	Length of rectangular top plate	700	mm
19	Breath of rectangular top plate	250	mm
20	Thickness of rectangular top plate	3	mm
21	Mass of rectangular top plate	3	kg
22	Weight of rectangular top plate	29	N

Grips: The test piece grip consists of two shafts made of mild steel that hold the test piece up and down. The test piece and the tip of each shaft are threaded so that the two can be fastened together easily.

Table 3: Grip design dimensions

S/N	DIMENSIONS	VALUES	UNITS
1	Length of the upper shaft	330	mm
2	Length of the down shaft	200	mm
3	Diameter of each shaft	15	Mm
4	Mass of the up shaft	0.41	Kg
5	Weight of the up shaft	4	N
6	Mass of the down shaft	0.32	Kg
7	Weight of the down shaft	3.1	N

Axial or normal stress acting on the shaft: This stress is present in the upper and lower test piece grip and it is gotten from the Eqn. (1):

$$\sigma_a = \frac{F}{A} \qquad (1)$$

Where σ_a = Axial stress, F = Axial force as a result of the action of weight on the load beam = 19.62N, A = Area of the shaft under consideration = $1.77 \times 10^{-4} m^2$.
Hence, the axial stress is 0.11MPa.

2.2.2. Load Application System

Mechanical Advantage: The load application system is of the first class lever type. It consists of a load beam which is pivoted by a pillow box bearing, with the effort applied at the right hand side with the corresponding effort at the left hand side. The free body diagram for the load application system is shown in fig. 1.

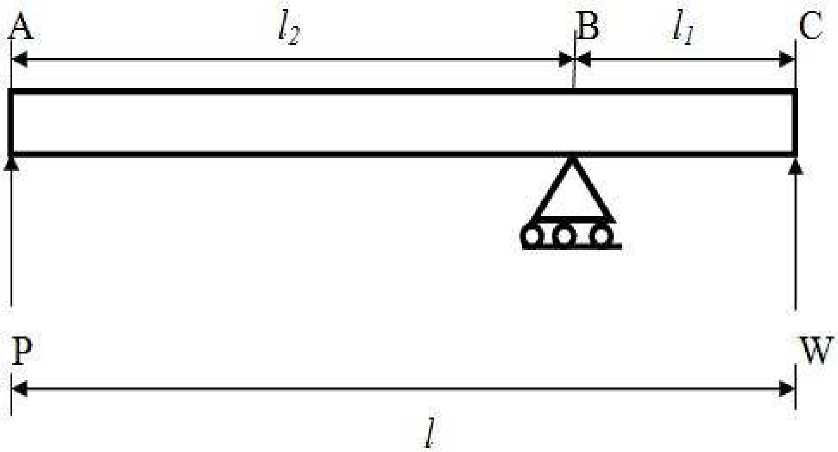


Fig 1: Free Body Diagram of a First Class Lever System [9]

Consider a straight lever with parallel forces acting in the same plane as shown in Fig. 1. The points A and C through which the effort (P) and load (W) is applied respectively. Point B is the fulcrum about which the lever is supported and capable of turning. The perpendicular distance between the load point and fulcrum (l_1) is known as the load arm and the perpendicular distance between the effort point and fulcrum (l_2) is called the effort arm [9].

According to the principle of moments;

$$W \times l_1 = P \times l_2 \quad \text{or} \quad \frac{W}{P} = \frac{l_2}{l_1} \qquad (2)$$

Where l_1 = 10cm and l_2 = 60cm. Hence, M.A = 6:1

Maximum Load Applied to the Hanger: The maximum weight applied to the hanger is that which if exceeded results in the toppling of the machine.

$$\begin{aligned} \text{Total weight of the machine} \\ &= \text{Weight of the load application system} \\ &+ \text{weight of the heat generation and control system} \\ &+ \text{Weight of the strain measuring system} \\ &+ \text{Weight of the fixtures, grips and the frame} \\ &+ \text{weight of specimen} \qquad (3) \end{aligned}$$

Where: Weight of the load beam = 5.3N, Weight of the load hanger = 1.962N, Weight of the load application system = 22N, Weight of the pillow box bearing and connecting shaft = 14.7N, Weight of heat generation and control system = 134N, Weight of the heating chamber = 101N, Weight of the control box = 33N, Weight of the strain measuring system = Weight of the dial gauge and stand = 2.5N, Weight of the frame and grips = 92N.
Hence, total weight of the machine = 250.5N (25kg)
Therefore maximum weight to be applied to the load hanger (effort) which if exceeded will topple the machine is 250.5N (25kg).

Pillow Block Bearing and Connecting Shaft: The fulcrum of the load application system consists of a pair of pillow box bearing which is connected with the help of a 20mm diameter and 130mm length of shaft.

A pillow block bearing is a type of solid bearing which is the simplest form of journal bearing. It is simply a block of cast iron with a hole for a shaft providing running fit. The lower portion of the block is extended to form a base plate with two holes to receive bolts for fastening it to the frame. An oil hole is drilled at the top for lubrication. Since there is no provision for wear adjustment, this type of bearing is used when the shaft speed is not very high and the shaft carries light loads only [9].

The connecting shaft connects the load beam with the two pairs of the bearing. The shaft helps to create a smooth movement of the load beam on load application because as the bearing rotates the shaft, the load beam which is welded onto the shafts rotates also [9]. The materials used for the shaft have the following properties: high strength, good machinability, low notch sensitivity factor, good heat treatment, and high wear resistant.

2.2.3. Heating Generation and Control System

Volume of the Heating Chamber: The volumes of the exterior and interior of the heating chamber are given as;

$$V = L\, b\, h \quad (4)$$

Where; L = Length of the exterior and interior of the chamber are 250mm and 174mm respectively, b = Breath of the exterior and interior of the chamber are 250mm and 174mm respectively, h = height of the exterior and interior of the chamber are 300mm and 224mm respectively.

Hence, the volumes of exterior and interior heating chamber, V, are $0.0188m^3$ and $0.00678m^3$ respectively.

Area of the Heating Chamber: The area of the exterior and interior heating chamber is given as;

$$A = 2(Lb + Lh + bh) \quad (5)$$

Hence, area of exterior and interior heating chamber, A, are $0.425m^2$ and $0.217m^2$ respectively.

Quantity of Heat Generated in the Heating Chamber: Consider the heating element which is a current carrying electrical conductor [10]. When electrical current passes through the conductor, heat is generated (Q_g) and it is given by;

$$Q_g = I^2 R \quad (6)$$

$$Q_g = \frac{V^2}{R} \quad (7)$$

$$Q_g = IV \quad (8)$$

Where; Q_g = Quantity of heat generated = 1900W, R = Electrical resistance of the conductor material, V = Voltage flow through the conductor = 240V, I = Current flow through the conductor.

Hence, the value of resistance, R and current, I are 30Ω and 7.9A respectively.

The heating element has a rating of 1900W and 240V. Therefore the quantity of heat generated is 1900W.

Quantity of Heat Transferred: The quantity of heat transferred through each of the three modes of heat transfer (conduction, convection and radiation) is equal to the amount of heat generated in the heating chamber [10]; Rate of electrical energy dissipated in the chamber = Rate of heat transferred across the wall.

Therefore, the quantity of heat transferred across the walls of the of the heating chamber is 1900W

Heat Transfer through Conduction: Using Fourier's law of heat conduction;

$$Q = kA\frac{T_1 - T_2}{x} \quad (9)$$

Where; Q = Heat flow through the body per unit time or the quantity of heat transferred through conduction (in watts), A = Surface cross sectional area of heat flow, T_1 = Temperature of the interior of the furnace, T_2 = Temperature of the exterior of the furnace, x = Thickness of insulation, and k = Thermal conductivity of the insulating material

The following are the assumptions on which Fourier's law is based [10]; Conduction of heat takes place under steady state conditions, The heat flow is unidirectional, The temperature gradient is constant and the temperature profile is linear, There is no internal heat generation, The boundary surfaces are isothermal in character, The material is homogenous and isotropic (i. e., the value of thermal conductivity is constant in all directions).

Heat Conduction through a Composite Wall (Steady-State One Dimension): The general heat conduction equation in Cartesian coordinates;

$$\frac{\partial^2 t}{dx^2} + \frac{\partial^2 t}{dy^2} + \frac{d^2 t}{dz^2} + \frac{q_g}{k} = \frac{1}{a} \cdot \frac{\partial t}{\partial \tau} \qquad (10)$$

Since the heat conduction under the conditions, steady state ($\frac{\partial t}{\partial \tau} = 0$), one-dimension$\left[\frac{\partial^2 t}{dy^2} = \frac{d^2 t}{dz^2} = 0\right]$ and with no internal heat generation is considered, the equation reduces to $\frac{\partial^2 t}{dx^2} = 0$ [10].

Consider the fig. 2 which represents a side of the heating chamber being treated as a composite wall through which heat flows only in the x-direction.

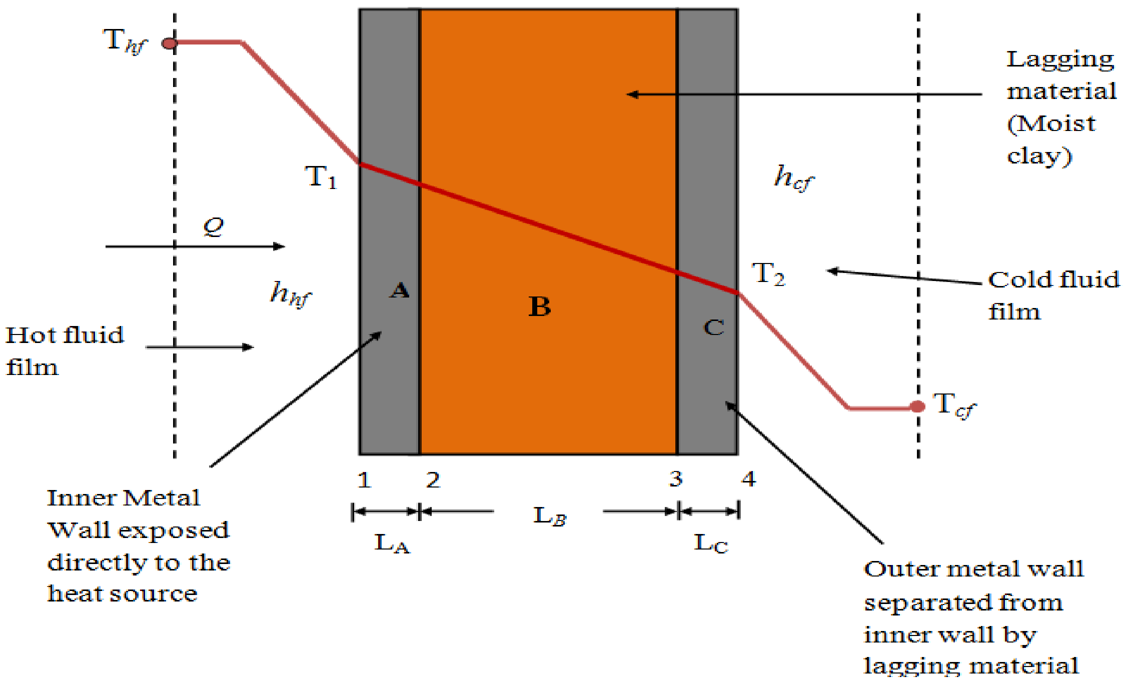


Fig. 2: Heat Transfer through a Composite wall [10]

Where; Q = Quantity of heat that is transferred between the layers of the wall, L_A = Thickness of the interior metal surface, L_B = Thickness of the insulating material, L_C = Thickness of the exterior metal surface, T_1 and T_4 ($T_1 > T_4$) = Temperature at the wall surface '1' and '4' respectively, T_2 and T_3 = Temperature of the wall surface '2' and '3' respectively, T_{hf} = Temperature of the hot fluid, T_{cf} = Temperature of the cold fluid, h_{hf} = Convective heat transfer coefficient of the hot fluid, h_{cf} = Convective heat transfer coefficient of the cold fluid. (The suffices *hf* and *cf* stand for hot fluid and cold fluid respectively.)

Since the quantity of heat transmitted per unit time through each layer is the same, then the equations of heat flow by conduction through the different layers of the composite walls are given by

$$Q = \frac{k_A A(T_1 - T_2)}{L_A} \quad (11)$$

$$Q = \frac{k_B A(T_2 - T_3)}{L_B} \quad (12)$$

$$Q = \frac{k_C A(T_3 - T_4)}{L_C} \quad (13)$$

Thickness of the Insulation: The thickness of insulation can be obtained through the Fourier's law of heat conduction for a composite wall.

Summing the three Eqns. (11, 12, 13);

$$Q = \frac{A(T_1 - T_4)}{\left[\frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C}\right]} \quad (14)$$

Where; k_A = Thermal conductivity of the Interior metal surface, k_B= Thermal conductivity of the lagging material, k_C = Thermal conductivity of the exterior metal surface, Q = 1900W A = Surface cross sectional area of the chamber in the direction of heat flow = the Area of the interior of the heating chamber = 0.217m^2 (Calculated), T_1 = 300^{0}C, T_2 = 70^{0}C, L_A and L_C = 1.0mm = 1×10^{-3}m, k_A and k_C = 45Wm^{-1}K^{-1} (Mild steel), k_B = 0.15Wm^{-1}K^{-1}(moist clay). Therefore, the thickness of the insulating chamber (L_B) = 4.0 ×10^{-3}m (40mm).

Heat Transfer by Convection: Consider the fig 2 which represents a side of the heating chamber being treated as a composite wall through which heat flows only in the x-direction. Since the quantity of heat transmitted per unit time through each layer is the same, then the equations of heat flow by convection through the different layers of the composite walls;

$$Q = h_{hf} A\left(T_{hf} - T_1\right) = h_{cf} A\left(T_4 - T_{cf}\right) \quad (15)$$

Where; h_{hf} = Convective heat transfer coefficient of the hot fluid, h_{cf} = Convective heat transfer coefficient of the cold fluid, Q = 1900W, A = 0.217m^2, T_1 = T_{hf} = 300^{0}C, T_4 = 70^{0}C, T_{cf}= 25^{0}C.

Therefore, the heat convective transfer coefficient of the hot and cold fluids are; h_{hf} = 8755.76Wm^{-2}K^{-1} and h_{cf} = 162.143Wm^{-2}K^{-1} respectively.

Overall Heat Transfer Coefficient

While dealing with problems of fluid to fluid heat transfer across a metal boundary, it is usual conventional to adopt an overall heat transfer coefficient (U), which gives the heat transmitted per unit area per time per degree temperature difference between the bulk fluids on each side of the metal [10]. Referring to fig. 2 the equations of heat flow through the fluid and the metal surface;

$$Q = h_{hf} A\left(T_{hf} - T_1\right) \quad (16)$$

$$Q = \frac{k_A A(T_1 - T_2)}{L_A} \quad (17)$$

$$Q = \frac{k_B A(T_2 - T_3)}{L_B} \quad (18)$$

$$Q = \frac{k_C A(T_3 - T_4)}{L_C} \quad (19)$$

$$Q = h_{cf} A\left(T_4 - T_{cf}\right) \quad (20)$$

Summing Eqns. (16, 17, 18, 19 and 20);

$$Q = \frac{A(T_1 - T_4)}{\left[\frac{1}{h_{hf}} + \frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C} + \frac{1}{h_{cf}}\right]} \quad (21)$$

If U is the overall coefficient of heat transfer;

$$Q = UA(T_{hf} - T_{cf}) = \frac{A(T_1 - T_4)}{\left[\frac{1}{h_{hf}} + \frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C} + \frac{1}{h_{cf}}\right]} \quad (22)$$

$$U = \frac{1}{\left[\frac{1}{h_{hf}} + \frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C} + \frac{1}{h_{cf}}\right]} \quad (23)$$

Where ; $L_A = L_C = 1\times10^{-3}$m, $L_B = 4.0 \times10^{-3}$m, k_A and k_C= 45$Wm^{-1}K^{-1F}$ (Mild steel), k_B = 0.15$Wm^{-1}K^{-1}$(moist clay), h_{hf} = 8755.76$Wm^{-2}K^{-1}$, h_{cf} = 162.143$Wm^{-2}K^{-1}$.
Therefore; U = 30.31$Wm^{-2}K^{-1}$.

2.2.4. Strain Measuring Instrument

The maximum amount of extension obtained is 4mm and the dial gauge used is calibrated to an accuracy of 0.01mm and also measures a maximum extension of 10mm. The stand for the dial gauge will be held in such a way that the movable tip will rest directly on a bolt which is welded to the top of the shaft so that any slightest extension on deformation will be measured by the inward movement of the sterm.

2.2.5. Specimen Design

Any specimen to be tested on the machine must have an overall length of 145mm, gauge length of 65mm and a cross sectional end diameter of 20mm. Using a tap of 12mm, an internal thread is created at the two ends of the Teflon specimen.

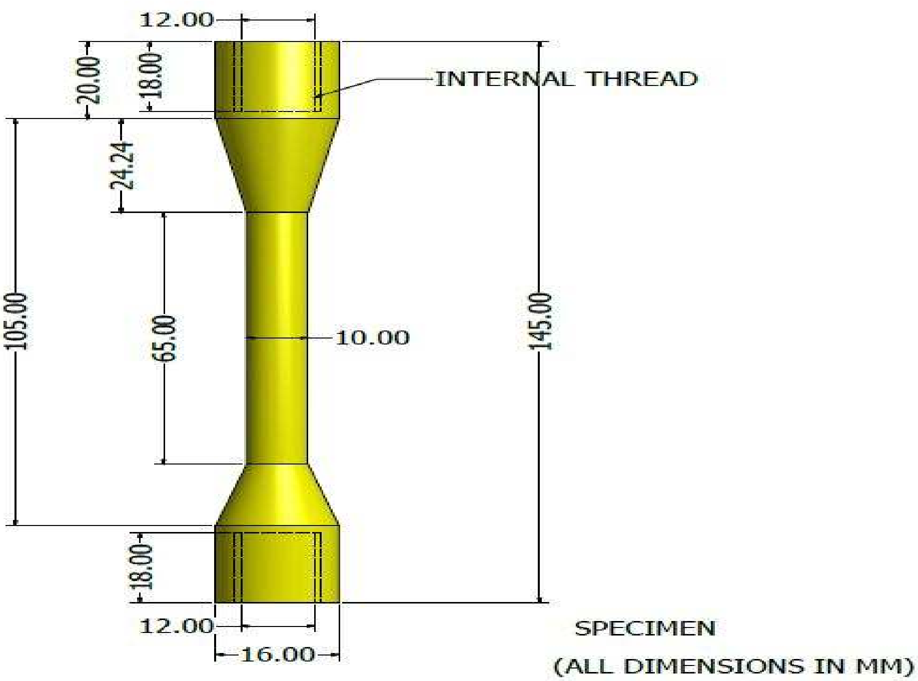


Fig. 3: Internal Threaded End Specimen

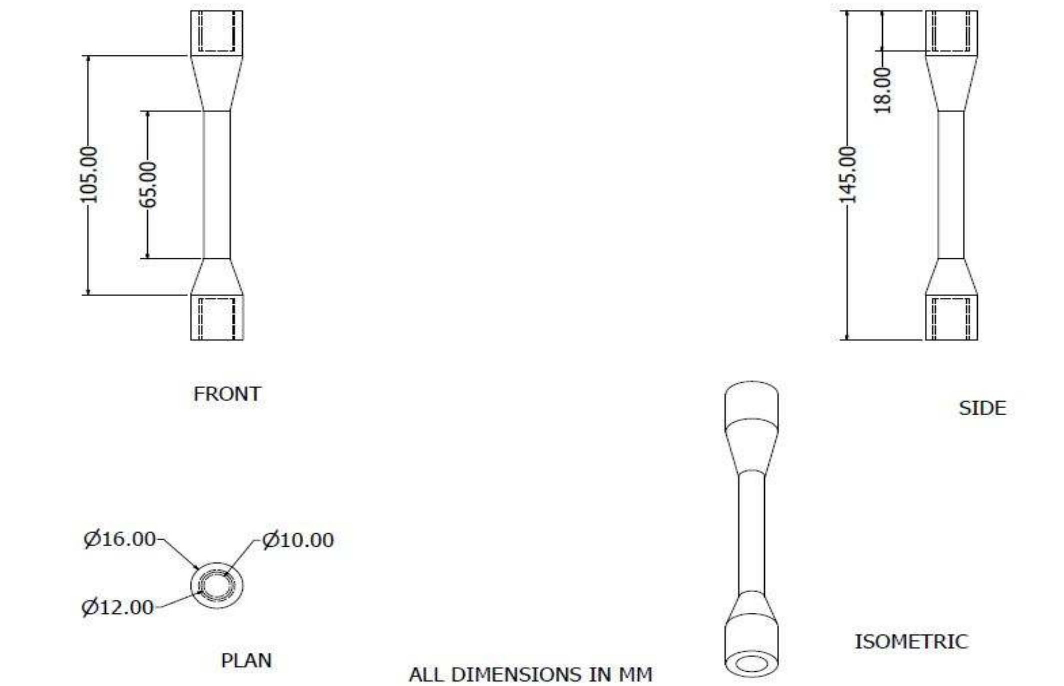


Fig. 4: Projected View of the Specimen

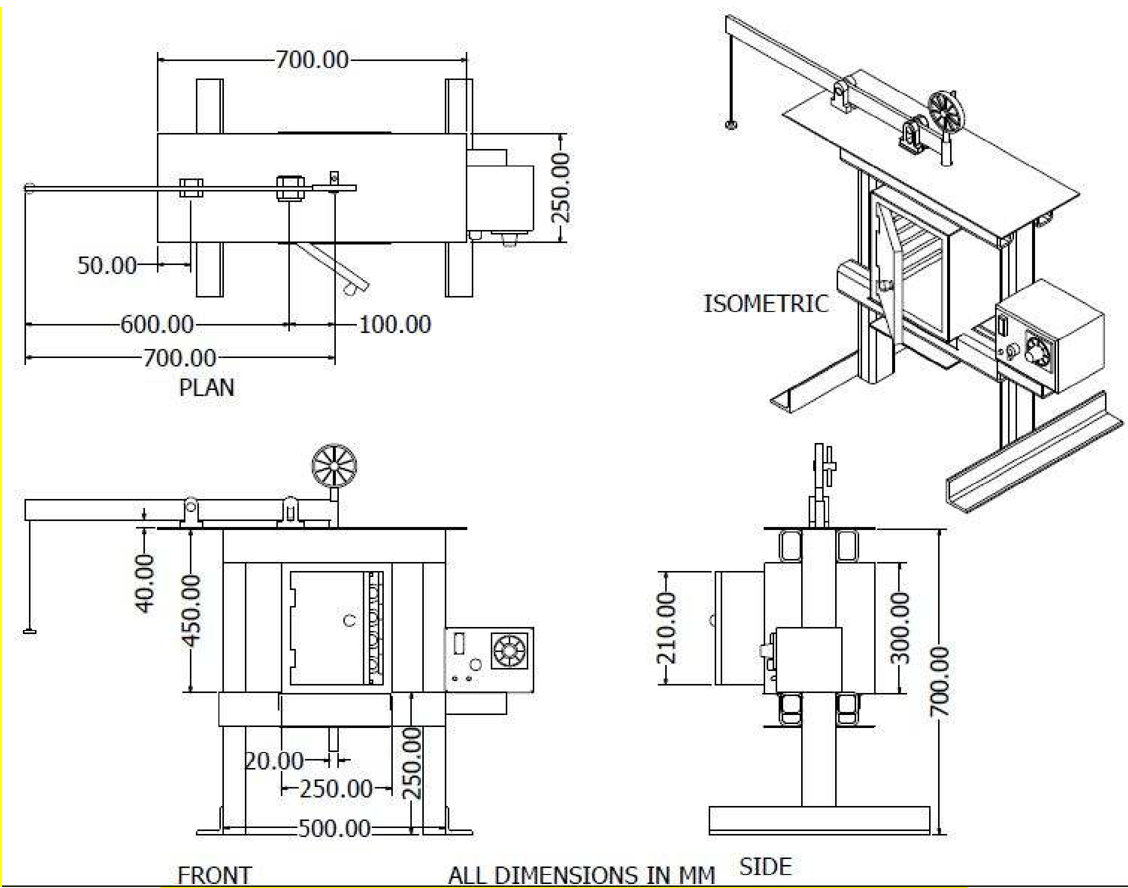
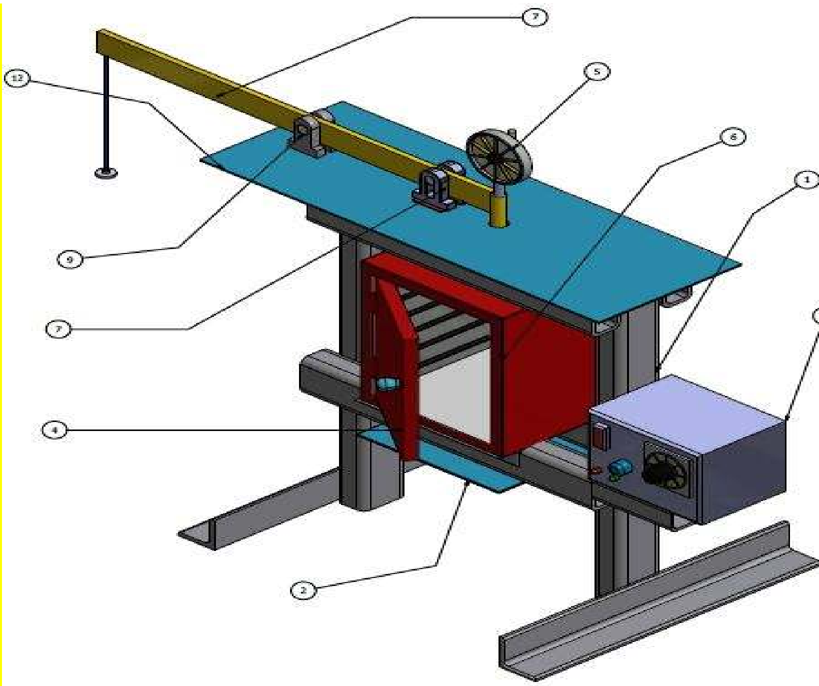


Fig. 5: Projected View of Creep Test Machine with Dimensions



S/N	DESCRIPTION
1	Rectangular tubing
2	Bottom plate
3	Down test piece grip
4	Chamber door
5	Dial gauge
6	Heating Chamber
7	Load beam (Lever arm)
7	Pillow block bearing
8	Locking pin slot
9	Locking pin
10	Specimen
11	Control box
12	Rectangular top plate

Fig. 6: Isometric View of the Tensile Creep Test Machine

Table 4: Standard Internal Threaded-End Specimen Dimensions, mm [11]

Specific Length	Dimension (mm)
Gauge length	65
Overall length	145
Length of reduced section	105
Length of end section	20
Diameter	10
Diameter of end section	16

The tensile force and stress acting on the specimen as a result of an applied load (effort) can be determined as shown below; Consider a load of mass 1.5kg acting on the load beam;

$$p \times l_2 = W \times l_1 \qquad (24)$$

Where; P = Applied load (Effort) = 14.7N, l_2= Effort arm = 600mm, l_1 = Load arm = 100mm, W = the corresponding tensile force (Load).

Hence; W = 88.3N and using Eq.(1); Tensile stress acting on the specimen, σ = 0.44MPa

Similarly, the corresponding tensile force and stress that would be created when loads of 1kg, 2kg and 3kg act on the lever arm can be calculated using the above method and is tabulated in table 5.

Table 5: Varying Load, Corresponding Tensile Force and Stress Acting on the Specimen

S/N	Mass of Applied load (kg)	Applied load (Effort in N)	Corresponding Tensile force (Load in N)	Corresponding Tensile stress (MPa)
1	1	9.81	58.8	0.29
2	1.5	14.7	88.2	0.44
3	2	19.6	117.6	0.58
4	3	29.4	176.4	0.88

3. Results and Discussion

Experimental creep tests were carried out on Polytetrafluoroethylene (Teflon) specimen with a cross sectional diameter of 16mm, gauge length of 65mm and an overall length of 145mm. The experiment carried out was of two types; Constant load at varying temperature and Constant temperature at varying load.

3.1. Constant Load at Varying Temperature Experiment

Three sets of experiments were conducted under this type. A load of 2kg (0.58MPa) was made to act on the specimen at varying temperatures of 80^0C, 100^0C, and 120^0C.

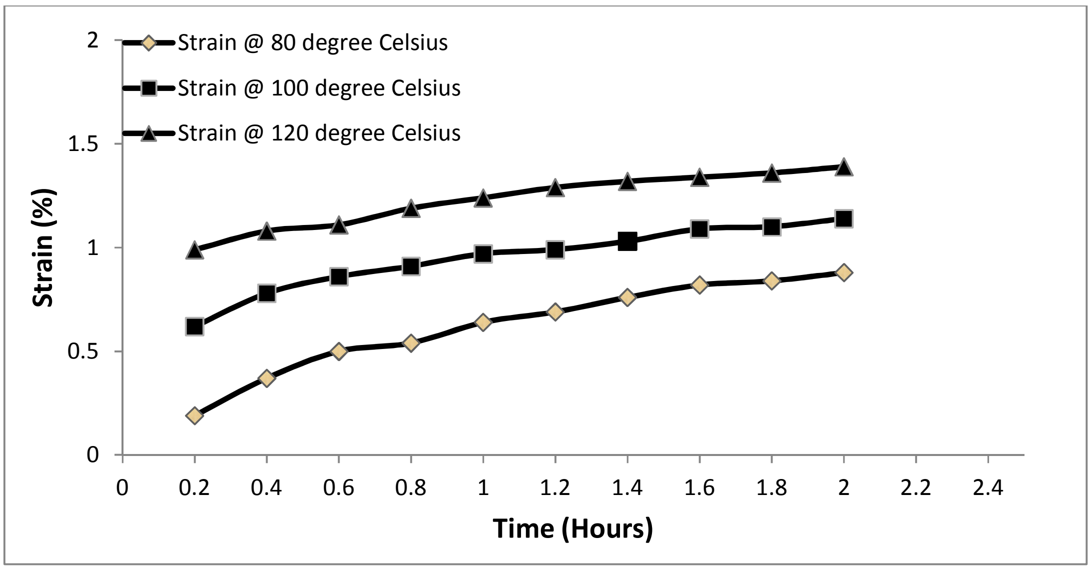


Fig. 7: Creep Curves for Teflon at Constant Load of 2kg (0.58MPa) and Varying Temperatures of 80^0C, 100^0C and 120^0C

Fig. 7 shows the Creep Curves for Teflon at constant load of 2kg (0.58MPa) and varying temperatures of 80^0C, 100^0C and 120^0C within a time interval of two hours. These Creep curves show excellent agreement with experimentally determined data using stress relaxation tests [12]. A clear observation of the three plots show that an increase in temperature at constant load for a given period of time produces more extension; hence an increase in the strain and also causes a decrease in creep rate. The slope of each curve is the creep rate$\left(\frac{d\varepsilon}{dt}\right)$ for that particular curve. A clear observation shows that the steady state creep decreases gradually as temperature increases.

3.2. Constant Temperature at Varying Load Experiment

Three sets of experiments were conducted under this type. Loads of 1kg, 2kg and 3kg were made to act on the specimen at constant temperature of 100^0C

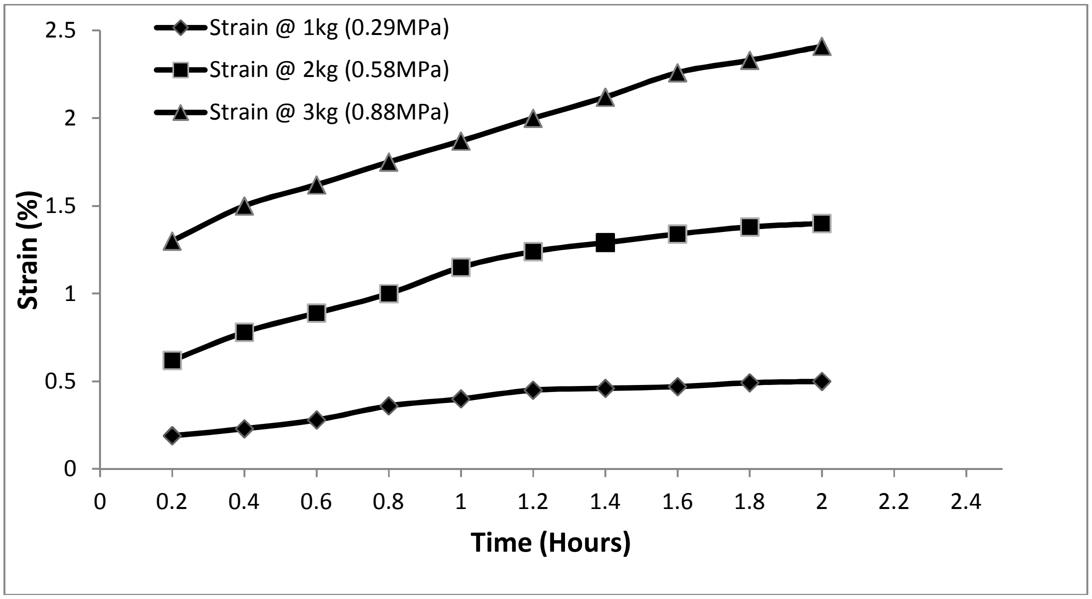


Fig. 8: Creep Curves for Teflon at Constant Temperature and Varying Loads of 1kg, 2kg and 3kg

Fig. 8 shows the Creep Curves for Teflon at constant temperature of 100^0C and varying load of 1kg (0.29MPa), 2kg (0.58MPa), and 3kg (0.88MPa) within a time interval of two hours. These Creep curves show excellent agreement with experimentally determined data using stress relaxation tests [12]. A clear observation of the three plots show that an increase in load (stress) at constant temperature for a given period of time produces more extension; hence an increase in the strain and also causes an increase in the creep rate. The slope of each curve is the creep rate$\left(\frac{d\varepsilon}{dt}\right)$ for that particular curve. A clear observation shows that the steady state creep increases gradually as the applied load (stress) increases.

4. Conclusion

The aim of this work which is to design and construct a tensile creep testing machine that would be used to perform simple creep tests on Polytetrafluoroethylene (Teflon) has not only been achieved but also this apparatus can also be produced locally using available materials. Tests conducted with this machine were found reliable and the results did not deviate so much from standard results.

Creep tests were carried out on Polytetrafluoroethylene (Teflon) test-piece of overall length of 145mm, gauge length of 65mm and cross sectional diameter 16mm; results obtained were in agreement with what is obtainable in practice. The testing machine now provides additional testing facilities for engineering students to carry out creep test on thermoplastic materials, aluminum and lead in the department of mechanical engineering laboratory of any university. It must be noted that the creep test machine must not be used for materials that take very high time to creep like metals with very high melting temperature. The creep testing machine developed in this work has proven to be satisfactory and cost effective.

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