ISSN: 0974-5823 Vol. 7 No. 4 April, 2022

International Journal of Mechanical Engineering

Modification of Varying Load Creep Testing Machine to find Creep Behaviour of Lead Material

Arvind Totey and Dr. Hardik Bhupendrabhai Ramani

Department of Mechanical Engineering,
Dr. A.P.J. Abdul Kalam University, Indore (M.P.) - 452010

Abstract

This paper covers the design analysis and fabrication of a tensile creep test machine for determining the creep behaviour curve for thermoplastic materials like polypropylene and light metals like lead. The purpose of the work was to fabricate a machine at low cost and may be used in college laboratory to demonstrate creep behaviour curve. The lever mechanism of conventional machine is replaced by a connecting mild steel metalwire. The load is applied with the help of turn buckleof 22500N. Different capacities of tension spring areused to vary loads. The tension spring of 39.24N, 245.25N and 392N is used. A low heat treatment furnace of capacity below 200ºc is designed. The temperature is indicated on PID temperature controller.

Keywords: Thermoplastic, Turnbuckle, Tension spring, Creep test, design, mild steel, furnace, lead.

Objectives of Project: The objective of this work is to design and fabricate a Creep test apparatus whichcan be used in laboratory to demonstrate creep behaviour of engineering materials without using expensive creep testing machine.

1. Introduction

A creep-testing machine measures the creep (the tendency of a material after being subjected to high levels of stress, e.g. high temperatures, to change itsform in relation to time) of an object. It is a device that measures the alteration of a material after it has been put through different forms of stress. Creep machines are important to see how much strain(load) an object can handle under pressure, so engineers and researchers are able to determine what materials to use. The device generates a creep time-dependent curve by calculating the steady rate of creep in reference to the time it takes for the material to change. Creep machines are primarily used by engineers to determine the stability of a material andits behaviour when it is put through ordinary stresses.

The first creep testing machines were created in 1948 in Britain to test materials for aircraft to see how they would stand in high altitudes, temperatureand pressure. The machines were first developed to further calculate and understand the steady rate of creep in materials. Creep is the tendency of a material to change form over time after facing high temperature and stress. Creep increases with temperature and it is more common when a materialis exposed to high temperatures for a long time or atthe melting point of the material. Creep machines are used to understand the creep of materials and determine which type can do the job better, which is important when making and designing materials for everyday uses. They most commonly test the creep of alloys and plastics for the understanding of their properties and advantages of one material's use over another. Different stages of creep are shown in fig no 1.

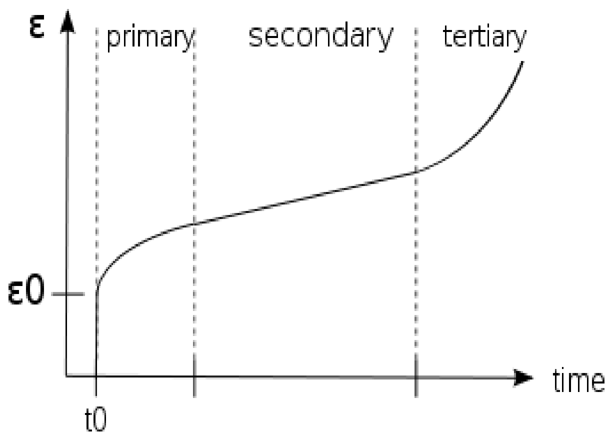


Figure 1: stages of creep

2. Methodology

2.1 Design of Machine Components

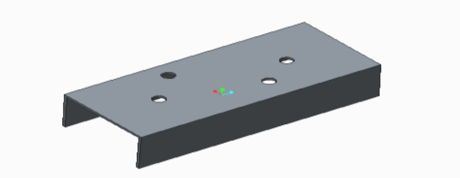
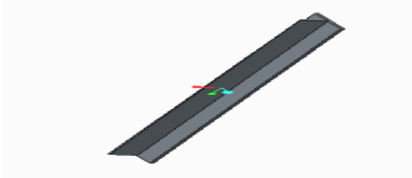
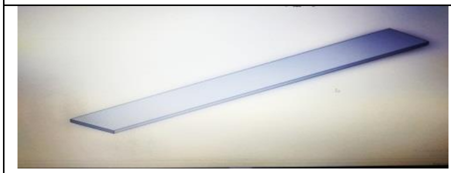
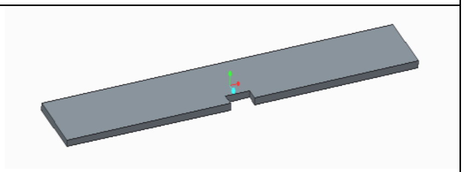
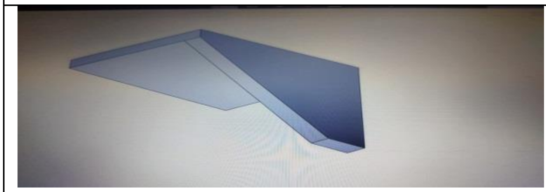
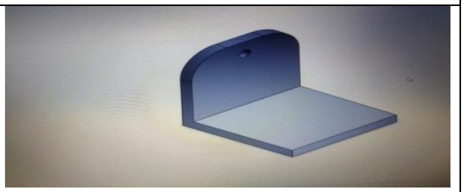
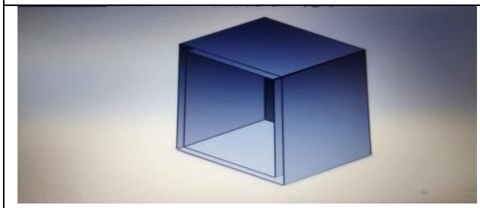
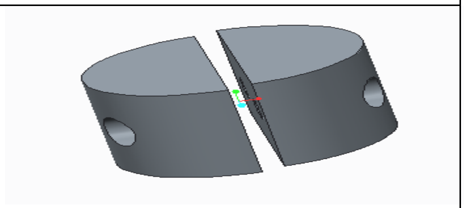
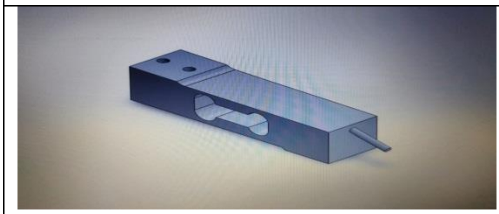
Machine Components Parts	
Components of Creep Testing Machine	
1.Base part	2. Column
	
3. Column Support Plate	4. Rectangular Top Plate
	
5. Extended Top angle	6. Bracket for Load Cell
	
7. Heating Chamber	8. Test piece grip
	
9. Load cell	10.Load hanger
	
11. Turnbuckle	12. Tension helical spring
	

Table 1: Machine Components Parts

3. Test Specimens

Test specimens for Tensile Creep Testing Machine used are lead. The standard test specimen should be in the form of "I" Section

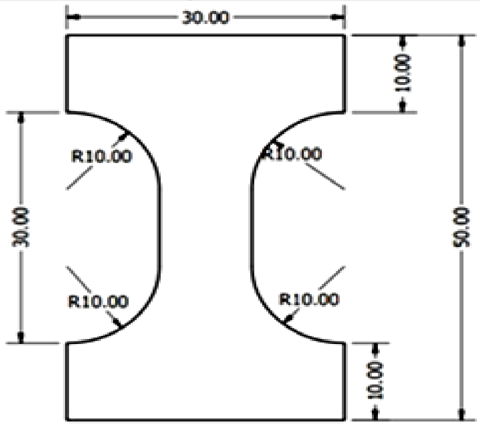


Figure 2: Test Specimens Geometry

4. Design Calculations for Furnace

The components of the furnace are as follows:
The Heating element, Outer Casing, Insulating Materials, Grippers, Digital Temperature Indicator
The dimensions of the furnace are assumed asfollows:-
Outer Length = 152mm Outer Breadth = 128mmOuter Height = 224 mmInner Length = 124 mm Inner Breadth = 115mmInner Height = 200mm

The furnace is designed for maximum temperatureup up to 200^o C and the outer surface temperature is isassumed to be 30^o C. for testing the specimen is fixed in the grippers in furnace which are used to hold the specimen in testing period. The lower gripper is fixed and the upper gripper is movable.
After fixing the test specime, desired load is applied via turn buckle. When the desired load is achieved, required temperature is set inside the furnace by the help of digital temperature controller. Due to applied temperature and load after some time duration, creep phenomena are generated in the test specimen and elongation of length is produced as a result.
Taking properties at the required temperatures fromdata book such as density (ρ), specific heat (Cp), thermal conductivity (k), kinematic viscosity (υ), and number (Pr).

At To=30^{o}C.
GrL=241.62x10^6 (at x=L=224mm) Gr_LxPr = 169.37x10^{6,} Calculating Nusselt no, Nu=0.59x (Gr_LxPr)$^{0.25}$ Nu=67.30, Nu=$\frac{hoxL}{k}$,
h_o= 9.00 w/m-K similarly, at Ti=200^o CGr_L=23.17x10^{6,} Gr_L*Pr=15.76x10^{6}Nu=37.17, hi =7.30 w/m-k

Calculating heat dissipated through wall of the furnace, Where A_1= 0.124m^2 A_2=0.15m^2 A_3=0.164m^2 K=0.087(from data book for bison sheet) Q_w= 60 watt, Calculating heat dissipated through grippers, selecting cast steel as a material for gripper as it can sustain the required temperature, Volume=Πxr^{2}xh Where r=35x10^{-3}m h=70x10^{-3}m, Volume=2.69x10^{-4}m^3, Density=7753 kg/m^3 , , Specific heat= 486 J/kg-KQ_g=mCpΔT, Assuming t=15 minutes, M= 2.31x10^{-3}, Qg=191.45 watt. The specimen to tested is in the form of I section.

Therefore, selecting Teflon as the material forspecimen as its creep temperature is 130.72^{o}C.which is in the range.
Adding all the heat dissipated QT=252.25 watt, this energy is absorbed by the elements of the Furnace; hence we have to consider heating coil having wattage close to the obtained result.

5. Design of Turnbuckle

Step 1:- Selection of Material for turnbuckle, Stainless steel Sut = 465 MPa, Syt = 270 MPa
Step 2:- Selecting M8 designated Turnbuckle for Max load application, d = 8mm, d_c = 6.466 mm, P= 400N
Tensile Stress σ_t = 12.18 N/mm^{2,} Torsional moment M_t = 313.6N-mm shear stress, τ = 5.91 N/mm^2
The principle shear stress is given by, τ_{max} = 8.486 N/mm^{2,} Factor of safety, *f s = 15.90*
The factor of safety is satisfactory. Therefore, the nominal diameter and pitch of the threaded portion of the rod should be 8mm and 1.25 mm respectively. Equating shear resistance of the threaded to the tension in the rod, $\pi d_c l r$ = P, τ = 27 N/mm^2, $\pi d_c l r$ = P, π x 6.466 x *l* x *27 = 400* l=0.73 m, l=d=8mm, l= 1.25d = 1.25x8, l = 10mm, assumed as 9mm.

6. Design of Coupler

D = 8.468 mm
Standard portion, D = d =8, D = 1.5d = 1.5 x 8, D = 12 m, assumed as 11mm

Check for Design M_t = 313.6 N-mmr = D/2=12/2, r = 6 mm, J = 1035.25 mm^4 τ =1.66 N/mm^2
σ_t = 8.935 N/mm^2 , σ max = 9.23 N/mm2 , Factor of safety 17.90 is satisfactory, Now remaining dimension of turnbuckle., D_1 = d + 10 = 8 + 10D_1 = 18mm, D_2 = 2xD_1 = 2x18D_2 = 36mm, L = 6xd =6x8, L = 48 mm

7. Design of Spring

Assume material: - SAE6145- oil quenched and drawn 425°c, From data book by B.D. Shiwalkar, Sut=1570 N/mm^2, G=84x10^3 N/mm^2
Step 1:- Wire diameter of spring Shear stress (τ) = 0.5x Sut = 0.5x1570, τ =785N/mm^2, Load (P) = 4Kg = 4x9.81 = 39.24N, Nahl factor; K = 1.2525, Where, C = 6(standard value),d = 0.978 mm , selected the wire diameter value as 1mm
Step 2:- Mean coil Diameter
D = 5.868 mm, So selecting safe value as D = 10 m
Step 3:- No of active Coils

Assume deflection (δ) = 150 mm for load of 4kg i.e.39.24N, N = 40.23 turns = 41 turns Minimum safe number of turns occurring to be 41 turns. Hence, selecting **N** = 44 turns.
Step 4:- Required spring rate k = 0.261 N/mm

Step 5:- Actual spring rate k = 0.243 N/mm .Selecting the following design dimensions as d=1mm, D=10mm, N=44 turns

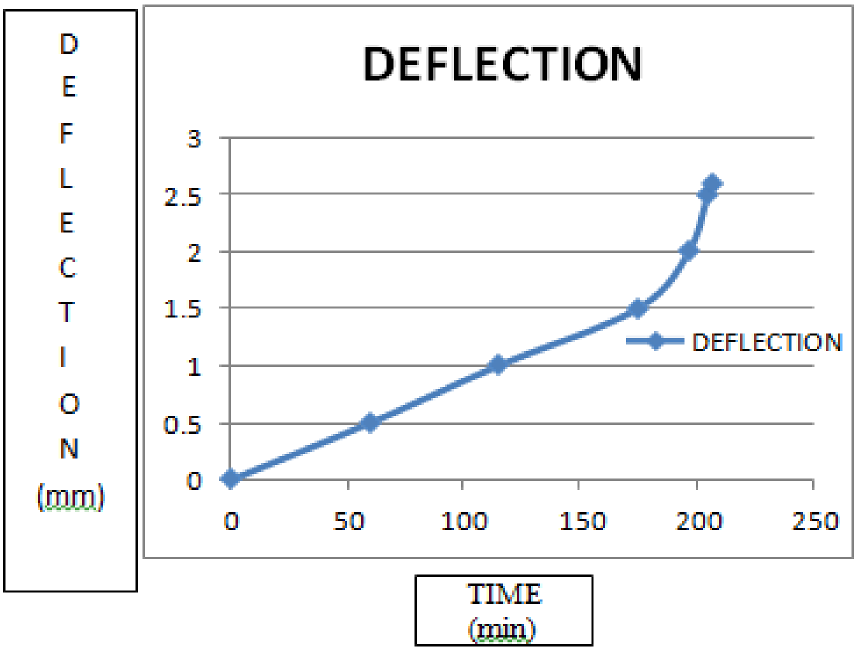
8. Experimentations

8.1. Experimentation-1

Material	**Lead**
Constant temperature	70°C
Constant load	3kg
Time (min)	Deflection (mm)
0.00	-
60	0.5
115	1.0
17	1.5
197	2.0
205	2.5
207	2.6

Table 2: Experimentation-1

Figure 3: Lead Sample, Expt.1



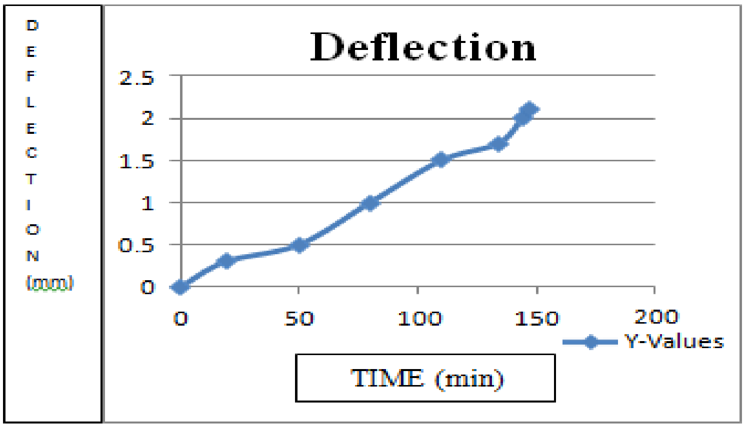
Graph 1: Deflection vs Time Graph

8.2. Experimentation-2

Material	Lead
Constant temperature	75°C
Constant load	2.5kg
Time(min)	Deflection(mm)
O	0
19	0.3
50	0.5
80	1
90	1.5
134	1.7
144	2
147	2.1

Table 2: Experimentation-2

Figure 4: Lead Sample, Expt.2



Graph 2: Deflection vs Time Graph

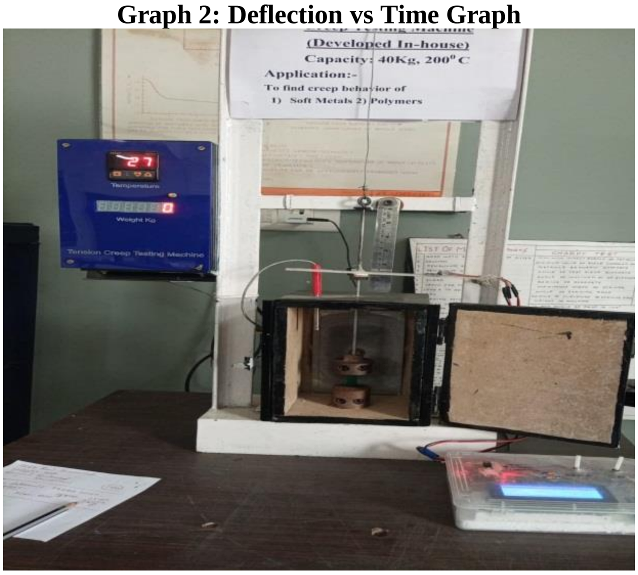


Fig No. 5 Actual Experimental Setup

9. Result and Discussion

Experimental creep test were performed on lead specimen with thickness of 1.5 mm and gauge lengthof 30 mm. In each experiment a constant temperature and load is maintained and creep behaviour is studied with respect to time. Deflectionof Lead material at constant Load and Temperature

The purpose of this project was to design and fabricate a creep test apparatus which can be used inlaboratory to demonstrate creep behaviour of engineering material without using expensive creeptesting machine. Turnbuckle of stainless steelhaving S_{ut} = 465 MPa and S_{yt} = 270 MPa, M8designated was selected according to design calculation and a tensile spring SAE6145- oil quenched drawn 425^{o}c having S_{ut} =1570N/mm^2 andshear modulus of 84x10^3 N/mm^2 were selected according to design calculations

10. Future Scope of Action

Analysis work using different materials can be carried out by using the machine. By adding more electronic component like extensometer and data acquisition system, etc., the machine can be made fully automatic and more accurate analysis can be done.

11. References

1. Kenneth Kanayo Alaneme, Bethel Jeremiah Bamike, Godwin Omlenyi, “Design and Performance Evaluation of a Sustained Load Dual Grip Creep Testing Machine”, Journal of Minerals and Materials Characterization and Engineering, Vol. 2, Issue 2, Page 531-538, 2014.
2. Muhammad Zubair Khan , Hassan Saleem, AdilMahi1 , Aleemullah, Fazal Ahmed Khalid ,Syed Asad Ali Naqvi, Tak-Hyoung Lim, Rak- Hyun Song, “Design and Fabrication of High Temperature Creep Testing Machine’’, American Journal of Materials Engineering and Technology, Vol. 3, Issue 3, Page 51-57,2015.
3. J. L. Chukwuneke1, P. C. Okolie1 , D. C. Ugwuegbu2 and J. E. Sinebe3, “Design Analysis and Fabrication of a Tensile Creep Testing Machine”, British journal of applied sciences and technology,Vol.14, Issue3,Page 1-13,2016.
4. Salah K. Jawad, Investigation of the Dimensions “Design Components for the Rectangular Indirect Resistance Electrical Furnaces”, American Journal of Engineering and Applied Sciences, Vol. 3 Issue2, Page 350-354, 2010.

5. M Scibetta , A. Pellettieri, P. Wouters, A. Leenaerts, G. Verpoucke, “Design and Fabrication of a Dead Weight Equipment to Perform Creep Measurements on Highly Irradiated Beryllium Specimens”, in Proc. HOTLAB Plenary Meeting (Halden, Norway, Sept.2004) pp.-142
6. Jan Kolarika,, Alessandro Pegorettib, “Non-linear tensile creep of polypropylene: Time-strain superposition and creep predictions Engineering and Industrial Technologies” ,Polymer, Vol. 47 Pages 346–356, 2006
7. Jonathon Tanks, Katherine Rader, Stephen Sharp, Takenobu Sakai, “Accelerated creep and creep-rupture testing of transverse unidirectional carbon/epoxy lamina based on the stepped isostress method”, Composite structures Charlottesville, Vol.159, Pages 455-465, 2017.
8. Rongguo Zhao, Chaozhong Chena, QifuLia, Xiyan Luoa , “Accelerated characterization for long-term creep behavior of polymer” in Proc. International Conference on Experimental Mechanics · (china,Nov.2008)pp.-73751D-1-73751D-6
9. McDanels, D. L., “Analysis of stress-strain, fracture and ductility behaviour of aluminium matrix composites containing discontinuous SiC reinforcement”. Metall. Trans. A, Vol.16, Pages1105-1115,1985
10. B. Ralph, H.C. Yuen and W.B. Lee, “The processing of metal matrix composites — an overview”, Journal of Materials Processing Technology, Vol. 63, Issue 1-3, Pages 339-353, 1997
11. S.V.S. Narayana Murty, B. Nageswara Rao, B.P. Kashyap, “On the hot working characteristics of 6061Al–SiC and 6061–Al_2O_3 particulate reinforced metal matrix composites, Composites science and technology Vol.63, Pages 119-135,2003
12. Barbara Previtali, Dante Pocci , Cataldo Taccardo,” Application of traditional investment casting process to aluminium matrix composites, Composites: Part A, Vol. 39,Issue 1-2, Pages1606- 1617,2008

