Design and Fabrication of Creep Testing Machine

Objective :

Designed and developed a custom creep testing setup to analyze time-dependent deformation in materials. Included casting and testing of aluminum composite samples, with service life prediction through extrapolation of lab-based creep data to real-world conditions.

Abstract :

The work intends to provide single specimen creep testing machine for laboratory use. This will enhance selection of appropriate materials for national building/advancement. The method employed involves selection of material, design of components of machine, production of components and assembling of the components. The machine comprises of a lever arm, supported with pivot pin and rest pin on the columns.

The project entails designing and building a device to conduct creep tests on different materials that are Utilized in high-temperature applications. It is possible to apply a maximum load of 2kN to the specimen and conduct tests at a maximum temperature of 400°C. Lever loading mechanism is used by the machine to apply load. Every component was created, and a stress analysis was carried out. After being manufactured individually, the components were put together. In accordance with ASTM standard E-139-06, the machine was able to successfully complete tensile creep tests for several materials at varied temperatures.

A thorough explanation of the fabrication process is provided, emphasizing important elements including material selection, machining methods, and assembly processes. Through experimental validation, the machine's performance is assessed, showcasing its capacity to apply controlled loads and uphold stable temperature conditions within the intended range.
Furthermore, real-time monitoring of creep deformation is made possible by the machine's data collecting system, which makes it easier to accurately characterize the behavior of materials under creep conditions.

Introduction :

Creep is a time dependent slow deformation of materials under constant stress. This phenomenon usually occurs at higher stress (less than yield strength) and temperature values and rate of deformation of material is dependent on stress value, material properties, time and the temperature.

Engineering components in power plants, oil refineries and chemical industries normally operate at temperature around 500oC. The operating temperatures of nuclear power plants and space rockets are even higher (around 1000oC), which necessitates materials with high creep resistance. Creep in system components may have catastrophic consequences, therefore, by using testing methods, we are capable of determining the condition and development of creep at any early and non-critical stage.

In literature it is revealed that the compressive creep test is relatively simple and has been frequently used to characterize the creep behavior of materials at high temperatures. The tensile creep test, on the other hand, has been used to a more limited extent.
In these studies, where the creep tests have been conducted, the costs of test fixtures and specimen preparation were one of the limiting factors. This paper will describe design, stress analysis, material selection and fabrication of creep testing machine which is able to perform tensile creep tests at various loads and temperatures upto 700°C.

Single specimen creep testing machine is use to predict the strength and dimensional changes of materials which occur as a result of constant applied load and temperature over a period of time.
Creep is defined as-time dependent deformation of material under constant load and temperature.
In design of a product, allowances for creep are made based on the reliable experimental data in estimating the service life of the material. It is equally important to be able to extrapolate creep data into regions where creep data are not available.

Creep problems are prevalent and need data into regions where creep data are not available. Creep problems are prevalent and need of creep entirely, it is necessary that creep data be made available for any material through scientific research, before such material can be employed in engineering services. Creep can occur at any temperature higher than approximately half the absolute melting point in Kelvin scale.

Solder has a melting point of 183 "C (456 K), so room temperature at 25 °C (298 K) is more than half the melting point. Therefore creep is expected to occur at room temperature in solder when subject to a sufficient stress,
The objectives of this research includes: To develop a single specimen creep testing machine using locally sourced materials; To demonstrate creep as a phenomenon in metals using solder as specimen.

Literature Review :

This research paper focuses on the design and performance evaluation of the machine. The machine's design was related to the locally available parts and its cost effectiveness. The machine Consist of casing and frame, heating furnace along with grippers, load arm and manual application of load with the help of load hanger. The machine's repeatability, reproducibility, heating capacity, creep elongation with respect to time, load and temperature application were analyzed.

The study is related to the creep testing machine and Optimization of Heating Coil Design for determining creep curves of different materials at elevated temperature. Approximately 22 kg load was applied at 300°C temperature. In this machine a lever mechanism is used to measure the applied load. The applied load gives the elongation maximum to 55percent in the specimen. The components of the machine were fabricated separately. Creep test was carried out on different materials using ASTM standard E-139-06 .

This work is related to the Optimization in Design of creep machine and intended to derived creep behavior results for Aluminum Composite Samples .

It has the four common primary systems. The insulating material for the heating chamber is clay and the maximum temperature of chamber is 300 degree celcius.

The Indirect Resistance Electrical Furnaces (IREF) based on analytical and experimental analyses was carried out. The analytical analysis focused on a constant set of equations representing the internal and external flow of heat energy in the furnace, which demonstrated, relatively with the surface area of walls, heat transferring inside the furnace chamber to get a creation mathematical model including the joining between the temperature required design components (furnace walls, Thickness and electrical power supply).

The experimental analysis has divided in to tow parts; first part based on process number of practice experiments with three prototypes have manufactured in certain engineering dimensions that changed in three different volumes of furnace, which are considered, i.e., chamber volume of furnace is the design dimensions component., which showed the direct effect of the design dimensions components on the performance specifications of furnace that involve the required temperature response, temperature stability and the deviation in the setting value of temperature.

Beryllium is an important material to be used in the blanket of fusion reactors. It acts as a neutron multiplier that allows tritium production. In order to use this material effectively, some data on creep and swelling Behavior are needed. This paper describes preliminary microstructural investigations and the qualification of a creep set-up that will be used to measure creep of highly irradiated beryllium from the BR2 research reactor matrix [5]. This paper deals with the creep behavior of polypropylene materials. The creep of polypropylene materials is due to time and stress induced in the material. Different species of polypropylene materials were tested. For different stress values, the time – tensile elongation were acquired.

<u>Problem Formulation</u> :

Research Gap

The research gap was identified through various literatures. After referring the above problems in existing machine, it has been proposed to design a new machine while taking care of above problems and Also cost effectives of operation

- For testing of creep phenomenon for a material, the load acting on the specimen should be constant for the whole test duration. For this, lever arm should be kept horizontal throughout the experimentation. But in existing design lever is not maintained in horizontal position due to constant elongation in the specimen. For this automatic lever Levelling is highly recommended which increases the cost of machine.

- The second problem was related to the power ratio of lever arm. Power ratio is the ratio of load acting physically to the load acting on specimen. Initially power ratio is calculated for lever arm but due to constant tilting of lever arm the current value of power ratio changes continuously hence because of this phenomenon the load acting on the specimen changes continuously.

- As we have discussed above for the position of horizontal lever, there was no mechanism added in the apparatus to maintain the lever arm horizontal.

- For creep testing, the load acting should be in vertical direction constantly. But as the position of horizontal lever arm changes, it makes an angle with load acting in downward direction. Because of this x- coordinate and y- coordinate of acting load is formed. As the time passes, the angle between lever arm and applied load increases. Hence the x- coordinate of load goes on increasing and y coordinate goes on decreasing. Because of this, the load acting on the specimen reduces as time passes.

i Image of Creep Testing Machine

Experimental Result and Data :

To obtain experimental results from a creep testing machine with a Electric heating chamber, you would typically follow these steps:

1. Preparation and Setup Material Selection:

    - Choose the material to be tested and prepare test specimens according to standard dimensions (e.g., ASTM E139 for metals).
    - Mounting Specimens: Secure the specimens in the creep testing machine.
    - Electric Heating Chamber Configuration: Set up the gas heating chamber around the specimen, ensuring proper Heating and temperature control.

2. Conducting the Test Heating:
   Heat the specimen to the desired temperature (300 degree Celsius) using the Electric heating chamber. Ensure uniform temperature distribution.

   Load Calculation:
   Aluminium Composite – 6063 TS

Yield Strength (Syt)	110 MPa
Load Applied	34 Kg

Considering Factor of safety = Syt/4 = S`yt

For 300 degree Celsius
Factor of Safety = S`yt/2 = S``yt = Syt/8
S``yt = 110/8 = 13.75 MPa
Force = (13.75 × 0.25) × 10^2 = 343.75 N

In terms of Kgs
= 343.75/10 ~ 34 Kg
Apply a constant load of 34kg to the specimen and start the timer

Monitoring: Continuously monitor and record the temperature, applied load, and specimen deformation over time using extensometers and a data acquisition system.

Data Collection :

3. Data Collection During the test,

   the following data points are typically recorded:

   Time (t): Duration of the test is 48hrs.

   Temperature (T): Temperature of the specimen is 300˚ C.

   Applied Load (σ): Constant stress or load applied to the specimen is 34 kg.

   Strain (ε): Deformation of the specimen over time.

4. Data Analysis The experimental results are analysed to derive important creep properties.

   Here's an example of how the results might be presented and analysed:

	Before	After 48hrs
Area (L×B)	$(0.5\times0.5)cm^2$	$(0.5\times0.4)cm^2$
Length	7.8 cm	8.2 cm

Strain(ΔL) =Change in Length = (8.2-7.8)cm = 0.4cm = 4mm

% Elongation = (8.2 – 7.8) × 100 / 7.8 =5.12 %

<u>Conclusion:</u> The experimental results from a creep testing machine with a Electric heating chamber provide valuable insights into the long-term behavior of materials under high stress and temperature conditions. This information is crucial for the design and assessment of materials in high-temperature applications such as turbines, reactors, and structural components in power plants.

Conclusion :

While performing creep test on Tension Creep Testing Machine, the first step is to fix the Specimen in the furnace. The specimen needs to be fixed in between the grippers with the help of all alien key. As the two grippers fixed and movable, the movable gripper is connected to the hot pull rod along with the adjustable pointer. After fixing the specimen in the furnace, the pointer is set to zero position on the scale. This is the initial stage in which the test material is not under any kind of load. When the power supply is switched on, the temperature sensor inside the furnace will indicate the temperature on digital temperature indicator along with the load which is zero. The hot poll rod is connected to turnbuckle via wire rope.

Thus when the coupler of the turnbuckle is rotated in clockwise direction, the two ends of the coupler comes closer and thus tension is created in the wire rope. Due to this mechanism of turnbuckle, load is applied on the test material. The other end of turnbuckle is connected to load cell via spring. Load cell is a sensor which converts a load or force into electrical signals with the help of strain gauges which are basic elements of load cell. When a force is applied strain gauge gets compressed, its length gets reduced which depends on the magnitude of force applied. The amount of load applied or removed is displayed on digital indicator.

After applying load to the specimen, the desired temperature which needs to be achieved for the test is set using temperature controller. Now desired load is acting on the specimen, under the effect of desired temperature. Thus because of this two parameters, elongation in the specimen will take place. But one thing should be noted that creep is a time dependent phenomenon, hence it will take time. Because of the elongation of the specimen, the pointer which is attached to the hot pull rod will get displaced.

The amount of displacement should be noted along with the time taken for displacement. Due to this elongation tension in the wire rope is reduced, thus in order to compensate this tension, spring is connected to the turnbuckle. Earlier the spring was in tension because of the applied load but as the elongation takes place, the tension in the wire rope reduces result of which spring contracts and proper tension is maintained in the wire rope.