MECHANICS OF SOLIDS

CREEP

You should judge your progress by completing the self-assessment exercises.

On completion of this tutorial you should be able to do the following.

- Explain the phenomenon of creep.
- Explain the way creep is measured and presented.
- Explain a strain – time graph.
- Define limiting creep stress.
- Explain the various factors that affect the creep rate.
- Explain the way different materials creep.

You should be familiar with basic stress and strain theory.

INTRODUCTION

Creep is a phenomenon where some materials grow longer over a period of time, when a constant tensile stress is applied to it. The material may well fail although the tensile stress is well below the ultimate value.

TEST MACHINE

A simple laboratory test machine is illustrated below. The specimen (usually lead or polymer) is fitted into the clamps with a pin at each end. The weights (W) create the tensile force (F) through a simple lever such that $F = W\ L_2/L_1$. A dial gauge may be used to measure the extension of the specimen although an electronic instrument may also be used for recording directly into a computer.

The specimens are normally rectangular in section as they are cut from thin plate.
The tensile stress is $\sigma = F/A$. A is the cross sectional area.
The strain is $\varepsilon = x/L_o$ where x is the extension and Lo the gauge length of the specimen.

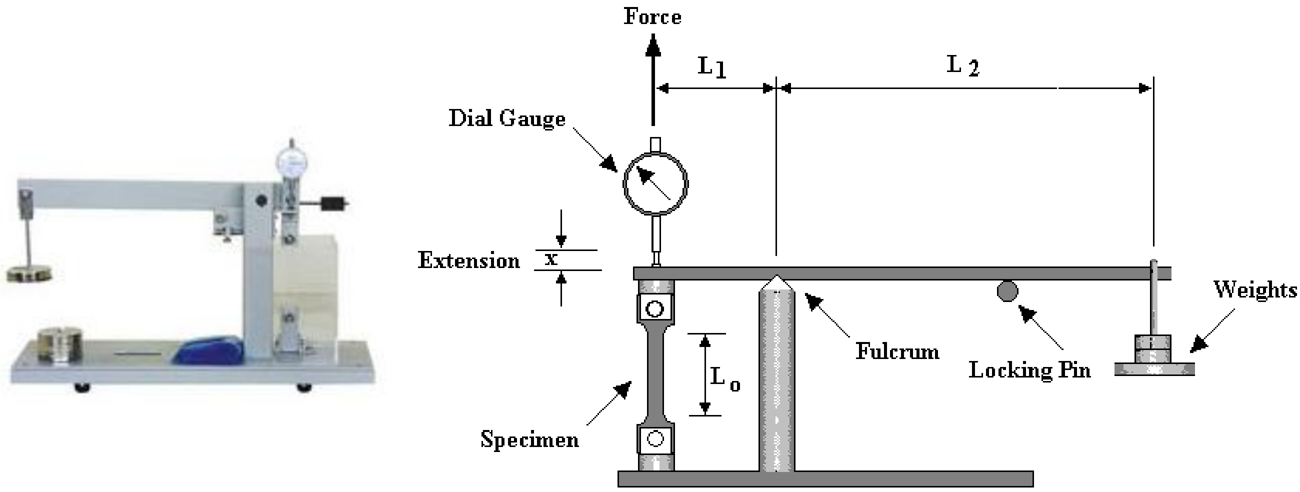


Figure 1

The lever is locked in place by a locking pin. A weight is added and the dial gauge is adjusted to zero. The locking pin is removed and a stop watch started at the same moment. Recordings are taken of extension and time. These are plotted to produce an extension time graph. A better machine would use electronic instruments and plot the graph automatically.

TYPICAL RESULTS

A typical result for a lead specimen is shown below.

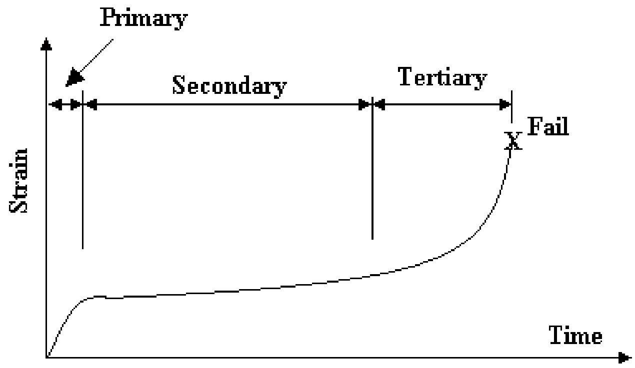


Figure 2

CREEP CHARACTERISTICS

Creep usually occurs in three stages called ***primary***, ***secondary*** and ***tertiary***. In the primary stage extension is fast but this stage is not always present. In the second stage the extension is at a constant rate and relatively slow. In the tertiary stage the extension quickens again and leads to failure.

The creep rate is affected by the stress. The higher the stress, the quicker the creep.

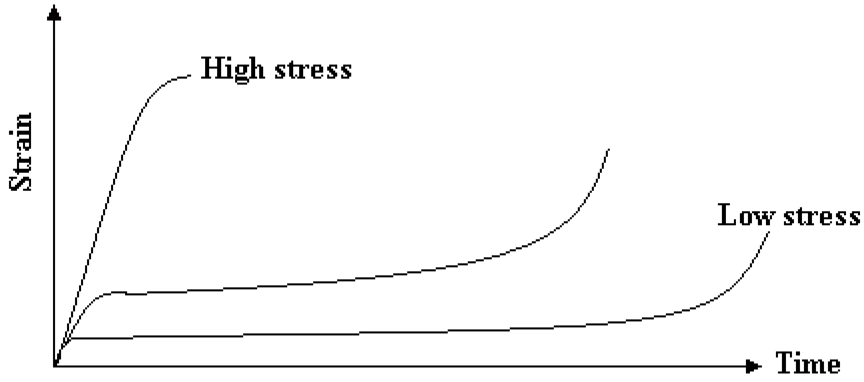


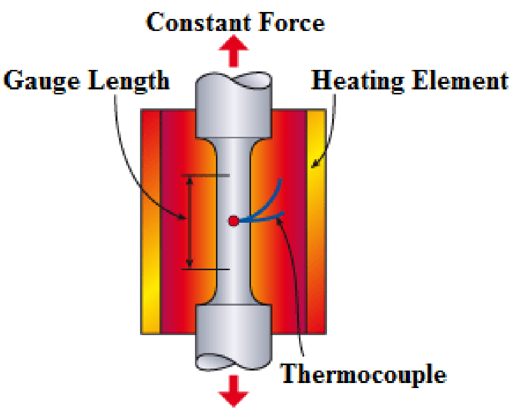
Figure 3

FACTORS AFFECTING CREEP

Most materials will not creep at all until a certain stress level is applied. This level is called the ***limiting creep stress***.

Metals like lead creep very easily at room temperatures and so do polymers. This is made much worse when the polymer is warmed.

The limiting creep stress of metals is reduced at high temperatures. This is a very important factor in the design of turbine blades. In gas turbines, the blades are subject to high temperatures and prolonged periods of centrifugal force that causes them to creep. If the tip of the blades touch the casing, a catastrophic failure will occur. Much research has been conducted into finding creep free materials for turbines.



Test machines for high temperature creep use a heated oven to surround the specimen.

Ceramic materials are much less likely to exhibit creep tendencies and there is research into composite ceramics for high temperature components. Even so, a sheet of glass in a window for a very long time will measurably thicken at the bottom due to its own weight.

Another way of indicating creep properties are to state the stress values that produce a certain % extension within a stated time. For example: not more than 0.5 % within the first 24 hours.

CREEP MECHANISM

To understand the mechanism of creep you need to have a good knowledge of metallurgy. Here is a very basic description. There are three basic mechanisms.

DISLOCATION SLIP AND CLIMB.

In crystalline materials, dislocations slip through the stressed crystal lattice. A molecule with a free bond forms the dislocation as shown. When the material is stressed the bonds can jump as shown until the molecule with the free bond is at the edge. Dislocations can move in either direction and climb when they meet obstacles such as impurities. Generally, they accumulate at the crystal boundary.

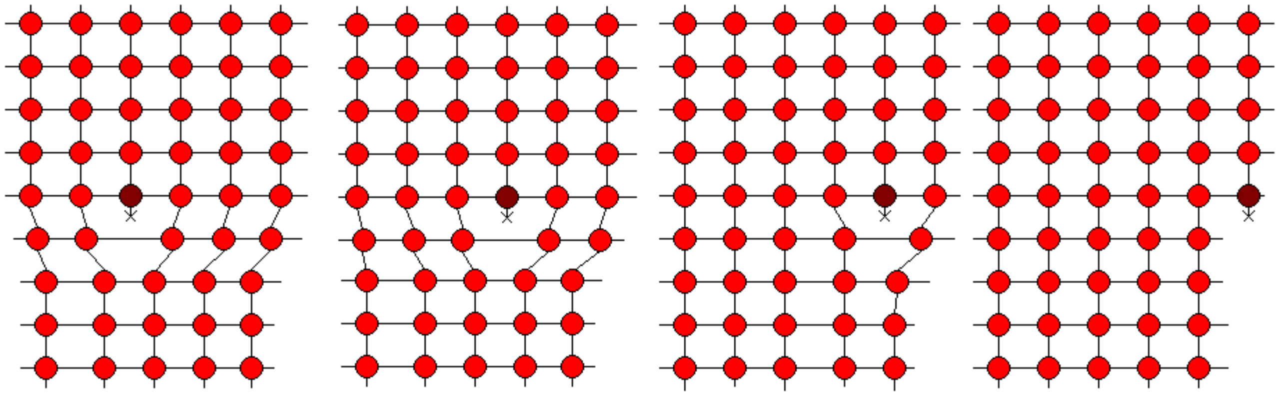


Figure 4

GRAIN BOUNDARY SLIDING.

As dislocations gather at the grain boundary, voids are created and these change into ruptures as the material starts to fail. In the tertiary stage of creep the grain slip at their boundaries.

DIFFUSION FLOW.

At low stress and high temperatures, atoms diffuse from the sides of the grains to the top and bottom thus making them longer

SELF ASSESSMENT EXERCISE

Read up as much as you can find from any source about creep. Write a short dissertation on creep. In your dissertation, you should do the following.

- ***Describe the cause of creep in materials.***
- ***Describe the effect of creep.***
- ***Describe examples of engineering structures and/or components in which creep is an important design consideration.***
- ***Explain the method used to define the life of a component.***
- ***Explain why the polymer materials used for fizzy drink bottles must not creep excessively.***