5.4 CREEP

When a material has to support a load for a very long period of time, it may continue to deform until a sudden fracture occurs or its usefulness is impaired. This permanent deformation (time dependent) is known as creep. Normally which is considered when metals and ceramics are subjected to high temperatures. But for some materials such as polymers, composites, wood and concrete, temperature is not a constraint and yet creep can occur strictly from long-term load application. In some soft metals such as zinc and lead, creep occurs over a relatively short period of time. Creep occurs in steel to a slight extent at normal temperatures but becomes very important at above 316°C temperatures.

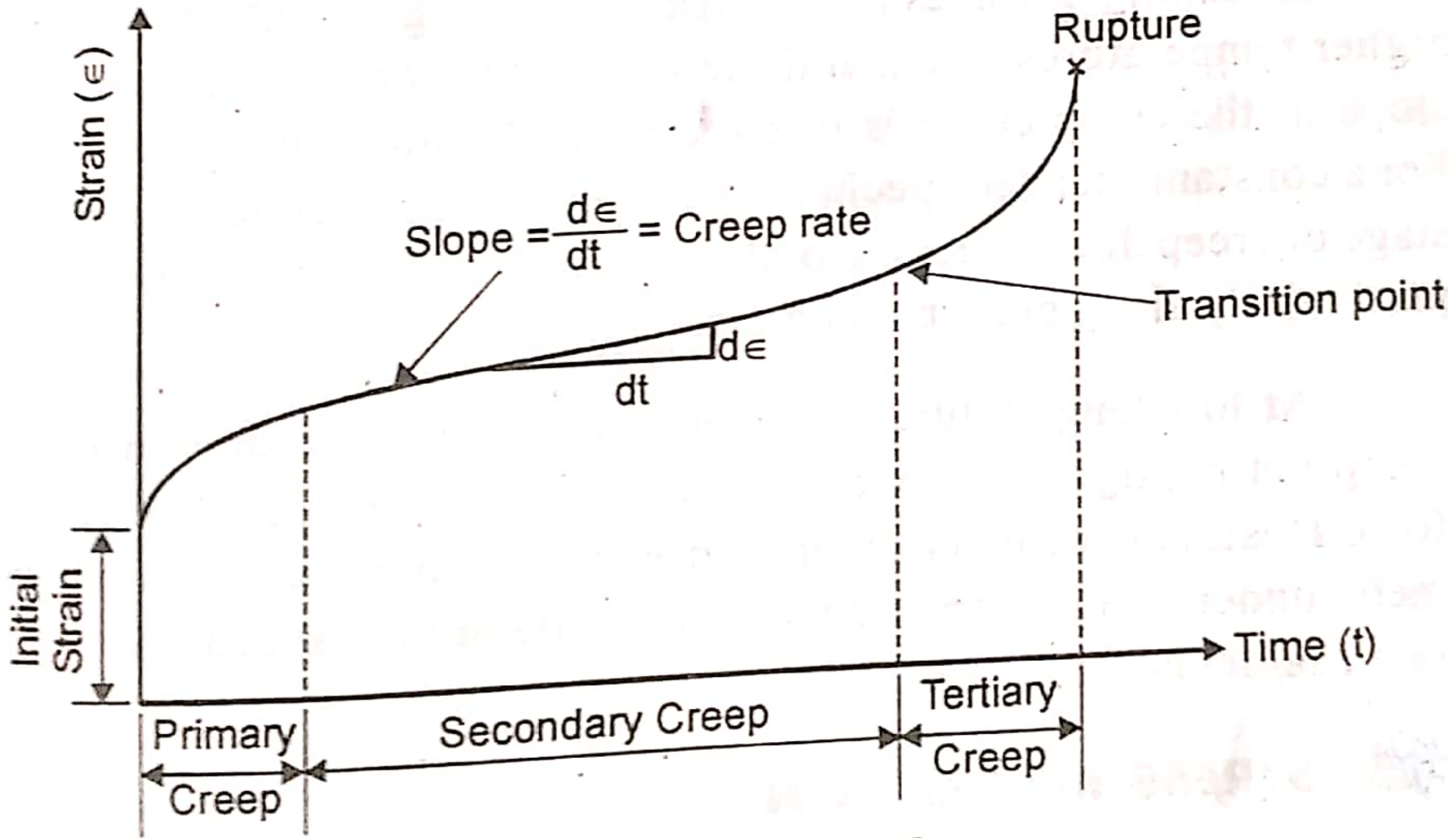

Figure 5.5 Typical Creep Curve

Creep strength represents the highest initial stress the material can withstand during a specified time without causing a given amount of creep strain. It will vary with temperature and for design, a given temperature, duration of loading and allowable creep strain must all be specified. There are several methods are exist for determining an allowable creep strength for a particular material. A typical creep curve shown in figure 5.5 with three different stages.

In figure 5.5, there is an initial strain or instantaneous strain occurs on the specimen. After this initial strain the specimen exhibits decreasing strain rate with time in primary zone. Following this, a second stage of creep occurs in which the strain variation with time is constant and also which is referred to steady-state creep. The slope of the creep curve ($d\varepsilon/dt$) is designated as creep rate. Finally, a tertiary stage creep occurs in which the creep rate rapidly increases with time upto the strain at rupture or fracture. The shape of the creep curve depends strongly on the applied load and temperature.

During primary creep the metal-strain-hardens to support the applied load and the creep rate decreases with time and as further strain hardening becomes more difficult. During secondary creep at higher temperatures, the metals continues to elongate. Hence, the slope of the creep curve is referred to as the minimum creep rate. For a constant - loaded specimen the creep rate accelerates in tertiary stage of creep due to necking of the specimen and formation of voids, particularly along grain boundaries.

At low temperatures and stresses, metals only show primary creep but negligible secondary creep, since the temperature is low for diffusional recovery creep. In general, both the stress on the metal undergoing creep and its temperature are increased, the creep rate ($d\varepsilon/dt$) is also increased.

5.5 STRESS RELAXATION

Stress relaxation is closely related to creep whereas creep involves an increase in strain under constant stress over a period of time, relaxation is the decrease in stress experienced over a period of time under constant strain. The cause of the stress relaxation is that viscous flow in the material's internal structure occurs by the mechanical untangling. Stress relaxation allows the material to attain a lower energy state, simultaneously, if there is sufficient activation energy for the process to occur. For polymeric materials relaxation is temperature - dependent and associated with an activation of energy.

The rate at which stress relaxation occurs is depends on the time, which is the property of a material and defined as the time needed for the stress to decrease to 0.37/e of the initial stress.

The rate of stress relaxation is given by,

$$\sigma = \sigma_o e^{-t/\tau} \quad \text{... 5.22}$$

where,

σ = Stress after time (t)

σ_o = Initial stress

τ = Relaxation time

Since, the relaxation time (τ) is the reciprocal of a rate, we can relate it to the temperature (T) in kelvins by,

$$\frac{1}{\tau} = C\, e^{-Q/RT} \quad \text{... 5.23}$$

where,

C = Rate constant independent of temperature

Q = Activation energy for the process

R = Molar gas constant