Creep in Materials

Dr. Sanjay S. Latthe

Self-cleaning Research Laboratory, Department of Physics,
Vivekanand College, Kolhapur (Autonomous)
(Affiliated to Shivaji University, Kolhapur)
Maharashtra, India.

Creep


(a)
(b)

Creep

- When a **weight** is hung from a piece of material and left for a number of days, the material will stretch. This is said to be **Creep**.
- Problems with creep increase when the materials are subject to **high temperature** or the materials themselves have low melting points such as lead.
- Creep can cause materials to **fail** at a stress well below there tensile strength.

- Materials are often placed in service at elevated **temperatures** and exposed to static **mechanical stresses.** Deformation under such circumstances is termed **Creep.**
- For e.g., turbine rotors in jet engines and steam generators that experience centrifugal stresses, and high-pressure steam lines).

Creep Behavior

- Allow a specimen to a constant load or stress while maintaining the temperature constant;
- Deformation or strain is measured and plotted as a function of elapsed time.

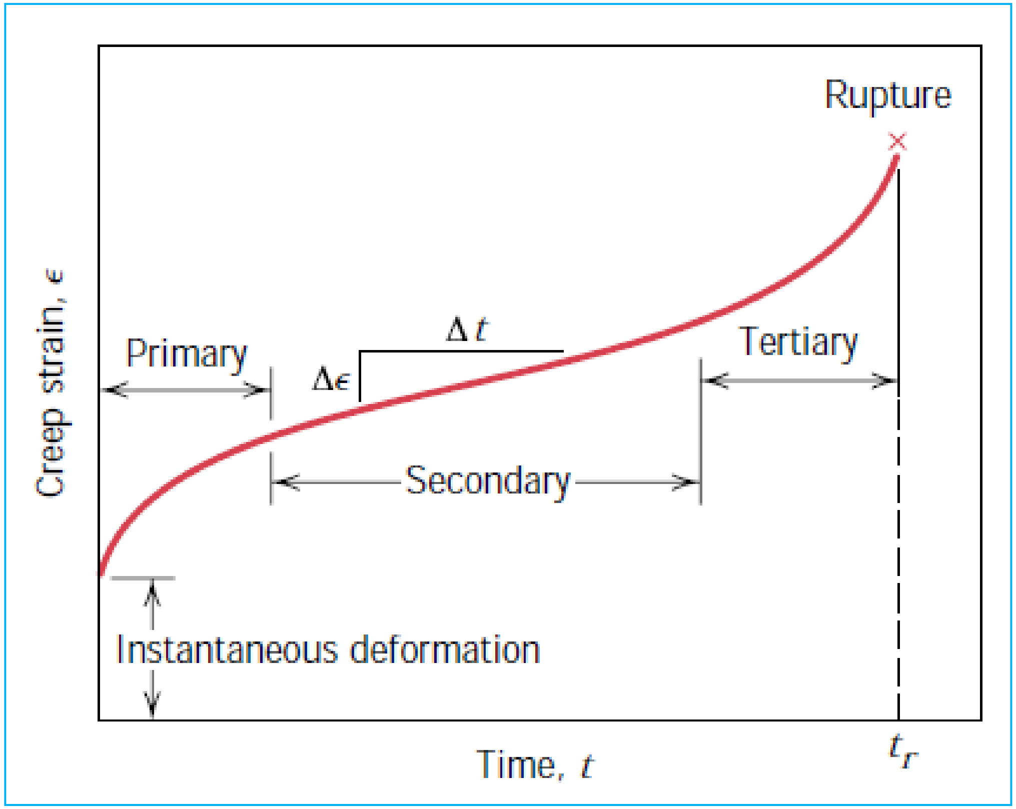


Fig: **Typical creep curve of Strain versus Time at constant stress and constant elevated temperature**.

- The minimum creep rate ΔƐ/Δt is the slope of the linear segment in the secondary region.
- Rupture lifetime t_r is the total time to rupture.

➢ Upon application of the load there is an **instantaneous deformation**, which is mostly elastic.

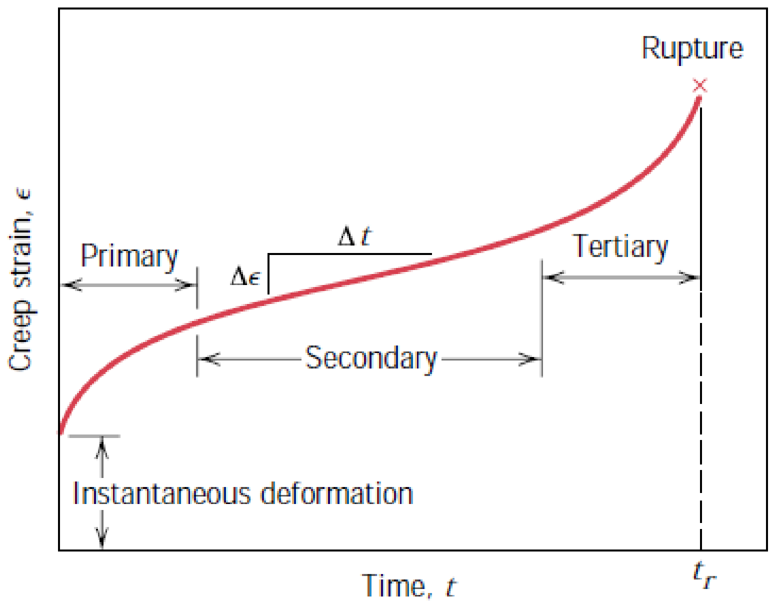
➢ Creep curve consists of three regions:

✓ ***Primary* or *transient creep*** occurs first, (continuously decreasing creep rate); that is, the slope of the curve diminishes with time. This suggests that the material is experiencing an **increase in creep resistance** or strain hardening deformation becomes more difficult as the material is strained.

✓ For ***secondary creep***, sometimes termed ***steady-state creep***, the rate is constant; that is, the plot becomes linear. This is often the stage of creep that is of the longest duration. The constancy of creep rate is explained on the basis of a balance between the competing processes of strain hardening and recovery, recovery being the process whereby a material becomes softer and retains its ability to experience deformation.

✓ Finally, for ***tertiary creep***, there is an acceleration of the rate and ultimate failure. This failure is frequently termed *rupture* and results from microstructural and/or metallurgical changes.

✓ For example, grain boundary separation, and the formation of internal cracks, cavities, and voids. Also, for tensile loads, a neck may form at some point within the deformation region. These all lead to a decrease in the effective cross-sectional area and an increase in strain rate.



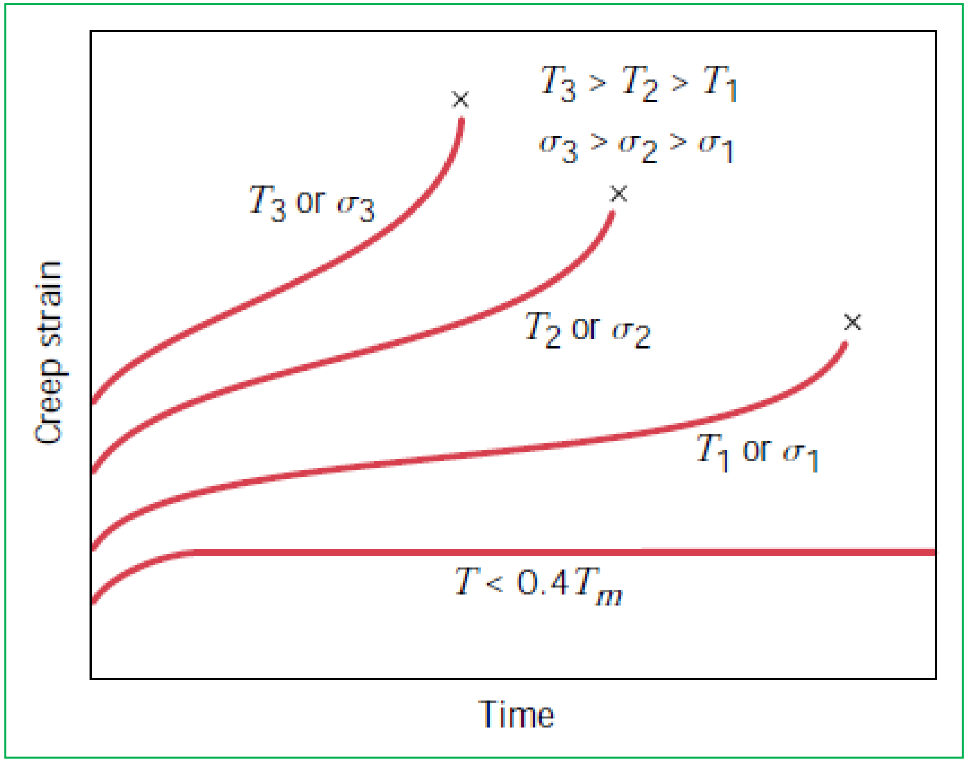
Specimen Preparation for Creep Test

- For metallic materials most creep tests are conducted in uniaxial tension using a specimen having the same geometry as for tensile tests.
- On the other hand, uniaxial compression tests are more appropriate for brittle materials; these provide a better measure of the intrinsic creep properties in as much as there is no stress amplification and crack propagation, as with tensile loads.
- Compressive test specimens are usually right cylinders or parallelepipeds having length-to-diameter ratios ranging from about 2 to 4.
- For most materials creep properties are virtually independent of loading direction.

Applications of Creep Test

- The most important parameter from a creep test is the slope of the secondary portion of the creep curve $\Delta \varepsilon / \Delta t$; this is often called the minimum or *steady-state creep rate* ε_s.
- It is the engineering design parameter that is considered for long-life applications, such as a nuclear power plant component that is scheduled to operate for several decades, and when failure or too much strain is not an option.
- For many relatively short-life creep situations (e.g., turbine blades in military aircraft and rocket motor nozzles), *time to rupture*, or the *rupture lifetime* t_r, is the dominant design consideration. Of course, for its determination, creep tests must be conducted to the point of failure; these are termed *creep rupture* tests.

Stress and Temperature Effects



Influence of stress and temperature on creep behavior

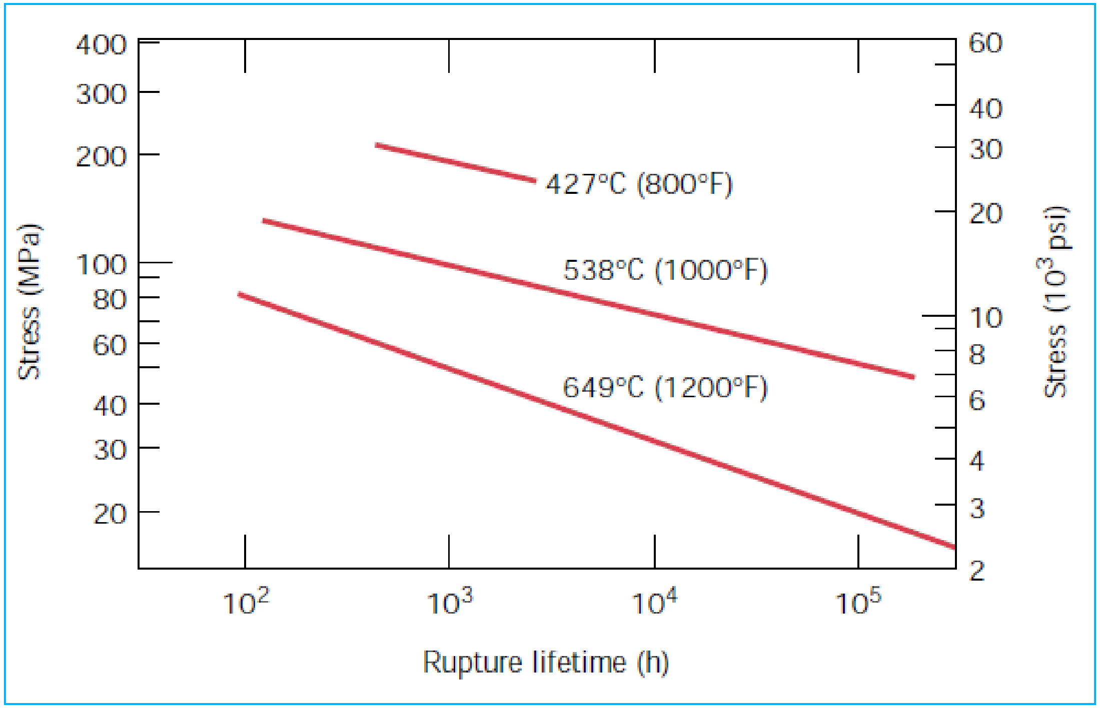
- Both temperature and the level of the applied stress influence the creep characteristics.
- At a temperature substantially below 0.4*Tm*, (Tm = absolute melting temperature) and after the initial deformation, the strain is virtually independent of time.
- With either increasing stress or temperature, the following will be noted:

(1) the instantaneous strain at the time of stress application increases;

(2) the steady-state creep rate is increased; and

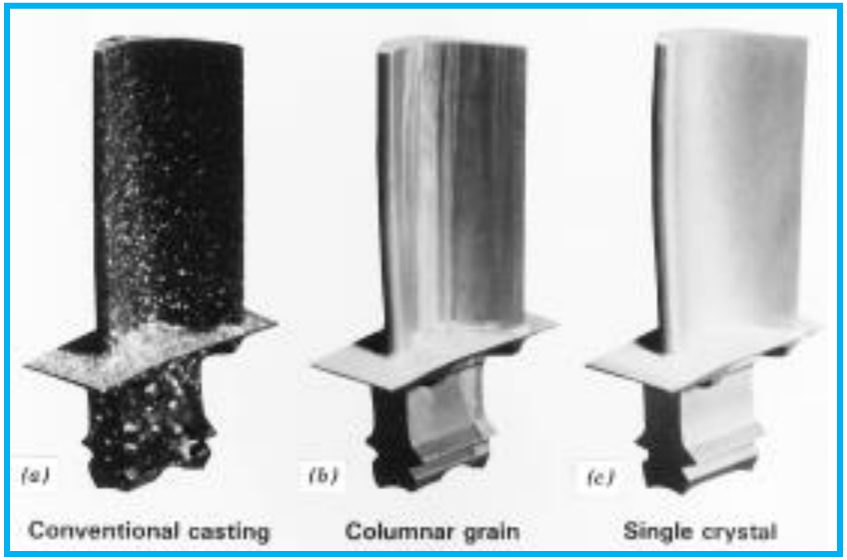
(3) the rupture lifetime is diminished.

Stress (logarithmic scale) versus Rupture lifetime (logarithmic scale) for a low carbon–nickel alloy at three temperatures.



- The results of creep rupture tests are most commonly presented as the logarithm of stress versus the logarithm of rupture lifetime.
- Plot for a nickel alloy in which a linear relationship can be seen to exist at each temperature.
- For some alloys and over relatively large stress ranges, nonlinearity in these curves is observed.
- Both temperature and stress effects on the steady-state creep rate are represented graphically as logarithm of stress versus logarithm of ε_s for tests conducted at a variety of temperatures.

- There are several factors that affect the creep characteristics of metals.
- These include melting temperature, elastic modulus, and grain size.
- In general, the higher the melting temperature, the greater the elastic modulus, and the larger the grain size, the better is a material’s resistance to creep.
- Relative to grain size, smaller grains permit more grain-boundary sliding, which results in higher creep rates.
- This effect may be contrasted to the influence of grain size on the mechanical behavior at low temperatures.
- Stainless steels, the refractory metals and the superalloys are especially resilient to creep and are commonly employed in high-temperature service applications.
- The creep resistance of the cobalt and nickel superalloys is enhanced by solid-solution alloying, and also by the addition of a dispersed phase which is virtually insoluble in the matrix.
- In addition, advanced processing techniques have been utilized; one such technique is directional solidification, which produces either highly elongated grains or single-crystal components.



Figure

(a) Polycrystalline turbine blade that was produced by a conventional casting technique.

(b) High-temperature creep resistance is improved as a result of an oriented columnar grain structure produced by a sophisticated directional solidification technique.

(c) Creep resistance is further enhanced when single-crystal blades are used.