بسم الله الرحمن الرحيم

Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

14.04.2019 – Week 10

Creep test

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Outline

- Introduction.
- Creep testing.
- Creep stages.
- Effect of Temperature & stress level.
- Mechanism of Creep.
- Use of Creep Data
- Solved example.

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Introduction

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Creep

When a weight is hung from a piece of lead and left for a number of days the lead 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.

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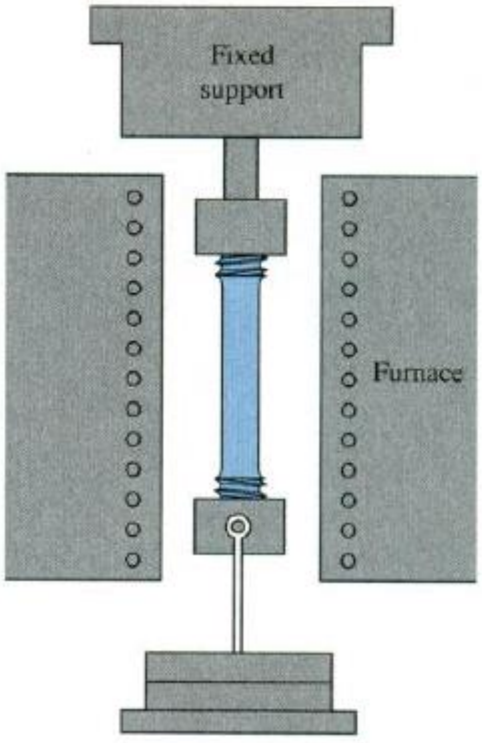
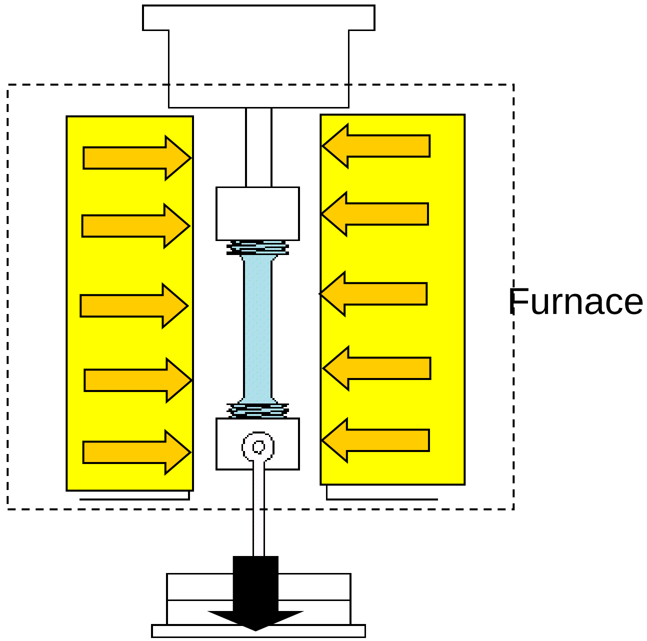
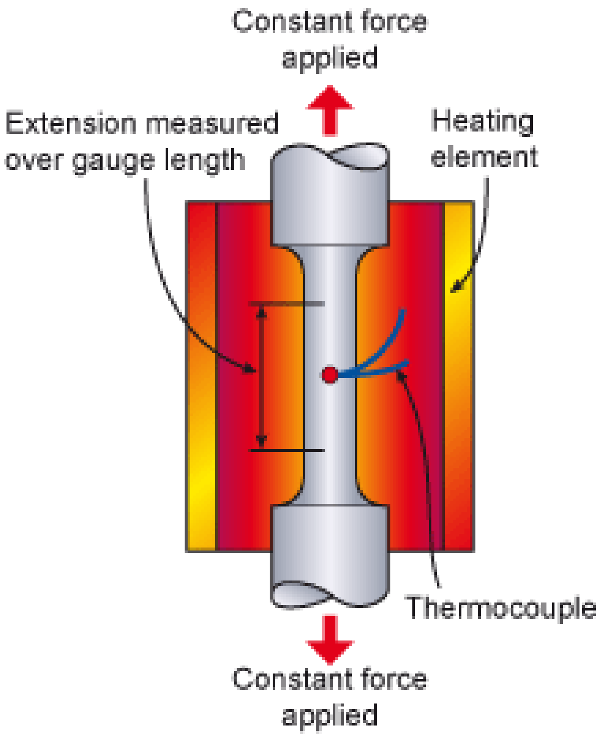
Creep Test

Time-dependent deformation due to constant load at high temperature (> 0.4 T_m)

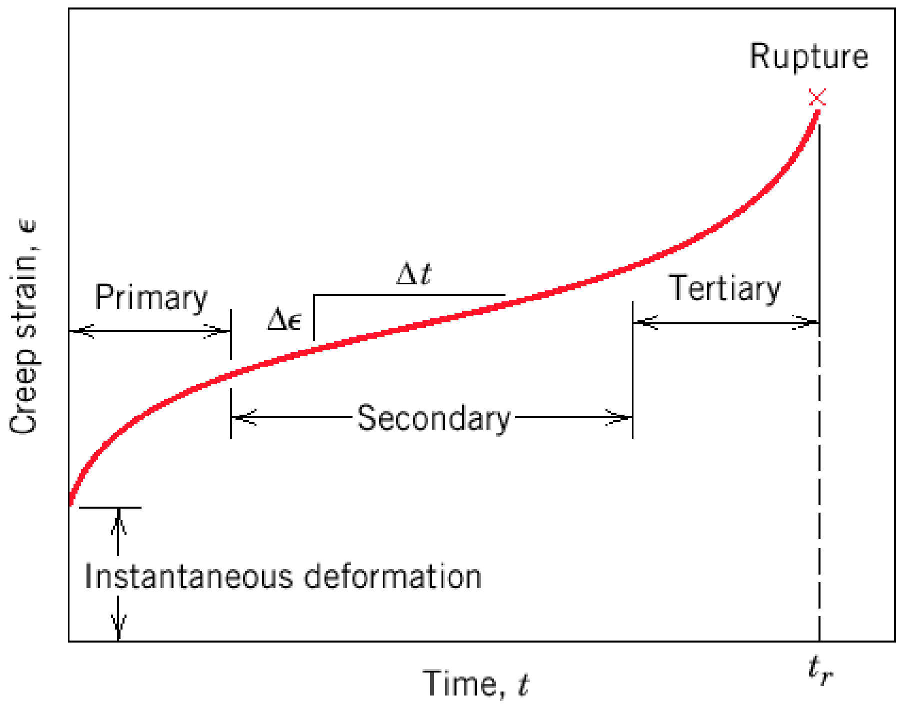
Examples: turbine blades, steam generators.





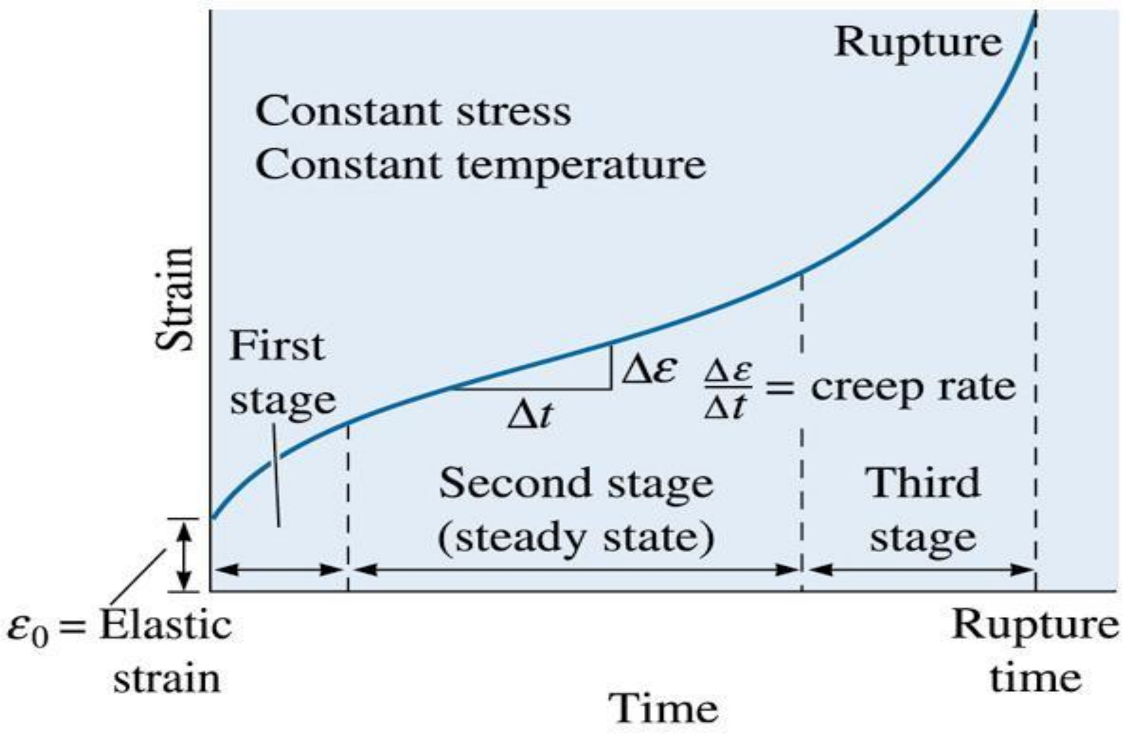


Stages of Creep



1. **Instantaneous deformation, mainly elastic.**
2. **Primary/transient creep. Slope of strain vs. time decreases with time: work-hardening**
3. **Secondary/steady-state creep. Rate of straining constant: work-hardening and recovery.**
4. **Tertiary. Rapidly accelerating strain rate up to failure: formation of internal cracks, voids, grain boundary separation, necking, etc.**

Typical Creep Curve



A typical creep curve showing the strain produced as a function of time for a constant stress and temperature

The Creep curve shown in Fig. demonstrates three stages:

Primary creep: $\varepsilon = A\, t^{1/3}$

Secondary creep: $\varepsilon = \varepsilon_o + \beta\, t$ **minimum creep rate , a dynamic equilibrium between stress and microstructure.**

The minimum creep rate β is used in computations of the useful life.

Stages of Creep

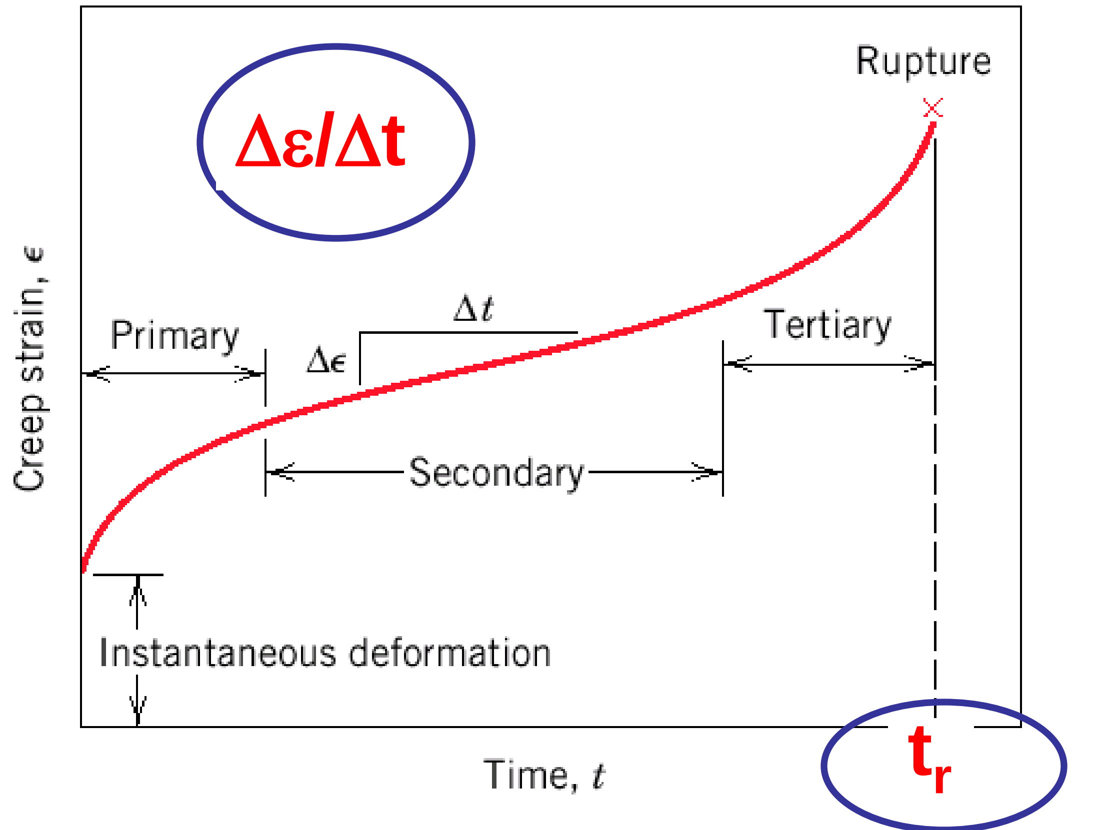
Secondary/steady-state creep:

Longest duration

Long-life applications

Time to rupture (rupture lifetime, t_r): $\dot{\varepsilon}_s = \Delta\varepsilon / \Delta t$

Important for short-life creep



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Watching the test

1

2

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

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Effect of Temperature & stress level.

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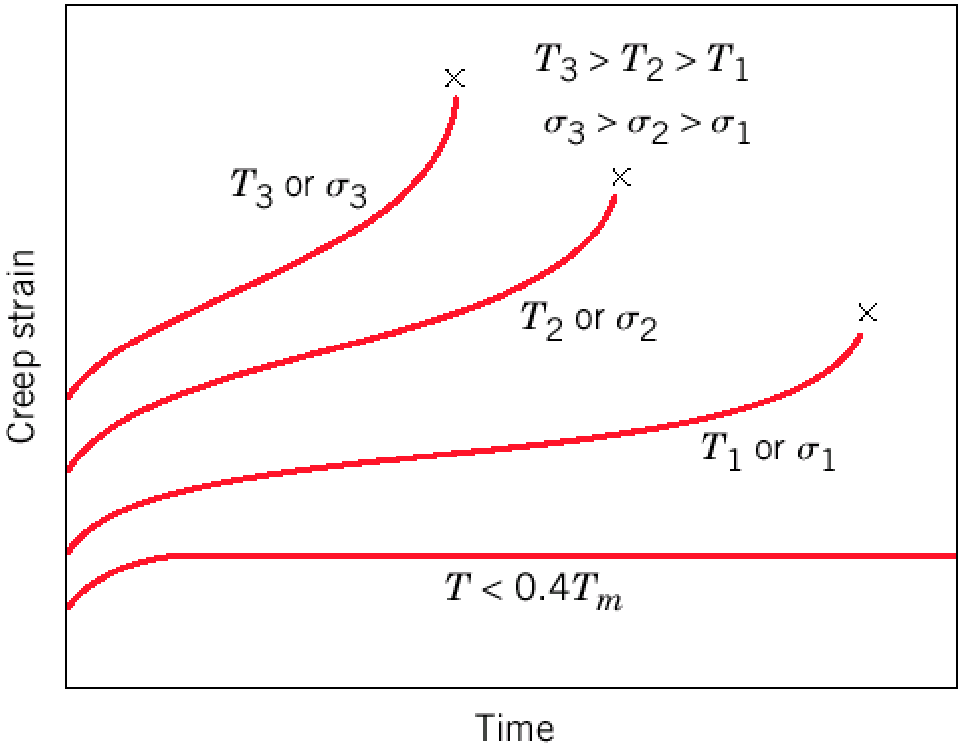
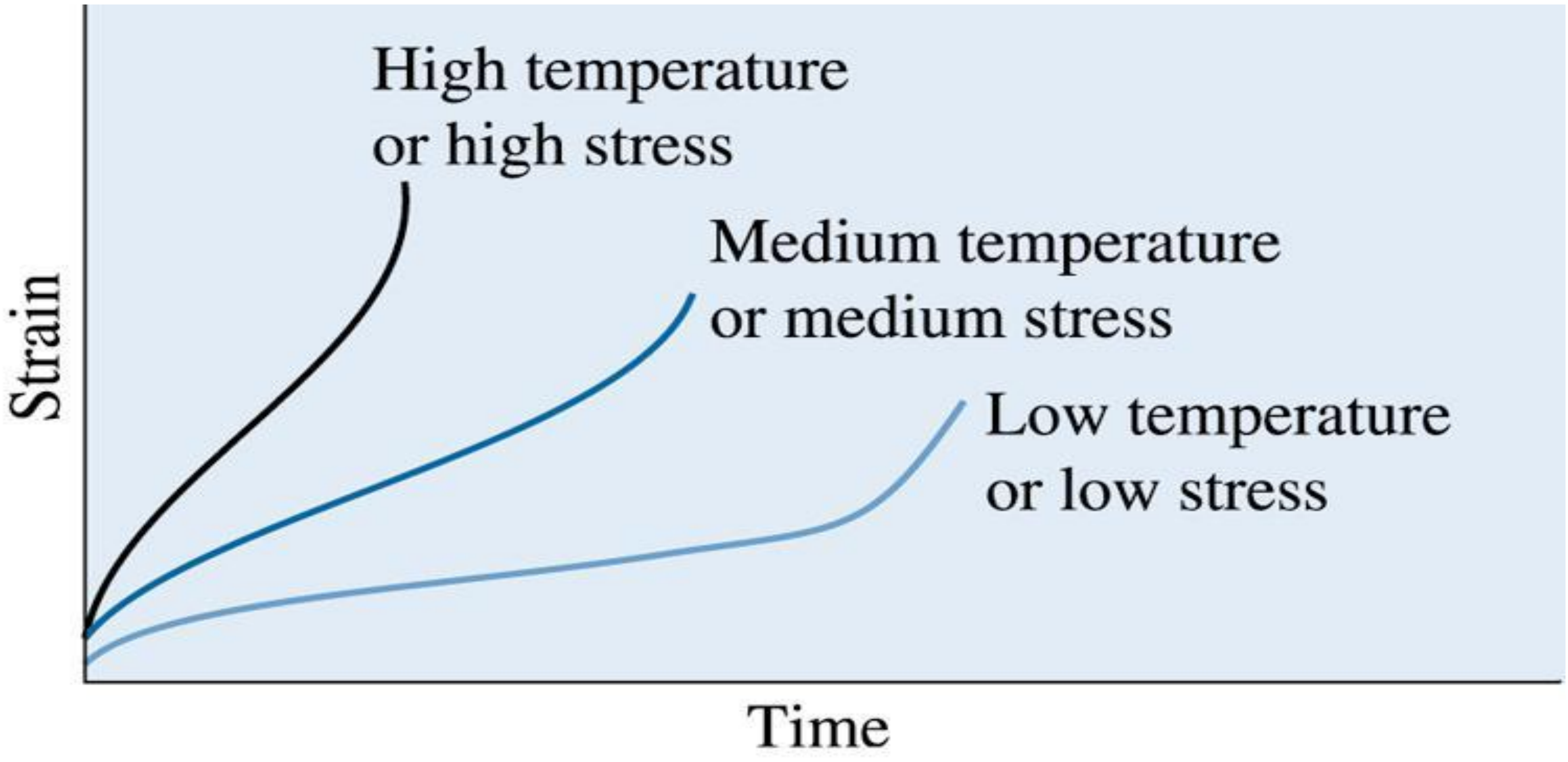
Effect of Temperature

With **increasing stress or temperature**:

- **The instantaneous strain increases**
- **The steady-state creep rate increases**
- **The time to rupture decreases**



Effect of Temperature



The effect of temperature or applied stress on the creep curve

Stages of Creep

increasing stress or temperature:

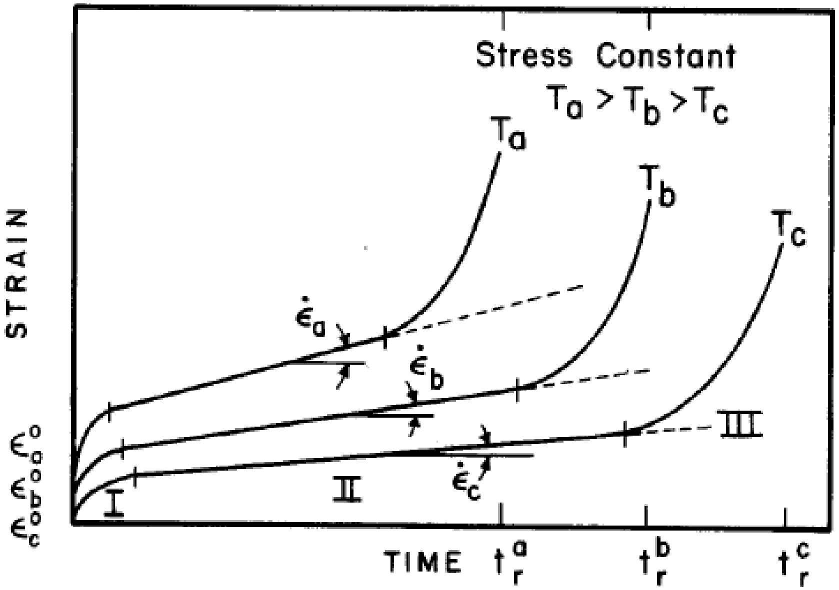


Figure 13.2 Creep strain vs. time at a constant engineering stress and different temperatures.

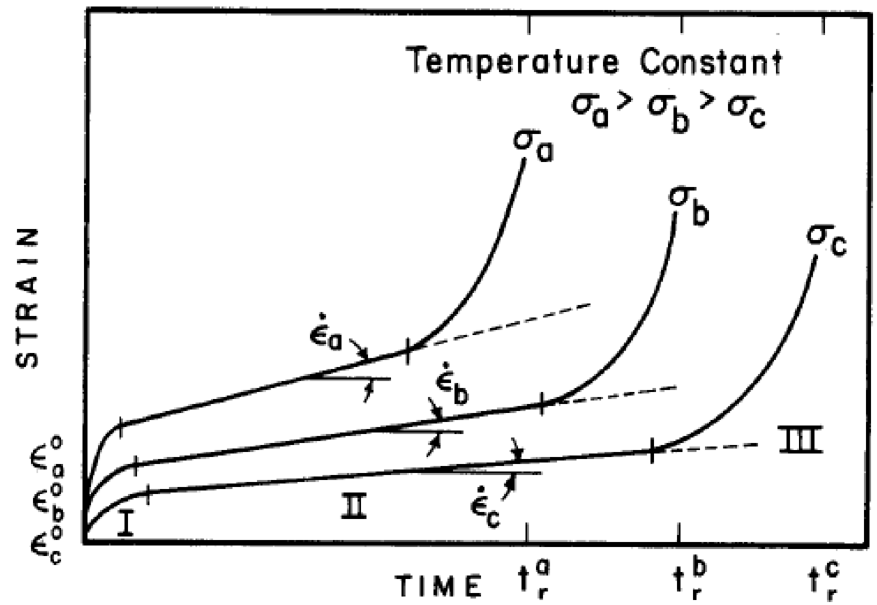


Figure 13.1 Creep strain vs. time at difference constant stress levels and temperature.

Characteristics

Creep characteristics of the metals are affected by;

Melting Temp.

Elastic Modulus

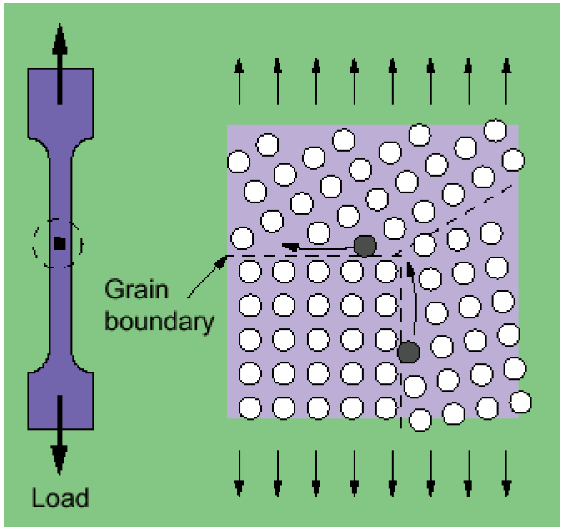
Grain Size.

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. Smaller grains permit more grain boundary sliding.

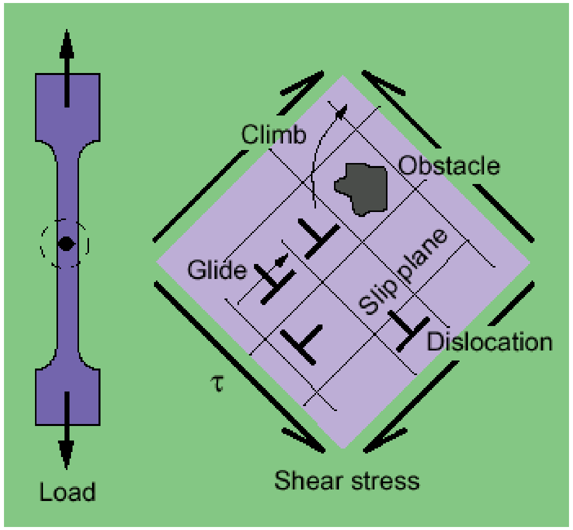
Mechanism of Creep

Different mechanisms act in different materials and under different loading and temperature conditions:

- **Stress-assisted vacancy diffusion**
- **Grain boundary diffusion**
- **Grain boundary sliding**
- **Dislocation motion**

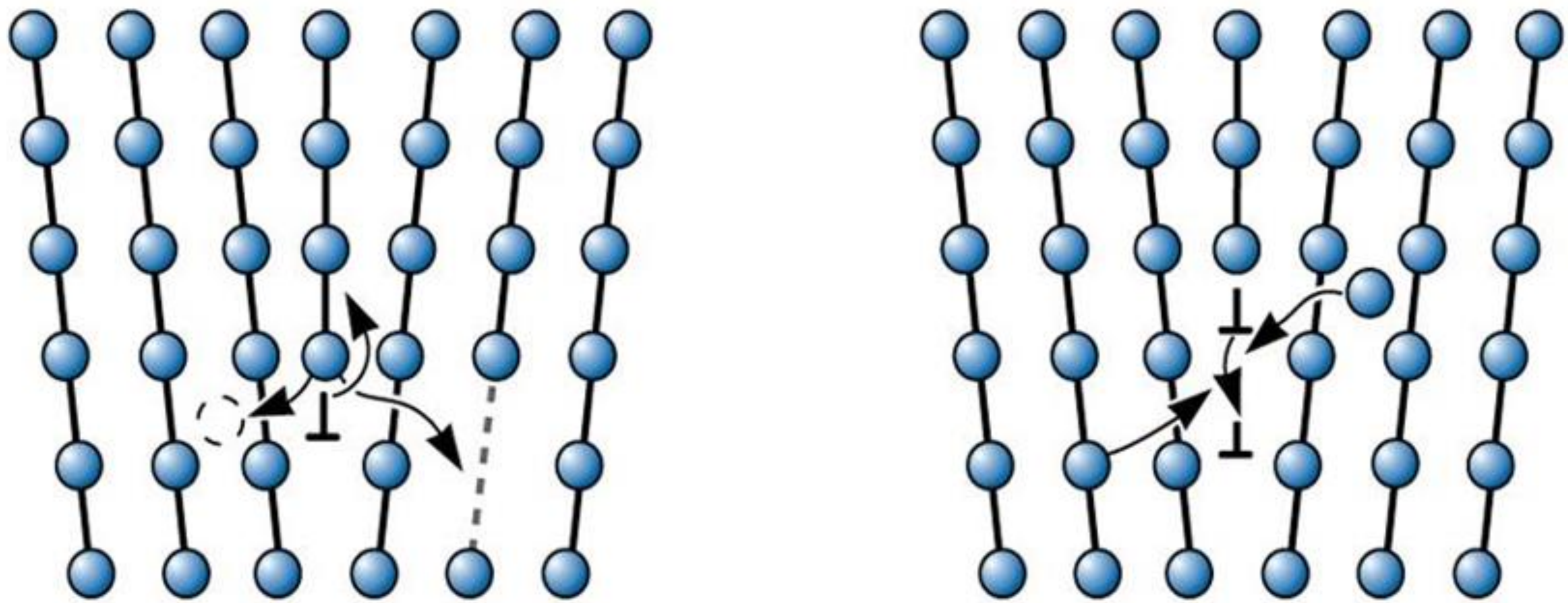


Grain boundary diffusion



Dislocation glide and climb

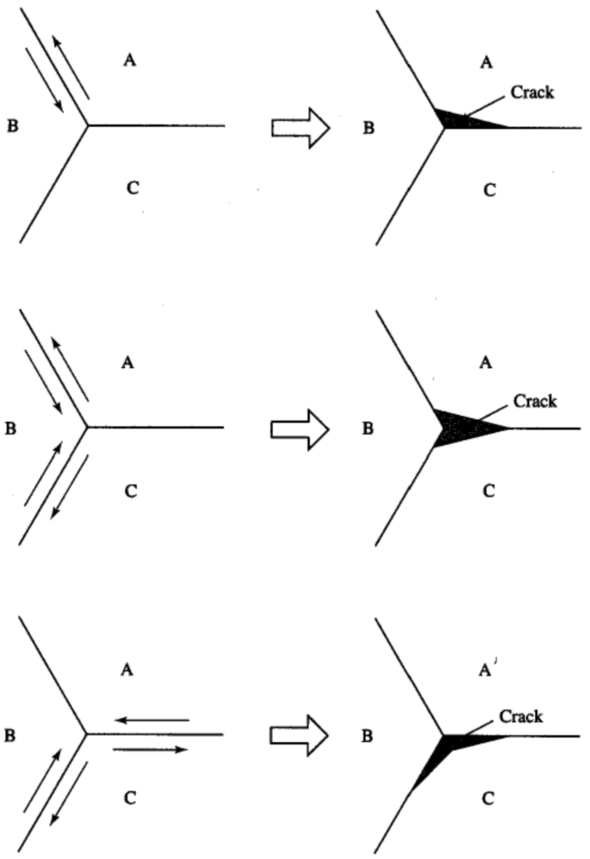
Dislocation Movement



(a) (b)

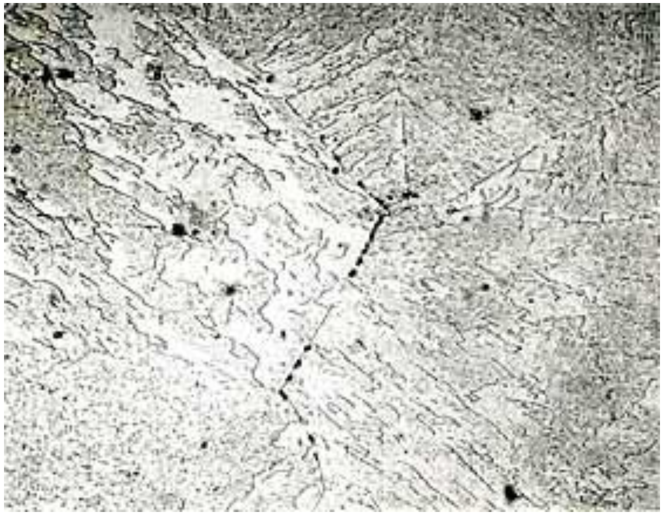
Dislocations can climb (a) when atoms leave the dislocation line to create interstitials or to fill vacancies or (b) when atoms are attached to the dislocation line by creating vacancies or eliminating interstitials

Crack formation



–7 Grain boundary sliding and the resultant cracks that form at triple points.

Cavitation & cracking under SEM



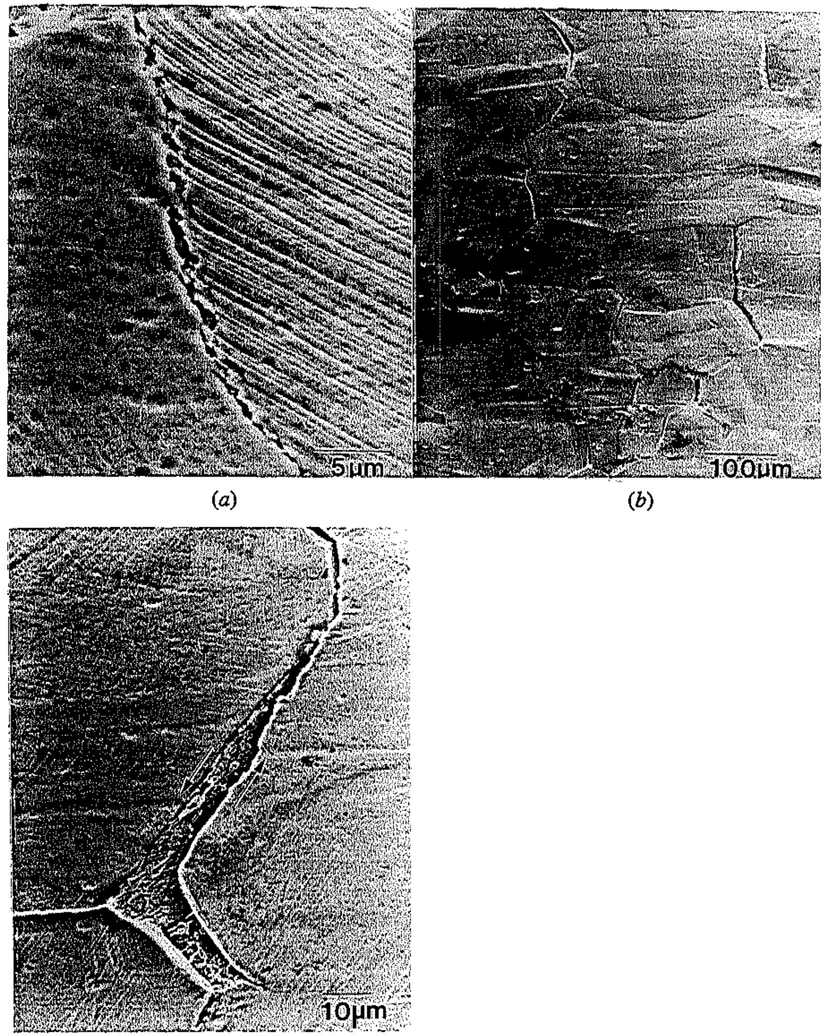
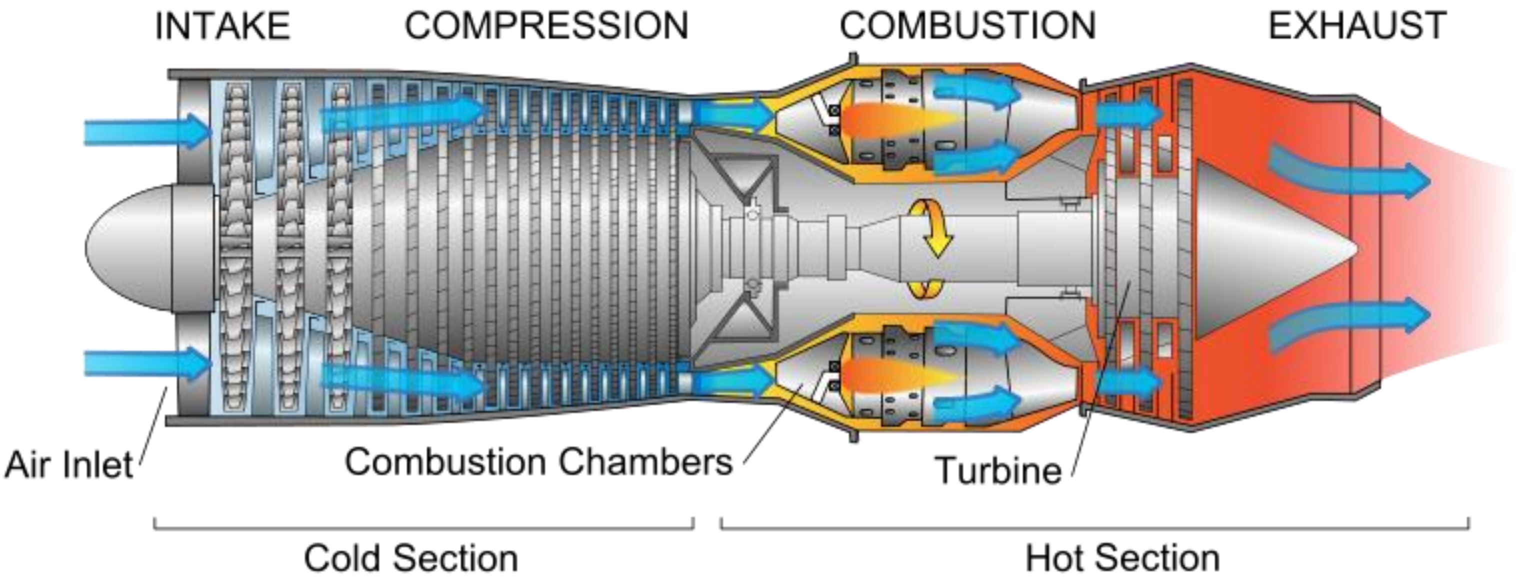
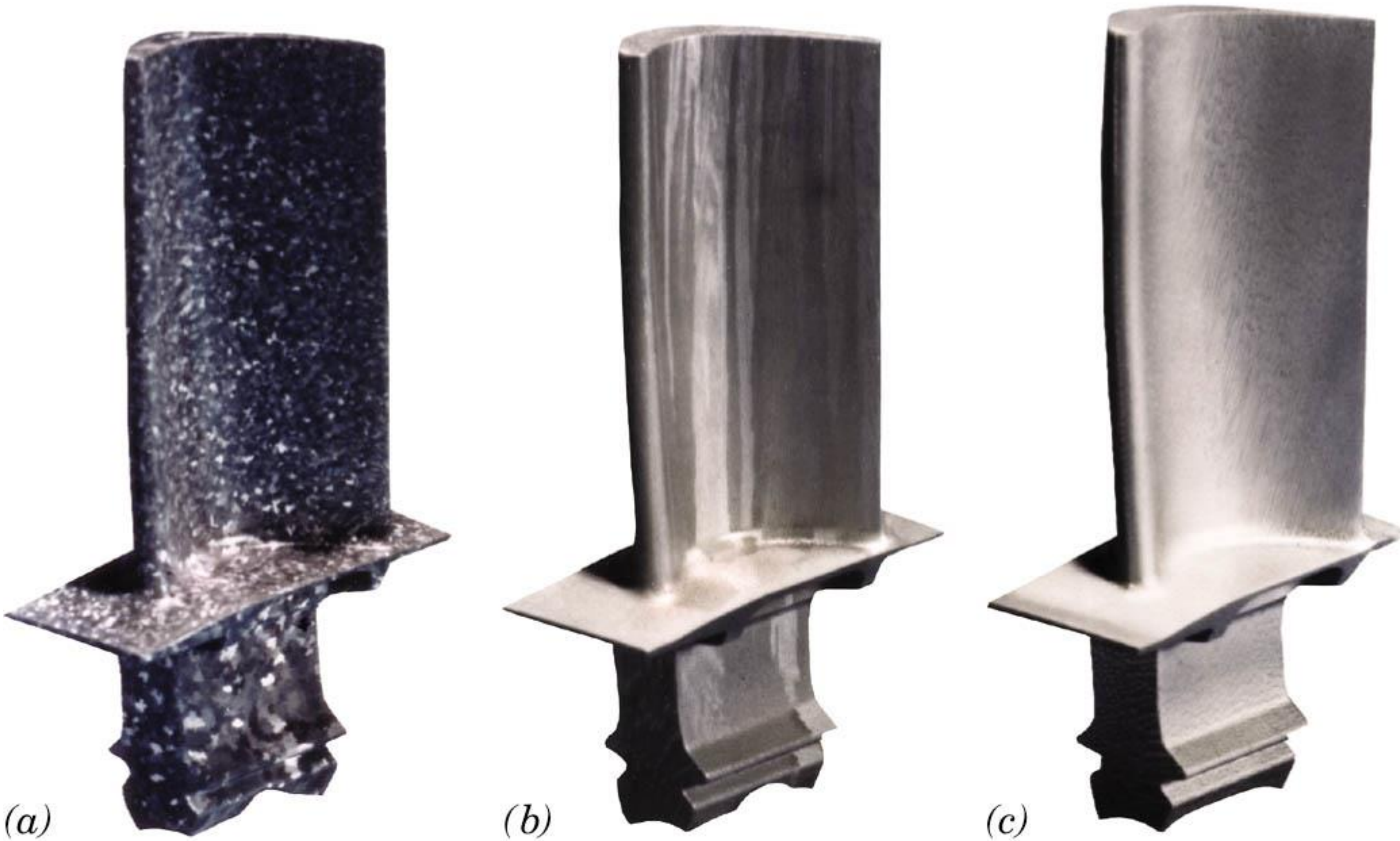


FIGURE 5.37 **Cavitation and cracking in UHP Ni-16Cr-9Fe allow after 35% elongation at 360°C in argon. Initial strain rate was 3×10^{-7} sec^{-1}. (*a*) slip-boundary induced cavitation. (*b*) intergranular cracking in UHP alloy; (*c*) triple point cracking. Note involvement of grain boundary sliding (i.e., displacement of fudiciary markings) and grain boundary microvoid coalescence on new fracture surface. (Courtesy Jason L. Hertzberg.)**

Typical Engine

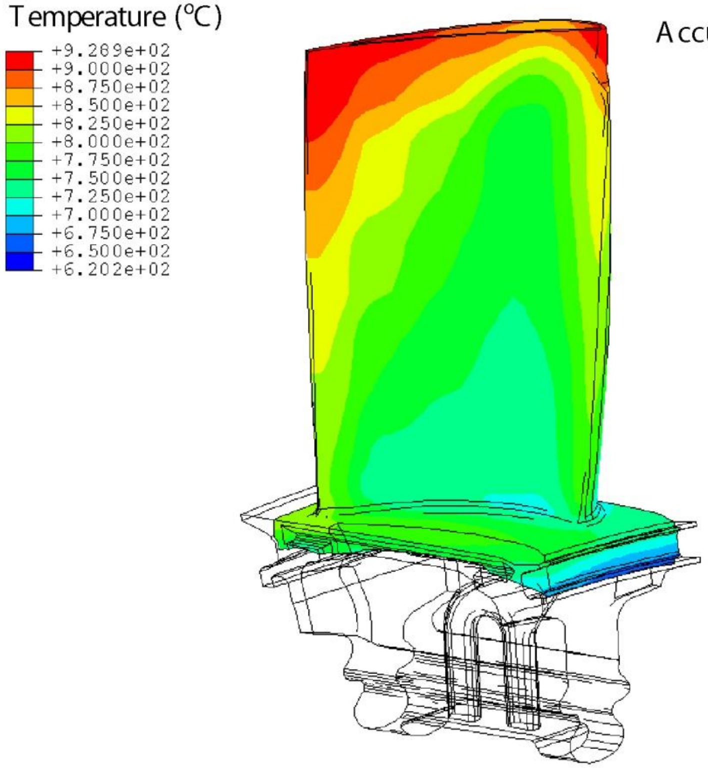


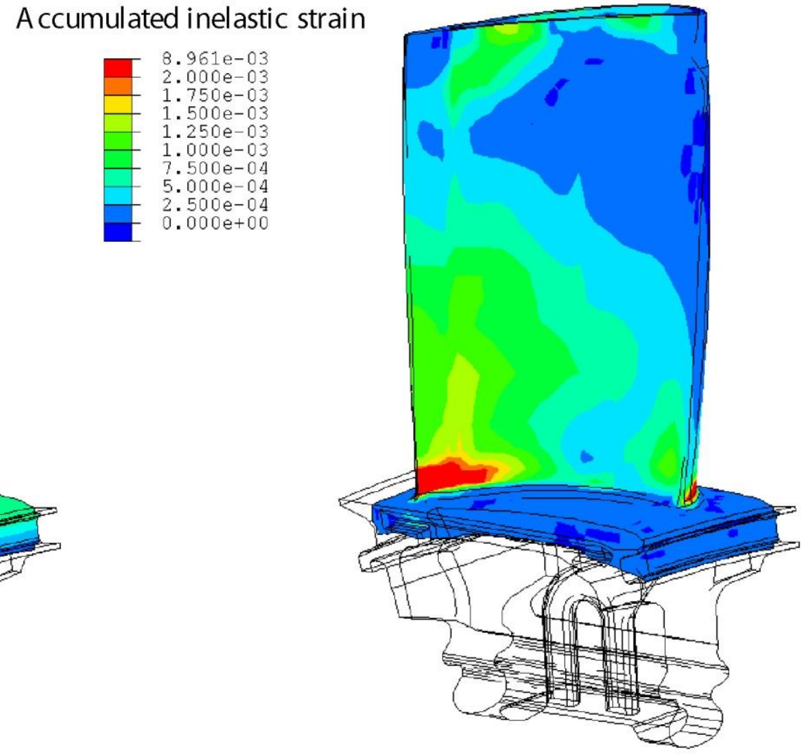
Gas Turbine Blades



Conventional casting   Columnar grain   Single crystal

Temp. and Strain





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Use of Creep Data

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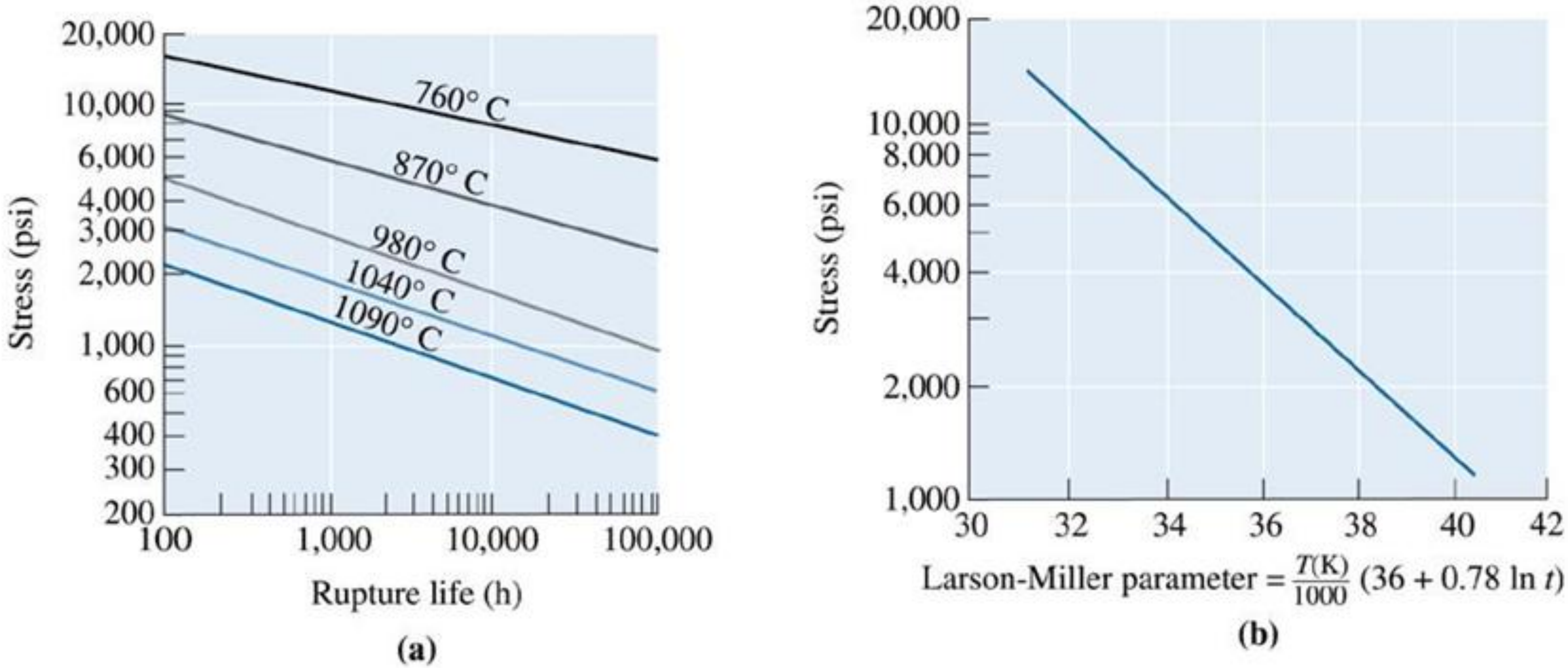
Use of Creep Data

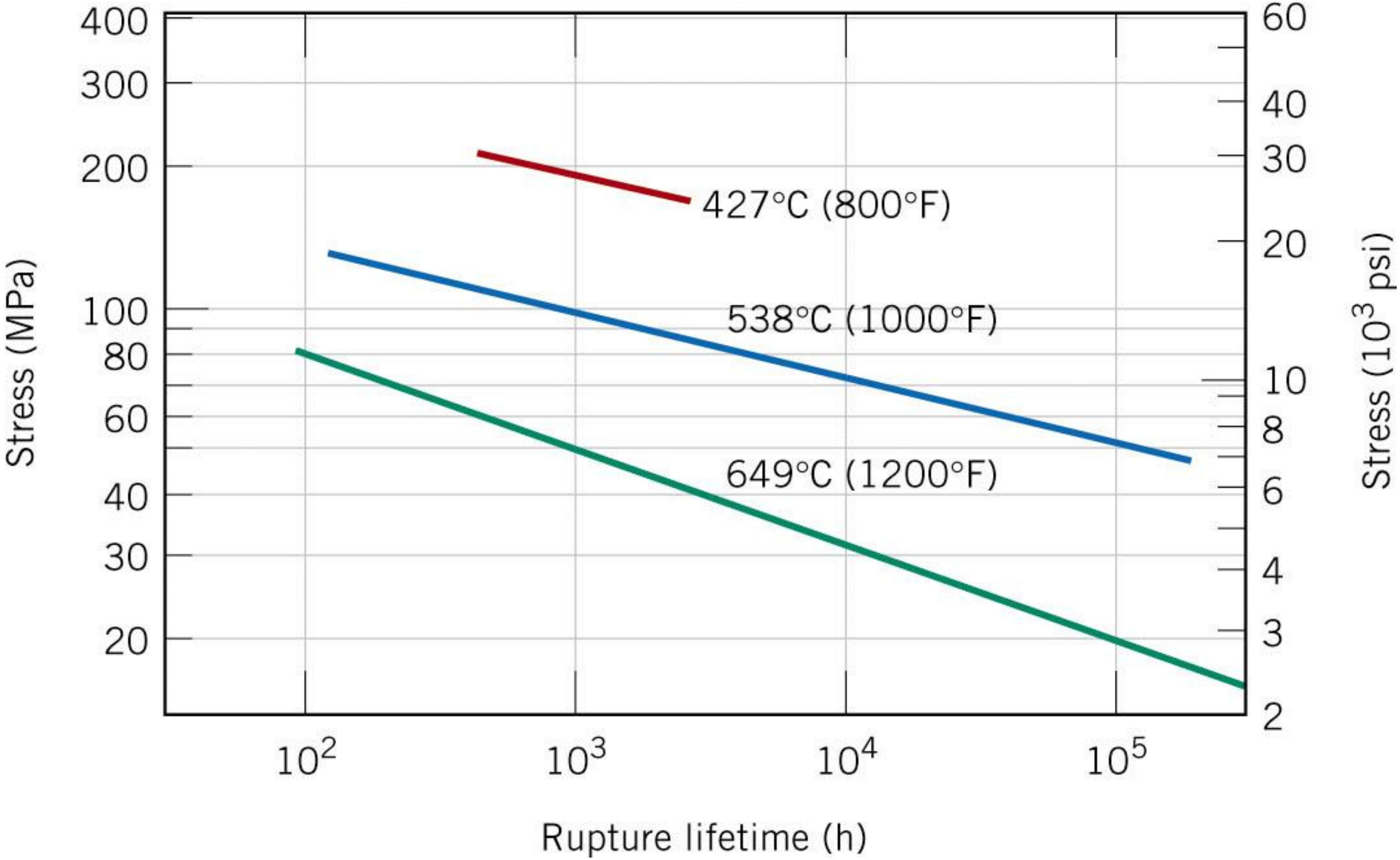
- Stress-rupture curve - A method of reporting the results of a series of creep tests by plotting the applied stress versus the rupture time.
- ***Larson-Miller parameter*** - A parameter used to relate the stress, temperature, and rupture time in creep.

Use of Creep Data

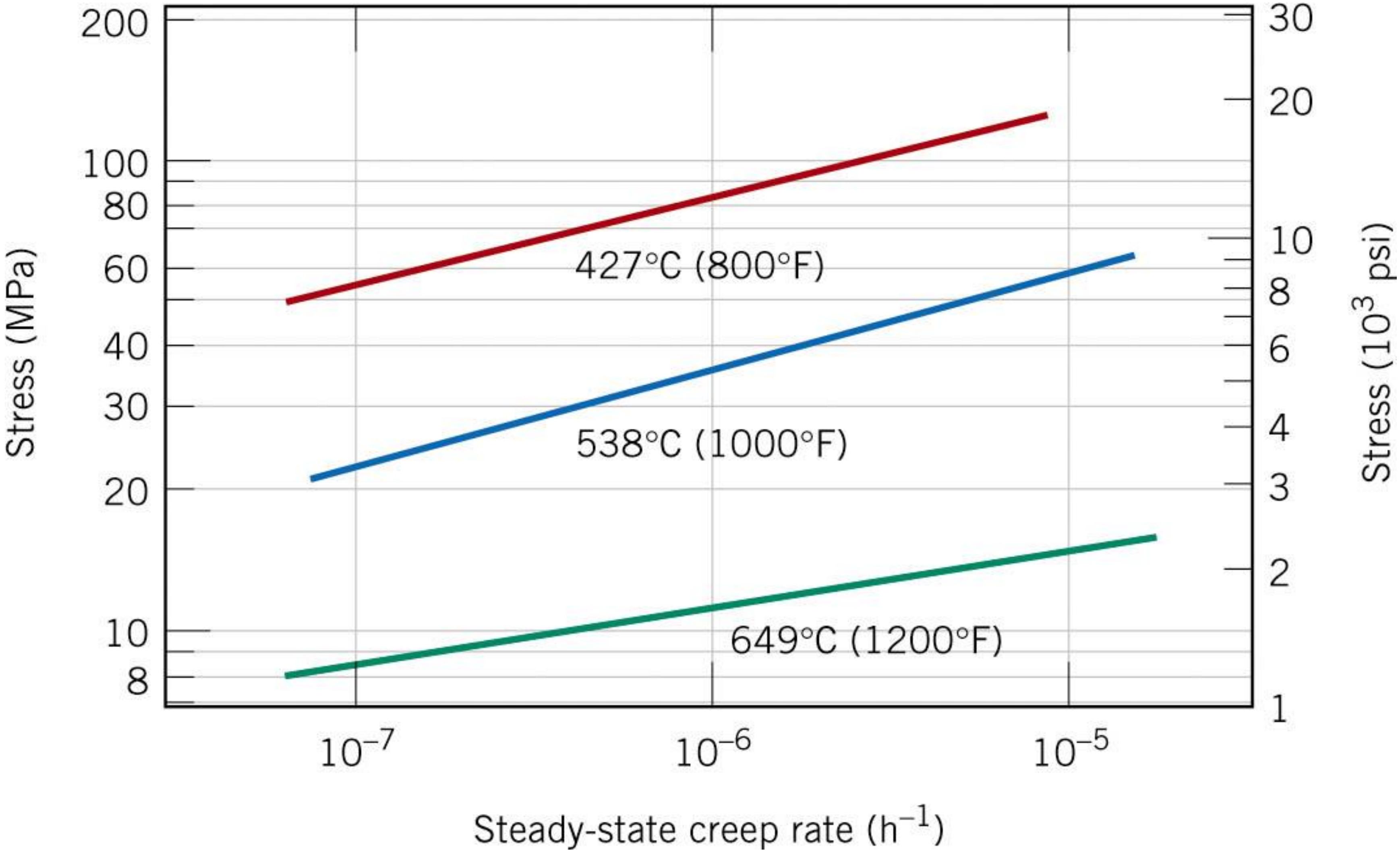


Results from a series of creep tests. (a) Stress-rupture curves for an iron-chromium-nickel alloy and (b) the Larson-Miller parameter for ductile cast iron

Use of Creep Data



Use of Creep Data



Larsen-Miller parameter

O **Larsen-Miller parameter** $P_{LM} = T\,(C + \log t_R)$

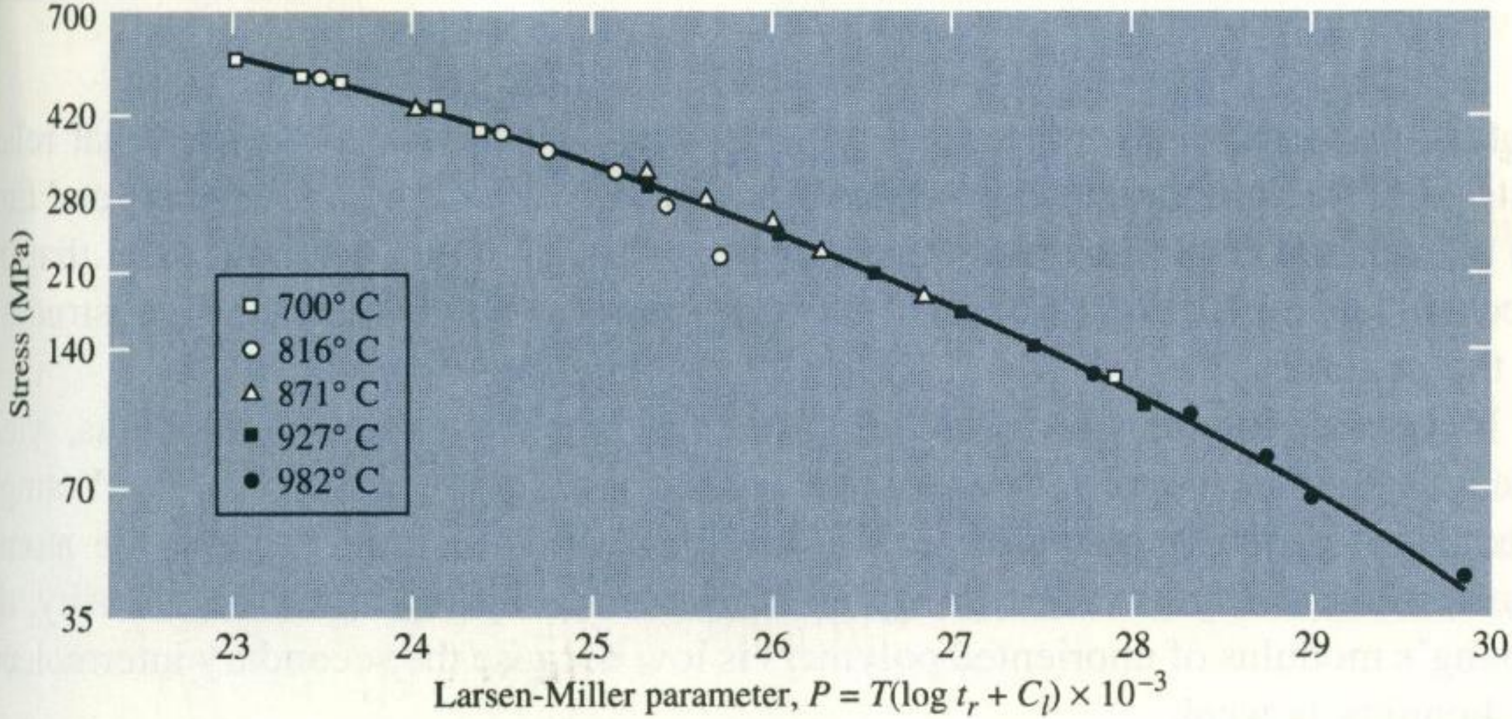


Figure 9.6–10 Master curve plotting creep rupture data at various temperatures for Astroly. Such a plot is called a Larsen–Miller diagram.

Solved example

An Astroloy jet engine blade will be used at $871^{o}C$ at $\sigma = 200$ MPa

a. Determine the life of the blade (C=20)

b. Estimate the maximum service temperature if a life of 500 hours is required

From the curve above: at $\sigma = 200$ MPa $\quad P_{LM} = 26500$

$$26500 = (871+273)[\,20 + \log t_R]$$

$$\log t_R = 3.164 \qquad t_R = 1460 \text{ hours} \qquad \text{(a)}$$

$$26500 = T\,(20 + \log 500)$$

$$T = 1167\text{ K} = 894^{o}C \qquad \text{(b)}$$

i.e. an increase of $23^{o}C$ in service temperature cuts the rupture life to about one third of its value.