CREEP FAILURE

- The start of tertiary creep indicates that damage in the metal had occurred, which will end in creep failure.
- “But why should tertiary creep occur at all?”
- It has been shown that in steady-state creep there is a balance between two opposing tendencies: The trend for the strength of the material to increase during creep by strain hardening and the trend for the strength to decrease by recovery.
- “ What happens to upset this balance when tertiary creep begins?”

CREEP FAILURE

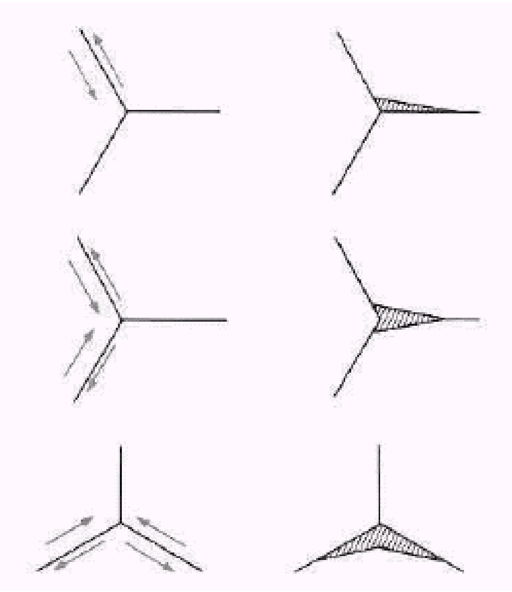
- Steady-state creep is only a metastable state that can be brought to an end by irreversible changes

- The onset of creep is an indication that voids or cracks are forming in the material, the number of these voids increases with strain and time. By reducing the net cross-sectional area of load bearing material, these voids must weaken the material and help to induce tertiary creep.

- Two types of voids have been mainly observed in alloys after creep: round and wedge shaped voids

- The mechanism of void formation involves grain boundary sliding

- Wedge crack:
  - ✓ Initiate mostly at grain boundaries which are aligned for max shear.

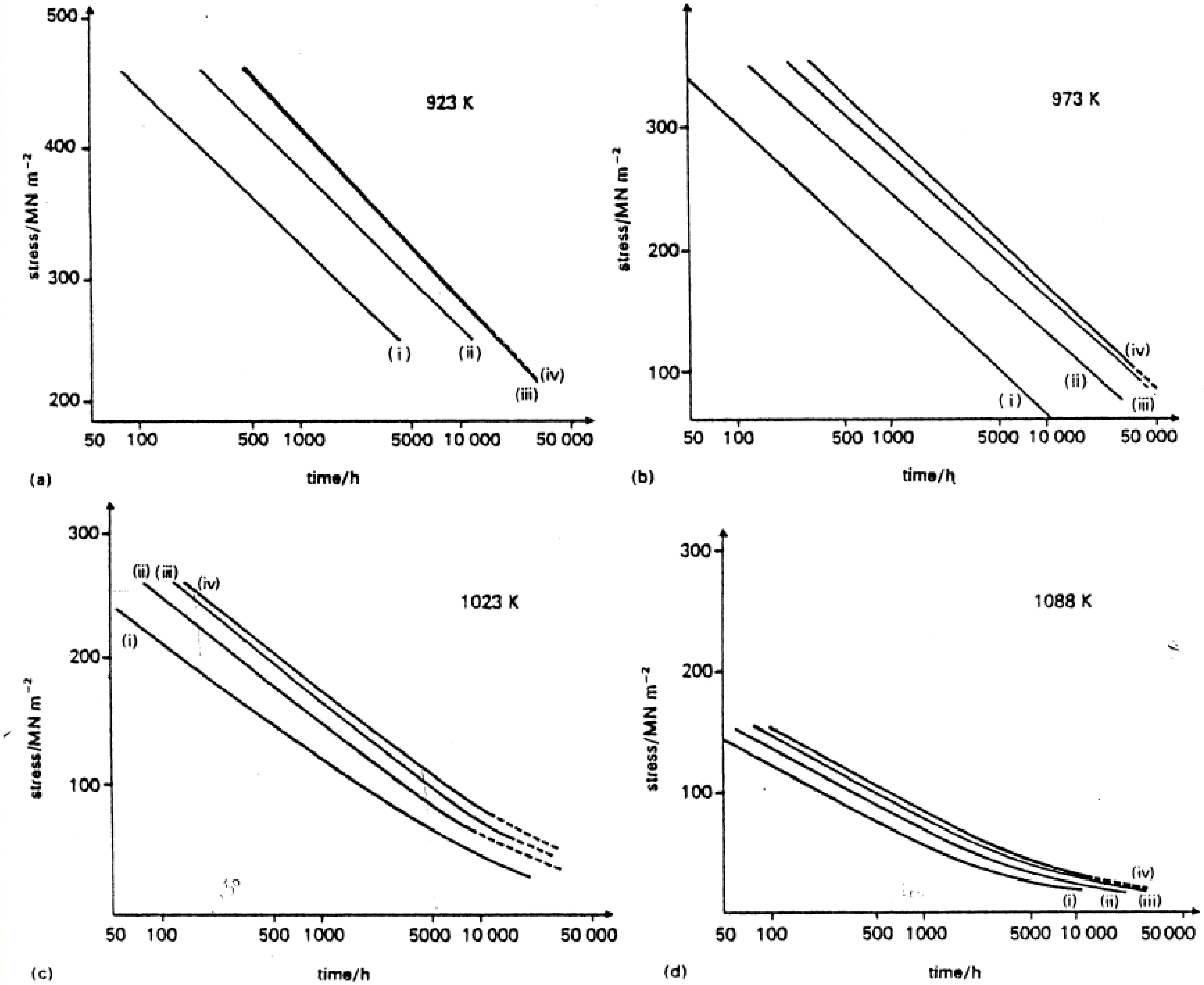


- Round or elliptical cavities (r-cracks)
  - ✓ form in the grain boundaries that are aligned normal to the tensile stress

Presenting Creep Data

- Creep deformation involves 4 major variables: stress, strain, time and temperature
- The method of presenting data used depends on the particular question to which a design engineer requires an answer
- One important information is the time it will take a specimen of a material to reach a particular creep strain at a specified temperature
- This is provided by plotting *isometric stress-time* curves

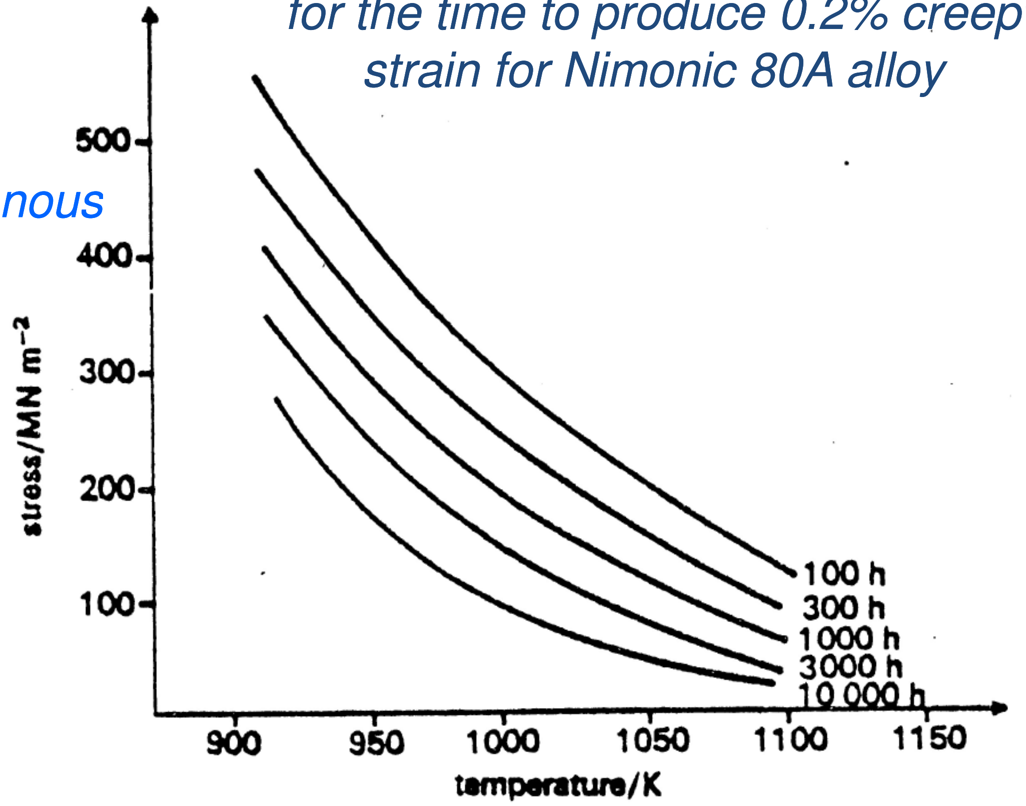
Strain
(iv) > (iii) > (ii) > (i)



Isometric stress-time curves for different strains

- Other important question an engineer might ask is:
- My component must not exceed a creep strain of 0.1% in 500 hours, What is the maximum stress the material will support at 1000 K?
- In this case we use *Isochronous stress-temperature curves*

Isochronous stress-temperature curves for the time to produce 0.2% creep strain for Nimonic 80A alloy



Prediction of long-time properties

- For long-time creep and stress rupture data
  - ✓1% deformation in 100,000 h (11.4 years!!!)
  - ✓Impractical to collect data from normal laboratory test.
  - ✓Therefore, we need to perform creep test/creep rupture test at temperatures in excess, and making suitable extrapolation to the in-service condition.

Larson-Miller Parameter

- Stress rupture or failure data for high temperature resistant alloys are often plotted as *log stress to rupture vs. a combination of log time to rupture and temperature*. The *Larson-Miller* (LM) parameter is most widely used.

$$\boxed{P(\text{Larson-Miller})\text{parameter} = T(\log t_r + C)}$$

- **T, is the temperature in K.**
- **t_r, stress-rupture time, hours**
- **C, constant, is assumed to have a value of 20.**

- In terms of K-hours:

$$\boxed{P(LM) = \{T(0C) + 273(20 + \log tr)\}}$$

- According to the *Larson-Miller* parameter, at a given stress level the log time to stress rupture (failure) plus a constant multiplied by the temperature remains constant for a given material.

CREEP CONTROL

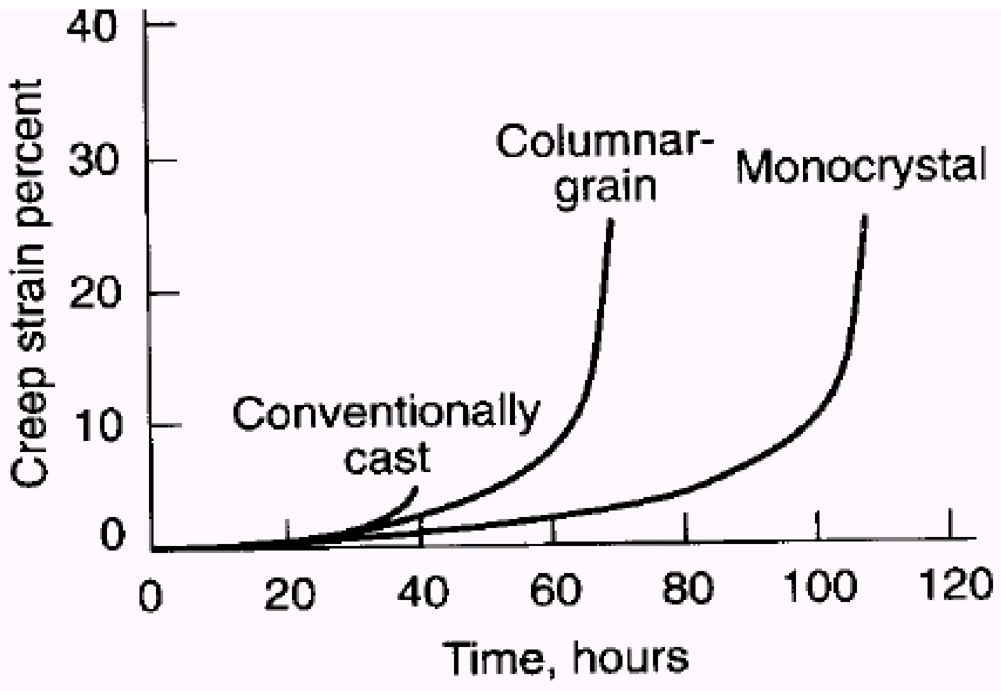
- The objectives of creep control are to produce (use) a material that is stable under specified levels of stress, temperature and environment.
- The material should not change its dimensions (or creep) and should not lose its integrity or fracture.
- In practice true stability at high temperature has never been achieved and the development of alloys is a matter of trying to retard inevitable changes in the material
- “There is a finite lifetime for a component in service under stress at high temperature”

Example: turbine blades for jet engines

- The strategy used to develop Nickel-based superalloys for turbine blades has 3 aims:

1. to inhibit the oxidation of the alloy (add Chromium)
2. to inhibit the deformation of the grains (add Aliminium and titanium)
3. to inhibit the deformation between the grains.

    - Introduce precipitates at the grain boundaries (carbides) which reduce grain boundary sliding
    - Align the grain parallel to the applied stress (directional solidification)
    - Completely remove the grain boundaries (single crystal turbines)



Comparison of creep properties at 980ºC and 207 MPa of MAR-M200 in equiaxed casting, DS and SC turbine blades

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