Failure Mechanism

Engineering Materials and Metallurgy

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Common Metal Failures

How to know the reason behind these failures ?

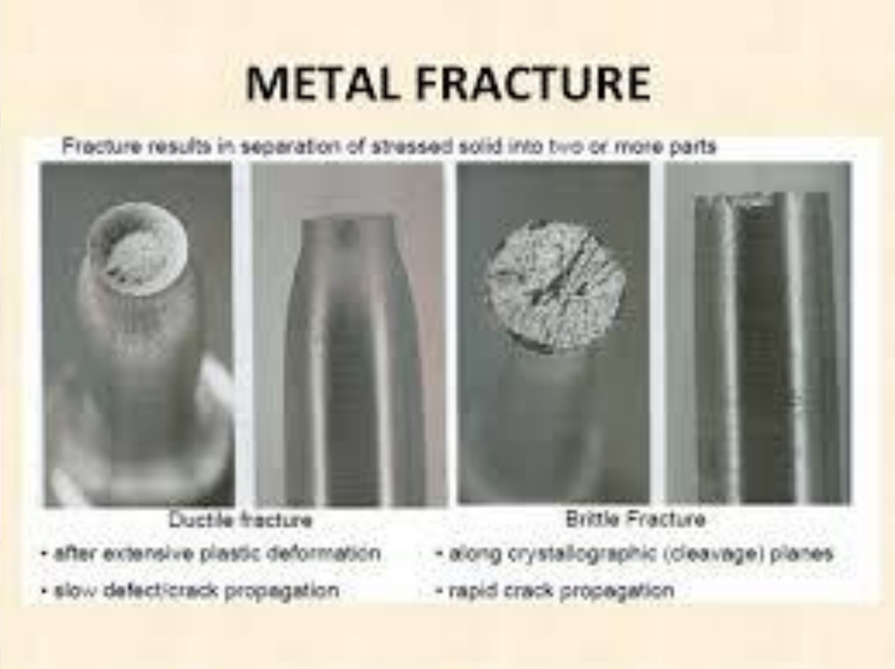
FAILURE MECHANISM

Fracture Modes

- Simple fracture is the separation of a body into 2 or more pieces in response to an applied stress that is static (constant) and at temperatures that are low relative to the T_m of the material.

- **Ductile fracture**
  - Accompanied by significant plastic deformation

- **Brittle fracture**
  - Little or no plastic deformation
  - Sudden, catastrophic

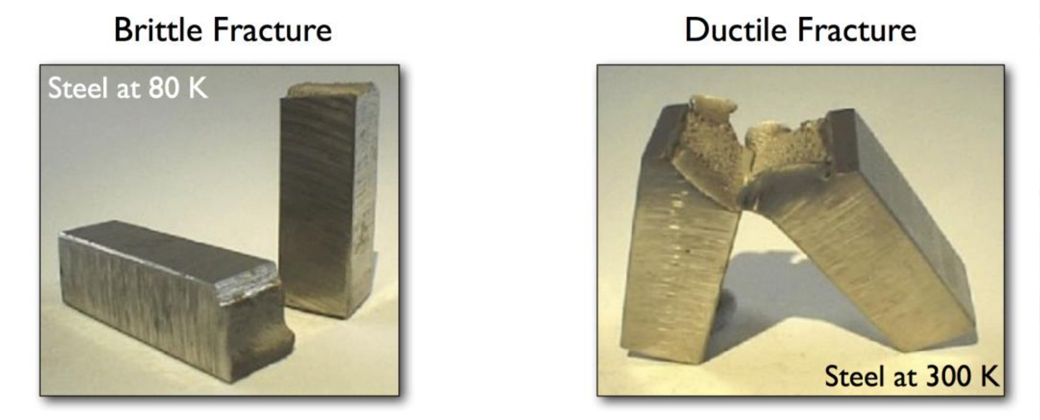


Fracture Mechanism

Imposed stress ➡ Crack Formation ➡ Propagation

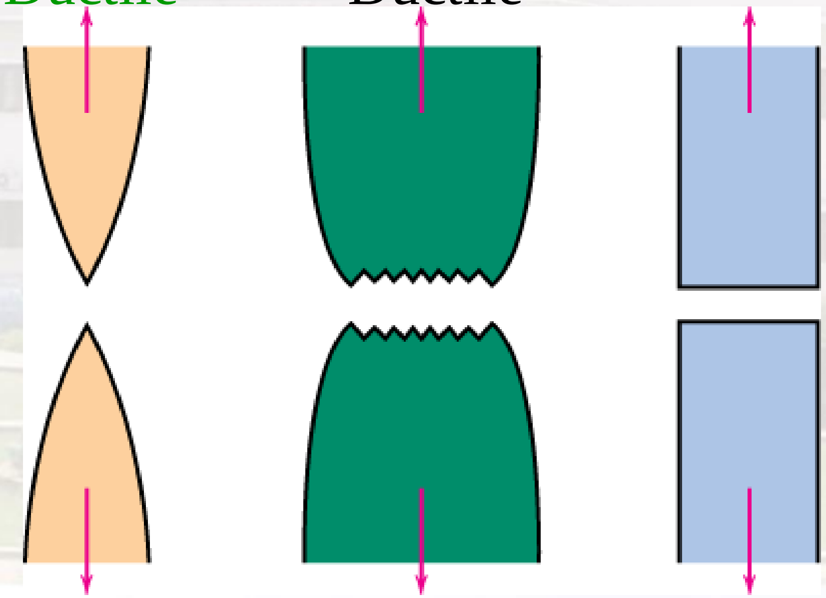
- Ductile failure has extensive plastic deformation in the vicinity of the advancing crack. The process proceeds relatively slow (stable). The crack resists any further extension unless there is an increase in the applied stress.

- In brittle failure, cracks may spread very rapidly, with little deformation. These cracks are more unstable and crack propagation will continue without an increase in the applied stress.



Ductile vs Brittle Failure

Fracture behavior:	Very Ductile	Moderately Ductile	Brittle



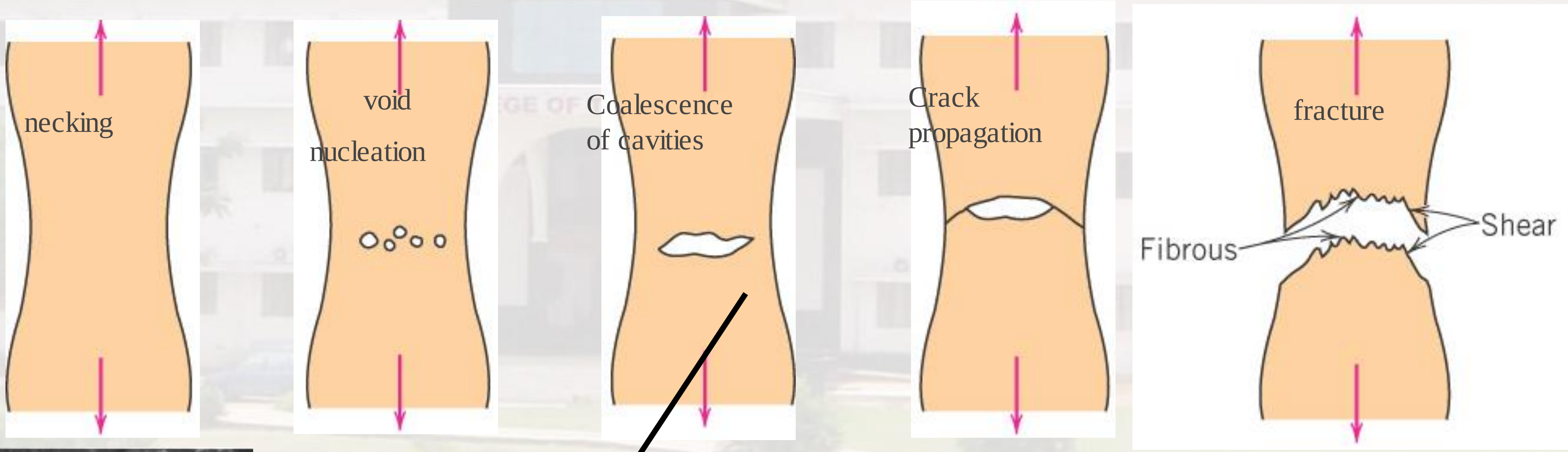
	Large	Moderate	Small

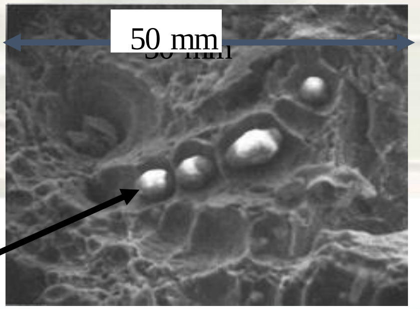
- Ductile fracture is usually more desirable than brittle fracture.

Ductile:	Brittle:
Warning before fracture	No warning

Moderately Ductile Failure

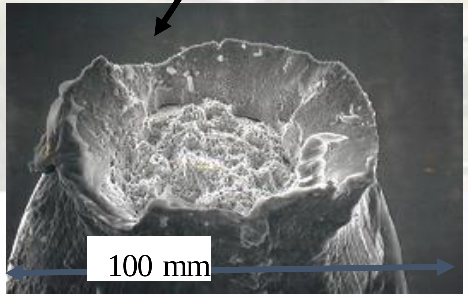
Evolution to failure





particles serve as void nucleation sites.

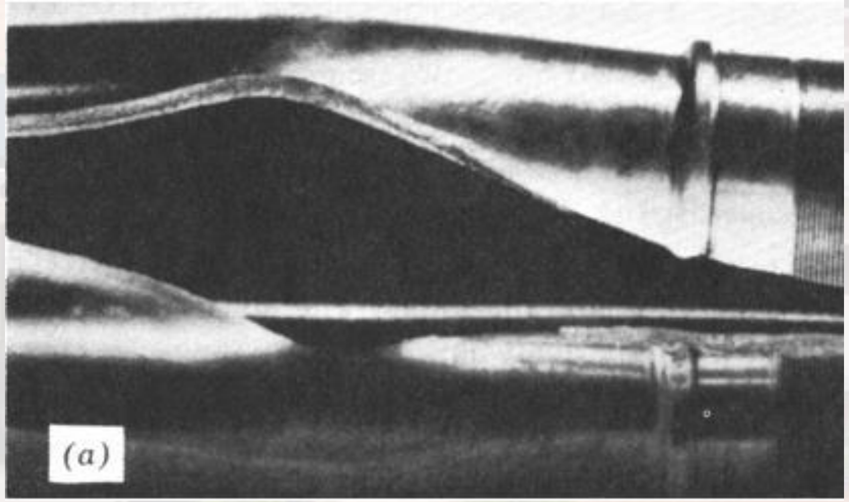
From V.J. Colangelo and F.A. Heiser, *Analysis of Metallurgical Failures* (2nd ed.), Fig. 11.28, p. 294, John Wiley and Sons, Inc., 1987. (Orig. source: P. Thornton, *J. Mater. Sci.*, Vol. 6, 1971, pp. 347-56.)



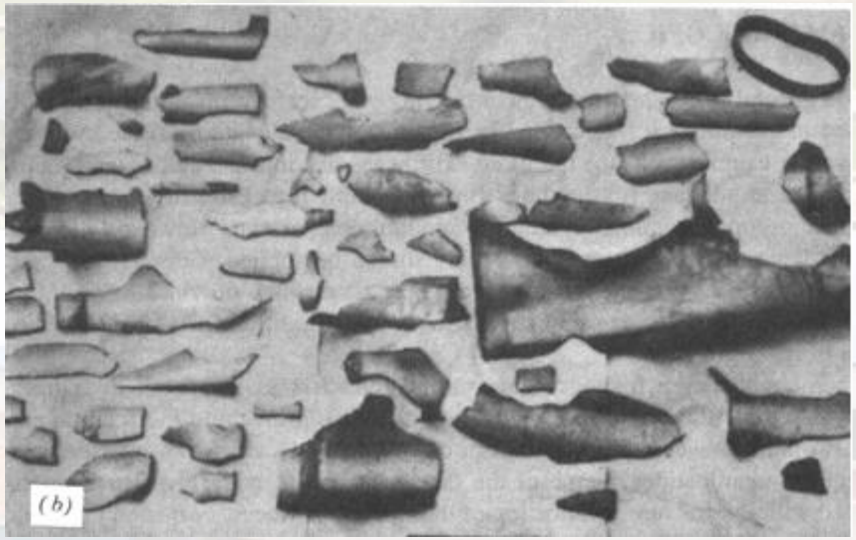
Fracture surface of tire cord wire loaded in tension. Courtesy of F. Roehrig, CC Technologies, Dublin, OH. Used with permission.

Example: Pipe Failures

- **Ductile failure:**
  -- one piece
  -- large deformation



- **Brittle failure:**
  -- many pieces
  -- small deformations

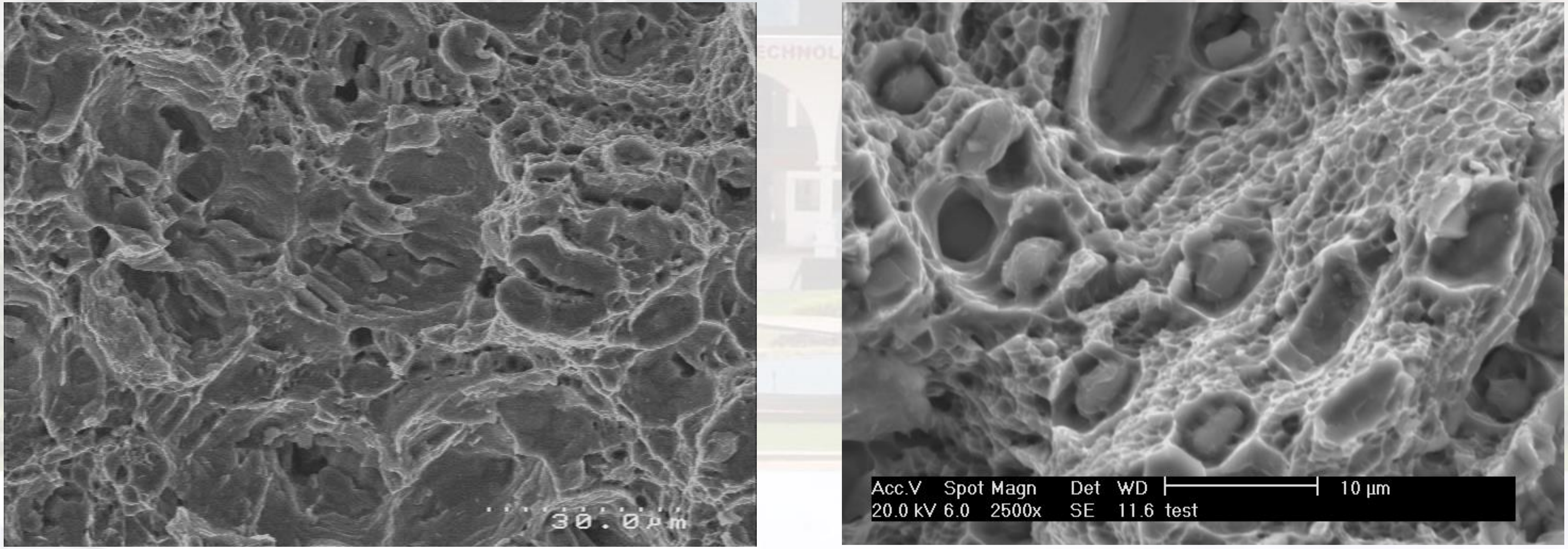


Ductile vs. Brittle Failure

(a) Cup-and-Cone fracture

(b) Brittle Fracture

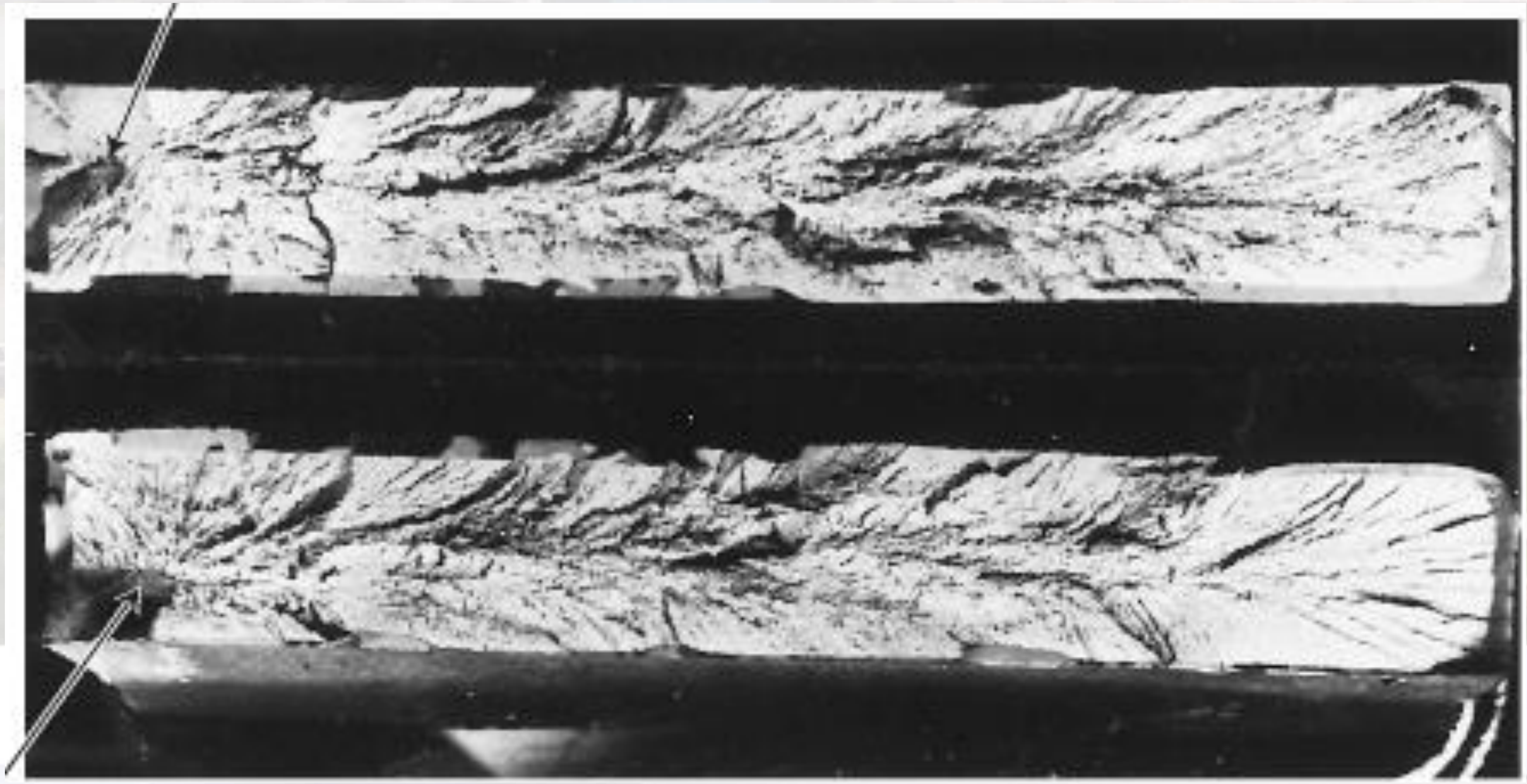
Ductile Failure



SEM Image

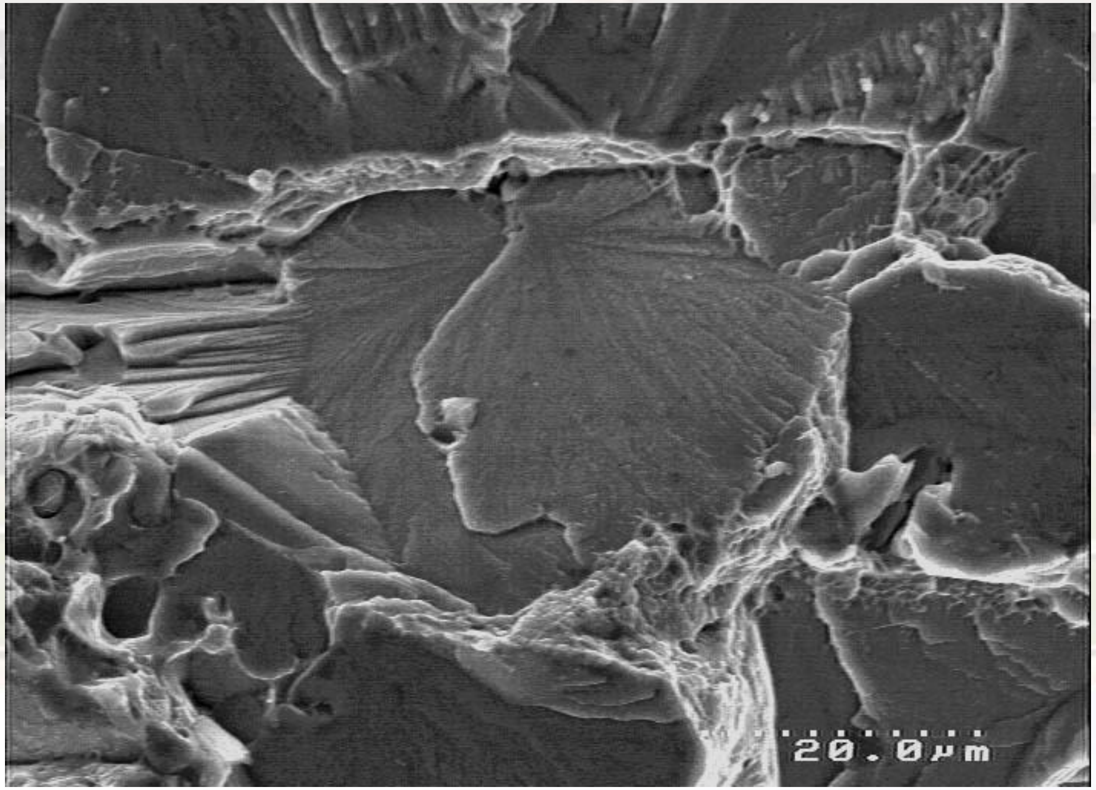
Brittle Fracture

Arrows indicate point at failure origination



Distinctive pattern on the fracture surface: V-shaped "chevron" markings point to the failure origin.

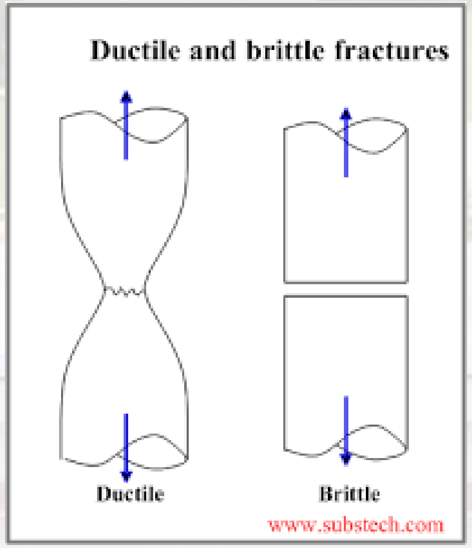
Brittle Fracture



SEM Image

Ductile vs Brittle

- The effect of a stress raiser is more significant in brittle than in ductile materials.
- For a ductile material, plastic deformation results when the maximum stress exceeds the yield strength.
- This leads to a more uniform distribution of stress in the vicinity of the stress raiser; the maximum stress concentration factor will be less than the theoretical value.



- In brittle materials, there is no redistribution or yielding.

THANK YOU

Assessment

https://play.kahoot.it/v2/?quizId=ab08ee90-15f5-4bf3-b608-dccf227edbf2