8.1 材料的韧脆转变

Dongsheng Wen

为什么要关注？

1986-1-28, Space Shuttle *Challenger* Disaster…

https://www.oringsusa.com/o/261-2/
https://en.wikipedia.org/wiki/Space_Shuttle_Challenger_disaster
https://en.wikipedia.org/wiki/Space_Shuttle_Solid_Rocket_Booster

为什么要关注？

Presidential Commission
on the
Space Shuttle Challenger Accident

June 6, 1986

Dear Mr. President:

On behalf of the Commission, it is my privilege to present the report of the Presidential Commission on the Space Shuttle Challenger Accident.

Since being sworn in on February 6, 1986, the Commission has been able to conduct a comprehensive investigation of the Challenger accident. This report documents our findings and makes recommendations for your consideration.

Our objective has been not only to prevent any recurrence of the failure related to this accident, but to the extent possible to reduce other risks in future flights. However, the Commission did not construe its mandate to require a detailed evaluation of the entire Shuttle system. It fully recognizes that the risk associated with space flight cannot be totally eliminated.

Each member of the Commission shared the pain and anguish the nation felt at the loss of seven brave Americans in the Challenger accident on January 28, 1986.

The nation's task now is to move ahead to return to safe space flight and to its recognized position of leadership in space. There could be no more fitting tribute to the Challenger crew than to do so.

Sincerely,

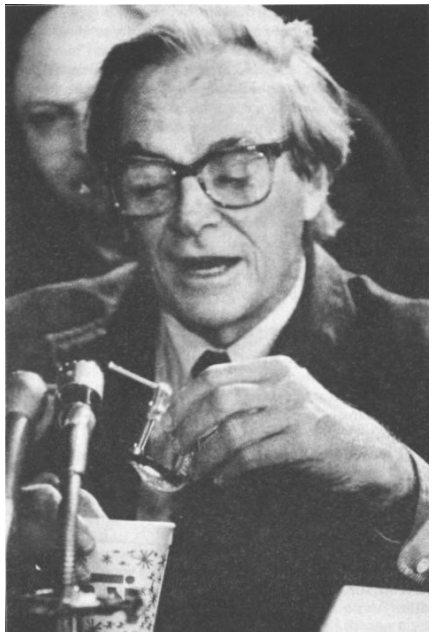
William P. Rogers
Chairman

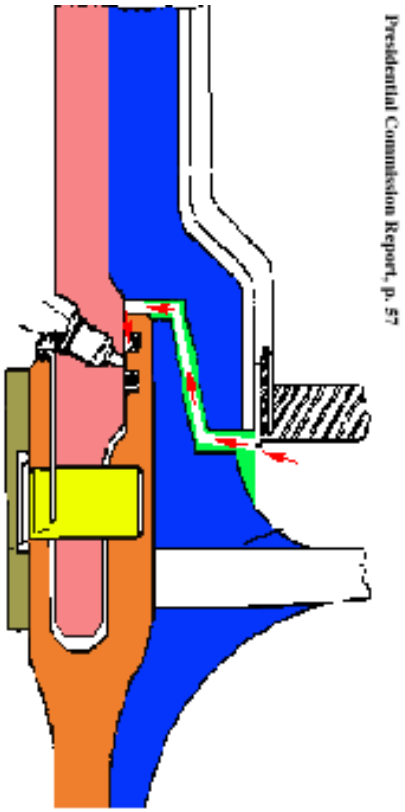
The President of the United States
The White House
Washington, D. C. 20500

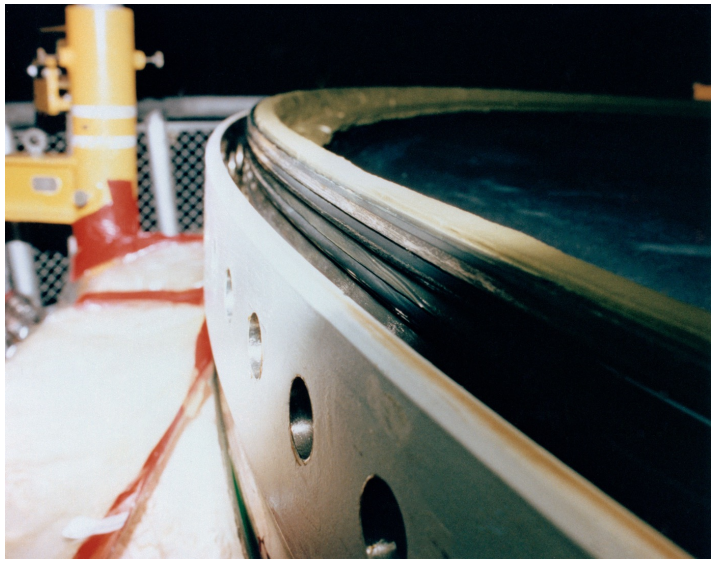
600 Maryland Avenue, S.W. Washington, D.C. 20024 (202)453-1405

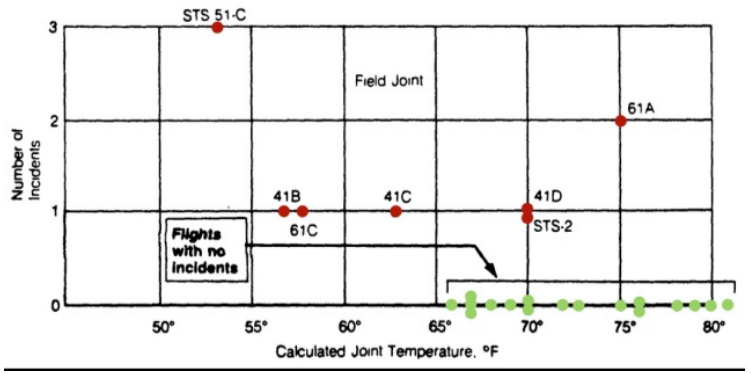
https://www.oringsusa.com/o/261-2/
https://en.wikipedia.org/wiki/Space_Shuttle_Challenger_disaster
https://en.wikipedia.org/wiki/Space_Shuttle_Solid_Rocket_Booster

为什么要关注？





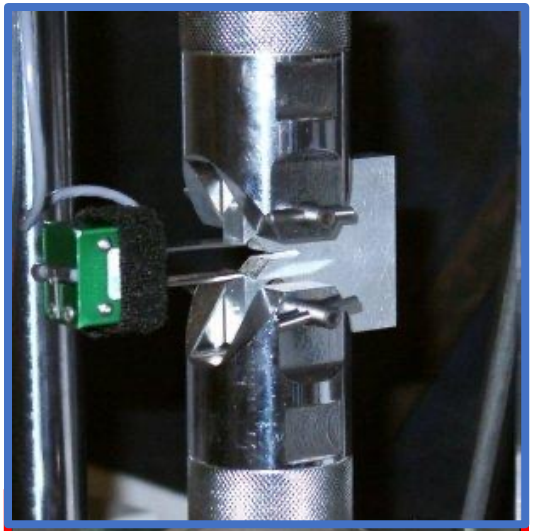




https://www.oringsusa.com/o/261-2/
https://en.wikipedia.org/wiki/Space_Shuttle_Challenger_disaster
https://en.wikipedia.org/wiki/Space_Shuttle_Solid_Rocket_Booster

材料的韧性脆性转变

- 实验测试手段

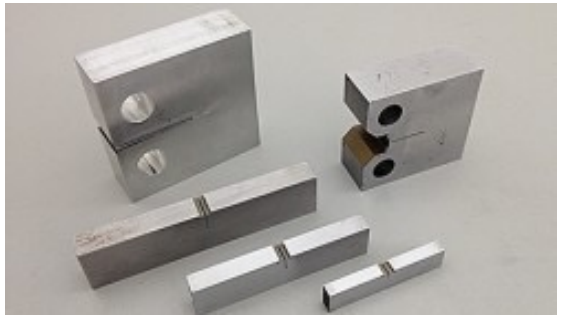


指标
K-factor

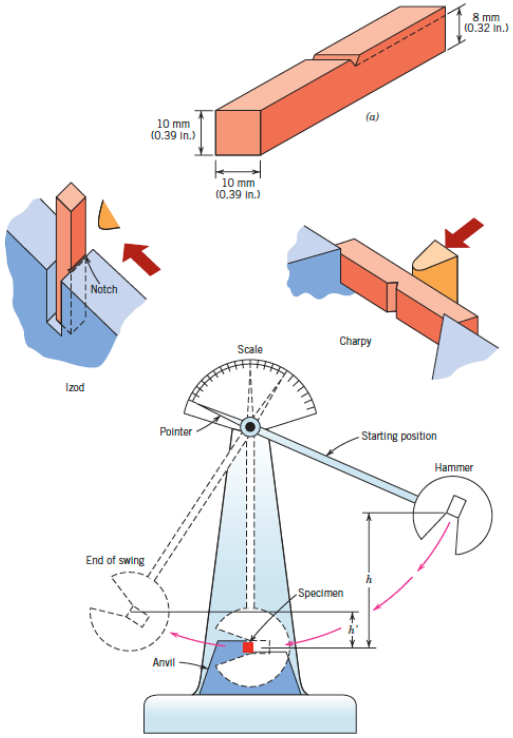
J-integral

CTOD

CTOA



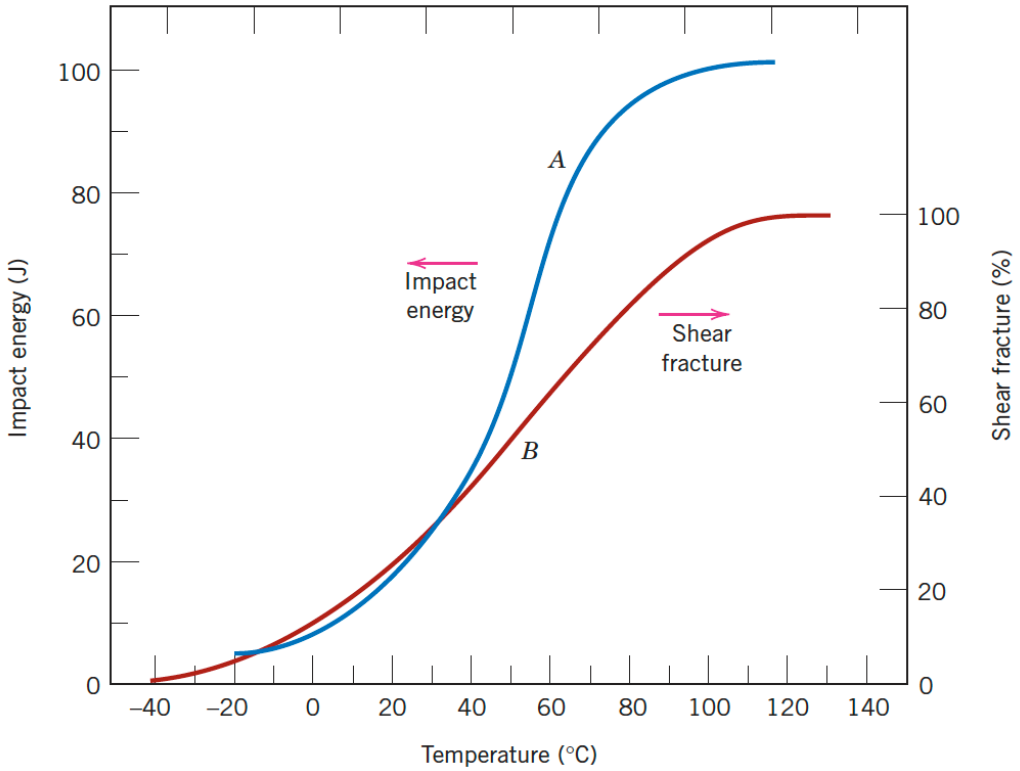
Charpy Test



https://www.testresources.net/applications/test-types/fracture-test/fracture-toughness-test-for-metallic-materials-k1c-testresources/
https://www.testresources.net/applications/test-types/fracture-test/j-integral-fracture-toughness-test-equipment-j1c/
Zhu, X.K. and Joyce, J.A., 2012.. *Engineering Fracture Mechanics*, *85*, pp.1-46.

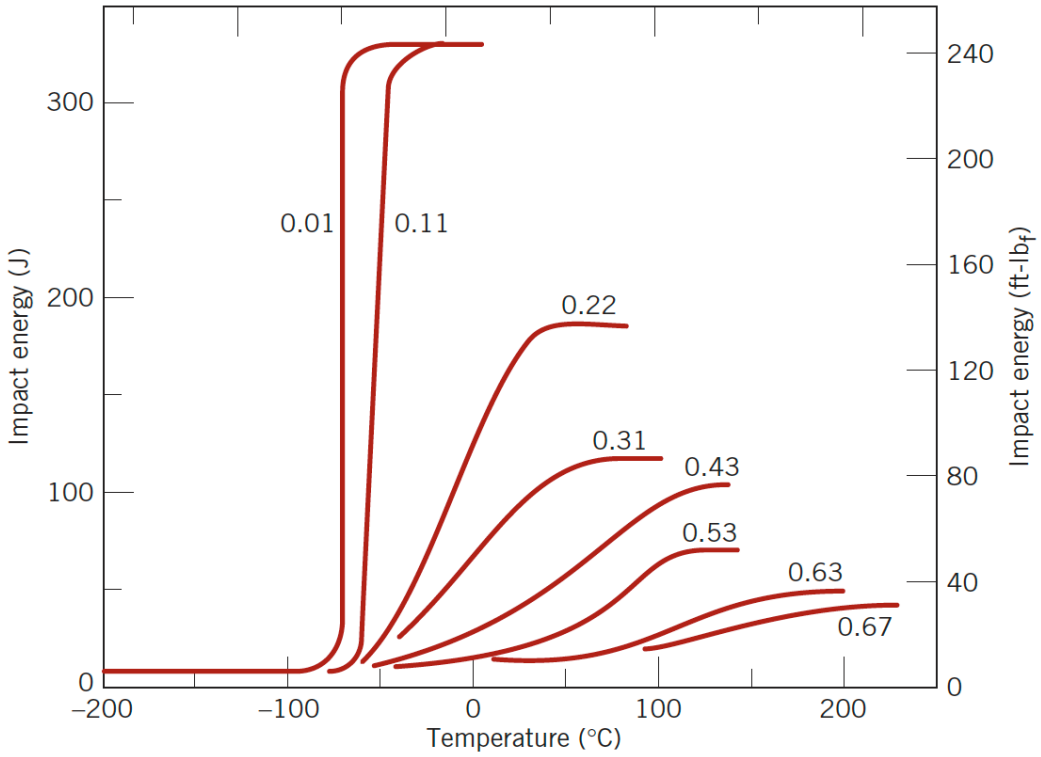
材料的韧性脆性转变

- Fe-BCC
  - 碳钢



材料的韧性脆性转变

- Fe-BCC
  - 含碳量



材料的韧性脆性转变

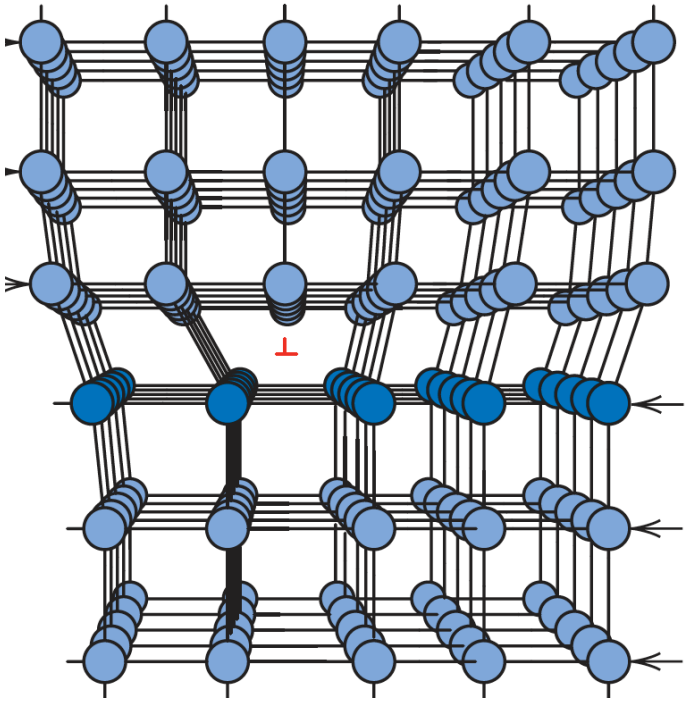
- 为什么？

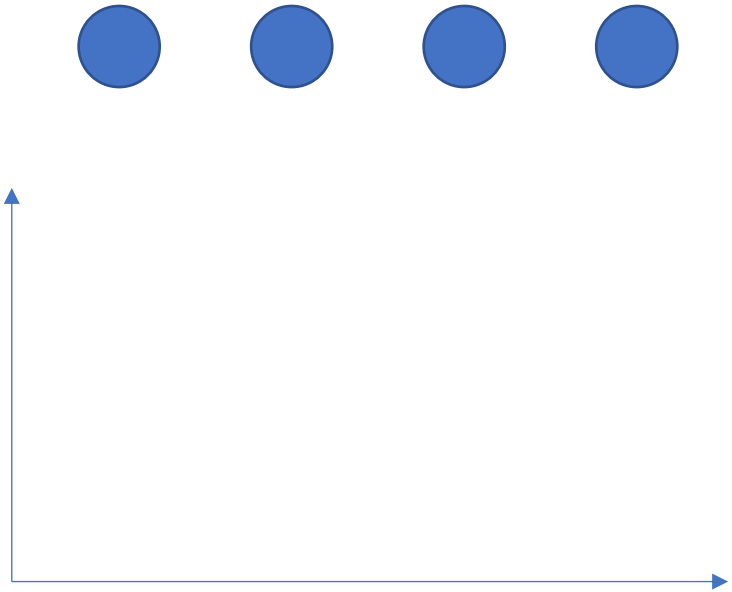
Table 7.1 **Slip Systems for Face-Centered Cubic, Body-Centered Cubic, and Hexagonal Close-Packed Metals**

Metals	*Slip Plane*	*Slip Direction*	*Number of Slip Systems*
	Face-Centered Cubic		
Cu, Al, Ni, Ag, Au	{111}	$\langle 1\bar{1}0 \rangle$	12
	Body-Centered Cubic		
α-Fe, W, Mo	{110}	$\langle \bar{1}11 \rangle$	12
α-Fe, W	{211}	$\langle \bar{1}11 \rangle$	12
α-Fe, K	{321}	$\langle \bar{1}11 \rangle$	24
	Hexagonal Close-Packed		
Cd, Zn, Mg, Ti, Be	{0001}	$\langle 11\bar{2}0 \rangle$	3
Ti, Mg, Zr	$\{10\bar{1}0\}$	$\langle 11\bar{2}0 \rangle$	3
Ti, Mg	$\{10\bar{1}1\}$	$\langle 11\bar{2}0 \rangle$	6

材料的韧性脆性转变

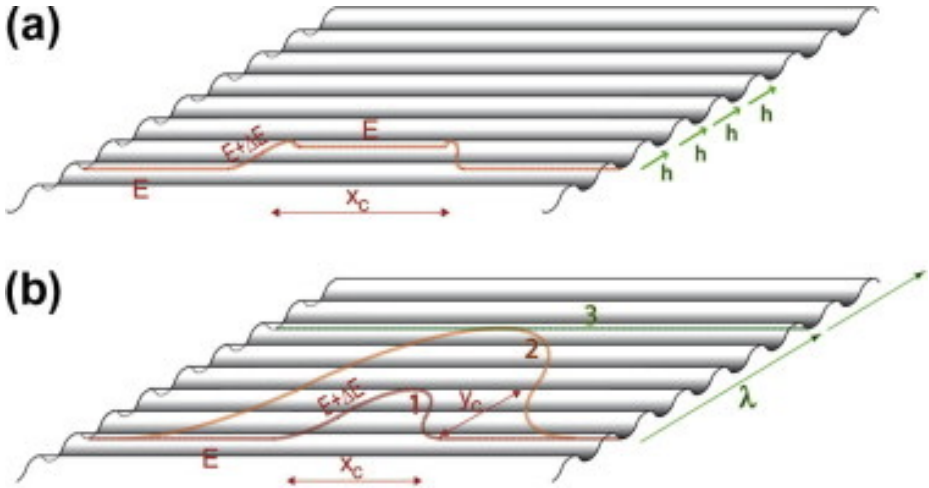
- 有滑移系位错就会动了吗？

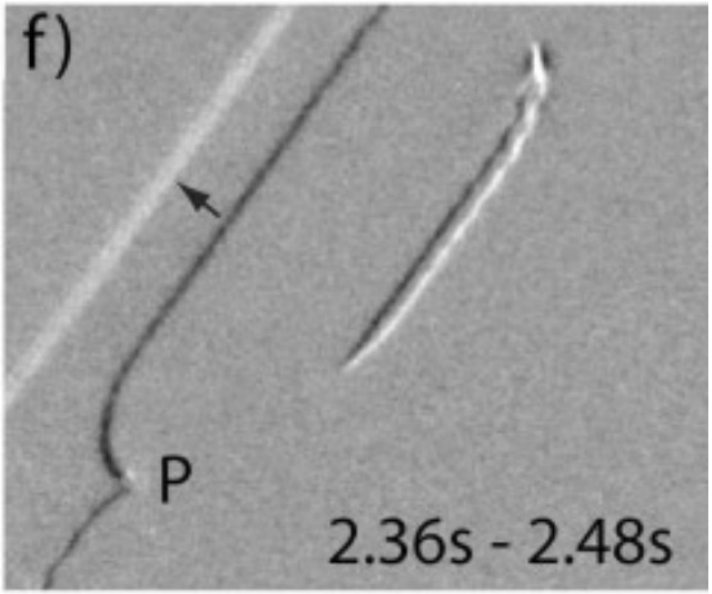


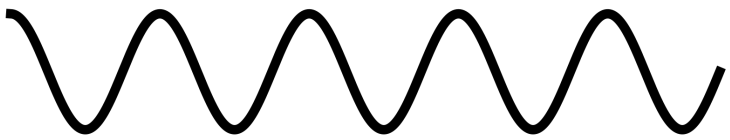


材料的韧性脆性转变

- 有滑移系位错就会动了吗？





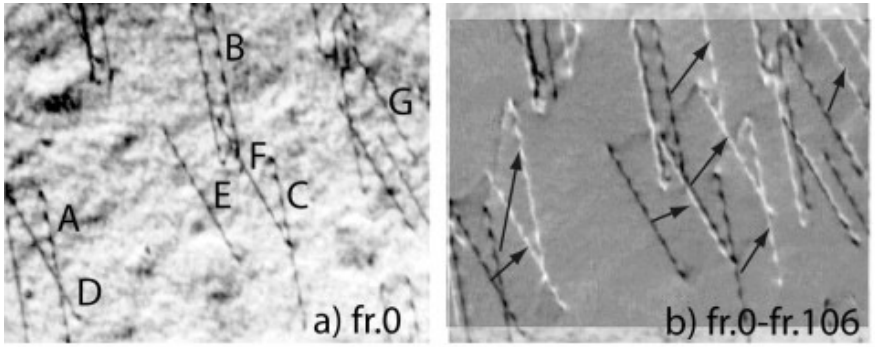


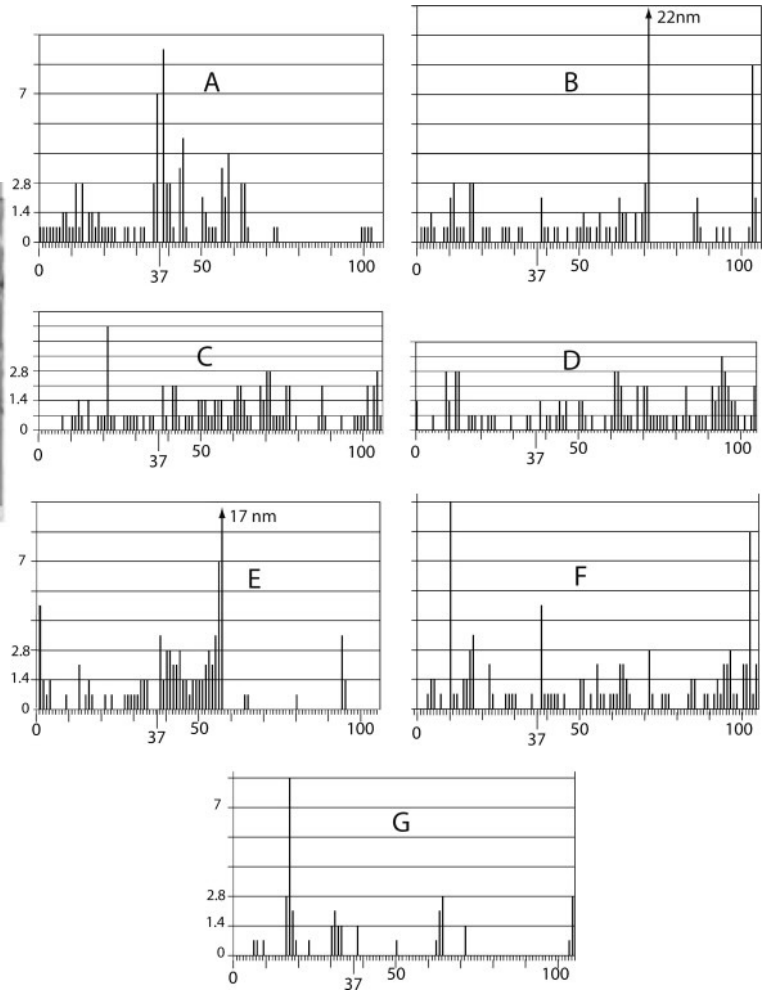
Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part II. In situ straining experiments at low temperature. *Acta Materialia*, *58*(9), pp.3504-3515.
Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part I. In situ straining experiments at room temperature. *Acta Materialia*, *58*(9), pp.3493-3503.

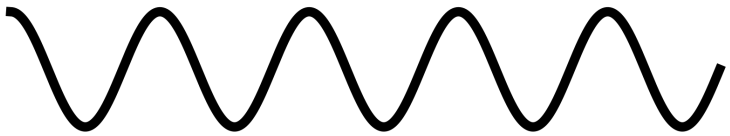
材料的韧性脆性转变

- 位错移动的速度和温度

110 K





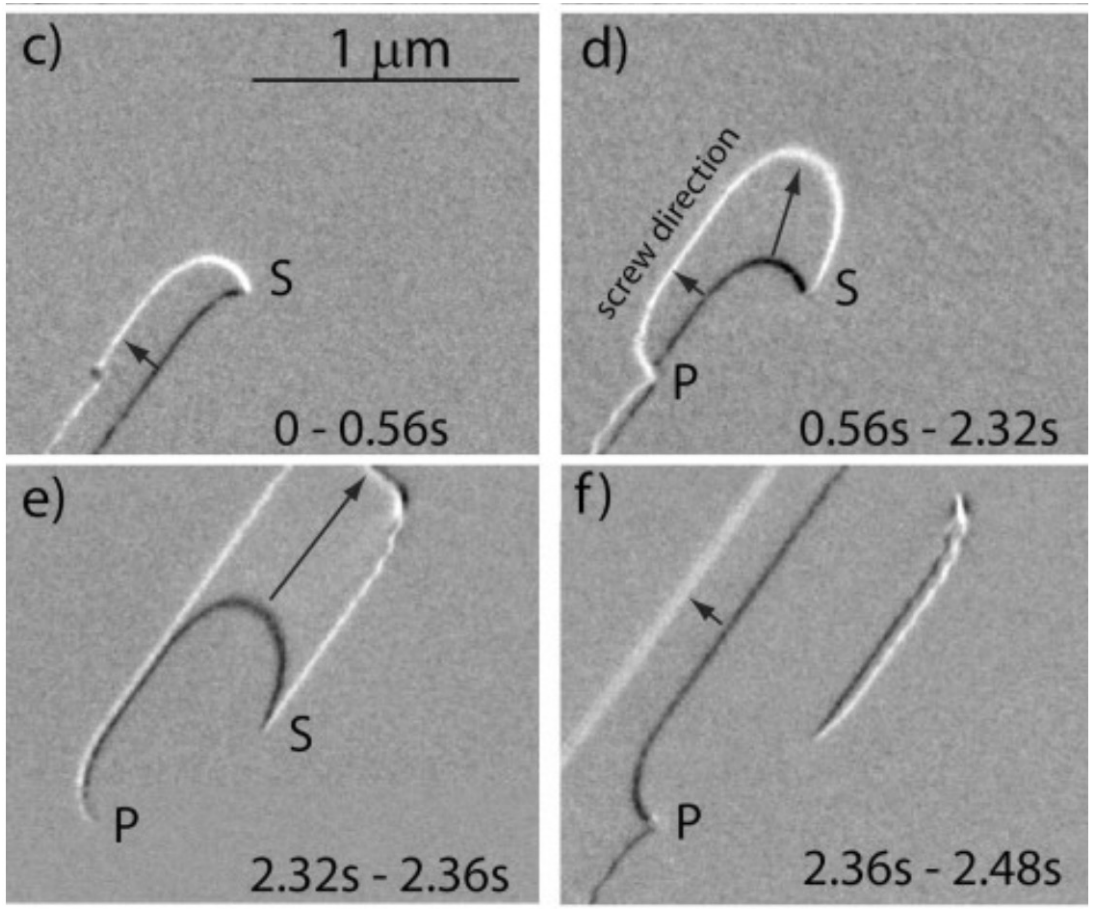


Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part II. In situ straining experiments at low temperature. *Acta Materialia*, *58*(9), pp.3504-3515.
Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part I. In situ straining experiments at room temperature. *Acta Materialia*, *58*(9), pp.3493-3503.

材料的韧性脆性转变

- 位错移动的速度和温度

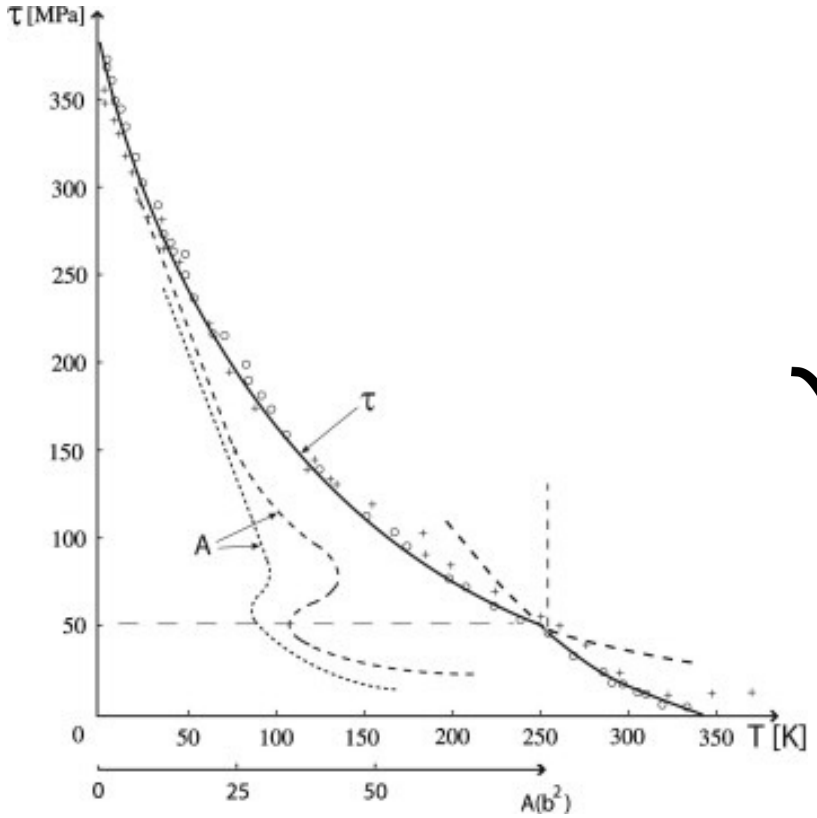
300 K

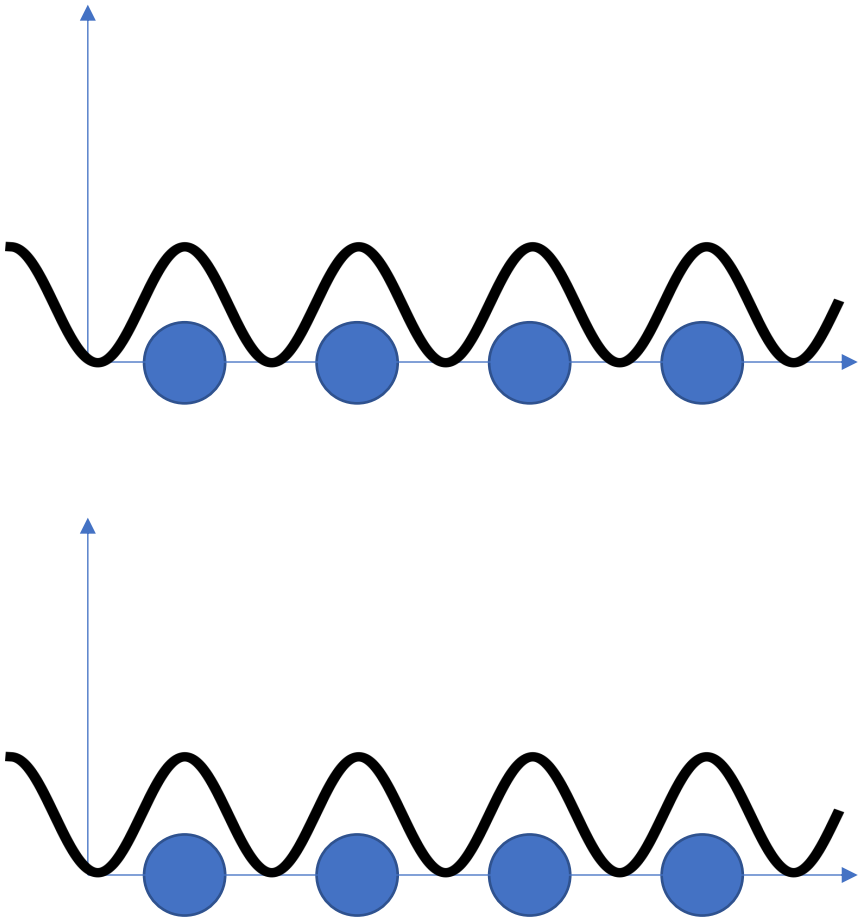


Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part II. In situ straining experiments at low temperature. *Acta Materialia*, *58*(9), pp.3504-3515.
Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part I. In situ straining experiments at room temperature. *Acta Materialia*, *58*(9), pp.3493-3503.

材料的韧性脆性转变

- 温度与位错的热激活





Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part II. In situ straining experiments at low temperature. *Acta Materialia*, *58*(9), pp.3504-3515.
Caillard, D., 2010. Kinetics of dislocations in pure Fe. Part I. In situ straining experiments at room temperature. *Acta Materialia*, *58*(9), pp.3493-3503.

材料的韧性脆性转变

- 为什么FCC没有？

Slip Plane	*Slip Direction*	*Number of Slip Systems*
Face-Centered Cubic		
{111}	$\langle 1\bar{1}0 \rangle$	12
Body-Centered Cubic		
{110}	$\langle \bar{1}11 \rangle$	12
{211}	$\langle \bar{1}11 \rangle$	12
{321}	$\langle \bar{1}11 \rangle$	24

Kashyap, K.T., Bhat, A., Koppad, P.G. and Puneeth, K.B., 2012. On Peierls Nabarro stress in iron. *Computational materials science*, *56*, pp.172-173.

小结

- 韧性脆性转变的机制？

材料的韧性脆性转变

- 疑问得到回答了吗？

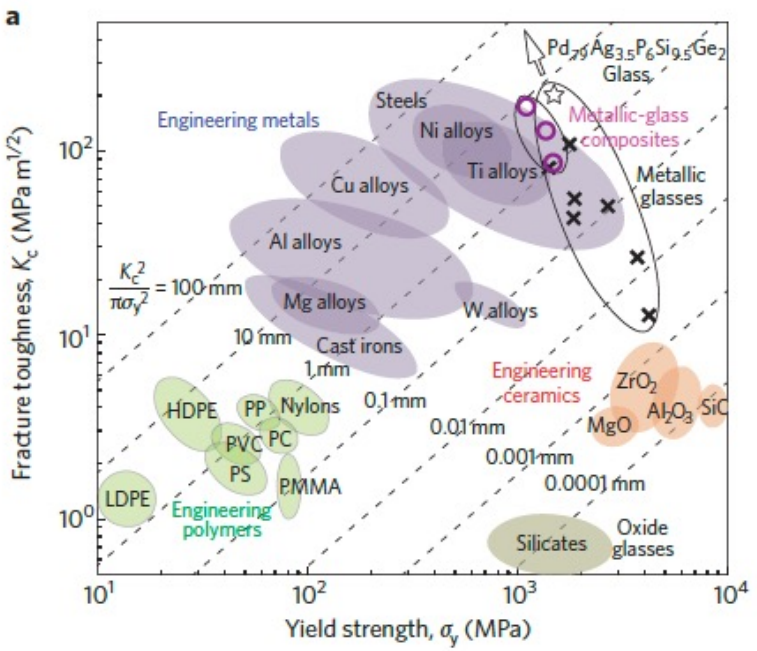
材料的韧性脆性转变

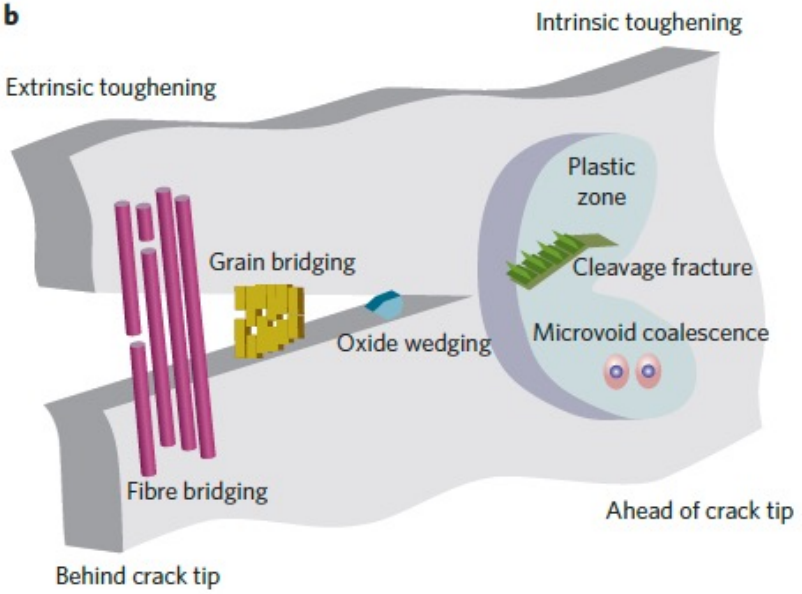
- 如何又韧又强？

nature materials
PROGRESS ARTICLE
PUBLISHED ONLINE: 24 OCTOBER 2011 | DOI: 10.1038/NMAT3115

The conflicts between strength and toughness

Robert O. Ritchie





8.2 疲劳

8.3 蠕变

下节课：9.1 相图-1