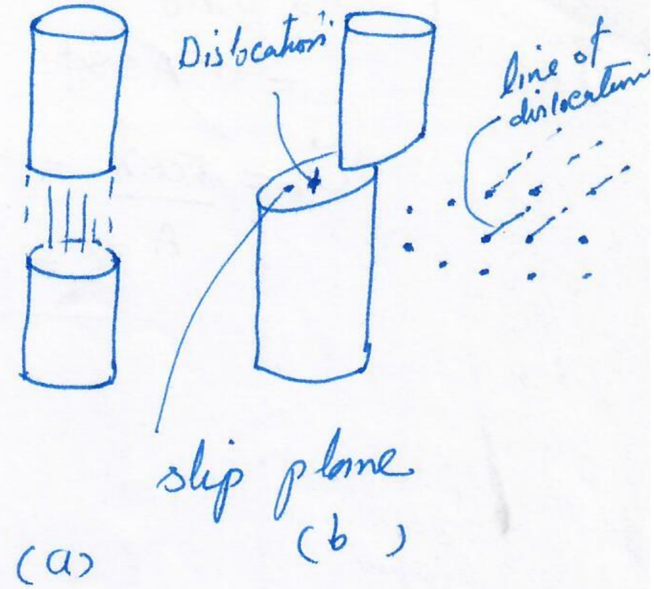
Significance of Dislocations



Without dislocations (a), a material will fail by breaking all of the bonds across the surface A_0. However when a dislocation slips (b), the bonds are only broken along the line of the dislocation.

EXAMPLE

A typical dislocation density in soft copper is 10^6 cm/cm^3. If the dislocations in 1000g of copper were placed end to end, how many miles of dislocation would be available?

(Normally dislocation density of 10^6 cm/cm^3 are typical of the soft materials)

The density of copper is $8.93\ Mg/m^3$ (Mega)

$\therefore$ Volume of copper $= \dfrac{1000g}{8.93g/cm^3} = 112\ cm^3$

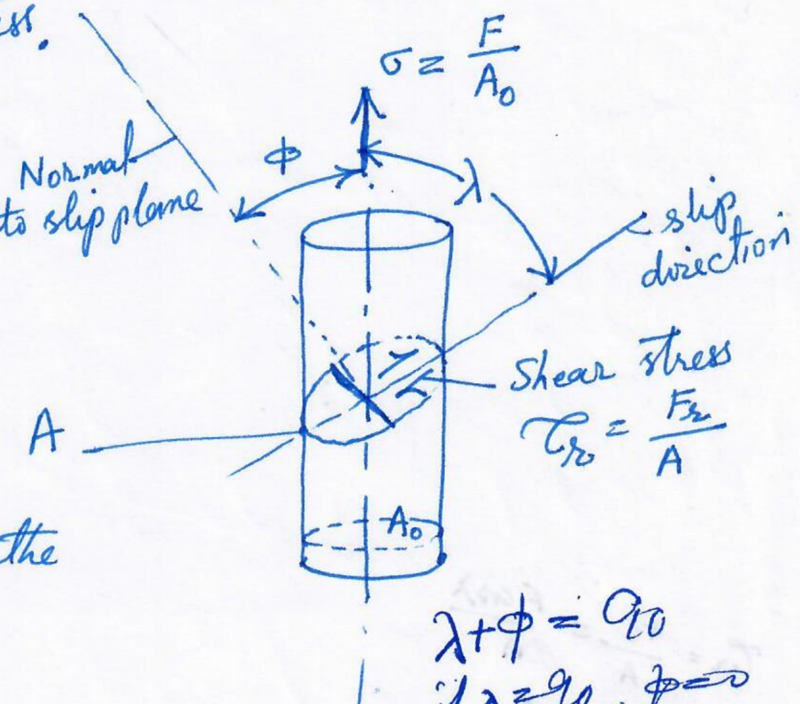
$$\text{Length} = (112\ cm^3)(10^6\ cm/cm^3) = 1.12 \times 10^8\ cm$$

$$= \frac{(1.12 \times 10^8\ cm)}{(2.54\ cm/in.)(12\ in/ft)(5280\ ft/mile)}$$

$$= 696\ \text{miles.}$$

SCHMID'S LAW

We can understand the difference in behaviour of metals that have different crystal structures by examining the slip process.



A resolved shear stress τ may be produced on a slip system, causing the dislocation to move on the a ~~slip system,~~ slip plane in the slip direction.

$$\lambda + \phi = 90$$

if $\lambda = 90$, $\phi = 0$

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where $\tau_r = \frac{F_r}{A}$ = resolved shear stress in the slip direction.

$\sigma = \frac{F}{A_0}$ = unidirectional stress applied to the cylinder.

$$A\cos\phi = A_0$$

$\propto$ F_r = $F\cos\lambda$ = $\sigma A_0 \cos\lambda$

$\lambda \rightarrow$ angle between the slip direction and the applied force

$\phi \rightarrow$ Angle between the normal to the slip plane and the applied force

$F_r = F \cos\lambda$

resolved

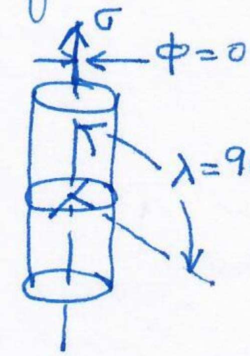
$A_0 = A \cos\phi$

$A_0 = A\cos\phi$

Schmid's Law

$\tau_r = \sigma \cos\phi \cos\lambda$ where $\tau_r = \dfrac{F_r}{A}$, $\sigma = \dfrac{F}{A_0}$

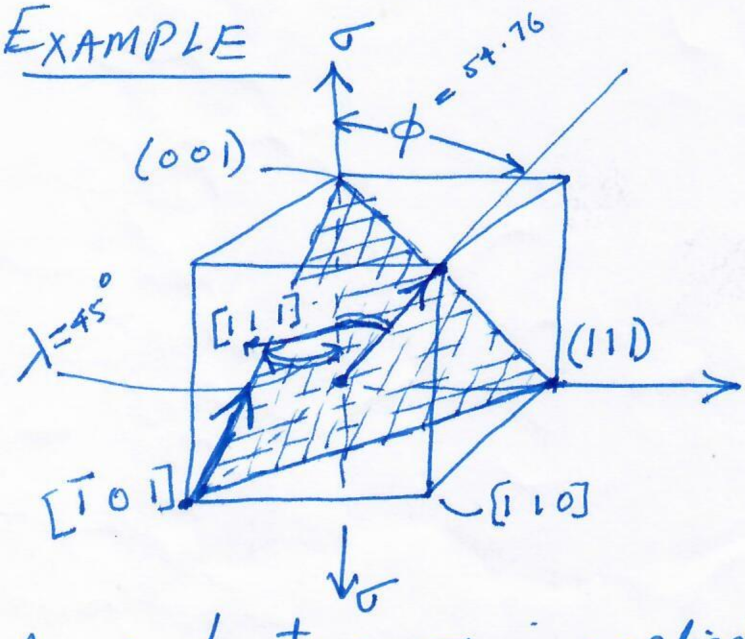
when the slip plane is perpendicular to the applied stress σ, the angle λ is 90^0 and no shear stress is resolved

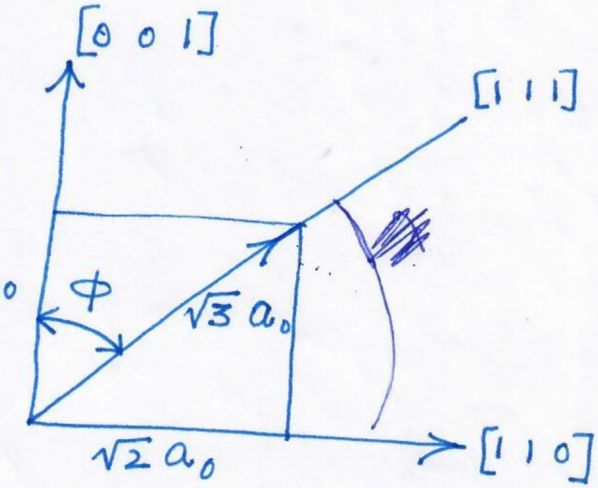


EXAMPLE

If λ or ϕ is 90^0
no slip will occur

EXAMPLE





A normal stress σ is applied in the [0 0 1] direction of the unit cell. This produces an angle λ of 45^0 to the [$\bar{1}$ 0 1] slip direction and an angle ϕ of 54.76^0 to the

EXAMPLE

Calculate the resolved shear stress on the (111) [$\bar{1}$ 0 1] slip system if a stress of 70 MPa is applied in the [0 0 1] direction of an FCC unit cell.

Solution

From Fig. $\lambda = 45^0$, $\cos\lambda = 0.707$

The normal to the (111) plane must be the [111] direction. One can find

$$\cos\phi = \frac{1}{\sqrt{3}} = 0.577 , \ \phi = 54.76^0$$

$$\tau_r = \sigma \cos\lambda \cos\phi = (70\ MPa)(0.707)(0.577)$$

$$= 28.56\ MPa$$

Critical resolved shear stress is the

τ_{crss} is the minimum shear stress required to break enough metallic bonds in order for slip to occur. Thus slip occurs, causing the metal to deform, when the applied stress produces a resolved shear stress that equals the critical resolved shear stress, slip occurs.

$$\tau_r = \tau_{crss}$$

EXAMPLE

Consider a slip system in which $\lambda = 70^0$, $\phi = 30^0$

Solution since at 35 MPa slip just starts to occur in $\tau_{CRSS} = \tau_R$.

$\tau_{CRSS} = \tau_R$ when slip begins

$$\tau_{CRSS} = \sigma \cos\lambda \cos\phi = (35\,MPa)(\cos 70)(\cos 30)$$

$$= 10.37\,MPa$$