(1) When n dislocations pile up under shear stress τ, the first dislocation at $x = 0$ feels a concentrated stress of $n\tau$.

(2) Yielding is considered to occur when the concentrated stress $n\tau$ reaches a certain critical value τ_{crit}. That is, $n = \tau_{crit} / \tau$.

(3) Pile-up distance l and stress τ are related as $l \propto n / \tau$.

(4) From (2) and (3), we have $l \propto 1/\tau^2$ or $\tau \propto l^{-1/2}$.

(5) If $l \propto d$, then we have the second term of (6.5).

6.4.3 von-Mises criterion

plastic deformation → occurs by shear → constant volume ($\varepsilon_{ii} \equiv \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} = 0$)

To change the shape of a polycrystal arbitrarily, at least five (5) independent slip systems must exist.

For crystals such as hcp, if the number of independent slip systems is less than five, extensive palstic deformation is not possible. → brittle fracture

Chapter 7 Strengthening Mechanisms

7.1 Various strengthening methods

Except composites, all the mothods are to make dislocation motion more difficult by introducing various obstacles.

Table 7.1 Various strengthening methods

Name	Characteristics
solid-solution hardening	introduction of interstiatial or substitutional atoms of different kind
precipitation hardening	distribution of fine precipitates
dispersion hardening	distribution of 2^{nd} phase particles
work hardening	increase in dislocation density by plastic deformation
fine-grain hardening	reducing grain size (Hall-Petch relationship)
composites	mixing different materials

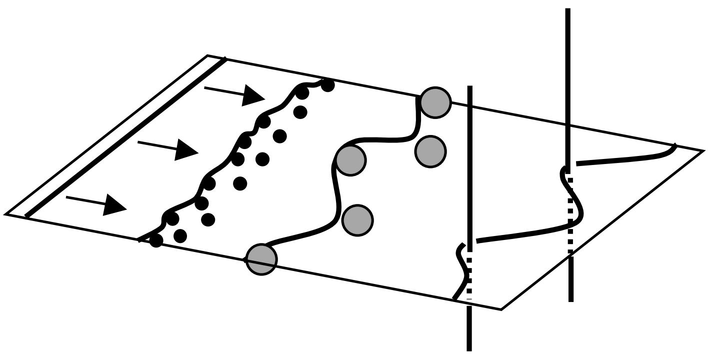

Fig. 7.1 Various obstacles against dislocation motion.

7.2 Absolutely strong obstacles (dispersion hardening)

Orowan mechanism

(1) The dislocation bow out between two particles.
(2) Yielding occurs when the bowed-out dislocation becomes semi-circular in shape.
(3) After the yielding, the dislocation leaves Orowan loops around the particles.
(4) The formation of the Orowan loops makes the dislocation motion more and more difficult. This results in large work-hardening.

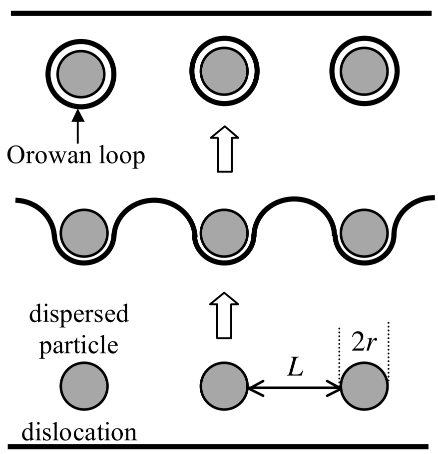

Fig. 7.2 Orowan mechanism for dispersion hardening.

CRSS for the Orowan mechanism (Orowan stress) (from Eq.(5.2))

$$\boxed{\tau = \frac{\mu b}{L}} \qquad (7.1)$$

7.3 Less strong obstacles (solid-solution hardening, precipitation hardening)

For either attractive or repulsive interaction between the dislocation and the obstacle, dislocation motion becomes difficult.

Yielding occurs before the dislocation becomes semi-circular in shape.

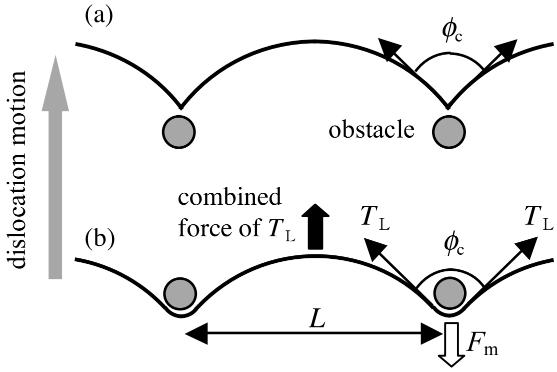

Fig. 7.3 Dislocation bow-out between obstacles. Interaction between the dislocation and the obstacles is (a) attractive, (b) repulsive.

- F_m : The maximum force of an obstacle to resist dislocation motion.
- ϕ_c : critical angle for the dislocation to overcome an obstacle.
- τ_m : CRSS

$$\tau_m b L = F_m \qquad (7.2)$$

$$F_m = 2T_L \cos(\phi_c / 2) \qquad (7.3)$$

From (7.2) and (7.3), we can say that

・strong obstacles ・・・ $F_m / (2T_L) \approx 1$, $\phi_c \approx 0$ (yielding at semi-circular dislocation shape)
・weak obstacles ・・・ $F_m / (2T_L) << 1$, $\phi_c \approx \pi$ (yielding before semi-circular shape)

If we know F_m (or ϕ_c) and L, we find τ_m. → hardening theories

7.4 Are the strong obstacles more effecive in material strengthening than the weak obstacles?

Answer → NO!!

Usually, weak obstacles are much smaller than strong obstacles. This means that much more weak obstacles can be distributed on a unit area of a slip plane. Naturally, L in Eq. (7.2) can be made much smaller. Therefore, even when F_m is small, τ_m can be large.

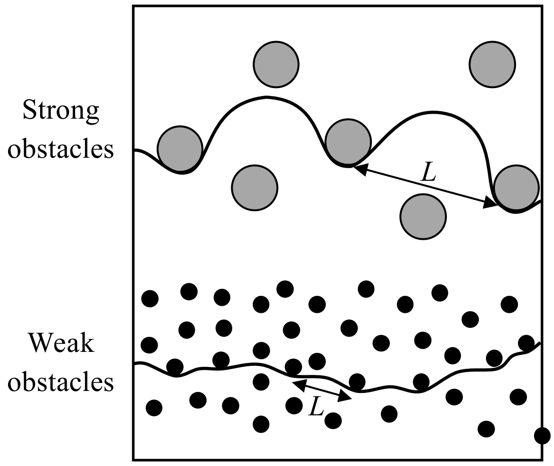

Fig. 7.4 Strong obstacles *vs* weak obstacles. See the difference in the distance between obstacles L.

Problem 7.1

We know that slip deformation occurs more uniformly in dispersion-hardened alloys than in precipitation-hardened alloys. Explain the reason why.
