## *Mechanisms of plastic deformation in metals*

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(Under section 3 of UGC Act 1956)

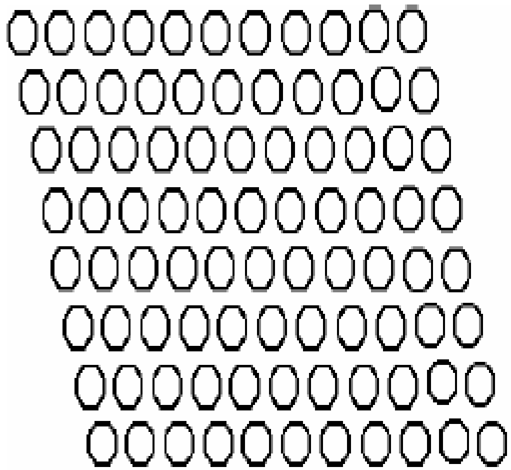
- Two prominent mechanisms of plastic deformation, namely ***slip and twinning .***
- **Slip** is the prominent mechanism of plastic deformation in metals. It involves sliding of blocks of crystal over one other along definite crystallographic planes, called slip planes.
- it is analogous to a deck of cards when it is pushed from one end. Slip occurs when shear stress applied exceeds a critical value.

- During slip each atom usually moves same integral number of atomic distances along the slip plane producing a step, but the orientation of the crystal remains the same.
- Generally slip plane is the plane of greatest atomic density, and the slip direction is the close packed direction within the slip plane.

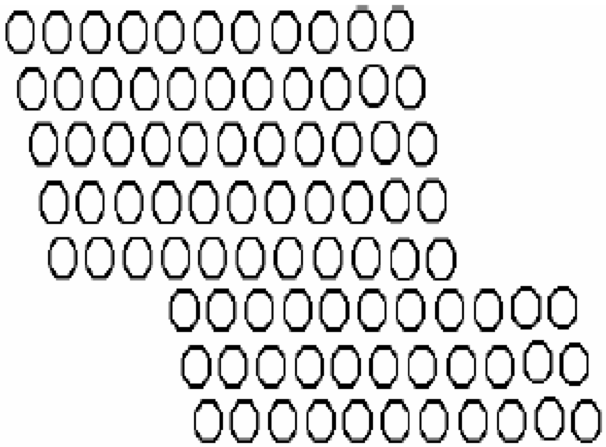
**Twining :**

- Portion of crystal takes up an orientation that is related to the orientation of the rest of the untwined lattice in a definite, symmetrical way.

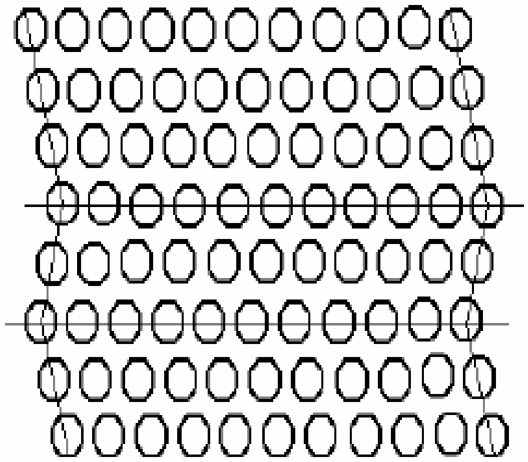
- The twinned portion of the crystal is a mirror image of the parent crystal.
- The plane of symmetry is called twinning plane.
- The important role of twinning in plastic deformation is that it causes changes in plane orientation so that further slip can occur.



Undeformed Crystal



After Slip



After Twinning

# Strengthening mechanisms in Metals

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**For single phase metals :**

- grain-size reduction
- solid-solution alloying
- strain hardening

**Multi-phase metallic materials :**

- Precipitation hardening
- Dispersion hardening
- Fiber strengthening
- Martensite strengthening

# Strain hardening *or work hardening:*

- The phenomenon where ductile metals become stronger and harder when they are deformed plastically is called strain hardening *or work hardening.*
- Intensity of strain hardening can be gaged from the slope of the flow curve, defined by the parameter strain hardening exponent, *n. It is measure of the ability of a metal to strain harden .*
- For a given amount of plastic strain, higher the value of n, greater is the strain hardening.
- Increasing temperature lowers the rate of strain hardening, and thus the treatment is given, usually, at temperatures well below the melting point of the material. Thus the treatment is also known as cold working.

- The consequence of strain hardening a material is improved strength and hardness but material's ductility will be reduced.
- Strain hardening is used commercially to enhance the mechanical properties of metals during fabrication procedures.
- In addition to mechanical properties, physical properties of a material also changes during cold working. There is usually a small decrease in density, an appreciable decrease in electrical conductivity, small increase in thermal coefficient of expansion and increased chemical reactivity (decrease in corrosion resistance).

# *Solid Solution Strengthening :*

- Impure foreign atoms in a single phase material produces lattice strains which can anchor the dislocations.
- Effectiveness of this strengthening depends on two factors Size difference and volume fraction of solute.
- Solute atoms interact with dislocations in many ways:

-elastic interaction

-modulus interaction

-stacking-fault interaction

-electrical interaction

-short-range order interaction

-long-range order interaction

- Elastic, modulus, and long-range order interactions are of long-range i.e. they are relatively in sensitive to temperature and continue to act about 0.6*Tm.*

# *Dispersion Hardening :*

- In dispersion strengthening, hard particles are mixed with matrix powder and consolidated and processed by powder metallurgy techniques.
- Second phase shall have very little solubility in the matrix, even at elevated temperatures .
- Dislocation moving through matrix embedded with foreign particles can either cut through the particles *or bend around and by pass them.*
- Cutting of particles Is easier for small particles which can be considered as segregated solute atoms.Effective strengthening is achieved in the bending process,when the particles are submicroscopic in size.

# *Fiber strengthening :*

- Second phase material can also be introduced into matrix in form of fibers to strengthen it.
- Prerequisites are materials to be used as fibers include high strength and/or high strength-to-weight ratio.
- Fibers usually, thus, have high strength and high modulus while the matrix must be ductile and non-reactive with the fibers.
- Fibers may be long and continuous or they may be discontinuous.
- Examples for fiber material: Al2O3, boron, graphite, metal, glass, etc. Examples for matrix material: metals, polymers. Fiber reinforced materials are an important group of materials known as composite materials

# Superplasticity :

- Superplasticity is the capability to deform crystalline solids in tension to unusually large plastic strains, often well in excess of 1000%.
- This phenomenon results from the ability of the material to resist localized deformation much the same as hot glass does .
- As high elongations are possible, complex contoured parts can be formed in a single press cycle often eliminating the need for multipart fabrications.
- Thus materials with superplastic properties can be used to form complex components in shapes that are very near the final dimension