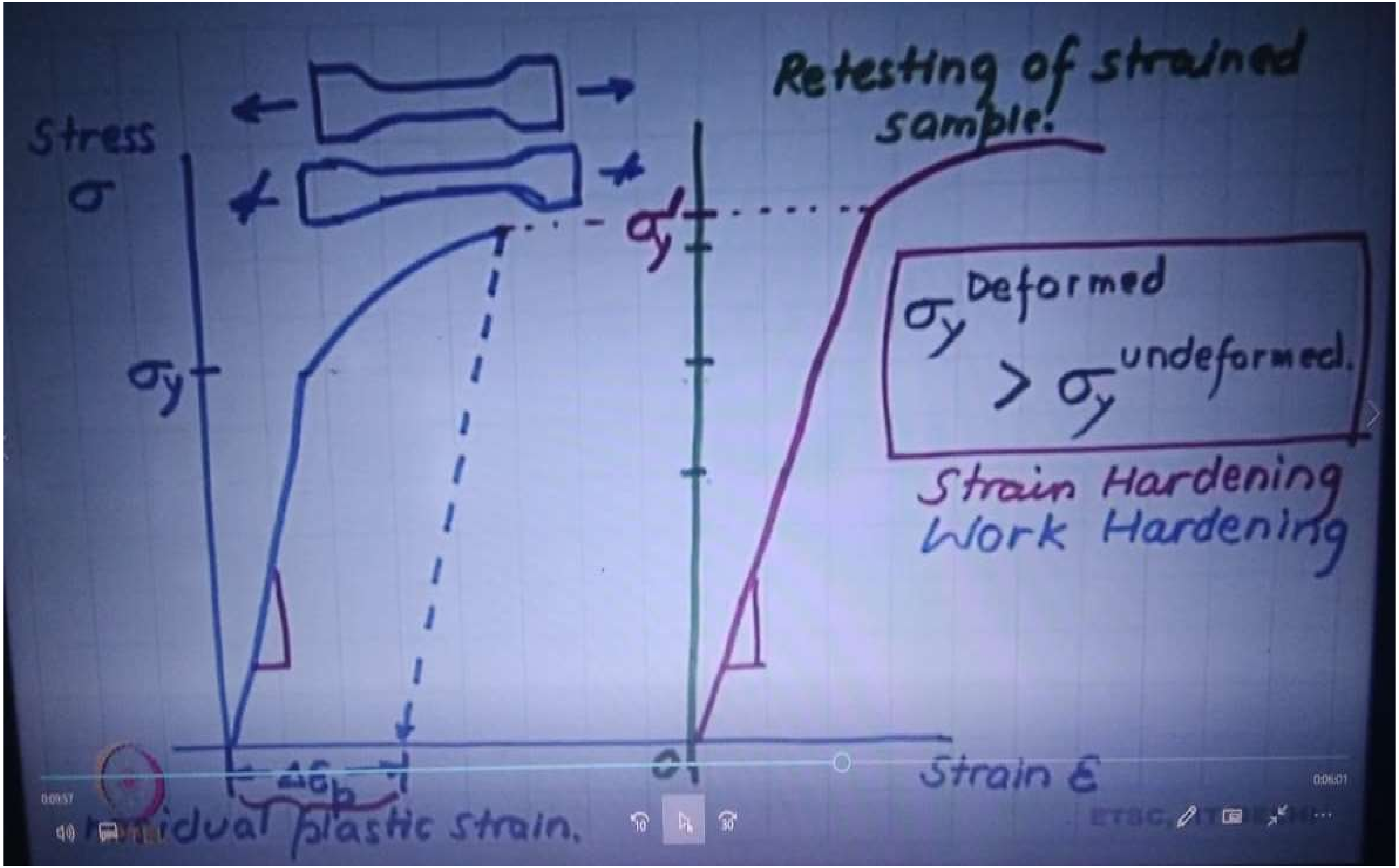
CLASS -5

9th August 2021

STRAIN HARDENING



(1) Plastic deformation increases the dislocation density.

(2) Dislocation weakens the crystal.

(1) + (2) $\Longrightarrow$ Deformed crystal should be weaker !

Experimentally, Deformed crystal is stronger (Strain Hardening).

Dislocation - Dislocation Interactions.

⇒ Interference by other dislocation for motion of a given dislocation

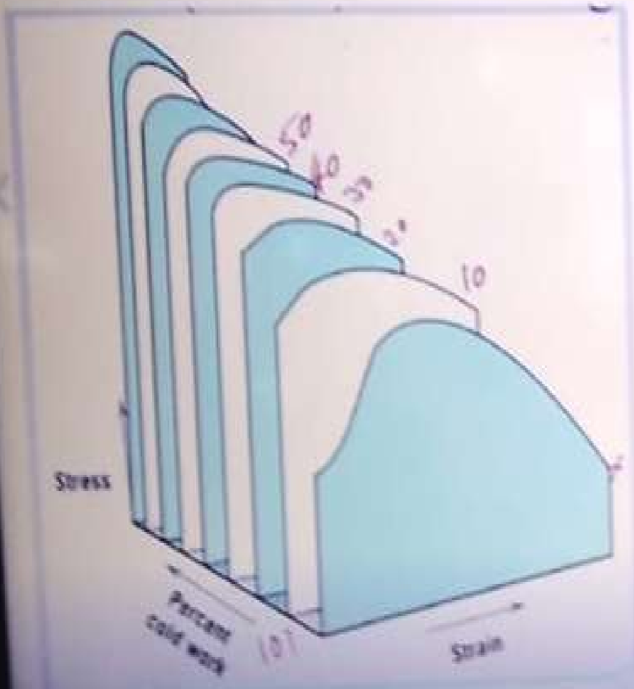
→ Difficulty in motion

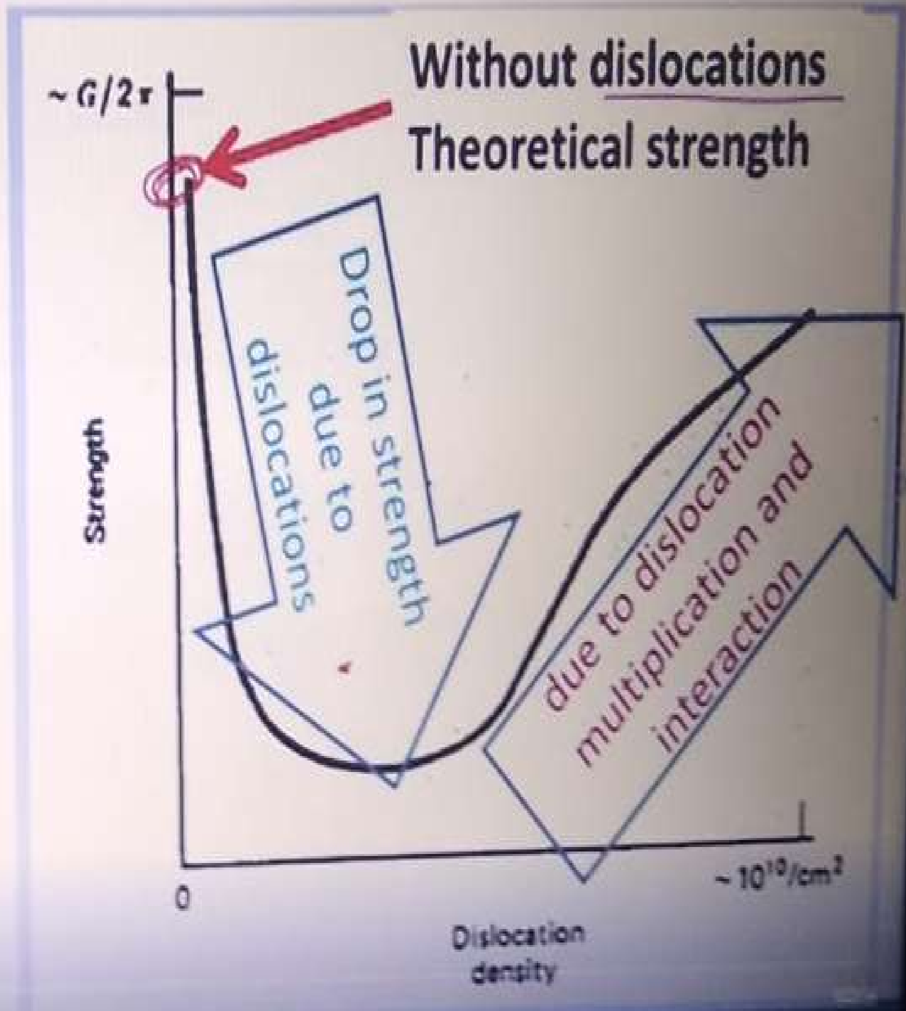
⇒ Strengthening

- FEW PERCENT OF PLASTIC DEFROMATION
- 50,000 KM LINES IN EACH CUBIC CENTIMETER
- IF YOU ENLARGE A CUBIC CENTIMETER TO THE SIZE OF THE AUDITORIUM, THESE LINS WILL BE LOOKED AS A SPIDER'S WEB IN THREE DIMENSIONS OF MESH SIZE VARYING FROM 0.1 MM TO 1.0 MM
- MOVENT THEREFROE, BECOMES VERY TOUGH
- TEM GIVES MISLEADING INFORMATION AS IT REPRESENT A VERY SMALL PART OF MATERIAL AND THEY TEND TO MISS MOST OF THE DISLOCATION NODES AND GIVE THE IMPRESSION THAT DISLOCATION DISLOCATION IS LESS TIGHTLY LINKED THAN IT REALLY IS

Strength and dislocation density

Taylor (1934) first recognized that work hardening is due to dislocation interactions.





Taylor's theory

- Moving dislocations interact with each other and get trapped.
- Trapped dislocations give rise to internal stresses that increase the stress necessary for deformation.
- The effective internal stress, τ, caused by these interactions is the stress necessary to force two dislocations past each other

$$\tau = Kb\sqrt{\rho}$$

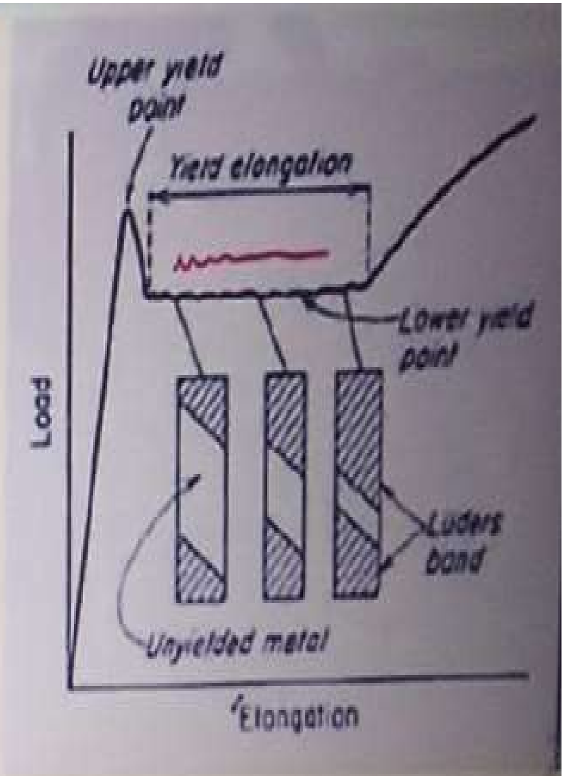
→ dislocation density

$\frac{m}{m^3}$ ⇒ no of dislocat/m^2

Mean spacing between dislocations, $L = \rho^{-0.5}$

Yield point phenomenon

Yield point elongation - Metals, particularly low-carbon steel , show a localised heterogeneous transition from elastic to plastic deformation.



- The load after the upper yield point suddenly drop to approximately constant value (lower yield point) and then rises with further strain.
- The elongation which occurs at constant load is called the yield-point elongation, which is heterogeneous deformation.
- Lüder bands are formed at approximately 45° to the tensile axis during yield point elongation and propagate over the specimen.

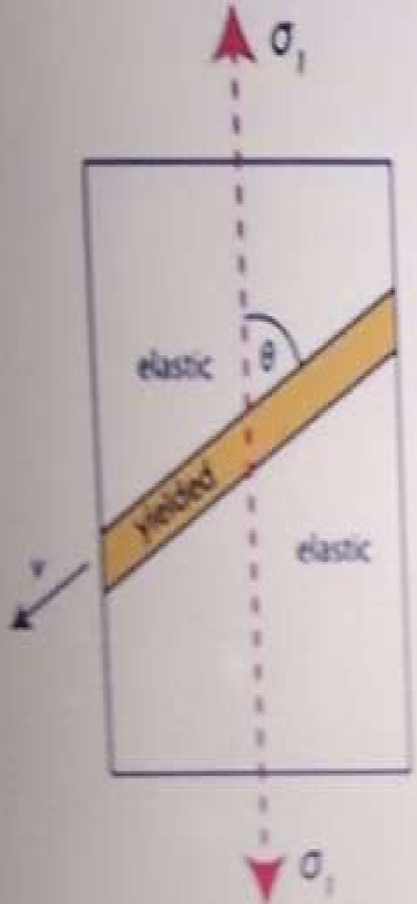
HARTMANN LINES,STRETHER STRAINS - PIOBERT EFFECT

The upper and lower yield point

- The upper yield point is associated with small amounts of interstitial or substitutional impurities.
- The solute atoms (C or N) in low carbon steel, lock the dislocations, - raise the initial yield stress (Upper yield point)
- When the dislocation is pulled free from the solute atoms, slip can occur at lower stress - The lower yield point
- The magnitude of the yield-point depends on interaction energy, concentration of solute atoms

The yield point phenomenon has been observed in Fe, Ti, Mo, Cd, Zn, Al alloys

The upper and lower yield point



Lüders bands formation in steel,
(Mike Meier, University of California, Davis.)

Luder bands affect surface finish of the formed component (sheet metal work on car bodies). Prompted development of IF (interstitial free) steels.

[redacted] the upper yield point can be roughly twice the lower yield point. However, it is more usual to obtain an upper yield point 10 to 20 percent greater than the lower yield point.

The onset of general yielding occurs at a stress where the average dislocation sources can create slip bands through a good volume of the material. Thus, the general yield stress can be expressed as

$$\sigma_0 = \sigma_s + \sigma_i \tag{6-16}$$

where σ_s is the stress to operate the dislocation sources and σ_i is the friction stress representing the combining effect of all the obstacles to the motion of dislocations arising from the sources. [redacted] as LiF and Ge crystals and copper whiskers. In these materials the dislocation density is quite low and impurity pinning cannot explain the effect. A more general theory has been advanced[1] for all materials which exhibit a *yield drop*, i.e., where the stress falls rapidly once yielding begins. Impurity locking thus becomes a special case of yield-point behavior.

The relation between the strain rate imposed on the material by the test and the dislocation motion is given by

$$\dot{\varepsilon} = b\rho\bar{v}$$

where ρ is the density of mobile dislocations and $\bar{v}$ is the average dislocation velocity. The dislocation density increases with strain and $\bar{v}$ is a very strong function of stress

$$\bar{v} = \left(\frac{\tau}{\tau_0}\right)^{m'}$$

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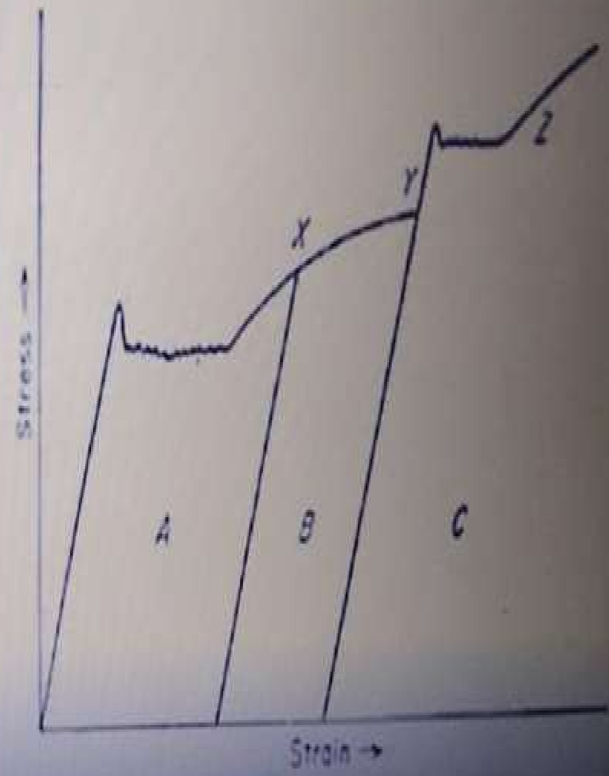
where τ_0 is the resolved shear stress corresponding to unit velocity. For materials with a low initial dislocation density (or with strongly pinned dislocations, as in iron) the only way that $b\rho\bar{v}$ can match the imposed strain rate is for $\bar{v}$ to be high. But, according to Eq. this can only be achieved at a high stress. However, once some dislocations begin to move they begin to multiply and ρ increases rapidly. Although this introduces some strain hardening, it is more than compensated for by the fact that $\bar{v}$ can drop and with it the stress needed to move the dislocations can drop. Thus, the stress required to deform the specimen decreases once yielding begins (yield drop). Finally, the increasing dislocation density produces increased strain hardening through dislocation interactions and the stress begins to increase with further strain. (here is the

Strain aging

Strain ageing is a phenomenon in which the strength of a metal increased with lose in ductility after being heated at relatively low temperature after cold-working.

- Reloading at X and straining to Y does not produce yield point.
- After this point if the specimen is reloading after ageing the Yield point will reappear at a higher value.
- This reappearance of the yield point is due to the diffusion of C and N atoms to the core of dislocation and acting as anchor



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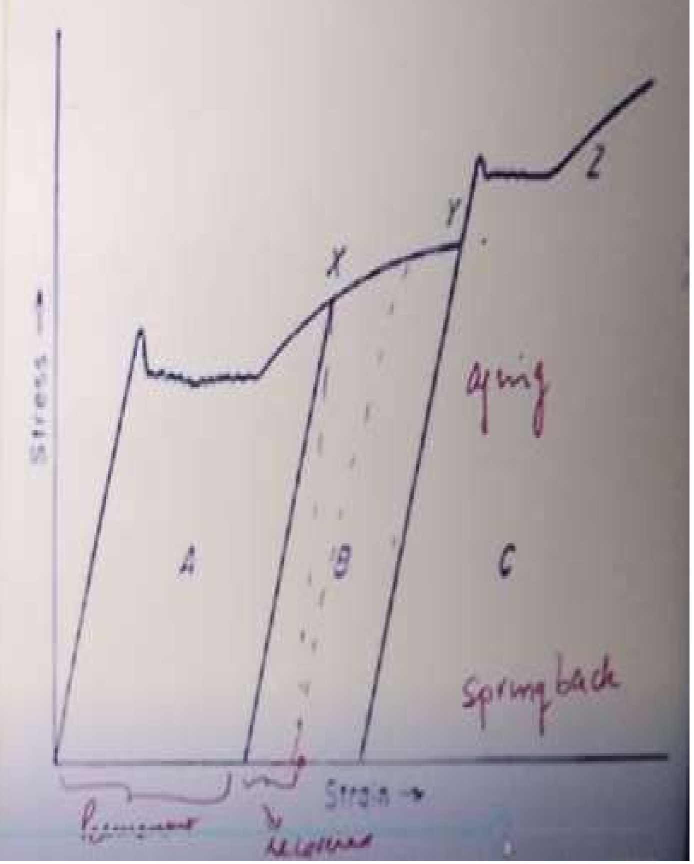


Strain aging

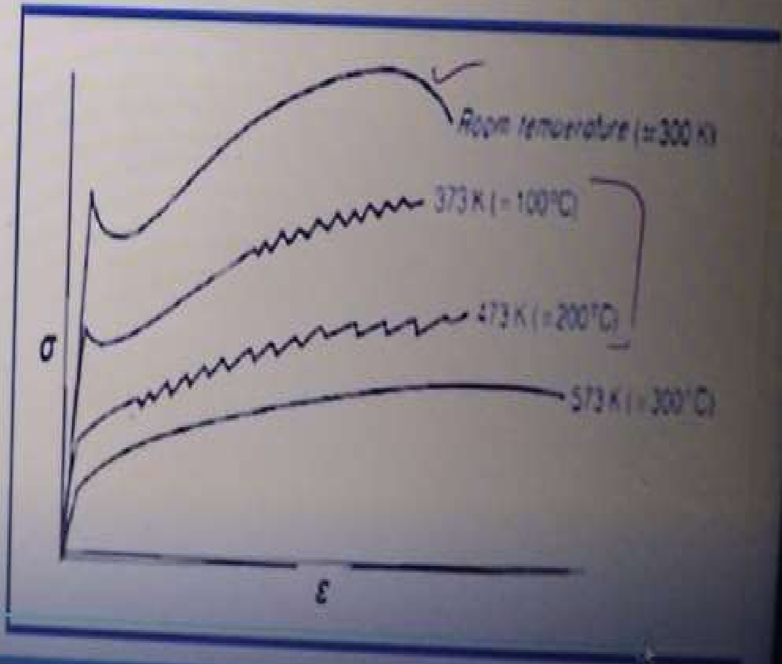
Strain aging should be eliminated in deep drawing steel since it leads to surface marking or stretcher strains .

The amount of C and N should be lowered by adding elements such as Al, Ti, B to form carbides or nitrides

Dynamic strain ageing

Strain ageing is also associated with serrated stress-strain curves or repeated yielding, due to high speed of diffusion of solute atoms to catch and lock dislocations.

This dynamic strain ageing is also called Portevin-LeChatelier effect



Dynamic strain aging is detrimental to the ductility of the material

THANK YOU