Yield point phenomenon

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

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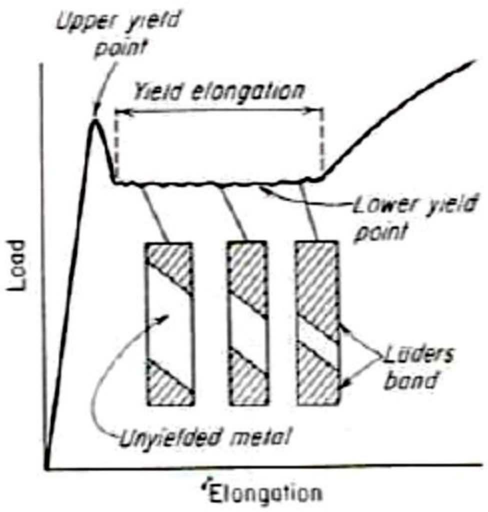


• The load after the upper yield point suddenly drop to approximately constant value (lower yield point) and then rises with further strain.

• The elongation which occurs at constant load is called the yield-point elongation, which are heterogeneous deformation.

• Lüder bands or stretcher strains are formed at approximately 45^{o} to the tensile axis during yield point elongation and propagate over the specimen.

Note: The yield point phenomenon has also been observedin other metals such as Fe, Ti, Mo, Cd, Zn, Al alloys.

The upper 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.

• The breakaway stress required to pull a dislocation line away from a line of solute atoms is

$$\sigma \approx \frac{A}{b^2 r^2}$$

Where A is $4Gba^3\varepsilon$, a is atomic radius r_o is the distance from the dislocation core to the line of solute atoms ~ 0.2 nm.

• When the dislocation is pulled free from the solute atoms, slip can occur at lower stress. → the lower yield point.

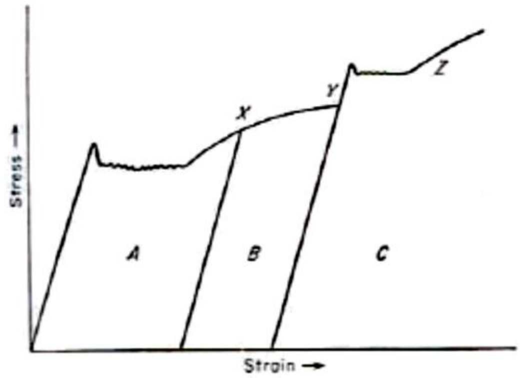
The magnitude of the yield-point effect depends on interaction energy, concentration of solute atoms.

Note: Upper yield point is promoted by using elastically rigid machine, careful axial alignment of specimen (free from stress concentrations, high strain rate, low temperature.)

Strain ageing

Strain ageing is a phenomenon in which the metal increase in strength while losing ductility after being heated at relatively low temperature or cold-working.

The reappearing of the (higher) yield point after ageing is obtained, see fig.



Strain ageing in low carbon steel.

• Reloading at X and straining to Y does not produce yield point.

• After this point if the specimen is reloading after ageing (RT or ageing temp) the yield point will reappear at a higher value.

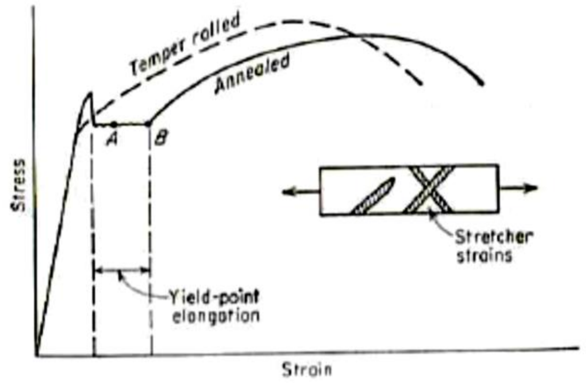
• This reappearance of the yield point is due to the diffusion of C and N atoms to anchor the dislocations.

• N has more strain ageing effect in iron than C due to a higher solubility and diffusion coefficient.

Stretcher strains

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

• To solve the problem, the amount of C and N should be lowered by adding elements such as Al, V, Ti, B to form carbides or nitrides.



Relation of stretcher strain in stress-strain curve

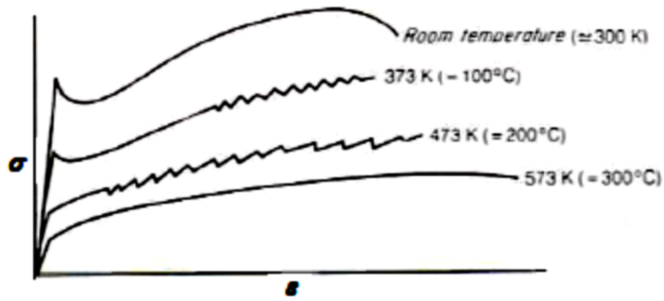
Stretcher strain in low-carbon steel

Serrated stress strain curves

• Strain ageing increases yield point but lower ductility.

• 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.



Portevin-LeChaterier effect.

Blue brittleness

Blue brittleness occurs in plain carbon steel in which discontinuous yielding appears in the temperature range 500 to 650 K.

During this blue brittleness region, steels shown

• Decreased tensile ductility.

• Decreased notched-impact resistance.

• Minimum strain rate sensitivity.

Note: This is just an accelerated strain aging by temperature.