MANUFACTURING SCIENCE-I

UNIT-3

METAL FORMING PROCESS

Forming can be defined as the process in which desired shape and size are obtained through the plastic deformation of the material the stresses include during the process are greater than the yield strength of loading applied may be tensile, compressive, bending or shearing or the combination of the above. Forming is very economical since there is no loss of material.

ELASTIC DEFORMATION:

If an external load is applied to a metallic piece it is deformed elastically displacing individual atoms from their equilibrium position. Tensile stresses developed try to increase the inter atomic spacing while compressive stresses try to decrease on the removal of load the loading does not exceed the elastic limit original position of the atoms are regained elastic behaviour is governed by Hooke's law.

PLASTIC DEFORMATION:

It is the permanent deformation which present even after the removal of external loads in crystalline materials at temp. Level greater than 0.4 T_m . the permanent deformation is called plastic deformation. It is the function of stress temp. rate of straining and the stress may be tensile compressive or shear. This deformation takes place by the process slip and twining the plastic deformation makes the forming process possible like rolling and forging etc.

PLASTIC DEFORMATION AND YIELD CRITERIA:

The plastic deformation takes place when applied stress level exceed. The surface level defined the yield stress, following are the two criterion.

1. **TRESCA'S MAX SHEAR STRESS CRITERIAN:**

According to Tresca the plastic flow initiates when the max shear stress reaches a limiting value defined as shear yield stress (K)

If the principle stresses at a point in the material are σ_1 σ_2 and σ_3 ($\sigma_1 \geq \sigma_2 \geq \sigma_3$) then

max shear stress τ_{max} is given by

$$\tau_{max} = ½ (\sigma_1 - \sigma_3)$$

Plastic deformation occurs when

$$\tau_{max} = K$$

Hence Tresca criteria become

$$½ (\sigma_1 - \sigma_3) = K\text{----------} \qquad (1)$$

It is evident from the equation that yielding is independent of intermediate principle stress σ_2.

2. **VAN MISES MAX DISTORTION ENERGY CRITERIAN:**

According to van mises the plastic flow occurs when the shear strain energy reaches the critical value.

The shear strain energy per unit volume (ε) can be express in terms of three principle stress as

$$E= 1/6G [(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]$$

According to this criterion plastic flow occurs when the RHS of the above equation reaches a critical valve say ‘A’ hence the criteria becomes

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 6AG = C\text{----------} \qquad (2)$$

Where C is constant

In this criterion the initiation of plastic deformation of flow depends on all three principle stresses.

RELATIONSHIP BETWEEN TENSILE AND SHEAR YIELD STRESSES:

To applied the yield criteria it is necessary to know the right hand side of equation (2) Material properties are determined from uniaxial tensile test which give the value of tensile yield stress (σ_y) which can be used to determine the shear yield stress (K)

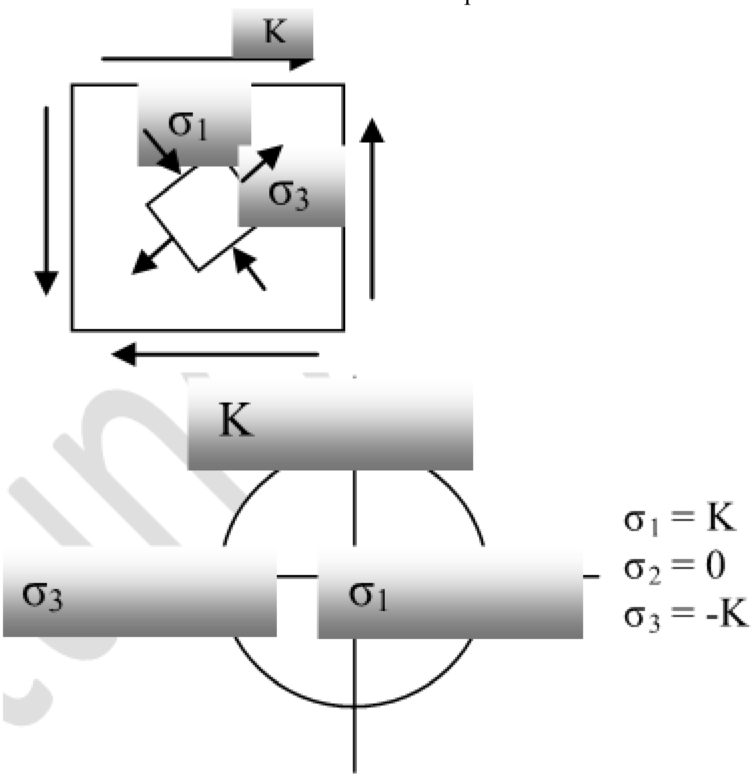
When yielding occurs under Uniaxial tensile loading

$\sigma_1 = \sigma_y, \quad \sigma_2 = \sigma_3 = 0$

Hence the constant from equation (2) will be

$C = 2\,\sigma_y^2$

Considering yielding under pure torsion the state of stress in a material for a two dimensional situation is shown with the help of Mohr’s circle



It is clear from Mohr’s Circle that

$$\sigma_1 = K, \quad \sigma_2 = 0, \sigma 3 = -K$$

Substituting these values in equation (2) we get

$$C = 6K^2$$

Since the constant C is independent of type of loading the relation between K and σ_y can be obtain by equating the two values of C

$$K = \sigma_y/\sqrt{3}$$

Applying Tresca's yield criterion to these two pure loading conditions. The relation between K and σ_y is

$$K = \sigma_y/2$$

COLD AND HOT WORKING OF METALS

COLD WORKING:

Plastic deformation of metals below the recrystallization temperature is known as cold working. It is generally performed at room temperature. In some cases, slightly elevated temperatures may be used to provide increased ductility and reduced strength. Cold working offers a number of distinct advantages, and for this reason various cold-working processes have become extremely important. Significant advances in recent years have extended the use of cold forming, and the trend appears likely to continue.

In comparison with hot working, the **advantages** of cold working are

1. No heating is required
2. Better surface finish is obtained
3. Better dimensional control is achieved; therefore no secondary machining is generally needed.
4. Products possess better reproducibility and interchangeablity.
5. Better strength, fatigue, and wear properties of material.
6. Directional properties can be imparted.
7. Contamination problems are almost negligible.

Some **disadvantages** associated with cold-working processes are:

1. Higher forces are required for deformation.
2. Heavier and more powerful equipment is required.
3. Less ductility is available.
4. Metal surfaces must be clean and scale-free.
5. Strain hardening occurs (may require intermediate annealing).
6. Undesirable residual stresses may be produced

Cold forming processes, in general, are better suited to large-scale production of parts because of the cost of the required equipment and tooling.

HOT WORKING:

Plastic deformation of metal carried out at temperature above the recrystallization temperature, is called hot working. Under the action of heat and force, when the atoms of metal reach a certain higher energy level, the new crystals start forming. This is called recrystallization. When this happens, the old grain structure deformed by previously carried out mechanical working no longer exist, instead new crystals which are strain -free are formed. In hot working, the temperature at which the working is completed is critical since any extra heat left in the material after working will promote grain growth, leading to poor mechanical properties of material.

In comparison with cold working, the **advantages** of hot working are

1. No strain hardening
2. Lesser forces are required for deformation
3. Greater ductility of material is available, and therefore more deformation is possible.
4. Favourable grain size is obtained leading to better mechanical properties of material

5. Equipment of lesser power is needed
6. No residual stresses in the material.

Some **disadvantages** associated in the hot-working of metals are:

1. Heat energy is needed
2. Poor surface finish of material due to scaling of surface
3. Poor accuracy and dimensional control of parts
4. Poor reproducibility and interchangeability of parts
5. Handling and maintaining of hot metal is difficult and troublesome
6. Lower life of tooling and equipment.