METAL FORMING TECHNOLOGY (PCPD4306)

By
Mr. HIMANSU SEKHAR DASH
Assistant Professor

DEPARTMENT OF PRODUCTION ENGINEERING
INDIRA GANDHI INSTITUTE OF TECHNOLOGY, SARANG
(An Autonomous Institute of Government of Odisha)
Dhenkanal, Odisha- 759146
www.igitsarang.ac.in

INDIRA GANDHI INSTITUTE OF TECHNOLOGY, SARANG
B. TECH SYLLABUS FOR PRODUCTION ENGINEERING
(2018-19 Admission Batch)
5th Semester

PCPD4306	METAL FORMING TECHNOLOGY	3L-0T-0P	3 Credits

Course Objective
This course provides basic knowledge to understand and apply the mechanism of deformation for different metal forming processes and develop analytical relation between input and output parameters of process.

Module I **[12]**
Introduction: Principle of plastic deformation and yield criteria, Recrystallization, Fundamental of hot and cold Working processes, advantages and disadvantages; Effect of strain rate on forming process. Methods of metal forming processes, advantages, disadvantages and application.

Module II **[12]**
Forging: Classification of forging, closed die forging, Open die forging, Drop forging, Machine forging, Load estimation in forging, analysis of forging: sticking friction model, sliding friction model, pre forming operations: Fullering, Drawing, Offsetting, Edging, Flattening, Chamfering, Bending, Swaging, Finishing, Trimming, Defects in forging.
Rolling: Assumptions, Neutral point, deformation angle, Principle of rolling, Rolling stand arrangement, Rolling load calculation, Power required for rolling, Roll passes, Flat rolling, Pipe rolling, Defects in rolled products.

Module III **[12]**
Extrusion: Extrusion types, Forward, backward extrusion, Hydrostatic Extrusion, Impact Extrusion, Calculation of force in extrusion, Load estimation in extrusion, Extrusion of tubes, Defects in Extrusion.
Drawing: Wire drawing, Different types of lubricant condition, Drawing load and force calculation, Tube drawing, Types of mandrel, Drawing defects.

Module IV **[08]**
Sheet Metal Forming: Sheet metal working-shearing, Major operation, Minor operation, Mechanism of Blanking, Piercing, Load estimation in blanking and piercing, Methods of reducing shear force, **Deep Drawing Operation**. Design of blank, Load required, Blank holder force, stresses induced, Draw ratio method, Defects in deep drawing operation.
Bending: Principle of bending, Types of bending, Spring back effect.

Text Books:
1. Manufacturing Technology, P. N. Rao Vol. 3 3rd Edition, TMH Publication
2. Manufacturing Engineering and Technology, S. Kalpakian, S. Schimid, Pearson Publication

Reference Books:
1. Mechanical metallurgy by G. W Dieter

Learning Outcomes:
Upon successful completion of the course, student will able to:
- *Understand the properties of ductile metals*
- *Understand the effects of temperature, speed on metal forming process*
- *Understand the principle, procedure and applications of Bulk Metal Forming and Sheet Metal Forming*

MODULE-I

INTRODUCTION

Metal forming processes, also known as mechanical working processes, are primary shaping processes in which a mass of metal or alloy is subjected to mechanical forces. Under the action of such forces, the shape and size of metal piece undergo a change. By mechanical working processes, the given shape and size of a machine part can be achieved with great economy in material and time. Metal forming is possible in case of such metals or alloys which are sufficiently malleable and ductile. Mechanical working requires that the material may undergo "plastic deformation" during its processing. Frequently, work piece material is not sufficiently malleable or ductile at ordinary room temperature, but may become so when heated. Thus we have both hot and cold metal forming operations.

When a single crystal is subjected to an external force, it first undergoes elastic deformation; that is, it returns to its original shape when the force is removed. For example, the behavior is a helical spring that stretches when loaded and returns to its original shape when the load is removed. If the force on the crystal structure is increased sufficiently, the crystal undergoes plastic deformation or permanent deformation; that is, it does not return to its original shape when the force is removed.

There are two basic mechanisms by which plastic deformation takes place in crystal structures. One is the slipping of one plane of atoms over an adjacent plane (called the slip plane) under a shear stress. The behavior is much like the sliding of playing cards against each other. Shear stress is defined as the ratio of the applied shearing force to the cross-sectional area being sheared, just as it takes a certain magnitude of force to slide playing cards against each. In other word we can say that a single crystal requires a certain amount of shear stress (called critical shear stress) to undergo permanent deformation. Thus, there must be a shear stress of sufficient magnitude within a crystal for plastic deformation to occur; otherwise the deformation remains elastic.

The second and less common mechanism of plastic deformation in crystals is **twinning**, in which a portion of the crystal forms a mirror image of itself across the plane of twinning. Twins form abruptly and are the cause of the creaking sound ("tin cry") that occurs when a tin or zinc rod is bent at room temperature. Twinning usually occurs in HCP metals.

Commonly used Yield Criteria:

The yield criteria of materials limit the elastic domain during loading whereas the failure criteria give the maximum stress that can be applied. We use the yield criteria for metals alloys and failure criteria for geo material like soil and concrete.

Some of the commonly used yield criteria are

- Von Mises yield criteria (Von Mises (1913) suggested that yielding will occur when second invariants of deviatoric stress tensor reaches a critical value.)
- Tresca yield criteria (According to the Tresca yield criteria, yielding of material begin to occur when maximum shearing stress at a point reaches a critical value)

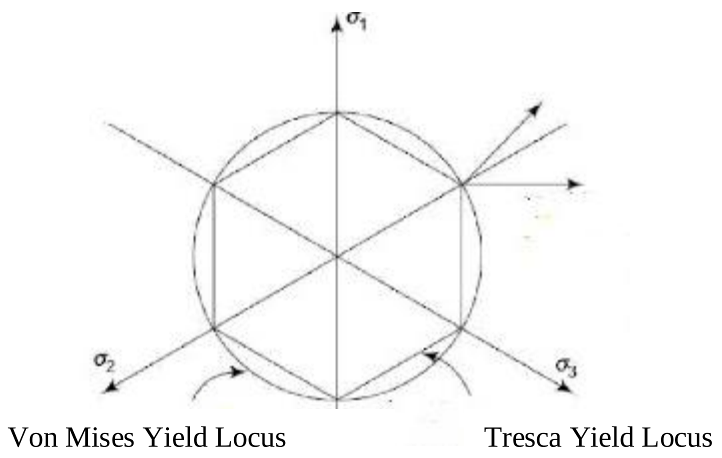


Fig 1: Locus of Tresca and Von Mises yield criteria on Deviatoric Plane

Classification of Metal Working based on temperature

Cold Working: Cold working may be defined as plastic deformation of metals and alloys at a temperature below the recrystallization temperature for that metal or alloy. In cold working process the strain hardening which occurs as a result of mechanical working, does not get relieved. In fact as the metal or alloys gets progressively strain hardened, more and more force is required to cause further plastic deformation. After sometime, if the effect of strain hardening is not removed, the forces applied to cause plastic deformation may cause cracking and failure of material.

Hot Working: Hot working may be explained as plastic deformation of metals and alloys at such a temperature above recrystallization temperature at which recovery and recrystallization take place simultaneously with the strain hardening.

Recrystallization temperature is not a fixed temperature but is actually a temperature range. Its value depends upon several factors. Some of the important factors are:

- **Nature of metal or alloy:** It is usually lower for pure metals and higher for alloys. For pure metals, recrystallization temperature is roughly one third of its melting point and for alloys about half of the melting temperature.
- **Amount of cold work already done:** The recrystallization temperature is lowered as the amount of strain-hardening done on the work piece increases.
- **Strain-rate:** Higher the rate of strain hardening, lower is the recrystallization temperature. For mild steel, recrystallization temperature range may be taken as 550–650°C. Recrystallization temperature of low melting point metals like lead, zinc and tin, may be taken as room temperature. The effects of strain hardening can be removed by annealing above the recrystallization temperature.

Advantages and Disadvantages of Cold and Hot Working Processes:

- As cold working is practically done at room temperature, no oxidation or tarnishing of surface takes place. No scale formation is there, hence there is no material loss where as in hot working, there is scale formation due to oxidation besides, hot working of steel also results in partial decarburization of the work piece surface as carbon gets oxidized as CO2.
- Cold working results in better dimensional accuracy and a bright surface. Cold rolled steel bars are therefore called bright bars, while those produced by hot rolling process are called black bars (they appear greyish black due to oxidation of surface.
- In cold working heavy work hardening occurs which improves the strength and hardness of bars, and high forces are required for deformation increasing energy consumption. In hot working this is not so.
- Due to limited ductility at room temperature, production of complex shapes is not possible by cold working processes.
- Severe internal stresses are induced in the metal during cold working. If these stresses are not relieved, the component manufactured may fail prematurely in service. In hot

working, there are no residual internal stresses and the mechanically worked structure is better than that produced by cold working.

- The strength of materials reduces at high temperature. Its malleability and ductility improve at high temperatures. Hence low capacity equipment is required for hot working processes. The forces on the working tools also reduce in case of hot working processes.
- Sometimes, blow holes and internal porosities are removed by welding action at high temperatures during hot working.
- Non-metallic inclusions within the work piece are broken up. Metallic and non-metallic segregations are also reduced or eliminated in hot working as diffusion is promoted at high temperatures making the composition across the entire cross-section more uniform.

Typical stress strain curves for easy deformation:

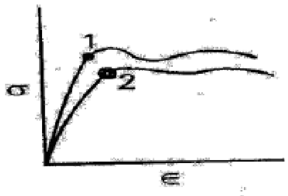
In Mechanical working of metals it is important to know that efforts are to be made to make the metal undergo deformation easily with less effort. The following figures illustrate what are the typical characteristics involved in the material.

For easy deformation of metal the stress strain curve should have:

1. Lower yield point
2. Gentle slope
3. Larger elongation behavior

1. Stress strain curve should have Lower yield point:

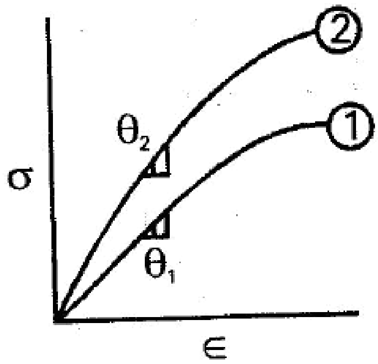
The load required for deformation is directly proportional to the yield point. Hence, if the yield point is high, higher load is required and lower the yield point of the material, lower is the loads required for deformation. The material with lower yield point can be easily shaped. In the figure material 2 has the lower yield point as compared to 1. Hence, it is easier to deform material 2. Whenever a material is heated to higher temperature the yield point is reduced and it becomes easier to deform.



σ-∈ Curve for easy deformation

2. **Stress strain should have Gentle slope:**

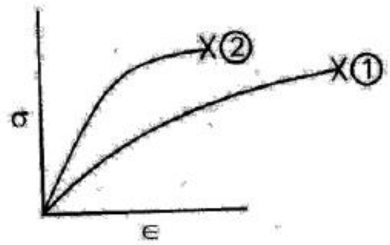
The stress strain curve should have lower gradient ie., gentle slope. It means the stiffness of the material must be low. Stress strain curve with lower gradient will have gentle slope. Gentle slope needs lesser strain rate and hence lower rate of loading. In figure material 1 has lower slope as compared to 2. Hence, material 1 is easier to deform



Slope of σ-∈ Curve

3. **Stress Strain curve should have Larger elongation behavior:**

A material with larger elongation will undergo more deformation without undergoing fracture, and it is extremely to shape the material. In the figure material 1 has larger elongation as compared to 2. Hence, material1 can be easily deformed.

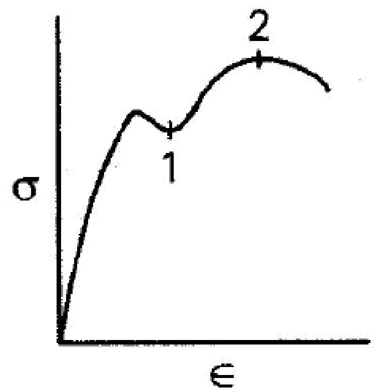


σ-∈ Curve with larger elongation

Strain hardening Type:

Some materials undergo strain hardening which means higher loads are required for deformation and more resistance is offered by the material. In the stress strain curve the strain hardening portion is represented by 12. If the slope12 is high, strain hardening of the material is more and it becomes difficult to deform.

By heating the material it can be softened and strain hardening is eliminated.



σ-∈ showing strain hardening

Effect of strain rate on Metal Forming Process:

Strain rate is the rate at which strain is induced in the metal. It is also a measure of rate of deformation, as the metal is being worked at a known speed. Viz., the rate at which deformation is taking place.

If V = Deformation Velocity, T = Instantaneous thickness of the metal

Then strain rate, έ = V/t

As strain rate increases, the metal becomes hardened and flow stress increases. An increase in the strain rate increases the strain hardening in the metal. The metal temperature required for deformation increases with increase in strain hardening.

Higher the rate of strain hardening, lower is the recrystallization temperature. For mild steel, recrystallization temperature range may be taken as 550–650°C. Recrystallization temperature of low melting point metals like lead, zinc and tin, may be taken as room temperature. The effects of strain hardening can be removed by annealing above the recrystallization temperature.

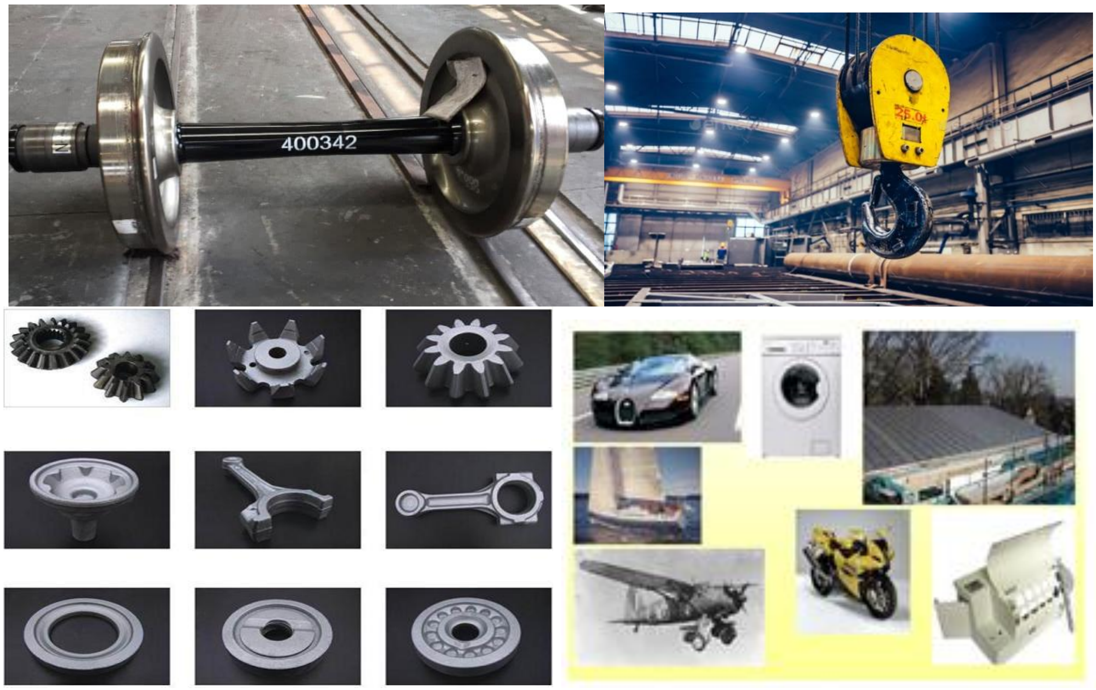
Advantages of Metal Forming Process:

- No wastage of Material
- Grain Orientation is possible
- Material would be converted from Isotropic to Anisotropic
- Strength and Hardness of the material is increasing.
- Good Surface Finish.
- Close Dimensional Accuracies also possible.

Disadvantages of Metal Forming Process:

- The product becomes highly anisotropic in nature.
- Final product has to be obtained after machining of the wrought product except in the case of structural components.
- Needs additional equipment and machinery for metal working process. Hence, initial investment is high.
- Maintenance cost is high.
- More safety precautions are to be exercised as hot metal and additional equipment's are used.
- The Force and Energy required for the metal forming process is much higher than the other manufacturing process.
- Except forging operation all other metal forming process are used for producing uniformed cross-section component only.
- In some metal forming process the surface finish is poor and poor dimensional accuracies produced

Applications of Metal Forming Process:



REFERENCE:

1) Metal Forming process by R. Ganesh Narayan, IIT Guwahati
2) Principles of metal forming Technology, by Prof. P. K. Jha, IIT Roorkee, NPTEL.
3) Fundamentals of Manufacturing Process, by Prof. D. K. Dwivedi, IIT Roorkee, NPTEL.
4) M.P. Groover, Fundamental of modern manufacturing Materials, Processes and systems, 4ed.
5) Manufacturing Engineering and Technology, S. Kalpakian, S. Schimid, Pearson Publication
6) “Mechanical Metallurgy” by G. W Dieter.