CONCEPT OF STRAIN HARDENING AND EFFECTS OF MECHANICAL WORKING

Advantages of metal working process

* Product with consistent high quality can be manufactured.
* Defects such as porosity and discontinuities are minimized.
* Inclusions get distributed evenly throughout the product.
* Grains are oriented in a particular direction and directional properties are obtained.
* In hot working the grains will be uniform and the properties are also uniform.
* In cold working the properties are enhanced due to strain hardening effect.
* Large tonnage can be easily produced.
*The process can be easily mechanized.

Limitations of Mechanical working process

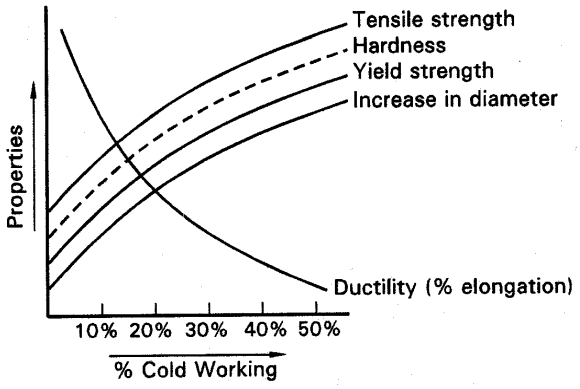
*The product becomes highly anisotropic in nature.
*Final product has to be obtained after machining of the wrought product except in the case of structural components.
*Needs additional equipment and machinery for metal working process. Hence, initial investment is high.
*Maintenance cost is high.
*More safety precautions are to be exercised as hot metal and additional equipments are used.

Concept of cold working

Consider a cylindrical metal piece with a known height, H and diameter, D. Let us subject the piece to compressive load at room temperature. We shall take that the height is reduced by 10%,20%,30% ….. etc., Each of these reduction in height represents %cold working. For each of these the diameter the Tensile strength, hardness, yield strength, %elongation were measured. It is seen that the %elongation decreases with increase in %cold working whereas other properties UTS, YS, Hardness increases and the diameter of the specimen also increases as shown in the figure.

Similarly the specimen can be subjected to tensile load also.

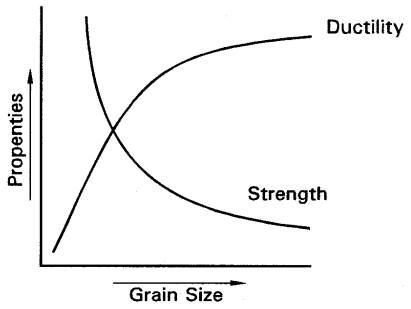
The changes that take place in the material due to cold working is an important aspect which needs to be born in mind while designing various steps in MW process.



Effect of cold working on properties

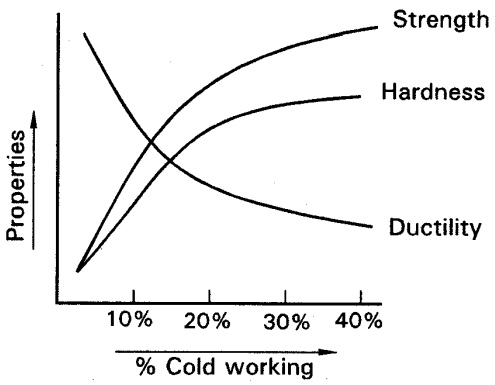
Effect of Mechanical Working on the properties of the Metal

Due to working of the metal there will be changes in the grain structure. The grains may be elongated in one direction from its equiaxed shape. The pores are reduced and the inclusions are fragmented and distributed evenly in the metal. In hot working the coarse equiaxed grains will become fine equiaxed. The changes obtained in cold working is appreciable.
The behaviour of the metal with changes in grain size is shown in the figure. As grain size becomes coarse the strength property comes down and ductility increases.



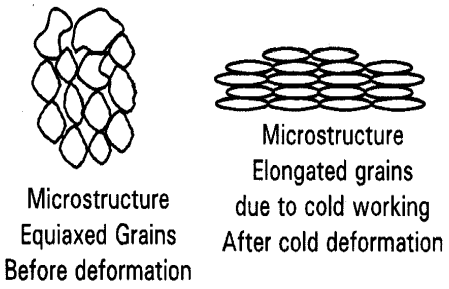
Variation of properties with respect to grain size

As the percentage of cold working increases the material becomes strain hardened, the hardness and strength properties are increased but the ductility property decreases as shown in the figure.



Variation of properties as a function of % cold working

It can be summarized as follows. Equiaxed grains will give uniform properties in all directions. Deformed grains show higher strength properties in the elongated direction.



Effect of cold working on grain structure

Concept of strain hardening

Straining of the metal/alloy occurs when subjected to cold working process. The metal will show more and more resistance for the external load as the cold working is Continued. At some it may become very difficult to deform the metal. This phenomenon is referred to as strain hardening effect. This can be explained in simple terms as given below.

All metals have atoms arranged in a repetitive manner in three dimensions referred to as crystalline structure. The structure is associated with imperfections in the form of dislocations. These dislocations starts moving towards the grain boundary region under the influence of external load. The dislocations get piled up near the grain boundaries. The density of dislocations increases due to Frank Reed source and may reach a value as high as 10^8-10^{12}/cm^2. Since, dislocations pile up near the grain boundary the density increases and the mean free path for the movement of dislocations decreases. The metal offers more resistance to external force. The metal will realize higher strength and this goes on building up till all the dislocations are brought near the grain boundary. Then annihilation of like and unlike dislocations takes place. The net existing dislocations will then become effective. During this period the load required for

deformation increases. This phenomenon is referred to as"Strain Hardening". If the cold working stress exceeds this range the metal will fracture.
To take care of this the metal is subjected to annealing before further working.

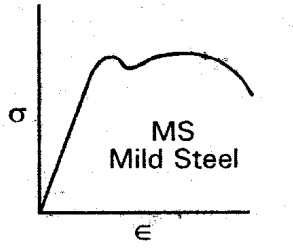
In Mechanical working of metals, the metal is subjected to external load and is deformed plastically. The given shape is obtained and is retained even after the removal of the load. The metal is subjected to stress and is strained. Hence, to understand the different mechanical working process, it is necessary to understand the stress strain relationship of metals, types of stress and strains, deformation process, theories used for the prediction of plastic deformation etc.,

For easy mechanical working of metals the nature of stress strain curve needs to be **reviewed.** The factors associated with stress strain needs to be studied.

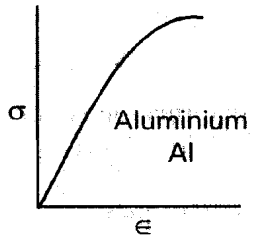
Different stress- strain curves

Some typical stress strain curves are shown below

Different stress strain curves
There exists relationship between stress and strain for all materials and it is very useful information for a design engineer and metallurgist alike. It clearly exhibits the behavior of the material. In order to understand the same we shall now look into stress strain curves of various materials. A study of these will help us in understanding the mechanical working process in a better way. The following figures represents pictorially the features of stress **and strain** behavior.



a) Highly ductile material



b) Mildly ductile material

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