FIRST CLASS

2018-2019

The principles of production processes

References

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K. I. ABASS

FUNDAMENTALS OF METAL FORMING

Metal forming includes a large group of manufacturing processes in which plastic deformation is used to change the shape of metal workpieces. Deformation results from the use of **a tool, usually called a die** in metal forming, which applies stresses that exceed the yield strength of the metal. The metal therefore deforms to take a shape determined by the geometry of the die. Stresses applied to plastically deform the metal are usually compressive. However, some forming processes stretch the metal, while others bend the metal, and still others apply shear stresses to the metal. To be success fully formed, a metal must possess certain properties. Desirable المرغوب فيه properties include low yield strength and high ductility. These properties are affected by temperature. Ductility is increased and yield strength is reduced when work temperature is raised.

- The effect of temperature gives rise to distinctions الفروق between **cold working, warm working, and hot working**.
- Strain rate and
- Friction are additional factors that affect performance in metal forming.

1. OVERVIEW OF METAL FORMING

Metal forming processes can be classified into two basic categories:
Bulk Deformation processes and Sheet Metal Working processes (Figure 1).

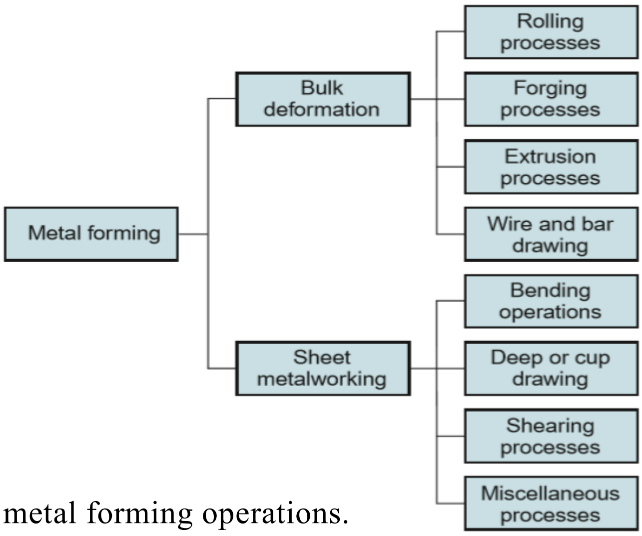

FIGURE 1. Classification of metal forming operations.

Bulk Deformation processes

Bulk deformation processes are generally characterized by significant deformations and massive ضخمة shape changes, and the surface area-to-volume of the work is relatively small. The term bulk describes the work parts that have this low area to-volume ratio. Starting work shapes for these processes include cylindrical billets and rectangular bars. (Figure 2)

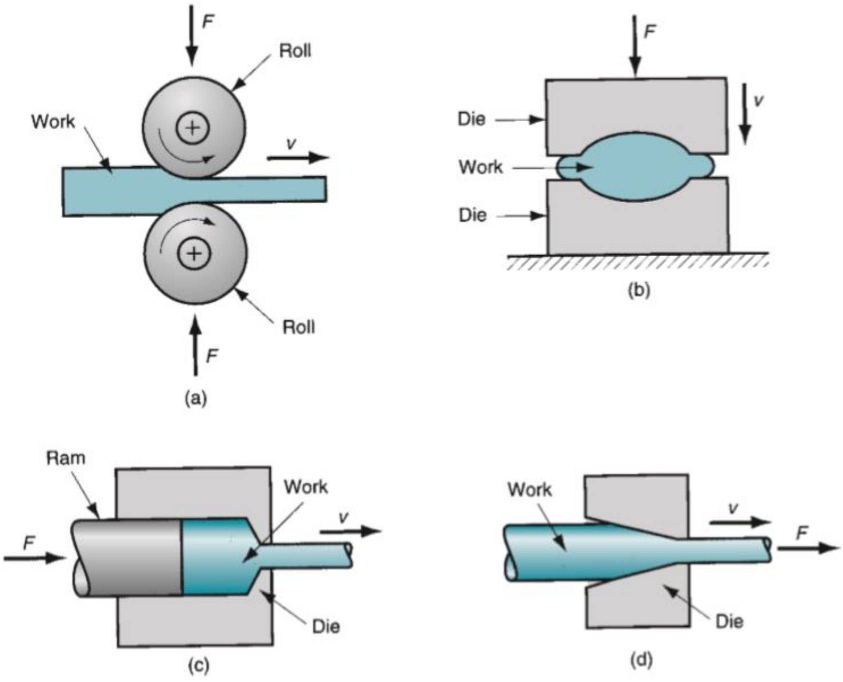

FIGURE 2. Basic bulk deformation processes:
(a) rolling, (b) forging, (c) extrusion, and (d) drawing.
Relative motion in the operations is indicated by v; forces are indicated by F.

- Rolling. This is a compressive deformation process in which the thickness of a slab or plate is reduced by two opposing cylindrical tools called rolls. The rolls rotate so as to draw the work into the gap between them and squeeze it.
- Forging. In forging, a work piece is compressed between two opposing dies, so that the die shapes are imparted to the work. Forging is traditionally a hot working process, but many types of forging are performed cold.
- Extrusion. This is a compression process in which the work metal is forced to flow through a die opening, there by taking the shape of the.
- Drawing. In this forming process, the diameter of a round wire or bar is reduced by pulling it through a die opening.

Sheet Metal Working processes

Sheet metal working processes are forming and cutting operations performed on metal sheets, strips, and coils. The surface area-to-volume ratio of the starting metal is high; thus, this ratio is a useful means to distinguish bulk deformation from sheet metal processes. Press working is the term often applied to sheet metal operations because the machines used to perform these operations are presses (presses of various types are also used in other manufacturing processes). A part produced in a sheet metal operation is often called a stamping. Sheet metal operations are always performed as cold working processes and are usually accomplished using a set of tools called a punch and die. The punch is the positive portion and the die is the negative portion of the tool set. The basic sheet metal operations are sketched in Figure 3 and are defined as follows:

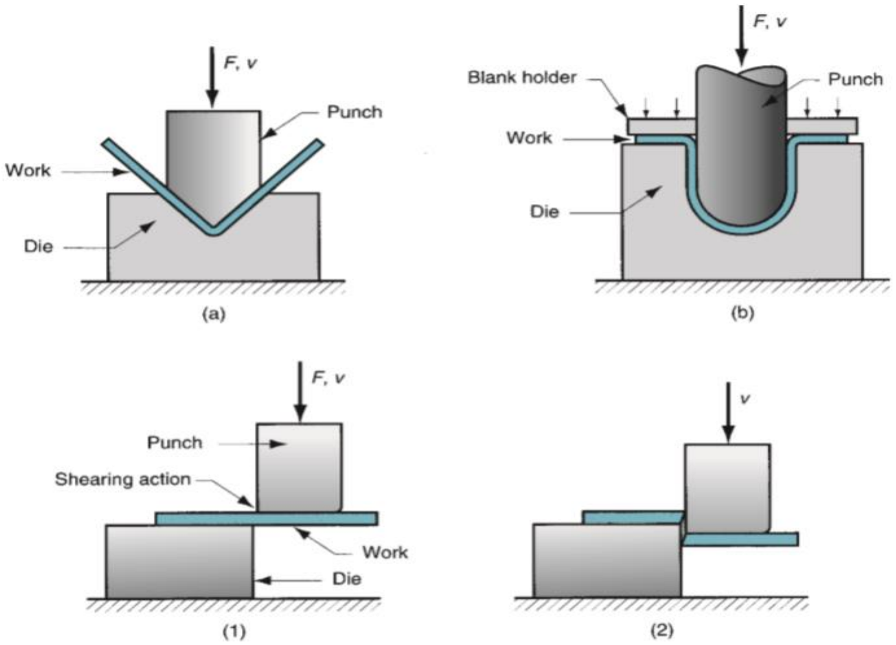

FIGURE 3. Basic sheet metalworking operations:
(a) bending, (b) drawing, and (c) shearing: (1) as punch first contacts sheet, and
(2) after cutting. Force and relative motion in these operations are indicated by F and v.

- Drawing. In sheet metalworking, drawing refers to the forming of a flat metal sheet into a hollow or concave shape, such as a cup, by stretching the metal. A blank holder is used to hold down the blank while the punch pushes into the sheet metal, as shown in Figure 3(b). To distinguish this operation from bar and wire drawing, the terms cup drawing or deep drawing are often used.
- Bending. Bending involves straining of a metal sheet or plate to take an angle along a (usually) straight axis.

- Shearing. This process seems somewhat out-of-place in a list of deformation processes, because it involves cutting rather than forming. A shearing operation cuts the work using a punch and die, as in Figure 3(c). Although it is not a forming process, it is included here because it is a necessary and very common operation in sheet metalworking.
- The miscellaneous processes within the sheet metal working classification in Figure 1 include a variety of related shaping processes that do not use punch and die tooling. Examples of these processes are stretch forming, roll bending, spinning, and bending of tube stock.

2. MATERIAL BEHAVIOR IN METAL FORMING

Consider able insight about the behavior of metals during forming can be obtained from the stress–strain curve. The typical stress–strain curve for most metals is divided into an elastic region and a plastic region. In metal forming, the plastic region is of primary interest because the material is plastically لدن and permanently بشكل دائم deformed in these processes. The typical stress–strain relationship for a metal exhibits elasticity below the yield point and strain hardening above it. In the plastic region, the metal's behavior is expressed by the flow curve:

$$\sigma = K\epsilon^{n}$$

where K the strength coefficient, MPa; and n is the strain-hardening exponent. The stress σ and strain ϵ in the flow curve are true stress and true strain. The flow curve is generally valid as a relationship that defines a metal's plastic behavior in cold working.

The flow curve describes the stress–strain relationship, (FIGURE 4) in the region in which metal forming takes place. It indicates the flow stress of the metal-the strength property that determines forces and power required to accomplish a particular forming operation.

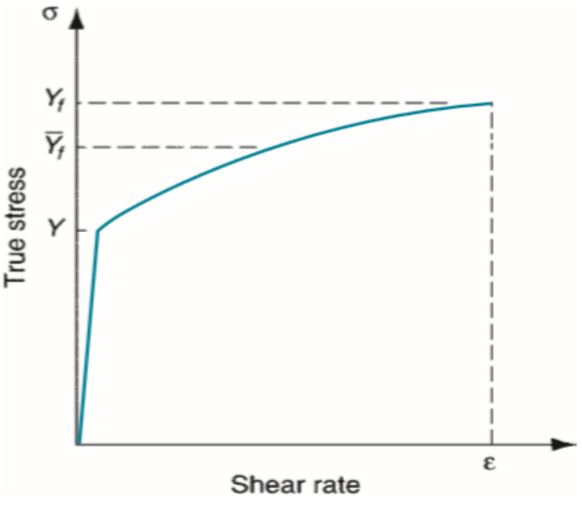

FIGURE 4 Stress–strain curve indicating location of average flow stress

3. TEMPERATURE IN METAL FORMING

For any metal, the values of K and n depend on temperature. Strength and strain hardening are both reduced at higher temperatures. These property changes are important because they result in lower forces and power during forming. In addition, ductility is increased at higher temperatures, which allows greater plastic deformation of the work metal. We can distinguish three temperature ranges that are used in metal forming: cold, warm, and hot working.

Cold Working Cold working (also known as cold forming) is metal forming performed at room temperature or slightly above.

Significant advantages of cold forming compared to hot working are

(1) greater accuracy, meaning closer tolerances can be achieved;

(2) better surface finish;

(3) higher strength and hardness of the part due to strain hardening;

(4) grain flow during deformation provides the opportunity for desirable directional properties to be obtained in the resulting product; and

(5) no heating of the work is required, which saves on furnace and fuel costs and permits higher production rates. Owing to this combination of advantages, many cold forming processes have become important mass-production operations. They provide close tolerances and good surfaces, minimizing the amount of machining required so that these operations can be classified as net shape or near net shape processes.

Disadvantages or limitations associated with cold forming operations:

(1) higher forces and power are required to perform the operation;

(2) care must be taken to ensure that the surfaces of the starting workpiece are free of scale and dirt; and

(3) ductility and strain hardening of the work metal limit the amount of forming that can be done to the part.

In some operations, the metal must be annealed تعتيق in order to allow further deformation to be accomplished إنجاز. In other cases, the metal is simply not ductile enough to be cold worked.

To overcome the strain-hardening problem and reduce force and power requirements, many forming operations are performed at elevated مرتفعة *temperatures. There are two elevated temperature ranges involved, giving rise to the terms warm working and hot working.*

Warm Working Because plastic deformation properties are normally enhanced by increasing workpiece temperature, forming operations are sometimes performed at temperatures somewhat above room temperature but below the recrystallization temperature. The term warm working is applied to this second temperature range. The dividing line between cold working and warm working is often expressed in terms of the melting point for the metal. The dividing line is usually taken to be 0.3 Tm, where Tm is the melting point (absolute temperature) for the particular metal. The lower strength and strain hardening at the intermediate temperatures, as well as higher ductility, provide warm working with the following advantages over cold working:

(1) lower forces and power,
(2) more intricate معقدة work geometries possible, and
(3) need for annealing التصلب may be reduced or eliminated القضاء عليه.

Hot Working Hot working (also called hot forming) involves deformation at temperatures above the recrystallization temperature. The recrystallization temperature for a given metal is about one-half of its melting point on the absolute scale. In practice, hot working is usually carried out at temperatures somewhat above 0.5 Tm. However, the deformation process itself generates heat, which increases work temperatures in localized regions of the part. This can cause melting in these regions, which is highly undesirable غير مرغوب فيها. Also, scale on the work surface is accelerated at higher temperatures. Accordingly, hot working temperatures are usually maintained within the range 0.5Tm to 0.75Tm. The most significant advantage of hot working is the capability to produce substantial plastic deformation of the metal-far more than is possible with cold working or warm working.

All of this results in the following advantages relative to cold working:

(1) the shape of the work part can be significantly altered تغيير إلى حد كبير,

(2) lower forces and power are required to deform the metal,

(3) metals that usually fracture in cold working can be hot formed,

(4) strength properties are generally isotropic because of the absence of the oriented grain structure typically created in cold working, and

(5) no strengthening of the part occurs from work hardening. This last advantage may seem inconsistent, since strengthening of

The metal is often considered an advantage for cold working. However, there are applications in which it is undesirable غير مرغوب فيها for the metal to be work hardened because it reduces ductility, for example, if the part is to be subsequently وفي وقت لاحق processed by cold forming.

Disadvantages of hot working include

(1) lower dimensional accuracy,

(2) higher total energy required (due to the thermal energy to heat the workpiece),

(3) work surface oxidation (scale),

(4) poorer surface finish, and

(5) shorter tool life.

Recrystallization of the metal in hot working involves atomic diffusion نشر ذرية , which is a time-dependent process.

Metal forming operations are often performed at high speeds that do not allow sufficient time الوقت الكافي for complete recrystallization of the grain structure during the deformation cycle itself. However, because of the high temperatures, recrystallization eventually does occur تحدث في نهاية المطاف. It may occur immediately following the forming process or later, as the workpiece cools.