Chapter 6: Bulk Metal Forming (Rolling, Forging, Extrusion and Drawing)

Forming and shaping. Although there are not always clear distinctions between the words **forming** and **shaping**, the former generally indicates changing the shape of an existing solid body. Thus, in forming processes, the starting material (usually called the **workpiece**, **stock**, or **blank**) may be in the shape of a **plate**, **sheet**, **bar**, **rod**, **wire**, or **tubing**. On the other hand, shaping processes typically involve **molding** and casting, producing a part that generally is at or near the final desired shape.

Rolling. Rolling is the process of reducing the thickness or changing the **cross-section** of a long workpiece by compressive forces applied through a set of **rolls** (see Fig. 1), a process that is similar to rolling **dough** with a **rolling pin**. Rolling is first carried out at elevated temperatures (**hot rolling**). During this phase, the coarse-grained, brittle, and porous structure of the **ingot** or the continuously cast metal is broken down into a **wrought structure**, having a finer grain size and enhanced properties, such as increased strength and hardness. Subsequently, rolling can be performed at room temperature (**cold rolling**), whereby the rolled sheet has higher strength and hardness, and better surface finish. Cold rolling will, however, result in a product with **anisotropic** properties, due to **preferred orientation** or mechanical **fibering**.

Plates generally have a thickness of more than 6 mm, and are used for structural applications, such as **ship hulls**, **boilers**, **bridges**, and **heavy machinery**. Sheets are generally less than 6 mm thick, and are typically provided to manufacturing **facilities** as **coils**, weighing as much as 30,000 kg, or as flat sheets for further processing into a wide variety of sheet-metal products. Sheets are used for trucks and aircraft bodies, appliances, food and beverage containers, and kitchen and office equipment. Aluminum **foil** typically has a thickness of 0.008 mm, although thinner foils, down to 0.003 mm, also can be produced.

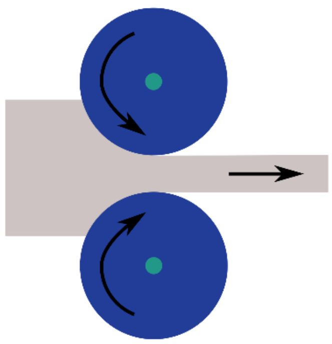


Fig. 1 Schematic illustration of rolling process

A. According to the description provided in the following paragraph, refer to the (roll gap**, h_o, h_f, V_o, V_f **and** V_r**) on Fig. 1.

The <u>Flat-rolling</u> Process A schematic illustration of the flat-rolling process is shown in Fig. 1. A metal **<u>strip</u>**, of thickness h_o, enters the **<u>roll gap</u>** and is reduced to thickness h_f by a pair of rotating rolls, each powered individually by electric motors. The surface speed of the rolls is V_r. The velocity of the strip increases from its entry value of V_o as it moves through the roll gap, and is highest at the exit from the roll, where it is denoted as V_f. The metal accelerates in the roll gap, in the same manner as an **<u>incompressible</u>** fluid flows through a converging **<u>channel</u>**.

Hot rolling The initial rolling steps (breaking down) of the material is usually done by hot rolling**,** above the recrystallization temperature of the metal. The rolled product of the first hot-rolling operation is called **<u>bloom</u>, <u>slab</u>,** or **<u>billet</u>** (see Fig. 2). A bloom usually has a square cross-section, at least 150 mm on the side, whereas a slab is usually rectangular in cross-section. Blooms are further processed by **<u>shape rolling</u>** into structural shapes, such as I-beams and railroad rails. Slabs are rolled into plates and sheets. Billets usually are square (with a cross-sectional area smaller than that for blooms), and are later rolled into various shapes, such as round rods and bars, using shaped rolls.

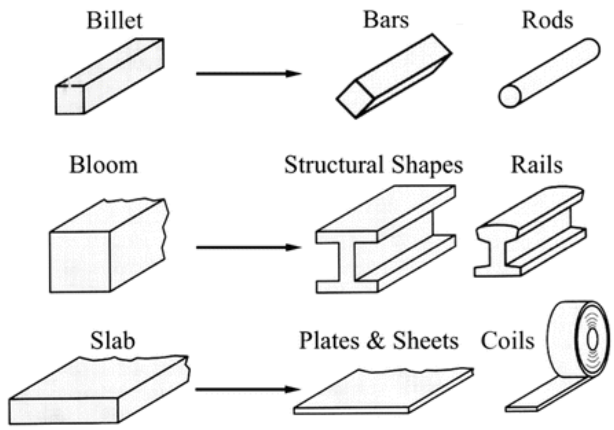


Fig. 2 Visualization from a billet, bloom, or slab to its final form.

<u>Pack rolling</u> Pack rolling is a flat-rolling operation in which two or more layers of sheet are rolled together, thus increasing **<u>productivity</u>**. Aluminum foil, for example, is pack rolled in two layers, thus only the top and bottom outer surfaces are in contact with the rolls. Note that one side of aluminum foil is matte, while the other side is shiny. The foil-to-foil side has a matte and satiny finish, whereas the foil-to-roll side is shiny and bright.

B. Write a short descript about the following rolling processes.

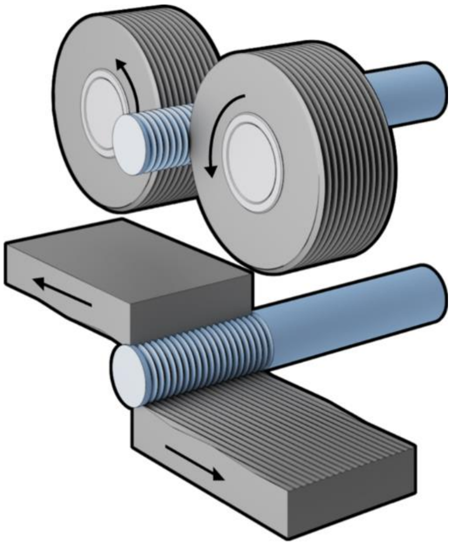


Fig. 3 Thread-rolling process

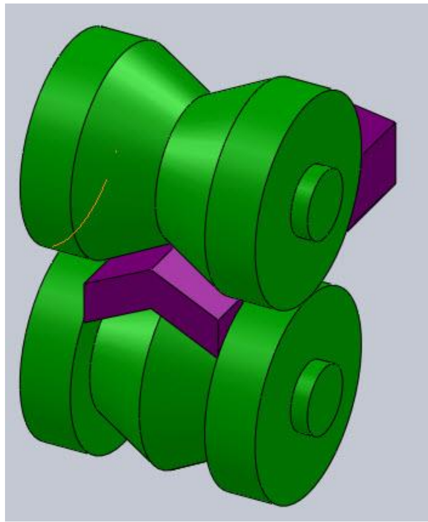


Fig. 4 Shape-rolling process

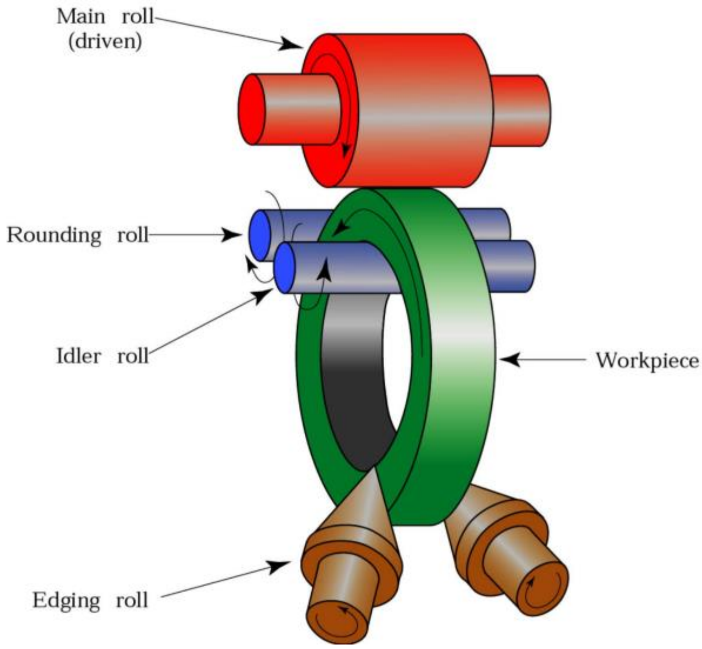


Fig. 5 Ring-rolling process

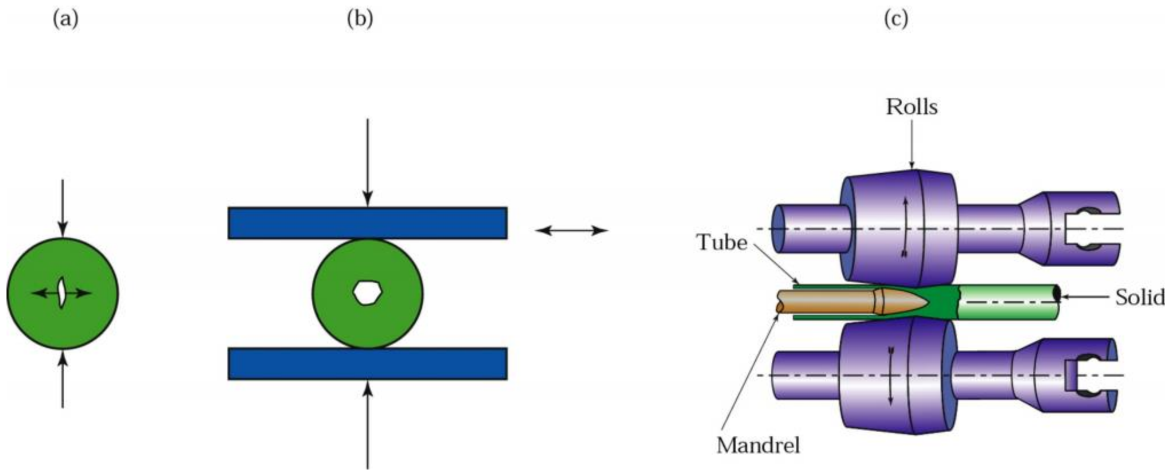


Fig. 6 Cavity formation in a solid round bar and its utilization in the rotary tube **piercing** process for making **seamless** pipe and tubing. (The Mannesmann process)

C. Fill in the blanks with the following words.

toughness, tooling, press, compressive, hammer

Forging Forging is a basic process in which the workpiece is shaped by ………………….. forces applied through various dies and ……………….. . Because the metal flow in the die and the material's grain structure can be controlled, forged parts have good strength and …………………, and are very reliable for highly stressed and critical applications. Simple forging operations can be performed with a heavy …………………… and an **anvil**, as has been done traditionally by **blacksmiths**. Most forgings require a set of dies and such equipment as ………………… or powered hammers.

Open-die forging Open-die forging is the simplest forging operation. Although most open-die forgings generally weigh 15 to 500 kg, forgings as heavy as 275 metric tons have been made. Open-die forging can be simply described by a metal workpiece (blank), placed between two flat dies, and reduced in height by compressing it (Fig. 7), a process called **upsetting** or **flat-die forging**. The die surfaces may have shallow cavities or features to produce relatively simple shapes.

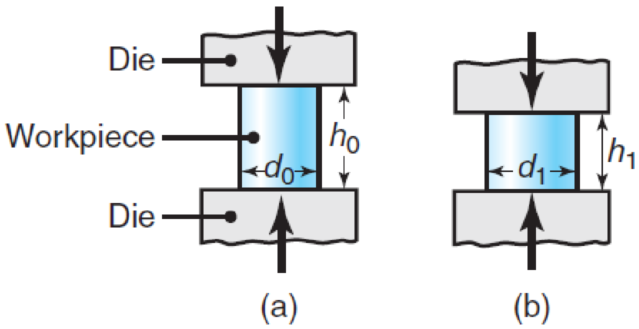


Fig. 7 (a) Solid cylindrical billet upset between two flat dies. (b) Uniform deformation of the billet without friction.

Impression-die forging In impression-die forging, the workpiece takes the shape of the die cavity while being forged between two shaped dies (Fig. 8). This process is usually carried out at elevated temperatures, in order to lower the forging forces and develop enhanced ductility of the workpiece. During deformation, some of the material flows outward and forms a **flash**.

D. Translate the terms and expressions on Fig. 8.

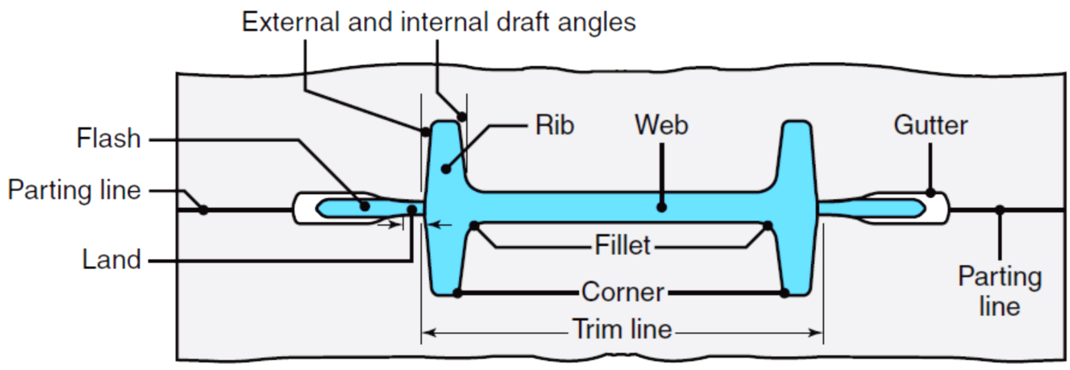


Fig. 8 Standard terminology for various features of a forging die.

Preforming operations Preforming operations are typically used to enhance the **distribution** of the material into various regions of the blank, using simple dies of various **contours**. In **fullering**, material is distributed away from a region in the dies. In **edging**, it is gathered into a localized region. The part is then formed into a rough shape by a process called **blocking**, using **blocker dies**. The final operation is the finishing of the forging in impression dies, which give the forging its final shape; the flash is later removed by a **trimming** operation (Fig. 9).

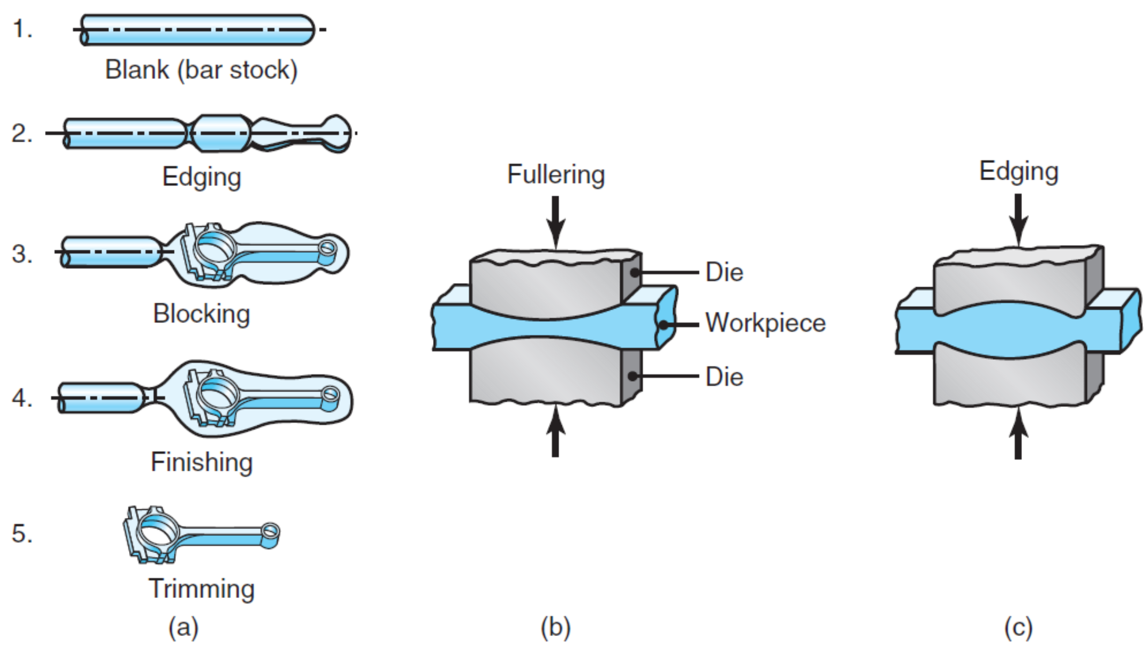


Fig. 9 (a) Stages in forging a **connecting rod** for an internal combustion engine,(b) Fullering and (c) edging operations .

Closed-die Forging. The process shown in Fig. 8 is also referred to as closed-die forging. In true closed-die forging, however, a flash does not form (hence the term **flashless forging**), and the workpiece completely fills the die cavity.

E. Write a short description about the following forging processes.

Coining	**heading** (**upset forging**)	**Piercing**
Hubbing	**Orbital Forging**	**Incremental Forging**
Isothermal Forging	**Rotary Swaging** (radial/rotary forging, or simply swaging)	
Tube Swaging		

Extrusion. In extrusion, a usually cylindrical **billet** is forced through a die (Fig. 10), in a manner similar to squeezing toothpaste from a tube. A wide variety of solid or hollow cross-sections can be produced by extrusion, which essentially are **semifinished** products. A characteristic of extrusion (from the Latin extrudere, meaning "to force out") is that **large deformations** can take place without fracture, because the material is under high **triaxial** compressive stresses. Since the die geometry remains unchanged throughout the process, extruded products typically have a constant cross-section.

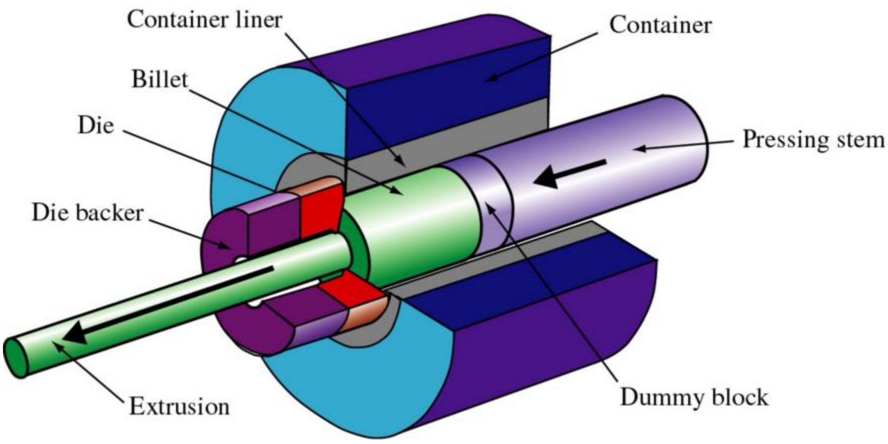


Fig. 10 Schematic illustration of the direct extrusion process.

Direct and indirect extrusion. In **direct** or **forward extrusion**, a billet is placed in a container (chamber) and forced through a die, as shown in Fig. 10. The **die opening** may be round, or it may have various shapes, depending on the desired profile. The function of the **dummy** block, shown in the figure, is to protect the tip of the **pressing stem** (**punch**), particularly in hot extrusion. In **indirect extrusion**, also called **reverse**, **inverted**, or **backward extrusion**, the die moves toward the unextruded billet (Fig. 11).

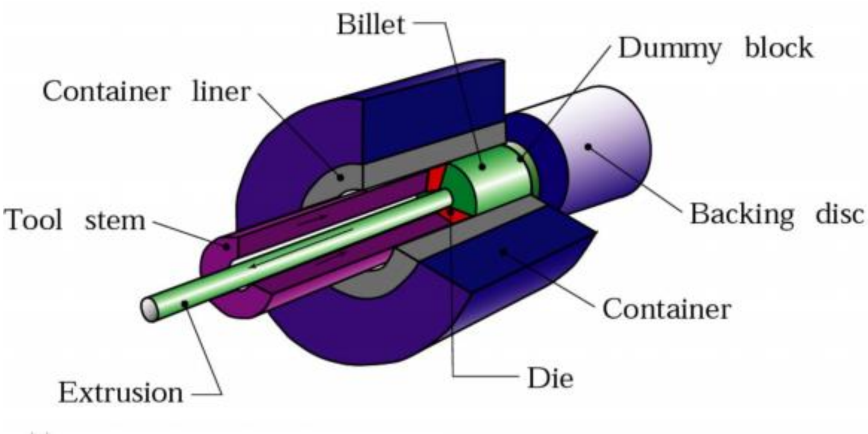


Fig. 11 Schematic illustration of the indirect extrusion process.

The <u>Drawing</u> Process. In drawing, the cross-section of a rod or wire is reduced or changed in shape by pulling (hence the term drawing) it through a die called a draw die (Fig. 12). The difference between drawing and extrusion is that in extrusion, the material is pushed through a die, whereas in drawing, it is pulled through it. Drawn rod and wire products cover a very wide range of applications, including shafts for power transmission, machine and structural components, blanks for bolts and rivets, electrical wiring, cables, tension-loaded structural members, welding electrodes, springs, paper clips, spokes for bicycle wheels, and stringed musical instruments.

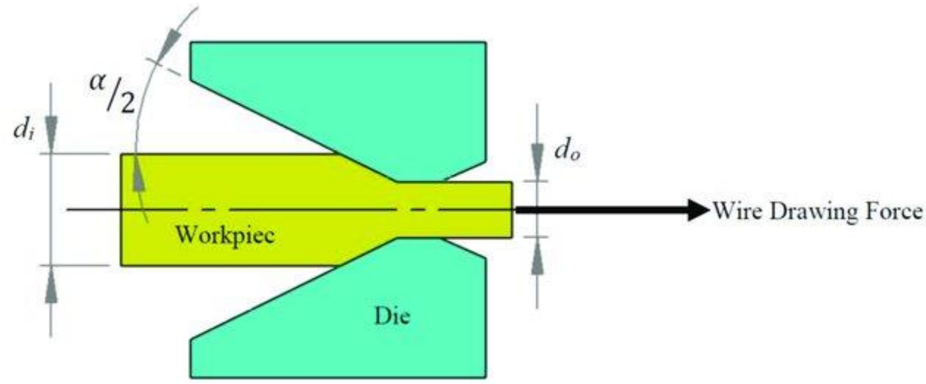
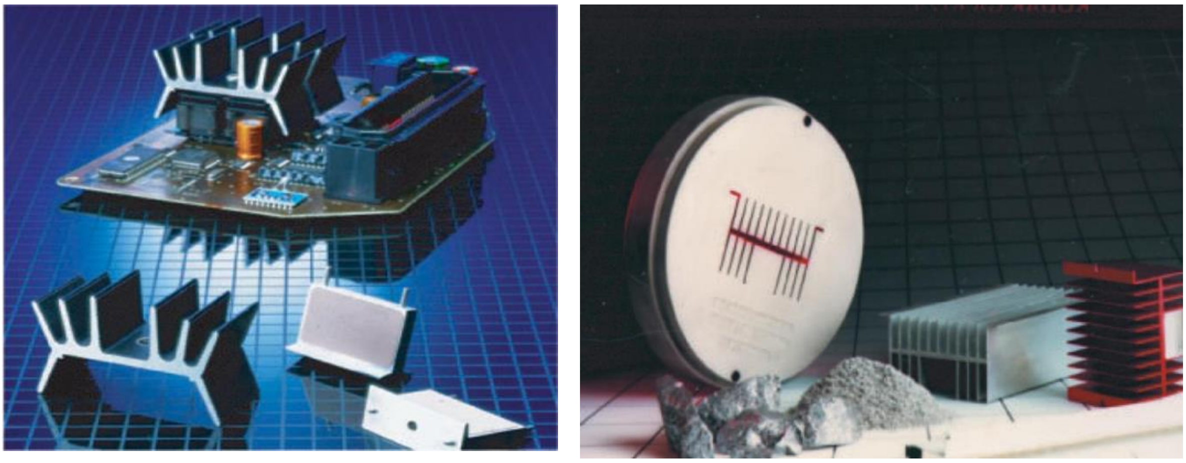


Fig. 12 Schematic representation of a typical pass in the wire drawing process.

Case Study: Manufacture of Aluminum Heat Sinks?

Aluminum is used widely to transfer heat for both cooling and heating applications, because of its very high thermal conductivity. In fact, on a weight-to-cost basis, no other material conducts heat as efficiently as does aluminum. Hot extrusion of aluminum is attractive for **<u>heat-sink</u>** applications, such as those in the electronics industry. Fig. 13 shows an extruded heat sink, used for removing heat from a transformer on a printed circuit board. Heat sinks usually are designed with a large number of **fins**, that maximize the surface area and are evaluated from a thermodynamics standpoint, using computer simulations. The fins are very difficult and expensive to machine, forge, or roll form, but they can be made economically by hot extrusion, using dies made by **electrical-discharge machining**.



(a) (b)

Fig. 13 (a) Aluminum extrusion used as a heat sink for a printed circuit board, (b) extrusion die and extruded heat sinks.

Video: Die forging processes (Click this link or scan the QR code).

F. Translate the following sentences into English.

۱. در فرآیند نورد با اعمال نیروی فشاری توسط مجموعه ای از غلتک ها، کاهش ضخامت یا تغییر سطح مقطع در یک تسمه (strip) بلند رخ می دهد.

۲. در مورد فلزات و آلیاژهای که در دمای اتاق انعطاف پذیری کافی ندارند و یا به منظور کاهش نیروهای مورد نیاز، می توان عملیات اکستروژن را در دماهای بالا انجام داد.

۳. در عملیات کشش، به منظور افزایش عمر قالب و پرداخت سطح محصول و نیز کم کردن نیروهای کشش و افزایش دما انجام روانکاری ضروری است.