Chapter 7: Sheet Metal Forming

Introduction. Products made of **sheet metals** are all around us. They include a very wide range of consumer and industrial products, such as beverage cans, cookware, file cabinets, metal desks, appliances, car bodies, trailers, and aircraft fuselages. There are numerous processes employed for making sheet-metal parts. The terms **pressworking** or **press forming** are commonly used in industry to describe these operations, because they typically are performed on **presses**, using a set of dies. A sheet-metal part produced in presses is called a **stamping** (after the word *stamp,* first used around 1200 a .d ., and meaning "to force downward" or "to pound"). Low-carbon steel is the most commonly used sheet metal, because of its low cost and generally good strength and **formability** characteristics. Aluminum is the most common material for such applications as beverage cans, packaging, kitchen utensils, and where corrosion resistance is an important factor. The common metallic materials for aircraft and aerospace applications are aluminum and titanium, although they are being replaced increasingly with **composite materials**.

A. Fill in the blanks with the following words.

clearance, shear, deburring, blank, dull, die

Shearing. All sheet-metal forming operations begin with a **……..** of suitable dimensions and removed from a large sheet (usually from a coil) by shearing. Shearing subjects the sheet to …….. stresses, generally using a **punch** and a …… . The **clearance** is a major factor in determining the shape and the quality of the sheared edge. As clearance increases, the deformation zone becomes larger and the sheared-edge surface becomes rougher. A **burr** is a thin edge or ridge, as shown in Fig. 1. Burr height increases with increasing …….. and ductility of the sheet metal. **……..** tool edges contribute greatly to large burr formation. The process of removing burrs from sheared sheets called **…… .**

Shearing Operations. The most common shearing operations are **punching,** where the sheared **slug** is **scrap** or may be used for some other purpose and **blanking,** where the slug is the part to be used and the rest is scrap (Fig. 2). **Die Cutting**. This is a shearing operation that consists of the following basic processes: **Perforating**: punching a number of holes in a sheet, **Parting**: shearing the sheet into two or more pieces, **Notching**: removing pieces from edges, **Lancing**: producing a **tab** without removing any material.

Fine Blanking. Square edges with very smooth sheared surfaces can be produced by fine blanking. The sheet is tightly locked in place, and thus it doesn't have the type of **distortion** of the material shown in Fig. 1. The fine-blanking process involves clearances on the order of 1 % of the sheet thickness and the dimensional tolerances typically are on the order of ±0.05 mm.

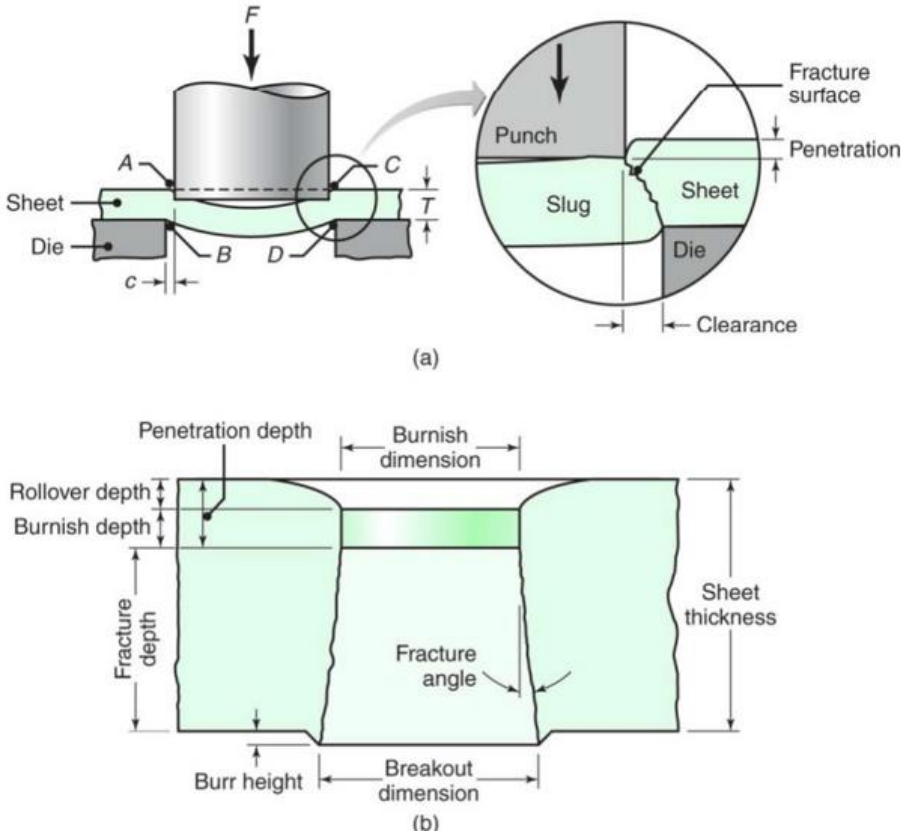


Fig. 1 (a) Schematic illustration of shearing with a punch and die, indicating some of the process variables, (b) characteristic features of a punched hole

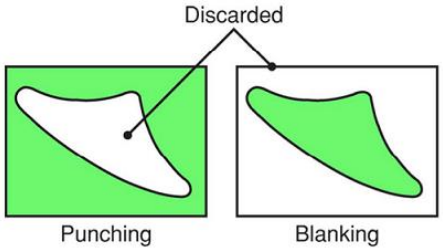


Fig. 2 Punching (piercing) and blanking.

Compound Dies. Several operations may be performed on the same sheet in one **stroke**, and at one **station**, with a compound die.

Progressive Dies. Parts requiring multiple forming operations can be made, at high production rates, using progressive dies. The sheet metal is fed through as a coil strip,

and different operations (such as punching, blanking, and notching) are performed at the same station of the machine, with each stroke using a series of punches.

Sheet-metal formability Sheet-metal formability is generally defined as the ability of the sheet metal to undergo the required shape change without failure, such as by cracking, **wrinkling**, **necking**, or **tearing**.

Bending. Bending is one of the most common forming operations. Bending also imparts stiffness to the part, by increasing its **moment of inertia**. Note, for example, how **corrugations**, **flanges**, **beads**, and **seams** (see Fig. 3) improve the stiffness of structures without adding weight. As a specific example, observe the diametric stiffness of a can with and without circumferential beads.

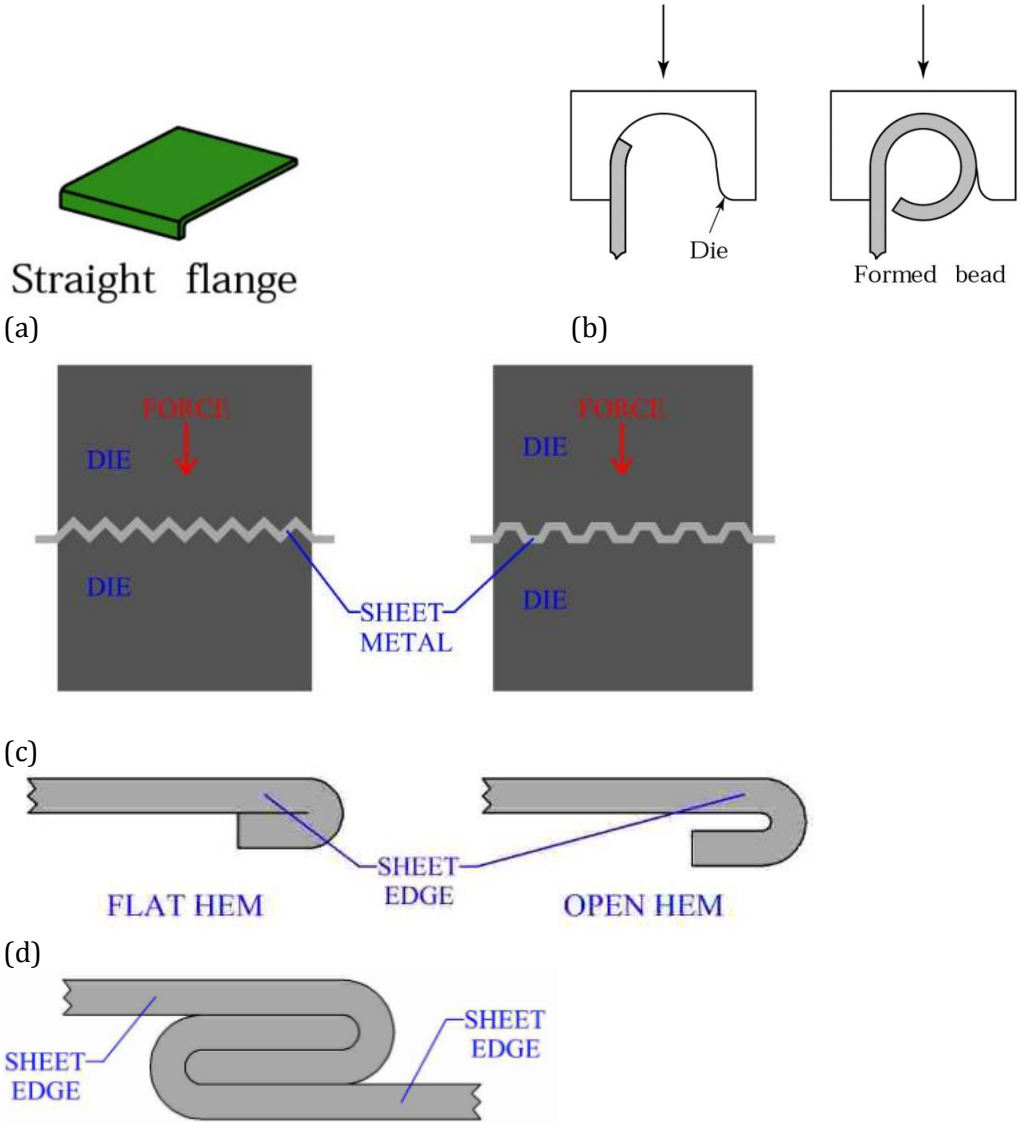


Fig. 3 Schematic illustration of (a) flange, (b) bead, (c) corrugation, (d) seam and (d) hem used for stiffening of sheet metals

Springback. Because all materials have a finite modulus of elasticity, plastic deformation is always followed by some elastic recovery when the load is removed. In bending, this recovery is called springback, which can easily be observed by bending and then releasing a piece of sheet metal or wire.

Press-brake Forming. Sheet metal or plate can easily be bent with simple fixtures using a press. Sheets or narrow strips that are 7 m or even longer usually are bent in a **press brake**. The machine utilizes long dies, in a mechanical or hydraulic press, and is particularly suitable for small production runs.

Stretch Forming. In stretch forming, the sheet metal is clamped along its edges and then stretched over a male die, called **form block** or **form punch**. The die can move upward, downward, or sideways, depending on the particular design of the machine. Stretch forming is used primarily to make aircraft wing-skin panels, fuselages, and boat hulls.

B. Fill in the blanks with the following words.

blankholder, opening, scrap, cavity, wavy

Deep Drawing. It can be noted that numerous sheet metal parts are cylindrical or box shaped, such as pots and pans, all types of containers for food and beverages and stainless steel kitchen sinks. Such parts usually are made by a process in which a punch forces a flat sheet-metal blank into a die ……., as shown in Fig. 4. Consider the case of a round sheet-metal blank placed over a circular die ……., and held in place with a **……** . The punch travels downward, forcing the blank into the die cavity, thus forming a cup.

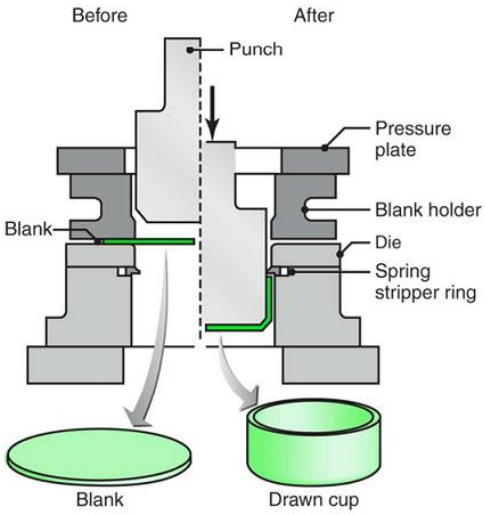


Fig. 4 Schematic illustration of the deep-drawing process on a circular sheet metal blank; the stripper ring facilitates the rem oval of the formed cup from the punch.

Earing. In deep drawing, the edges of cups may become ……., called earing (Fig. 5). Ears are objectionable on deep-drawn cups because they have to be trimmed off, as they serve no useful purpose, and interfere with further processing of the cup, resulting in …… . Earing is caused by the **planar anisotropy** of the sheet metal, and the number of ears produced may be two, four, or eight, depending on the processing history and microstructure of the material.

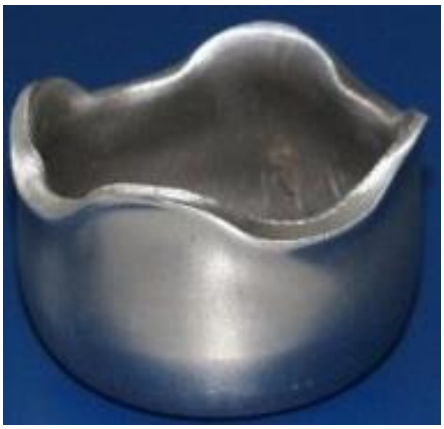


Fig. 5 Earing in a drawn cup, caused by the planar anisotropy of the sheet metal.

Spinning. Spinning is a process that involves forming of axisymmetric parts over a **mandrel**, using various tools and rollers; a process similar to that of shaping clay on a potter's wheel. In conventional spinning, a circular blank of flat or preformed sheet metal is placed and held against a mandrel, and rotated while a rigid tool shapes the material over the mandrel (Fig. 6). The tool may be activated either manually or, for higher production rates, by computer-controlled mechanisms.

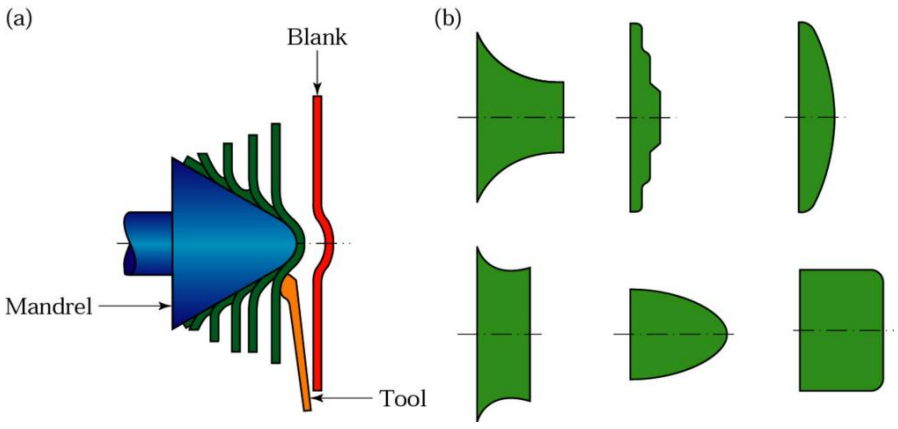


Fig. 6 (a) Schematic illustration of the conventional spinning process. (b) Types of parts conventionally spun. All parts are axisymmetric.

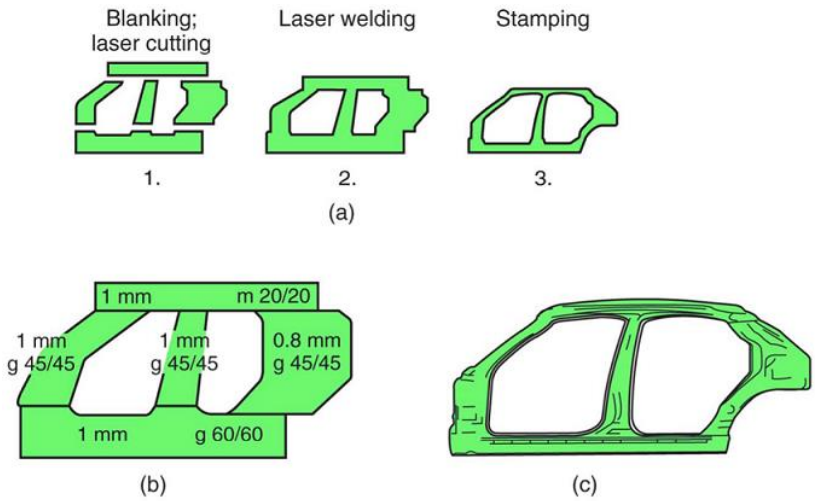
C. Write a short descript about the following rolling processes.

Beading	Flanging	Hemming	Seaming
Bulging	Ironing	Embossing	

Case Study. Tailor-welded Sheet Metal for Automotive Applications

In the sheet-metal forming processes, the blank is usually a one-piece sheet of constant thickness, and cut (blanked) from a large sheet. An important variation from this practice involves laser-beam **butt welding** of two or more pieces of sheet metal with different shapes and thicknesses. The strips are welded to obtain a locally thicker sheet or add a different material, which are called **tailor-welded** sheet metals.

An example of the use of tailor-welded sheet metals in automobile bodies is shown in Fig. 7. Note that five different pieces are first blanked, which includes cutting by laser beams. Four of these pieces are 1 mm thick, and one is 0.8 mm thick. The pieces are laser butt welded and then stamped into the final shape. In this manner, the blanks can be tailored to a particular application, not only as to shape and thickness, but also by using different-quality sheets, with or without **coatings**. Laser-welding techniques are highly developed and the joints are very strong and reliable. The combination of welding and forming sheet-metal pieces makes possible significant flexibility in product design, formability, structural stiffness, and **crash** behavior of an automobile. It also makes possible the use of different materials in one product, weight savings, and cost reductions in materials, scrap, assembly, equipment, and labor.



Legend: g 60/60 (45/45) **Hot-galvanized** alloy steel sheet. Zinc amount: 60/60 (45/45) g/m^2.
m 20/20 Double-layered iron-zinc alloy **electroplated** steel sheet. Zinc amount 20/20 g/m^2.

Fig. 7 Production of an outer side panel of a car body by laser butt welding and stamping.

Video: Manufacturing of Aluminum Beverage Cans (Click this link or scan the QR code).

D. Translate the following sentences into English.

۱. در حین انجام کشش عمیق، با حرکت ورق خام (بلانک) به داخل حفره قالب، تنش‌های فشاری محوری در فلنج ایجاد می شود. این تنش‌های فشاری عامل ایجاد چین‌خوردگی در ناحیه فلنج است.

۲. حد مجاز خمش (bend allowance)، طول محور خنثی در خم بوده و برای تعیین طول ورق خام قطعه‌ای که قرار است خمکاری شود استفاده می شود.

۳. پس از اینکه ورق خام از یک ورقه بزرگتر یا کلاف بریده شد، توسط فرآیندهایی مانند برش، کشش عمیق و خمکاری به شکل مورد نظر در می‌آید.