METAL CASTING PROCESSES

Metal casting processes divide into two categories, based on mold type:

(1) Expendable mold القالب الاستهلاكي:

In expendable mold casting operations, the mold is lost in order to remove the cast part. Production rates in expendable-mold processes are often limited by the time required to make the mold rather than the time to make the casting itself.

(2) Permanent mold القالب الدائمي:

In permanent-mold casting processes, the mold is invented out of metal اخترع من أصل (or other durable material مادة دائمة) and can be used many times to make many castings. Accordingly وبناء على ذلك, these processes have a higher production rates.

1. SAND CASTING, صب الرمل

Nearly all casting alloys can be sand cast; indeed, it is one of the few processes that can be used for metals with **high melting temperatures**, such as steels, nickels, and titanium's. Its versatility استعمالاته permits يسمح the casting of **parts ranging in size from small to very large** and in **production quantities from one to millions**.

Sand casting, also known as **sand-mold casting**, consists of:

- pouring molten metal into a sand mold; صب المعدن المنصهر
- allowing the metal to solidify; السماح لهذا المعدن ان يتصلب
- breaking up the mold to remove the casting; كسر القالب
- the casting must then be cleaned and inspected; and تنظيفها وفحصها
- heat treatment to improve metallurgical properties. المعالجة بالحرارة

- The cavity in the sand mold is formed by **packing التعبئة sand around a pattern نموذج**, and then removing the pattern by **separating the mold into two halves**.
- The mold also contains **the gating and riser system**.
- If the casting is to have internal surfaces, a **core** must be included in the mold.

The production sequence is outlined in Figure 2:

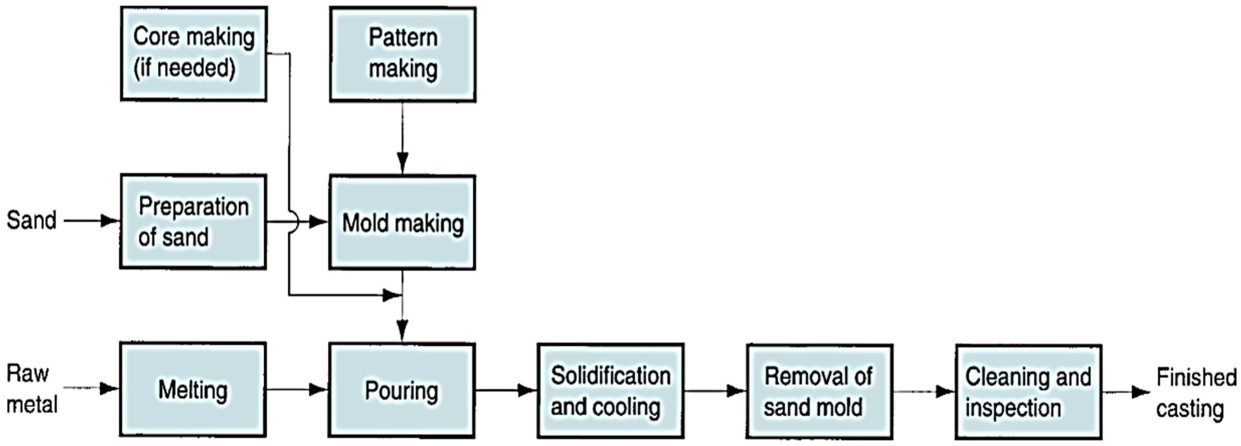


FIGURE 2 Steps in the production sequence in sand casting

1.1 PATTERNS AND CORES

Sand casting requires a pattern-a full-sized model of the part, enlarged موسع to account for shrinkage and machining allowances in the final casting. Materials used to make patterns include wood, plastics, and metals.

Wood is a common pattern material because it is easily shaped. **Its disadvantages** are that it tends to distortion التشويه, and it is abraded متآكل by the sand being compacted around it, thus limiting the number of times it can be reused إعادة استخدام.

Metal patterns are more expensive to make, but they last much longer.

Plastics represent a compromise between wood and metal.

Selection of the appropriate pattern material depends on the total quantity of castings.
There are various types of patterns, as illustrated in Figure 3.

The simplest is made of one piece, called a **solid pattern**-same geometry as the casting, adjusted تعديل in size for shrinkage تقلص and machining التشغيل. *(Figure 3-a)*
Although it is the easiest pattern to fabricate, it is not, to use in making the sand mold.
Determining the location of the parting line خط الفصل between the two halves of the mold can be a problem, and including the gating system and sprue into the mold is left to the judgment الحكم and skill مهارة of the foundry worker.
Consequently ونتيجة لذلك, are limited to very low production quantities.

Split patterns consist of two pieces, dividing the part along a plane according with the parting line of the mold. Split patterns are appropriate for complex part geometries and mode rate production quantities. *(Figure 3*-b)

For higher production quantities, ***match-plate*** *or* ***cope-and-drag patterns*** *are used.*

In **match-plate patterns**, the two pieces of the split pattern are attached to opposite sides of a wood or metal plate. Holes in the plate allow the top and bottom (cope and drag) sections of the mold to be aligned accurately. *(Figure 3*-c)

Cope-and-drag patterns are similar to match-plate patterns except باستثناء that split pattern halves are attached to separate plates, so that the cope and drag sections of the mold can be fabricated independently, instead of using the same tooling for both. *(Figure 3*-d)

If the casting is to have internal surfaces, a **core** is required. A core is a full-scale model of the interior surfaces of the part. It is inserted into the mold cavity prior السابقة to pouring صب, so that the molten metal will flow and solidify between the mold cavity and the core to form the casting's external and internal surfaces. *(Figure 4-a)*

The core is usually made of sand, compacted into the desired shape. As the actual size of the core must include allowances for shrinkage and machining.

Depending on the geometry of the part, the core may or may not require supports to hold it in position in the mold cavity during pouring. These supports, **called chaplets**, are made of a metal with a higher melting temperature than the casting metal. *(Figure 4-b)*

For example, steel chaplets would be used for cast iron castings.

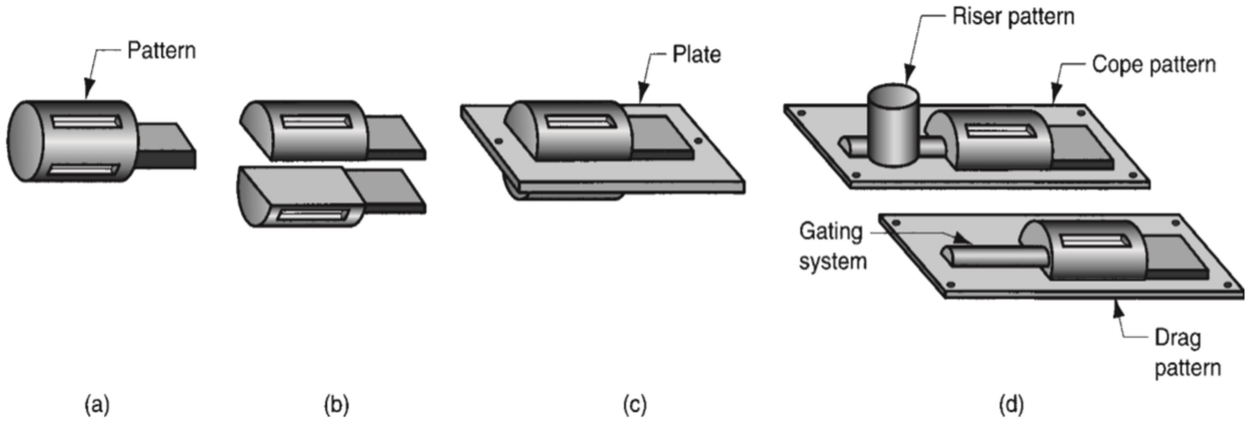


FIGURE 3 Types of patterns used in sand casting:
(a) solid pattern, (b) split pattern, (c) match-plate pattern, and (d) cope-and-drag pattern.

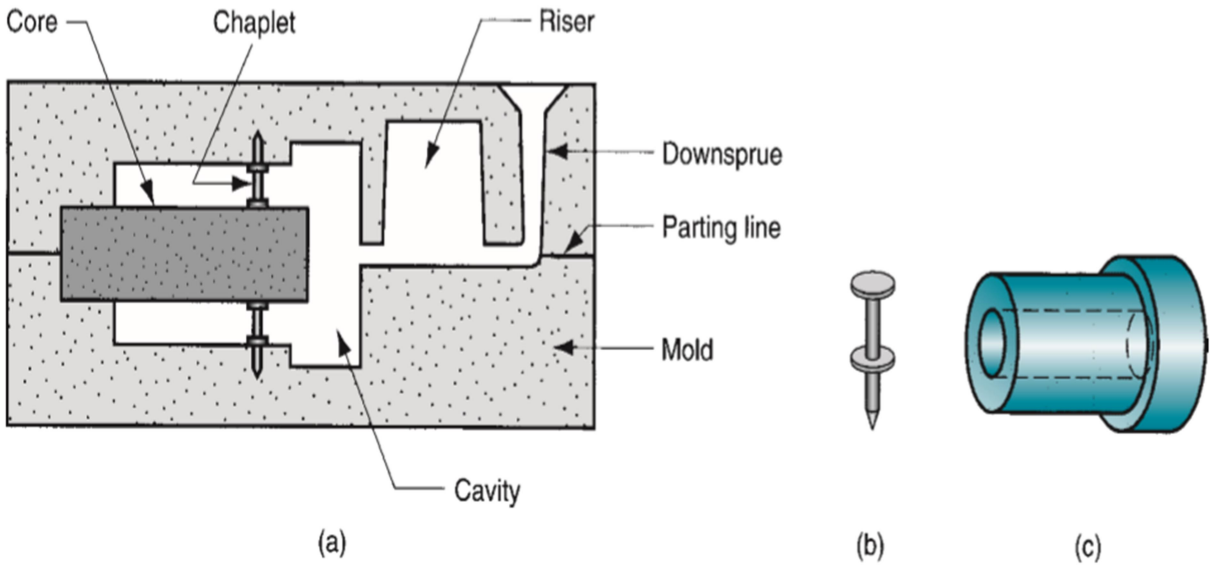


FIGURE 4 (a) Core held in place in the mold cavity by chaplets, (b) possible chaplet design, and (c) casting with internal cavity.

1.2 MOLDS AND MOLD MAKING

Foundry sands are **silica (SiO_2) or silica mixed with other minerals**. The sand should possess **good refractory properties-capacity** خصائص ذات سعة حرارية to standup under high temperatures without melting. Other important features of the sand include **grain size, distribution of grain size in the mixture**, and shape of the individual grains.

Small grain size provides a better surface finish on the cast part, but large grain size is more permeable نفاذية (to allow escape of gases during pouring).

Molds made from grains of **irregular shape الشكل غير النظامية tend to be stronger than molds of round grains because of interlocking تشابك**, yet interlocking التشابك الجيد tends to restrict permeability تقييد نفاذية.

The grains of sand are held together by **a mixture of water and bonding clay** طين الربط. A typical mixture (by volume) is 90% sand, 3% water, and 7% clay.

Other bonding agents عوامل الربط الأخرى can be used in place of clay, including organic resins الراتنجات العضوية (e.g., phenolic resins) and inorganic binders موثقات غير العضوية (e.g., sodium silicate and phosphate). Besides sand and binder, additives are sometimes combined with the mixture to enhance properties such as strength and/or permeability of the mold.

To form the mold cavity, the traditional method is to compact the molding sand around the pattern for both cope and drag in a container called **a flask**. The packing process is performed by various methods.

The simplest is hand ramming, accomplished manually by a foundry worker. In addition, various machines have been developed to mechanize the packing procedure.

These machines operate by any of several mechanisms, including:

(1) **squeezing** الضغط the sand around the pattern by pneumatic pressure بالهواء المضغوط;

(2) **a jolting** هز action in which the sand, contained in the flask with the pattern, is dropped repeatedly in order to pack it into place; and

(3) **a slinging** إلصاق action, in which the sand grains are impacted against the pattern at high speed.

Several indicators are used to determine the quality of the sand mold:

(1) **strength** قوة - the mold's ability to maintain its shape and resist erosion caused by the flow of molten metal; it depends on grain shape, adhesive qualities of the binder, and other factors;

(2) **permeability** قدرة نفاذية -capacity of the mold to allow hot air and gases from the casting operation to pass through the voids in the sand;

(3) **thermal stability** الثبات الحراري -ability of the sand at the surface of the mold cavity to resist cracking and buckling upon contact with the molten metal;

(4) **collapsibility** قابلية الانهيار -ability of the mold to give way and allow the casting to shrink without cracking the casting; it also refers to the ability to remove the sand from the casting during cleaning; and

(5) **reusability** ويمكن إعادة استخدام -can the sand from the broken mold be reused to make other molds?

These measures are sometimes incompatible.

Sand molds are often classified as green-sand, dry-sand, or skin-dried molds.

Green sand molds are made of a mixture of sand, clay, and water, the word green referring to the fact that the mold contains moisture at the time of pouring.

Green-sand molds possess sufficient strength for most applications, good collapsibility, good permeability, good reusability, and are the least expensive of the molds.

Moisture in the sand can cause defects in some castings, depending on the metal and geometry of the part.

A dry-sand mold is made using organic binders rather than clay, and the mold is baked in a large oven at temperatures ranging from 200C to 320 C. Oven baking strengthens the mold and hardens the cavity surface. A dry sand mold provides better dimensional control in the cast product, compared to green-sand molding.

However, dry-sand molding is more expensive, and production rate is reduced because of drying time. Applications are generally limited to medium and large castings in low to medium production rates.

A skin-dried mold, the advantages of a dry-sand mold is partially achieved حققت by drying the surface of a green-sand mold to a depth of 10 to 25 mm at the mold cavity surface, using torches مشاعل, heating lamps مصابيح التدفئة, or other means.

Special bonding materials must be added to the sand mixture to strengthen the cavity surface. The preceding mold classifications refer to the use of conventional binders consisting of either clay-and-water or ones that require heating to cure. In addition to these classifications, ***chemically bonded molds have been developed*** *that are not based on either of these traditional binder ingredients. Some of the binder materials used in these ''no-bake'' systems include furan resins راتنجات الفوران (consisting of furfural alcohol, urea, and formaldehyde), phenolics, and alkyd oils. No-bake molds are growing in popularity due to their good dimensional control in high production applications.*

1.3 THE CASTING OPERATION

After the core is positioned (if one is used) and the two halves of the mold are clamped together, then casting is performed. Casting consists of pouring, solidification, and cooling of the cast part. The gating and riser system in the mold must be designed to deliver liquid metal into the cavity and provide for a sufficient reservoir of molten metal during solidification shrinkage. Air and gases must be

allowed to escape. One of the hazards during pouring is that the buoyancy قابلية الطفو of the molten metal will displace تحل محل the core. Buoyancy results from the weight of molten metal being displaced by the core, according to Archimedes principle مبدأ أرخميدس. The force tending to lift رفع the core is equal to the weight of the displaced liquid less the weight of the core itself. Expressing the situation in equation form,

$$F_b = W_m - W_c \qquad (1)$$

Where F_b = buoyancy force, N (lb); W_m = weight of molten metal displaced, N (lb); and % W_c = weight of the core, N (lb). Weights are determined as the volume of the core multiplied by the respective densities of the core material (typically sand) and the metal being cast. The density of a sand core is approximately 1.6 g/cm^3.

Densities of several common casting alloys are given in Table 1.

TABLE 11.1 Densities of selected casting alloys.

Metal	Density g/cm^3	Density lb/in^3	Metal	Density g/cm^3	Density lb/in^3
Aluminum (99% = pure)	2.70	0.098	Cast iron, gray[a]	7.16	0.260
Aluminum-silicon alloy	2.65	0.096	Copper (99% = pure)	8.73	0.317
Aluminum-copper (92% Al)	2.81	0.102	Lead (pure)	11.30	0.410
Brass[a]	8.62	0.313	Steel	7.82	0.284

Example 1 Buoyancy in Sand Casting

A sand core has a volume 1875 cm^3 and is located inside a sand mold cavity. Determine the buoyancy force tending to lift the core during pouring of molten lead into the mold?

Solution: Density of the sand core is 1.6 g/cm^3.

Weight of the core is 1875 (1.6) = 3000g = 3.0 kg.

Density of lead, based on Table 1, is 11.3 g/cm^3.

The weight of lead displaced by the core is 1875 (11.3) = 21,188 g = 21.19kg.

The difference = 21.19 - 3.0 = 18.19 kg.

Given that 1 kg = 9.81 N, the buoyancy force is therefore F_b = 9.81 (18.19) = 178.4 N.

Following solidification and cooling, the sand mold is broken away from the casting to retrieve the part. The part is then cleaned-gating and riser system are separated, and sand is removed. The casting is then inspected.