Chapter 4: Metal Casting

Introduction. The **casting** process basically involves (a) **pouring** molten metal into a **mold**, **patterned** after the part to be cast, (b) allowing it to solidify, and (c) removing the part from the mold. Important considerations in casting operations are:

- **Flow** of the molten metal into the mold **cavity**, and design of **gating** systems or pathways for molten metal to fill the cavity
- Solidification and cooling of the metal in the mold
- Influence of the mold material.

Solidification of Metals.

- **Pure Metals.** Because a **pure metal** has a clearly defined melting, or freezing, point, it solidifies at a constant temperature. Pure aluminum, for example, solidifies at 660°C and tungsten at 3410°C. After the temperature of the molten metal drops to its freezing point, its temperature remains constant while the **latent heat** of **fusion** is given off. The **solidification front** (the solid– liquid interface) moves through the molten metal from the mold walls in toward the center. The solidified metal, called the casting, is then removed from the mold and allowed to cool to ambient temperature.
- **Alloys**. Solidification in alloys begins when the temperature drops below the **liquidus**, and is complete when it reaches the **solidus**. Within this temperature range, the alloy is in a **mushy** or **pasty** state, consisting of columnar **dendrites** (from the Greek *dendron*, meaning "akin to," and *drys*, meaning "tree"). The study of dendritic structures, although complex, is important, because such structures can contribute to **detrimental** factors, such as **compositional variations**, **segregation**, and **microporosity** within a cast part.

Effects of Cooling Rates. Slow cooling rates, on the order of 10^2 K/s, or long local solidification times, result in **coarse** dendritic structures, with large spacing between dendrite arms. For higher cooling rates, on the order of 10^4 K/s, or for short local solidification times, the structure becomes **finer**, with smaller dendrite arm spacing. For still higher cooling rates, on the order of from 10^6 to 10^8, the developed structures are **amorphous**.

A. Fill in the blanks with the following words.

cavity, gating system, shrinkage, risers, runners

Fluid Flow. To emphasize the importance of **fluid** flow in casting, consider a basic **gravity casting** system, as shown in Fig. 1. The molten metal is poured through a **pouring basin or cup**; it then flows through the **..........................** (consisting of **sprue**, **runners**, and **gates**) into the mold .... The sprue is a **tapered** vertical channel through which the molten metal flows downward in the mold. .... are the channels that carry the molten metal from the sprue into the mold cavity or connect the sprue to the gate (that portion of the runner through which the molten metal enters the mold cavity). **..................**, also called **feeders**, serve as **reservoirs** of molten metal to supply any molten metal necessary to prevent **porosity** due to **....................** during solidification.

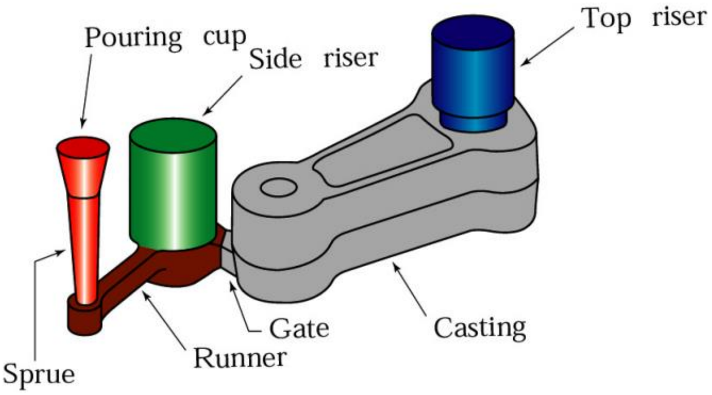

Fig. 1 Schematic illustration of a typical riser-gated casting.

Shrinkage. Because of their thermal **expansion** characteristics, metals usually shrink (**contract**) during solidification and while cooling to room temperature. Shrinkage, which causes dimensional changes and sometimes **warping** and cracking, is the result of the following three sequential events: 1. Contraction of the molten metal as it cools prior to its solidification 2. Contraction of the metal during phase change from liquid to solid 3. Contraction of the solidified metal (the casting) as its temperature drops to ambient temperature.

B. Fill in the blanks with the following words.

refractories, permanent, sand, investment casting, grain size, expendable

Classification of Casting Practices. Based on mold materials, **pattern** production, molding processes, and methods of feeding the mold with molten metal, the casting **practices** can be categorized as follows:

1. Expendable molds: typically made of …………………, **plaster**, ceramics, and similar materials, and generally mixed with various **binders** (bonding agents) for improved properties. A typical **sand mold** consists of 90% sand, 7% clay, and 3% water. These materials are **…………………** (i.e., they are capable of withstanding the high temperatures of molten metals). After the casting has solidified, the mold is broken up to remove the casting, hence the word ………………… . The mold is produced from a pattern; in some processes, and although the mold is expendable, the pattern is reused to produce several molds. Such processes are referred to as *expendable-mold, permanent-pattern casting processes.* On the other hand, **……………………..** requires a pattern for each mold produced, and is an example of an *expendable-mold, expendable-pattern process.*

2. Permanent molds, made of metals that maintain their strength at high temperatures. As the name implies, the molds are used repeatedly, and are designed in such a way that the casting can be removed easily and the mold used for the next casting. Metal molds are better heat conductors than expendable nonmetallic molds, hence the solidifying casting is subjected to a higher rate of cooling, which in turn affects the microstructure and …………………… within the casting.

3. Composite molds, made of two or more different materials (such as sand, graphite, and metal), combining the advantages of each material. These molds have a …………….. and an expendable portion, and are used in various casting processes to improve mold strength, control the cooling rate, and optimize the overall economics of the casting operation.

C. Translate the words on the figure into Persian.

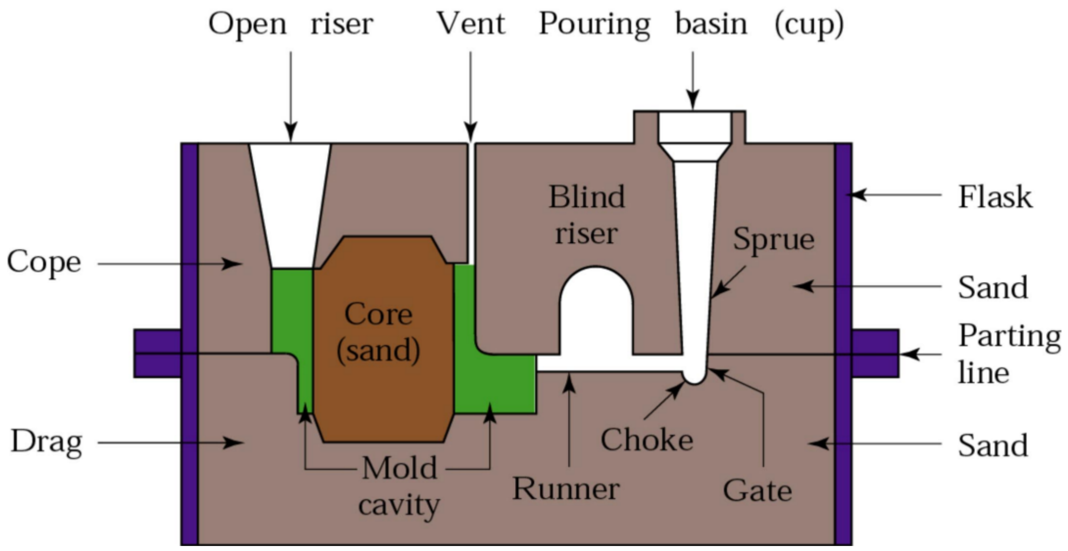

Fig. 2 Schematic illustration of a sand mold, showing various **features**.

cope	drag	mold cavity	runner	choke
نیمه بالایی قالب	…………………	حفره قالب	…………………	…………………
gate	parting line	sprue	riser	vent
…………………	…………………	…………………	…………………	…………………
pouring basin	flask	core		
…………………	محفظه	…………………		

D. Write a short description about the casting processes illustrated in Figs. 3 and 4.

Investment (lost wax) casting. …

Die Casting. …

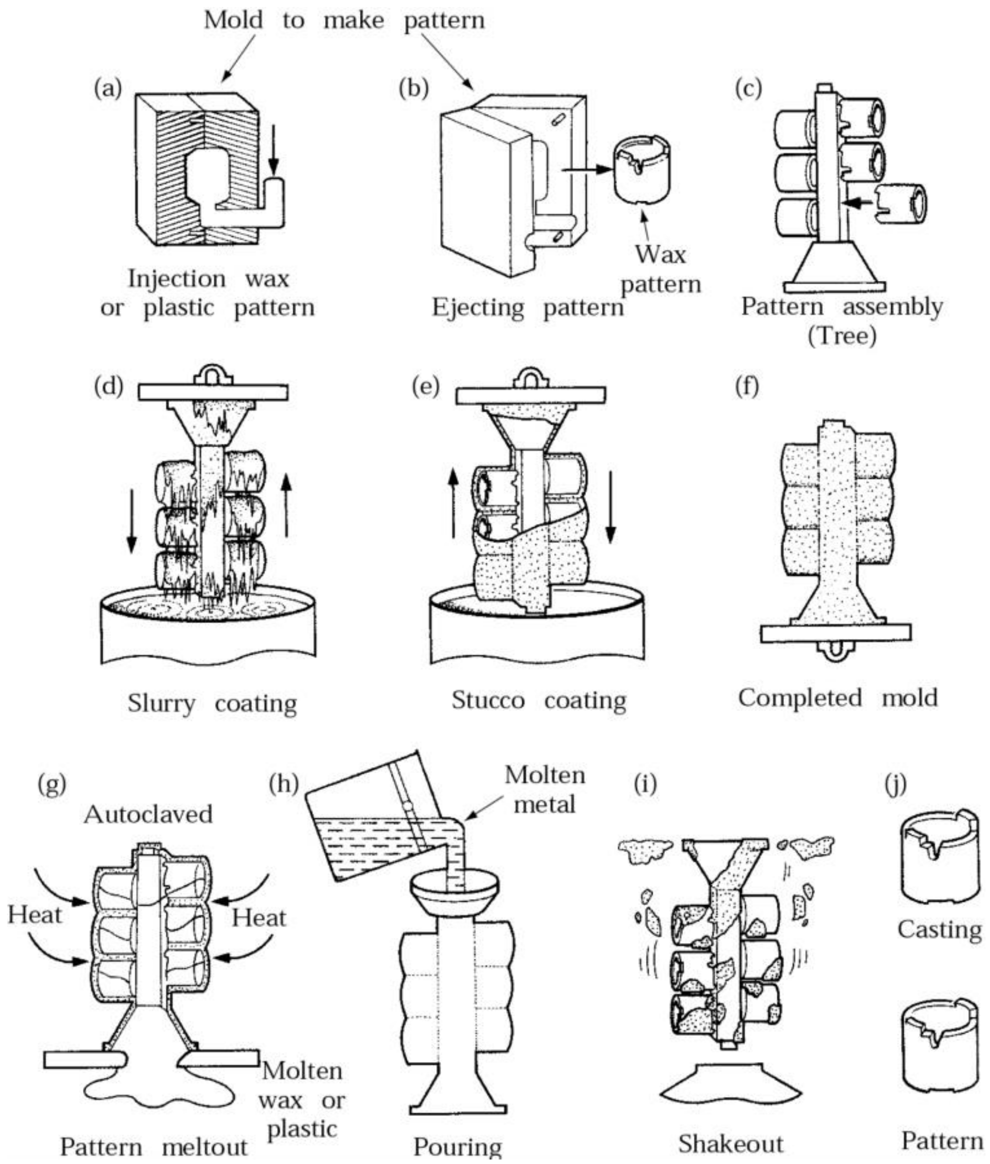

Fig. 3 Schematic illustration of investment casting, (**lost wax** process).

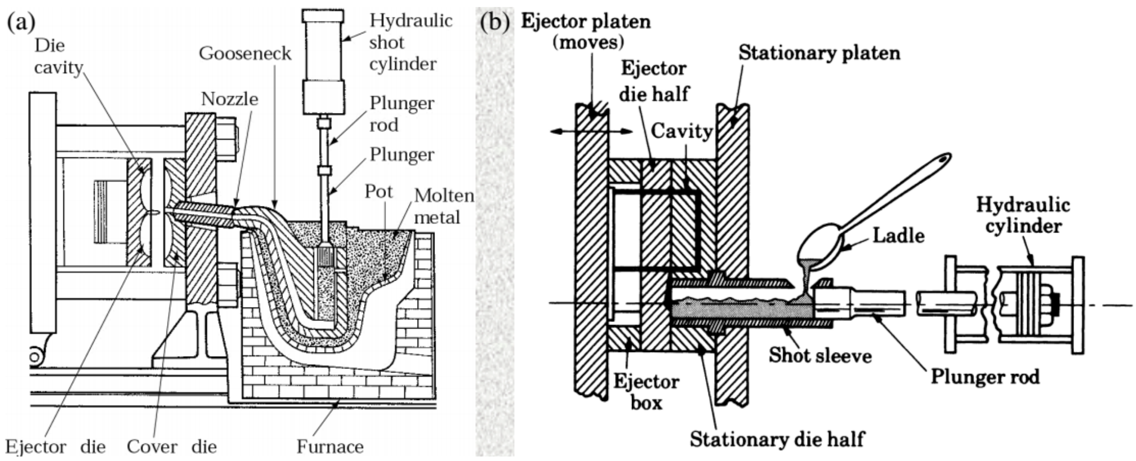

Fig. 4 (a) Schematic illustration of the hot-chamber; (b) the cold-chamber die-casting processes.

F. Translate the following words into Persian.

Shell Molding	Vacuum Molding	Expanded Polystyrene Process
Centrifugal Casting	Plaster Mold Casting	Ceramic Mold Casting
Lost Foam Casting	Slush Casting	

Case study 1. Lost-Foam Casting of Engine Blocks

One of the most important components in an **internal combustion engine** is the **engine block**. Economic benefits can be attained through casting more complex geometries and by incorporating multiple components into one part. Recognizing that evaporative-pattern casting can simultaneously satisfy all of these requirements, Mercury Castings built a lost-foam casting line to produce aluminum engine blocks and **cylinder heads**.

One example of a part produced through lost foam casting is a 45-kW, three-cylinder engine block used for **marine** applications, such as an **outboard motor** on a small boat illustrated in Fig. 5. Previously manufactured as eight separate die castings, the block was converted to a single 10-kg casting, with a weight and cost savings of 1 kg and $25, respectively, on each block. Lost-foam casting also allowed **consolidation** of the engine's cylinder head and the **exhaust** and cooling systems into the block, thus eliminating the associated machining operations and **fasteners** required in sand-cast or die-cast designs.

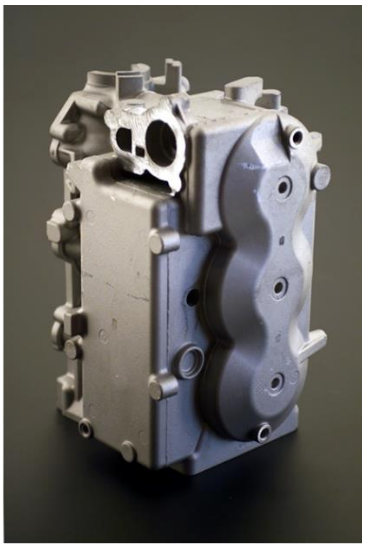

Fig. 5 (a) Metal is poured into mold for lost foam casting of a 60 hp, three-cylinder marine engine, (b) finished engine block.

Case study 2. Lost Wax Casting (Click this link).

E. Translate the following sentences into English.

۱. ریخته گری یک فرآیند انجماد است که در آن فلز مذاب در قالب ریخته شده و اجازه داده می‌شود تا خنک شود. فلز مذاب ممکن است قبل از رسیدن به حفره قالب از میان مسیرهای متنوعی (حوضچه باrریز، راهگاه بارریز، راهگاه ها، تغذیه ها و راهباره) عبور کند.

۲. در فرآیند ریخته گری تحت فشار، فلز مذاب با فشاری بین ۰/۷ تا ۷۰۰ مگاپاسکال به داخل حفره قالب رانده می شود. دو نوع اصلی دستگاه ریخته گری تحت فشار وجود دارد که عبارتند از: محفظه گرم و سرد.

۳. قطعات ریخته گری عموماً تحت عملیات ثانویه ای مانند عملیات حرارتی و ماشینکاری قرار می گیرند تا شکل نهایی مورد نظر، خصوصیات سطحی، صافی سطح و دقت ابعادی مورد نیاز حاصل شود.