In the name of God

Technical English Language

for Materials Engineering and Metallurgy

Lesson 6: Casting and Solidification

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Fall 2025

1. Introduction to Casting

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Casting may be used to create artistic sculptures.

2. Metal Casting

In metalworking, casting involves pouring a liquid metal into a mold, which contains a hollow cavity of the desired shape, and then is allowed to solidify. The casting process is subdivided into two main categories: expendable and non-expendable mold casting.

Casting is a solidification process, which means the solidification phenomenon controls most of the properties of the casting. Moreover, most of the casting defects occur during solidification, such as gas porosity and solidification shrinkage.

3. The gating system

The gating system serves many purposes, the most important being conveying the liquid material to the mold, but also controlling shrinkage, the speed of the liquid, turbulence, and trapping dross. The gates are usually attached to the thickest part of the casting to assist in controlling shrinkage. In especially large castings, multiple gates or runners may be required to introduce metal to more than one point in the mold cavity. The speed of the material is important because if the material is traveling too slowly it can cool before completely filling; leading to misruns and cold shuts. If the material is moving too fast then the liquid material can erode the mold and contaminate the final casting.

4. Shrinkage

There are three types of shrinkage: shrinkage of the liquid, solidification shrinkage and patternmaker's shrinkage. The shrinkage of the liquid is rarely a problem because more material is flowing into the mold behind it. Solidification shrinkage occurs because metals are less dense as a liquid than a solid, so during solidification the metal density dramatically increases. Patternmaker's shrinkage refers to the shrinkage that occurs when the material is cooled from the solidification temperature to room temperature, which occurs due to thermal contraction.

5. Riser and riser aids

Risers are the most common way of providing directional solidification. It supplies liquid metal to the solidifying casting to compensate for solidification shrinkage. For a riser to work properly, the riser must solidify after the casting, otherwise it cannot supply liquid metal to shrinkage within the casting. Riser adds cost to the casting. Another way to promote directional solidification is by adding chills to the mold. A chill is any material which will conduct heat away from the casting more rapidly that the material used for molding.

6. Mold cavity

The mold cavity of a casting does not reflect the exact dimensions of the finished part due to a number of reasons. These modifications to the mold cavity are known as allowances and account for patternmaker's shrinkage, draft, machining, and distortion. In non-expendable processes, these allowances are imparted directly into the permanent mold, but in expendable mold processes they are imparted into the patterns, which later form the mold cavity. Note that for non-expendable molds an allowance is required for the dimensional change of the mold due to heating to operating temperatures.

7. Filling

There are a few common methods for filling the mold cavity: gravity, low-pressure, high-pressure, and vacuum. Vacuum filling, also known as counter-gravity filling, is more metal efficient than gravity pouring because less material solidifies in the gating system. Gravity pouring only has a 15 to 50% metal yield as compared to 60 to 95% for vacuum pouring. There is also less turbulence, so the gating system can be simplified since it does not have to control turbulence. In addition, because the metal is drawn from below the top of the pool the metal is free from dross and slag, as these are lower density (lighter) and float to the top of the pool. The pressure differential helps the metal flow into every intricacy of the mold.

8. Macrostructure of Casting

The grain macrostructure in ingots and most castings have three distinct regions or zones: the chill zone, columnar zone, and equiaxed zone. The Fig. 1 depicts these zones.

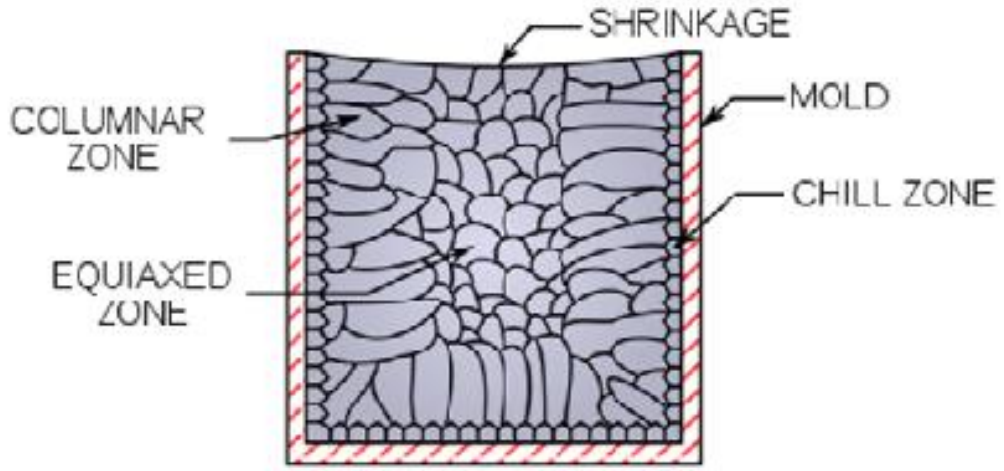

Fig. 1. the chill zone, columnar zone, and equiaxed zone of Macrostructure of Casting

The chill zone is named so because it occurs at the walls of the mold where the wall chills the material. Here is where the nucleation phase of the solidification process takes place. As more heat is removed, the grains grow towards the center of the casting. These are thin, long columns that are perpendicular to the casting surface, which are undesirable because they have anisotropic properties. Finally, in the center the equiaxed zone contains spherical, randomly oriented crystals. These are desirable because they have isotropic properties. The creation of this zone can be promoted by using a low pouring temperature, alloy inclusions, or inoculants.

9. Sand casting

Sand casting is one of the most popular and simplest types of casting that has been used for centuries. Sand casting allows smaller batches to be made compared to permanent mold casting and at a very reasonable cost. Not only does this method allow manufacturers to create products at a low cost, but also there are other benefits to sand casting, such as very small size operations. Sand casting also allows most metals to be cast depending on the type of sand used for the molds.

10. Investment casting

Investment casting is a process that has been practiced for thousands of years, and is one of the oldest known metals forming techniques. Investment casting derives its name from the fact that the pattern is invested, or surrounded, with a refractory material. The wax patterns require extreme care for they are not strong enough to withstand forces encountered during the mold making. One advantage of investment casting is that the wax can be reused.

11. Die casting

The die casting process forces molten metal under high pressure into mold cavities. Most die-castings are made from nonferrous metals, specifically zinc, copper, and aluminum based alloys, but ferrous metal die-castings are possible. The die casting method is especially suited for applications where many small to medium sized parts are needed with good detail, a fine surface quality and dimensional consistency.

12. Semi-solid metal casting

Semi-solid metal (SSM) casting is a modified die casting process that reduces or eliminates the residual porosity present in most die-castings. Rather than using liquid metal as the feed material, SSM casting uses a higher viscosity feed material that is partially solid and liquid. A modified die-casting machine is used to inject the semi- solid slurry into re-usable hardened steel dies. The high viscosity of the semi-solid metal, along with the use of controlled die filling conditions, ensures that the semi-solid metal fills the die in a non-turbulent manner so that harmful porosity can be essentially eliminated.

13. Defects in Castings

Under practical conditions, castings like all metallurgical products contain voids, inclusions, and other imperfections which contribute to a normal quality variation. Such imperfections begin to be regarded as true defects or flaws only when the satisfactory function or appearance of the product is in question. Consideration must then be given to the possibility of salvage or, in more serious cases, to rejection and replacement.

The logical classification of casting defects presents great difficulties because of the wide range of contributing causes, but a rough classification may be made by grouping the defects under certain broad types of arrangement adopted for the present passage. Seven categories of defects are considered, as follows:

1. Shaping faults arising in pouring.
2. Inclusions and sand defects.
3. Gas defects.
4. Shrinkage defects due to volume contraction in the liquid state and during solidification.
5. Contraction defects occurring mainly or wholly after solidification.
6. Dimensional errors.
7. Compositional errors and segregation.

Although these are not mutually exclusive, they afford reasonably clear let lines of division in most cases.

- Choose the best choice using your knowledge of metallurgy and the details in the previous reading.

1. The cooling of a metal from high temperature to room temperature is accompanied by considerable …… .

a) expansion b) circulation ✓ c) contraction d) modification

2. Under practical conditions, castings like all metallurgical products contain ……. which …….. to a normal quality variation.

a) inclusions, indicate b) voids, suggest c) porosity, point ✓ d) imperfections, contribute

3. Heat treatment of castings has a broad purpose; the relief of …… created in cooling process.

✓ a) stresses b) temperatures c) stages d) refinements

4. In materials science and engineering, …..…….. refers to very small holes scattered through a casting.

a) segregation b) embrittlement ✓ c) pinhole porosity d) eccentricity

5. In casting ingots, the desire is to ……. metal as free of …… as possible.

a) cast, solidification ✓ b) obtain, flaws c) strengthen, dislocations d) melt, cracks

6. In metallurgy, ……. is metal oxides in or on the surface of molten metal.

a) dross b) crucible ✓ c) flux d) refractory

7. In foundry industry, some production problems are closely ……. with improper designing. The cooperation between designers and producers can ……. the problem.

a) extruded, liberate b) collapsed, exhibit ✓ c) associated, diminished d) encounter, completes

8. In founding industry, …… is the science of melting and casting of metals into useful objects.

a) die casting ✓ b) foundry c) welding d) wetting

4. Selected vocabulary

En	Fa	En	Fa
Coarse/fine grain	درشت/ریزدانه	Vent	هواکش
Shrinkage	انقباض (انجمادی)	Chill	مبرد
Contraction	انقباض (حرارتی)	Fluidity	سیالیت
Mold or die	قالب	Investment casting	ریخته‌گری دقیق
Void or porosity	حفره	Squeeze casting	ریخته‌گری کوبشی
Slag	سرباره	Centrifugal casting	ریخته‌گری گریز از مرکز
Dross	تفاله	Continuous casting	ریخته‌گری مداوم
Contamination	آلودگی	Aluminum scrap	قراضه آلومینیوم
Pattern	الگو	Gas entrapment	به دام افتادن گاز
Pouring	ریختن	microsegregation	ریزجدایش
Turbulence	اغتشاش	Solidification front	جبهه انجماد
Gating system	سیستم راهگاهی	Solidification range	محدودهٔ انجماد
Riser	تغذیه	Compositional gradient	گرادیان ترکیبی
Core	ماهیچه	Equiaxed grain	دانه هم‌محور