Lecture 1: Introduction of Solidification and Casting

MT321: Principles of SolidificationLecture 1: Introduction of Processing Solidification and Casting

What is casting?

 Casting is one of the major manufacturing processes for making metallic components with desired shapes and bulk solid metallic materials with regular shapes, and it starts with metallic liquid.

Examples of Applications of Casting

 car wheels, engine heads, engine blocks, steel blocks, aluminium alloy billets, steel slabs.









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Continuous casting processes for making steel or aluminium slabs, billets or strips

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What happens during casting?

During casting, liquid metal is poured into the cavity of a mould which then allows the liquid to cool and solidify in a controlled fashion.

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http://v.youku.com/v_show/id_XMzg0MzUzMDEy.html

http://v.youku.com/v_show/id_XMzQ0NDg3MzQ0.html?from=y1.2-1-103.3.3-1.1-1-2

http://v.youku.com/v_show/id_XMzQ0NDg3NDI0.html?from=y1.2-1-103.3.1-1.1-1-0

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The Importance of Casting

- Casting of metallic liquid is one of the most widely used processes for making shaped components since liquid has a nature of taking the shape of its container.
- Casting of metallic liquid is also one of the most important steps of making solid metallic materials since metals and alloys are often first produced in liquid state. Why?
 - Examples: steel making, aluminium alloy smelting, making gold

 Metal casting played a critical role in the historical development and civilization of human being.



Bronze artefacts made and used by human society thousands years ago

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The Importance of Solidification Casting forms the shape of a shaped component or a piece of material from liquid.

- Solidification controls the microstructure of the component or material formed during casting. This microstructure is called as-solidified microstructure.
- For shaped components made from casting, the assolidified microstructure is generally completely or partly kept in the final products, so the as-solidified microstructure can control the properties of the products when they are used.

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Dendrites of water in ice

Question: Why are ice cubes harder than ice cream?

Microstructure of an aluminium ingot

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For a piece of material made from casting, its assolidified microstructure is mostly destroyed by further thermomechanical processing of the material such as rolling, extrusion and forging. In this case, as-solidified microstructure controls the formability of the cast material.

Basic Steps of Casting

- Making mould: A mould with a cavity of required shape is made out of a moulding material and cores.
 - Types of moulding materials:
 - Expendable: sand, ceramic.
 - Permanent: metals, graphite.

Melting: a sufficient amount of liquid is generated through melting metals. Desired alloy compositions are made up during melting by mixing different elemental metals and/or master alloys.

Types of melting furnaces include:

- Cupola: widely used in old days for melting cast iron.
- Electric arc furnaces
- Induction furnaces.
- Gas fired furnaces.



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- Pouring: the mould cavity is filled with liquid metal or alloy in a controlled fashion.
- Solidification of liquid: the liquid solidifies in the mould cavity.

Removing casting from mould.

- It is important to decide at which point should the casting be removed from the mould and how the casting be removed.
- Casting cleaning: remove accessory attachments (risers, runners) and moulding materials stuck on the surface.

Casting Terminology



FIGURE 13-2 Cross section of a typical two-part sand mold, indicating various mold components and terminology.

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Solidification and Casting

How does liquid metal/alloy solidify?

- When being cooled, liquid of pure metals and eutectic alloys solidifies at a constant temperature.
- Liquid of most alloys used in industry do not have eutectic compositions and thus solidify across a range of temperatures which can normally be found out from binary or ternary alloy phase diagrams.





Phase diagram and companion cooling curve for an alloy with a freezing range. The slope changes of the cooling curve indicates the onset and termination of solidification.

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- During very slow cooling, the temperature at which solidification starts is called <u>liquidus temperature</u>, and the temperature at which the solidification finishes is called <u>solidus temperature</u>.
- The difference between liquidus temperature and solidus temperature is called <u>freezing range</u>.

Nucleation and Growth of Schideation is the process through which unstable solid embryos in the liquid becomes stable nuclei.

It is the birth of solid.

Nucleation of solid is not an easy process:

- Liquid may have to be cooled to a temperature much lower than the liquidus temperature.
- Some solid particles (grain refiner particles) may need to be added to assist nucleation.



Without adding grain refiner

0.02wt% carbon is added to the melt to form grain refiner particles

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- Growth is the process in which solid nuclei grow into large solid grains which may have either equiaxed, columnar or dendritic shapes:
 - Heat is released when solid grows.
 - The heat must be removed, otherwise, the growth will stop.
- The direction of solid growth is controlled by the way heat is removed.

In the "Solidification and Casting" part of the course, we will study the fundamental concepts, scientific principles, relationships and general knowledge underlying the solidification and casting processes of liquid metals and alloys which are widely used in making shaped components and materials with regular shapes in industry. Enjoy!