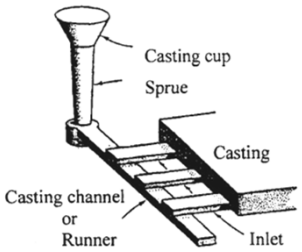
Casting Processing, MH2252, 6 credits



Lecture 3
Casting Hydrodynamics

Today´s topics – Lecture 3

- Repetition
  - Component Casting
- Cast House Processes
  - Continuous Casting
  - Ingot Casting
  - Near Net Shape Casting (The Hazelett Casting Machine)
  - The ESR Process
- Casting Hydrodynamics
  - Gating Systems in Component Casting
  - Basic Hydrodynamics
  - Inclusion Control in Gating Systems
  - Maximum Fluidity Length

Intended learning outcomes

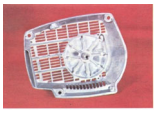
After passing the course the student should be able to:

- **Give example of and justify for the use of common casting processes for manufacturing of components, as well as blanks (work pieces) (TEN2)**
- **Apply and calculate fluid dynamic processes for metal flow at tapping and filling of a casting system for manufacturing of components, as well as blanks (work pieces) (TEN2)**
- Explain principles and justify adopted models for heat transport at the moulding and solidification of metals (TEN2)
- Explain and justify for structure and structure formation in casted materials and the appearance of micro and macro segregations during solidification (TEN2)
- Explain the origin of casting defects such as shrinkage, gas porosity, slags, secondary phases and cracks and methods and processes to control and minimize these (TEN2)
- Dimension and simulate a casting system with the purpose of minimizing casting defects and maximizing yield, and present this in a scientific context (PRA1)
- Describe and give examples of the complexity of a real industrial process chain for casting of components or blanks and present this during a seminar (STU1)

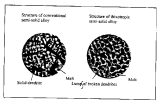
Industrial Casting – Component Casting

- Nonrecurrent Moulds
  - Sand moulding
  - Shell mould Casting
  - Investment Casting

- Permanent Moulds
  - High Pressure Die Castning
  - Die Casting (gravity die casting)
  - Low-Pressure Die Casting
  - Squeeze Casting
  - Centrifugal casting



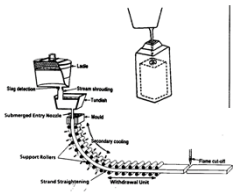
- Thixomoulding/Rheocasting

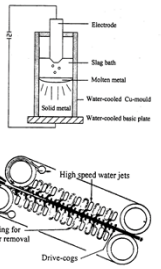


Lect.3-4

Industrial Casting - semi-finished products (blanks)

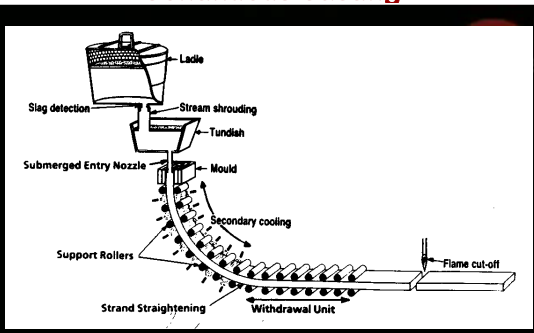
- Cast House Processes (for plastic forming)
  - Continuous Casting
  - Ingot Casting
  - Near Net Shape Casting
  - The ESR Process





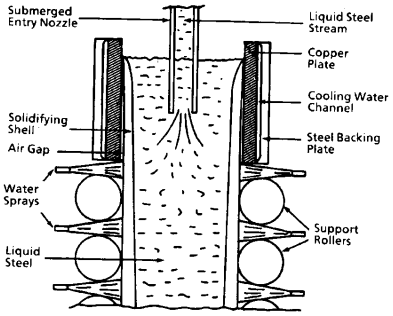
Lect.1-2-5

Continuous Casting



Lect.3-6

Continuous Casting - SEN



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Continuous Casting - Castings

Billet, Bloom, Slab and Rounds

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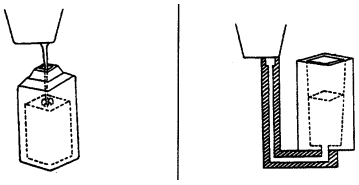
Ingot Casting



Downhill Casting

Uphill Casting

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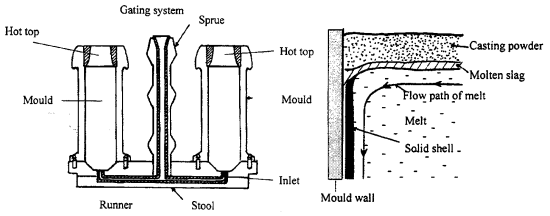
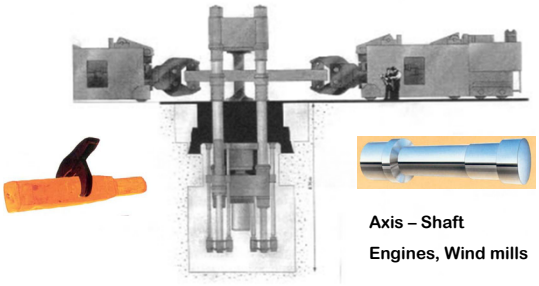
Ingot Casting - Uphill



Uphill Casting Solidification

Lect.1-2-10

Ingot Casting – Components

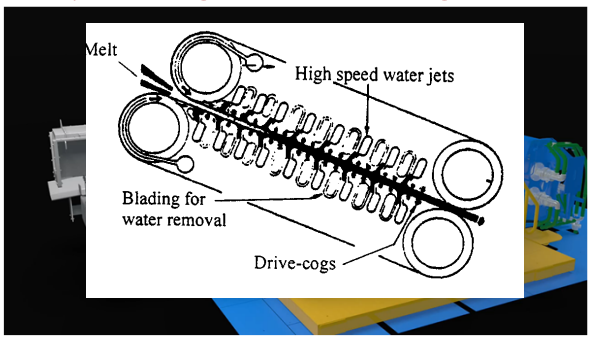


Axis – Shaft

Engines, Wind mills

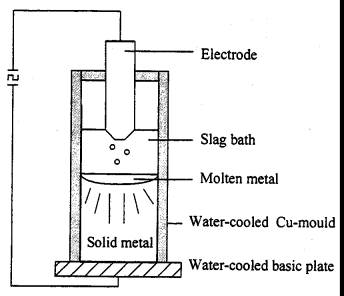
Lect.1-2-11

Some Other Casting Methods - Near Net Shape Casting - Hazelett Casting Machine



Lect.3-12

ESR - Electro Slag Remelting



Refining of ingots

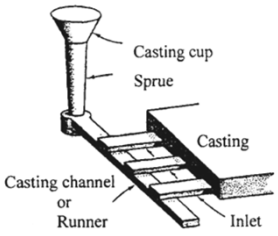
Casting Hydrodynamics – The melt flow

- General
  - Teeming
  - Gating system
  - Inclusions - convection
  - Fluidity

Lect.3-14

Gating System

- Purpose
  - Provide the mould with melt at the proper rate
  - No unnecessary temperature losses
  - Without undesired gas and slag inclusions



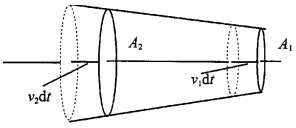
- Gating systems are characterized by the ratios between the cross-sectional area of the sprue (A_s), the runner (A_r) and the ingates (A_i).

  For an unpressurized system: $A_s:A_r:A_i = 1,0:1,3:1,5$

Lect.3-15

Basic Hydrodynamics

- Principle of Continuity
  - Incompressible Liquid



$$v_1 A_1 = v_2 A_2$$

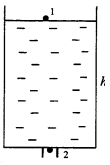
- No fluid appears or disappears during the flow
- The fluid flow volume is constant by time

Basic Hydrodynamics

- Bernoulli's Equation
  - Laminar flow

$$p_1 + \rho g h_1 + \frac{\rho v_1^2}{2} = p_2 + \rho g h_2 + \frac{\rho v_2^2}{2}$$

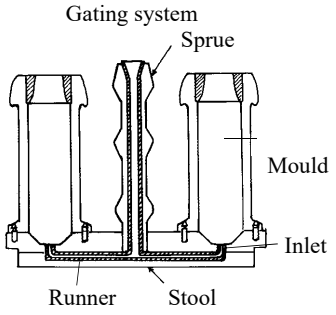
Teeming a ladle



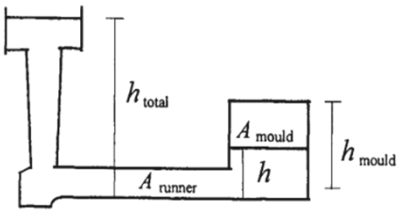
- The first part: Pressure work
- The second part: Potential energy
- The third part: Kinetic energy

- $A_1 >> A_2 \rightarrow v_1 << v_2 \rightarrow v_1 \approx 0$ (Principle of Continuity)
- Torricelli's law: $v_2 = \sqrt{2gh}$

Gating Systems at Ingot Casting - Uphill Casting (penetrable mould)

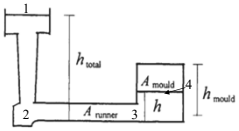


Gating Systems at Ingot Casting - Uphill Casting (penetrable mould)



Schematic figure

Hydrodynamics at Uphill Casting



$$v_2 = \sqrt{2g(h_{tot} - h)}$$

Melt velocity at point 2, from Bernouilli's eq (Torricelli's law with back pressure).

$$A_m dh = A_i \sqrt{2g(h_{tot} - h)} \cdot dt$$

Height (volume) change, dh, by the time dt, at point 4, by combining with the Principle of continuity

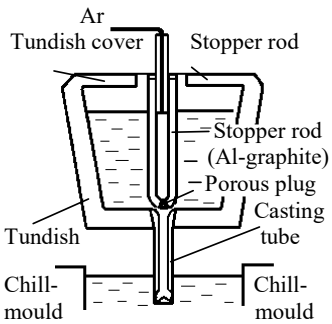
$$\frac{A_i}{A_m} \int_0^{t_f} dt = \frac{1}{\sqrt{2g}} \cdot \int_0^{h_m} \frac{dh}{\sqrt{h_{tot} - h}}$$

Integrate

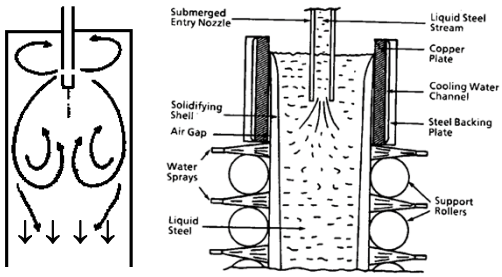
$$t_f = \frac{2A_m}{A_i\sqrt{2g}} \cdot \left(\sqrt{h_{tot}} - \sqrt{h_{tot} - h_m}\right)$$

The filling time, t_f

Gating Systems at Continuous Casting



Flow Pattern of the Melt



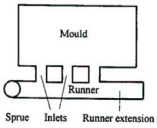
Flow pattern of the melt around a casting tube in the mould

Lect.3-22

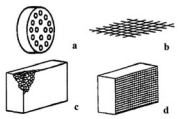
Inclusion Control -I

- Swirl trap

- Runner Extension

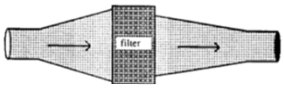


- Ceramic Filters



Lect.3-23

Inclusion Control - Ceramic Filters

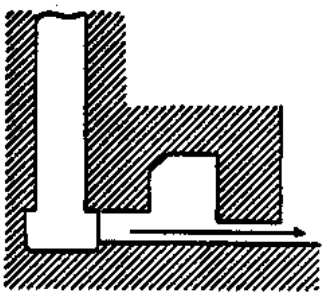


Sketch of the metal flow in a ceramic filter

- Physical screening
- Chemical attraction

Lect.3-24

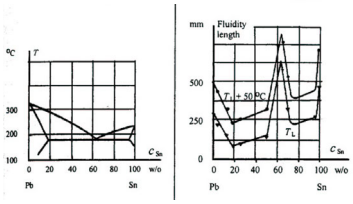
Inclusion Control-II



Mechanical impurity trap

Maximum Fluidity Length

- Fluidity spiral for check of the maximum fluidity length



Maximum fluidity length for the system Pb-Sn

Recommended reading in "Materials Processing during Casting", by Hasse Fredriksson and Ulla Åkerlind

Chapter: ❑ 3.1 – 3.7