KTH Industriell teknik
och management

# EXAM IN MH2252 CASTING PROCESSING

# PART I

**Date:** **2021-10-22**
**Time:** **08.00 - 13.00**
**Location:** **Digital**

## Means of assistance, part 1

- **The textbook "Materials Processing during Casting" by Hasse Fredriksson and Ulla Åkerlind, or alike.**
- **"Beta Mathematics handbook" or any formula/table collection**
- **Dictionaries (as well electronic ones)**

## Information

- The written examination is divided into two parts. The first part (Part I) is handed out when the examination starts. The second part (Part II) is handed out when Part I is handed in. No time limit exists between the two parts of the examination.

- The exam consists of assignments on the course's five learning objectives. To pass the exam, grade E, a basic / sufficient level of knowledge corresponding to approximately 50% correct answers of each ILO. Higher grades are given at good (C)/very good knowledge (A) of the learning objectives. Completion grade Fx can be offered when a basic/sufficient level of knowledge has not been shown in all learning objectives.

Examiner: Anders Eliasson, tel. 08-790 7255, anderse@kth.se
**Responsible teacher: Anders Eliasson, tel. 073 614 95 73**

## Submission

You should handwrite the exam on paper; you will need to scan the handwritten text with the app ScanPro. The app converts the picture file to a PDF document. After scanning your paper, you need to transfer the PDF file to your computer and upload it in Canvas assignments!

Obs, det går även bra att svara på Svenska.

Both results and the assessed examinations are published approximately 15 correcting days after the examination, latest by 2021-11-15.

Appeal of reassessment and completion of the exam (Fx) should take place within 3 weeks from the date of notification. In case of reassessment, contact the ITM's student office, and by completion of the exam (Fx), the course responsible.

*Note, this cover sheet should be separated and not scanned*

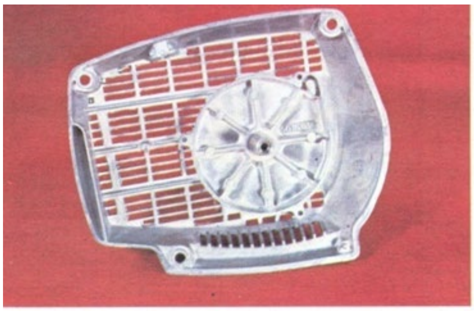
Name:.................................................................................. Personal number:..................................................

**Problem 1 (15p) Casting processes for component casting and cast house processes (LM1)**

Foundry production of components are done either in non-recurrent moulds or in permanent moulds.

- First, suggest, motivate and describe a suitable casting method for each of these components
- Second, motivate for an alternative casting method, for each of these components

Exhaust manifold made in grey cast iron



Cover for chainsaw in aluminium

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**Problem 2 (10p) Casting hydrodynamics for metal flow at tapping and filling (LM2)**

The hydro mechanical laws "Principle of Continuity" and "Bernoulli's eqn" are valid for molten metals as for other fluids, for example water.

Below is a picture of a water tap:

- Derive by help of these laws both an expression of the final velocity and an explanation of the conical appearance of the water jet in the picture.
- Given that, the water jet area in the sink has the same area as of the water tap (more of a cylindrical appearance than a conical one). How do you explain this behaviour of the water jet by the help of the same laws?

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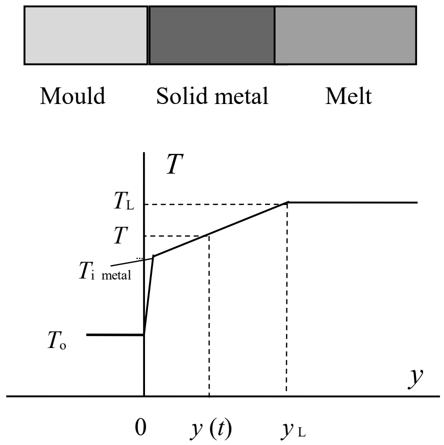
**Problem 3 (10p) Heat transport and solidification of metals (LM3)**

Heat transport and solidification at casting processes are often very complicated. At poor contact between a solidifying metal and the mould the below temperature distribution is estimated.

- Give and explain the modifications done by the temperature distribution at the poor contact-casting model.
- Give and explain the temperature distribution and the resulting solidification time equation at thin component castings.



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**Problem 4 (10p) Structure formation and micro and macro segregations during solidification (LM4)**

In steel ingots, it appears many different types of macro segregations. One will result in a formation called V-segregation (as well found in continuous castings).

- Describe and explain the appearance of V-segregations in ingots. Please make use of both text and sketches in your explanation.
- Discuss and motivate for your estimated explanation (this is important!).

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**Problem 5 (10p) Casting defects, porosity, slags, secondary phases and cracks (LM5)**

At solidification of cast materials, it may appear some kind of porosity in castings with some different origin.

- Describe and explain how to distinguish between so-called shrinkage and gas porosity.

Shrinkage porosity can be divided into two subgroups: micro-, and macro porosity (pipe).

- Describe and explain the influence of alloy composition and cooling conditions on the appearances of micro-, and macro porosity.

Please make use of sketches as well to back up your explanations.

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# PART II

**Date:** 2021-10-22
**Time:** 08.00 - 13.00
**Location:** Digital

**<u>Means of assistance</u>**

- **"Materials Processing during Casting" by Hasse Fredriksson and Ulla Åkerlind - it is as well found electronically in the Canvas activity..**
- **"Beta Mathematics handbook" or any formula/table collection**
- **Calculator**
- **Dictionaries (as well electronic ones)**

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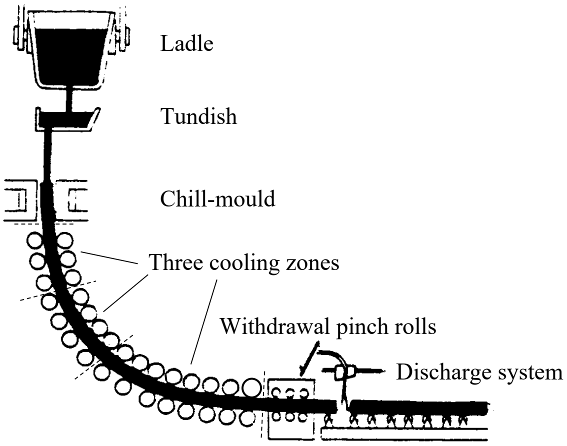
**Problem 6 (15p) Casting hydrodynamics for metal flow (LM2). Casting processes for component casting and cast house processes (LM1)**

A scrap-based steel plant has a continuous casting machine with a slab cross-section of 150 x 1500 (mm). The diameter of the submerged entry nozzle is 5 cm and the heat transfers coefficient in the chill mould is 1200 W/m²K. Aside from the 1 m long copper chill-mould, the caster is equipped with three secondary cooling zones as seen in the table.




| Cooling zone | Heat transfer coefficient $W/m^2 K$ | Zone length m |
|---|---|---|
| Chill-mould | 1200 | 1.0 |
| 1 | 500 | 2.5 |
| 2 | 200 | 5.0 |
| 3 | 50 | 7.5 |

Material constants

| | |
|---|---|
| $\rho$ | $= 7.9 \cdot 10^3$ kg/m³ |
| $(-\Delta H)$ | = 272 kJ/kg |
| $k$ | = 30 W/m K |
| $c_p^{Fe}$ | = 420 J/kg K |
| $T_L$ | = 1470 °C. |

a) Calculate the maximum casting rate of the machine.
b) Calculate the minimum height of liquid metal in the tundish to ensure a steady flow of material to the strands.

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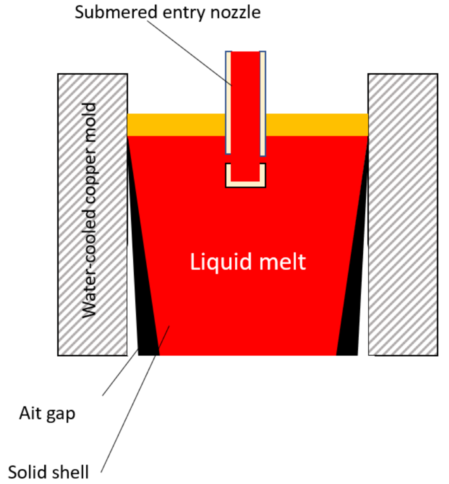
**Problem 7 (15p) Heat transport and solidification of metals (LM3). Structure formation and micro and macro segregations during solidification (LM4)**

At continuous casting the metal flows from the ladle via the tundish down into a vertical water-chilled copper mould. During the passage, the melt starts to solidify and a solid shell is formed. A necessary condition is that the shell gets such mechanical properties that it is rigid outside the chill-mould. The continuous caster casts a 200 mm x 1600 mm cross-section slab.




a) If the heat transfer coefficient between solid shell and the copper mold is 1000 W/m$^2$K and the copper mold is 1 m in depth, what is the maximum casting rate if the solid shell thickness must be a minimum of 10 mm at mold exit?

Material constants

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$T_0$ = 100 $^{O}$C

$T_L$(steel) = 1470 $^{O}$C

$\rho_{steel}$ = $7.70 \cdot 10^3$ kg/m$^3$

$-\Delta H_{steel}$ = 290 kJ/kg

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b) Given the relationship

$$v_{growth} \cdot {\lambda_{den}}^2 = 10^{-12}\ m^3/s$$

What is the dendrite arm spacing at the solidification front the moment the strand leaves the mold?

*Hint: Ignore Nussels number if it is smaller than 1.*

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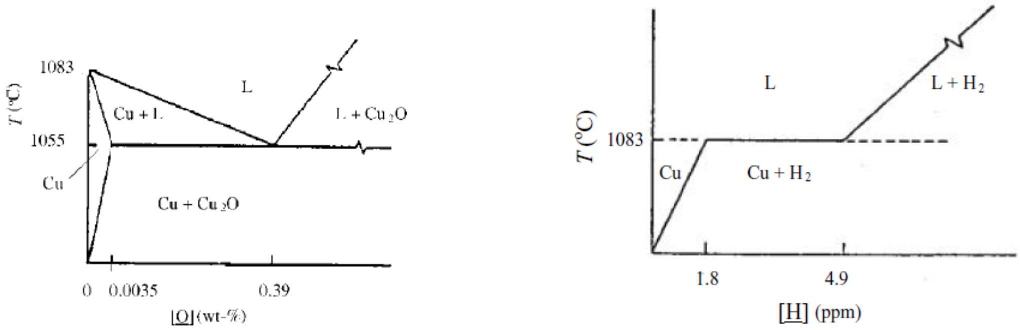
**Problem 8 (15p) Casting defects, shrinkage, gas porosity, slags (LM5). Structure formation and micro and macro segregations during solidification (LM4)**

A copper cube, 200 mm x 200 mm x 200 mm is to be casted in a sand mould. An initial attempt to cast the copper cube without a feeder is made. ome gas pores are observed at close to the centre of the casting at an estimated solid fraction, fs = 0.9. It is known that the initial oxygen content in the copper melt is 0.01 wt%, and there are some hydrogen present in the melt at the beginning. The solubility product of the water vapour formation reaction is:

$$c_{\underline{H}}{}^2 c_{\underline{O}} = 2 \cdot 10^{-11} p_{H_2O}$$

a) Assuming that water vapour is the only gas, which could possibly form porosity during solidification, estimate the initial dissolved hydrogen in the melt. Below gives the binary phase diagrams of the systems Cu-O and Cu-H.




Simplified phase diagram of the system Cu–O at 1 atm $O_2$. Simplified phase diagram of the system Cu–H at 1 atm $H_2$.

b) A cylindrical feeder is placed on top of the casting. Design a suitable feeder dimension based on the material constants below. Note you need to consider some geometrical equations for cylinders to solve the problem:

$V = \pi r^2 \cdot h$ and

$A_{Surface} = 2\pi r \cdot h + 2\pi r^2$

Material constants

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| | |
|---|---|
| $-\Delta H_{Cu}$ | = 200 kJ/kg |
| $T_L$(Cu) | = 1084 °C |
| $T_0$ | = 20 °C |
| β (Cu) | = 3.8 % |
| $\rho_{sand}$ (cylinder) | = $1.5 \cdot 10^3$ kg/m$^3$ |
| $c_p^{sand}$ (cylinder) | = $0.27 \cdot 10^3$ J/kgK |
| $k_{sand}$ (cylinder) | = 1.45 J/msK |
| $\rho_{sand}$ (feeder) | = $0.9 \cdot 10^3$ kg/m$^3$ |
| $c_p^{sand}$ (feeder) | = $0.20 \cdot 10^3$ J/kgK |
| $k_{sand}$ (feeder) | = 0.41 J/msK |

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