MechEng 714: SOLIDIFICATION PROCESSING

COURSE GOALS AND OBJECTIVES

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SCHEDULE  Monday 13:00 to 16:00 hours (1pm to 4pm)

LOCATION  JHE/323

TEXT  Course notes will be provided in the duration of the course.
The following textbooks were used in developing the course material
(1) W. Kurz and D.J Fischer, Fundamentals of Solidification 4th Revised Edition,
(2) M. Flemings, Solidification Processing, McGraw-Hill Inc., USA 1974
(3) D. M. Stefanescu, Science and Engineering of Casting Solidification, Second
(4) Solidification and Casting, Eds. B. Cantor and K. O’Reilly, Institute of
(5) M.E. Glicksman, Principles of Solidification: An Introduction to Modern
and several others; use the library

GOALS  To gain a new appreciation for the art of solidification processing (casting) through
the rigours of a fundamental understanding of the science.

OBJECTIVES  Upon completion of this course the student should be able to:
• Know various solidification processes (casting).
• Understand the structure of liquid metals and alloys, broadly.
• Analyze heat transport in solidification.
• Understand pure metal solidification.
• Understand alloy solidification through heat and mass transport.
• Relate solidification microstructure to process conditions.
• Evaluate solidification parameters from experiment results.
• Gain insight in numerical models for solidification
• Knowledge about defects formed during solidification.
• Appreciate recent advances in the field of near net shaped casting.

GRADING  Tentative (subject to change with
advanced notice)
Group Assignments  60%
Midterm Examination  20%
Final Exam  20%
ALL DIGITAL SUBMISSIONS FOR GRADING MUST ADHERE TO HIGH STANDARDS AKIN TO THAT IN NOTABLE JOURNAL PUBLICATIONS.

Each week will have a set of specific learning outcome, which shall be the focus of the weekly lectures and practice problems given to students to work on their own time. The students’ efforts on the practice problems will not be graded but will certainly enhance knowledge on the topic and prove beneficial during exams.
## COURSE OUTLINE

<table>
<thead>
<tr>
<th>Week Number</th>
<th>Topics</th>
<th>Details</th>
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|             | Solidification Processes (Casting in today’s Commerce) | Historical Perspective of Casting  
Length Scales  
DC and Continuous Casting Processes  
Net Shaped Casting Processes  
Necessity of the Variety of Processes  
Casting Materials and Applications  
Future Prospects |
|             | Liquid to Solid | Atomic Structure of Liquid Metals and Alloys  
Atomic Bonding and Flow of Metallic Liquids  
Theory of Metallic Liquid State  
Transformation of Liquid to Solid  
Latent Heat of Fusion  
Pure and Binary Systems  
Introduction to Eutectics and Peritectics |
|             | Thermodynamics of Solidification | Free Energy  
Entropy and Reversibility  
Energy Balances  
Source Term Generation  
Sharp Interface Energetics (Stefan’s Problem)  
Shrinkage and Chvorinov’s Rule |
|             | Energy Transport | Heat Flow  
Rate of Solidification  
Analyze a laboratory experiment of Unidirectional solidification. |
|             | Solute Redistribution | Solid-Liquid Interface  
Fluid Feedability (Capillarity)  
Diffusion and Convection/Advection  
Solid/Liquid Interface Characteristics  
Constitutional Undercooling  
Stability of solidifying interface  
Mullins-Sekerka Stability Criterion  
Interface gradient and velocity relationships |
|             | Solute Redistribution | Perturbation Analyses of S/L Interface  
Analytical Models of Solute Redistribution |
|             | Solidification Microstructure | Growth of Perturbed Interface  
Ivantsov’s Proposition  
The Mushy Zone  
Planar/Cellular/Dendritic Growth  
Macrosegregation  
Solute Microsegregation  
Atomically Rough and Smooth Interface  
Growth Directionality and Morphology (Interface Surface Stiffness) |
|             | Solidification Microstructure | S/L Interface Undercooling  
Polyphase solidification  
Eutectic Solidification  
Peritectic Solidification  
Solute Trapping  
Rapid Solidification |
|             | Nucleation | Homogeneous Nucleation  
Heterogeneous Nucleation  
Grain Refinement |
| Solidification Defects | Dissolved Gas  
Pin Holes  
Porosity  
Shrinkage  
Hot Tear  
Inclusions |
|------------------------|--------------------------------------------------|
| Fluid Dynamics          | Fluid Flow during Mould Filling (Macro)  
Ten rules for Good Casting  
Micro Scale Fluid Flow  
Effect of Forced Convection on Microstructure  
Non-Dendritic Castings |