MS2084 Phase Transformations and Kinetics in Steels

Academic Year	2023-2024	Semester	1 & 2 from AY23/24 S2
Course Coordinator	A/P Aravind Dasari		
Course Type	Core		
Pre-requisites	MS1017 Introduction to Materials Science		
	MS1018 Properties of Materials		
	MS2016 Introduction to Metallurgy*		
AU	1		
Grading	Letter Grading		
Contact Hours	13 (Lecture 5 h, Tutorial 2 h, Laboratory 6 h)		
Proposal Date	1 March 2023		

** Even if a student fails MS2016, the student can take this new experiential learning module.*

Course Aims

The fundamental understanding of phase transformations in materials is the key for tuning their structure and properties. This course will provide the necessary basic knowledge to relate bonding, diffusion, and temperature (heat treatment) in solids, particularly steel, to their evolution of structure/phase and properties. That is, it presents the connections between thermodynamic concepts, phase transformations and materials properties. More specifically, the students will have the opportunity to experience the fundamental concepts lectured in class through experimental work and analyzing/reflecting on the obtained data, and ultimately connecting with the concepts.

The students after listening to the content will work in the lab in groups on different carbon steel samples. They are expected to polish, etch, and understand the grain and microstructure along with their impact and hardness properties before subjecting to different heat treatment conditions. The students will be austenizing the samples and cool them using different cooling rates to achieve desired effect on properties.

Intended Learning Outcomes (ILO)

By the end of this course, you (as a student) would be able to:

1. Identify carbon sites (interstitial positions – octahedral and tetrahedral) in both ferrite and austenite iron lattices; and illustrate their importance in terms of strength and hardness of the system.
2. Demonstrate the use of Time-Temperature Transformation (TTT) diagrams.
3. Describe the effects of changing process parameters on the microstructure of steels.
4. Explain the mechanisms of phase transformations in steels (based on diffusion and diffusionless transformations).
5. Describe martensitic and pearlitic transformations.
6. Explain the importance and types of cast iron, effects of cooling rate on the microstructure of cast iron, and significance of carbon equivalent.

Course Content

No	Topic	Hours
1	Introduction to phase transformations and kinetics	1
2	TTT charts and the different types of transformations	1
3	Diffusionless transformations	1
4	Diffusion-based transformation	1
5	Cast iron	1
6	Laboratory – group project	6
7	Tutorials on the concepts discussed	2
	Total	**13**

Assessment (Includes both continuous and summative assessment)

Component	ILO Tested	EAB Graduate Attributes	Weightage	Team / Individual	Rubrics
1. CA1: Quiz	1 to 6	(a), (b)	25%	Individual	Demonstration of understanding of the concepts, Appendix 1
2. CA2: Project work	1 to 6	(a), (c), (d), (h), (i), (j)	65% (55% + 10%)	Group & Individual	10% in the 65% will be set aside for peer-assessment within the group; For the 55%, please see Appendix 1
3. Class Participation	1 to 6	(b)	10%	Individual	N.A.
Total			**100%**		

EAB Graduate Attributes[1]	
a)	**Engineering Knowledge** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems.
b)	**Problem Analysis** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c)	**Design/Development of Solutions** Design solutions for complex engineering problems and design systems, components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d)	**Investigation** Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e)	**Modern Tool Usage**

[1] *Reference: EAB Accreditation Manual*

	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering problems, with an understanding of the limitations.
f)	**The Engineer and Society** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
g)	**Environment and Sustainability** Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.
h)	**Ethics** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i)	**Individual and Team Work** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j)	**Communication** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k)	**Project Management and Finance** Demonstrate knowledge and understanding of engineering management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l)	**Life-long Learning** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Formative Feedback

- CA questions will be thoroughly discussed in the class;
- Feedback will be provided to the students on their approaches, common mistakes, and other general issues;
- Class average marks will be posted. Each student will also be informed of his/her CA marks;
- Students are encouraged to drop by coordinator's office during the consultation hours to discuss and clarify any questions relating to the course.
- A general feedback on students' performance in the project work will also be provided.

Learning & Teaching Approach

Approach	How does this approach support students in achieving the learning outcomes?
Interactive and physical classes	As the concepts described in the course relate the structure of metallic solids to properties, thorough understanding of the concepts is required. Though lecture notes are provided to students, they are encouraged to refer different books and the self-assessment questionnaires are designed to test the students' critical understanding of the subject. That is self-directed learning is encouraged. Interactive platforms like Wooclap will be used to promote discussions. The questions are also designed from that viewpoint (as open ended) to achieve the said learning outcomes.
Experiential learning	The adoption of experiential learning methodology will be critical in enhancing the depth of students' understanding about the topic. The theoretical portion can be effectively connected to the hands-on laboratory project that the students will be carrying out.
Collaborative work	As the students will be working in groups on the laboratory project, the discussions among the group members on the data they are obtaining, and other aspects will be another way to improve their subject understanding.

Readings & References

Suggested reading:

- Phase Transformations in Metals and Alloys, 3rd edition, David A Porter, Kenneth E Easterling, Mohamed Sherif, 2009, CRC Press, ISBN: 978-1-42006-210-6.
- Theory of Transformations in Steels, 1st edition, H.K.D.H. Bhadeshia, 2021, CRC Press, ISBN: 978-1-00305-678-2.
- Phase Transformations in Steels, Editors: Elena Pereloma and David V. Edmonds, Vol. 2, Woodhead Publishing Series in Metals and Surface Engineering, 2012, ISBN: 978-1-84569-970-3
- Fundamentals of solidification, 4th edition, W. Kurz and D.J. Fisher, 1998, Trans Tech Publications, ISBN: 978-0-87849-804-8.

Additional reading:

- Materials science and engineering: an introduction, Willian D Callister, Wiley.
- Introduction to the thermodynamics of materials, 5th edition by David Gaskell, Yaylor and Francis, 2008.

Course Policy & Student Responsibility

(1) CA: Absentees must be supported by a medical certificate or other valid official documents.
(2) Wooclap: Students have to register for Wooclap accounts using their NTU email address. These questions will be posed in every lecture or tutorial and the active participation is accounted.
(3) Students are expected to attend the pre-laboratory briefings, complete the safety training, and attend all the experimental trainings.

Absenteeism

This module requires you to contribute to teamwork. Therefore, absence from group discussions and experiment planning is unacceptable without a valid reason/supporting documents. Otherwise, this will affect your overall course grade.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office	Phone	Email
A/P Aravind Dasari	ABN-B2c-14/15	67906402	aravind@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/Activities
1	Phase transformations – importance of ΔG, types of transformations, nomenclature of steels, and growth rate relationship	1 to 6	Face to face lecture, tutorials and self-assessment questions
2	Phase transformations – TTT curves, homogeneous versus heterogeneous nucleation, precipitate free zones, and introduction to characteristics of martensite	1 to 6	Face to face lecture, tutorials and self-assessment question
3	Martensitic transformation-atomistic model and other diffusionless transformations; Pearlitic and other diffusion based transformations, and cast iron	1 to 6	Face to face lecture, tutorials and self-assessment questions
4, 5, 6	Experimental planning, execution, analysis and report writing	1 to 6	Training on equipment and go through the different experiments.