GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-IV

Course Title: Heat Treatment
(Course Code: 4342103)

Diploma Programme in which this course is offered	Semester in which offered
Metallurgy Engineering	4th Semester

1. RATIONALE

The various products of metals and alloys used in different industries like Automobiles, Mining, Oil & gas, Transportation, Manufacturing, etc. These products require certain Mechanical properties like Hardness, Toughness, Strength, Fatigue resistance, Creep resistance etc. to function properly without failure in the field. These properties can be Introduced and improved in Metals and alloys by various heat treatment processes. The diploma engineers are expected to supervise these heat treatment processes for quality outputs. Hence, this course deals with the understanding of principles and procedures of different types of heat treatment processes for engineering metals and alloys. This course will help the student to understand the underlying physical metallurgy principles and application of different types of heat treatment processes for obtaining the desired properties in the alloys.

2. COMPETENCY

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire the following competency:

- **Apply the knowledge of various heat treatment operations to achieve desired properties.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

1. Select appropriate heat treatment process to get desired properties.
2. Interpret T.T.T. and C.C.T. diagrams of various steels.
3. Select surface hardening processes for steel based on applications.
4. Examine quality control parameter of heat treatment processes.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	4	5	30*	70	50	50	200

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T****–Tutorial/Teacher Guided Theory Practice;* ***P*** *-Practical;* ***C*** *– Credit;* ***CA*** *- Continuous Assessment;* ***ESE*** *-End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. Some of the PrOs marked '*' are compulsory, as they are crucial for that particular CO. These PrOs need to be attained at least at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain.'

Sr. No.	EXERCISES/ PRACTICAL	Unit No.	Approx. Hrs. Required
1.	Interpret T.T.T. diagram of eutectoid steel, hypo eutectoid steel and hyper eutectoid steel.	II	4
2.	Perform annealing heat treatment on steel specimen and study its effect on microstructure and hardness of steel.	III	6
3.	Perform normalizing heat treatment on steel specimen and study its effect on microstructure and hardness of steel.	III	6
4.	Perform hardening heat treatment on steel specimen and study its effect on microstructure and hardness of steel.	IV	6
5.	Perform tempering heat treatment on steel specimen and study its effect on microstructure and hardness of steel.	IV	6
6.	Determine Hardenability of steel by Jominy End Quench Test.	IV	6
7.	Perform carburizing on carbon steel and analyze its effect on hardness.	V	6
8.	Perform induction hardening on carbon steel and analyze its effect on hardness.	V	6
9.	Analyze effect of nitriding, cyaniding and flame hardening process during industrial visit.	V	6
10.	Identify defects occurs in Heat treated products.	VI	4
	Total hours		**56 Hrs.**

Notes:

i. *More* ***Practical Exercises*** *can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some* ***sample*** *'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed* ***Practical Exercises*** *of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs.	Weightage in %
1	Identification of the raw material	20
2	Operate equipment and set-up carefully	20
3	Observation and recording of results	20
4	Interpretation of the result and conclusion	20

5	Submission of report within time limit and attendance in the laboratory	20

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical's in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrOs. No.
1.	Muffle furnace Maximum Operating Temperatures: 1200 °C Heating element: Kanthal wire microprocessor based PID temperature controller	2,3,4,5,6
2.	Carburizing furnace Maximum Operating Temperatures: 1500 °C	7
3.	Induction Hardening Machine	8
4.	Metallography Specimen preparation set up	2,3,4,5
5.	Double Disc Polishing Machine, Electrolytic polishing and etching machine	2,3,4,5
6.	Metallurgical Microscope Magnification: 1000 X	2,3,4,5,10
7.	Image Analyzer	2,3,4,5,10
8.	Rockwell/Brinell/Digital Portable Hardness Testing Machine	2 to 10
9.	Jominy End Quench set up	6
10.	Magnetic particle testing Machine / Ultrasonic testing Machine	10

7. AFFECTIVE DOMAIN OUTCOMES

The following sample Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Aware about the various heat treatment processes used to change properties of the alloys.
b) Participates in class discussion related to heat treatment operations.
c) Work as independently individuals, displays teamwork, displays leadership quality and professional commitment to ethical practice on daily basis.
d) Practice environment friendly methods and processes.
e) Be aware about the safety aspects during the heat treatment process.

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of Revised Bloom's taxonomy that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Major Learning Outcomes	Topics and Sub-topics
Unit – I Introduction to Heat Treatment Processes	1.a State importance of heat treatment process. 1.b Classify heat treatment processes.	1.1 Introduction to heat treatment 1.2 Steps involved in heat treatment process 1.3 Classification of heat treatment process
Unit – II Phase Transformations	2.a Construct T.T.T. diagram of various steels. 2.b Discuss austenite to pearlite, bainite and martensite transformation. 2.c Understand parameters and alloying element affects the T.T.T. diagram. 2.d Apply knowledge of T.T.T. diagram in different applications. 2.e Plot C.C.T. diagram.	2.1 Limitations of Fe-Fe_3C diagram 2.2 Construction of Time Temperature Transformation diagram 2.3 T.T.T. diagram of hypo eutectoid steel, eutectoid steel, hyper eutectoid steel 2.4 Pearlitic transformation, Bainitic transformation, Martensitic transformation 2.5 Factors affecting T.T.T. diagram and its limitations 2.6 Applications of T.T.T. diagram 2.7 Effect of alloying elements on T.T.T. diagram 2.8 C.C.T. diagram
Unit – III Annealing & Normalizing	3.a Discuss annealing processes based on temperature, phase transformation and purpose. 3.b Describe normalizing process. 3.c Differ annealing and normalizing processes.	3.1 Principle, and objectives of annealing 3.2 Various annealing processes used for steels 3.3 Principle, objectives, and process of normalizing 3.4 Difference between annealing and normalizing process
Unit – IV Hardening & Tempering	4.a Describe Hardening Mechanism. 4.b Select proper quenching media based on application. 4.c Discuss process and importance of hardenability. 4.d Explain need and Importance of Tempering. 4.e Discuss precipitation hardening.	4.1 Principle and objectives of Hardening Process 4.2 Heat removal Mechanism during Quenching 4.3 Characteristics of quenchants and quenching media 4.4 Hardenability and Jominy End Quench Test 4.5 Need of Tempering process 4.6 Three stage Tempering process 4.7 Precipitation Hardening

Unit	Major Learning Outcomes	Topics and Sub-topics
Unit – V Surface Hardening Processes	5.a Explain the importance of surface hardening process. 5.b Classify surface hardening processes. 5.c Describe different surface hardening processes.	5.1 Need of Surface hardening processes 5.2 Carburizing Process 5.3 Nitriding Process 5.4 Cyaniding Process 5.5 Induction Hardening Process 5.6 Flame hardening Process
Unit – VI Quality Control in Heat Treatment	6.a Identify defects occurring during heat treatment process. 6.b Describe the factors affecting the quality of heat treatment of products.	6.1 Defects and remedies during Heat treatment process 6.2 Factors affecting the quality of Heat treatment product

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of theory marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Heat Treatment Processes	02	02	02	-	04
II	Phase Transformations	10	06	08	04	18
III	Annealing & Normalizing	08	04	06	04	14
IV	Hardening & Tempering	10	04	06	04	14
V	Surface Hardening Processes	08	02	06	06	14
VI	Quality Control in Heat Treatment	04	02	02	02	06
	Total	**42**	**20**	**30**	**20**	**70**

Legends: R = Remember; U = Understand; A = Apply and above levels (Bloom's revised taxonomy)

Notes:

1. This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may slightly vary from above Table.
2. Ask the questions from each topic as per marks weightage. Numerical questions are to be asked only if it is specified. Optional questions must be asked from the same topic.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related co-curricular activities which can be undertaken to accelerate the attainment of the various outcomes in this course:

Students should conduct following activities in group

1. Visit nearby industries engaged in Heat Treatment (if any) and study the processes are being used.
2. Create data bank of mechanical properties of different grade of steel in as cast and heat-treated condition and compare the difference in both.
3. List heat treatment operations used to develop different products.
4. Compare T.T.T. and C.C.T. diagram.
5. Group discussion on effect of heat treatment on microstructure and properties of various alloys.
6. Group discussion on environmental issues and control in the industrial heat treatment.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (MOOCs) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) Different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About 20% of the topics/sub-topics which are relatively simpler or descriptive in nature is to be given to the students for self-learning, but to be assessed using different assessment methods.
e) With respect to section No.10, teachers need to ensure to create opportunities and provisions for co-curricular activities.
f) Guide students on how to address issues on environment and sustainability using the knowledge of this course.
g) Encourage students to read temper designations.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based. However, in the fifth and sixth semesters, it should be preferably be individually undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups must be formed for micro-projects, the number of students in the group should not exceed three.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based, or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than 16 (sixteen) student engagement hours during the course. The student ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

1. Study the effect of annealing and normalizing on microstructure and mechanical properties of medium carbon steel.
2. Study the effect of hardening and tempering on microstructure and mechanical properties of medium carbon steel.
3. Study the effect of precipitation hardening on aluminium alloy.
4. Compare surface hardening methods based on process and applications.
5. Make a report on "Effect of Full annealing on Hypo Eutectoid steel, Eutectoid steel and Hyper Eutectoid Steel."
6. Examine and draw microstructure of same steel in different Heat-treated conditions.
7. Make the list of steel which are not used in heat treated condition.
8. Study various defects occurs on specimen after heat treatment process.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author / Editor	Publication with place, year, and ISBN
1.	Heat Treatment: Principles and Techniques	T. V. Rajan, C. P. Sharma, Ashok Sharma	Prentice-Hall of India Pvt. Ltd., New Delhi, 2007, ISBN 978-8120307162
2.	Heat Treatment of Metals	Vijendra Singh	Standard Publishers Distributors, New Delhi, 2020, ISBN 978-8180140389
3.	Heat Treatment of Metals	B. Zakharov	CBS Publishers, New Delhi, 1998, ISBN 978-8123906010
4.	Heat Treatment of Metals Volume 1	J. L. Smith, G. M. Russel, S. C. Bhatia	CBS Publishers, New Delhi, 2008, ISBN 978-8123916446
5.	Introduction to Physical Metallurgy	Sidney H. Avner	Mc-Graw Hill Education, 2017, ISBN 978-0074630068
6.	Heat Treatment, Selection, and Application of Tool Steels	William E. Bryson	Hanser Publications; 2nd Revised ed. Edition, 2009, ISBN 978-1569903766
7.	Handbook of Heat Treatment of Steels	K. H. Prabhudev	Tata McGraw-Hill Publishing Ltd. New Delhi, 2003, ISBN 978-0074518311

14. SOFTWARE/LEARNING WEBSITES

1 https://nptel.ac.in/courses/113104074
2 https://nptel.ac.in/courses/112104219
3 https://msvs-dei.vlabs.ac.in/Quenching.php
4 https://www.sm-furnaces.com/blog/4-types-of-heat-treating/
5 https://www.youtube.com/watch?v=6jQ4y0LK1kY
6 https://fractory.com/heat-treatment-methods/
7 https://www.iqsdirectory.com/articles/heat-treating.html

15. PO-COMPETENCY-CO MAPPING

Semester IV		Heat Treatment [Course Code: 4342103]						
		POs						
Competency & Course Outcomes		PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design / development of solutions	PO 4 Engineering tools, Experimentation & Testing	PO 5 Engineering practices for society, Sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency		***Apply the knowledge of various heat treatment operations to achieve desired properties.***						
Course Outcomes								
CO1:	Select appropriate heat treatment process to get desired properties.	3	3	2	2	1	3	3
CO2:	Interpret T.T.T. and C.C.T. diagrams of various steels.	3	2	1	-	-	2	3
CO3:	Select surface hardening processes for steel based on applications.	3	2	2	2	1	3	2
CO4:	Examine quality control parameter of heat treatment processes.	3	1	1	1	-	-	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons:

Sr. No.	Name and Designation	Institute	Email
1	Ms. Sonam M. Patel, Lecturer Metallurgy Engineering	Dr. S. & S. S. Ghandhy College of Engineering & Technology, Surat	sonampatel22@gmail.com
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