

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Semester -V

Course Title: Welding Metallurgy

(Course Code: 4355503)

Diploma programmer in which this course is offered	Semester in which offered
Fabrication Technology	5 th Semester

1. RATIONALE

Welding is one of the major manufacturing process used in the fabrication of process equipment, steel structures, piping and ship building. Metallurgy of welding plays an important role for getting quality welding. This course provides the knowledge about metallurgical effect of welding in various ferrous and nonferrous metals like carbon steel, various types of stainless steel, aluminum and titanium. Student will be able to select best welding process for the particular parent metal and according to it different parameters and consumables will be selected. This course make student capable of understanding the effect of different welding parameters on weld quality. Student will understand heat flow in around the weld, calculate cooling rate and solidification time of weld joint. He / She can understand effect of carbon equivalent on the weld properties. Welding will produce residual stresses. This leads to distortion, cracking and corrosion in the weld joint. Hence remedies must be applied. This course will provide knowledge regarding it. Student will get primary knowledge of WPS and PQR preparation which is essential for working as welding engineer / fabrication engineer in the industry.

2. COMPETENCY

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

- Describe welding metallurgy of carbon steel, low alloy steel, stainless steel, aluminum and titanium with focus on residual stresses developments, distortion and its remedies.

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:

CO1. Understand the welding metallurgy basics and weld joint microstructure.

CO2. Describe the weldability of carbon steel.

CO3. Describe the weldability of stainless steel.

CO4. Describe the weldability of Aluminum and titanium

CO5. Describe the residual stresses and distortion in welding.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				Total Marks
L	T	P		Theory Marks		Practical Marks		
			C	CA	ESE	CA	ESE	
4	0	2	5	30*	70	25	25	150

(*): 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. These PrOs need to be attained to achieve COs.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Study the Heat Affected Zone.	1	2
2	Study the effect of alloying element on weld joint properties.	1	2
3	Study effect of weld edge preparation on weld metal deposition.	1,2	4
4	Study the effect of welding current and electrode diameter on weld bead.	1,2	2
5	Study the effect of welding speed on weld bead.	1,2	2
6	Measure the hardness on base metal, HAZ and weld metal.	1,2	4
7	Study Heat treatment, preheat and PWHT.	1,2	2
8	Demonstrate welding of carbon steel and prepare QW401 to QW410 points of WPS.	2	2
9	Demonstrate welding of stainless steel and prepare QW401 to QW410 points of WPS.	3	2
10	Study the schaeffler diagram and delong diagram.	3	2
11	Demonstrate the welding of aluminum.	4	2
12	Identify different types of distortion in welding and find out its causes & suggest its remedies.	5	2
	TOTAL HOURS.		28

Note : 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.

- i. Boiler suit, safety shoes & other safety items are compulsory while attending laboratory and has to be brought by students. (annexure-1)

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 %
For PrOs no: 6		
1	Knowledge of experiment	20
2	Performance	30
3	Procedure followed	30
4	Quality of report	10
5	Punctuality	10
Total		100

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
For PrOs no: 1,2,3,4,5,7,8,9,10,11,12		
1	Knowledge of experiment	30
2	Quality of report	30
3	Participation	20
4	Punctuality	10
5	Originality	10
Total		100

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipment with broad specifications for the PrOs are 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	PrO. No.
1.	SMAW welding power source and accessories.	3,4,5,6,8
2.	Hardness tester	6
3.	Digital Weighing scale	3
4.	GTAW welding power source and accessories.	9,11

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 fulfill the development of this course competency.

- a) Follow safety practices in laboratory.
- b) Practice good housekeeping.
- c) Work as a leader/a team member.
- d) Maintain tools/equipment
- e) Follow ethical practices

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 & 4th 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	Unit Outcomes (UOs)	Topics and Sub-topics
Unit-I Basic Metallurgy of fusion welds	1.1 Describe welding metallurgy 1.2 Describe application of Fe-C, T.T.T. & C.C.T. diagram in welding 1.3 Describe gas metal reactions 1.4 Describe effect of different welding parameter on quality of welding 1.5 Describe weld joint structure	1.1 Introduction of welding metallurgy 1.2 Welding arc 1.3 Heat flow in and around weld metal 1.4 Metallurgical effects of welding 1.5 Weld metal solidification 1.6 Absorption of gases by weld 1.7 Gas metal reactions 1.8 Porosity in weld 1.9 Slag inclusion 1.10 Fe-C, T.T.T. and C.C.T. diagrams 1.11 Different micro constituents observed in welding 1.12 Thermal effects of welding on parent metal and its mechanical properties 1.13 Effect of welding parameter on weld quality 1.14 Hydrogen embrittlement and cracking 1.15 Grain size control 1.16 Weld cracking 1.17 Corrosion of weld 1.18 Weld decay 1.19 Dilution 1.20 Effect of alloying elements on tensile strength of weld metal 1.21 Lamellar Tearing

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
		1.22 Reheat cracking
UNIT– II Weldability of carbon steel	2.1. Describe the weldability of the low carbon steel 2.2. Describe the weldability of the medium & High carbon steel 2.3. Calculate carbon equivalent in low carbon steel. 2.4. Describe weldability of the HSLA steel 2.5. Identify the welding variables of WPS and PQR for carbon steel	2.1 Weldability of carbon steel 2.2 Weldability of low carbon steel 2.3 Weldability of medium carbon steel 2.4 Weldability of high carbon steel 2.5 Weldability of high strength low alloy (HSLA) steels 2.6 Weldability of low alloy steels 2.7 WPS preparation as per ASME Section IX for carbon steel
UNIT– III Weldability of stainless steel	3.1. Describe the weldability of stainless steel 3.2. Identify the problems of welding of austenitic stainless steel 3.3. Draw the schaeffler and delong diagram 3.4. Identify the welding variables of WPS and PQR for stainless steel	3.1 Types of stainless steel 3.2 Welding of Austenitic stainless steel <ul style="list-style-type: none"> 3.2.1 Electrode and filler metal 3.2.2 Welding procedure 3.2.3 Weld metal 3.2.4 Schaeffler diagram 3.2.5 Delong diagram 3.3 Problems associated with welding of Austenitic stainless steel <ul style="list-style-type: none"> 3.3.1 Ferrite and Sigma phase formation 3.3.2 Carbide precipitation 3.3.3 Remedies of carbide precipitation 3.3.4 Knife edge attack 3.3.5 Stress corrosion cracking 3.4 PWHT of Austenitic stainless steel weldments. 3.5 Weldability of Ferritic stainless steel 3.6 Preheat & PWHT of Ferritic stainless steel weldments 3.7 Weldability of Martensitic stainless steel 3.8 Preheating and PWHT of MSS weldments 3.9 Weldability of PH stainless steel 3.10 Weldability of Duplex Stainless Steel 3.11 WPS preparation as per ASME SEC-IX STAINLESS STEEL
Unit -IV Weldability of	4.1 Describe welding characteristics of aluminum	Weldability of Aluminum & its alloys 4.1 Characteristics and application of

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Aluminum and Titanium alloys	<p>and its alloys</p> <p>4.2 Describe different welding processes used for welding of aluminum and its alloys</p> <p>4.3 Describe welding processes and procedure used for Titanium welding</p> <p>4.4 Describe problems associated with welding of Titanium</p>	<p>Aluminum</p> <p>4.2 Welding characteristics of Al & its alloys</p> <p>4.3 Processes used for welding Aluminum & its alloys</p> <p>4.4 Problems encountered in welding of Aluminum</p> <p>Weldability of Titanium & its alloys</p> <p>4.5 Characteristics of Titanium</p> <p>4.6 Titanium alloys</p> <p>4.7 Welding of Titanium and its alloys</p> <p>4.8 Welding processes and procedure used for Titanium welding</p> <p>4.9 Joint design selection, pre-cleaning, preheating, selection of preheat and interpass temperature, Protection during Titanium welding, Welding process selection, PWHT</p> <p>4.10 Problems associated with welding of Titanium</p>
Unit -V Residual welding stresses and distortion	<p>5.1. Describe the residual Stresses</p> <p>5.2. Describe the control of residual stresses</p> <p>5.3. Describe the distortion</p> <p>5.4. Describe the control of distortion</p>	<p>5.1. Definition and concept of residual stresses</p> <p>5.2. Types of residual stresses</p> <p>5.3. Residual stresses in welds</p> <p>5.4. Effects of thermal stresses</p> <p>5.5. Control of residual stresses</p> <p>5.6. Need for residual stress relieving</p> <p>5.7. Methods of residual stress relieving</p> <ol style="list-style-type: none"> 1) Design consideration 2) Material selection 3) Preheating 4) Welding procedure 5) Welding sequence 6) PWHT 7) Natural ageing 8) Peening 9) Vibratory stress relieving (VSR) <p>5.8. Concept of distortion</p> <p>5.9. Types of distortion</p> <p>5.10. Control of welding distortion</p> <p>5.11. Effect of metal properties on welding distortion</p>

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basic Metallurgy of fusion welds	20	3	15	7	25
II	Weldability of carbon steel	8	0	7	4	11
III	Weldability of stainless steel	12	3	7	4	14
IV	Weldability of Aluminum and Titanium alloys	8	3	7	0	10
V	Residual welding stresses and distortion	8	3	7	0	10
	TOTAL	56	12	43	15	70

Legends: R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks and marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.

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 perform following activities in group and prepare reports/charts for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

- a) Prepare solutions of different assignments given by subject faculty.
- b) Collect videos, animation explaining welding metallurgy.
- c) Prepare power point presentation on weld ability topics

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) '**L**' in **section No. 4** means 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**.

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-projects are group-based (group of 3 to 5). However, **in the fifth and eighth semesters**, 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 duration of the micro project should be about **14-16 (fourteen to sixteen) student engagement hours** during the course. The students 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:

- a. **Prepare a quiz on weldability**
- b. **Chart making:** Prepare the charts on weldability of the different metals given by faculty.
- c. **Video Preparation:** Student has to prepare his/her video on explaining different weldability of metals and preparation of WPS/PQR.
- d. **E-learning projects:** Students have to use internet and other online resources for preparation of report and/or download video on the topic given by the subject teacher within the syllabus or beyond the syllabus.
- e. **Report preparation:** Student has to use different books, technical magazine, journals etc. for preparation of a report on the topic given by the subject teacher within the syllabus or beyond the syllabus.
- f. **Power point presentation:** Students has to prepare a power point presentation of 10 to 15 slides on the topic given by the subject teacher within the syllabus or beyond the syllabus. In the end of presentation student has to ask at least 3 to 5 MCQ based question to identify the gain of listeners at the end presentation.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Welding Technology	O. P. khanna	Dhanpat Rai Publication
2	Welding Engineering & Technology	Dr. R. S. Parmar	Khanna Publishers
3	Welding Metallurgy	Sindo Kou	A John Wiley & Sons, Inc., Publication
4	Modern arc welding	S. V. Nadkarni	Oxford Publication
5	Welding technology & design	V. M. Radhakrishnan	New Age International publication

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
6	Welding technology for engineers	Baldev raj V shekhar A K Bhaduri	Narosa publication

14. SOFTWARE/LEARNING WEBSITES

- <https://www.youtube.com/watch?v=m2B8t8vzeUE&list=PLbMVogVj5nJSjLB85-HKhw1aCIBxn3pWj>
- https://www.youtube.com/watch?v=cQEUJnMYf_U&list=PLwdnzlV3ogoUQnGO8eFFygVBTjF0xyYMq
- <https://www.youtube.com/watch?v=m2B8t8vzeUE>
- https://www.youtube.com/watch?v=UXpvmEJ477o&list=PLLy_2iUCG87DMpCKrUQxEi4he6NwDYMSN
- https://www.youtube.com/watch?v=KMcsjCXfLQw&list=PLyAZSyX8Qy5Am_2StOOQ5vCUE3VlcAenE
- https://www.youtube.com/watch?v=2rxbxNem1il&list=PLyqSpQzTE6M_ON8uXt-PP8uX6hMWJeYSJ

15. PO-COMPETENCY-CO MAPPING

Semester V	Welding Metallurgy (Course Code:4355503)						
	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	<ul style="list-style-type: none"> Describe welding metallurgy of carbon steel, low alloy steel, stainless steel, aluminum and titanium with focus on residual stresses developments, distortion and its remedies. 						
Course Outcomes CO1. Understand the welding metallurgy basics and weld joint microstructure.	3	2	-	1	1	-	1
CO2. Describe the weldability of carbon steel.	3	1	-	1	1	-	1
CO3. Describe the weldability of stainless steel.	3	1	-	1	1	-	1
CO4. Describe the weldability of Aluminum	3	-	-	1	1	-	1

and titanium.							
CO5. Describe the residual stresses and distortion in welding.	3	-	-	-	1	-	1

Legend: '3' for high, '2' for medium, '1' for low and '-' for no correlation of each CO with PO.

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	Mr. Samir Y. Merchant I/C. H.O.D. Fabrication Technology Department	Sir Bhavsinhji Polytechnic Institute Bhavnagar	9428408314	symerchant72@gmail.com
2.	Mr. Nilesh M. Bhangale Lecturer Fabrication Technology Department	Sir Bhavsinhji Polytechnic Institute Bhavnagar	9016926792	nileshbhangalefabtechbpi@gmail.com
3.	Mr. Kapilkumar B. Pipavat Lecturer Fabrication Technology Department	Sir Bhavsinhji Polytechnic Institute Bhavnagar	9427343525	Kbpipavat.bpti@gmail.com

ANNEXURE-1

❖ SAMPLE SAFETY CONTRACT:

(To be filled by the students and submitted to concerned faculty/staff)

-- Use for reference purposes only --

- 1. You have to read and sign the safety contract.
- 2. The safety contract says that you understand that safety is your responsibility.
- 3. The safety contract to be signed before you carry out any work in the laboratory and if you don't observe and obey the safety rules, you will not be allowed in the laboratory.

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Safety Contract

Date: _____

Name of Institute: _____

Name of Course with Code: Welding Metallurgy 4355503

Name of Faculty/Staff with Designation: 1. _____

2. _____

3. _____

I RECOGNIZE THAT:

- 1. Safety is my responsibility while using any tool or equipment.
- 2. Safety regulations have been provided to me.
- 3. The possibility of accident and injury increases if I do not follow all the safety guidelines.
- 4. I must act responsibly to ensure my own safety & the safety of others in the work area.

I AGREE TO:

- 1. Never work in the shop without my faculty's/instructor's supervision.
- 2. Read and practice all the safety regulations that have been distributed to me in this course or have been posted in the work areas.
- 3. Act in a responsible manner at all times in the laboratory.
- 4. Follow all instructions given by the faculty.
- 5. Immediately report any unsafe condition or activity to my faculty.
- 6. Wear eye protection at all times when working with tools or working anywhere near someone who is using tools.
- 7. Cut or Tie back long hair, remove jewellery, secure loosed clothing, and wear boiler suit & safety shoes in the laboratory.
- 8. Clean all work areas and put equipment away before leaving the laboratory.

I, _____, have read and agree with all the safety instructions.

Particulars:

Programme: _____

Batch No.: _____

Enrollment No.: _____

Student Signature
