

GUJARAT TECHNOLOGICAL UNIVERSITY, AHMEDABAD, GUJARAT

**COURSE CURRICULUM
COURSE TITLE: WELDING METALLURGY
(COURSE CODE: 3355503)**

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

1. RATIONALE

Welding is one of the major manufacturing processes used in the fabrication of process equipments, 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, aluminium and titanium. The student will be able to apply knowledge and skills of welding metallurgy in producing products of quality as per requirement of the customers.

2. LIST OF COMPETENCY

The course content should be taught and curriculum should be implemented with the aim to develop required skill in the students so that they are able to acquire following competency :

- Use knowledge and skills of welding metallurgy for improving quality of welded joints.

3. COURSE OUTCOMES

The theory should be taught and practical should be carried out in such a manner that students are able to required learning outcomes in cognitive, psychomotor and affective domain to demonstrate following course outcomes-

- Demonstrate weld joint structure.
- Describe basic concept and physical metallurgy of welding.
- Describe effect of different welding parameter on weld quality
- Describe welding metallurgy of Carbon steel, Alloy steel, Stainless steel, Aluminium and Titanium
- Demonstrate distortion of weld joint due to residual stresses.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P)	Examination Scheme				Total Marks
L	T	P		Theory Marks		Practical Marks		
L	T	P	C	ESE	PA	ESE	PA	150
4	-	2	6	70	30	20	30	

Legends: L-Lecture; T – Tutorial/Teacher Guided Student Activity; P - Practical; C – Credit;; ESE - End Semester Examination; PA - Progressive Assessment.

5. COURSE CONTENT DETAIL

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
Unit – I Metallurgy of Welding	1a. Describe welding metallurgy 1b. Describe application of Fe-C, T.T.T. & C.C.T. diagram in welding 1c. Describe effect of different welding parameter on quality of welding 1d. Explain the thermal effects of welding on parent metal. 1e. Define weld cracking, corrosion of weld, weld decay and dilution. 1f. Explain hydrogen embrittlement and cracking.	METALLURGY OF WELDING 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 Fe-C, T.T.T. and C.C.T. diagrams 1.10 Thermal effects of welding on parent metal and its mechanical properties 1.11 Effect of welding parameter on weld quality 1.12 Hydrogen embrittlement and cracking 1.13 Grain size control 1.14 Weld cracking 1.15 Corrosion of weld 1.16 Weld decay 1.17 Dilution
Unit– II Weld Joint Microstructure	2a. Describe weld joint micro structure 2b. Define fusion boundary and Heat affected zones. 2c. Explain effect of alloying element on microstructure. 2d. Describe delta and sigma phase in welds.	WELD JOINT MICROSTRUCTURE 2.1 Introduction 2.2 Weld metal zone 2.2.1 General theory of solidification of metal and alloys 2.2.2 Effect of welding speed on grain structure 2.2.3 Properties of weld metals 2.3 Fusion boundary zone 2.4 Heat affected zone 2.5 Properties of HAZ 2.6 Microstructural products in weldments 2.7 Microstructure of multi-run welds 2.8 Effect of alloying elements on microstructure

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
Unit- III Welding Of Carbon Steel	3a Describe welding metallurgy of carbon steel 3b Prepare WPS & PQR as per ASME sec IX for welding of carbon steel by SMAW process 3c Distinguish between weld ability of low, medium and high carbon and HSLA steels.	2.9 Delta and sigma phase in welds WELDING OF CARBON STEEL 3.1 Types of carbon steel 3.2 Weldability of carbon steel 3.3 Weldability of low carbon steel 3.4 Weldability of medium carbon steel 3.5 Weldability of high carbon steel 3.6 Weldability of high strength low alloy (HSLA) steels 3.7 Weldability of low alloy steel 3.8 WPS & PQR preparation as per ASME SEC-IX (SMAW Process)
Unit-IV Welding Of Stainless steel	4a. Describe welding metallurgy of stainless steel 4b. Draw and explain Schaeffler and Delong Diagram. 4c. Explain problems and their reasons in welding of Austenitic stainless steel. 4d. Prepare WPS & PQR as per ASME sec IX for welding of stainless steel by GTAW process. 4e. Discuss weldability of MSS, FSS, PHSS and DSS	WELDING OF STAINLESS STEEL 4.1 Types of stainless steel 4.2 Welding of Austenitic stainless steel 4.3 Schaeffler diagram 4.4 Delong diagram 4.5 Problems associated with welding of Austenitic stainless steel 4.5.1 Ferrite and Sigma phase formation 4.5.2 Carbide precipitation 4.5.3 Knife edge attack 4.5.4 Stress corrosion cracking 4.6 PWHT of Austenitic stainless steel weldments 4.7 Weldability of Ferritic stainless steel 4.8 PWHT of Ferritic stainless steel weldments 4.9 Weldability of Martenstic stainless steel 4.10 Preheating and PWHT of MSS weldments 4.11 Weldability of PH stainless steel 4.12 Weldability of DSS 4.13 WPS & PQR preparation as

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
		per ASME SEC-IX (GTAW Process)
Unit – V Welding Of Aluminium and its alloys	5a. Describe welding metallurgy of Aluminium & its alloys 5b. Describe different process for welding Aluminium and its alloys. 5c. Explain problems encountered in welding of Aluminium.	WELDING OF ALUMINIUM AND ITS ALLOYS 5.1 Characteristics and application of Aluminium 5.2 Welding characteristics of AL & its alloys 5.3 Processes used for welding Aluminium & its alloys 5.4 Problems encountered in welding of Aluminium
Unit– VI Welding Of Titanium & its alloys	6a. Describe welding metallurgy of Titanium & its alloys 6b. Describe welding processes for Titanium. 6c. Explain problems associated with titanium welding.	WELDING OF TITANIUM AND ITS ALLOYS 6.1 Characteristics of Titanium 6.2 Titanium alloys 6.3 Welding of Titanium and its alloys 6.4 Welding processes and procedure used for Titanium welding 6.5 Joint design selection, preheating, selection of preheat and interpass temperature, Protection during Titanium welding, Welding process selection, PWHT 6.6 Problems associated with welding of Titanium
Unit– VII Residual Welding Stresses And Distortion	7a. Describe effect of residual stresses in welding & its control 7b. Describe types of distortion in welding & its control	RESIDUAL WELDING STRESSES AND DISTORTION 7.1 Definition and concept of residual stresses 7.2 Types of residual stresses 7.3 Residual stresses in welds 7.4 Effects of thermal stresses 7.5 Control of residual stresses 7.6 Need for residual stress relieving 7.7 Methods of residual stress relieving 1) Design consideration 2) Material selection

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
		3) Preheating 4) Welding procedure 5) Welding sequence 6) PWHT 7) Natural ageing 8) Peening 9) Vibratory stress relieving (VSR) 7.8 Concept of distortion 7.9 Types of distortion 7.10 Control of welding distortion 7.11 Minimizing distortion in repair work 7.12 Effect of properties on welding distortion

6. SUGGESTED SPECIFICATION TABLE WITH HOURS & MARKS (THEORY)

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total
I	Metallurgy of Welding	10	7	7	0	14
II	Weld Joint Microstructure	10	0	5	5	10
III	Welding of Carbon Steel	8	0	5	5	10
IV	Welding of Stainless steel	12	3	4	7	14
V	Welding of Aluminium and its alloys	4	3	3	0	6
VI	Welding of Titanium & its alloys	4	3	3	0	6
VII	Residual Welding Stresses And Distortion	8	3	4	3	10
	TOTAL	56	19	31	20	70

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

NOTE: Suggested specification table shall be treated as a general guidance for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

7. SUGGESTED LIST OF EXERCISE/PRACTICAL/EXPERIMENTS

The practical/exercises should be properly designed and implemented with an attempt to develop different types of skills (**outcomes in psychomotor and affective domain**) so that students are able to acquire the competencies/programme outcomes. Following is the list of practical exercises for guidance.

Note: Here only outcomes mainly in psychomotor domain are listed as practical/exercises. However, if these practical/exercises are completed appropriately, they would also lead to development of certain outcomes in affective domain which would in turn lead to development of **Course Outcomes** related to affective domain. Thus over all development of **Programme Outcomes** (as given in a common list at the beginning of curriculum document for this programme) would be assured.

Faculty should refer to that common list and should ensure that students also acquire outcomes in affective domain which are required for overall achievement of Programme Outcomes/Course Outcomes

S. No.	Unit No.	Exercise / Practical (Outcomes in psychomotor domain)	Approx Hrs. Required
1.	I	Determine hardness of Base metal, HAZ and Weld metal	2
2.	I	Measure effect of welding current on weld quality	2
3.	I	Measure effect of welding arc travel speed on weld quality	2
4.	II	Calculate weight of weld metal deposition	2
5.	III	Prepare WPS for welding of carbon steel by SMAW process	2
6.	IV	Prepare WPS for welding of Stainless steel by GTAW process	2
7.	IV	Weld given pieces of Stainless Steel	2
8.	V	Weld given pieces of Aluminium	2
9.	VII	Identify different types of distortion in welding and find out its causes & suggest its remedies	4
10	VII	Perform Heat treatment exercise of carbon steel welded joint as per UCS-56	4
11	III,IV, V,VI	Identify structure of weld joint of different metal by etching	4
Total Hrs.			28

8. SUGGESTED LIST OF PROPOSED STUDENT ACTIVITIES

Following is the list of proposed student activities:

- i. Explore internet and find latest development in welding metallurgy for different metals and present in groups about these developments.
- ii. Prepare as many jobs in workshop as possible and study quality of weld and distortions. Identify reasons for poor quality or defects if any.

9. SPECIAL INSTRUCTIONAL STRATEGIES (if any)

- i. Arrange visit to a fabrication industry and discuss different welding process in use
- ii. Collect sample of joints created with different weld processes and discuss quality of these welds and reasons for defects if any.
- iii. Show video films/animation films/photographs of different welding process and discuss their features .
- iv. Arrange expert lecture by some experienced welding engineer.

10. SUGGESTED LEARNING RESOURCES

A. List of Books

S.No.	Title of Books	Author	Publication
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
6	Welding technology for engineers	Baldev Raj V Shekhar A K Bhaduri	Narosa publication

B. List of Major Equipment/ Instrument

- i. Welding transformer
- ii. GTAW welding machine (inverter type)
- iii. Hardness testing machine
- iv. Muffle furnace
- v. Tong tester
- vi. Weld geometry etching kit
- vii. Grinding machine
- viii. Metallurgical microscope with still camera
- ix. Prepared specimens for Metallurgical microscope

C. List of Software/Learning Websites

- i. <http://www.britannica.com/EBchecked/topic/639223/welding>
- ii. <http://www.twi-global.com/technical-knowledge/job-knowledge/welding-of-hsla-steels-098/>
- iii. http://site.ge-energy.com/businesses/ge_oilandgas/en/newsletter/
- iv. <http://www.weldingtipsandtricks.com/welding-metallurgy-6.html>

11. COURSE CURRICULUM DEVELOPMENT COMMITTEE

Faculty Members from Polytechnics

- **Prof. P. B. Pathak**, I/C HOD, Deptt. of Fabrication Technology, Sir B.P.I., Bhavnagar
- **Prof. B. K. Gandhi**, Sr. Lecturer, Deptt. of Fabrication Technology, Sir B.P.I., Bhavnagar
- **Prof. S. Y. Merchant**, Sr. Lecturer, Deptt. of Fabrication Technology, Sir B.P.I., Bhavnagar

Co-coordinator and Faculty Members from NITTTR Bhopal

- **Dr. A. K. Sarathe**, Associate Professor Deptt. of Mechanical Engineering
- **Dr. C. K. Chugh**, Professor Deptt. of Mechanical Engineering