



Department of Mechanical & Mechatronics

College of Engineering

Salahaddin University – Erbil (SUE)

Subject: Welding Metallurgy

Course Book – *(Junior + Senior) Students*

Lecturer's name AHMED SAMIR, PhD

Academic Year: 2023

Course Book

1. Course name	Welding Metallurgy
2. Lecturer in charge	AHMED SAMIR, Lecturer
3. Department/ College	Mechanical & Mechatronics Dept./Engineering College
4. Contact	e-mail: ahmed.anwar@su.edu.krd Tel: (optional)
5. Time (in hours) per week	Theory: 4 h Practical: 2 h
6. Office hours	6 h
7. Course code	3138
8. Teacher's academic profile	Ph.D. P.E. Material Science & Welding Metallurgy M.Sc. P.E. Material Science & Welding Metallurgy
9. Keywords	WM; Welding Metallurgy; ASA
10. Course overview:	
<p>The Welding Metallurgy course offers an in-depth exploration of welding and metallurgy's fundamental principles and practices. This course is designed for individuals seeking to enhance their knowledge and skills in understanding the behavior of materials during the welding process and how it influences the quality and integrity of welded joints.</p> <p>Throughout the course, students will delve into the intricate relationship between welding and metallurgy, gaining a comprehensive understanding of the physical and chemical transformations that occur when metals are subjected to welding processes. Students will learn to make informed decisions when selecting welding materials, processes, and parameters for specific applications by studying the underlying principles of metallurgy.</p> <p>The course begins with an introduction to the various welding processes, including gas welding, arc welding, and resistance welding. Students will explore the advantages, limitations, and practical considerations associated with each process, enabling them to make informed choices based on the requirements of a given welding project.</p> <p>The course then delves into the heat flow and thermal cycles during welding. Students will learn about heat sources, heat transfer mechanisms, and the resulting thermal cycles experienced by the welded materials. Understanding these concepts is crucial for predicting the microstructural changes and their influence on the mechanical properties of welded joints.</p> <p>The phase transformations in welding are another critical aspect covered in the course. Students will explore the solidification process, microstructure formation, heat-affected zone (HAZ), and weld zone formation. Additionally, they will study grain growth, recrystallization, and the effect of these phenomena on the properties of welded materials.</p>	

Welding metallurgy of specific materials is thoroughly examined, focusing on steels, non-ferrous alloys, stainless steels, and non-metallic materials. The course highlights the weldability of different materials, including their carbon content, alloying elements, and thermal properties. Special attention is given to common challenges encountered when welding these materials and strategies for mitigating issues such as weld cracking, distortion, and reduced mechanical performance.

The course also covers welding defects and inspection techniques. Students will learn to identify and analyze various types of defects during welding, such as porosity, cracks, and incomplete fusion. They will gain an understanding of non-destructive and destructive testing methods used to assess the quality and integrity of welds, including visual inspection, radiography, ultrasonic testing, and mechanical testing.

Advanced welding techniques and emerging trends in welding metallurgy are explored in the latter part of the course. Students will be introduced to cutting-edge technologies such as laser welding, electron beam welding, and friction stir welding. They will also explore the impact of additive manufacturing (3D printing) on the welding field, welding automation, and robotics.

Throughout the course, students can apply their knowledge through hands-on laboratory sessions and welding exercises. This practical experience will reinforce the theoretical concepts covered in the lectures and allow students to develop their skills in welding metallurgy.

By the end of the Welding Metallurgy course, students will have gained a comprehensive understanding of the metallurgical principles underlying welding processes. They will have the knowledge and skills to analyze and select appropriate welding materials, identify and prevent welding defects, and produce high-quality welded joints. Whether pursuing a career in welding, materials engineering, or related fields, this course provides a solid foundation for success in welding metallurgy.

11. Course objective:

1. Understand the basic principles of metallurgy and their application in welding:

- Gain knowledge of the structure and properties of metals.
- Understand the influence of metallurgical factors on welding processes and outcomes.
- Comprehend the relationship between metallurgical properties and weldability.

2. Identify different welding processes and their advantages and limitations:

- Familiarize yourself with various welding methods, such as gas, arc, and resistance welding.
- Understand each welding process's strengths, weaknesses, and suitable applications.
- Gain the ability to select appropriate welding processes based on specific project requirements.

3. Analyze the effects of welding on the microstructure and mechanical properties of metals:

- Explore the changes in metals during the welding process, including solidification, grain growth, and phase transformations.
- Understand how welding parameters and thermal cycles influence microstructural characteristics.
- Evaluate the impact of microstructural changes on the mechanical properties of welded joints.

4. Evaluate and select suitable welding materials for specific applications:

- Learn to assess the weldability of different materials, including steels, non-ferrous alloys, stainless steels, and non-metallic materials.
- Understand the significance of material properties, alloying elements, and heat treatment concerning welding.
- Gain the ability to make informed decisions when selecting welding materials based on project requirements and performance expectations.

5. Recognize common welding defects and develop strategies for their prevention and repair:

- Identify and understand the causes of common welding defects, such as porosity, cracks, and incomplete fusion.
- Learn preventive measures to minimize the occurrence of welding defects.
- Gain knowledge of appropriate repair techniques for welding defects to ensure the integrity of welded joints.

6. Gain practical experience through hands-on welding exercises and laboratory sessions:

- Participate in practical welding exercises to apply theoretical knowledge in a real-world setting.
- Develop practical skills in preparing welding joints, selecting parameters, and executing welding processes.
- Gain proficiency in using welding equipment and tools while adhering to safety guidelines.

7. Learn about advanced welding techniques and emerging technologies in welding metallurgy:

- Explore advanced methods such as laser welding, electron beam welding, and friction stir welding.
- Understand these advanced techniques' advantages, limitations, and potential applications.
- Stay updated on emerging trends and technologies in welding metallurgy, such as additive manufacturing (3D printing) and welding automation.

The Welding Metallurgy course aims to provide students with a comprehensive understanding of the metallurgical principles and processes involved in welding. By achieving these course objectives, students will have the knowledge and skills to produce high-quality welded joints, analyze welding-related issues, and make informed decisions in various welding applications.

12. Student's obligation

Students have certain obligations and responsibilities to maximize their learning experience and make the most of the Welding Metallurgy course. These obligations include:

1. **Active Participation:** Students are expected to actively participate in all aspects of the course, including attending lectures, engaging in class discussions, and asking questions when clarification is needed. Active participation fosters a deeper understanding of the subject and encourages a dynamic learning environment.
2. **Timely Completion of Assignments:** Students must complete and submit assignments within the given deadlines. Timely completion demonstrates responsibility and allows for constructive feedback from instructors, enabling students to improve their understanding of welding metallurgy concepts and their practical application.
3. **Preparation for Classes:** Students should come prepared for each class by reviewing assigned readings, lecture notes, and pre-class materials. This preparation helps students grasp the content more effectively and contributes to meaningful class discussions.
4. **Laboratory Safety:** Students must adhere to safety protocols and guidelines during laboratory sessions or practical exercises. This includes wearing appropriate personal protective equipment (PPE), following proper handling procedures for welding equipment and materials, and being mindful of potential hazards in the welding environment.
5. **Respect for Peers and Instructors:** Students are expected to treat their peers and instructors respectfully, fostering a positive and inclusive learning environment. This includes active listening, offering constructive feedback, and maintaining professionalism.
6. **Attendance and Punctuality:** Regular attendance and punctuality are essential for optimal learning. Students should attend all lectures, laboratory sessions, and scheduled group activities. If unable to attend, students should inform the instructor and arrange to catch up on missed material.
7. **Utilization of Resources:** Students are encouraged to utilize resources such as textbooks, reference materials, online resources, and supplementary readings to enhance their understanding of welding metallurgy. They should also take advantage of opportunities for additional support, such as office hours or tutoring services if needed.
8. **Academic Integrity:** Students must uphold high standards of academic integrity by avoiding plagiarism, cheating, or any form of dishonesty in their coursework or examinations. Proper citation and acknowledgment of sources should be practiced when referencing external information.
9. **Continuous Learning:** As welding metallurgy evolves, students should demonstrate a commitment to lifelong learning. They should remain updated on industry advancements,

emerging technologies, and research in welding metallurgy and actively seek opportunities to expand their knowledge beyond the course curriculum.

By fulfilling these obligations, students can optimize their learning experience in the Welding Metallurgy course, develop a solid foundation in welding metallurgy principles, and enhance their skills in applying welding processes and materials. These obligations contribute to individual academic growth and promote a collaborative and engaging learning environment for all participants.

13. Forms of teaching

Powerpoint presentation sessions, practical testing machines
Weekly 4 h Theoretical Lectures + 2 h Practical Lectures

14. Assessment scheme

Award credit points it is necessary to pass the module exam.

The module exam (Theoretical + Practical) → [Written 120 min for Theoretical + 30 min Practical Exam]

Student attendance is required in all classes. If the absences exceed 10%, the student will be terminated from the class.

The students should succeed in the midterm & the lab exams; otherwise, the student will lose the chance of final exam participation & will be terminated from the class.

15. Student learning outcome:

Learning Outcomes: Welding Metallurgy

Upon completing the Welding Metallurgy course, students can expect to achieve the following learning outcomes:

1. Comprehensive Understanding: Students will understand the fundamental principles of metallurgy as they apply to welding processes. They will grasp the relationship between metallurgical factors and welding outcomes, enabling them to make informed decisions in selecting welding materials, processes, and parameters.

2. Knowledge of Welding Processes: Students can identify and differentiate between various welding processes, including gas welding, arc welding, and resistance welding. They will understand each process's advantages, limitations, and practical considerations, allowing them to select the most suitable method for specific welding applications.

3. Analysis of Microstructural Changes: Students will be able to analyze and interpret the microstructural changes during weldings, such as solidification, grain growth, and phase transformations. They will understand the influence of welding parameters and thermal cycles on microstructural characteristics and their subsequent impact on the mechanical properties of welded joints.

4. Selection of Welding Materials: Students can evaluate and select appropriate welding materials for specific applications. They will consider material properties, alloying

elements, and heat treatment to ensure compatibility and optimize weldability. They will also understand the importance of material selection in achieving desired mechanical performance and structural integrity.

5. Prevention and Mitigation of Welding Defects: Students will be able to identify common welding defects, understand their causes, and develop strategies for their prevention and repair. They will acquire knowledge of preventive measures and appropriate techniques to mitigate defects such as porosity, cracks, and incomplete fusion, ensuring the production of high-quality welded joints.

6. Practical Application of Skills: Through hands-on laboratory sessions and welding exercises, students will develop practical skills in preparing welding joints, selecting parameters, and executing welding processes. They will gain welding equipment and tools proficiency while adhering to safety guidelines, translating theoretical knowledge into practical application.

7. Awareness of Advanced Techniques and Emerging Trends: Students will be exposed to advanced welding techniques, such as laser welding, electron beam welding, and friction stir welding. They will understand their advantages, limitations, and potential industrial applications. Additionally, students will be aware of emerging trends in welding metallurgy, including additive manufacturing (3D printing) and welding automation, allowing them to stay informed about the latest developments in the field.

8. Critical Thinking and Problem-Solving: Students will develop critical thinking and problem-solving abilities by analyzing welding metallurgy challenges. They can evaluate complex welding scenarios, consider multiple factors, and propose practical solutions to optimize welding outcomes and address specific welding-related issues.

9. Continuous Learning and Professional Development: Students will recognize the importance of lifelong learning in welding metallurgy. They will have the foundational knowledge and skills to pursue further education, professional certifications, or career advancement opportunities in welding, materials engineering, or related fields.

By achieving these learning outcomes, students will understand welding metallurgy principles, practices, and applications. They will be prepared to apply this knowledge to real-world welding projects, contribute to the advancement of the welding industry, and pursue further studies or professional development opportunities in welding metallurgy.

16. Course Reading List and References:

- Sindo Kou "Welding Metallurgy" Second Edition.
- Xin Sun "Failure mechanisms of advanced welding processes."

17. The Topics:	Lecturer's name
<p>Week 1: Introduction to Welding Metallurgy</p> <ul style="list-style-type: none"> - Overview of welding processes - Introduction to metallurgical principles in welding - Weldability of different materials <p>Week 2: Heat Flow and Thermal Cycles</p> <ul style="list-style-type: none"> - Heat sources in welding - Heat transfer mechanisms - Thermal cycles during welding <p>Week 3: Phase Transformations in Welding</p> <ul style="list-style-type: none"> - Solidification and microstructure formation - Heat-affected zone (HAZ) and weld zone characteristics - Grain growth and recrystallization <p>Week 4: Welding Processes</p> <ul style="list-style-type: none"> - Gas welding processes (oxyacetylene welding, oxyfuel gas welding) - Arc welding processes (shielded metal arc welding, gas metal arc welding, gas tungsten arc welding) - Resistance welding processes (spot welding, seam welding) <p>Week 5: Welding Metallurgy of Steels</p> <ul style="list-style-type: none"> - Carbon steels and alloy steels - Hardenability and weldability - Martensitic transformation and weld cracking <p>Week 6: Welding Metallurgy of Non-ferrous Alloys</p> <ul style="list-style-type: none"> - Aluminum and aluminum alloys - Copper and copper alloys - Titanium and titanium alloys <p>Week 7: Welding Defects and Inspection</p> <ul style="list-style-type: none"> - Types of welding defects - Non-destructive testing (visual inspection, radiography, ultrasonic testing) - Destructive testing (tensile testing, impact testing, bend testing) <p>Week 8: Welding of Dissimilar Metals</p> <ul style="list-style-type: none"> - Welding of different material combinations - Challenges and considerations in dissimilar metal welding - Joining techniques (brazing, soldering) <p>Week 9: Welding Metallurgy of Stainless Steels</p>	<p>AHMED SAMIR</p> <p>Theoretical session per week (4 h)</p>

<ul style="list-style-type: none"> - Austenitic stainless steel - Ferritic stainless steel - Duplex and super duplex stainless steels <p>Week 10: Welding Metallurgy of Non-metallic Materials</p> <ul style="list-style-type: none"> - Welding of polymers and composites - Thermoplastics and thermosetting plastics - Ceramic and glass welding <p>Week 11: Advanced Welding Techniques</p> <ul style="list-style-type: none"> - Laser welding - Electron beam welding - Friction stir welding <p>Week 12: Emerging Trends in Welding Metallurgy</p> <ul style="list-style-type: none"> - Additive manufacturing (3D printing) and its impact on welding - Welding automation and robotics - Prospects and research directions 	
<p>18. Practical Topics (If there are any)</p>	
<ol style="list-style-type: none"> 1. Microscopic examination 2. Vickers Hardness testing 3. Tensile Testing 4. NBending test 5. Metallographic testing 	<p>AHMED SAMIR Research Assistance Eng. Aveen Fathil Practical session per week (2 h)</p>
<p>19. Examinations:</p> <p>1. Compositional: Provided with the extra file document.</p> <p>2. True or false type of exams:</p> <p>Provided within the extra document with its answer keys</p> <p>3. Multiple choices:</p> <p>120 MCQ banks provided additional documents.</p>	
<p>20. Extra notes:</p> <p>Student attendance is required in all classes. If the absences exceed 10%, the student will be terminated from the class.</p> <p>The students should succeed in the midterm & the lab exams; otherwise, the student will lose the chance of final exam participation & will be terminated from the class.</p>	
<p>21. Peer review</p>	<p>پیداچونہوہی ھاوہل</p>