Syllabus: Welding Metallurgy and Material Testing, WELD 1410

Part 1: Course Information

Description

The course is designed for students with experience in welding but little or none in the principles of metallurgy. The course begins at the atomic level with atomic bonding, defects in metal crystals and moves to the evolution of weld microstructure in the fusion and heat- affected zones of aluminum alloys. Welding parameters are correlated to these zones and related to tensile properties, microhardness, and weld integrity.

The microstructure of aluminum welds will be revealed in the laboratory using standard metallographic techniques. Defects such as extraneous particles, porosity, and flaws (such as cracking) will be noted and recorded digitally in micrographs (pictures). Digital recording and analysis of the weld microstructures will be accomplished with an upright metallurgical microscope. Microhardness measurements will be made across each weld zone using a microhardness tester. The microstructure of the aluminum alloy welds will finally be related to welding parameters and weld integrity.

This course is designed to meet over a period of 14 weeks, 1 meetings per week, and 3 hours per meeting in a combined lecture-lab meeting.

Prerequisites

None

Required Materials

Graphic Slides taken from the internet course on welding aluminum alloys: www.nrc.gov/docs/ML1215/ML12157A607.pdf

Pace Technologies “Metallographic Handbook” by Donald C. Zipperian, PhD, Copyright 2011

Recommended Reference Materials

Tools to be used

For list of equipment, see Lab Manual.

Part 2: Course Learning Outcomes (CLOs)

The course learning outcomes are to have students:

1. Describe basic physical metallurgy starting at the atomic level, with bonding, defect structure, phase diagrams and diffusion and moves towards the development of metal microstructure.

2. Describe how metals solidify, how phases nucleate and grow, and the mechanisms by which metal alloys are strengthened. Describe the development of the fusion and heat-affected zones during the welding of aluminum.

3. Describe how weld variables such as pool shape, travel speed, cooling rate and other variables affect the subsequent weld microstructure.

4. Determine how the weld variables and weld microstructure affect the mechanical properties of the weld will be able to identify the microstructure of acceptable welds.

5. Prepare metallographic samples of aluminum alloy welds in the laboratory to reveal their microstructure. Measure and interpret the microhardness across a weld.

Part 3: Course Topics and Roadmap

Roadmap

The following roadmap is recommended for instructors

Week	• **Lecture Topics** • **CLOs**	**Main Concepts, Terms, and Skills**	• **Course Materials,** • **Homework & Projects**
1	• Basic Principles • 1	• Types of Atomic Bonds • Metallic Bonding • Elastic Modulus	Slides 1-6
2	• Crystal Structure	• Defects in Metals	Slides 7-13

	• & Defects • 1	• Solid Solutions • Line & Planar Defects	Quiz
3	• Phase Diagrams • 1 - 2	• Types of Phase diagrams • Microstructural Evolution	Slides 14-20
4	• Diffusion • 2	• Diffusion in Metals • Interdiffusion of 2 Metals • Diffusion in Weld Zones	Slides 21-24 Summary M-1 Test #1
5	• Strengthening mechanisms • 2	• Solid Solution strengthening • Strain Hardening • Precipitation Hardening	Slides 25-36
6	• Basic of Welding Metallurgy • 2 - 3	• Microstructure & Properties • Metallurgical Processes • The Fusion Zone	Slides 37-45
7	• Dilution • 2	• Calculation of Dilution • Dilution in Aluminum Alloys	Slides 46-52 Summary M-2 Test #2
8	• Fusion Zone • 2 - 3	• Surface Tension/Fluid Flow • Types of Nucleation • Heterogeneous Nucleation • Epitaxial Nucleation at Fusion Boundary	Slides 53-61
9	• Welding Parameters • 3 - 4	• Effect of Travel Speed • Effect of GL, R, and Composition • Effect of Cooling Rate • Weld Metal Epitaxial Nucleation	Slides 62-68
10	• Fusion Zone • Boundaries	• Solidification Grain & Subgrain Boundaries • Migrate Grain Boundary • Partially Melted Zone (PMZ)	Slides 69-75 Summary M-3 Test #3
11	• Microstructure/ Mechanical Prop • 4 - 5	• Microstructure of 6061-T6 Aluminum Alloy • Unmixed Zone (UMZ) • Partially Melted Zone (PMZ)	Slides 76-83
12	• Boundaries in Weld Zone • 4 - 5	• Grain Boundary Liquation in the PMZ • The “True” Heat Affected Zone (HAZ) • Effect of Recrystallization on Mech. Properties	Slides 84-92
13	• Residual Stresses • 4	• Factors Influencing Residual Stresses • Fundamental Types of Distortion • Microhardness Testing	Slides 93-98
14	• Mechanical Testing of Welds • 4 – 5	• Tensile Testing Welds • Stress-Strain Curves • Bend Tests • Fractography	Slides 99-106 Summary M-4 Test #4

Part 4: Grading and Assessment

Graded Assignments

Four Module Tests are included as separate documents. Lab reports with template and description of the course project are included in the lab manual.

Proposed Grading Schedule

- Module Tests (4) 60%
- Lab Reports (14) 20%
- Course Project (1) 20%

Part 5: Notes to Program Administrators

Resources

Abrasive Cutter (e.g., MEGA M250)
Specimen Mounting Press (e.g., TERA Press TP 7001)
Grinder/Polisher (e.g., NANO 1000T)
Inverted Metallurgical Microscopes (e.g., IM 3000)
Microhardness Tester (e.g., HV-1000Z)
Universal Testing Machine
Fumehood and Sinks (for etching)
Optional: Scanning Electron Microscope

Class requires use of Keller's Solution. Please verify safe handling instructions of this reagent with the EHS Officer.

Instructor Qualification

- Bachelor's or higher degree in a qualifying field or
- Bachelor's or higher degree in any discipline and certifying credentials:
  - 30 undergraduate hours or 18 graduate hours of coursework in a qualifying field, or
- Bachelor's or higher degree with relevant supplemental experiential experience:
  - Two years professional employment or
  - Research or publications, or
- A.A.S. in a qualifying discipline and four years of relevant professional employment

Qualifying fields:

Metallurgical Engineering
Mechanical Engineering
Construction Technology
Quality Assurance/Quality Control Technology

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