MTGN 477 METALLURGY OF WELDING - LABORATORY
Fall Semester 2006

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Time:  Thursday 8:00 a.m. - 10:00 a.m.

Room:  Welding Lab
        Physical Metallurgy Lab

Laboratory Topics: Each lab work will include the design of an experimental matrix and the selection of welding parameters. The weld specimens prepared will be characterized using chemical, metallurgical and mechanical testing techniques. Individual written reports will be required. The organization of the laboratory work, as well as the results presented will be considered in the determination of the final lab grade.

Lab 2 – October – Measurement of temperature and arc welding parameters (Short report.)

Lab 3 – October – Measurement of diffusible hydrogen using gas chromatography and arc emission spectrometer (Short report.)

Lab 4 – November – Characterization of explosive bonding (Long Report)

Lab 5 – November and December – Design and manufacture of a shield metal arc welding electrode for high nickel alloys (Long Report)
**Topic:** Physical Measurements in Welding Processes

**Objectives:** This laboratory program is designed to measure weld temperature and electric arc signals. Experiments will be conducted to observe the influence of welding parameters (current and voltage) on weld heating and cooling. The effect of welding parameters on arc behavior will also be examined.

**Equipment & Materials:**
(a) GTA welding equipment;
(b) W electrode (1/8 in. diameter)
(c) GMA welding equipment;
(d) E70S-3 electrode;
(e) Thermocouples;
(f) Arc signal current and voltage sensors;
(g) A/D converter;
(h) PC with data capture software;
(i) Base metal: Low carbon structural steel (A-36 grade)
(j) Shielding gas: 90%Ar 10%O\(_2\) mixture

**Experimental Procedure:**
(a) Fine holes will be drilled from the back side of low carbon steel plates to position thermocouples at locations that correspond to the coarse grained and fine grained heat affected zones of a weld;
(b) Conduct GTA welding with varied current and voltage for temperature monitoring;
(c) Save temperature data for later processing;
(d) Collect electrical signals that correspond to temperature-time data;
(e) Conduct GMA welding with varied current and voltage for different arc conditions;
(f) Collect arc current and arc voltage data;
(g) Save electrical signal data for later processing
(h) Process arc current and arc voltage data for spectrum density calculation;
(i) Photograph arc, if possible.

**Expected Results and Analysis:**
(a) Plot the temperature-time diagrams;
(b) Measure peak temperatures, \( t_{1000}, t_{100}, \) and \( \Delta t_{8/5} \);
(c) Relate temperature measurements with welding conditions;
(d) Description of the arc shape (from observations in lab).
(c) Examine the current and voltage sensors and understand their functions;
(f) Plot voltage-time and current-time plots for each of the welding conditions;
(g) Determine the statistics of current and voltage data;
(h) Relate current and voltage with welding conditions;
(i) Process current-time and voltage-time data using FFT algorithm;
(j) Plot power spectrum versus frequency diagrams;
(k) Identify high power density phenomena and relate them to metal transfer mode;

**Report:** Long report required for this laboratory.

### GTA Welding Experiments
- **Electrode type** -
- **Electrode diameter** -
- **Shielding gas type** -
- **Shielding gas flow rate** -
- **Temperature data capture rate** -

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<tr>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Travel Speed (ipm)</th>
<th>Heat Input (kJ/mm)</th>
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* 3 thermocouples used for measurement per weld set

### GMA Welding Experiments
- **Electrode type** -
- **Electrode diameter** -
- **Shielding gas type** -
- **Shielding gas flow rate** -
- **Electric arc signal data capture rate** -

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Targeting different transfer modes in the three weld sets
**Topic:** Measurement of diffusible hydrogen using gas chromatography and arc emission spectrometer

**Objectives:** This laboratory program is designed for the students to acquire the knowledge and practice of experimental determination of hydrogen in a welding arc and diffusible hydrogen in steel weld metals.

**Equipment & Materials:**
(a) GMA welding equipment;
(b) Diffusible hydrogen fixture;
(c) Emission spectrometer;
(d) Gas chromatography;
(e) Gas storage canisters;
(f) Ice and water;
(g) Welding wire: E70S-3;
(h) Base metal: Low carbon structural steel (A-36 grade);
(i) Shielding gas: 90%Ar 5%O₂ mixture;
(j) Leco interstitial hydrogen analyzer;
(k) Data acquisition system.

**Experimental Procedure:**
(a) Bead-on-plate (BOP) GMA welds;
(b) Arc emission spectrometry – (maybe) in 2 locations in the arc;
(c) Arc signal data processing
(d) Slag cleaning and weld preparation;
(e) Gas collection in canisters
(f) Gas chromatography measurements;
(g) Diffusible hydrogen calculation
(h) Residual hydrogen analysis.

**Expected Results/Correlation/Learning:**
(a) Arc emission spectrometry – procedure and calculation;
(b) Arc temperature determination;
(c) Arc hydrogen concentration determination;
(d) AWS A4.3 Diffusible hydrogen determination specification;
(e) Details of the diffusion hydrogen determination;
(f) Interstitial (total) hydrogen determination;
(g) Details of gas chromatography hydrogen determination;
(h) Hydrogen content calculation.

**Topics for consideration:**
Source of hydrogen, hydrogen in the arc, effect of diffusible hydrogen on steel welds, principles of determination, effect of welding parameters on diffusible hydrogen
measurement.
**Topic:** Characterization of Explosive Bonding

**Objectives:**

**Equipment & Materials:**

**Experimental Procedure:**

**Expected Results/Correlation/Learning:**

**Topics for consideration:**
Performance of dissimilar metal joints, corrosion behavior of dissimilar welds, intermetallic formation – thermodynamics and kinetics, and principles of SEM and EDS.
**Topic:** Design and manufacture of a shield metal arc welding electrode for high nickel alloys

**Objectives:** This laboratory program has as objective the investigation of the design methodology of arc welding consumables for high nickel alloys. What is the optimal flux coating for high melting temperature materials with sluggish flow in the liquid state? What is the optimal flux coating for elemental recovery in the weld pool?

**Equipment & Materials:**
- (a) Electrode extruder
- (b) Powder processing equipment
- (c) SMA welding equipment;
- (d) High nickel rods
- (e) Optical microscope;
- (f) Glow discharge sputtering spectrometer;
- (g) Inductively coupled plasma (ICP) spectrometer;
- (h) SEM/EDS;
- (i) Base metal: nickel or Inconel plates.

**Experimental Procedure:**
- (a) Design one flux composition;
- (b) Blend flux powders and extrude coated electrodes;
- (c) Bead-on-plate (BOP) SMA welds; Welding parameters to be provided by TA (prior testing);
- (d) Sample characterization - Metallography (Macro and micro);
- (e) Defect characterization;
- (f) Chemical Analysis – weld and slag;

**Expected Results:**
- (a) Description of weld pool behavior;
- (b) Description of slag coverage;
- (c) Description of weld macro-and microstructure;
- (d) Description of weld composition;
- (e) Calculation of elemental recovery;
- (f) Proposal of new flux systems;

**Topics for Consideration:**
Oxygen and nitrogen control in molten weld pool, molten metal flow in weld pool, influence of flux ingredients on base metal wetting and defect formation, slag coverage, chemical reactions in weld pool.