Lecture 23

Chapter 30
Fusion Welding Processes

Introduction

• Fusion welding
  – Two pieces are joined together by the application of heat
    • Melting and fusing the interface

• Filler metal
  – Extra metal added (melted) to form joint
    • Rod
    • Wire

• Welds without filler metal – autogenous
Oxyfuel-Gas Welding

- Use of fuel gas with oxygen to produce a flame
- Most common oxyfuel-gas welding operation – oxyacetylene-gas welding
- Primary reaction
  \[ C_2H_2 + O_2 \rightarrow 2CO + H_2 + \text{heat} \]
  - 1/3 of total heat generation
- Secondary reaction
  \[ 2CO + H_2 + 1.5O_2 \rightarrow 2CO_2 + H_2O + \text{heat} \]
  - 2/3 of total heat generation

Oxyacetylene Flame Types

- Neutral flame – Acetylene : Oxygen - 1:1 (no excess oxygen)
- Oxidizing flame – excess oxygen; used with Cu and Cu alloys
- Carburizing (reducing) flame – insufficient oxygen for full combustion, lower temperatures; used for brazing, soldering, and flame hardening
Oxyfuel-Gas Welding

- Other fuel gases – typically have lower temperatures
  - Hydrogen
  - Methylacetylene propadiene

- Uses
  - Metals with lower melting temperatures
  - Thinner and smaller parts

Filler Metals

- Rods or wire
  - Bare
  - Coated in flux
    - Flux is an oxidation retardant, when it melts and evaporates it forms a gaseous shield around the weld zone

- Slag developed from oxides, fluxes, electrode-coating materials protects the molten puddle of metal as it cools
Welding Practice and Equipment

- Economical method
  - Low equipment cost
  - Portable / versatile
- Max thickness .25”
- Steps
  - Prepare pieces
  - Adjust flame
  - Torch at 45° and filler at 30°
  - Touch filler rod to joint

Arc Welding

- Welding heat is supplied by electrical energy – 30,000 °C
- Types of arc welding
  - Non-consumable electrode
    - Tungsten Inert Gas (TIG) – Gas Tungsten-Arc Welding (GTAW)
    - Plasma-arc
    - Atomic-hydrogen
  - Consumable electrode
    - Shielded metal-arc
    - Submerged-arc
    - Metal Inert Gas (MIG) – Gas Metal-Arc Welding (GMAW)
Nonconsumable Electrode

- Electrode – Tungsten
- Shielding gas is necessary due to high temperatures
  - Prevents oxidation of workpiece
- Electrical specifications
  - DC is typically used
  - Straight polarity – Direct Current Electrode Negative (DCEN)
    - Workpiece = Anode (positive)
    - Electrode = Cathode (negative)
    - Welds are narrow and deep
  - Reverse polarity – Direct Current Electrode Positive (DCEP)
    - Welds are wider and shallower than DCEN

TIG Welding

- GTAW
  - Metals welded
    - Al
    - Mg
    - Ti
    - Refractory metals
  - Use constant current – typically 200 or 500 A
  - AC used for Al and Mg because the AC removes the oxides
• Shielded metal-arc welding (Stick Welding)
  – 50% of all large-scale industrial welding operations
  – 50 – 300 A run between the stick and the workpiece
  – Arc process
    • Touch stick to workpiece
    • Move stick away from workpiece to sufficient distance to maintain arc
  – Electrodes are coated
    • Coating deoxidizes the weld area and provides shielding gas
  – Thicknesses welded 0.12 - .75” – single pass
  – Thicker with multi-pass

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TABLE 27.2

The prefix “E” designates arc welding electrode. The first two digits of four-digit numbers and the first three digits of five-digit numbers indicate minimum tensile strength:

- E60XX 60,000 psi minimum tensile strength
- E70XX 70,000 psi minimum tensile strength
- E110XX 110,000 psi minimum tensile strength

The next-to-last digit indicates position:
- EXX1X All positions
- EXX2X Flat position and horizontal fillets

The last two digits together indicate the type of covering and the current to be used. The suffix (Example: EXXXX-A1) indicates the approximate alloy in the weld deposit:

- A1 0.5% Mo
- B1 0.5% Cr, 0.5% Mo
- B2 1.25% Cr, 0.5% Mo
- B3 2.25% Cr, 1% Mo
- B4 2% Cr, 0.5% Mo
- B5 0.5% Cr, 1% Mo
- C1 2.5% Ni
- C2 3.25% Ni
- C3 1% Ni, 0.35% Mo, 0.15% Cr
- D1 and D2 0.25–0.45% Mo, 1.75% Mn
- G 0.5% min. Ni, 0.3% min. Cr, 0.2% min. Mo, 0.1% min. V, 1% min. Mn (only one element required)
SMAW Welding

Schematic illustration of the shielded metal-arc welding process. About 50% of all large-scale industrial welding operations use this process.

Economic Comparison of Welding Processes

**TABLE 27.1**

<table>
<thead>
<tr>
<th>Joining process</th>
<th>Operation</th>
<th>Advantage</th>
<th>Skill level required</th>
<th>Welding position</th>
<th>Current type</th>
<th>Distortion*</th>
<th>Cost of equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielded metal-arc</td>
<td>Manual</td>
<td>Portable and flexible</td>
<td>High</td>
<td>All</td>
<td>ac, dc</td>
<td>1 to 2</td>
<td>Low</td>
</tr>
<tr>
<td>Submerged arc</td>
<td>Automatic</td>
<td>High</td>
<td>Low to medium</td>
<td>Flat and ac, dc</td>
<td>1 to 2</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Gas metal-arc</td>
<td>Semiautomatic or automatic</td>
<td>Low to high</td>
<td>All</td>
<td>ac, dc</td>
<td>2 to 3</td>
<td>Medium to high</td>
<td></td>
</tr>
<tr>
<td>Gas tungsten-arc</td>
<td>Manual or automatic</td>
<td>Most metals</td>
<td>Low to high</td>
<td>All</td>
<td>ac, dc</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Flux-cored arc</td>
<td>Semiautomatic or automatic</td>
<td>High</td>
<td>All</td>
<td>dc</td>
<td>1 to 3</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Oxyfuel</td>
<td>Manual</td>
<td>Portable and flexible</td>
<td>High</td>
<td>All</td>
<td>—</td>
<td>2 to 4</td>
<td>Low</td>
</tr>
<tr>
<td>Electron-beam, Laser-beam</td>
<td>Semiautomatic or automatic</td>
<td>Medium to high</td>
<td>All</td>
<td>—</td>
<td>3 to 5</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

* 1, highest; 5, lowest.