Gas Shielded Welding Processes

Gas Metal Arc Welding (GMAW)
Gas Metal Arc Welding

Process Fundamentals

- In GMAW the welding heat source is an arc maintained between a consumable wire electrode and the workpiece.
- The weld is formed by melting and solidification of the joint edges together with filler material transferred from the electrode.
- An flow of inert gas shields the high-temperature arc and weld pool from reactions with the surrounding atmosphere.
GMAW Process Fundamentals

- Shielding Gas In
- Electrode
- Conductor
- Wire Guide and Contact Tube
- Gas Nozzle
- Gas Shield
- ARC
- Base Metal
- Weld Metal

Lecture 4
GMAW Metal Transfer Modes

- Short Circuiting or "Dip" Transfer
- Globular Transfer
- Spray Transfer
- Pulsed or Synergic Transfer
GMAW Short Circuiting Transfer
GMAW Globular Transfer Mode

R-Anode reaction
P-Electromagnetic "pinch" force

(A)

(B)
GMAW Spray Transfer

Variation in volume and rate of drop transfer with welding current

![Graph showing variation in volume and rate of drop transfer with welding current.]

- Drop Volume
- Transfer Rate
- Transition Current

- 1/16 in. (1.6 mm) Mild Steel Electrode, DCRP
- Argon-1% Oxygen Shielding Gas
- 1/4 in. (6.4 mm) Arc Length

Lecture 4
GMAW Spray Transfer
GMAW Pulsed Transfer

- Pulse frequency and amplitude determine wire melting rate
- "Synergic" control automatically gives the optimum pulse conditions for a given wire feed rate
GMAW Welding Procedures

- Process Variables
  - Welding current (electrode melting rate)
  - Polarity
  - Arc voltage (length)
  - Travel speed
  - Electrode extension
  - Electrode size
  - Shielding gas composition
GMAW Electrode Melting Rate

![Graph showing the relationship between welding current and wire feed speed for different electrode diameters. The graph includes curves for 0.030 in. (0.8 mm), 0.035 in. (0.9 mm), and 0.062 in. (1.6 mm) electrodes.](image)
GMAW Torch Geometry

Contact tube

Nozzle

Contact Tube to Work Distance

Electrode Extension

Arc Length
GMAW Consumables

- Electrode composition is usually similar to desired weld metal composition with additional deoxidizers e.g. Si, Al, Ti
- Electrodes are covered by AWS and other specifications
  - Carbon steel electrodes AWS A 5.18.
- Shielding Gases
  - Various shielding gases are used depending on metal being welded and desired transfer mode
  - Principally Ar, CO2 and mixtures of Ar-CO2, O2 or He
  - Several commercial "brand-name" compositions
# GMAW Typical Welding Procedures

**Carbon Steel**

<table>
<thead>
<tr>
<th>Joint</th>
<th>T (mm)</th>
<th>R (mm)</th>
<th>F (mm)</th>
<th>A (Deg)</th>
<th>Wire Dia (mm)</th>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Wire Feed (mm/s)</th>
<th>Shielding Gas</th>
<th>Gas Flow Rate (l/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.5</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>65</td>
<td>19</td>
<td>64</td>
<td>75% Ar</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25% CO₂</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>5.25</td>
<td>1.6-4</td>
<td>2</td>
<td>80</td>
<td>1.1</td>
<td>250</td>
<td>26</td>
<td>100</td>
<td>95% Ar</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5% CO₂</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>5.25</td>
<td>1.5-4</td>
<td>3</td>
<td>80</td>
<td>1.1</td>
<td>250</td>
<td>26</td>
<td>100</td>
<td>96% Ar</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5% CO₂</td>
<td></td>
</tr>
</tbody>
</table>
GMAW Welding Gun

Wire Conduit
Electrode
Shielding Gas Path
Input Water Line
Water Chamber
Contact Tip
Gas Nozzle
Power Block
Control Switch
Power Cable/Return Water
GMAW Applications

- Aluminum alloys, copper/bronze, magnesium, titanium, austenitic stainless steels, nickel alloys
- Sheet metal fabrication (short circuit mode)
  - eg automotive, appliance, light structures
- General structural fabrication (spray/pulsed mode)
- High production, mechanised and robotic welding
GMAW Mechanized Application

Field welds in oil/gas transmission pipelines

2 external GMAW heads

6 internal GMAW heads

pneumatic alignment clamps

Weld preparation and bead sequence
GMAW: Mechanized Applications

Nuclear Fuel
Dry Storage

Transfer Flask
Shielded Workstation
TV camera
Welding guns & seam tracker

Loading Shaft

Spent Fuel Bay
Fuel container
Cover seal welded after loading
Fuel Bundles

Underwater loading station

Lecture 4
GMAW: Mechanized applications

Shielded station wall

Welding guns mounted on automatic seam trackers

TV Camera

Turntable

Welding power supply

Shielding Gas

Wire feeder

Control Panel

Video monitor
# Process Control

<table>
<thead>
<tr>
<th>Component</th>
<th>Status</th>
<th>Weld Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEAM TRACKER</strong></td>
<td>Weld overlap</td>
<td>Cycle start</td>
</tr>
<tr>
<td></td>
<td>Tracking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drive In/Out</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Idle</td>
<td>Cycle end</td>
</tr>
<tr>
<td><strong>TURNTABLE</strong></td>
<td>Motion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Idle</td>
<td></td>
</tr>
<tr>
<td><strong>WELDING</strong></td>
<td><strong>EQUIPMENT</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welding Current</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shield gas flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Idle</td>
<td></td>
</tr>
</tbody>
</table>
GMAW Capabilities & Limitations

+ Applicable to range of metals and thicknesses
+ Higher production rates than SMAW or GTAW
+ No flux or slag residues
+ Adaptable to manual or mechanized/robotic applications

- Complex equipment and set up
  - Wire feeding can be temperamental
- Less portable than SMAW
- Gas shield sensitive to air currents
WELDING PROCESSES

GAS TUNGSTEN ARC WELDING (GTAW)
GTAW: Process Fundamentals

- In GTAW the welding heat source is an arc maintained between a non-consumable tungsten electrode and the workpiece.
- Inert gas shields the arc and weld zone from atmospheric contamination.
- Filler need not always be added (autogenous welding).
- Filler if required is added to the weld pool in the form of wire or rod.
GTAW: Process Fundamentals

- DIRECTION OF WELDING
- CURRENT CONDUCTOR
- GAS NOZZLE
- NON-CONSUMABLE TUNGSTEN ELECTRODE
- FILLER METAL
- INERT GAS SHIELD
- ARC
- SOLIDIFIED WELD METAL
GTAW: Process Variables

- Welding current
  - DC, pulsed DC, high frequency pulsation, AC, variable polarity AC
- Arc length (Voltage)
- Weld travel speed
- Oscillation
- Filler addition
- Shielding gas composition & flow rate
  - generally Ar or He or mixtures.
GTAW: Current Polarity

- DCEP is mostly used
  - approx 70% of heat produced at anode (workpiece)
- DCEN used to disperse tenacious surface oxides when welding Al, Mg
- AC also used in Al welding
  - variable polarity pulsed AC
GTAW: Effect of Polarity

[Diagram showing different stages of a GTAW process]
GTAW: Arc Voltage

TUNGSTEN ARC, ALUMINUM

ARC LENGTH
- 0.08 in. (2 mm)
- 0.16 in. (4 mm)

ARC VOLTAGE, V

ARC CURRENT, A

HELUM
ARGON

Lecture 4
Pulsed GTAW (PGTAW)

Pulsed DC advantages:

- Greater penetration for given average current
- Minimizes heat affected zone & distortion
- Improved capability to weld in all positions
GTAW: Gas backing

Diagram showing a gas backing setup for welding.
GTAW: Pipe internal purge

Diagram:
- GAS INLET
- FILL WITH INERT GAS
- PIPE
- WELD JOINT
- PURGE GAS OUTLET
- BAFFLE
GTAW Equipment Schematic

TORCH

TUNGSTEN ELECTRODE

GAS PASSAGES

ARC

WORKPIECE

POWER SOURCE

INERT GAS SUPPLY

ELECTRICAL CONDUCTOR

INSULATING SHEATH

SHIELDING GAS
GTAW Torch

- POWER CONDUCTOR
- COOLING WATER IN/OUT
- SHIELDDING GAS INLET
- HANDLE
- SHIELDDING GAS OUTLET
- TUNGSTEN ELECTRODE
Mechanized GTAW Applications

- Mechanization of
  - weld head travel motions
  - wire feed (if required)
  - process controls: start/stop sequence, weld current profile, shielding gas flow, etc

- Typical applications: Pipe, tube, tube-tubesheet welding, longitudinal welds in formed tubes.

- Advantages of mechanization
  - increased productivity
  - reduced weld defect rates
  - shorter joint completion times
  - reduced need for skilled labour
Hot Wire GTAW
GTAW Deposition Rates

DEPOSITION RATE (lb/hr)

HOT WIRE WITH OSCILLATION

HOT WIRE

COLD WIRE

ARC ENERGY (kW)

0 2 4 6 8 10

0 1 2 3 4 5 6 7 8 9

Lecture 4
Narrow-Gap GTAW

Special Narrow-Gap Torch

Narrow-Gap Joint Preparation
# GTAW Capabilities & Limitations

| + Superior quality welds free from flux residues or spatter |
| - Low deposition rates |
| + Excellent control of penetration |
| - Higher welder skill required in manual processes |
| + Applicable to almost all metals |
| - Gas shielding sensitive to air currents |
| + Adaptable to manual or precision mechanized applications |