8. Gas Metal Arc and Flux Cored Arc Welding

8.1. Process Descriptions

Both the gas metal arc welding (GMAW) and flux cored arc welding (FCAW) processes use a similar principle and the same equipment, although they are usually considered separate processes.

In both processes, continuously fed wire is melted in an arc struck between the tip of the wire and the work piece. The wire is fed from the wire feeder through a gun (torch) to the arc by wire feed rolls. The weld pool is usually protected from oxidation by shielding gas, which is delivered to the weld through the gun. The wire diameter is small, ensuring a high current density and burn-off rate because of resistance heating. The small wire is flexible ensuring the gun can be manipulated by hand or a robot.

GMAW uses a solid wire, while FCAW uses a wire containing a flux that provides additional protection of the weld pool. There are versions of FCAW that do not require shielding gas.

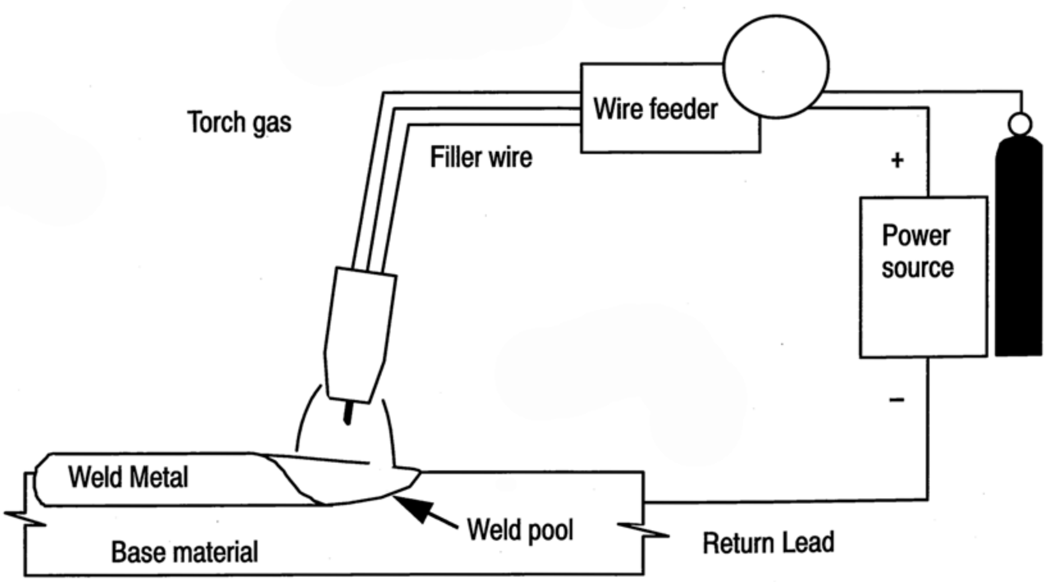

Figure 33 GMAW and FCAW Principles of Operation

Alternative names used for GMAW are metal inert gas welding (MIG), metal active gas welding (MAG), semi-automatic (automatic) and CO_2 welding. The correct Australian term is GMAW. MIG is a popular term as it rolls easily off the tongue.

GMAW and MMAW are used in a *semi-automatic* mode when the gun is held in the welder's hand. Mechanisation is possible by mounting the gun on a fixture and moving the workpiece or alternatively mounting the gun on a moving positioner or robot.

8.2. Equipment

The equipment necessary for GMAW and FCAW comprises a power source, wire feeder, gun assembly and shielding gas.

8.2.1. Power Source Characteristics

The power source must supply direct current, with a constant voltage characteristic for most welding. Power sources vary considerably in complexity. Low cost equipment generally is a transformer with just the necessary ancillary power for the wire feeder. The more sophisticated equipment has microprocessor control and it may be based on small inverter transformers.

The use of the CV power source provides a self-correcting action to compensate for inadvertent variation in torch to work distance. The wire feed rate is considerably faster than involuntary hand movement. If the torch-work distance is shortened, the voltage is momentarily increased causing a large reduction in current, which compensates for the reduction in stick out. The converse happens if the distance is increased.

8.2.1.1 Ancillary Functions

Auxiliary power is provided for the gas solenoid, wire feeder motor and other equipment. Sometimes the power source has built in meters. There may also be variable inductance or slope controls.

8.2.1.2 Electrical Connections

The electrode lead connects the power source to the wire feeder. The current-return lead connects the workpiece to the power source. An ancillary lead provides current to the wire feed motor. A contactor lead connects between the wire feeder and the trigger in the gun to turn on the power, gas and wire when needed. Poor connections in the electrode or return leads will affect welding performance because of the high currents they carry. The voltage drop at poor connections will vary as they heat up, varying arc conditions.

8.2.2. Wire Feeders

The wire feeder must be able to push the wire down the liner at a smooth constant speed and with a rapid start. Jerky feed causes current fluctuation, arc instability, weld bead shape irregularity, and a high risk of defects. Selection of the correct feed rolls, correct adjustment of feed roll tension, and ensuring the liner and contact tip are in good condition and are as straight as possible are essential to avoiding feeding problems.

Feed systems may have one or two pairs of drive rolls, usually with a quick-release catch to speed changing of the consumable reel. The rolls have to be selected for the type of wire to be used. Knurled rolls are used to feed flux-cored wire, while there are rolls with a precise 'U' groove to grip soft wires, such as aluminium.

The wire feed unit usually has the voltage and wire feed controls, as well as a switch for inching the wire. The gas solenoid is usually at the wire feeder. It may also have timers to allow spot welding, burn back, gas preflow and other functions.

The welding and wire feeder that is contained as one unit is popular in smaller fabrication shops, but for heavy fabrication the wire feeder should be separate from the power source for portability. The gun conduit has to be kept short to avoid wire feed problems, and is limited to a maximum length of 5m. There can be up to 100m of cable between the wire feeder and the power source. The wire feeder should be compact for access into difficult areas.

Usually the wire feeder has a separate power supply, although there are a few models that are powered by the welding current.

8.2.3. Welding Guns.

The welding gun assembly comprises:

- a handle or grip for hand holding or fixing to manipulating equipment,
- a trigger to actuate the wire feed motor and gas solenoid, (separate pendants are available for mechanised welding),
- a flexible conduit to carry the current, trigger leads, gas, consumable and water cooling (if available),
- an easily removed nozzle (for quick cleaning), to shroud the weld area with a laminar flow of shielding gas,
- a flexible liner to carry the filler wire with the minimum of friction,
- A replaceable copper contact tip, to allow the electrode to pick up the current close to the arc.

Guns come in a variety of sizes to suit the current required. Lower capacity guns are lighter, more flexible and easily handled. Those for over 300 amps are usually water-cooled. 'Air cooled' (shielding gas cooled) guns are simpler but often heavier and less flexible than their water-cooled alternatives.

Guns are available with built in feed rolls (push-pull guns) for difficult-to-handle filler wires. Spool guns have built in feed rolls and provision to carry a small (1 or 5kg) spool of wire.

8.2.4. Gas Shielding Equipment

Shielding gas is usually supplied in pressurised cylinders of various sizes, although many larger fabricators have a bulk supply of welding gas. Carbon dioxide is stored as a pressurised liquid and it is important the gas is drawn from the top of the cylinder. A typical flow rate of about 10 to 20L/min is required to ensure smooth laminar flow, depending on the nozzle size. If too low, there is insufficient gas cover; if too high the gas is turbulent and the shielding breaks down. It is necessary to fit a heater to the regulator for carbon dioxide to prevent it from freezing and stopping the gas flow.

Generally, mixed gases are supplied from cylinders, although gas-mixing equipment is available. Regulators and hoses should be suited to the gas type.

The gas shield is sensitive to draughts. GMAW is usually successful indoors, but special care is usually necessary out of doors.

8.3. Process Variables

The factors affecting welding are the wire material and size, shielding gas, current type (steady or pulsed), polarity, current (wire feed speed), voltage, stick-out, electrode angle and sometimes circuit impedance. Welding has to be tuned by correct selection of parameters and a wrong selection will result in a poor weld or inability to weld at all.

8.3.1. Wire Feed Speed and Current

Adjusting the wire feed speed is used to adjust the welding current. The welding current *(I)* is related directly to the wire feed speed *(WFS)* by Equation 19.

$$WFS = aI + bLI^2 \quad \text{Equation 19}$$

Where a and b are constants which depend on the wire type and diameter and L is the electrode stick out.

Increasing current increases depth and width of penetration, deposition rate and size of weld bead. It also affects metal transfer.

8.3.2. Polarity

GMAW and FCAW mostly use DCEP as this gives a stable arc, smooth metal transfer, wide current range, good penetration and good bead shape.

DCEN is seldom used because the transfer is globular and no longer axial. It has some use for surfacing where reduced penetration reduces dilution. AC is not used.

8.3.3. Voltage

Voltage settings affect weld bead shape and metal transfer. Generally, higher voltages are selected with higher wire feed speeds (currents). The correct voltage depends on the current, material welded, joint type, position, electrode size, stick out and shielding gas. Increasing voltage tends to smooth and flatten the weld. Reducing it will lead to deeper penetration. Only a narrow range of voltage is suitable for a particular current level, wire size, stick-out and shielding gas. Excessively high voltage causes arc instability, porosity, spatter and undercut. Excessively low voltage will result in stubbing of the electrode and arc instability.

8.3.4. Electrode Stick-out or Extension

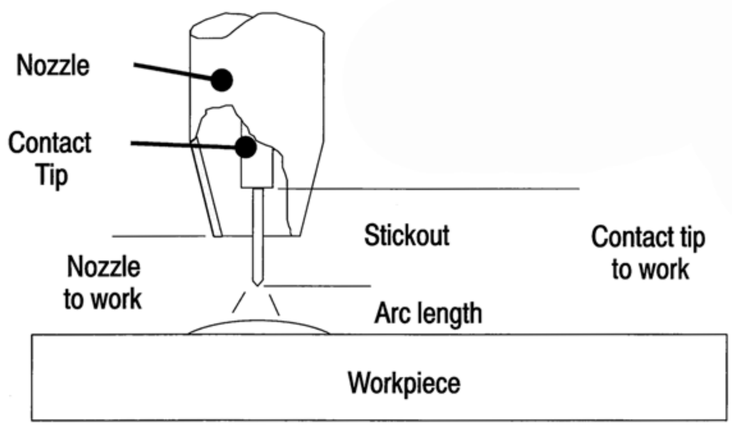

Figure 34 Gun Nozzle Terminology

The wire between the contact tip and the arc (stick-out or extension) is carrying the full welding current. Its electrical resistance is dependent on the wire diameter and the stick-out length. The length of the stick-out can be varied by the welder and has an important effect on the arc. Long stick-out reduces the actual arc voltage, narrowing the bead. Short-stick out increases actual arc voltage. The correct stick-out for GMAW is 6 to 13mm for dip transfer and 13 to 25mm for other modes of transfer. Refer to the consumable supplier for the correct stick-out for FCAW.

8.3.5. Gun Angle or Weld Progression

GMAW and FCAW can be undertaken with the electrode oriented for forehand or backhand welding. The torch angle has a more profound effect on penetration and bead shape than current or voltage.

AISC

An Engineer's Guide to Fabricating Steel Structures

Volume 1: Fabrication Methods

by John Taylor BSc, Sen.MWeldI

AUSTRALIAN INSTITUTE OF STEEL CONSTRUCTION
A.C.N. 000 973 839

AUSTRALIAN INSTITUTE OF STEEL CONSTRUCTION
A.C.N. 000 973 839

AN ENGINEER'S GUIDE TO FABRICATING STEEL STRUCTURES
VOLUME 1 - FABRICATION METHODS

NATIONAL LIBRARY OF AUSTRALIA
CARD NUMBER AND ISBN 0-909945-88-8

Published by:
AUSTRALIAN INSTITUTE OF STEEL CONSTRUCTION

FIRST EDITION 2001

National Library of Australia Cataloguing-in-Publication entry:

Taylor, John Stuart.
An engineer's guide to fabricating steel structures. Volume 1, Fabrication methods

Bibliography.
Includes index.
ISBN 0 909945 88 8 (v. 1).

ISBN 0 909945 89 6 (set).

1. Building, Iron and steel. 2. Welding. 3. Steel, Structural.
I. Australian Institute of Steel Construction.
II. Title.

624.1821

Set
ISBN 0-909945-89-6
9 780909 945893

Production by Redmark Pty. Ltd.
6 Kuru Street, North Narrabeen, NSW 2101, Australia

Enquiries should be addressed to the publisher:
Australian Institute of Steel Construction
Business address - Level 13, 99 Mount Street, North Sydney, NSW 2060, Australia.
Postal address - P.O. Box 6366, North Sydney, NSW 2059, Australia.

Disclaimer:

Contents