6. Manual Metal Arc Welding

6.1. Outline

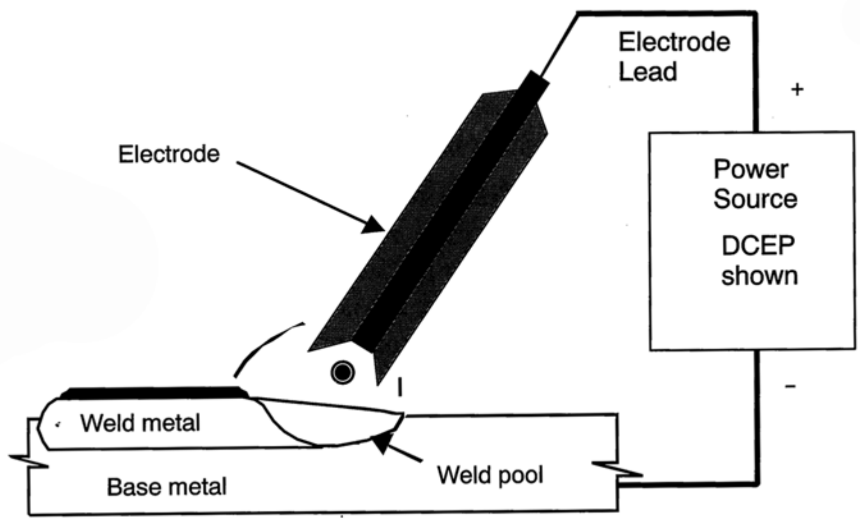

Figure 26 MMAW Process Outline

Manual metal arc welding is defined as the coalescence of metals produced by the heat from an electric arc between the tip of a covered electrode and the surface of the joint being welded. The welder inserts a covered electrode into the electrode holder and strikes the arc by tapping the tip onto the workpiece. Once alight, the arc fuses the base material and the tip of the electrode. The welder then moves the arc at a steady speed along the joint to keep the weld pool a constant size. The slag forms a protective cover over the hot weld pool until it has solidified. The welder may need to hold a constant arc length of 2 to 3mm, or in some cases can touch the electrode to the joint, which is known as touch welding. Once the electrode is consumed down to a stub of 40 to 50mm the arc is broken, the crater cleaned of slag, a new electrode inserted into the holder and the process repeated. Once the weld run is completed, it is cleaned of slag.

Alternative names for the process are shielded metal arc welding (SMAW), which is used in the USA, and stick welding. The electrodes are sometimes known as stick electrodes or covered electrodes.

MMAW is a relatively simple process that has played a vital role in the development of welding. Until the early 1980s, more welding was deposited with this process than all others put together. Sales of MMAW electrodes are now falling, being replaced by GMAW and FCAW. However, MMAW will continue to be used where other processes cannot. Other processes are judged against this benchmark.

Its main features are:

- Simplicity, versatility and portability

- Can be used where access is difficult or remote
- Can be used to join a wide range of materials
- Often excellent weld metal properties and quality,
- Low sensitivity to wind and drafts
- Moderate tolerance to base material contamination
- Low travel speeds and deposition rates,
- Short set-up times,
- Low capital cost.

MMAW can be used to weld a wide range of materials over 3mm thick. The low travel speed means the welder finds it easier to avoid welding defects, particularly if access is restricted. As MMAW has been the process most used for welder training, skill in it is widespread. The processes FCAW, GMAW and SAW have higher deposition rates, but are more likely to suffer weld defects. Often the increase in productivity of the alternatives is offset by higher process set-up times, training and capital cost. MMAW will for always be cost effective for on-site maintenance.

While the process can be described as mature, it is subject to continuing development. The process origins go back to the last century, when bare wire electrodes were found to weld better if wrapped in paper. The modern covered electrode is attributed to the Swede Oscar Kjellberg (pronounced Shellberg) who was one of the pioneers of ESAB, currently one of the major welding suppliers in the world. Early electrodes were made by wrapping wire with paper or asbestos twine. This was replaced with dip coating (which is still used for some types). Most modern electrodes have an extruded covering.

6.2. Equipment

6.2.1. Power Source Characteristics

The welding machine is usually an ac transformer, dc transformer-rectifier or motor generator with a constant-current, (CC) volt-amp characteristic. Small inverter power sources have useable levels of current, but with far less weight. Pulsed current is not used for MMAW.

The CC power sources give a stable current. Inadvertent changes in the arc length will give little variation in the arc power. More advanced machines for MMAW have adjustable slope. A shallow slope allows the welder to vary the power by varying the arc length. A steep slope is preferred where less control is required and for larger electrode sizes. Constant voltage power sources are unusable for MMAW.

MMAW operates mostly using direct current electrode positive (DCEP) or ac. AC is preferred for the low cost of the power source and where arc blow (magnetic arc deflection) is a problem. DCEP is preferred for better arc stability, particularly at low current giving easier starting, a smoother arc and less risk of snapping out or sticking. Some electrodes only work using DCEP. Others operate better with DCEN polarity, particularly when welding root runs.

6.2.2. Ancillary Equipment

A hand-held shield or welding helmet, gloves, chipping hammer, electrode holder and leads are essential ancillary tools. Receptacles to scrap hot stub ends and a quiver or hot box to keep the electrodes in are usually provided. Little else is required, although for high quality work an angle grinder is necessary to clean off protrusions that might otherwise cause slag traps.

6.3. Joints, Positions and Techniques

Electrodes are available for welding most materials in any position, although some electrode types may only operate in flat or horizontal positions. Electrodes for welding vertical down are relatively rare.

MMAW can be used for a variety of welding joints. Including:

- Cladding, buttering and pad welds.
- Fillet welds.
- Single and double welded butt welds
- Tee and corner joints.
- Pipe joints including T, K and Y connections set-on and set-in branches in all positions.

6.4. Limitations of MMAW

The low level of productivity is the main reason for the replacement of MMAW by GMAW or FCAW. The need for frequent electrode replacement giving a duty cycle that rarely exceeds 25% is the main problem, although the time for slag removal can be considerable. Electrodes are expensive, certainly in comparison to solid wire. They are wasteful in that 30 to 50% is lost as slag, spatter and stub ends.

Because the process involves flux, MMAW can suffer inclusions if the slag is not properly removed, or if it rolls ahead of the arc and is welded over. Welds may suffer porosity at start or end of weld bead if the gas shielding is inadequate for some reason. Poor practice may cause incomplete fusion, undercut, excessive or insufficient penetration, excessive weld metal and spatter.

Flux coatings are a potential source of hydrogen, particularly the rutile and cellulose classes. There is therefore a higher risk of hydrogen cracking than for flux-free processes. Cellulosic and rutile electrodes require higher preheat than for any other process to avoid cracking.

Because the electrode is live all the time, there is a high risk that the welder will accidentally strike the workpiece causing a surface scar known as an arc strike. These burn holes, or hard spots may suffer cracking. Processes such as FCAW and GMAW have less risk of this problem, because the current is switched on only when needed. There is a higher risk of stray currents or electric shock because the electrode holder is always alive.

Although the skills necessary for MMAW are relatively common, quality is very dependent on skill level.

6.5. Welding Electrodes

Covered electrodes are solid or tubular rods 200 to 450mm long with an extruded or dipped flux coating. One end of each rod is bared for about 30mm, so that it can be gripped in a holder. The striking end is ground with a cone to make the striking easy. It may also have a conducting tip applied by dipping, painting or metal spraying.

Convenience and electrical resistance determine electrode length. Electrodes over 350mm long become increasingly more difficult to handle, even though they are more economic (lower stub end losses and less frequent changes). If the electrical conductivity of the core wire is low (alloy steel) the length is limited by current carrying capacity. If they are too long, the electrode overheats and the coating breaks down as the electrode is burned, and the welder has to discard a long stub.

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Volume 1: Fabrication Methods

by John Taylor BSc, Sen.MWeldl

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