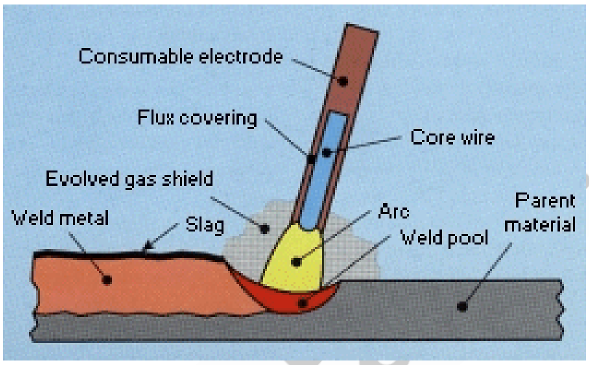
The Manual Metal Arc (MMA) process



Manual metal arc welding was first invented in Russia in 1888. It involved a bare metal rod with no flux coating to give a protective gas shield. The development of coated electrodes did not occur until the early 1900s when the Kjellberg process was invented in Sweden and the Quasi-arc method was introduced in the UK. It is worth noting that coated electrodes were slow to be adopted because of their high cost. However, it was inevitable that as the demand for sound welds grew, manual metal arc became synonymous with coated electrodes. When an arc is struck between the metal rod (electrode) and the workpiece, both the rod and workpiece surface melt to form a weld pool. Simultaneous melting of the flux coating on the rod will form gas and slag which protects the weld pool from the surrounding atmosphere. The slag will solidify and cool and must be chipped off the weld bead once the weld run is complete (or before the next weld pass is deposited). The process allows only short lengths of weld to be produced before a new electrode needs to be inserted in the holder. Weld penetration is low and the quality of the weld deposit is highly dependent on the skill of the welder.

Types of flux / electrodes

Arc stability, depth of penetration, metal deposition rate and positional capability are greatly influenced by the chemical composition of the flux coating on the electrode. Electrodes can be divided into three main groups :

- Cellulosic
- Rutile
- Basic

Cellulosic electrodes contain a high proportion of cellulose in the coating and are characterised by a deeply penetrating arc and a rapid burn-off rate giving high welding speeds. Weld deposit can be coarse and with fluid slag, deslagging can be difficult. These electrodes are easy to use in any position and are noted for their use in the 'stovepipe' welding technique.

Features:

- deep penetration in all positions
- suitability for vertical down welding
- reasonably good mechanical properties
- high level of hydrogen generated - risk of cracking in the heat affected zone (HAZ)

Rutile electrodes contain a high proportion of titanium oxide (rutile) in the coating. Titanium oxide promotes easy arc ignition, smooth arc operation and low spatter. These electrodes are general purpose electrodes with good welding properties. They can be used with AC and DC power sources and in all positions. The electrodes are especially suitable for welding fillet joints in the horizontal/vertical (H/V) position.

Features:

- moderate weld metal mechanical properties
- good bead profile produced through the viscous slag
- positional welding possible with a fluid slag (containing fluoride)
- easily removable slag

Basic electrodes contain a high proportion of calcium carbonate (limestone) and calcium fluoride (fluorspar) in the coating. This makes their slag coating more fluid than rutile coatings - this is also fast-freezing which assists welding in the vertical and overhead position. These electrodes are used for welding medium and heavy section fabrications where higher weld quality, good mechanical properties and resistance to cracking (due to high restraint) are required.

Features:

- low weld metal produces hydrogen
- requires high welding currents/speeds
- poor bead profile (convex and coarse surface profile)
- slag removal difficult

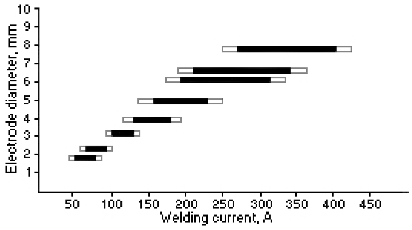
Metal powder electrodes contain an addition of metal powder to the flux coating to increase the maximum permissible welding current level. Thus, for a given electrode size, the metal deposition rate and efficiency (percentage of the metal deposited) are increased compared with an electrode containing no iron powder in the coating. The slag is normally easily removed. Iron powder electrodes are mainly used in the flat and H/V positions to take advantage of the higher deposition rates. Efficiencies as high as 130 to 140% can be achieved for rutile and basic electrodes without marked deterioration of the arcing characteristics but the arc tends to be less forceful which reduces bead penetration.

Power source

Electrodes can be operated with AC and DC power supplies. Not all DC electrodes can be operated on AC power sources, however AC electrodes are normally used on DC.

Welding current

Welding current level is determined by the size of electrode - the normal operating range and current are recommended by manufacturers. Typical operating ranges for a selection of electrode sizes are illustrated in the table.



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As a rule of thumb when selecting a suitable current level, an electrode will require about 40A per millimeter (diameter). Therefore, the preferred current level for a 4mm diameter electrode would be 160A, but the acceptable operating range is 140 to 180A.

What's new

Transistor (Inverter) technology is now enabling very small and comparatively low weight power sources to be produced. These power sources are finding increasing use for site welding where they can be readily transported from job to job. As they are electronically controlled, add-on units are available for TIG and MIG welding which increase the flexibility.

Electrodes are now available in hermetically sealed containers. These vacuum packs obviate the need for baking the electrodes immediately prior to use. However, if a container has been opened or damaged, it is essential that the electrodes are redried according to the manufacturer's instructions.

Equipment for MMA welding

Although the manual metal arc (MMA) process has relatively basic equipment requirements, it is important that the welder has a knowledge of operating features and performance to comply with welding procedures for the job and, of course, for safety reasons.

The main components of the equipment required for welding are:
- Power source
- Electrode holder and cables
- Welder protection
- Fume extraction

Tools required include : a wire brush to clean the joint area adjacent to the weld (and the weld itself after slag removal) ; a chipping hammer to remove slag from the weld deposit ; and, when removing slag, a pair of clear lens goggles or a face shield to protect the eyes (lenses should be shatter-proof and noninflammable).

Power source

The primary function of a welding power source is to provide sufficient power to melt the joint. However with MMA the power source must also provide current for melting the end of the electrode to produce weld metal, and it must have a sufficiently high voltage to stabilise the arc.

MMA electrodes are designed to be operated with alternating current (AC) and direct current (DC) power sources. Although AC electrodes can be used on DC, not all DC electrodes can be used with AC power sources.

As MMA requires a high current (50-300A) but a relatively low voltage (10-50V), high voltage mains supply (240 or 440V) must be reduced by a transformer. To produce DC, the output from the transformer must be further rectified. To reduce the hazard of electrical shock, the power source must function with a maximum no-load voltage, that is, when the external (output) circuit is open (power leads connected and live) but no arc is present.

The no-load voltage rating of the power source must be in accordance with the type of welding environment or hazard of electrical shock. The power source may have an internal or external hazard reducing device to reduce the no-load voltage; the main welding current is delivered as soon as the electrode touches the workpiece. For welding in confined spaces, you should use a low voltage safety device to limit the voltage available at the holder to approximately 25V.

There are four basic types of power source:
- AC transformer
- DC rectifier
- AC / DC transformer-rectifier
- DC generator

AC electrodes are frequently operated with the simple, single phase transformer with current adjusted by means of tappings or sliding core control. DC rectifiers and AC / DC transformer-rectifiers are controlled electronically, for example by thyristors. A new generation of power sources called inverters is available. These use transistors to convert mains AC (50Hz) to a high frequency AC (over 500 Hz) before transforming down to a voltage suitable for welding and then rectifying to DC. Because high frequency transformers can be relatively small, principal advantages of inverter power sources are undoubtedly their size and weight when the source must be portable.

Electrode holder and cables
The electrode holder clamps the end of the electrode with copper contact shoes built into its head. The shoes are actuated by either a twist grip or spring-loaded mechanism. The clamping mechanism allows for quick release of the stub end. For efficiency the electrode has to be firmly clamped into the holder, otherwise poor electrical contact may cause arc instability through voltage fluctuations. Welding cable connecting the holder to the power source is mechanically crimped or soldered.

It is essential that good electrical connections are maintained between electrode, holder and cable. With poor connections, resistance heating and, in severe cases, minor arcing with the torch body will cause the holder to overheat. Two cables are connected to the output of the power source, the welding lead goes to the electrode holder and the current return lead is clamped to the workpiece. The latter is often wrongly referred to as the earthlead. A separate earth lead is normally required to provide protection from faults in the power source. The earth cable should therefore be capable of carrying the maximum output current of the power source.

Cables are covered in a smooth and hard-wearing protective rubberised flexible sheath. This oil and water resistant coating provides electrical insulation at voltages to earth not exceeding 100V DC and AC (rms value). Cable diameter is generally selected on the basis of welding current level, As these electrode types are When welding, the welder air movement should be from duty cycle and distance of the work from the power source. The higher the current and duty cycle, the larger the diameter of the cable to ensure that it does not overheat (see BS 638 Pt 4). If welding is carried out some distance from the power source, it may be necessary to increase cable diameter to reduce voltage drop.

Care of electrodes
The quality of weld relies upon consistent performance of the electrode. The flux coating should not be chipped, cracked or, more importantly, allowed to become damp.

Storage
Electrodes should always be kept in a dry and well-ventilated store. It is good practice to stack packets of electrodes on wooden pallets or racks well clear of the floor. Also, all unused electrodes which are to be returned should be stored so they are not exposed to damp conditions to regain moisture. Good storage conditions are 10 degrees C above external air temperature. As the storage conditions are to prevent moisture from condensing on the electrodes, the electrode stores should be dry rather that warm. Under these conditions and in original packaging, electrode storage time is practically unlimited. It should be noted that electrodes are now available in hermetically sealed packs which obviate the need for drying. However, if necessary, any unused electrodes must be redried according to manufacturer's instructions.

Drying of electrodes
Drying is usually carried out following the manufacturer's recommendations and requirements will be determined by the type of electrode.

Cellulosic coatings
As these electrode coatings are designed to operate with a definite amount of moisture in the coating, they are less sensitive to moisture pick-up and do not generally require a drying operation. However, in cases where ambient relative humidity has been very high, drying may be necessary.

Rutile coatings
These can tolerate a limited amount of moisture and coatings may deteriorate if they are overdried. Particular brands may need to be dried before use.

Basic and basic / rutile coatings
Because of the greater need for hydrogen control, moisture pick-up is rapid on exposure to air. These electrodes should be thoroughly dried in a controlled temperature drying oven. Typical drying time is one hour at a temperature of approximately 150 to 300 degrees C but instructions should be adhered to.

After controlled drying, basic and basic/rutile electrodes must be held at a temperature between 100 and 150 degrees C to help protect them from re-absorbing moisture into the coating. These conditions can be obtained by transferring the electrodes from the main drying oven to a holding oven or a heated quiver at the workplace.

Protective clothing
When welding, the welder must be protected from heat and light radiation emitted from the arc, spatter ejected from the weld pool, and from welding fume.

Hand and head shield
For most operations a hand-held or head shield constructed of lightweight insulating and non-reflecting material is used. The shield is fitted with a protective filter glass, sufficiently dark in colour and capable of absorbmg the harmful infrared and ultraviolet rays. The filter glasses are graded according to a shade number which specifies the amount of visible light allowed to pass through - the lower the number, the lighter the filter. The correct shade number must be used according to the welding current level, for example:

Shade 9 - up to 40A
Shade 10 - 40 to 80A
Shade 11 - 80 to 175A
Shade 12 - 175 to 300A
Shade 13 - 300 to 500A

Clothing
For protection against sparks, hot spatter, slag and burns, a leather apron and leather gloves should be worn. Various types of leather gloves are available, such as short or elbow length, full fingered or part mitten.

Fume extraction
When welding within a welding shop, ventilation must dispose harmlessly of the welding fume. Particular attention should be paid to ventilation when welding in a confined space such as inside a boiler, tank or compartment of a ship.

Fume removal should be by some form of mechanical ventilation which will produce a current of fresh air in the immediate area. Direction of the air movement should be from the welder's face towards the work. This is best achieved by localised exhaust ventilation using a suitably designed hood near to the welding area.

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