3 TIG welding

3.1 A description of the method

TIG welding (also called Gas Tungsten Arc Welding, GTAW) involves striking an arc between a non-consumable tungsten electrode and the workpiece. The weld pool and the electrode are protected by an inert gas, usually argon, supplied through a gas cup at the end of the welding gun, in which the electrode is centrally positioned.

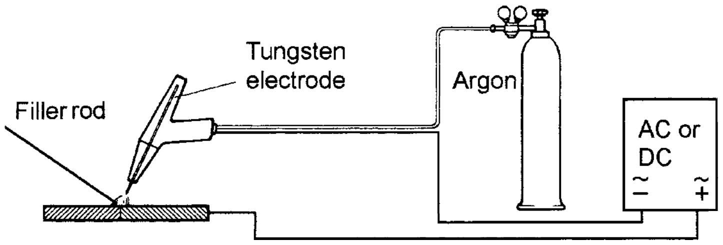

Figure 3.1 Schematic diagrum of TIG welding equipment.

TIG welding can also be used for welding with filler material, which is applied in rod form by hand similar to gas welding. Tools for mechanised TIG welding are used for applications such as joining pipes and welding tubes into the end plates of heat exchangers. Such automatic welding tools can incorporate many advanced features, including mechanised supply of filler wire.

Characteristics of the method include:

- the stable arc
- excellent control of the welding result.

The main application for TIG welding is welding of stainless steel, welding of light metals, such as aluminium and magnesium alloys, and the welding of copper. It is also suitable for welding all weldable materials, apart from lead and zinc, with all types of joints and in all welding positions. However, TIG welding is best suited to thin materials, from about 0.5 mm up to about 3 mm thick. In terms of productivity, TIG welding cannot compete with methods such as short arc welding.

3.2 Equipment

The following equipment is required for TIG welding:

- welding gun
- HF (= high-frequency) generator for ignition of the arc
- a power source
- shielding gas
- control equipment

The welding gun

The basic requirement applicable to the welding gun is that it must be easy to handle and well insulated. These requirements apply for manual welding, but are less important for mechanical welding. There are two main types of welding guns: water-cooled and air-cooled. Present-day welding guns of these two types can carry welding currents of:

- water-cooled: maximum about 400 A
- air-cooled: maximum about 200 A.

Figure 3.2 Examples of TIG welding guns.

Striking the arc

A TIG welding arc is generally ignited with the help of a high-frequency generator, the purpose of which, is to produce a spark which provides the necessary initial conducting path through the air for the low-voltage welding current. The frequency of this initial ignition pulse can be up to several MHz, in combination with a voltage of several kV. However, this produces strong electrical interference, which is the main disadvantage of the method.

It is not good practice to strike the arc by scraping the electrode on the workpiece: this not only presents risk of tungsten inclusions in the weld, but also damages the electrode by contaminating it with the workpiece material.

Another method of striking the arc is the 'lift-arc' method, which requires the use of a controllable power source. The arc is struck by touching the electrode against the workpiece, but in this case the special power source controls the current to a sufficiently low level to prevent any adverse effects. Lifting the electrode away from the workpiece strikes the arc and raises the current to the pre-set level.

The power source

TIG welding is normally carried out using DC, with the negative connected to the electrode, which means that most of the heat is evolved in the workpiece. However, when welding aluminium, the oxide layer is broken down only if the electrode is connected to the positive pole, this then results in excessive temperature of the electrode. As a compromise, aluminium and magnesium are therefore generally welded with AC.

TIG power sources are generally electronically controlled, e.g. in the form of an inverter or a thyristor-controlled rectifier. The open-circuit voltage should be about 80 V, with a constant-current characteristic.

When welding with **AC** (a sine wave), the HF generator is engaged all the time: if not, the arc would extinguish on the zero crossings.

Square wave AC

A number of new designs of power sources appeared during the 1970s, based on new technology involving a square waveform. This means that the zero crossings are very fast, which has the effect of:

- generally not needing a continuous HF ignition voltage for **AC** TIG welding
- making it possible to vary the proportions of the positive and negative polarity currents, which means that it is possible to control the penetration and oxide break-down, for example, when welding aluminium.

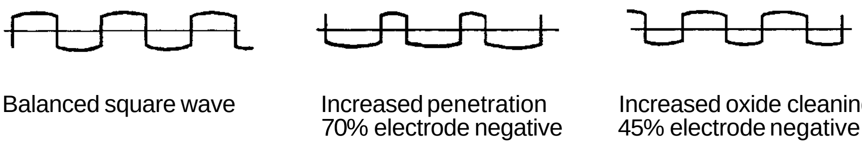

Figure **3.3** *Use of a square wave and balance control in TIG welding.*

Figure 3.3 shows the current waveform of a square wave supply. The balanced curve (left) has a very fast zero crossing, as opposed to that of a conventional sinusoidal waveform. The ability to shift the balance point of the two polarities means that, in certain cases, the welding speed can be increased by 50–75 %. The normal setting of the balanced waveform has 50 % negative polarity on the electrode. The two curves to the right show 70 % negative130 % positive polarity (for greater penetration or speed) and 45 % negative155 % positive (for improved oxide breakdown).

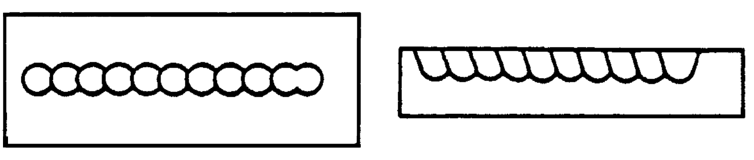

Figure 3.4 The principle for pulsed TIG requires the weld pool to partly solidify between the pulses.

Thermal pulsing

This is used to provide better control of the melt pool and the solidification process. The pulse frequency is set sufficiently low to allow the melt pool to partially solidify between each pulse. Supplying the heat in pulses has several benefits:

- Less sensitivity to gap width variations
- Better control of the weld pool in positional welding
- Better control of penetration and the penetration profile
- Reduced sensitivity to uneven heat conduction and removal.

Control equipment

The necessary control equipment depends on to what extent the welding process is mechanised. However, it is usual for the pre-flow and post-flow of the shielding gas, and the HF generator, to be automatically controlled. Crater filling by slope-down of the current, and the ability to pulse the current, are also often employed. Gas pre-flow and post-flow protect the electrode and the weld pool against oxidation.

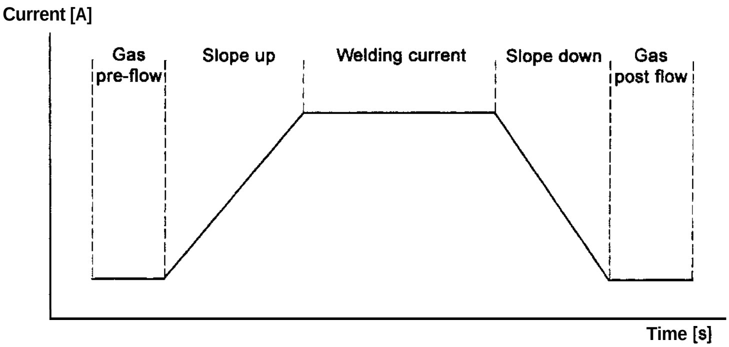

*Figure 3.5 Example of **a** welding sequence.*

The electrode

The electrode material should provide a combination of the following characteristics:

- Low electrical resistance
- High melting point
- Good emission of electrons
- Good thermal conductivity.

The material that best meets these requirements is tungsten.

TABLE 3.1 Examples of ISO 6848 TIG welding electrodes.

Additive	Proportion, %	Colour coding	Type	Current
	0	green	WP	AC
thorium	2	red	WT20	DC
zirconium	0.8	brown	WZ8	AC
lanthanum	1	black	WL10	AC, DC
cerium	2	grey	WC20	AC, DC

Pure tungsten electrodes are used when welding light metals with AC: for other welding applications, the electrodes often incorporate an admixture of 2 % thorium oxide, which improves the stability of the arc and makes it easier to strike. Thorium is radioactive, but is not so dangerous that special precautions are required, apart from taking care when grinding to avoid inhaling the grinding dust. Alternative non-radioactive oxide additives that can be used are those of zirconium, cerium or lanthanum, as shown in Table 3.1.

The electrode diameter is an important variable. The best arc stability is obtained with a high current load, which means that the diameter should be chosen so that the electrode tip is neither too hot nor too cold: see Figure 3.6.

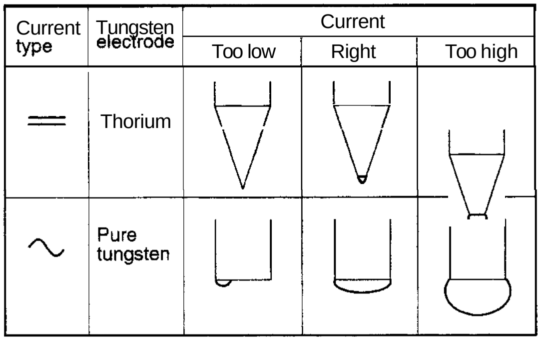

Figure 3.6 ***TIG electrode tips, showing the effects of too high or too low welding current in relation to the electrode diameter.***

For DC welding, the tip of the electrode is ground to an approximate 45° angle. The use of a special electrode grinding machine guarantees this angle is always the same, as this would otherwise affect the arc and its penetration into the workpiece material. Electrodes intended for use with AC welding are not ground: instead, the current is increased until it melts the tip of the electrode into a soft, rounded shape.

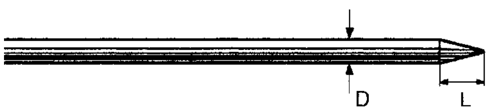

Figure 3.7 Normally the tip of the electrode is ground to a length L = 1.5–2 times the diameter (D).

If the electrode has too long a stickout, i.e. if the distance between the gas cup and the tip of the electrode is too great, the protection provided by the shielding gas will be less effective. A 'gas lens' is a wire mesh inside the gas cup which reduces eddies in the gas flow, thus extending the length of the laminar flow of the gas without mixing it with air.

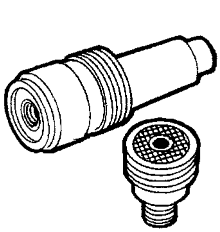

Figure 3.8 Examples on gas lenses.

3.3 Consumables

Fillers for TIG welding are used in the form of a wire, which is fed into the joint either by hand or mechanically. Welding performance can be improved by using the hot wire system, to feed the wire at an elevated temperature. Thin materials (up to 3–4 mm) can be butt-welded from one side, with the weld metal consisting entirely of molten workpiece material. Higher workpiece thicknesses require some form of joint preparation, with a filler being added in order to fill the joint. The use of fillers is always recommended when welding mild steel in order to reduce the risk of pores.

Shielding gases for different workpiece materials

Steel

Argon is generally used for TIG welding of unalloyed steels, low-alloyed steels and stainless steels. For mechanical welding of all these metals, the shielding gas may be argon, with an admixture of hydrogen or helium.

A small addition of nitrogen may be used when welding duplex stainless steels in order to ensure the correct ferritic/austenitic balance.

When making quality welds with TIG, it is also very common to use a **root** gas in order to protect the root side of the weld against oxidation. This is particularly important in the case of stainless steels or when welding easily-oxidised materials. The root gas is often a mixture of nitrogen/hydrogen, or pure argon.

Aluminium and its alloys

The shielding gas for aluminium and aluminium alloys is usually argon, possibly with the addition of helium. Helium improves the heat transfer, and is used when welding thicker sections. The welding current is normally **AC** or, at low current levels, it may be DC with the electrode connected to the positive.

Under certain conditions, horizontal and horizontal-vertical welds can be welded with **DC** if pure helium is used as the shielding gas and the electrode is connected to the negative. The higher arc voltage that results from the use of helium supplies more heat to the base material and thus increases the rate of welding. This higher heat input also means that butt joints can be made in thicker sections. The open-circuit voltage of the power source should be sufficiently high to prevent the arc from being extinguished as a result of the higher voltage drop in pure helium.

The use of argon as the shielding gas improves oxide breakdown performance, arc stability and weld quality.

Copper and its alloys

Argon is suitable for welding copper in all positions, and gives excellent results when welding metal thicknesses up to about 6 mm. The high thermal conductivity of the metal generally requires preheating.

The best shielding gas for use when welding workpieces more than 6 mm thick is helium, or helium containing 35 % argon.

Titanium

Successful titanium welding requires an extremely high purity of shielding gas, not less than **99.99%**. In addition, extra shielding gas is generally required. Either helium or argon can be used, although argon is generally preferred for metal thicknesses up to about 3 mm due to its higher density and good shielding performance. The use of pure helium is recommended when welding thick sections, due to the resulting higher heat content of the arc.