The success of a welding operation requires to have a joint free of any traces of oxide or contaminant in order to ensure a good metallurgical continuity through the welded joint. Those eventual contaminations will affect the welded metal and the quality of the fusion with the base material, also it will generate some inclusions in the weld. The presence of those inclusions will degrade the performance of the joint, like the ductility in the case of steels or the electrical and thermal conductivity in the case of the aluminum and copper alloys.

Among the common welding processes, the TIG process (GTAW) provides a better protection of the molten pool against air contamination. Besides, it remains the most recommended welding process in the following different situations:

- Assembling of cryogenic installations (low temperatures) where according to the codes and standards in effect, high toughness levels are required in the welded metal.
- Welding of refractory metals (niobium, tantalum, molybdenum, etc.) that are highly sensitive for oxidation at high temperatures.
- Welding of ‘highly reactive metals with air: magnesium, aluminum, titanium, zirconium.

The other main advantage of the TIG process consists in the fact that the filler metal is introduced directly and separately in the molten pool without any cleaning and cathode scouring during the welding. As the solid rods don’t include any flux to dissolve oxides or clean the impurities on the base metal surface, a good mechanical cleaning is required before welding in order to take out the layer of dust, reduce the oxide skin and expose the base material. This step has much importance in obtaining a good quality joint especially on highly reactive metals to oxygen such as magnesium or aluminum where the oxide tends quickly to get thick.

Metals and types of oxides

In the TIG welding, the type of welding current AC or DC and also the polarity, straight ‘normal’ (DC-, DCEN) or reverse (DC+, DCEP), depend to a large extent on the base metal, thus on the nature of its oxide. For that, it would be suggested to distinguish two principal classes of metals. Metals and/or alloys were the oxide is tenacious and stable: magnesium, aluminum, aluminum-bronze, zinc, copper-beryllium, stainless steel and nickel alloys containing chromium, aluminum or titanium. Metals and alloys whose oxide are unstable and/or crusty such as mild steels, low alloy steels, cast iron, copper and alloys (brass, bronze, copper-nickel), nickel and the alloys without Cr, Al, Ti, etc.

This distinction allows first to determine some approach relating to the selection of the type of current and also the polarity to be used in the TIG welding. Also, it is also question to mention here the fact that the metals whose oxide are unstable are roughly insensible to the type of current contrary to the metals that are very easily oxidizable at room temperature.

Effect of electric current and polarity

The inert gases employed in the TIG welding are ionized under the effect of electric arc. The ionization and the expansion of these gases have a double effect: the stabilization of the electric arc and the protection of the weld pool, the base metal and the end of the filler metal against air contamination. Furthermore, the positive charges resulting from the gas ionization are accelerated and directed by the electric field toward the negative pole (cathode). Thus, depending on the electric current type and polarity in direct current, the different mechanisms in TIG welding are the following:

- Direct current reverse polarity (DC+, DCEP): Most of the heat is concentrated on the electrode (positive electrode) and not on the part. This polarity is used for the welding of the thin sections where the penetration is not really an important factor versus to the importance to avoid the deformation and the burning of the plate. So in that case it is recommended to maintain a short arc to reduce the welding energy and in the same way the distortion tendency.
- Direct current straight polarity (DC-, DCEN): The produced alternative current gives less deep penetration than the direct polarity DCEP and reduce the arc blowing problem. Initially, the inconvenience of the alternative current was linked to the fact that the arc turns off at the current maximum and when the current passes by the zero level. The high frequency alternative current development is advantageous to remedy to this problem in allowing the arc to reinitiate with a minimum of energy. The produced alternative current gives the bead features on the weld pool.

In AC welding, the positive / negative alternation ratio could be controlled in order to adjust the joint penetration ratio versus the surface action cleaning and vice versa. As shown on the below diagram, we establish the following figures:

- 50% (+) / 50% (-): the electrode and the part will alter at each half cycle, the cleaning effect and the penetration are distributed equally.
- 10% (+) / 90% (-): the part is used as an anode (positive pole) during only 10% of the cycle and the tungsten electrode as a cathode (negative pole) during 90% of the cycle. The result is that the penetration is at maximum and that the cleaning effect is less.
- 65% (+) / 35% (-): the part is used as an anode (positive pole) during 65% of the cycle and the cathode as a negative pole during only 35% of the cycle. This will give maximum cleaning and less penetration.

The following table summarizes some TIG process polarity data for some metals and alloys.

<table>
<thead>
<tr>
<th>Metal / Alloy</th>
<th>Current and polarity</th>
<th>Type of arc and remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>DC- (DCEP)</td>
<td>Unstable and very crusty oxide, very localized healing by TIG welding is beneficial for very high thermal conductivity metal, DCEN (DC-) polarity compensates thermal loss.</td>
</tr>
<tr>
<td>Beryllium-copper</td>
<td>AC</td>
<td>Stable beryllium oxide layer</td>
</tr>
<tr>
<td>Aluminum</td>
<td>AC</td>
<td>Stable aluminium oxide layer</td>
</tr>
<tr>
<td>Magnesium</td>
<td>AC- (DCEP) on this section DC- (DCEN) for automatic welding on sections thicker than 1/4 (0.25 in) the base metal must be cleaned immediately prior to welding</td>
<td></td>
</tr>
<tr>
<td>Stainless steel</td>
<td>DC- (DCEN)</td>
<td>Stable chromium oxide</td>
</tr>
<tr>
<td>Nickel</td>
<td>DC- (DCEN)</td>
<td>AC to reduce deformations</td>
</tr>
<tr>
<td>Refractory metals</td>
<td>Cu, Al</td>
<td>Unstable and very crusty oxide, Stable oxide on Alloys with Cr, Al or Ti</td>
</tr>
<tr>
<td>Mild and low alloy steels</td>
<td>Cu, Al</td>
<td>High temperature metals that are very sensitive</td>
</tr>
</tbody>
</table>

In brief, the electric current type and the polarity in direct current (DC-, DCEN) are the features of the bead that the welding is schematized on the below figure

### Effect of the balance control in AC mode on the bead features

- **DC- (DCEP):** The part will alter at each half cycle, the cleaning effect and the penetration are distributed equally.
- **DC+ (DCEP):** The part is used as an anode (positive pole) during only 10% of the cycle and the tungsten electrode as a cathode (negative pole) during 90% of the cycle. The result is that the penetration is at maximum and that the cleaning effect is less.
- **50% (+) / 50% (-):** the electrode and the part will alter at each half cycle, the cleaning effect and the penetration are distributed equally.
- **10% (+) / 90% (-):** the part is used as an anode (positive pole) during only 10% of the cycle and the tungsten electrode as a cathode (negative pole) during 90% of the cycle. The result is that the penetration is at maximum and that the cleaning effect is less.
- **65% (+) / 35% (-):** the part is used as an anode (positive pole) during 65% of the cycle and the cathode as a negative pole during only 35% of the cycle. This will give maximum cleaning and less penetration.

Some data on the polarity of the TIG process and the type of arc and remarks
AZG TUNGSTEN ARC WELDING: Electrical current and polarity

The TIG process (GTAW) provides a better protection of the molten pool against air contamination.

The success of a welding operation requires to have a joint free of any traces of oxide or contaminant in order to ensure a good metallurgical continuity through the welded joint. Those eventual contaminants will affect the welding of the base metal and the quality of the fusion with the base metal, also it will generate some inclusions in the weld. The presence of those inclusions will degrade the performance of the joint, like the ductility in the case of steels or the electrical and thermal conductivity in the case of the aluminum and copper alloys.

Among the common welding processes, the TIG process (GTAW) provides a better protection of the molten pool against air contamination. Besides, it remains the most recommended welding process in the following different situations:

- Assembling of cryogenic installations (low temperatures) where the increase in the frequency will allow to have a tighter cone arc which reduces the size of the arc and that the cleaning effect is less;
- Welding of refractory materials (niobium, tantalum, molybdenum, etc.) that are highly sensitive for oxidation at high temperatures.
- Welding of highly reactive metals with air: magnesium, aluminium, titanium, zirconium.
- Welding of refractory materials (niobium, tantalum, molybdenum, etc.) that are highly sensitive for oxidation at high temperatures.

Effect of electric current and polarity

The inert gases employed in the TIG welding are ionized under the effect of the electric current, resulting in a higher voltage and a higher arc energy. The choice of the electric current type and polarity directly influences the penetration and cleaning effect of the welding process.

In AC welding, the positive / negative alternation ratio could be controlled in order to adjust the joint penetration ratio versus the surface action cleaning and vice versa. As shown on the below diagram, we establish the following figures:

50% (+) / 50% (-): The electrode and the part will alter at each half cycle, the cleaning effect and the penetration are distributed equally.

10% (+) / 90% (-): The part is used as an anode (positive pole) during only 10% of the cycle and the tungsten electrode as a cathode (negative pole) during 90% of the cycle. The result is that the penetration is at maximum and that the cleaning effect is less.

65% (+) / 35% (-): The part is used as an anode (positive pole) during 65% of the cycle and the electrode as a cathode (negative pole) during only 55% of the cycle. This will give maximum cleaning and less penetration.

The following table summarizes some TIG process polarity data for some metals and alloys.

**Variation of the penetration-cleaning rate for welding**

<table>
<thead>
<tr>
<th>Metal / Alloy</th>
<th>Current and polarity</th>
<th>Type of oxide and remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>DC- (DCEP)</td>
<td>Unstable and very crumbly oxide, high inclusions in the weld; better welding by TIG welding is beneficial for very high thermal conductivity metal.</td>
</tr>
<tr>
<td>Beryllium-copper</td>
<td>AC</td>
<td>Stabilized beryllium oxide layer</td>
</tr>
<tr>
<td>Aluminum</td>
<td>DC- (DCEP) on this section DC- (DCEP) for automatic welding on sections thicker than 1/4&quot; (6.35 mm). The base metal must be cleaned immediately prior welding.</td>
<td></td>
</tr>
<tr>
<td>Stainless steel</td>
<td>DC- (DCEP)</td>
<td>Stable chromium oxide</td>
</tr>
<tr>
<td>Nickel</td>
<td>DC - (DCEP)</td>
<td>Unstable and very crumbly oxide, high inclusions in the weld; better welding by TIG welding is beneficial for very high thermal conductivity metal.</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>AC - (DCEP)</td>
<td>Stable chromium oxide</td>
</tr>
</tbody>
</table>

In AC welding, the positive / negative alternation ratio could be controlled in order to adjust the joint penetration ratio versus the surface action cleaning and vice versa. As shown on the below diagram, we establish the following figures:

50% (+) / 50% (-): The electrode and the part will alter at each half cycle, the cleaning effect and the penetration are distributed equally.

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65% (+) / 35% (-): The part is used as an anode (positive pole) during 65% of the cycle and the electrode as a cathode (negative pole) during only 55% of the cycle. This will give maximum cleaning and less penetration.

There is a great article about the effect of the electric current and polarity in your work place, more details on page 4. We did not forget Flash and he back and will answer to some problems regarding welding and cleaning. Finally, we have a great article about the effect of the electric current and polarity in the TIG process. Good reading!