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Tungsten Electrode Tip Geometry for TIG Welding

Energy density is one of the key parameters in practically all welding process where the energy is directed at a certain location. Processes include resistance welding (current per unit area), laser welding (photon kW per unit area), ultrasonic welding (vibration energy per unit area), electron beam welding (electrons per unit area), and all arc welding process (current per unit area). While energy density is the core value, it takes two factors to properly control energy density. For example, in laser welding, energy density is controlled by the laser power (programmed in the controller) and spot size (controlled by the focus lens). Quite often, the users are comfortable with changing the settings on the machine, but may not appreciate the importance of the hardware that is required to produce the required energy density. Even minor variations in energy density can cause significant changes in the welding quality, and can leave the user perplexed as to cause of process variation.

In TIG (also known by the formal name of GTAW) welding, the energy density is controlled by the tip of the tungsten rod (Figure 1) where the electrons are emitted from the surface of the tungsten and charge (no pun intended) towards the parts to be welded. Tungsten electrodes are usually ground to fine point and end up looking like a sharpened pencil. However, if the electrode has an extremely fine pointed tip then the tip gets saturated quite quickly and electrons then start coming off the conical sides of the tip. Since electrons will come off mostly perpendicular to the surface, the arc becomes wide and energy density drops significantly. So instead of a fine tip producing a strong intense arc, the fine tip actually produces a broad diffused arc. See Figure 2 for details.

Diameter of the tip (Figure 1) should be a controlled parameter since that diameter will control energy density of the focused arc. In the context of TIG welding, the focused arc is the sharpest arc that can be produced for a given value of current. The tip diameter should be optimized to have the required energy density for a given current being used during the stable portion of the welding cycle. If the tip diameter is too small, some of the electrons will jump off the sides and produce a wider arc. If the tip diameter is too big, then the arc will not have the required energy density; additionally, the arc may wander around the tip surface. A larger tip can also cause issues with arc start, though it is not as critical with high-frequency arc starting available on newer power supplies. Tip diameter is important in both automated as well as manual welding applications. Welding tips are prepared in the machine shop on a grinder but usually not to any specifications. A better approach would be to have a part drawing for the tip for each application with the following specified on the drawing:

1. Tungsten alloy: Pure, Ceriated, Thoriated, Lanthanated, etc.
2. Tungsten electrode diameter
3. Taper angle (range of 30 to 60 degrees)
4. Tip diameter (usually a 1/3 of shank diameter)
5. Grinding marks – Along the length of the tungsten

Grinding marks are another important factor that is easily missed. If the marks are along the length of the electrode, the electrons are more likely to be ejected from the tip. If the marks are along the circumference, then the electrons are more likely to be ejected from the conical sides, which is not the preferred location. A dedicated tip grinder should be available in the shop and should be operated by trained personnel.

Even though the tip may have the correct size and shape to begin with, the tip shape can change with time. The tip should be inspected frequently with a 10x magnifier. If the tip diameter or overall tungsten diameter is too small, the tip might get overheated during welding and exhibit cracking or may have been partially chipped off. If the tip has inadvertently come in contact with molten metal, it might produce a non-symmetric shape of the welding arc.

Most of TIG welding of is done in DCEN (Direct Current Electrode Negative) mode, where the electrode is always negative, and part is always positive. During DCEN welding, the electrons always jump from the tungsten to the part; this act of electrons jumping from the tungsten surface tends to cool the surface and the tip can have a long life as long as it is sized correctly. However, when welding aluminum it may be necessary to weld in the AC mode where the current switches direction every "half" cycle. Using half in quotation marks as the inverter power supplies have the ability to provide current in unbalanced form. For example, the user can setup the welding unit to provide 100 amps for 70% of the AC cycle (DCEN) and 30 amps for 30% of the AC cycle (DCEP). During the DCEP portion of the cycle, electrons jump from the aluminum surface to the tip, and results in removal of the oxide film on the molten aluminum. It is during DCEP phase that the electrons cause significant heating of the electrode tip. Depending on the AC balance and current settings, the tip can quickly change shape and can produce a ball of tungsten at the tip. The DCEP phase also produces a frosty appearance on the parent metal surface adjacent to the aluminum fusion zone. However, the frost zone can be significantly reduced by reducing energy (current and %AC balance) in the DCEP phase, while still producing sufficient cleaning action. On aluminum that is etched, kept clean, and wire brushed prior to welding, and AC balance of 95% (so mostly DCEN) may be sufficient to make a good weld while minimizing the frosting effect; see Figure 3 for a comparison. Another benefit of reducing energy in DCEP phase is that the electrode tip does not get hot enough to ball up and now you have a controlled tip geometry and well-controlled energy density; one of the key variables in TIG welding.

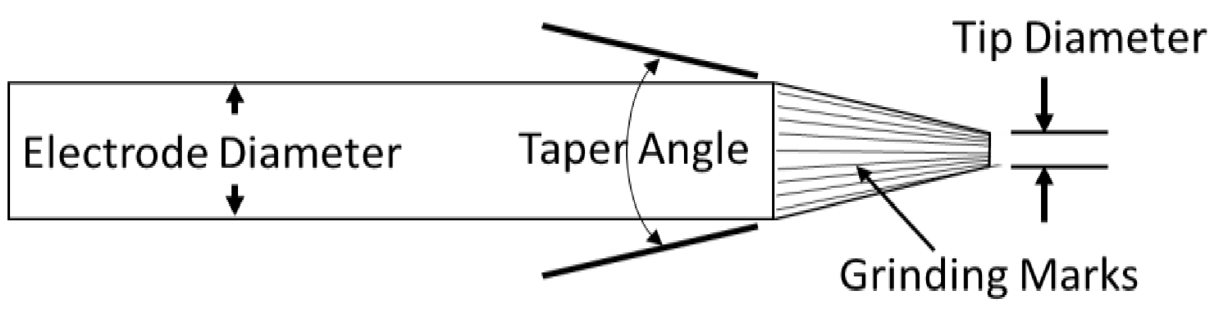

Figure 1. Shows a schematic of a tungsten electrode with a taper and flat tip. Also shows direction of grinding marks on the electrode.

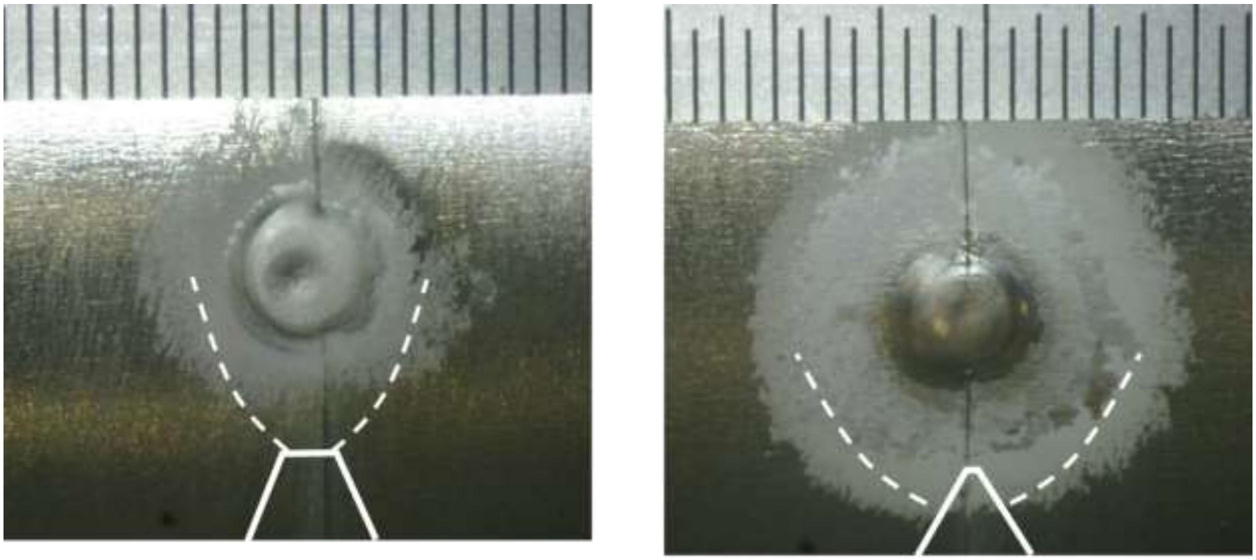

Figure 2. Shows two images of tack welds made on Aluminum with a blunt tip (left) and a fine tip (right) with same AC balance. The blunt tip produces a more focused arc compared to the fine tip, as is evidenced by a much smaller frosty zone around the tack weld.

Figure 3. Shows two images of tack welds made on Aluminum with an AC balance of 60% (left) and 95% (right). The photo on the right with 95% AC balance has a minimal (5%) DCEP component and produces a much weaker frost effect which can be easily wire brushed to expose an almost pristine surface.   In comparison, a 60% AC balance produces substantial frost which, on wire brushing, reveals significant surface melting.