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The erosion behaviour of pure tungsten electrodes in Gas Tungsten Arc Welding (GTAW)

Abstract

A cross-time study has been made on the erosion behaviour of Gas-Tungsten Arc Welding (GTAW) for pure tungsten electrode. Its behaviour during arcing was analyzed and compared from the points of view of metallurgical changes in electrode due to long-term operation. Metallographic studies of the electrodes indicate that the crack formation and grain growth during periodic temperature variations. These observations are discussed theoretically based on the experimental results and the thermal expansion parameters of Tungsten.

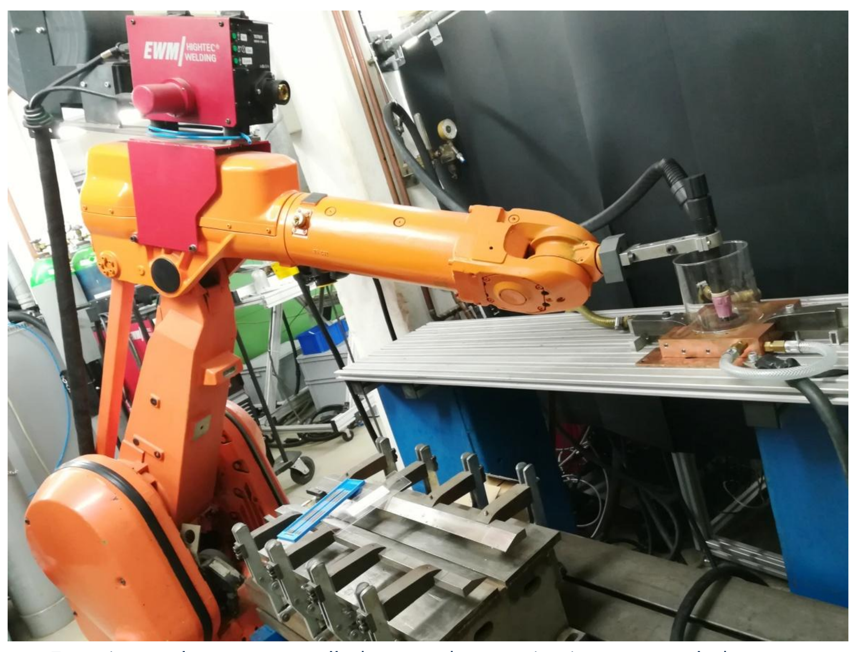
Motivation

One of the least discussed issue in **GTAW welding technology** is consumption / degradation of electrodes. The **tungsten electrodes** , doped with rare earth oxide particles exhibit quite stable behaviour towards arc due to more enhanced arc emission characteristics. With prolonged duty cycles, the rare earth oxide particles are depleted in the electrode tip region. Subsequently it behaves as pure tungsten electrode.

The most common erosion study is performed via electrode weight loss measurements The experimental study shows the evaporation of tungsten from hot surfaces and condensation on the relatively cold surfaces. Hence this quantitative data can't be relied for erosion measurements.

In this research, the in tungsten matrix, the post-arcing effect are discussed. The **steep temperature fluctuations** due to periodic arc switch on and off leads to linear dimensional changes and subsequently the trans-granular cleavage of the electrode tip.

Method



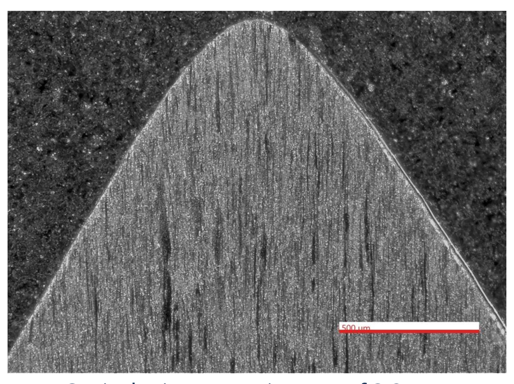
Experimental setup, controlled atmosphere arcing in water cooled copper plates

Note - It has been found that the frequent heating and cooling of the tungsten through its crystallisation temperature limit can leads to grain size modification. In industry, generally welding is performed in non-continuous time model. So, for each experiment, continuous arcing was performed only for 5 minutes. Again arcing was re- ignited after 1 minutes pause.

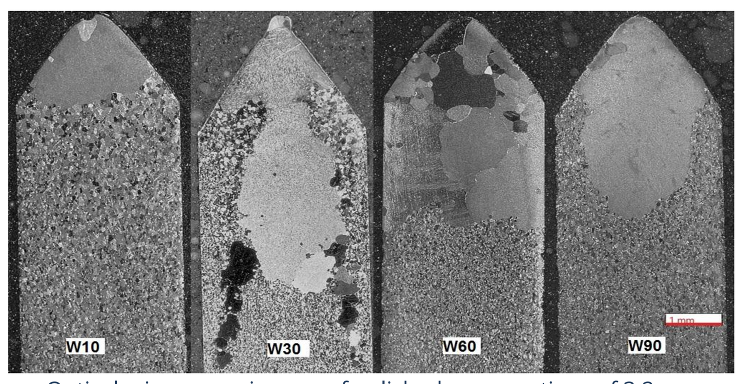
Process parameter	Details
Electrode type	pure tungsten (3.2 mm diameter(DIN EN ISO 6848)), 60 degree tip angle
Current	200 Ampere, DCEN
Shielding Gas	Argon, 12 L/min flow rate
Total Arcing Time of different electrodes	0, 5, 10, 15, 30, 45 and 90 minutes .
Arc Length	3 mm

Results

The **time of arcing (T)** is written with tungsten sample as **WT**, e.g. W10, W30 etc.

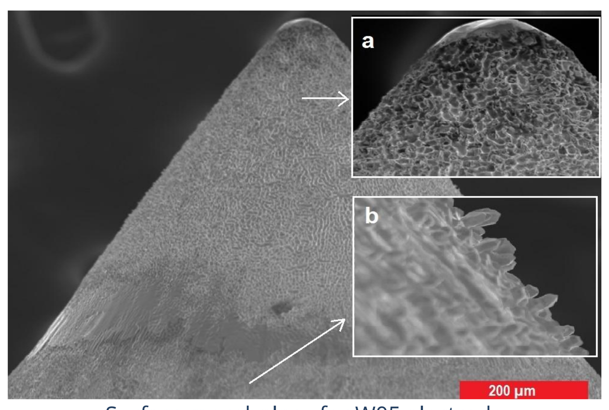


Optical microscope images of 3.2 mm diameter pure tungsten reference electrode,



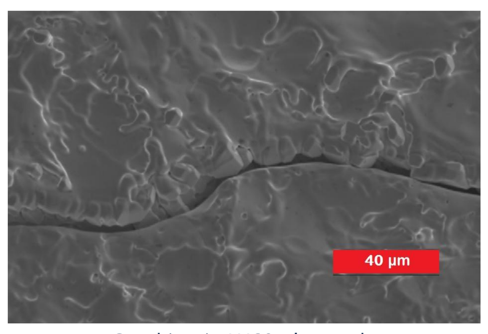
Optical microscope images of polished cross sections of 3.2 mm diameter pure tungsten used electrodes,

•The shows the longitudinal tungsten grains in reference electrode are due to swaging of sintered tungsten rods.
•The tungsten sample's temperature is raised above the brittle-to-ductile transition temperature and recrystallization temperature.
•A pure tungsten sample, whose deformation level is 90%, the recrystallization temperature is 1300 °C) .

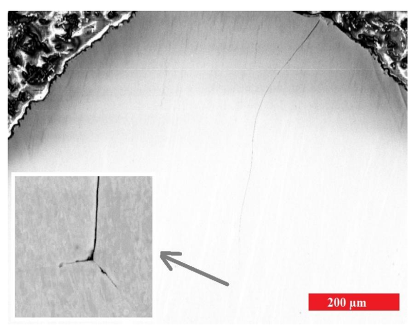


Surface morphology for W05 electrode

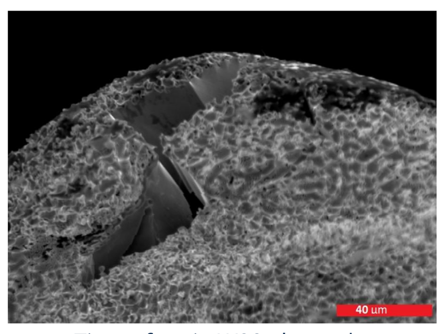
•The formation of zig-zag patches at the tip-there is a continuous development of pointed tips on surface, where electron emission takes place, these tips has localised low temperature due to electron cooling effect, but the surrounding regions are at high temperature due to plasma arc and inner resistive heating. so tungsten evaporation from those regions leads to crest and trough type wavy surface.
•The evaporated tungsten further condenses to the lower portion (b), and forms needle shaped tungsten cubic crystals.



Cracking in W60 electrode

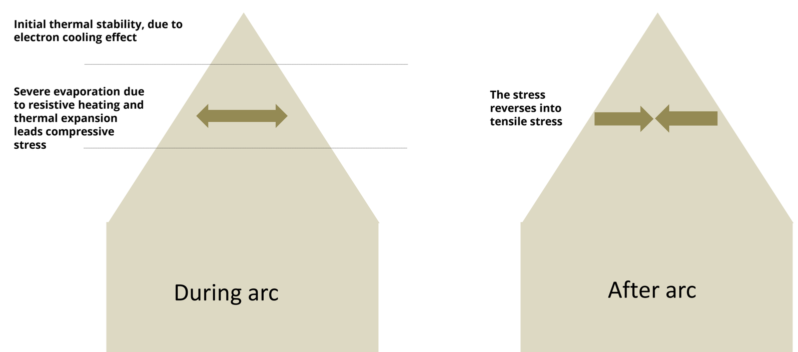


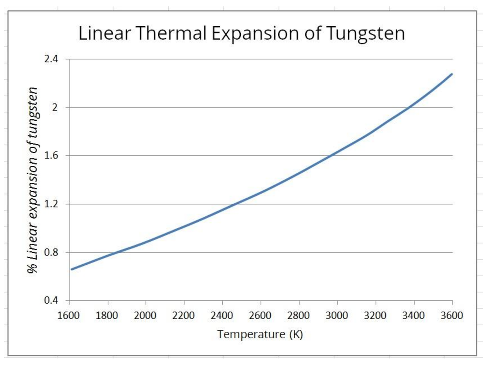
Crack root in W60 electrode



Tip surface in W90 electrode

•The continuous arc switch-on and switch-off , leads to periodical thermal expansion and contraction of electrode tip, which results the trans-granular cleavage, as shown by W60 and W90 electrodes.
•For W60, the crack propagation distance is upto approx 500 µm.
•With increasing arcing cycles, the creaks appeared at the tip in zone .(W90)





•There periodic stresses lead to serious surface damages such as crack networks, especially for high tensile stresses during the cool down
•The doping with small oxide particles (e.g. lanthanum oxide or yttrium oxide) increases the recrystallization temperature and the tungsten electrode can easily compensate the stresses by plastic deformation if the material is ductile.

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