Effect of Cryogenic Treatment on Tungsten Welding Electrode

R.J. Golden Renjith Nimal and N. Kohila

Abstract--- *Cryogenic treatment is the process of treating work pieces to cryogenic temperatures i.e. below −194 °C to remove residual stresses and improve wear resistance on steels and other materials. The process has a wide range of applications to industrial tooling for improvement, Some of the benefits of cryogenic treatment include longer part life, less failure due to cracking, improved thermal properties, better electrical properties including less electrical resistance, reduced coefficient of friction, less creep and walk, improved flatness, and easier machining. Cryogenic treatment has been widely acknowledged as a means of extending electrode life and low thermal shock and thus improving the life of electrode cycles. There are several theories concerning reasons for the effects of cryogenic treatment. One theory involves the more nearly complete transformation of retained austenite into martensite. Another theory is based on the strengthening of the material brought about by the precipitation of submicroscopic carbides as a result of the cryogenic treatment. Another theory is to relief of internal stresses and grain size reduction. Pure tungsten is used as electrodes for Resistance welding, when the electrodes are in direct contact with work piece, Grain coarsening are taken place in the tip area. This is called as Tip heating. The grain coarsening effect of electrode tip is delayed due to the cryogenic treatment of electrodes. This will improve the life of electrodes.*

Keywords--- *Tungsten Welding Electrode, Effect of Cryogenic, Work Pieces.*

I. INTRODUCTION

General

Deep Cryogenic Treatment (DCT) can be defined as "the creation of structural and mechanical changes in materials by exposing them to cryogenic temperatures." It exhibits great potential to increase the service life of industrial tools, gears, brake rotors, automotive, aerospace engine parts and some composites, as well as medical devices, dental materials and surgical implants. It is a process that has been reported to produce manifold enhancement of the performance and life of metals and some plastics, especially where fatigue failure and corrosion or abrasive failure are probabilities

In recent years, there has been an increased interest in the application of cryogenic treatment to enhance the properties of various materials. Cryogenic treatment is attempted by researchers as one of the way to improve the welding electrode life. For example resistance spot welding copper electrodes are used by the hundreds of thousands in the automotive industry. Typical failure is the result of a combination of stress fatigue failure and thermal cyclic fatigue. A big factor in their use is the down time on automated production machines to change or redress them.

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Deep cryogenic treatment of these copper electrodes has empirically shown a substantial increase in their time between maintenance.

Welding Electrodes

In arc welding, an electrode is used to conduct current through a work piece to fuse two pieces together. In the gas metal arc welding or shielded metal arc welding, the electrode is consumable, but in the gas tungsten arc welding, it is non-consumable. Welding electrodes is one of the fastest consumable in any resistance welding operation. The welding electrodes play three different roles in resistance welding process like maintaining uniform current density, concentrating current at welding points, and maintaining thermal balance during welding. Electrodes are available in many shapes, with the most common shape shown at Figure 1. Electrode material and shape are determined by considering the force necessary for welding and the thermal conductivity of the work pieces.

Welding low resistivity metals such as brass, copper and silver requires highly resistive electrode materials made from copper-tungsten, molybdenum, or tungsten. These electrode materials generate extra heat, which flows into the parts to make the weld.

Fig 1: Photographic View of Resistance welding electrode

RWMA Pure tungsten

Pure tungsten electrode is mostly used as a resistance welding electrode.

The high melting temperature, good electrical and thermal conductivity make tungsten the best choice for resistance welding electrode. The thermal conductivity of tungsten is superior to the molybdenum, given identical electrode geometry and weld current, both materials generate the same power. However, the tungsten electrode tip reaches a higher temperature than the molybdenum tip due to the higher thermal conductivity of tungsten. Table 1.1 shows the comparison of thermal conductivity and electrical resistivity of copper, molybdenum and tungsten.

Table 1.1: Comparison of Properties for Electrode material

Material	Resistivity (μΩcm)	Thermal Conductivity (W/mK @ 25°C)
Copper	1.72	401
Molybdenum	5.5	138
Tungsten	5.4	173

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The failure that occurs in the electrode is tip deformation. Electrode tip wear is happened due to the tip deformation on high temperature continuous welding process. With each subsequent weld, the residual electrode tip heat increases. This residual heat is difficult to dissipate because of the fastest weld rate (one weld per second). Residual tip heat is generally not an issue with manual welding due to the slow welding rate. This residual heat will coarsen the grain size of tungsten and will Detroit the shape of the electrode tip. This will cause a UN acceptable weld profile on welded sample. Different types of failure in welding electrode were tabulated in Table 1.2.

Table 1.2 Different types of Failure in welding electrode

Welding electrode failure	Appearance & Effects
Tip wear	Wear pattern is non-uniform across the profile and dimensions variations observed.
Tip oxidation	Electrode surface darkened and tend to chip off.
Severe tip-to-part sticking	Parent metal barrier stick with electrode and make the roughness on the surface.
Tip chipping	Grain coarsening of the tip is chipped in high stress area.

Cryo-Chamber

The cryogenic processor consists of a treatment chamber, which is connected to liquid nitrogen cylinder through insulated hose. The thermocouple inside the chamber senses the temperature and accordingly the temperature controller operates the solenoid valve to regulate the liquid nitrogen flow. The liquid nitrogen passes through the spiral heat exchanger and enters into the duct leading to the bottom of the chamber as nitrogen gas. The blower at the top of the chamber sucks the gas coming out at the bottom and makes it to circulate efficiently inside the chamber. The programmable temperature controller of the cryogenic processor can be used to set the cryogenic treatment parameters, which in turns control the process parameter like soaking time, temperature and cooling rate. Figure 1.3 shows the Schematic diagram of a cryo-chamber

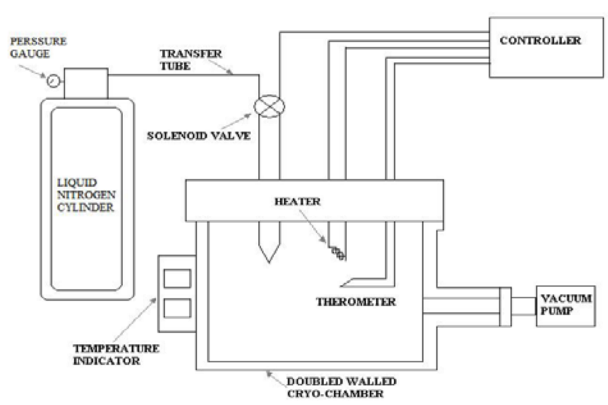


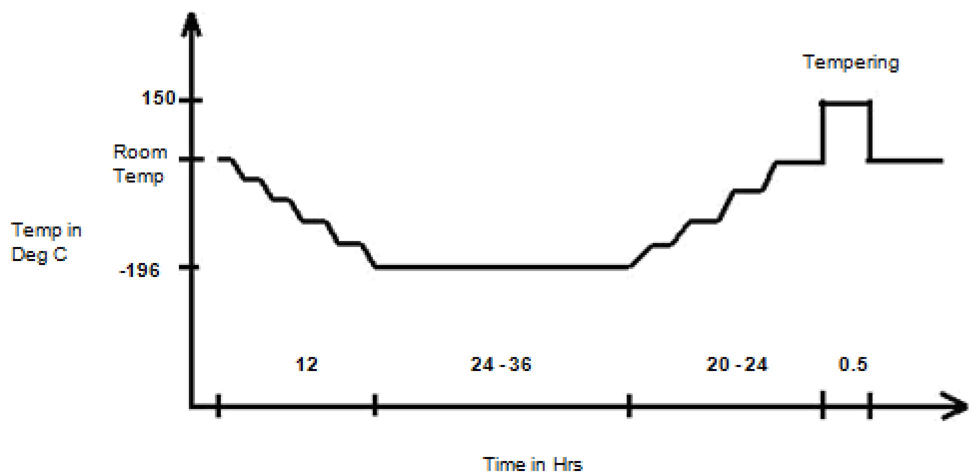
Fig. 2: Schematic Diagram of a Cryo-chamber

II. DEEP CRYOGENIC TREATMENT OF ELECTRODES

The following are the Cryogenic cycle followed for the study material

The process is based on a predetermined thermal cycle that involves cooling of the parts in a controlled cryogenic chamber. The material is slowly cooled to –196°c and "soaked" at deep cryogenic temperature for 20-40 hours. The material is then allowed to return to ambient temperature with controlled heating.

- The cryogenic cycle shall take 70-75 hours to complete. This process is carried out at controlled temperature profiles to avoid any possibility of thermal shock/ thermal stress that can be experienced when a part is subjected to abrupt or extreme temperature changes. In this process liquid nitrogen is used as a refrigerant.
- Cryogenic processing is not a substitute for heat treatment, but an extension of the heating / quenching / tempering cycle, but in most cases tempering is followed after cryogenic treatment.
- The typical process cycle is given below.



III. OBSERVATION AND ANALYSIS OF MICROSTRUCTURE OF ELECTRODES

3.1. Observation and analysis of microstructure with a scanning electrical microscope

The backscattering by a scanning electrical microscope (SEM) for tungsten welding electrode before and after deep cryogenic treatment is shown in Fig 3.

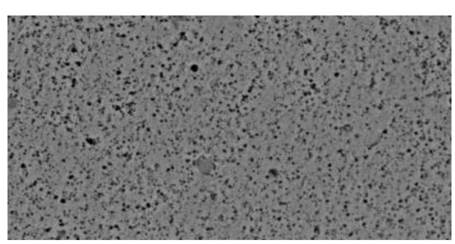


Fig 3: Microcavities before cryogenic treatment

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From Fig. 3.1, it can be seen that the soundness of the basal body before deep cryogenic treatment is lower and there are lots of microcavities, which destroys the lattice structure and continuity of the material. However, after a deep cryogenic treatment, the microcavities in the basal body were reduced significantly, and the soundness of the basal body was obviously increased.

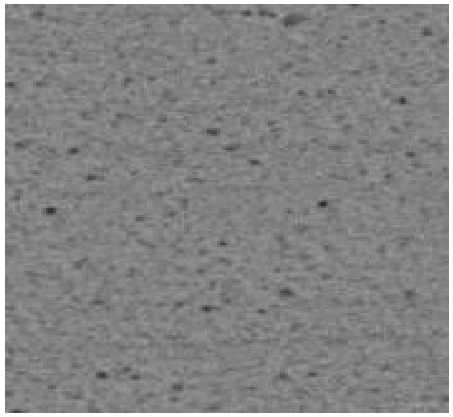

Fig 4: Microcavities after cryo treatment

3.2. Observation by X-ray diffraction

The grain size of electrode sample before and after deep cryogenic treatment is measured by X-ray diffraction. The change of grain size can be measured through measuring the width change of X-ray diffraction spectrum before and after deep cryogenic treatment. It shows that average grain size before and after deep cryogenic treatment is 150 and 85 nm. The grain size is clearly refined.

IV. PROPERTIES TESTING OF ELECTRODES

4.1. Hardness testing

The hardness of the electrode before and after deep cryogenic treatment is tested by the vickers-hardness testing unit. Testing data are shown in Table 4, which demonstrate that deep cryogenic treatment has small influence on the hardness of electrodes.

Table 4: Hardness Value of the Traditional route RMWA tungsten

Sl.No	Condition	Vicker's Hardness, HV			Mean
		Trial I	Trial II	Trial III	
1	Traditional route	235	240	242	239

4.2. Resistivity testing

Resistivity before and after deep cryogenic treatment is tested by the QJ-DC double arms electrical bridge, and the testing data are results are shown that cryo treated electrode has less resistivity than un cryo treated electrode.

V. WELDING TRIALS

Welding trials has been done by using the Resistance welding machine, The results are shown that cryo treated electrodes has improved the no of welds, the table 4 shows the profile of the electrodes before and after cryo treatment.

Sl.No	Condition	Top Portion (In mm)			Bottom portion(Inmm)		
		Sample I	Sample II	Sample III	Sample I	Sample II	Sample III
1	Traditional route	0.15	0.18	0.21	0.05	0.07	0.06
2	**DCT**	**0.04**	**0.07**	**0.08**	**-**	**-**	**-**

VI. CONCLUSION

The grainsized reduction of cryo treated electrodes and less resistivity is the reason for increasing the welding life of electrodes.

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