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Fundamental Study of Underwater Welding

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Abstract: Welding is an unavoidable process of modern engineering–mechanical, electrical, civil, automobiles, and marine aeronautical–in all branches. It is used in fabrications and erections in infrastructures and installations. It joins metals or thermoplastics. Forming a pool of molten mass – the weld puddle – and allowing it to cool to become a strong joint is the basis of the process of welding. For repairing to be carried out underwater, there is a separate process. That is called underwater welding. If damaged ships are to be repaired, underwater welding is the basic technology to be used. It is a highly-specialized profession more employed in the oil or shipping industry and also in the defense operations.

Keywords: Welding, Water, Joint, Weld puddle.

I. INTRODUCTION

Underwater welding, also known as hyperbaric welding is used to repair submerged metal structures without removing them from the water. This is done through several different processes: some dry, whereby water is pumped away from the area; and some wet, where the welder, using specialist equipment, must weld through the water. Underwater welders must also be skilled divers and able to work at extreme depths and water pressure. Hyperbaric welding is the process of welding at elevated pressures, normally underwater. Hyperbaric welding can either take place wet in the water itself or dry inside a specially constructed positive pressure enclosure and hence a dry environment. It is predominantly referred to as "hyperbaric welding" when used in a dry environment, and "underwater welding" when in a wet environment. Underwater hyperbaric welding was invented by the Russian metallurgist Konstantin Khrenov in 1932. The applications of hyperbaric welding are diverse—it is often used to repair ships, offshore oil platforms, and pipelines. Steel is the most common material welded.

Dry hyperbaric welding is used in preference to wet underwater welding when high quality welds are required because of the increased control over conditions which can be exerted, such as through application of prior and post weld heat treatments. This improved environmental control leads directly to improved process performance and a generally much higher quality weld than a comparative wet weld. Thus, when a very high quality weld is required, dry hyperbaric welding is normally utilized. Research into using dry hyperbaric welding at depths of up to 1,000 meters (3,300 ft) is ongoing. In general, assuring the integrity of underwater welds can be difficult (but is possible using various nondestructive testing applications), especially for wet underwater welds, because defects are difficult to detect if the defects are beneath the surface of the weld.

II. TYPES OF WELDING

A. Dry Welding

Dry hyperbaric welding involves the weld being performed at the prevailing pressure in a chamber filled with a gas mixture sealed around the structure being welded. Most welding processes SMAW, FCAW, GTAW, GMAW, PAW could be operated at hyperbaric pressures, but all suffer as the pressure increases. Gas tungsten arc welding is most commonly used. The degradation is associated with physical changes of the arc behavior as the gas flow regime around the arc changes and the arc roots contract and become more mobile. Of note is a dramatic increase in arc voltage which is associated with the increase in pressure. Overall a degradation in capability and efficiency results as the pressure increases.
Special control techniques have been applied which have allowed welding down to 2500m simulated water depth in the laboratory, but dry hyperbaric welding has thus far been limited operationally to less than 400m water depth by the physiological capability of divers to operate the welding equipment at high pressures and practical considerations concerning construction of an automated pressure / welding chamber at depth.

B. Dry welding in underwater may be achieved by several ways

1. Dry habitat welding

Welding at ambient water pressure in a large chamber from which water has been displaced, in an atmosphere such that the welder/diver does not work in diving gear. This technique may be addressed as dry habitat welding.

2. Dry chamber welding

Welding at ambient water pressure in a simple open-bottom dry chamber that accommodates the head and shoulders of the welder/diver in full diving gear.

3. Dry spot welding

Welding at ambient water pressure in a small transparent, gas filled enclosure with the welder/diver in the water and no more than the welder/diver's arm in the enclosure.

4. Dry welding at one atmosphere

Welding at a pressure vessel in which the pressure is maintained at approximately one atmosphere regardless of outside ambient water pressure.

5. Cofferdam welding

Welding inside of a closed bottom, open top enclosure at one atmosphere.

C. Wet Welding

Wet underwater welding commonly uses a variation of shielded metal arc welding, employing a waterproof electrode. Other processes that are used include flux-cored arc welding and friction welding. In each of these cases, the welding power supply is connected to the welding equipment through cables and hoses. The process is generally limited to low carbon equivalent steels, especially at greater depths, because of hydrogen-caused cracking.

D. Risks

The risks of underwater welding include the risk of electric shock to the welder. To prevent this, the welding equipment must be adaptable to a marine environment, properly insulated and the welding current must be controlled. Commercial divers must also consider the safety issues that normal divers face; most notably, the risk of decompression sickness following saturation diving due to the increased pressure of inhaled breathing gases. Many divers have reported a metallic taste that is related to the breakdown of dental amalgam. There may also be long term cognitive and possibly musculoskeletal effects associated with underwater welding.

III. CIRCUIT & PRINCIPLE OF OPERATION

Manual metal arc welding (MMA) is still one of the most important fusion welding processes, for both surface and underwater welding in today's construction industries. American terminology refers to it as Shielded Metal Arc Welding (SMAW). The definition of fusion welding, as stated in BS 499: Pt 1 1991 states, "any welding process in which the weld is made between surfaces brought together to a molten state, without hammering or pressure". Any arc-welding system in which the electrode is melted off to become part of the weld is described as metal-arc. Briefly, the process takes place in the following manner. The work to be welded is connected to one side of an electric circuit, via means of a cable. A flux-coated electrode is attached to a holder, also connected via a cable, both being attached to a power source. When the electrode makes contact with the work, an electrical contact is made. The electric current jumps the gap and causes a sustained spark (arc), which melts the base metal and the covering of the electrode forming a common weld puddle.

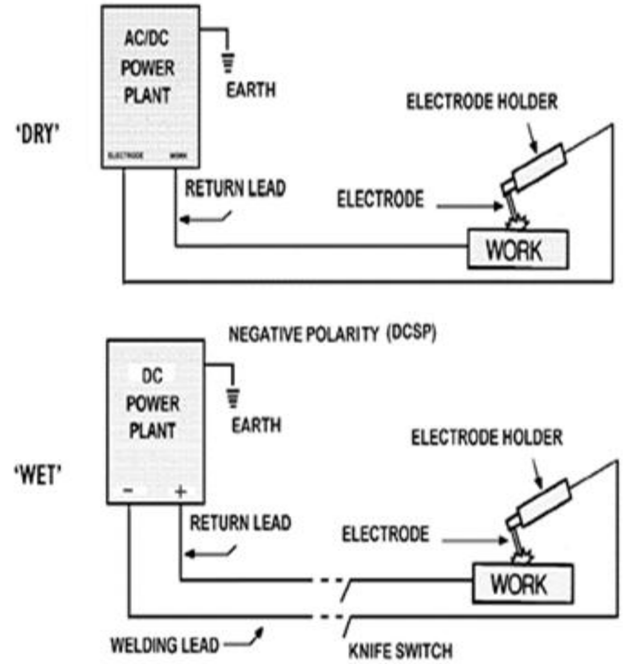

Fig1. A Typical Welding Circuit diagram for surface welding (top) and welding (bottom).

Compare the two diagrams in Figure 1 and you will notice a couple of differences for the wet welding one, namely; DC current only, the use of a knife switch and the double insulated cables. The polarity, which is generally DCSP (-), although can also work quite satisfactorily on DCRP (+), otherwise, the basic circuit is the same. After the arc is moved or discontinued, the metal solidifies so the previously melted metal has now fused into one piece. This melting action is controlled by varying the amount of electric current which flows across the arc, and by changing the size of the electrode. Typical temperatures that exist within the arc plasma can reach over 5000ºC. As the electrode melts, metal droplets are projected into the weldpool. This common pool of molten metal is called a puddle. This puddle solidifies behind the electrode as it is moved along the joint being welded. The result is a fusion bond and the metallurgical unification of the workpieces. Now, metals at high temperature are active chemically with the main constituents of air, oxygen and nitrogen. Should the metal in the molten puddle come in contact with air, oxides and nitrites (instant rust) would be formed, which upon solidification of the molten pool would destroy the mechanical properties of the weld joint. For this reason, the various arc-welding processes provide some means for shielding the arc and the molten puddle with a protective shield of gas, vapour and slag. This is referred to, as metallic arc shielding, and such shielding in MMA welding is accomplished by the flux covering of the electrode.

The slag even after the weld has solidified still has a protective function, as it minimizes contact of the very hot metal from the air, until the temperature lowers to a point where any reaction of the metal with air is eliminated. The arc itself burns in a small cavity formed inside the flux covering, which is designed to burn slower than the metal barrel of the electrode, thereby, assisting in protecting and controlling the metal droplets that leave the electrode. This barrel is called the cup or barrel length. For wet welding this particular function is very important, for without this mechanism the production of acceptable weld deposition would be difficult, as it greatly assists a constant and controlled arc length to be maintained. Therefore even in poor visibility, all the diver need do is exert a slight downward pressure on the electrode to maintain a constant feed rate, which keeps the flux chipping and burning away without the need for any arc length control, as such. Now, for underwater welding the arc does not behave as in air. The activity of the gas bubbles being particularly important, as this tends to create a rather unstable arc condition, compared with surface welding, together with a somewhat more confusing weld puddle, which must be mastered by the diver before successful welding can take place. Apart from this, with regard to the actual physical principles of operation, there is no difference between surface MMA welding and underwater wet-stick welding. Both processes use basically the same equipment with the exception of necessary waterproofing for the electrodes and certain other safety equipment.

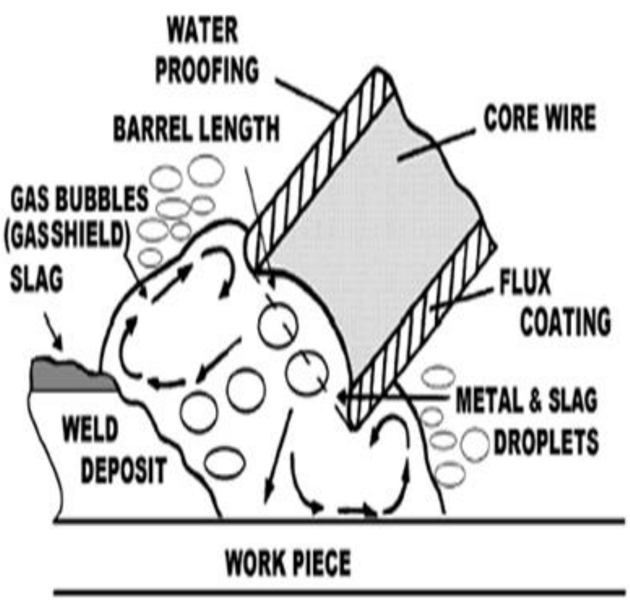

Fig2. Shielding of the welding arc and molten pool with a covered stick electrode.

IV. UNDERWATER TIG SEAL-WELDING

After local gas phase space is formed in the water, under water TIG(Tungsten inert gas) weld is processed in that gas phase space. The welding method is TIG welding which is broadly used and has a higher heat input than that of laser welding. However, if the condition of welding process is selected in broader range, high quality and stable welding process is possible and expected to be highly reliable. An appearance of welding bead and bead section after underwater welding procedure, are shown in Fig3. From this figure, it is confirmed that good welding is possible in the water.

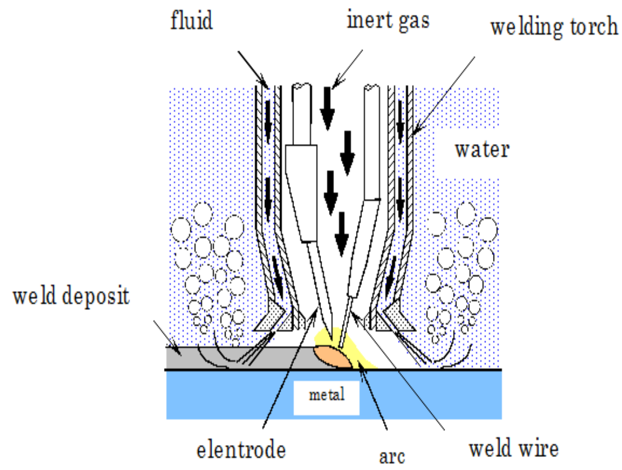

Fig3. Work of underwater welding.

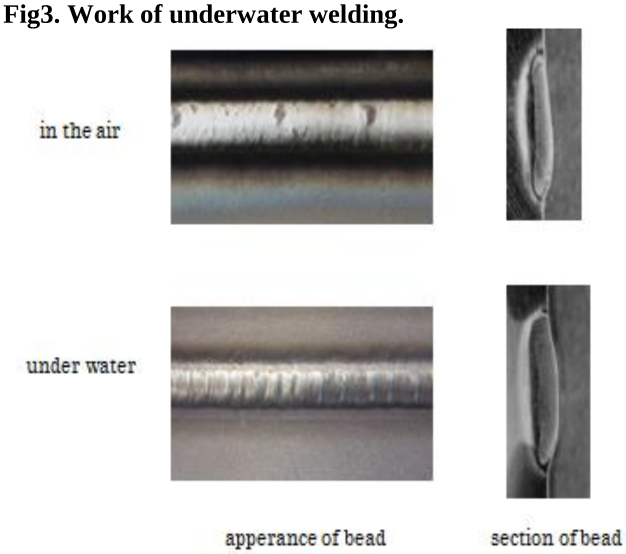

Fig4. Welding mock up test result (base metal : Alloy600).

A. Characteristics of A Good Underwater Welding:

The characteristics of a good underwater welding process are:

- Requirement of inexpensive welding equipment, low welding cost, easy to operate and flexibility of operation in all positions.
- Minimum electrical hazards, a minimum of 20 cm/min welding speed at least.
- Permit good visibility.
- Produce good quality and reliable welds.
- Operator should be capable in supporting himself.
- Easily automated.

B. Application of Underwater Welding:

The important applications of underwater welding are:

- Offshore construction for tapping sea resources.
- Temporary repair work caused by ship's collisions or unexpected accidents.
- Salvaging vessels sunk in the sea.
- Repair and maintenance of ships.
- Construction of large ships beyond the capacity of existing docks.

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