A TECHNICAL SEMINAR REPORT

ON

UNDERWATER WELDING

In partial fulfillment of the award for the degree of

BACHELOR OF TECHNOLOGY

IN

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ABSTRACT

In this study, a numerical method has been developed for modeling underwater welding. The geometry used in the study is a three-dimensional thick rectangular plate. Transient heat conduction in the plate has been calculated numerically including a point heat source simulating the arc and convective, radiative and boiling surface boundary conditions. Finite volume method has been used as the numerical scheme. A variable mesh size centered around the moving heat source has been used in the calculations. The validity of the results was checked by comparison with some solutions in the literature.

Welding is an unavoidable process of modern engineering – civil, electrical, mechanical, automobiles, 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.

Underwater welding can be classified as

1) Wet Welding

2) Dry Welding

In wet welding the welding is performed underwater, directly exposed to the wet environment. In dry welding, a dry chamber is created near the area to be welded and the welder does the job by staying inside the chamber.

1. INTRODUCTION:

1.1. OVERVIEW:

To improve the quality of the underwater welding and to accomplish a reliable, permanent underwater wet welding capability has a great importance in today's industrial facilities. With the development of underwater wet welding techniques, the time and the money required for permanent and temporary repairs of ships and other underwater structures can be minimized. Currently, underwater wet welding is used for the temporary repair needs. Because of their poor quality compared to surface (air) welds (they obtain 80% of the tensile and 50% ductility of the surface welds [1].), they must be replaced as soon as possible. Therefore, to develop a more efficient wet welding technique, a numerical model simulation is necessary.

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1.2. PROJECT OBJECTIVE:

In the present study, a numerical model has been developed for transient, three-dimensional conduction heat transfer in underwater welding process on a thick rectangular plate. The numerical scheme was based on finite volume model, including convection, radiation and boiling surface thermal boundary conditions. The different regimes of boiling were accounted for on the surface. A variable mesh size centered around an arc source moving at constant speed was used to determine temperature variations inside and around the weld pool. The weld pool region itself has been modeled as a solid region of thermal conductivity higher than the surrounding un melted solid region. The input data from the previous studies based on different methods were used to check the accuracy and the validity of the numerical method.

The fact that electric arc could operate was known for over a 100 years. The first ever underwater welding was carried out by British Admiralty – Dockyard for sealing leaking ship rivets below the water line.

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‘Van der Willingen’. In recent years the number of offshore structures including oil drilling rigs, pipelines, platforms are being installed significantly.

Some of these structures will experience failures of its elements during normal usage and during unpredicted occurrences like storms, collisions. Any repair method will require the use of underwater welding.

2. BACKGROUND

2.1 Previous Studies

Rosenthal did the most important early work on the theory of the effect of moving sources of heat in the late of 1930s. He studied the fundamentals of this theory and derived equations for two-dimensional and three-dimensional heat conduction in a solid when a moving source is in use [2]. The assumptions used by Rosenthal were: Point heat source, No melting, constant thermal properties, no heat loss from the work piece surface, infinitely wide work piece.

Recently, numerical analysis, methods and computer programs have been commonly used to develop the previous assumptions. In 1965, The Battelle Institute Geneva Laboratory in Switzerland conducted a computer-aided study about analyzing of heat flow in weldments. In 1970, M.I.T. researchers studied heat flow during underwater welding [3]. Oreper and Szekeley examined stationary, axisymmetric TIC (tungsten-inert-gas) welding process with a moving boundary by using finite difference method [4]. Kou and Wang performed computational studies of the GTA welding process. They presented a computer simulation of three-dimensional convection for an arc source moving at constant speed [5]. Correa and Sundell studied axisymmetric stationary arc source by using different grid sizes for computation of flow and electromagnetic fields [6]. Saedi and Unkel developed a thermal-fluid model of the weld pool. Their model was based on the stationary arc [7]. Zacharia et al. made three-dimensional calculations on the effects of the heat source in the stationary GTAW process [8]. Ule, Joshi and Sedy determined three-dimensional transient temperature variations in the GTAW process by using the explicit finite difference method. They used different mesh sizes and temperature dependent thermal properties. They also considered convective and radiative surface thermal conditions during calculations [9]. Kanouff and Greif studied the unsteady development of an axisymmetric arc weld pool in GTAW process. They used moving grids to follow the phase change boundary and considered the effects of Marangoni, Lorentz and buoyancy forces in the calculations [10]. Joshi, Dana, Schupp and Espinosa developed a three-dimensional numerical model to describe the flow circulation phenomena in aluminum weld pools under non-axisymmetric Lorentz force field [11,12].

2.2 Finite Volume Method

The finite volume method is one of the simple and well-established Computational Fluid Dynamics (CFD) techniques that were originally developed as a special finite difference method. The stages of the numerical algorithm in this method are as follows [13]:

1. .Formal integration of the governing equations of fluid flow over all the finite control volumes of the solution domain.

2. Discretisation involves the substitution of a variety of finite difference type approximations for the terms in the integrated equation representing flow process such as convection, diffusion and sources. This converts the integral equation into a system of algebraic equations.

3. Solution of the algebraic equations by an iterative method.

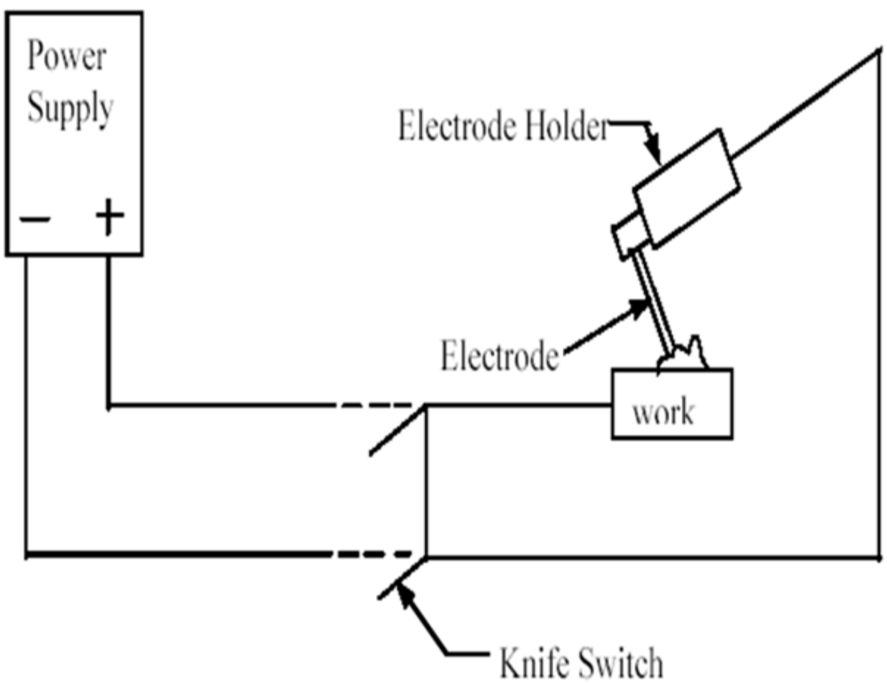
3. PRINCIPLE OF WORKING:

The work is connected to the positive side of dc source and electrode to the negative

The two parts of the circuit are brought together and then slightly separated.

An electric current occurs in the gap and causes a sustained spark which melts metal forming a weld pool.

WORKING PROCESS:



4. CLASSIFICATION:

Underwater welding can be classified as

1) Wet Welding

2) Dry Welding

In wet welding the welding is performed underwater, directly exposed to the wet environment.

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4.1. WET WELDING

Wet Welding indicates that welding is performed underwater, directly exposed to the wet environment. A special electrode is used and welding is carried out manually just as one does in open air welding.

FIGURE OF WET WELDING:

The increased freedom of movement makes wet welding the most effective, efficient and economical method.

Welding power supply is located on the surface with connection to the diver/welder via cables and hoses.

In wet welding MMA (manual metal arc welding) is used.

Power Supply used is DC

Polarity : -ve polarity

When DC is used with +ve polarity, electrolysis will take place and cause rapid deterioration of any metallic components in the electrode holder. For wet welding AC is not used on account of electrical safety and difficulty in maintaining an arc underwater.

The power source should be a direct current machine rated at 300 or 400 amperes. Motor generator welding machines are most often used for underwater welding in the wet. The welding machine frame must be grounded to the ship. The welding circuit must include a positive type of switch, usually a knife switch operated on the surface and commanded by the welder-diver. The knife switch in the electrode circuit must be capable of breaking the full welding current and is used for safety reasons. The welding power should be connected to the electrode holder only during welding.

Direct current with electrode negative (straight polarity) is used. Special welding electrode holders with extra insulation against the water are used. The underwater welding electrode holder utilizes a twist type head for gripping the electrode. It accommodates two sizes of electrodes.

The electrode types used conform to AWS E6013 classification. The electrodes must be waterproofed.

All connections must be thoroughly insulated so that the water cannot come in contact with the metal parts.

If the insulation does leak, seawater will come in contact with the metal conductor and part of the current will leak away and will not be available at the arc. In addition, there will be rapid deterioration of the copper cable at the point of the leak.

4.2. Hyperbaric Welding (dry welding)

Hyperbaric welding is carried out in chamber sealed around the structure o be welded. The chamber is filled with a gas (commonly helium containing 0.5 bar of oxygen) at the prevailing pressure. The habitat is sealed onto the pipeline and filled with a breathable mixture of helium and oxygen, at or slightly above the ambient pressure at which the welding is to take place. This method produces high-quality weld joints that meet X-ray and code requirements. The gas tungsten arc welding process is employed for this process. The area under the floor of the Habitat is open to water. Thus the welding is done in the dry but at the hydrostatic pressure of the sea water surrounding the Habitat.

FIGURE OF DRY WELDING:

5. RISKS INVOLVED

There is a risk to the welder/diver of electric shock. Precautions include achieving adequate electrical insulation of the welding equipment, shutting off the electricity supply immediately the arc is extinguished, and limiting the open-circuit voltage of MMA (SMA) welding sets. Secondly, hydrogen and oxygen are produced by the arc in wet welding.

Precautions must be taken to avoid the build-up of pockets of gas, which are potentially explosive.

The other main area of risk is to the life or health of the welder/diver from nitrogen introduced into the blood steam during exposure to air at increased pressure. Precautions include the provision of an emergency air or gas supply, stand-by divers, and decompression chambers to avoid nitrogen narcosis following rapid surfacing after saturation diving.

For the structures being welded by wet underwater welding, inspection following welding may be more difficult than for welds deposited in air. Assuring the integrity of such underwater welds may be more difficult, and there is a risk that defects may remain undetected.

6. ADVANTAGES AND DISADVANTAGES:

6.1. Advantages of Dry Welding

1) Welder/Diver Safety – Welding is performed in a chamber, immune to ocean currents and marine animals. The warm, dry habitat is well illuminated and has its own environmental control system (ECS).

2) Good Quality Welds – This method has ability to produce welds of quality comparable to open air welds because water is no longer present to quench the weld and H2 level is much lower than wet welds.

3) Surface Monitoring – Joint preparation, pipe alignment, NDT inspection, etc. are monitored visually.

4) Non-Destructive Testing (NDT) – NDT is also facilitated by the dry habitat environment.

6.2. Disadvantages of Dry Welding

1) The habitat welding requires large quantities of complex equipment and much support equipment on the surface. The chamber is extremely complex.

2) Cost of habitat welding is extremely high and increases with depth. Work depth has an effect on habitat welding. At greater depths, the arc constricts and corresponding higher voltages are required.

The process is costly – a $ 80000 charge for a single weld job. One cannot use the same chamber for another job, if it is a different one.

6.3. Advantages of Wet Welding

Wet underwater MMA welding has now been widely used for many years in the repair of offshore platforms.

The benefits of wet welding are: -

1) The versatility and low cost of wet welding makes this method highly desirable.

2) Other benefits include the speed. With which the operation is carried out.

3) It is less costly compared to dry welding.

4) The welder can reach portions of offshore structures that could not be welded using other methods.

5) No enclosures are needed and no time is lost building. Readily available standard welding machine and equipments are used. The equipment needed for mobilization of a wet welded job is minimal.

6.4. Disadvantages of Wet Welding:

Although wet welding is widely used for underwater fabrication works, it suffers from the following drawbacks: -

1) There is rapid quenching of the weld metal by the surrounding water. Although quenching increases the tensile strength of the weld, it decreases the ductility and impact strength of the weldment and increases porosity and hardness.

2) Hydrogen Embrittlement – Large amount of hydrogen is present in the weld region, resulting from the dissociation of the water vapour in the arc region. The H_2 dissolves in the Heat Affected

Zone (HAZ) and the weld metal, which causes Embrittlement, cracks and microscopic fissures.

Cracks can grow and may result in catastrophic failure of the structure.

3) Another disadvantage is poor visibility. The welder sometimes is not able to weld properly.

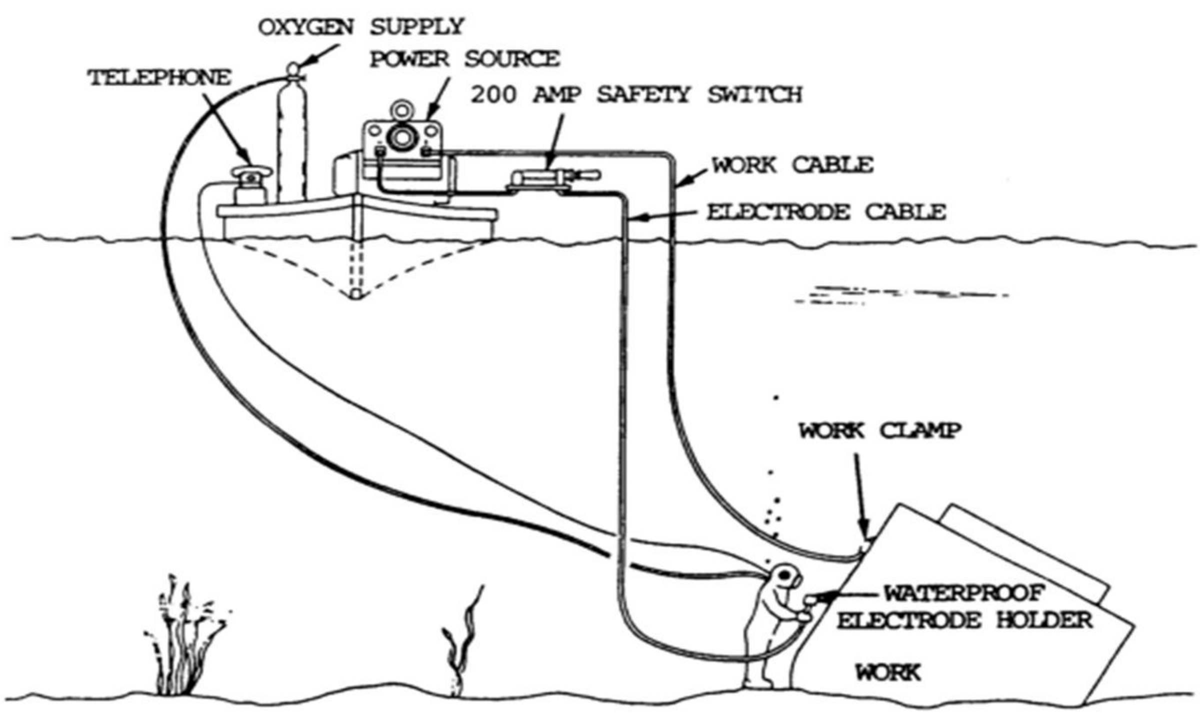
Principle of operation of Wet Welding:

The process of underwater wet welding takes in the following manner:

The work to be welded is connected to one side of an electric circuit, and a metal electrode to the other side.

These two parts of the circuit are brought together, and then separated slightly. The electric current jumps the gap and causes a sustained spark (arc), which melts the bare metal, forming a weld pool. At the same time, the tip of electrode melts, and metal droplets are projected into the weld pool. During this operation, the flux covering the electrode melts to provide a shielding gas, which is used to stabilize the arc column and shield the transfer metal.

ARRANGEMENTS OF UNDERWATER WELDING:



The arc burns in a cavity formed inside the flux covering, which is designed to burn slower than the metal barrel of the electrode.

7. Developments in Under Water Welding

Wet welding has been used as an underwater welding technique for a long time and is still being used. With recent acceleration in the construction of offshore structures underwater welding has assumed increased importance. This has led to the development of alternative welding methods like friction welding, explosive welding, and stud welding. Sufficient literature is not available of these processes.

8. Scope for further developments

Wet MMA is still being used for underwater repairs, but the quality of wet welds is poor and are prone to hydrogen cracking. Dry Hyperbaric welds are better in quality than wet welds. Present trend is towards automation. THOR – 1 (TIG Hyperbaric Orbital Robot) is developed where diver performs pipefitting, installs the track and orbital head on the pipe and the rest process is automated.

Developments of driverless Hyperbaric welding system is an even greater challenge calling for annex developments like pipe preparation and aligning, automatic electrode and wire reel changing functions, using a robot arm installed. This is in testing stage in deep waters. Explosive and friction welding are also to be tested in deep waters.

9. CONCLUSION:

Wet welding is still being used for underwater repairs, but the quality of wet welding is poor than dry welding.But the dry welding is costlier than wet welding.

So the present trend is towards automation.

Underwater welding is mostly employed in marine engineering products –in installations of oil and gas rigs. Underwater welding can be classified

depending upon the types of equipments and the types of procedures involved. The most common underwater welding process, known as manual metal arc building (MMA), is employed for deep water repairing activities.

Cofferdam welding process and Hyperbaric welding process are normally carried out for underwater welding operations. They are employed for welding steel pipelines, other offshore structures, submerged parts of large ships and underwater structures supporting a harbor. The safety measures include emergency air or gas supply, stand-by divers and decompression chambers.

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