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A COMPREHENSIVE EXPERIMENTAL INVESTIGATION ON HARDNESS OF UNDERWATER WELDS PERFORMED THROUGH GAS METAL ARC WELDING

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ABSTRACT

Gas metal arc welding (GMAW) is favoured for its adaptability, rapidity, and suitability for robotic automation in industrial settings. Local dry welding boasts a wide range of applications, frequently employed for the repair of ships, offshore oil platforms, and pipelines. It is the method of choice when aiming for top-tier weld quality. The drainage cover utilized in this welding process is crafted from aluminium. In the present investigation, we delve into underwater welding of local mild steel as the base material, employing a blend of argon and CO2 as the shielding gas, aluminium as the drainage cover. Vickers hardness test results reveal that the underwater welds exhibit higher hardness compared to land-based welds due to the rapid cooling rates involved.

Keywords: GMAW, Hardness, under water welds, Arc welding.

1. INTRODUCTION

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) and metal active gas (MAG) is a welding process in which an electric arc forms between a consumable MIG wire electrode and the workpiece metal(s), which heats the workpiece metal(s), causing them to fuse (melt and join). Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from atmospheric contamination. Where high integrity welds are required dry underwater welding may need to be undertaken. In dry underwater welding, the weld is performed at the prevailing pressure in a dry chamber filled with a gas mixture sealed around the structure being welded.

The applications of underwater welding are diverse and often used in underwater construction, ship repair and pipelines. Steel is the most common material welded.

2. LITERATURE REVIEW

With the serious need for technological advancement in marine engineering and nuclear power plant construction, local dry underwater welding suitable for automation applications is gaining popularity. When compared to the direct wet welding method, the local dry underwater method not only provides better arc stability and weld quality, but it is also less expensive. The drainage cover, an important device for local dry underwater welding, conducts gas or liquid from externally to internally, forming a stable area around the welding arc similar to the onshore welding zone, protecting arc burning, droplet transfer, and weld formation during the welding.Scholars have done a lot of research work on the development and optimization of the drainage cover because structural design and the protection mode of the drainage cover are closely related to weld formation. Hamasaki et al [2] proposed and successfully applied a water curtain and steel brush type micro drainage cover with automated welding to butt and fillet joints at a depth of 0.3 m. Although the spatter, porosity, and crack in the welding process were effectively reduced, the system still required a gas chamber type of drainage device, which could separate the parts to be operated and completed a weld to move the gas-chamber until the entire weld was completed, thus improving the quality of underwater welding between the terminal and the line.Rogalski et al [3] investigated the effects of the local dry underwater welding's combination of heat input and drainage gas on the microstructure and hardness of the fusion zone, and developed a formula to estimate the maximum hardness of the HAZ (Heat affected zone) based on heat input and gas flow. In the 1970s, the Harbin Welding Research Institute conducted research on local dry underwater welding and developed the CO2 semi-automatic all-position welding process.

3. METHODOLOGY

3.1. Selection of material and sample preparation

The work piece material selected is local mild steel. It is a type of carbon steel with a low amount of carbon – it is actually also known as “low carbon steel.” Aluminium 6061 is used as the drainage cover for the experiments. After welding is complete the transverse section of the samples is extracted from the welded plate. For studying the microstructure and hardness these samples were ground using silicon carbide papers of grades 320, 600, 800, 1000, 1200, 1500 and 2000 grit size.

3.2. Vicker’s hardness tester

In the current study a Vickers hardness tester fitted with optical microscope is used. Vickers hardness testing can be used to determine the hardness of all solid materials, including metallic materials. The Vickers Hardness value is defined by

$$HV = \frac{1.854\,F}{d^2} \text{................ (i)}$$

where d_m is the mean diagonal of the square indentation.

3.3. Methodology to obtain underwater welds

This modified welding torch consist a square plate of 100×100 sq. mm . This plate has two type inlets. In first inlet, the four inlets are tangentially orientated with regard to the outer nozzle & through these four nozzles we are trying to pass high velocity compressed air that will create a circulation motion inside conical channel. Second inlet of the welding torch is the arc shielding gas outlet nozzle, with a total diameter of 25 mm, comprising a conductive tip with a diameter of 6 mm in the middle. The cross-section area of the exit is substantially less than the size of the four inlets, resulting in faster gas movement & at the exit it will dispel the water and create an empty space at the welding region. The gas flow generates a hyperbaric and rotary gas block that prevents water from entering the welding zone.

Table 1 Experiments after the selection of welding parameters

S. No.	Welding Condition	Current (Amp)	Voltage (Volt)	Welding Speed (mm/min.)	Drainage Gas Pressure (MPa)	Shielding Gas Flow Rate (Litre/min.)
A	Atmospheric	120	17	300	0	10
B	Local dry	220	22	219.42	0.7	15
C	Local dry	240	25	214.18	0.7	25

Figure 1. Weld beads achieved during the welding process

4. RESULTS AND DISCUSSION

Vickers hardness values were measured at a distance measured from bottom of weld cross section. The hardness values were measured along three lines- the centre line, one line to the left (1 mm from the centre line), and one line to the right of the centre line (1 mm from the centre line). The hardness of welds was measured at a load of 500 grams and a dwell time of 15 seconds.

4.1. Hardness results

Vickers hardness values were measured at a distance measured from bottom of weld cross section. The hardness values were measured along three lines- the centre line, one line to the left (1 mm from the centre line), and one line to the right of the centre line (1 mm from the centre line). The hardness of welds was measured at a load of 500 grams and a dwell time of 15 seconds.

Table 1 Maximum hardness of weld and its location from centre line

	Sample A			**Sample B**			**Sample C**		
	Base metal	**HAZ**	**Fusion zone**	**Base metal**	**HAZ**	**Fusion zone**	**Base metal**	**HAZ**	**Fusion zone**
Distance from bottom of cross section (mm)	3	5	9	1	4	6	6	9	11

5. CONCLUSION

The following conclusions can be drawn from the studies carried out in this present work:

1. The GMAW underwater process, when used with drainage nozzle, has been found to produce high-quality weld joints without any cracks or porosities.
2. The welding input parameters have been suitably optimized to carry out the welding process.
3. Weld beads are found to be regular in experiments A, D and J with current 120, 220and 240 Ampere and voltage 17.1, 22 and24.5 Volt respectively for air and underwater weld.
4. Hardness of underwater welds have higher than welds made on land due to high cooling rate but we get comparatively low hardness for higher heat input weld.
5. Maximum Vicker’s hardness (259 HV) for sample-A was observed at left of the centre line and at 4 mm from bottom of cross section.
6. Maximum Vicker’s hardness (379 HV) for sample-B was observed at centre line of weld and at 4 mm from bottom of cross section.
7. Maximum Vicker’s hardness (347 HV) for sample-C was observed at centre line of weld and at 8 mm from bottom of cross section.

6. FUTURE SCOPE

1. Integration of robotic systems: Investigating the application of robotic systems in welding processes can lead to improved precision, consistency, and efficiency. Exploring the use of robotic arms or automated welding systems can help achieve higher-quality welds with enhanced control and repeatability.
2. Fabrication of modified nozzles: Designing and fabricating modified nozzles can optimize the water removal process and enhance the effectiveness of the welding operation. The development of innovative nozzle designs, such as those with enhanced water curtain configurations or adjustable parameters, can contribute to improved weld quality and water containment.
3. Welding on different materials: Expanding the scope of the project to include welding on materials other than mild steel can provide valuable insights into the adaptability and effectiveness of the GMAW underwater process. Conducting experiments and simulations on various materials, such as stainless steel, high strength low alloy, can help understand the challenges and opportunities associated with underwater welding on different substrates.
4. Study of additional welding and flow parameters: Exploring the effects of various welding and flow parameters, such as air flow rate, hydrogen diffusion, welding speed, and shielding gas composition, can further optimize the welding process. Understanding the influence of these parameters on water removal, weld quality, and mechanical properties can lead to improved process control and parameter optimization for achieving superior weld results.
5. Evaluation of weld quality and mechanical properties: Conducting comprehensive evaluations of weld quality and mechanical properties, such as tensile strength, impact toughness, and corrosion resistance, can provide a deeper understanding of the performance and reliability of underwater welds.

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