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"EXPERIMENTAL INVESTIGATION ON MECHANICAL HARDNESS OF UNDERWATER WELDED JOINTS"

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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, aluminum 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.

Key Words: *Underwater welding, Gas Metal Arc Welding (GMAW), drainage nozzle, Vickers hardness, weld quality, microstructure.*

I. 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.

II. 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 proposed and successfully applied a water curtain and steel

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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 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.

III. METHODOLOGY

3.1. Selection of material and sample preparation

Figure.1 Weld beads achieved during the welding process

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.

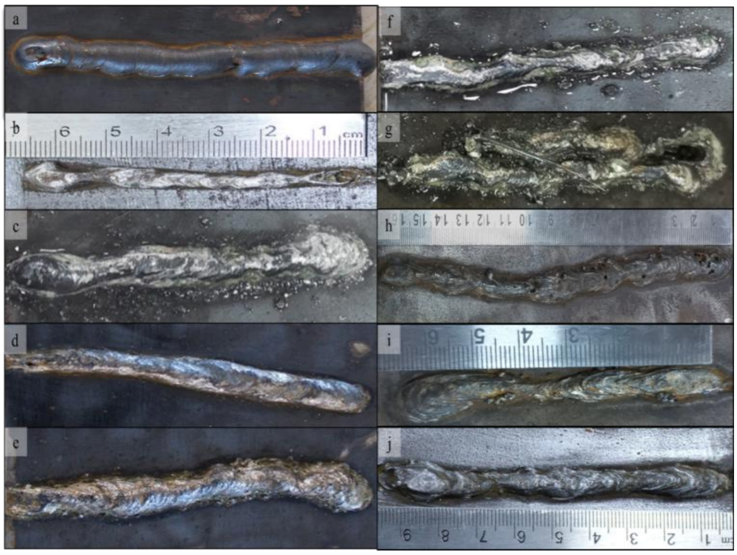

Figure. 2 Weld formation results as shown in (a), (b), (c), (d), (e), (f), (g) and (h) for sample no. A, B, C, D, E, F, G and H respectively

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3.2. Vicker's Hardness Tester

Figure. 3 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

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

where d_m is the mean diagonal of the square indentation.

IV. 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 centreline), and one line to the right of the centre line (1 mm from the centreline). The hardness of welds was measured at a load of 500 grams and a dwell time of 15 seconds.

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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)	2	4	8	1	4	6	5	8	10
Max. Hardness (HV)	195	236	226	199	379	319	188	347	316

4.2. 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.

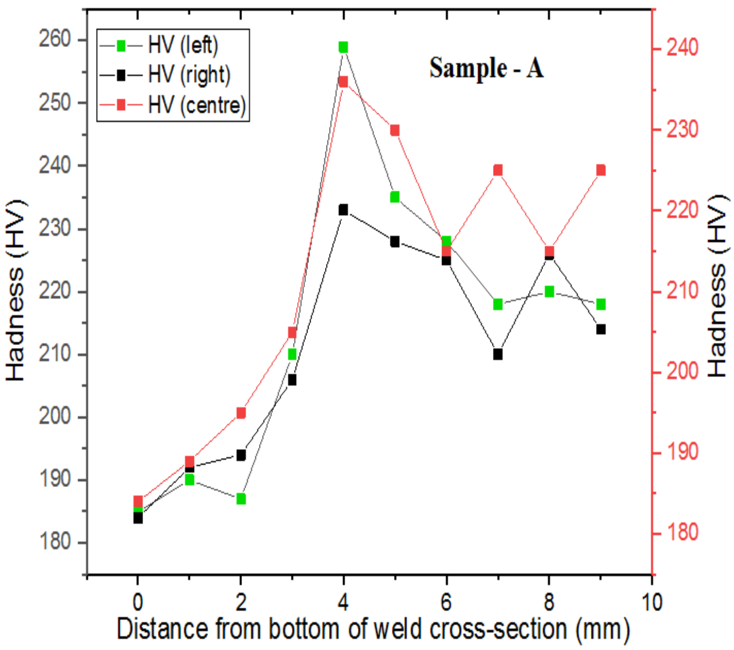

Figure. 4 Hardness measurements of Sample-A, at a specified distance from bottom of weld cross section and on centre line along with left and right side of centreline

As shown for the hardness values of sample-A i.e., air weld (shown in fig. 4), the max hardness value at base metal (BM) is 195 HV while along the heat affected zone (HAZ) is 259 HV and fusion zone (FZ) is 228 HV. The maximum hardness of weld lies at 4 mm from bottom of weld cross section for centre line as well as right and left side of centre line.

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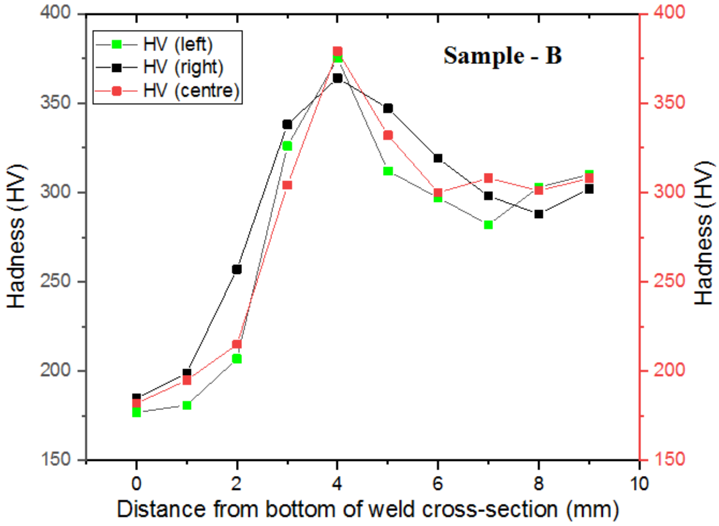

Figure. 5 Hardness measurements of Sample-B, at a specified distance from bottom of weld cross section and on centre line along with left and right side of centreline

As shown for the hardness values of sample B i.e., underwater weld sample at 45 mm water depth (shown in fig. 5), the hardness value at base metal (BM) side of right line is 199 HV while along the heat affected zone (HAZ) is 379 HV and hardness value at fusion zone (FZ) is 319. The maximum hardness of weld lies at 4 mm from bottom of weld cross section for centre line as well as right and left side of centre line.

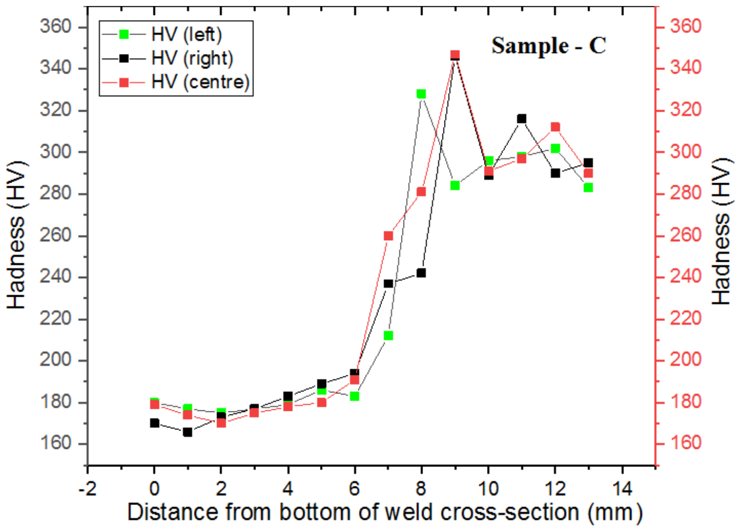

Figure. 6 Hardness measurements of Sample-C, at a specified distance from bottom of weld cross section and on centre line along with left and right side of centre line

As shown for the hardness values of sample C i.e., underwater weld sample at 200 mm water depth (shown in fig. 6), the maximum hardness value at base metal (BM) is 194 HV while along the heat affected zone (HAZ) is 347 HV and fusion zone (FZ) is 316HV. The maximum hardness of weld lies at 9 mm from bottom of weld cross section for centre line and right side while the maximum hardness of 328 HV for left side lies at a distance of 8 mm from bottom of weld cross section. Table 11 shows the maximum hardness of weld and its location from centre line at a distance from bottom of cross section.

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V. 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. Maximum Vicker's hardness (232 HV) for sample-A was observed at centre of the cross section and 5 mm from bottom line.
3. Maximum Vicker's hardness (372 HV) for sample-A was observed at centre of the cross section and 6 mm from bottom line.
4. Maximum Vicker's hardness (341 HV) for sample-A was observed at centre of the cross section and 9 mm from bottom line.

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