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Underwater Rotary Friction Welding of Aluminum

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Abstract
Underwater welding is widely used in underwater repair or assembly work such as construction of subsea pipelines, repair of ship failures and pilines or offshore structures, as well as ship salvage. Shielded metal arc welding is commonly used as an underwater welding process. Unfortunately, this process carries great risks such as the risk of electric shocks. This is why, for some years, other underwater welding processes have been tested, such as friction welding. This type of welding is based on the friction of the two parts to be welded. However, underwater friction welding remains a limited process at the stage of scientific research. In this present study, the underwater rotary friction welding of an industrial aluminum is presented. The welding was carried out in a specific assembly manufactured in our laboratory and which was very successful. The macrostructure of the welded joint has been presented.

Keywords: Underwater welding, Friction, Aluminum

Introduction

It has been recognized that welding processes can be divided into two large families, which are fusion welding and solidstate welding. Solid state welding is a type of welding that is performed without causing melting at the welded joint like solid state diffusion welding or friction welding [1,2]. Friction welding is the joining of two parts by the frictional heat generated at their contact interface due to the relative motion applied between them. This welding process is carried out in the solid state, that is to say at a temperature T below the melting temperature Tm of the material to be welded (approximately at T=0.7 Tm). The relative movement between the two parts can be created either by a linear movement, or by a rotational movement of one part with respect to the other which is generally held stationary. The second process is known as rotary friction welding (RFW) [3]. RFW is a solid-state welding process that is gaining popularity in industry due to advantages such as low welding heat input, high production efficiency, ease of fabrication and friend to the environment [4]. As illustrated in Figure 1, the RFW process is typically performed on two round bars by rotating the first bar relative to the other along their common axis with the application of axial pressure to improve friction., resulting in a rise in temperature in the contact area of the two bars. This rise in temperature causes a hot plastic deformation which favors the interdiffusion of the atoms of the two bars to create a solder joint. The main basic parameters of RFW are: rotation speed V (rpm), friction time (s), friction pressure (MPa), forging time (s) and forging pressure (MPa). It should be mentioned that the quality of the welded joint depends on these parameters. Since its invention in the early 1950s, many materials have been welded by RFW, such as the welding of two similar steels two similar aluminum alloys and the dissimilar welding of an aluminum alloy with steel...etc. However, this method is generally used in a dry environment, but in recent years, some attempts have been made to apply this method especially for marine applications [5-7]. However, underwater friction welding is not an easy task because the welding parameters must be well controlled.

Ikram et al. worked on a preliminary experimental study of underwater friction stir welding of butt joint of aluminum alloy plate (AA5083) [8]. They made a specific configuration to achieve their goal. In their research work, they changed the dwell time and the inclination angle of the welding and kept the same rotational speed and the same displacement speed in each sample in order to achieve successful welding. Chandoma et al. worked on the underwater friction stud welding of S355 steel by optimizing some parameters through an approach based on robust engineering design; they made a setup in order to perform the welding tests under water [9]. Sadeghi et al. worked on the metallurgical study of the underwater friction stir welding (UWFSW) process of the Al X4000 series in a specific configuration made for this reason [10]. They found that the underwater sample had no cracks or flaws and that the surface quality of the underwater sample was similar to that of another welded sample in the dry (air) state. Ratnayake and Brevik worked on the friction stir welding parameters of S235 steel underwater studs in a specific configuration [11]. The authors focused on the microstructure of the solder joint. For example, they mentioned martensite formation in the heat affected zone at the stud plat. From this literature review of previous research work on underwater friction welding, it can be concluded that the research work on underwater friction welding remains very limited and that the main welding processes used are only friction stir welding and friction stud welding and no rotational friction welding has been tried or studied.

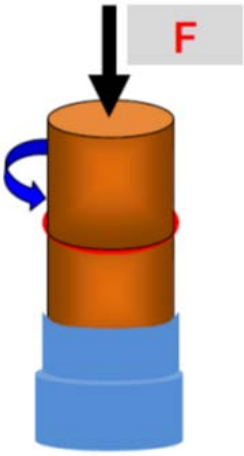

Figure 1: Schematic Representation of Rotary Friction Welding Process

Experimental Procedure

Friction-rotation welding was carried out on two industrial aluminum rods 6 mm in diameter and 50 mm in length. Welding is performed on a rotary friction welding machine which has been specially designed to achieve our purpose (Fig.2). The rotation speed that allows us to make a welded joint is 2500 revolutions per minute. This rotational speed value was determined after several heads by varying the rotational speed from 1500 rpm to 2500 rpm. Figure 2 illustrates all parts of the welding machine. The main parts are mentioned by the numbers 1, 2, 3 and 4. The two aluminum rods are immersed in a water tank (3) where the lower rod is fixed, on the other hand the upper rod is fixed to an electric motor (2) with variable speed (4) by applying a load using the arm (1) to control the time friction between the two bars and ensure quality welding of the two rods.

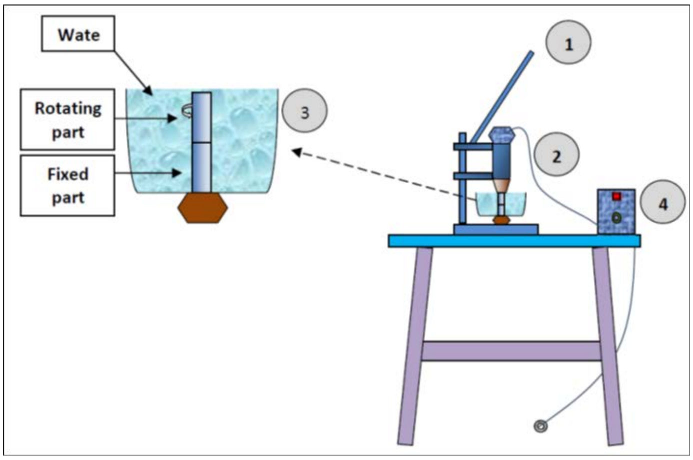

Figure 2: Rfw Machine Used for Underwater Welding.

• Load application arm, 2-Rotating part containing an electric motor, 3-Device containing a water tray, and 4-Rotation speed regulator.

• Figure 3: Shows the Two Aluminum Rods Immersed in Water and Which Are Brought into Contact Before the Start of Rotation of the Upper Rod.

Figure 3: The Two Aluminum Rods Immersed in Water

Results and Discussion

Figure 4 shows the successive images taken during the rotational friction welding of two aluminum rods. Figure 4a shows two aluminum rods that have been brought into contact before welding begins. Figure 4b shows the welding process after 6 s of friction which shows the beginning of the separation of the debris in the friction zone which passes into the water due to the high rotational speed (Fig. 4c). The assembly process of the two rods will end after 9 seconds of welding.

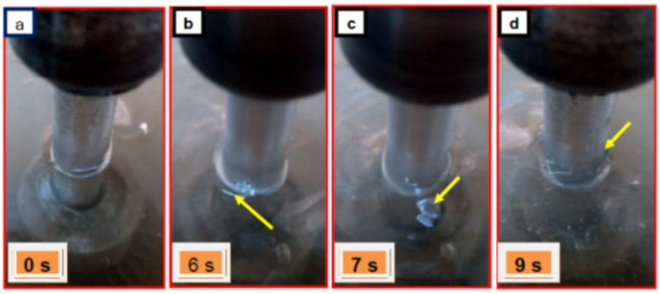

Figure 4: Sequence of the Frw of the two Aluminum Rods.

Figure 5 presents the result of the friction welding of aluminum to aluminum. As can be seen, the two aluminum parts were well welded (Fig.4a) and this was confirmed by the magnified observation of the welded joint and which shows the contact interface between the two aluminum parts. It is important to note that after rotational friction welding, the bead which usually forms in the contact zone between the two rods was not observed (Fig.4b), as it was generally seen in rotary dry welding process [12,13]. This behavior is due to the effect of water on the shape of the welded joint. It is also observed that during the welding process, the water undergoes heating under the action of friction but without reaching its boiling point.

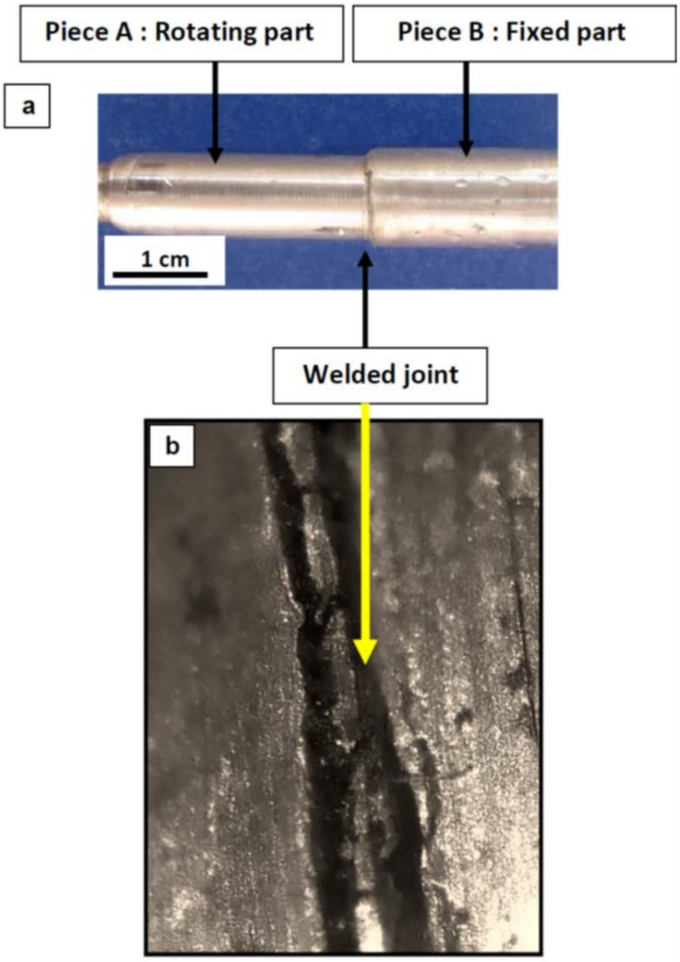

Figure 5: Rotary Friction Welding of Aluminum to Alumin(A) Welded Sample and (B) Magnification of the Welded Joint.

Conclusion

The purpose of this work was to perform underwater rotary friction welding which had not been used before. For this reason, a friction rotation welding machine is designed to achieve the objective of this study which is the welding of two rods of industrial aluminum. After several tests, the two rods were successfully welded under a rotation speed of 2500 rpm. This technique can be extended to the welding of other materials, provided that the welding parameters and in particular the speed of rotation are controlled.

Acknowledgment

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