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Underwater Friction Stir Welding: An Overview

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Abstract

In recent years, the research has become the primary aim in every field. Underwater Friction Stir Welding (UFSW) is one the advanced techniques of welding. It is really new and emerging technology. It is a solid state welding. In this method, non consumable tool runs over the substrates under the water without generating fumes. It consumes less energy. It provides improved mechanical properties. It gives really efficient joint. Very little work has been done in the field of UFSW. Research in this field can really boost up the researchers and academicians.

1. Introduction

Friction Stir Welding (FSW) was first patented in 1991 by Thomas et. al. from 'The Welding Institute', England. He found its application in various industries like aerospace, automobile, railway etc. It is a new emerging technology to join various types of metals ceramics, polymers etc. [1]. In recent years, under water friction stir welding has come into existence. Underwater Friction Stir Welding (UFSW) is a solid state welding process. It takes place at temperatures below the melting point of the material. In this method, a non-consumable rotating tool runs over the substrates under the water which results into the generation of heat due to friction. This leads to plastic deformation and softening of substrates near the tool area. Then, the substrates can be easily joined. It also minimizes various welding defects like porosity, shrinkage, splatter, embrittlement, solidification, cracking etc. UFSW is one of the advanced welding techniques in the present era.

This process doesn't require shielding gas and filler material for welding which make this process cheaper. It consumes less energy and gives improved mechanical properties. It also provides well defined variation in grain size between different zones along the high quality weld joint produced.

2. Literary Review

Qian et. al. (2012) used the “slipping and sticking” technology for 1100-H14. They studied torque oscillations which exist at the same frequency of tool rotation due to the cyclical material transfer in butt welds. But their study did not include lower frequency oscillations [2]. Thompson et. al. (2012) focused his study on the problem of keyhole generation at the end of the welded work-piece which causes wastage of material. They discovered “all-in-one-exit” key-hole elimination technique to tackle these process issues [3]. Kumar et. al. (2012) concluded that the rotational speed is most significant process parameter which has the highest influence on tensile strength and hardness, followed by tool pin profile and tool tilt. He verified this by conducting confirmation experiments. He also calculated the, predicted optimal value of tensile strength and hardness of dissimilar joints produced by friction stir welding which were 267.74 MPa and 80.55 HRB, respectively [4].

Debroy et. al. (2012) studied and then analyzed a method of generating tool durability maps which can correlate various process parameters involved in FSW to the tool life [5]. Chen et. al. (2012) discovered other similar processes like double-sided FSW where the top and bottom tool shoulders are not mechanically connected [6]. Gesto et. al. (2012) concluded that the value of hardness is higher rather than of those gained with conventional quenching and tempering techniques. He stated that FSP is a surface hardening technique for martensitic stainless steel [7]. Rai et. al. (2011) did a comparative survey on the selection of tool material on the basis of the substrate material and the welding parameters [8].

Kim et. al. (2010) studied the commercial finite volume method based upon the Eulerian formulation under the steady state condition for friction stir butt welding process. He also stated the thermal and deformation theories along with proper thermal boundary conditions for the baking plate. He resulted the characteristics like hardness, grain size and susceptibility of weld to abnormal grain growth after post heat treatment [9]. Lui et. al. (2010) resulted that the tensile strength of the joint can be improved from 324 MPa by external water cooling action in normal to 341 MPa. He concluded that, underwater joint tends to fracture at the interface between the weld nugget zone. He stated that, during tensile test, thermally mechanically affected zone is significantly different from the normal joint [10].

Nielsen et. al. (2009) studied that, the convex scrolled shoulder tool with a step spiral probe can offer larger process window, lesser process forces and the ability to operate at a zero degree tilt angle [11]. Kwon et. al. (2009) experimented on 5052 aluminium alloy plate using FSW. He concluded that grain size in the FSW zone is lesser than that of the base metal. He resulted that, tensile strength of the joint is more and ductility is less than that of the parent metal [12]. Yazdanian et. al. (2009) concluded about the effect of welding speed, pin length and rotation rate. He resulted that, the high rotation rate on AA6060 caused the weld to be weaker. [13].

Hwang et. al. (2008) conducted a FSW experiment on the A6061-T6 aluminium alloy specimen. He also discussed the process control of the tool during pin plunging, preheating and traversing for a successful weld joint [14]. Subramanian et. al. (2008)

studied about the probe geometry and testing the effect of various shapes of tools such as like straight cylindrical, tapered cylindrical, threaded cylindrical, square, and triangular. He conclude that the tool pin force and weld quality contributions during welding, are altered due to the optimization of the tool. He resulted that square pin profile is the perfect pin for FSW [15]. Liu e.t al. (2008) studied and analyzed the effects of varying tool shoulder and probe diameter, on the microstructure and mechanical properties of 6061-T651 butt welds [16].

Threadgill et.al. (2007) studied about the various weld zone in FSW. He stated that, the unaffected region is known as the parent metal. Heat affected zone (HAZ) is the one which gets affected only by heat whereas the region that is affected by both heat and plastic deformation is known as thermo mechanically affected zone (TMAZ). Sometimes it does not get completely recrystallized. The region which completely gets recrystallized is known as nugget [17]. Scialpi et. al. (2007) concluded that shoulder geometries features scrolls, a cavity and a fillet. He studied the effect of shoulder geometry on microstructure, tensile strength, and micro hardness of Al 6082 butt welds [18].

Heurtier et. al. (2006) studied about the three dimensional thermo mechanical model for a AA2024-T351 alloy friction stir weld. He found that, the results obtained are in correlation with the experimental results [19]. Khaled et. al. (2005) discussed about the basic principles of the friction stir welding. He concluded that at the time of welding, the tool rotates about it axis. The probe is inserted into the material. Shoulder of the tool applies downward force to top of the substrate. By this heat is generated and consecutively softens the material along the joint line. The rotating tool then moves along the weld line and causes the weld [20]. Schmidt et. al. (2004) constructed a analytical model depending upon the various assumptions of the contact conditions between the rotating tool surface and work piece for the heat generated during FSW [21].

Yang et. al. (2004) found that in welds of AA2024-T351 and AA2524-T351, banded microstructure results from periodic variations in the size of grains, the micro-hardness, and the concentration of base metal impurity particles [22]. Thomas et. al. (2003) observed that, 5083-O, aluminium alloy wrought sheet of 6mm thickness with a cylindrical threaded pin probe tool gives good appearance weld. He also concluded that bend test proves the quality of it to be weaker because of interfacial surface oxide layer. This tool profile gives a good quality weld in butt welding condition [23].

Lee et. al. (2003) concluded that, knowledge of thermal histories and temperature distribution is important for the FSW process which depicts successful implementation of the process. Some properties like, tensile strength and hardness of the cast aluminium alloy are improved by using FSP [24]. Krishnan et al. (2002) examined that in the extruded cylindrical section of material “onion rings” appear around the probe of the tool [25]. Thomas et al. (1999) experimented on the steel using friction stir welding. He concluded that, all the mechanical properties of the welded joints are similar to the base metal but wear of the tool is a significant barriers to the process capability [26].

3. Gaps in Litrature Review

From the above literature survey, it reveals that, little work is done on underwater friction stir welding. It is really an advanced technique of welding. Few researchers have used the optimization technique in the field of friction stir welding but very little in case of UFSW. UFSW is not explored yet.

4. Advantages and its Applications

There are various advantages of underwater friction stir welding. It has the ability to join light weight alloys underwater. It is very useful for Indian Navy. It also reduces the energy consumption of their joining processes. Cryogenic fuel tanks, military vehicles, rolling stock, and cold plates for thermal management, welding of the latest iMac are the various application of the friction stir welding process.

5. Conclusion

Underwater friction stir welding is really an innovative and novel technique of welding. In this present era, very few researchers and academicians have done the research on it. Research on underwater friction stir welding can really boost and pave the way to the research area in the field of friction stir welding.

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