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Evolution of Mechanical Properties and Microstructure of Friction Stir Welding of Aluminum and Magnesium Alloys

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ABSTRACT

In this work, the quite possibly the main welding process explicitly the class of the solid-state welding process that is friction state welding process was discussed. Based on a base of experimental research results, the typical mechanical properties of butt-welded joints of thermally unhardened magnesium AZ31B and aluminum 7075 alloys are determined. The efficiency of the application of the friction stir welding to make fine microstructures from the given alloys operating under variable loads is substantiated.

KEYWORDS

magnesium AZ31B, aluminum 7075, friction stirs welding, mechanical properties, microstructures.

INTRODUCTION

Magnesium alloys AZ31B and aluminum 7075 are thermally unhardened alloys that have good strength properties. These alloys are generally utilized because of their properties such as high corrosion resistance and good weldability. The improvement of the strength characteristics of these aluminum alloy and magnesium alloy is a relevant task. Today there are many ways to achieve the mentioned improvement, but the most promising is friction stir welding [1]. Friction stir welding (FSW) is the process of assembling parts in the solid state, wherein the friction heat generated by the rotating tool is used for connecting materials [2]. This process is currently broadly utilized and widely utilized for various applications. Explicitly this welding process really advancement began by the utilization of the moderately soft material like aluminum alloy and magnesium alloy.

Numerous focal points when contrasted with the combination welding measure regarding that explicitly or different mix of the material. Furthermore, while combination welding likewise makes a great deal of risks and afterward some ecological issue additionally in the event of erosion combination welding measure. In friction stir welding is extremely spotless interaction. Thus, it is likewise called the green innovation and along these lines; energy proficiency and climate amicability. Since for this situation there is simply the machine burns-through the electrical energy and afterward there is no development of the any gas and any sort of risky materials during handling of this during welding process solid state. A tool without consumables with a center probe pivoted and embedded into the partition surface between two workpieces before moving along the weld line (Figure 1). A large portion of the came about warmth happens under the apparatus projection as it moves along the segment limits, making the material warmth up and mollify [2, 3].

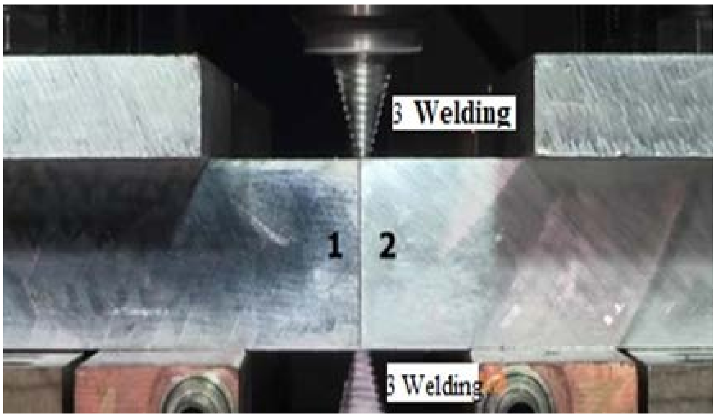

Figure 1. Friction stirs welding.

The tool also serves to contain the mollified material that is mechanically agitated to create a solid phase welding seam. This welding method is mainly used in the industry for joining all kinds of aluminum alloys such as casting, rolling or extrusion. FSW welds butt joints made of aluminum alloy with a thickness of 0.3 mm to 75 mm in one pass, contingent upon the raw material used, the power of the machine and the structural rigidity of the work piece [4-7]. In addition, steel, copper and titanium alloys undergo FSW and also plastics and metal matrix composites (MMC) undergo weld in this manner. It has been proven that this process can combine various combinations of these alloys. The mechanical properties of aluminum alloys welded by FSW turned out to be better than those of other types of welding (for example, than that of arc welding). This process usually has three main microstructural regions [8-10]:

1- Weld nugget zone.

2- Thermomechanical-affected zone

3- Heat-affected zone.

Although the weld nugget zone itself is a thermomechanical-affected zone, it is considered independently when it comes to microstructural features. This is because of the reality that the weld nugget zone undergoes dynamic recrystallization, while the thermomechanical-affected zone (TMAZ) does not undergo. But the exact composition and degree of microstructure composition in these zones depends on the material and processing conditions. They can, for example, differ contingent upon variables, for example, boundaries and design of the welding device utilized [11, 14]. The aim of this work is to contemplate the mechanical properties and microstructure of welded joints alloys of magnesium AZ31B and aluminum 7075, obtained by FSW.

MATERIALS AND TESTING

A joint was made of joint sheets with a thickness of 5 mm, from the alloys of magnesium AZ31B and aluminum 7075. Welding mode parameters are presented in table. 1. The list of equipment used in the study is presented in table. 2.

Table 1. Parameters of the FSW mode for sheets of AZ31B magnesium and 7075 aluminum alloys

FSW mode parameters	**Values**
Welding speed, m/h	12.5-28.2
A tool rotation speed, round/min	500-3000
Normal force of pressing the tool to workpieces, N	9000-9500
Tool tilt angle in the vertical plane, °	2-3
Pin length, mm	4.8
Pin diameter, mm	4.2
Shoulder diameter , mm	16

Table 2. List of equipment used in the study

Equipment	Application
Laboratory device on the basic of a vertical milling machine with CNC (with an indicator of vertical movement of the milling head) [5]	FSW
Servo - hydraulic complex MTS 318.25	mechanical testing
Microscope LEXT OLS4000	determination of grain size of fine structure

The samples that were used to calculate the tensile strength of the weld metal during tension and pressing of the metal in the weld nugget zone are shown in Fig. 2.

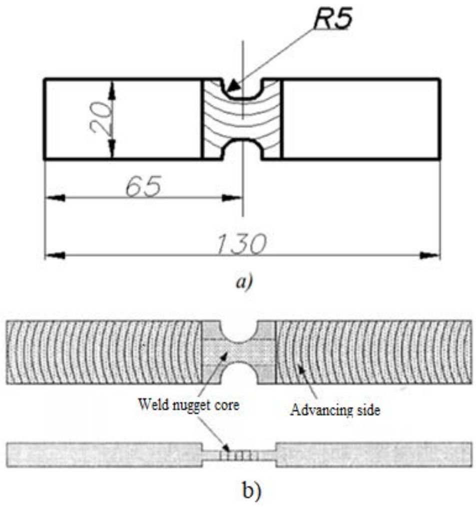

Fig. 2. (a) Sample for determining the tensile strength of the weld metal at FSW and (b) the scheme of cutting out the sample to determine the tensile strength of the weld nugget core

RESULTS AND DISCUSSION

The results of testing the samples of the studied alloys for static tension, as well as static and impact bends are presented in table. 3.

Table 3. Mechanical properties of welded joints obtained by FSW on the studied alloys

Alloy mark	State before FSW	Strength, MPa					tilt angle	Impact viscosity, kJ/m3	
		welded joint			nugget metal (stirring zone)	Weld nugget core		Weld nugget	Heat-affected zone
		Welded joint	Coef. Of tensile strength	Destruction zone of sample					
AZ31B	M	142	0.97	TMAZ	150	155	180	900	810
	H	186	0.70	Along the weld nugget zone	185	193	180	770	680
7075	M	354	0.96	TMAZ	366	380	180	224	200
	H	432	0.93	Along TMAZ at a distance of 3	480	492	170	362	315

Alloy mark	State before FSW	Strength, MPa					tilt angle	Impact viscosity, kJ/m3	
		welded joint			nugget metal (stirring zone)	Weld nugget core		Weld nugget	Heat-affected zone
		Welded joint	Coef. Of tensile strength	Destruction zone of sample					
				mm from the weld nugget core					

As a result of the tests carried out, it was found that the destruction of all samples was concentrated along the weld nugget core. In this case, the average values of the fracture stress of the samples cut along and across the welding direction are approximately equal. The obtained results of metallographic and structural studies have shown that, when welding sheets of the studied alloys with a thickness of 5 mm, a fine-grained structure with the same grain size is formed in the weld nugget core when decorating grain boundaries with solid oxide particles fig (3).

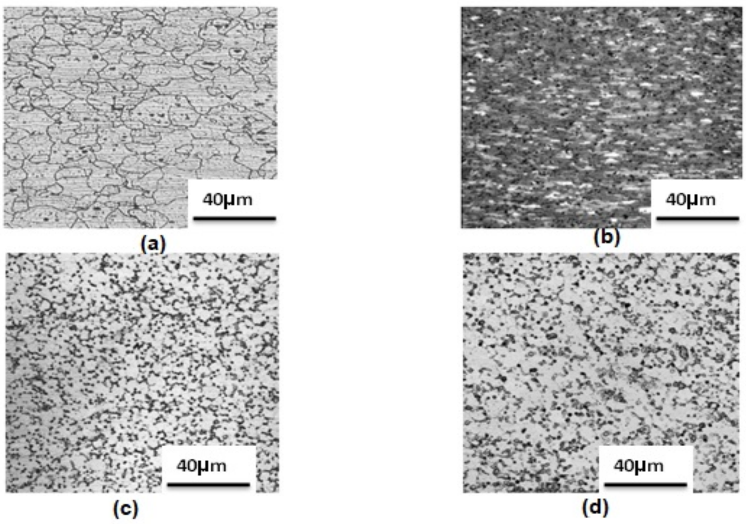

Figure 3. Microstructure of sheets of (a) AZ31B alloys, (b) 7075 alloys, (c) the core of the weld seam of AZ31B and 7075 (d) alloys with a thickness of 5 mm

The formation of this structure can be clarified by the extraordinary thermo mechanical action in the process of the FSW of the rotating tool and the dynamic recrystallization of the alloy being welded under the given conditions. As a result of the conducted studies, it was established that welded joints obtained in the solid phase by friction stir welding have a cyclic durability close to that of the base material (Fig. 4). Their fatigue resistance characteristics are higher than the values for joints made by non-consumable electrode argon-arc welding in the entire range of fatigue life of 10^5-$2•10^6$ voltage cycles, and the limited endurance limit based on $2•10^6$ cycles is 110 MPa, which is only 5% lower than for the base material.

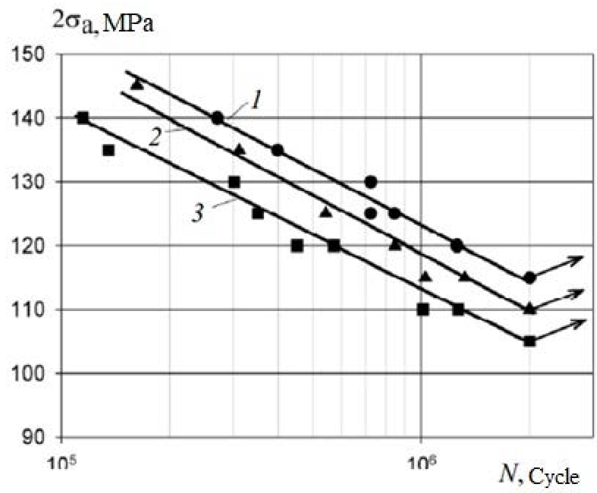

Figure 4. (1) Curves of fatigue of the base material and (2) welded joints obtained by FSW and (3) arc welding with non-consumable electrode.

CONCLUSION

FSW has a number of advantages over traditional welding processes:

- a largely defect-free joining method without hot cracks, porosity or hardening;
- Due to lower temperatures, there is a decrease in shrinkage and deformation in the material to be joined;
- No need for filler materials, flux or shielding gas required for aluminum alloys;
- Safe for the environment, as it does not emit smoke, splashes or ultraviolet radiation;
- Using of machine tool technology, which simplifies the automation process, provides high repeatability and reduces the need for qualified welders;
- The ability to join many “non-weldable" when welding aluminum and aluminum alloys (7xxx series).

While FSW has many advantages, there are several process-related limitations:

- The outlet hole remains after removing the tool from the materials to be joined;
- Huge pressing and movement forces are required during welding;
- Lack of flexibility in manual and arc processes, for example, welding can't be utilized where metals deposition is required.

Experimentally, by obtaining the characteristics of fatigue resistance, the efficiency of using the operations of friction stir welding instead of fusion welding for the manufacturing of structures from the given alloys operating under variable loads has been substantiated. It has been shown that the durability of the butt joints of the sheets of the indicated alloys, made by FSW, practically reaches the level of the base material.

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