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Mechanical characterization of friction stir welded dissimilar aluminium alloy using Taguchi approach

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Highlights

- Alloys of AA7020 and AA8014 used for FSW process.
- 1200rpm, 1400rpm and 1600rpm was used tool speed.
- Welding speed 200, 300 and 400mm/min was utilized.
- Axial force is highly influenced the maximum tensile strength.

Abstract

Friction stir welding (FSW), a type of solid-state welding, joins two metallic workpieces, whether they are the same or different, by plastically deforming the base metal. The metallic workpieces are heated by the friction between them, which results in plastic deformation and welding. The FSW parameters, however, are what primarily determine the weldability and strength of FSW joints. The research on the FSW parameters and their impact on the quality and weldability of aluminium alloys combined with comparable and dissimilar metals by the FSW method has been previously studied, and this review work highlights that research. The majority of comparable research studies concluded that important factors, such as welding speed, rotational speed, plunge depth, spindle torque, shoulder design, base material, pin profile and tool type have a significant impact on the weldability of the aluminium joint when using the FSW method. Aluminium alloy possesses high wear and corrosion resistance; it has to be used in numerous applications such as automobile field, marine and home appliances due to its low weight. This experimental work planned to weld of dissimilar aluminium alloys such as AA7020 and AA8014 through Friction Stir Welding (FSW) process. Taguchi optimization (L9) is considered for this experimental work to examining of mechanical strength such as tensile strength, tensile strength is conducted by using of Universal testing Machine (UTM). FSW parameters are selected as tool speed (1200 rpm, 1400 rpm and 1600 rpm), welding speed (200 mm/min, 300 mm/min and 400 mm/min) and axial force (4 kN, 6 kN and 8 kN). For the tensile strength analysis, the axial force is highly influenced and the maximum tensile strength of 175 MPa is attained.

Introduction

Aluminium alloy commonly used in all applications contrasts with other materials, the aluminium alloy easy to shapes different structures with simple mechanical action. The vehicle body has to be fabricated by using aluminium alloy, similarly used in aerospace applications. In thermal unit boiler construction, heat exchanger units and all boiler accessories are produced by using aluminium alloy. Aluminium alloy is classified into two types namely wrought alloy and cast alloy. Different combinations and different series of aluminium alloys are available such as 1xxx, 2xxx, 3xxx, 4xxx, 5xxx, 6xxx, 7xxx and 8xxx [1]. The procedure of welding is used to permanently combine various materials, and welding of Al and Mg alloys, both comparable and dissimilar, has gained substantial study attention. The primary focus today is on replacing heavy alloys with light alloys with FSW for weight reduction and fuel efficiency in automobiles, as well as for high-strength joints in electric tools, maritime equipment, space shuttles, turbines, and agricultural machinery. FSW is a solid-state welding process that produces materials with superior mechanical and microstructural qualities to those produced by traditional methods. Al with a density of 2.7 g/cm3 and its alloys are regarded as lightweight alloys and are easily accessible. They are also used extensively in packing films, power and electronic equipment, vehicle appliances, wind and solar power controllers, and other products [2]. Al alloys from the AA series have excellent qualities, such as being lightweight, very strong, naturally highly conductive, anti-erosion, and environmentally benign. Another prevalent element in saltwater is magnesium, which has a density of 1.74 g/cm3 and is lighter than aluminium [3]. Mg is thus a component utilised in the shipbuilding, car, and aerospace sectors. The qualities of magnesium alloys are respectable, including their specific strength, sound-dampening capacity, formability, and reusability. On the other hand, Mg's HCP crystal structure [4] causes it to have lower hardness, strength, fatigue, stiffness, creep, and corrosion-resistance qualities at ambient temperature. The use of various H13 tool steel tool profiles and welding settings was done, and the joint flaws were examined [5]. The parametric modelling approach was used to characterise the temperature details of FSW and processing for the AZ31-Mg alloy. The results were helpful in replicating weld temperature for processing a variety of metals and alloys. With FSW, two 6 mm thick plates of magnesium alloy AZ91 were bonded together at speeds ranging from 28 to 56 mm per minute while rotating the tool at 710 to 1400 rpm. Defects were spotted using optical, fluorescent penetrant, and tensile tests. A threaded straight cylindrical pin profile with an 18 mm shoulder diameter, a 710 rpm rotating speed (R s), and a 28 mm/min wedging speed (WS) was used to achieve sound joints. For FSW of Mg alloy AZ91, the tapered cylindrical pin profile proved inappropriate [6]. The plate thickness of the alloys Mg (AZ31B) and Al (AA6061) was 6 mm, connected by FSW. Greater tensile characteristics and efficiency (89%) were seen in joints with 21 mm shoulder diameter than with lower-strength BM [7]. FSW was used to combine Mg AZ31B-H24 and AA6061-T6 Al, with pin ranges ranging between 3.25 mm and 3.75 mm and welding speeds (WS) between 600 and 1000 rpm. At WS 4.25 mm pin, tunnel flaws were generated at 800 and 1000 rpm [8]. Intermetallic phases that develop during dissimilar welding using conventional welding are problematic because, depending on the thickness, they may substantially jeopardise the integrity of the junction [9]. Recently aluminium alloys are welded by different welding processes namely Tungsten Inert Gas welding (TIG), Metal Inert Gas welding (MIG), Plasma Arc Welding (PAC), Submerged arc welding, Laser beam welding etc [10]. Newly introduced the welding process for welding dissimilar materials is named Friction Stir Welding (FSW). The effect of processing parameters on the mechanical properties of the weld joint has been the subject of numerous investigations involving the welding of different aluminium alloys using various combinations of processing parameters of FSW, such as tool rotating speed (TRS), welding speed (WS), tool shoulder diameter, tool tilt angle, and tool pin profile, among others. [11]

examined the influence of TRS, WS, and five-pin profiles with a constant tool pin angle of 2° on the tensile strength, hardness, and microstructure of dissimilar AA2041/AA6061 weld joints. [12] investigated the impact of twin pin profiled tools with various TRS and WS on the welding of dissimilar AA2041/AA6061. [13] investigated the solid-state flow during FSW of AA6061 and AA2024. [14] discovered the influence of the advancing side of position on the ultimate tensile strength (UTS) of different AA2041/AA6061. [15] examined the influence of TRS, WS, and tool tilt angle on the joint efficiency of AA5083 and AA6082 by comparing the results of identical welding of AA5083 and 6082 with dissimilar weld joints of both materials. [16] have incorporated Tic micro and nanoparticles to improve the mechanical qualities of the welded junction. Also explored [17] was the influence of TRS, WS, and tool tilt angle changes on joint strength. To facilitate filling and handling, reinforcement particles were combined with ethanol, demonstrating the effect of TiC reinforcement on corrosion resistance. [18] improved the TRS and WS process parameters for FSW. Shoulder diameter and pin profile utilizing the Taguchi technique for optimization of a single reaction and the grey relation with weight approach for optimization of multiple responses. [19] examined the influence of the constant ratio of TRS to WS on the mechanical characteristics of triangular and pentagonal tool pins. Many studies have investigated the combining of aluminium alloy 5083 and aluminium alloy 6061 since both are widely utilised in the maritime industry [20]. FSW of AA5083-O with 6061-T6 was performed at four different tool rotation rates of 450, 560, 710 & 900 rpm, and the joint strength was compared to that of fusion welding, i.e., TIG and MIG welding with a filler rod of AA4043 [21], [22]. The FSW of AA5083/AA5083, AA6061/AA6061, and AA5083/AA5083 was compared at tool rotational speeds of 630 and 1600 rpm and at welding speeds of 16, 25, and 40 mm/min. To execute dissimilar welding of AA6061/AA5083, AA 6061 was placed on AS. 13 tests were conducted to create joints of AA6061 and AA5083 that were similar and distinct [23]. joined AA5083-H321 with AA6061; both have a thickness of 5 mm at four different WS of 40, 63, 80, and 100 mm/min with a constant TRS of 1120 rpm, a 2.5-degree tool tilt angle, and axial force with AA6061 on AS and AA5083 on RS for all trials [24].Though many dissimilar welding methods and different dissimilar aluminium alloys joint performed were reported in the literature, the unanswered question is: can alluminimum alloys like AA7020 and AA8014 join effectively? If so high finish and weld strength could be achieved? Which process will be better to join them? This investigation novelly chooses friction stir welding and tests to optimize the process parameters to maximize the welding strength.

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Hence the welding process is highly precise and adaptable for automation, main advantage of this welding is no need for filler material and electrodes for the joining of materials. The friction stir welding process is less time-consuming on processes and offered excellent joint strength. The FSW process cannot melt the material while in operation hence the microstructural properties are not affected and enhance the welded area. During the welding process, heat can be produced between the tool and the workpiece.

Section snippets

Experimental procedure

The aim of this research is to explore the potential possibilities of joining dissimilar metals and maximizing the welding strength by optimizing the process parameters. So the parameters and range of parameters were not only chosen based on the literature support but also on trial experiments. The best performing range of parameters considered for optimizing. This welding process is carried out in straight lines and longitudinal movement. At the time of welding the materials joining area has

Results and discussion

To increase the tensile strength of welded samples after FSW, process parameters in this study were optimised using the Taguchi method. Signal-to-noise ratios are created using the Taguchi method using experimental measurements. To maximise the responsiveness, larger-is-better signal-to-noise ratio (S/N ratio) requirements were used. The best conditions for high tensile strength are demonstrated by the major effect plots in Fig. 2 and the S/N ratios in Table 2. Additionally, Fig. 2 and Table 2

Conclusion

The FSW technique is discussed in this paper for joints between dissimilar aluminium alloy components used in the structural application of marine and other high-tech industries. The Taguchi approach was used to determine the optimal level of the process parameters in FSW and to assess each factor's contribution. The dissimilar aluminium alloy (AA7020 and AA8014) joints were produced successfully by using Friction stir welding and the tensile strength was analyzed, The findings of the current

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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