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Manufacturing of Aluminum Thin Cylindrical Parts By Using Friction Stir Welding Method

Ahmad Reza Sabet[1], Hamid Montazerolghaem[1, 2*]
[1]Department of Mechanical Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[2]Modern Manufacturing Technologies Research Center, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[*]Email of Correspanding Author: Montazerghaem@pmc.iaun.ac.ir
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Abstract
Recently friction stir welding for manufacturing of welded tubes has been developed. Friction stir welding is a continuous solid state welding process in which a non-consumable rotating tool using severe plastic deformation Can join materials can be join materials. Commonly, a portion of a specially shaped rotating tool is plunged between metalsjoint cross section and adjacent faces of the joint. After entering the rotating tool on the weld, a relative movement between the rotating tool and the friction heating surface creates a plastic deformation zone around the submerged sections of the tool. The work piece will be heated during the friction stir welding, but the work piece temperature will not reach to the melting point. One of the major problems for manufacturing the thin cylindrical tube is related to low mechanical strength while the melting method such as laser is applied. In this research, it is reveals that the friction stir welding method can be a reasonable technique for manufacture of thin cylindrical parts. In this paper, an attempt was made to show the possibility of frictional stir welding for manufacturing of thin cylindrical AA 6063aluminum parts. Various ranges of welding parameters include of rotation speed and welding speed are implemented to the thin thickness bent sheet i.e. 1.5 mm.By considering on obtained cylindrical tubes, it is found that the sound seem thin tube is achieved in rotational speed of 2500 rpm and welding speed of 4 mm/min respectively.

Keywords
Friction Stir Welding, Aluminum, Welding Parameters, Thin Tube

1. Introduction

Friction stir welding is a solid-state process in which continuity is done by Non-consumable rotating tool [1]. The tool includes various factors such as pin and shoulder provide rotation and movement in adjusted speeds, which cause plastic deformation under the shoulder of the tool due to severe friction. Thedeformed material under the shoulder is rotated by a pin and moved along the weld line[1, 2]. This is a combination of heating and frictional pressure for joining metal plates that are against each other [3]. A lot of researches have been done on extending this process for aluminum alloys, but there are relatively few amounts of aluminum tube welding [4, 5]. In Friction stir welding, the required temperature is generated through non-consumable rotating tool and then it moves the material and creates a new connection in the weld line [6]. There are many advantages that friction stir welding can offer compared to fusion processes, such as low distortion, very good mechanical properties in the weld area, and the ability to weld all aluminum alloys [7]. Some researchers analyzed the effect of the tool rotation speed [8, 9], as well as welding speed [10, 11] and relatively few researchers had been focused on both parameters simultaneously. Some published papers also analyzed the microstructures and mechanical properties of the obtained welds [12, 13]. Karthikeyan and Kumar examined the relationship between the process parameters, i.e tool dimension, tool rotation speedand welding speed, and the mechanical properties of the AA6063-T6 aluminum alloy [14]. Fu and et. al used the FSW process to join the aluminum alloy 6061T6 aluminum to AZ31B magnesium alloy [15]. Investigating the mechanical properties of aluminum tubes to demonstrate the possibility of friction stir welding for joining the similar aluminum 6061 tubes with thicknesses of 2, 3 and 4 mm longitudinally together was performed in several rotational speeds of the tool and welding speed [16, 17]. To the best knowledge of the authors there are no researches on longitudinally friction stir weld of thin bent sheets. Current research shows the possibility of frictional stir welding for manufacturing of thin cylindrical AA 6063 aluminum parts. Various ranges of welding parameters include of rotation speed and welding speed are implemented to the thin thickness bent sheet.

2. Materials and Method

The pieces used in this experiment are sheets made of commercial aluminum AL6063 with dimensions of 60mm×150 mm× 1.5 mm that were used in order to produce cylindrical pieces. The sheets used here are firstly bent in the shape of a cylinder parts using conventional rolling machine and then are welded by the use of frictional stir welding. The mechanical properties and the chemical compounds of the raw materials are illustrated in Table 1 and 2.

Table1. Mechanical properties of the aluminum sheets used in this study

Trade Mark	Type of heat treatment	Maximum Yield Strength (MPa)	Elasticity (%)	Yang Modules (GPa)
AL6063	O	149	5.7%	68.3

Table2. Chemical properties of the aluminum sheets

Series	Alloy	Fe	Cu	Mn	Mg	Cr	Zn	Tr	Si
6000	6063	0.35	0.1	0.1	0.45-0.9	0.1	0.1	0.1	0.2-0.6

For tailor friction stir welded Tubes, tool is made ofTungsten Carbide,in the form of a cylindrical pin. The diameter of the pin used was 2 mm and the shoulder diameter was 5 mm with a pin length of 1.3 mm as shown in Figure1. The schematic view of designed and manufactured tool is shown in Figure2.

Figure1. The designed and manufactured tools

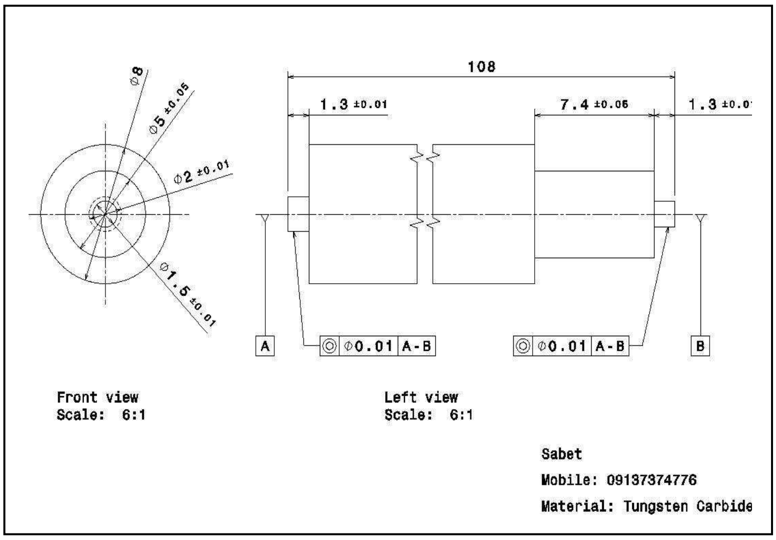

Figure2. Schematic view of manufactured tool

A suitable cylinder was designed, manufactured and used to apply longitudinal friction stir welding in aluminum curved bent sheet. In order to position the tested parts for the friction stir welding, 22 mm diameter cylindrical steel was used and the bent sheet is clamped in the customized fixturesothat the longitudinally welding operations can be done well as shown in Figure 3.

Figure3. Implementation of frictional stir welding process

During the welding process, the depth of the penetration of the tools was kept constant to a value of 1.45 mm. Many different experiments were primarily carried out in a wide range of welding and rotational speeds to obtain the suitable welding conditions. The full factorial experiments were carried out. Due to the adjustment of the rotational speed and welding speed, various weld qualities were obtained. The visual and macroscopic investigation was used for welded tubes.

3. Results and Discussions

A typical welded parts using friction stir welding method is shown in Figure4.

Figure4. Welded piece using frictional stir welding tube process: a) Rotational speed of 2000 rpm and welding speed of 12mm/min b) Rotational speed of 2500 rpm and welding speed of 8 mm/min c) Rotational speed of 2000 rpm and welding speed of 4 mm/min d) Rotational speed of 1600 rpm and welding speed of 8 mm/min

Figure 5 presents the macroscopic view of cylindrical welded cross section in various welding parameters.As reported in previous studies [18, 19] as well as friction stir welding of sheets and conducted results in this research for friction stir welding of thin tube, at very low welding speed, a rippled morphology of the top surface of the weld was observed. The formation of such rough seam is likely due to the material overheating, thereby its overflow. On the other hand, when the welding speed was increased or the tool rotation speed was decreased, i.e. the increase ofwelding pitch (the ratio of welding speed to rotational speed), the formation of defects can be appeared in the weld as seen in Figure 4, 5. In general, it was found that there was a range of welding parameters in which high-quality welds were obtained.Therefore, in order to obtain the flawless parts of the first series of experiments, it can be concluded that the range of experiments should be performed in the rotation speed between 2000rpm to 2500 rpm and welding speed with a range of 4mm/min to12mm/min. After conducting the non-destructive tests such as visual inspection and microscopic evaluations, it could be concluded from the experiments that the most suitable circumstances for executing the friction stir welding had been provided for the rotational speed of 2500 rpm and welding speed of 4mm/min.

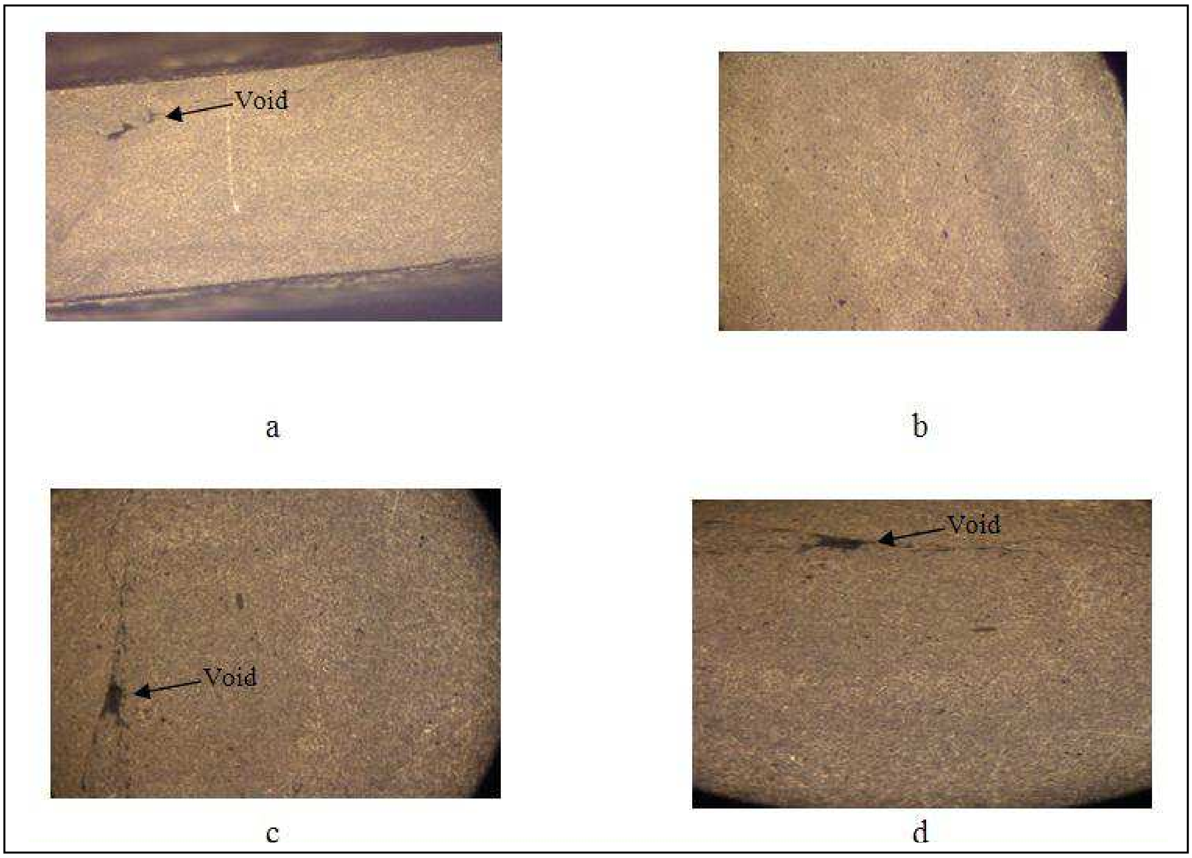

Figure5. The macroscopic view of welded cross section in various welding parameters: a) Rotational speed of 2000 rpm and welding speed of 12mm/min b) Rotational speed of 2500 rpm and welding speed of 8 mm/min
c) Rotational speed of 2000 rpm and welding speed of 4 mm/min d) Rotational speed of 1600 rpm and welding speed of 8 mm/min

The sound manufactured cylindrical partwhich was obtained is pictured in Figure 6.

a b

Figure6. Manufactured part in appropriate friction stir welding condition,rotation speed of 2500 rpm and welding speed of 4 mm/mina) The sound cylindrical part,b) cross section of the welded tube

It was concluded that the tool rotation and welding speeds combinations were considered regarding the fact that by increasing welding speed, rotational speed should simultaneously increase to moderate any defects in the joint. Alsoknowing that increasing tool rotational speed or decreasing welding speed will lead to enhance the stirring effect which results in improving the welding quality. In comparing of friction stir welding of thin bent sheet (to manufacture of thin tube) and flat sheet, it can be revealed that for welding of bent sheet due to the less contact surface between the tool and workpiece, the produced heat should be higher than the welding of flat sheets. On the other hand, it was concluded that the ratio of the tool rotation speed to the welding speed should be increased in manufacture of thin cylindrical tubes using friction stir welding. From performed experiments, it can be resulted that for increasing the contact surface between tool and bent sheet the plunge depth for welding of bent sheet should be more than implemented plunge depth in welding of flat sheet to achieve the sufficient material stirring and adequate generated heat input.

4. Conclusion

By carefully examining the obtained data, the following points will be briefly mentioned:

1) The appropriate range for the progressive and rotational paces was obtained to produce the thin cylindrical tubes by using frictional stir welding operations.

2) The proper friction stir welding condition to obtain the sound cylindrical part was rotational speed of 2500 rpm and welding speed of 4 mm/min while the plunge depth was 1.45 mm.

3) It was found that for friction stir welding of bent sheet due to prepare the heat input and material stirring, the higher tool rotation speed beside the lower welding speed, i.e. higher welding pitch, was needed in compare of friction stir welding of flat sheet.

4) In manufacture of thin cylindrical tube using friction stir welding of bent sheet, the plunge depth can be increased rather than friction stir welding of flat sheen.

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