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Manufacturing a Single Ultrasonic Tool Set of Vibrational friction stir welding in Bending and Axial Modes

A. Rezaei Shahreza, S. Amini*

Department of Mechanical Engineering, Kashan University, Kashan, Iran

ABSTRACT: Friction stir welding has been categorized amongst permanent joining methods. Since its thermomechanical nature, solid-state joining and high welding loads, Friction stir welding process needs sturdy tools, fixture, and machine tool. Combination of this process along with ultrasonic vibrations decreases welding loads and improves the weld quality. In this study, the idea of comparing superimposed axial and bending ultrasonic vibrational modes on friction stir welding process led to producing a unique set of friction stir welding tool along with an ultrasonic transducer. In fact, one of the aims of this study concerns designing a single ultrasonic assisted friction stir welding tool set which will be able to vibrate in both axial and bending modes separately in different frequencies. In addition, the impressive effects of mass and inertia variations on the weld, due to the usage of the distinct tool set for each modal frequency, will be removed. The final modal analyzed model was manufactured and the amplitude of vibrations in both mentioned modes was measured experimentally. Results indicated that the use of bending vibrations leads to the formation of joints with much more quality than implementing the axial vibrations. Furthermore, doubled amplitudes from 8 μm to 16 μm in bending mode, unlike axial mode, improved the weld ultimate tensile strength.

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1- Introduction

Hybrid application of ultrasonic vibrations assisted different production methods like forming, machining, welding, etc. and has helped effective parameters of the processes. Investigations revealed that superimposing ultrasonic vibrations improves surface finish while forming and machining loads are decreased [1-5]. The other application is related to applying ultrasonic vibrations on Friction Stir Welding (FSW) process. FSW process is a thermomechanical and solid-state permanent joining method which beside its advantages, huge amount of the welding loads is one of its deficiencies. Superimposing ultrasonic vibrations on FSW process have been conducted by several researchers to improve the welding process parameters.

Side and axial vibrations on the FSW tool were applied to the Aluminum 6061-T6 as a workpiece by Park [6] and Liu et al. [7], respectively. Whereas, the effects of bending vibrations on FSW process were examined by Amini et al. [3]. Generally, their results showed the use of vibrations enhances weld quality and reduces plunge welding loads by increasing weld zone temperature.

In order to adopt the more effective type of vibrations among axial and bending modes, the design of a single UaFSW tool set (FSW tool along with ultrasonic transducer), capable of vibrating in the mentioned modes, which makes a correct comparison is inevitable. The idea of using a single UaFSW tool set helps to remove mass difference effects of applying separate tool sets for each vibrational modes due to their varied dimensions. Thus, this study focuses on the design and manufacturing a single UaFSW tool set, which will be able to vibrate in both axial and bending modes separately in different frequencies but close to each other (not further than 3 kHz). Finally, the amount of amplitude effect for both vibrational types on Aluminum 6061-T6 plates with the thickness of 3 mm will be investigated.

Corresponding author, E-mail: Amini.s@kashanu.ac.ir

2- Methodology

2- 1- Design of UaFSW tool set

To compare ultrasonic vibration effects in axial and bending modes on FSW process, two distinct methods of tool and transducer design were taken into consideration. The first method was the design of two separate tool set for each mode, operating on resonance frequency equal to 20 kHz. Modal analysis results indicated a dimensional difference around 40 mm for the two tool sets, which could affect the amount of kinematic energy exerted to workpiece due to the varied tool set mass and inertia variations. Thus, the second method was implemented, indicating the use of single tool set capable of vibrating in both axial and bending modes in different frequencies but close to each other.

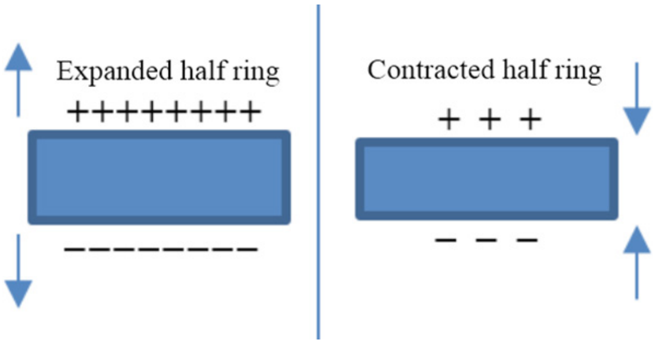
To produce ultrasonic bending vibrations, two sets of half piezoelectric rings were used, as shown in Fig.1, in which each half was actuated with 180° phase difference in respect to the other half. For axial mode, both halves were actuated without a phase difference. It should be noted that piezoelectric rings were cut by water jet machine.

MPI ultrasonic generator was used to generate high power AC electrical signals. Since the generator has just one output, to actuate piezoelectric rings in a bending mode, a transformer was devised which is capable of producing two AC outputs with 180° phase difference.

2- 2- Toolset design and experimental amplitude measurement

Modal analysis of the tool set was performed in ABAQUS software, considering ultrasonic transducer design constraints such as the position of tool set flange in the vibrational node for both modes. The tip of the tool set should be in a maximum amplitude, etc. [8, 9]. As Fig.2 shows, after extensive tries,

(a)



(b)

Fig. 1. (a) - Isometric view of 2 halves of a whole piezoelectric ring, (b)- Contraction and expansion for each half, due to actuation with 180° phase difference.

the final numerical model capable of vibrating in resonance frequencies of 19800 and 23800 Hz in bending and axial modes, respectively, was manufactured. Then, the amplitude of vibrations was measured experimentally using gap-sensor with the model number of PU-02A. The test results indicated an equal amplitude of 16 μm for north and south edge of tool tip in both vibrational modes.

2- 3- Experimental setup

As Fig.3 shows experimental UaFSW setup was mounted on a lathe machine tool. The effects of bending and axial amplitude amounts in 3 levels of 8, 16 μm and without vibration on an axial load of the UaFSW tool set in both plunge and welding phase, tool tip temperature and weld tensile strength were investigated in three levels of 0.08, 0.16 and 0.24 mm/rev welding feed rates.

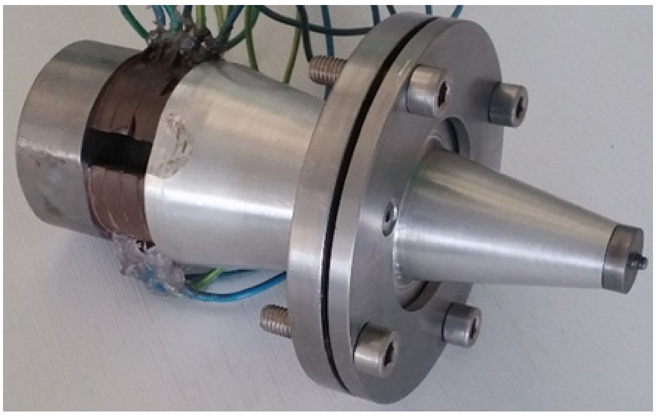


Fig. 2. Assembled UaFSW toolset

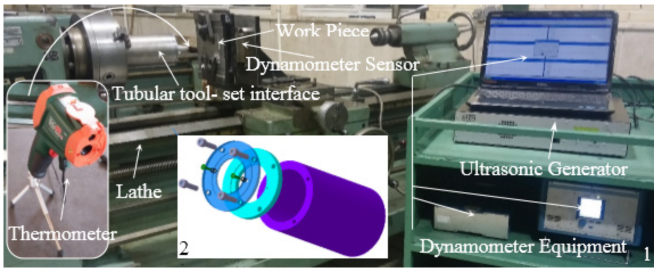


Fig. 3. 1- Experimental set up of UaFSW process, 2- Tubular interface between the toolset and the lathe chuck

3- Results and Discussion

Weld load, temperature and strength evaluations on UaFSW samples revealed the following results:

3- 1- Effects of amplitude and types of vibrations on loads of welding and plunge phase

In the plunge phase, superimposing ultrasonic vibrations in both modes plunge load with the decrease of 1300 and 700 N was reported for axial and bending modes, respectively. In welding phase, superimposing bending vibrations increases tool axial load, whereas axial vibrations reduce it. Welding feed rate increase enlarges weld load for each vibrational modes. Also, the doubled amplitude of vibrations reduces axial tool loads of both plunge (about 200 N) and welding phases.

3- 2- Effects of amplitude and types of vibrations on tool tip temperature

Added ultrasonic energy to the weld zone s in both modes leads to increasing tool tip temperature. The temperature in axial mode is reported higher than bending mode. Since in axial mode the whole tool button vibrates, while in bending mode, just 2 points of tool shoulder edge vibrate in maximum amplitude.

3- 3- Effects of amplitude and types of vibrations on the weld strength

The results of uniaxial tension tests revealed that the strength of bending and axial UaFSW samples increases around 10 percent and decreases around 20 percent, respectively. In bending UaFSW samples, higher amounts of weld strength is justified by a better plasticized material stirring, in comparison with axial UaFSW samples. Also, the best weld strength is concerned with the bending UaFSW sample with the highest welding feed rate (=0.24 mm/rev). That means, using bending vibrations assisted FSW process, improves the welding velocity.

Also, the variance analysis of the mentioned output data revealed that there are meaningful relations between input parameters variations and the outputs.

4- Conclusions

Superimposing ultrasonic vibrations in bending mode, in contrast to axial mode, improves the weld strength especially by doubling the vibration amplitude. Also, due to its better martial string pattern, higher welding velocities could be achieved.

References

[1] A. Barani, S. Amini, H. Paktinat, Built-up edge investigation in vibration drilling of Al2024-T6, *Ultrasonics*, 45 (2014) 1300–1310.

[2] R. Nosouhi, S. Behbahani, S. Amini, M. R. Khosrojerdi, Experimental and analytical study of the elliptical vibrationassisted turning process with the dynamic friction model, *Engineering Manufacturing*, 228 (6) (2014) 837–846.

[3] S. Amini, M. Mohammad Nazari, A. Rezaei, Bending vibrational tool for friction stir welding process, *Int J Adv Manuf Technol*, 222 (2015) 91-95.

[4] S. Amini, M.R. Amiri., A. Barani, Investigation of the effect of tool geometry on friction stir welding of 5083-O aluminum alloy, *Int J Adv Manuf Technol*, 76 (1-4) (2015) 255–61.

[5] M. Vahdati, R. Mahdavinejad, S. Amini, A. Abdullah, K. Abrinia, Design and manufacture of vibratory forming tool to develop ultrasonic vibration assisted incremental sheet metal forming process, *Modares Mech Eng*, 14(11) (2014) 68–76. (in Persian).

[6] K. Park, *Development and Analysis of Ultrasonic assisted friction stir welding process*, The University of Michigan, (2009).

[7] X. Liu, C.Wu, G. Kumar Padhy, Characterization of plastic deformation and material flow in ultrasonic vibration enhanced friction stir welding, *Scripta Materialia*, 102 (2015) 95–98.

[8] D. Ensminger, L. J. Bond. *Ultrasonics, Fundamentals, Technologies and Applications*. 3rd ed: CRC Press, D. Ensminger, L.J. Bond, Ultrasonics, Fundamentals, Technologies and Applications, 3rd ed: CRC Press, Taylor & Francis Group, (2012).

[9] K. Nakamura, *Ultrasonic Transducers: Materials and Design for Sensors, Actuators and Medical Applications*, 1st ed: Woodhead Publishing, (2012).

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