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Author: Y.B. Zhong C.S. Wu G.K. Padhy

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Effect of ultrasonic vibration on welding load, temperature and material flow in friction stir welding

Y. B. Zhong, C. S. Wu*, G. K. Padhy

MOE Key Lab for Liquid-Solid Structure Evolution and Materials Processing, and Institute of Materials Joining, Shandong University, Jinan, 250061, PR China

*Corresponding author. Tel./Fax: +86 531 88392711. *Email address*: wucs@sdu.edu.cn

Abstract: The main process variables were measured, characterized and compared in friction stir welding with/without ultrasonic vibration. The exerted ultrasonic vibration causes reduction in traverse force, tool torque and axial force of welding. Based on the measurement of thermal cycles in friction stir welding process, the thermal effect of ultrasonic vibration is negligible, and the mechanical coupling between ultrasonic vibration and tool action plays a more important role in affecting both the welding process effectiveness and the joint quality. Ultrasonic vibrations improved weld formation by either reducing or eliminating the weld defects, and the suitable process-parameter window is expanded. Dissimilar welding of AA6061-T6 to AA2024-T3 with ultrasonic vibration was used to characterize the enhanced material flow which results in the better weld formation.

Keywords: Friction stir welding; Ultrasonic vibration; Material flow; Welding load; Thermal cycle measurement

1. Introduction

Friction stir welding (FSW) is a solid state joining process, widely employed for the joining of aluminium and magnesium alloys. The working principle of FSW process is well documented. During the FSW, a rotating tool consisting of a profiled shoulder and a pin plunges into the faying faces of workpieces and dwells for 5-10 s. In the dwelling stage, the workpiece ahead of the tool is plasticized by the heat generated during tool-workpiece interaction and workpiece deformation. Next is the travelling stage where the tool is traversed along the faying faces at a constant rate. In this stage, the plasticized material in front of the tool is extruded and transferred to the back of the tool. This enables material mixing at atomic scale and produces a joint behind the tool. Although the FSW is a proven joining process of soft metals, Arora et al. (2012) have pointed out that it is associated with low welding speed and high welding loads, which reduce the productivity and energy efficiency of the process. DebRoy et al. (2012) have shown that unsuitable welding parameters cause inadequate heat generation which often leads to premature failure of the tool pin, especially in the joining of harder alloys. Specific tool materials and tool designs partly solve the above problem but such tools are expensive. Besides these, vivid research activities are under progress to make the FSW process feasible and sustainable for the joining of high-temperature materials such as steels and titanium alloys. According to a recent review by Padhy et al. (2015), various auxiliary energies were employed during the FSW process to reinforce the heat generation and other associated phenomena. Fei et al. (2016) employed laser as a secondary heat source in the FSW of Q235 steel to 6061-T6 aluminum alloy to study the effect of pre-hole offset on joint quality. Joo (2013) utilized a preceding gas tungsten arc