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Formability analysis of dissimilar tailor welded blanks welded with different tool pin profiles

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Abstract: An attempt has been made to study the tailor welded blanks (TWBs) made by friction stir welding (FSW) with five different tool pin profiles. The formability of welded blanks was evaluated at constant FSW process parameters. It has been found that the welded blanks with square pin profile tool produced better formability properties as compared to other tool pin profiles. It was found that the pulsating action of the square pin profile is said to be the reason for this improvement. A microstructural evaluation performed on the blanks revealed that the stir zone created by taper cylindrical and stepped cylindrical tools was less homogeneous than that of the square tool, resulting in less formability. The limiting dome height (LDH) of square pin profile tool was found to be 14 mm while those of taper cylindrical and stepped cylindrical tools are 12.5 mm and 12.4 mm, respectively.
Key words: aluminium alloys; tool pin profile; tensile testing; formability; microstructure

1 Introduction

Tailor welded blanks (TWBs) are mainly used in aerospace and automotive industries where lightweight parts are needed to meet economic and environmental benefits with high specific strength. Generally, TWBs are made with different materials, thicknesses, mechanical and microstructural properties. These blanks are welded together with suitable welding process and then formed into desired shapes before fabrication. Researchers made tailor welded blanks with different welding processes such as arc welding, laser welding and friction stir welding [1,2]. The fact that the welded blanks made with FSW process exhibit better weld properties than the blanks welded with other welding techniques is due to the stirring and extrusion action of the FSW tool, which produces equiaxed grains in the weld zone [3]. Tool pin geometry can be considered as the main parameter in the FSW process [4], because the pin stirs the material around it and avoids the formation of voids in the weld zone [5]. The tool pin profile decides the flow of plasticized material during the welding operation [6,7]. For better weld quality, adequate amount of metal has to be stirred and swept by the tool pin [8]. XU et al [9] studied the effect of process parameters and the tool pin profiles on the FSW process of AA2219 aluminium alloys. The results reveal that the tool pin profiles affect the tensile strength and ductility of welded blanks. VIJAY and MURUGAN [10] obtained higher tensile strength with square pin profiled tool than the other pin profiles. They attributed the pulsating stirring action of the square pin and dynamic volume to static volume ratio to be the reasons for this high strength. Recently, MORTEZA et al [11] have conducted FSW with H13 tool to weld dissimilar 5083 and 6061 aluminium alloys, and evaluated the formability with the LDH test. They observed that the failure occurred in the AA6061 blank side. According to PALANIVEL et al [12], the fact that the dissimilar welded aluminium blanks can be successfully welded with the FSW process and straight square pin profile tool to get better results than other pin profile tools is due to the pulsating action of the square pin. In the present work, tool pin profiles, which are simple and easy to manufacture, such as straight cylindrical (SC), taper cylindrical (TC), stepped cylindrical (ST), straight square (SS), and straight hexagonal (SH) profiles, have been used. The aim of the present work is to evaluate the formability properties of TWBs made with the above mentioned tool pin profiles.

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2 Experimental

Rolled plates of aluminium alloys AA6061-T6 and AA2014-T6 were used as base materials (BM) in the present work. The chemical compositions of base materials are shown in Table 1. The mechanical properties of base materials are shown in Table 2. The FSW was done with vertical milling machine by fixing the AA6061 blank on advancing side (AS) and AA2014 blank on retreating side (RS) on the machine table with bolts and clamps to constrain the movement of blanks during welding. The machine table can be moved in *X*-axis and *Y*-axis directions. Some FSW experiments were conducted to obtain the optimum process parameters to make welded blanks. Tool rotational speed of 900 r/min, welding speed of 24 mm/min and tool tilt angle of 1° have been used as process parameters. A non-consumable, H13 tool steel has been used as the FSW tool. Five different tool pin profiles were used to perform the friction stir welding, namely straight cylindrical (SC), taper cylindrical (TC), stepped cylindrical (ST), straight square (SS), and straight hexagon (SH), are shown in Fig. 1.

After welding, tensile test was performed on specimens to evaluate the tensile properties and these were extracted transversely to the weld direction and ASTM E8M standard guidelines were followed to prepare the specimens. In tensile testing, yield strength, tensile strength and elongation of each specimen were evaluated at room temperature on a universal tensile testing machine. Samples for microhardness were sliced from the cross section of the welded blanks and values were measured with Vickers microhardness tester with load of 200 g at dwell period of 10 s in the interval of 1 mm across the weld cross section. The formability of welded samples was analyzed with LDH test on a 50 t hydraulic press at a punch speed of 0.3 mm/s with a hemispherical punch. The hydraulic press and LDH tool set arrangements are shown in Figs. 2(a) and (b), respectively. The square (100 mm × 100 mm) samples

Table 1 Chemical composition of base materials

BM	Mass fraction/%					
	Mg	Si	Cu	Ti	Cr	Al
AA6061	0.60	0.76	0.025	0.017	0.043	Bal.
AA2014	0.46	0.75	3.98	0.026	0.017	Bal.

Table 2 Mechanical properties of base materials

BM	Yield strength/MPa	Tensile strength/MPa	Elongation/%	Micro-hardness (HV)
AA6061	198	273	22	115
AA2014	402	454	12	165

Fig. 1 Photographs of different tool pin profiles

Fig. 2 Hydraulic press (a) and punch, dies and welded blank (b)