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DESIGN OF EXPERIMENT STUDY OF FRICTION STIR WELDING OF ALUMINUM ALLOY 6063

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Abstract - *Design of experiments using Taguchi L16 orthogonal array was applied to study the effect of different process parameters on tensile strength of friction stir welded joints. Different process parameters namely tool rpm, welding speed and pin diameter were studied. Tensile strength of welded 5mm thick aluminum alloy 6063 was determined and it was observed that welding speed, tool rpm, tool shoulder diameter and tool pin diameter significantly affected the joint strength.*

Introduction

Friction stir welding (FSW) was invented by TWI in 1991 and has been observed to be particularly suitable for joining aluminum and its alloys [1,2]. Some recent applications on FSW of steel have also been reported [3]. Additionally, friction stir welding has been found to be an ideal process for joining dissimilar non-ferrous alloys [4]. Various modification of friction stir welding including use of vibration has been reported to improve the weld quality [5].Various authors have reported beneficial effect of using FSW compared to conventional joining techniques [6, 7]. Effect of process parameters has been subject of great interest and many researcher have reported studies in this area [8-10]. This study reports the use of Taguchi method to present the results of main FSW parameters on tensile strength of AA6063 weld joints.

Experimental procedure

A vertical milling machine was adapted to weld 5mm thick of commercially available 6063 aluminum alloy. The chemical composition and mechanical properties of this alloy are listed in Table 1 and 2 respectively. Aluminum alloy plates measuring 150 mm x 75 mm were joined together to achieve a 150 x 150 mm2 joint. Trial runs were conducted initially to determine the possible range of process parameters. Based on trial runs, were levels of each parameters were selected and these are listed in Table 3. Three tensile samples were cut from each plate and tested to ascertain the joint strength. Tensile samples dimensions were determine din accordance with subsize geometry listed in ASTM E8 standard. Tensile tests were carried out art a constant displacement rate of 5 mm/min.

Table 1: Chemical composition of aluminum alloy 6063

Mg	Fe	Si	Cr	Cu	Al
0.4	0.4	0.6	0.15	0.1	balance

Table 2: Mechanical properties of aluminum alloy 6063

Ultimate tensile strength (MPa)	Yield Strength (MPa)	Elongation (%)	Young's modulus (GPa)
210-230	170-190	10-12	69

Additionally, two samples measuring 25 mm x 150 mm were cut perpendicular to the welding direction for rough polishing and bend testing. Since, the milling machine was manually operated and it was difficult to maintain a constant tool plunge depth. Three welds showed the presence of root defects after U bend testing.

Table 3: Process parameters and selected levels

Parameters	Level 1	Level 2	Level 3	Level 4
Welding speed	45	60	75	90
Tool rpm	200	250	300	350
Tool shoulder diameter	10	12	14	16
Tool pin diameter	4	5	6	7

Results and discussion

ANOVA analysis of the welding experiment was conducted using standard spreadsheet software and the results are shown in Table 4. It was observed that welding speed was the most significant factor affecting the joint strength. Increasing welding speed results in reduced heat input per unit length of the weld and improves the tensile strength of the joint. As can be seen from Fig 1(a), the increase in strength is not substantial for highest welding speed. This can be attributed to presence of defects/ improper joint formation due to less tool rpm values, not commensurate with very high welding speeds. Fig.1 (b and c) show a reduction in reduction in tensile strength with increase in tool rpm and shoulder diameter due to increased heat input. Furthermore, too much plasticity on account of higher heat input also increased the flash and in accordance too much material was extruded out from the weld nugget region resulting in defects inside. In case of pin diameter the contribution to heat input was less and best results were achieved for 5 mm diameter value.

Table 4: ANOVA for mean effects of parameter

Source	DOF	Seq. SS	MS	F	%Contribution
Welding Speed	3	1.1	0.36	10.5	41.8
Tool rpm	3	0.51	0.17	5	19.7
Tool shoulder diameter	3	0.45	0.15	4.5	17.6
Pin diameter	3	0.43	0.15	4.4	17.4
Residual error	3	0.1			3.5
Total	15				100

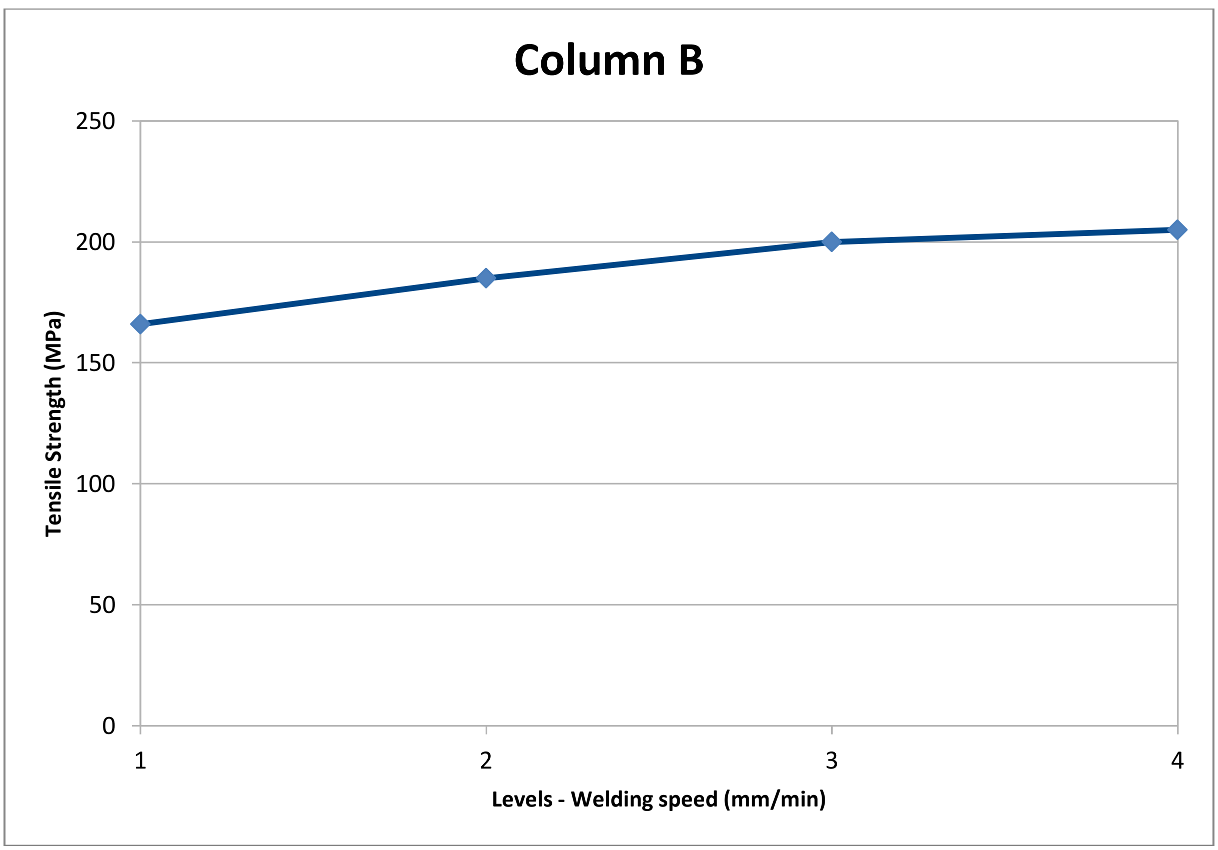

Fig. 1(a): Tensile strength as a function of welding speed

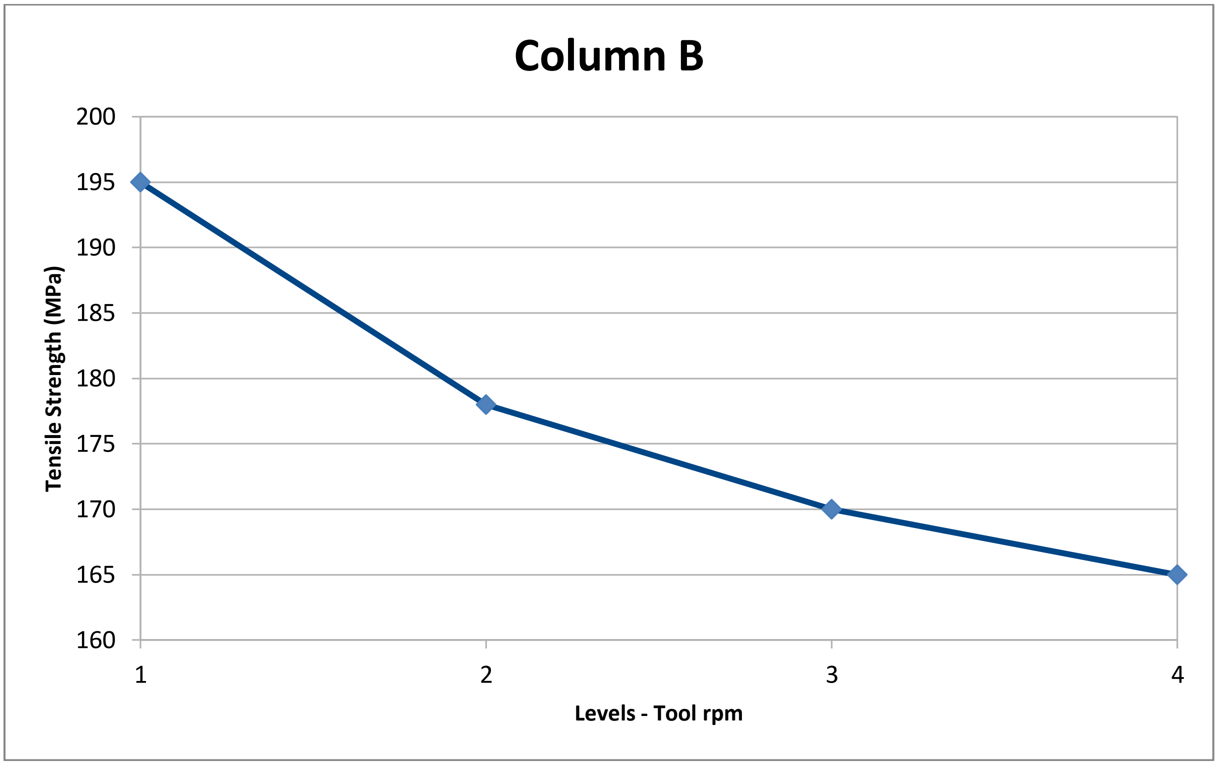

Fig. 1(b): Tensile strength as a function of tool rpm

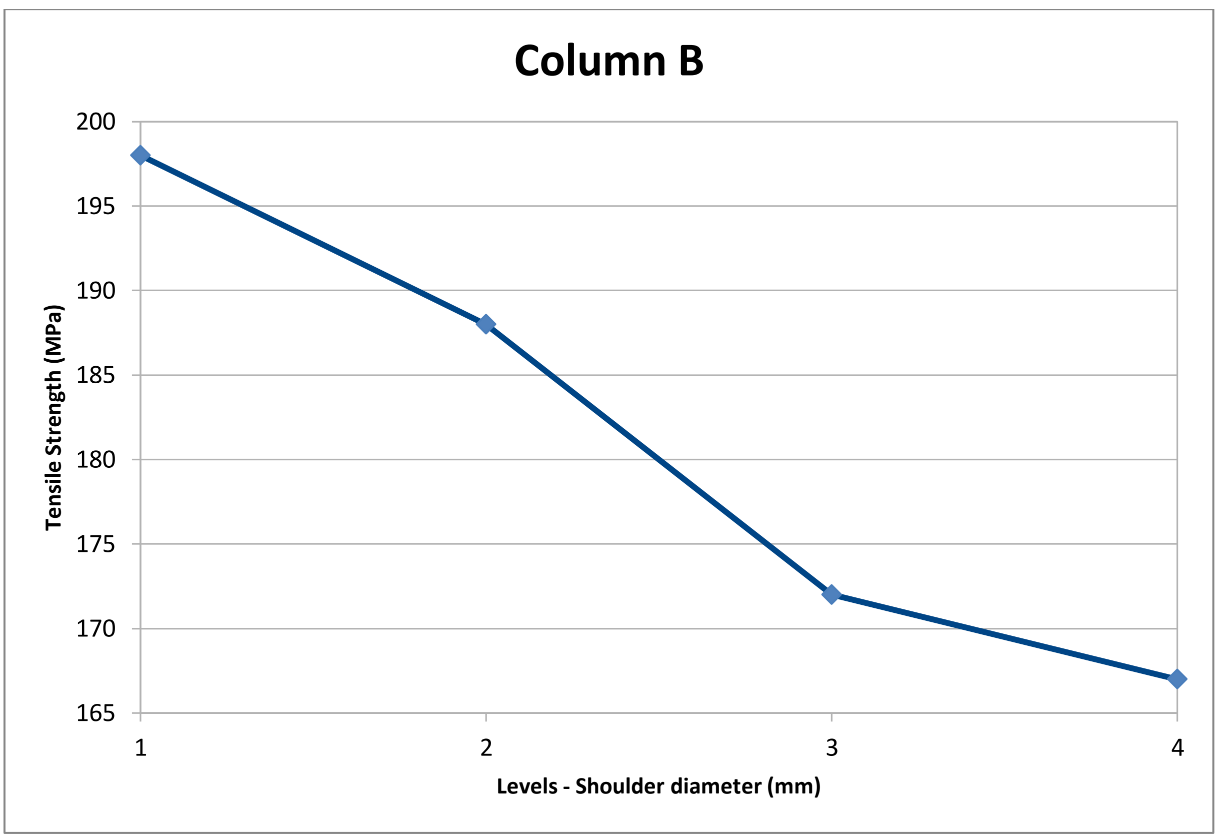

Fig. 1(c): Tensile strength as a function of tool shoulder diameter

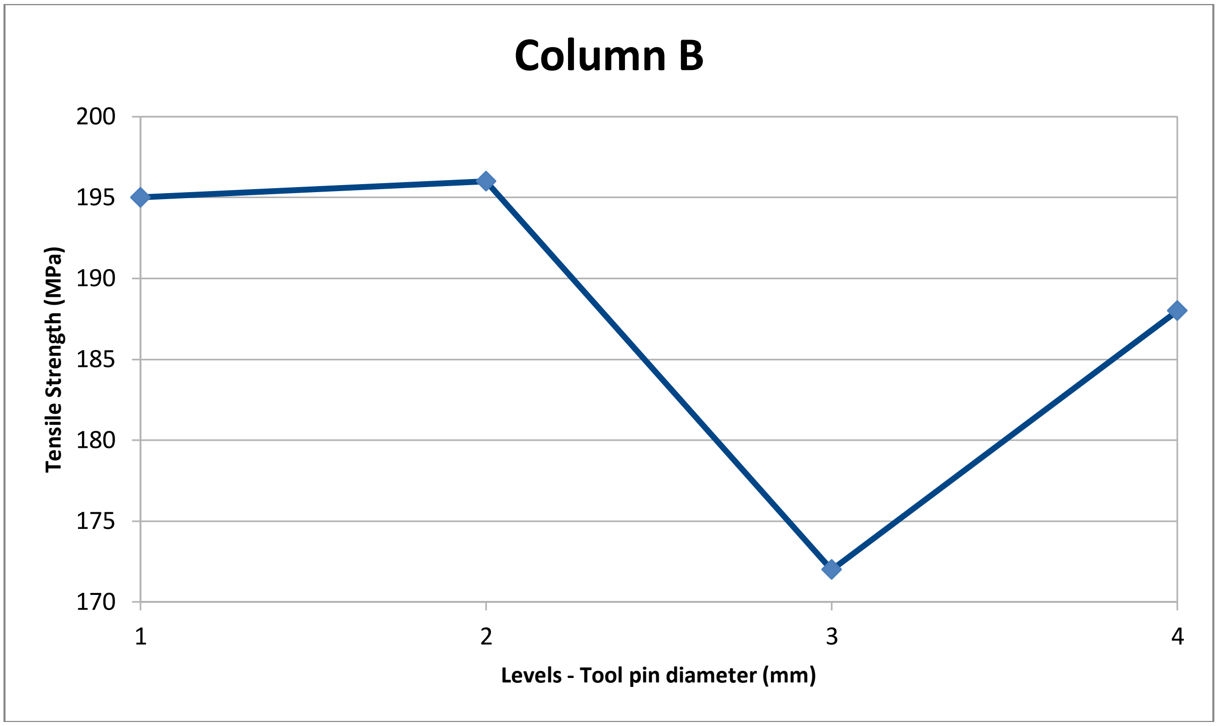

Fig. 1(d): Tensile strength as a function of tool pin diameter

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