An Investigation of Impact Strength of Solid-State FSW of Magnesium Alloy AZ31B

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ABSTRACT

Friction stir welding is a solid-state welding technique which is relatively new in the metal joining field and is used for the joining of soft metals like aluminium and magnesium alloys. The present study aims to develop a set of optimum parameters for the defect-free welding of AZ31B magnesium alloy. The effect of tool profile on the quality of the weld has also been studied with the help of two types of tools which are Cylindrical and Truncated Conical tool. Effect of Tool rotational speed and welding speed has also been analysed for its optimality. Charpy Impact test has been used for checking the mechanical properties of the welded specimens. In the study, it is found that the results obtained using the Conical tool were much superior as compared to the results obtained using the Cylindrical tool. It has also been found that the impact strength increases with an increase in the welding speed and decreases with an increase in the rotational speed.

INTRODUCTION

Friction stir welding (FSW) is an innovative technique to join metals in the plasticity field, thus before reaching ot its melting temperature. Accordingly, the joining procedure creates fantastic joint properties, is vitality effective, condition well-disposed and adaptable [1],[2]. It was created by Wayne Thomas at The Welding Institute, U.K. and the first and foremost patent were lodged in U.K. in December, 1991[3]. Since then it has found wide variety of applications especially in aerospace, shipbuilding and automobile area.

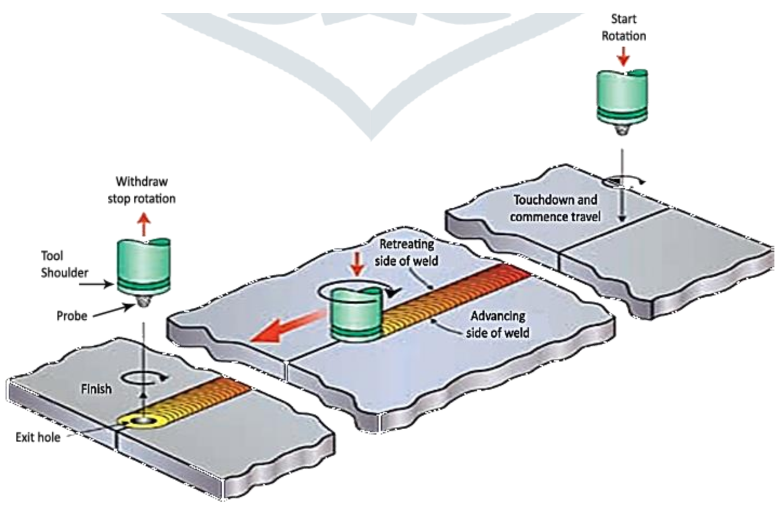


Figure 1: Process principle for FSW [1]

Jiang *et al.* 2004 [4] investigated the mechanical performance at the weld nugget for the fsw of dissimilar material AL 6061 –T6 and AISI 1018 steel grade as well as defect free weld has been produced, during their study they found that inter-metallic compounds of Al-Fe has been formed at the nugget zone due to this hardness was varied and formation of secondary phase at the interface and the high tensile strength was observed at the boundary between the nugget zone and thermo-mechanically affected zone. Amirizad *et al.* 2006 [5] studied Fswed of aluminium matrix composite of A356 & 15% SiCp, distribution of SiCp particle is homogenous in eutectic phase as well as improvement of mechanical properties i.e. young‘s modulus, yield strength, UTS strength, percentage elongation in order of 57%, 26%, 34% and 154% as compare to base material. Because of band like settlement of SiCp and silicon needles which indicates to enhance the hardness at the stir zone. Cavaliere *et al.* 2006 [6] studied about the behavior of mechanical properties i.e. tensile strength, endurance limit stress and micro-hardness of the FSW welded specimen as well as microstructural evolution has been done on as welded specimen and after rupture tested specimen.

MATERIALS AND METHOD

All the experiments are carried out on TAL made Vertimach V-350 VMC as shown in Table 1.

Table 1 Specifications of this equipment are

Maximum Spindle speed	8000 RPM
Maximum cutting feed	10,000 mm/min.
Axis travels: X-Axis, Y-axis, Z-Axis	450mm, 350mm & 350 mm respectively
Working Distance between tabletop to spindle face	200 mm to 550 mm
Table Size	600 x 400 mm
T slots	4 slots with pitch 100 mm.
Maximum load on tabletop	250 kg.

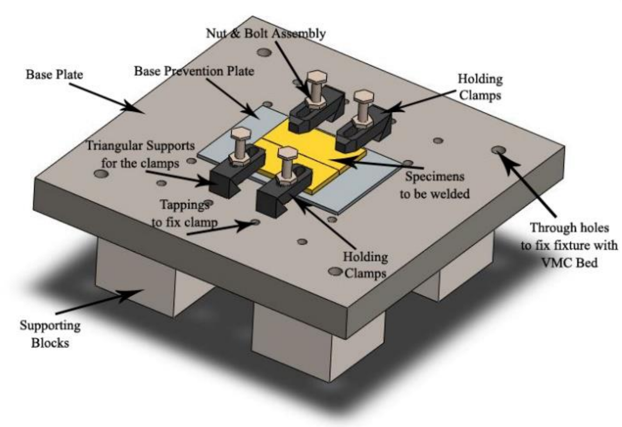


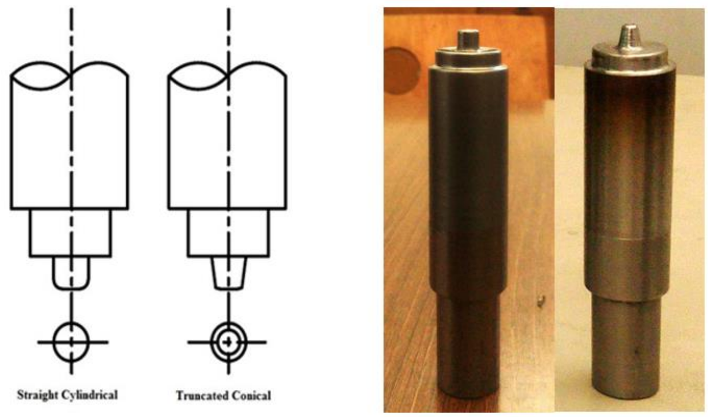
Figure 2 FSW Designed Fixture

FSW requires a proper fixture for holding the specimens during welding, as during plasticized stirring of the material there is much force exerted on the tool and specimens which may result in an imbalance of the specimens during the welding operation. A proper setup has been created as shown in Fig. 2. In this fixture, a 40 mm thick plate made up of mild steel material has been used. The dimension of this new plate is 400*400 mm. Hence this new fixture can be used for the welding of wide dimensions of the materials. For this purpose, two rows of tapping were done to adapt the magnesium plates of sizes more and less than 100 mm respectively. The composition of the selected material AZ31B is listed in Table 2.

Table 2 Mechanical properties and chemical composition

Al	Zn	Mn	Cu	Si	Fe	Ni	Mg
2.87	0.72	0.30	0.005	0.08	0.001	0.001	Bal.
UTS	YS	% elongation	Vicker Hardness				
284 MPa	196 MPa	11.8 %	71.26				

AZ31B plates with dimensions of 100*50*6 mm^3 were welded with the help of two types of tool configurations viz. Truncated Conical and Cylindrical Tool as shown in the Fig.3



(a) (b)

Figure 3 Tool Profiles used (a) Cylindrical, (b) Conical

Optimality conditions in FSW depend upon the various other parameters under which the study has been performed besides the variable parameters. In our study the other parameters used are tilt angle: 3.5^o, plunge depth: 0.35 mm, plunging speed: 10 mm/min, dwell time: 15 s and tool exiting speed: 20 mm/min.

All the tools were made up of the following characteristics:

Table 3 Tool Parameters

Tool material	H13
Probe length	5.45 mm
Shoulder diameter	18mm
Shoulder concavity	3^o
Probe diameter	
○ **Cylindrical Diameter**	○ 6 mm
○ **Conical**	○ Major Dia.= 6 mm & Minor Dia. = 4 mm

Various welding parameters at which the welding is performed are listed in Table 3. The specimens have been named from S1 to S12.

Table 4 Experimentation parameters

Tool	RPM	Feed	Specimen
Cylindrical	1450	80	S1
		100	S2
		120	S3
	1650	80	S4
		100	S5
		120	S6
Conical	1450	80	S7
		100	S8
		120	S9
	1650	80	S10
		100	S11
		120	S12

RESULTS AND DISCUSSION

To check the impact energy of the welded specimens, the Charpy test was used. Specimens were prepared according to the ASTM A370 standards. Notch was prepared in the shaper machine using a tool prepared specially for the above dimensions. In each case, two values of the Charpy test were taken for the single welded specimen and the average of these two values was taken to study and compare the results. These values are given in Table 4 and Table 5 for specimens welded using the Cylindrical tool and Conical tool respectively. During the Charpy impact testing, it was found that the impact energy increased with the increase in welding speed at constant rpm in all the cases. Also, it was found that in the case of a cylindrical tool, the energy absorbing strength of the welded joint was less reported at 1650 rpm compared to 1450 rpm. In case of the specimens welded using the conical tool, the impact energy was much more than the specimens welded using the cylindrical tool. It was also observed that by using conical tool profile impact strength declines with the increment of revolution speed from 1450 to 1650 RPM.

Table 5 Impact Energy of specimens welded using the Cylindrical Tool

Specimen	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Impact Energy	7	10	11	6	8	10

Table 6 Impact Energy of specimens welded using the Conical Tool

Specimen	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
Impact Energy	12	14	15	10	11	13

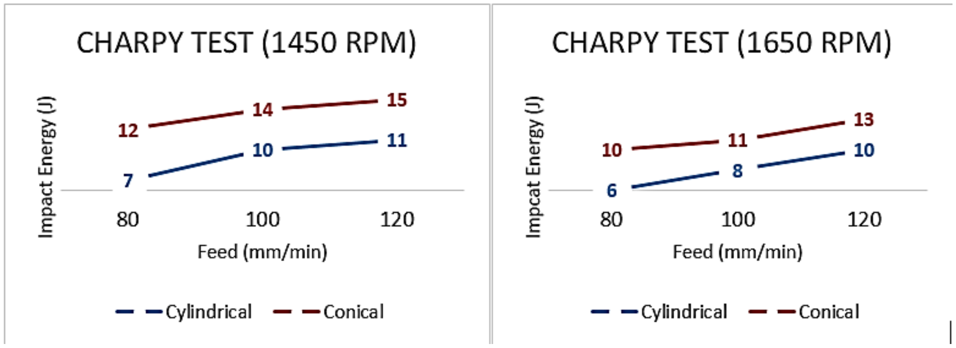


Figure 4 Charpy test variations with the studied parameters

The results of the Charpy tests have been plotted in Fig. 4. It can be clearly shown that the impact energy of the specimens welded using the conical tool was much higher than the impact energy of the specimens welded using the cylindrical tool. Also, by analysing both the figures in Fig. 30 it can be seen that the impact energy gets decreased with increase in the rpm. The impact of energy behaviour exactly complies with the behaviour given by Singh *et al.* in his paper [9]. In all the specimens, the welded specimen at travel rate of 80 mm/min reported minimum impact energy.

CONCLUSION

Efforts were made to depict the effect of tool profiles namely Cylindrical tool and Conical tool on the weld quality of Friction stir welded alloys. FSW experiments were performed on automated TAL made VMC Vertimach V-350 and a proper and rigid fixture was developed which could be fixed on this machine and which could keep the specimens rigid on their position during the welding. For AZ31B-H24 magnesium alloy, it was found that the S9 specimen i.e. welded specimen using conical tool profile at 1450 rpm and 120 mm/min gave very high weld quality with no defects, highest impact strength. The best surface finish was obtained in the welded specimen S11 i.e. welded specimen using conical profile at 1650 rpm and 100 mm/min. It is found that rotational speed is inversely proportional to the impact strength weld joint due to the high heat generated, which increases the cooling time and vice versa.

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