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Effect of Multipass Friction Stir Welded Processing Joint on Az31b/Tic Nano Composite Fabricated Via Fsw Technique

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ABSTRACT:

The main object of the present study is to investigate the effect of Nano-sized TiC particle on the metallurgical & mechanical properties of the friction stir welding (FSW) joints. Prior to FSW, Nano-sized TiC particles were incorporated into the joint line. Toward this end, friction stir welding was conducted by using H13 threaded taper pin tool. A multi pass FSW was carried out by using a tool rotational speed of 1250 rpm and the travelling speed of 40mm/min. Microstructural investigation was carried out through Optical Microscopy (OM) and Scanning Electron Microscopy (SEM). Onion ring structure consisting TiC particle-rich and TiC particle-free regions was observed in stir zone (SZ). Average Cluster size was evaluated using Energy Dispersive Spectroscopy (EDS) method. Using multi passes technique we have to evaluate the mechanical and metallurgical properties with the volume fraction of 12% in the TiC particles.

Key words: *Friction Stir Welding & Processing, Magnesium Alloy, TiC, Metallurgical properties & Mechanical properties.*

1. INTRODUCTION

Friction Stir Welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute), and the first patent applications were filed in the UK in December 1991.Friction Stir Welding is a solid-state process, which means that the objects are joined without reaching melting point.

In FSW, a cylindrical shouldered tool with a profiled pin is rotated and plunged into the joint area between two pieces of sheet or plate material. The parts have to be securely clamped to prevent the joint faces from being forced apart. Frictional heat between the wear resistant welding tool and the workpiece causes the latter to soften without reaching melting point, allowing the tool to traverse along the weld line. The plasticised material, transferred to the trailing edge of the tool pin, is forged through intimate contact with the tool shoulder and pin profile.[1]

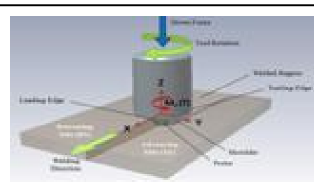

Fig-1 Friction Stir Welding Process

The drawbacks associated with the fusion welding include: (a) gas occlusion, (b) undesired interfacial chemical reactions between the reinforcement and the molten matrix alloys, and (c) segregation of particles during solidification [2,3]. In spite of fusion welding processes, the primary material does not melt and recast during friction stir welding process. In other words, FSW is a solid state method of joining materials [1]. Accordingly, FSW eliminates the above mentioned problems. More recently, various metal matrix composites have successfully been friction stir welded (FSWed), including 7005/Al2O3/10p [2], AZ91/SiC/10p [4], 6061/TiC/3 and 7p [5],6063/B4C/6 and 10.5p [6].

In this research work is carried out by similar joining of AZ31B Magnesium alloy along with incorporated at TiC Nano particle with 12 % Vol... Magnesium alloys have many attractive properties, such as low density and high specific strength. Welding parameters, tool geometry, and joint design exert significant effect on the material flow pattern and temperature distribution, thereby influencing the microstructure evolution of material.[2]The design of the shoulder and of the pin is very important for the quality of the weld. The pin of the tool generates the heat and stirs the material being welded but the shoulder also plays an important part by providing additional frictional treatment as well as preventing the plasticized material from escaping from the weld region.

According to a novel approach proposed by Sun and Fujii[7],micro-scaled SiC particles were introduced into the 2 mm thick copper plates using FSW technique. As a result, a copper matrix composite was successfully made within the stir zone (SZ). This approach, however, has never been attempted for magnesium MMC and alloys. Accordingly, with the aim of fabricating MMC, FSW was carried out on AZ31B using nano-sized TiC reinforcements. In this study, the effects of TiC Nano-particles as well as volume fraction and multiple pass numbers on microstructure, hardness, and tensile behavior of the FSWed joints have been investigated. In this study, a 6 mm thick AZ31B magnesium plate with the chemical composition shown in Table 1 was used.

2. EXPERIMENTAL WORK

Chemical composition and mechanical properties of both mg alloy(150mm×50mm×6mm) and TiC are provided table 1 and 2[11].

Al	**Mn**	**Zn**	**Si**	**Cu**	**Mg**
2.88	0.24	0.92	0.0115	0.0018	Bal.

Table 1:Chemical composition (wt %) of base metal

Purity	APS (Size)	range	Bulk density g/cm^3	True density g/cm^3	Crystal phase
>99%	40-60nm	0.92	0.08	4.93	cubic

Table 2:Chemical composition (wt %) of base metal

The particle sizes were mainly in the range of 45-65nm. Transmission electron micrograph of the as received TiC particles is shown in figure [2]. The friction stir welding tool was machined out H13 hardened steel is shown in figure [3], the tool had threaded taper pin profile, shoulder diameter of 18mm and projected area of the tool pin is 6mm×5.7mm [1].

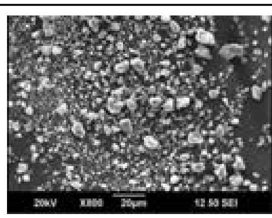

Fig 2 TEM image of TiC nanoparticle

Fig-3 H13 hardened steel

After cutting the magnesium plate into 150 mm ×50 mm strips a profile with 0.8 mm width, 5 mm depth and required length was machined on the adjoining side of each strip using the electrical discharge machining. The schematic view of the profile is shown in Fig. 4. The profile allowed a groove to be formed when two strips were put together. Afterward, the reinforcements were put into the groove and pressed tightly. A pinless tool was initially employed to cover the top of the grooves after filling with TiC particles to prevent the particles from scattering during FSP. Next, the rotational speeds 1250 rpm and traveling speed 40 mm/min were used to fabricated and further we apply the single and double passes are utilized and tested.

Sample specimens for tensile testing were carried out perpendicular to the FSP direction based on ASTM-E8 [8,9]. Prior to preparation of tensile and metallographic specimens' top surfaces of FSWed joints were machined to remove the marks left by the shoulder. According to ASTM-E8, the sub sized tensile specimen were electrically discharged machined perpendicular to the welding direction. Their tensile strength is estimated using a universal testing machine. The microhardness was measured by Vickers hardness tester (shimadzu type M) at a load of 24g and a dwell time of 10s [9]. Metallographic specimen was ground, polished and etched by kellar's solution for 11's. The mean grain was measured according with ASTM linear interrupt method [2].

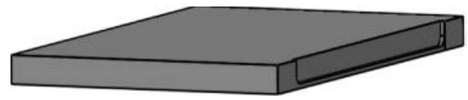

Fig. 4. Schematic view of the profile made adjoining side of a strip.

3. RESULTS AND DISCUSSIONS

Figure 5shows the upper surface appearance of the various fabricated MMC FSWed samples. The groove is effectively closed subsequent to FSW. Defects such as voids and cracks are not observed on the surface. The top surface shows very smooth quality and there is almost no prominence or depressions inspite of tool's stirring. The groove size is sufficient to produce sound MMC.

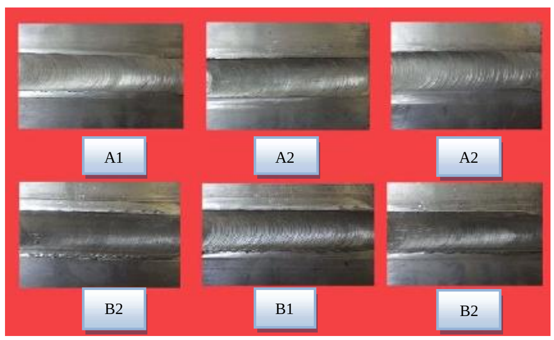

Fig-5 FSWed Samples

3.1. Microstructures

Figure 5 shows the macrograph of the FSP zone. A defect- free FSW zone is observed. Typical FSW defects (tunnel, pin hole, piping and worm hole) are absent. It is evident from the macrograph that the groove is completely bonded on all sides. The pin length is 0.7 mm higher than that of the groove depth which proves to be adequate to produce full penetration. Hence defects do not arise at the bottom side of the groove. The rubbing of the tool on the substrate generates frictional heat which plasticizes the alloy which reaches semi solid state (Mishra & Ma 2005). The vigorous stirring action of the tool distributes the packed TiC particles into the plasticized alloy. The translation of the tool moves the plasticized composite from advancing side to retreading side and forges at the back of the tool. Thus, MMC is produced by FSW. The FSW zone is typically about the size of the rotating pin, namely width and depth of 0.80 mm and 5mm, respectively.

The effect of volume fraction of TiC particles on the microstructure of AZ31/TiC MMCs is shown in the SEM micrographs presented in Fig. 6. Zero volume fractions refer to friction stir welded magnesium alloy which displays dynamically Recrystallized grains. The SEM micrographs as Presented in Fig. 6 show the variation of microstructures as a function of volume fraction of TiC particles at 1000 × magnification. The number of particles increases as well as the spacing between particles reduces when the volume fraction is increased. The uniform distribution of TiC particles can be attributed to adequate generation of frictional heat, stirring and plasticized material flow across the friction stir processed zone. Mild agglomerations are also noticed at few locations. The variation in the distribution of TiC particles across the FSP zone was found to be negligible. The microstructure was independent upon the location in the FSP zone. This can be attributed to proper mixing and symmetric material flow during FSP. It is evident from Fig. 2 that the FSP zone is almost symmetric about tool axis.

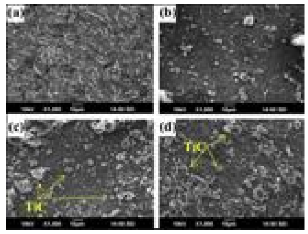

Fig. 6. SEM Micrograph of AZ31/TiC MMC containing TiC;
(a) 0 vol.%, (b) 12 vol.%, and single pass and double pass

The TiC particles are subjected to the severe plastic flow of magnesium alloy during FSP. Several investigators observed a change in the size and morphology of ceramic particles during FSW [8]. No such fragmentation of TiC particles was observed with the tooling and process parameters described within this work. The variation of TiC particle size in the composite as seen in Fig. 3 is minimum and negligible. The variations in the morphology of the TiC particles before (Fig. 1) and after (Fig. 6) FSP are negligible. TiC particles retain the initial size and morphology. This can be attributed to the initial morphology and size of TiC particles which have a minimum number of sharp edges.

Vol fraction/ No of passes	**0 % Vol without TiC**	**12 % Vol Tic Incorporated**		
		FSWed joint	**Single pass**	**Two Pass**
Name of the specimen	a	b	c	d
Grain size	-	3.3	4	4.3
Percentage of elongation	2.4	4.2	8.1	10.2
Avg microhardness value	72	112	116	119
UTS (MPa)	256	277	281	280

Table 3

As mentioned before, rotational speed of 1250 rpm and traveling speed of 40 mm/min was considered as the optimum processing parameters. To figure out how the reinforcements influence the SZ microstructure, all welding parameters in FSW of specimen No. d were kept identical to those of specimen No. c. However, no TiC Nano-particles was used during FSW of specimen No. a. According to grain size measurements, grain refinement in specimen No. d was superior to that of specimen No. b. larger grain size of specimen No. c is associated with the high heat input. However, smaller grain size of specimen No. d is due to the role of TiC.

3.2 Tensile properties

Several microstructural factors such as grains size, dislocation density, and interaction between the base metal and the reinforcing particles, influence mechanical properties [8]. Tensile properties of all the FSWed joints including UTS, percentage of elongation, and Vickers hardness (VH) are presented in Table 3.Of the six specimens, specimen No. c and No. d exhibited the highest and the lowest UTS, respectively. Moreover, although the UTS of specimen No. c was smoothly higher than that of the specimen No. d, the difference between UTSs and percentage of elongations of these specimens were negligible. Higher UTS of specimen No.c, however, could be attributed to its smaller grain size. It is observed that giving the multiple passes in the weld zone at single and double passes. On the other hand, considering tensile strength of specimens No. b and d revealed that the UTS of specimen No. c is superior to that of specimen No. a. Thanks to the presence of TiC Nano-particles, the UTS of specimen No. c improved by 31% with respect to specimen No. a.

3.3 Fractography

The resemblance of low-heat-input fractographs was also remarkable. A ductile fracture morphology which confirms the improved ductility was found in high-heat-input specimens. Besides, it is of great importance to note that in such specimens, fracture took place in base metal far from the stir zone. Along with the good bonding between dispersed TiC Nano-particles and the aluminum substrate, superior hardness of stir zone to base metal is another reason behind this behavior. Nonetheless, low-heat-input specimens fractured from the severely accumulated TiC Nano-particles area. This result is in good agreement with Barmouz et al. [8] and Sun and Fujii[12] findings in the case of copper. Sun and Fujii noted that one pass processed Cu joint containing TiC particles fractured in the area where TiC greatly aggregated [12].

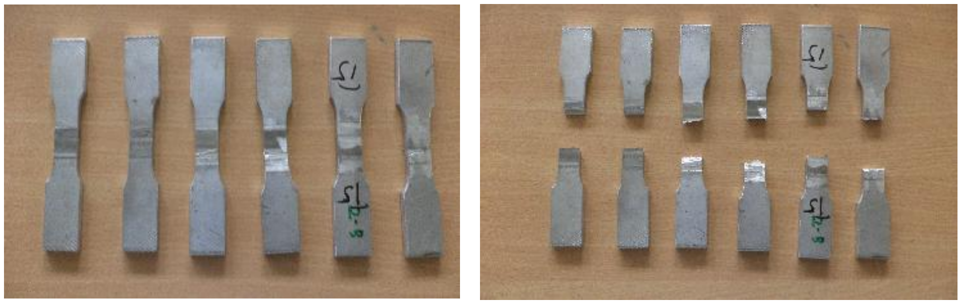

Fig. 7. Mating fracture surfaces of specimens

3.4. Hardness

The average hardness of as-received AZ31B magnesium alloy was 72HV. The microhardness of composite joints are in relationship with grain size, dislocation density, presence of reinforcing particles, and heat input. Finer grains are associated with greater hardness values, according to Hall–Petch[11]. Reinforcing particles, actually, have double effect on hardness. One arises from its hard nature and the second relates to the role of TiC particulates in grain boundary pinning [11]. For all composite joints, the micro hardness values were higher than one of the base material. However, the microhardness distribution along the stir zones were deviating. This phenomenon arises from the mode of distribution of the reinforcement [9]. On the other hand, the lowest average microhardness value was obtained in FSWed sample with TiC. Moreover, the hardness of two pass welded samples spcimens showed good correlation with corresponding cluster sizes as well as grain sizes.

4. CONCLUSIONS

In the present work, AZ31/ 0 Vol%, and 12 vol.% TiC MMCs were successfully synthesized using the novel method FSW joint strength was optimized by using novel FSP Multipass technique where employed. The microstructure of the composite was analyzed using scanning electron microscopy. The following conclusions were derived from the present work.

- FSP can be effectively used to synthesis AZ31/TiC MMCs without any kind of defects. Tic particles were distributed uniformly in the magnesium matrix without the formation of clusters.
- At high rotational speed (1250 rpm) powder dispersion Improved due to effective stirring action of the pin.
- There was no interfacial reaction between the magnesium matrix and the TiC particle. TiC particles were properly bonded to the magnesium matrix.
- UTS of specimen FSWed with powder at 1250 rpm and 40 mm/min was 31% superior to that of the specimen FSWed without powder.
- The addition of TiC particles led to 76.1% enhancement ofelongation.

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