Influence of Traverse Speed on Formability Limits of Friction Stir Processed Mg AZ31B Alloy

G.Venkateswarlu
Department of Mechanical Engineering, SCCE, Karimnagar, A.P, INDIA

ganta_hmp@rediffmail.com

Abstract

In this study, the effect of traverse speed on the formability of friction stir processed Mg AZ31B alloy sheets under plane strain condition has been investigated. Friction stir processing was carried out at traverse speeds in the range of 24 mm / min to 40mm / min with a constant rotational speed of 1150 rpm. Limiting the dome height test (LDH) has been carried out to find the formability of the material under plane strain condition. The results indicate that the traverse speed is the most significant factor for refining the material, thereby improving the formability and found that the optimal traverse speed gives highest formability.

Keywords: *Friction stir processing, microstructure, formability.*

1. Introduction

Magnesium alloy is one of the lightest metals in use for structural applications because of some of their unique properties such as low density, high strength to weight ratio, and good castability [1]. However, their usage in industrial applications is limited due to poor workability because of the limited number of available slip systems in the hexagonal close-packed (hcp) structure [2-3]. It has been reported that the ductility and formability of magnesium alloys can be improved through microstructural modifications of the material by severe plastic deformation techniques including equal channel angular processing (ECAP), high pressure torsion (HPT), and accumulative roll bonding (ARB), friction stir processing (FSP) etc. [4-6]. Friction stir surface processing (FSP) is an emerging surface engineering technique based on the principles of friction stir welding (FSW), a solid state joining process, developed initially for aluminium alloys by The Welding Institute (TWI) of the United Kingdom (UK) in 1991. FSP locally eliminates inherent casting defects and dramatically refines the grain structure, thereby improves properties of strength, ductility, corrosion resistance, fatigue strength, formability etc. [8-11]. Darras et al [12] studied the influence of various friction stir processing parameters on thermal histories and properties of commercial AZ31B-H24 magnesium alloy sheet. They concluded that grain refinement and homogenization of microstructure can be achieved in a single pass. Fine grain size can be obtained in a single pass friction stir processing through severe plastic deformation by controlling of heat input during processing [13]. Multi pass FSP produces equiaxed homogeneous microstructure having fine grains [14]. It has been reported that the most important parameters that influence the FSP are the tool rotational speed and traverse speed [15]. More studies are required to investigate the influence of FSP process variables on the resulting formability of magnesium alloy. The purpose of the present investigation is to study the influence of traverse speed on the formability of friction stir processed Mg AZ31B alloy under plane strain condition.

2. Experimental set up

In this investigation, the rolled sheet of magnesium AZ31B alloy supplied by Xi'an Yuchen Metal Products Co., Ltd, China was used as base material. The composition and mechanical properties of as received material are given in Table I and Table II, respectively. The sheet of 4 mm thickness was cut into the required size (150 mm x150 mm) using a milling machine. The friction stir processing was done on the vertical head milling machine with the position of the tool fixed relative to the surface of the sheet as shown in Fig.1. The work piece was firmly clamped to the bed and a specially made tool was plunged into the selected area of the material sheet for sufficient time in order to plasticize around the pin. After adequate plasticization, the tool was traversed across the surface of the material for a single pass. The entire sheet was processed with multiple passes. A non consumable taper threaded tool made of high carbon steel, H13 with a shoulder diameter of 18 mm, pin diameter of 6 mm, and a pin length of 3 mm was used. The range of traverse speeds utilized in the processing was varied between 24 mm / min and 40 mm / min, whereas the rotational speed (1150 rpm) was kept constant.

Fig1: Friction stir processing set up

Table 1. Chemical composition of mg AZ 31B-o (wt %)

Element	Al	Zn	Mn	Si	Ni	Fe	Mg
% Wt	3.02	0.89	0.29	0.026	.0009	0.0025	Bal

Table 2. Mechanical properties of as received material

Yield strength (MPa)	Ultimate tensile strength (MPa)	Elongation (%)	Hardness Kg/mm^2
163	210	6.93	79

The trail experiments were carried out to determine the plane strain condition by varying the sample width, it was found that a near plane strained condition could be achieved with a sample width of 60 mm. So, rectangular blanks of 100 mm x 60 mm were used to conduct LDH tests in plane strain condition. The samples were gridded with 2.5mm diameter circles to obtain forming limits of the alloy at plane strain condition. A circular lock beds were designed on the dais to restrict the flow of material from the flange region into the die. All LDH tests were carried out in dry condition at a punch speed of 0.3 mm/sec on 50 ton hydraulic press as shown in Fig.2. An optimum blank holding force in the range of 3-4 tons was applied. The punch was stopped immediately when the initiation of fracture was found on the specimen during tests. The dome heights and loads of the specimens were recorded and stored for every 5seconds interval of time using data loggers. In order to determine the minor and major strains, the minor and major diameters of the deformed circles (ellipses) were measured by a tool maker's microscope.

The microstructure of the base material and processed samples was examined by optical microscope. The specimens for microstructural analysis were sectioned to the required size and then polished using different grades of emery papers and etched with a standard reagent made of 4.2 g picric acid, 10 ml acetic acid, 10 ml diluted water, and 70 ml ethanol.

Fig 2: Hydraulic press with die set

3. Results and Discussion

In this investigation, microstructure analysis is focussed on the dynamically recrystallized stir zone. The initial average grain size of the base was 16.5 µm and its optical microstructure plot (OM) is shown in Fig.3 (a). It is observed from the microstructures that, the grains were refined after the FSP process, and the microstructure exhibited more homogeneous having smaller grain size than the base metal. This is due to refinement process that has taken place due to severe plastic deformation of the material during processing. The sample processed with a 24mm/min traverse speed has produced in a homogenous grain structure smaller grains as compared to base material. This is due to excessive heat generation during processing, resulting in grain growth of the material after refinement. More homogeneous equiaxed grains of average size of 6.2 µm were found in the samples processed with 32mm/min traverse speed. This is because of the intense plastic deformation that due to optimal heat input. Sample processed with 40mm/min has produced an inhomogeneous finer grain structure which subsequently leads to lower the formability but higher than the base material.

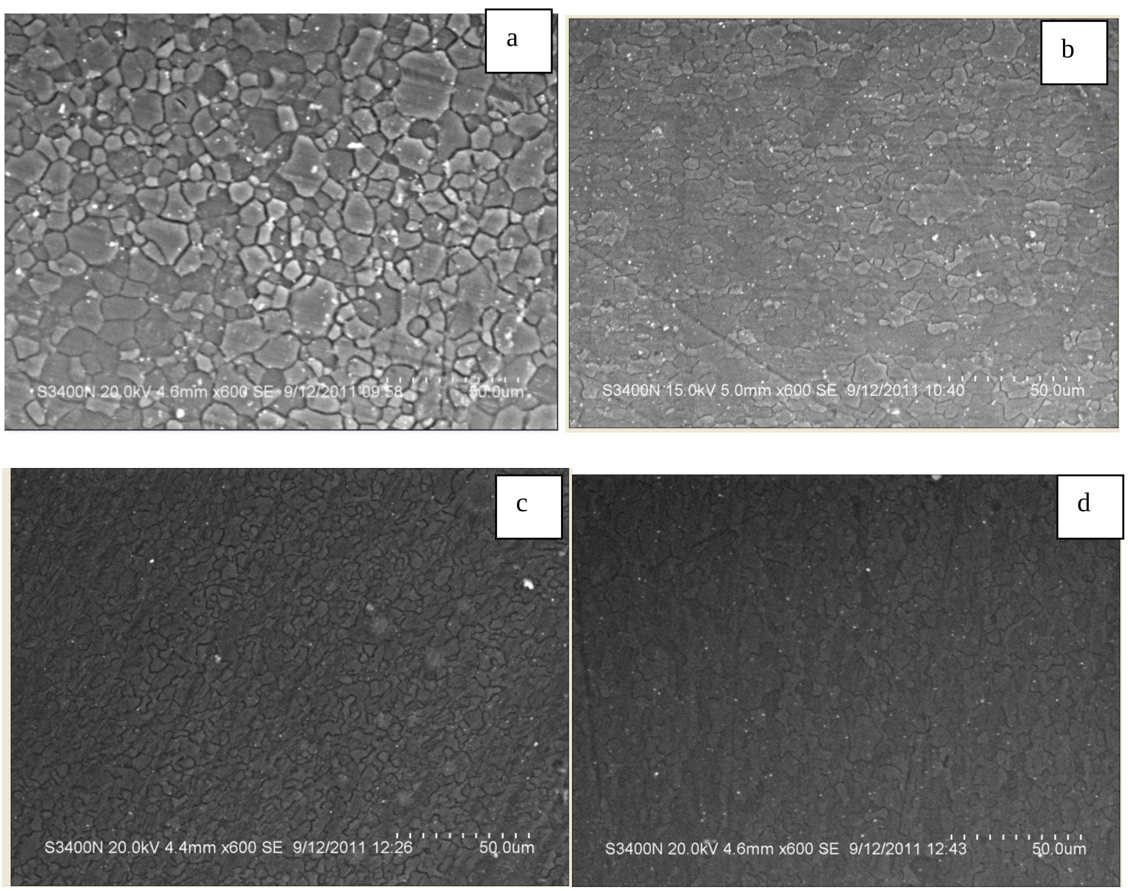

Fig 3: (a) Optical microstructure base material (b) FSPed material at traverse speed of 24mm/min (c) 32mm/min (d) 40mm/min

The formability limits of the base material and friction stir processed Mg AZ31 B alloy for various traverse speeds is shown in Fig.4. In FSP, the translation of the tool moves the stirred material from front to the back of the pin. The heating rate in a thermal cycle during FSP is a strong function of the traverse speed. Intense plastic deformation during friction stir processing results in the generation of fine crystallized grains that lead improvement in formability. It is observed from the Fig.4 that the traverse speed influences the formability of friction stir processed Mg AZ 31 Alloy. The formability limits are lower at lower traverse speed (24 mm/min) but higher than due to slight refinement of grains (Fig .3 (b)). When the traverse speed increases from 24 mm/ min to 32mm / min, formability limits of the FSPed material increases and higher than the base and samples processed with 24 mm/ min and 40 mm/ min due to more homogeneous fine grain microstructure (Fig.3 (c)) Further increase in traverse speed (40 mm/ min), result in formability limits are lower than the samples processed with 32mm/ min but higher than base material and samples processed with 24mm/min. This is due in the homogeneous fine grain microstructure (Fig.3 (d)).

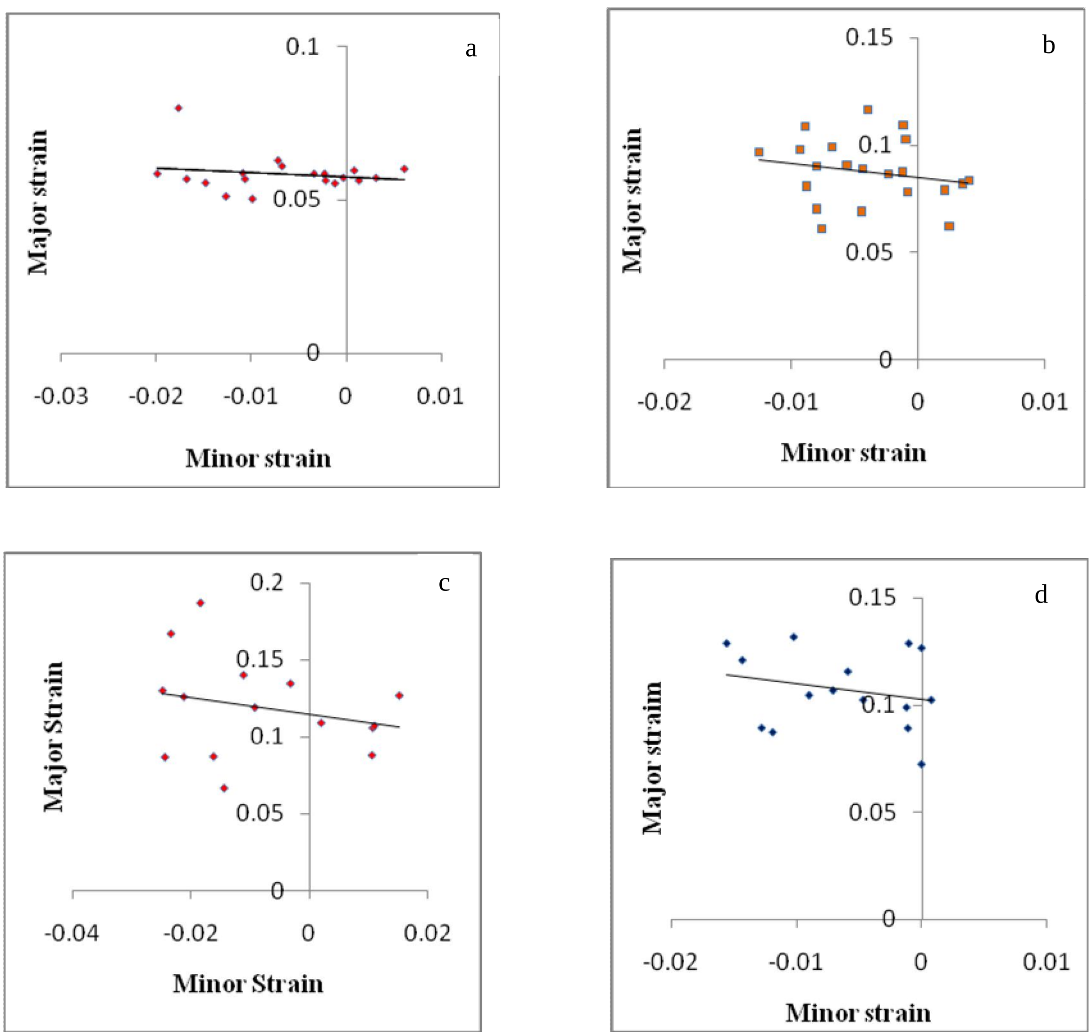

Fig 4: Fracture Limits of (a) base material (b) at T.S of 24mm/min (c) 32mm/min (d) 40mm/min

4. Conclusions

Friction stir processing has been successfully carried out at traverse speeds in the range of 24 mm / min to 40mm / min with a constant rotational speed of 1150 rpm. Friction stir processing improves the formability limits of Mg AZ 31B alloy through microstructural modification.

References

[1] R.S.Busk, Magnesium Production Design, New York, Marcel Dekker Inc, 1986, pp. 13.
[2] E.Aghion, B.Bronfin, and D.Eliezer, 2001, "The role of the magnesium industry in protecting the environment", Journal of Material Processing Technology, Vol. 117, 2001, pp. 381–385.
[3] M.T.Perez-Prado and O.A.Ruano, "Texture evolution during annealing of magnesium AZ31 alloy", Scripta Materialia, Vol. 46, 2002, pp.149–155.
[4] J. Zrnik, S.V. Dobatkio and I. Mamuzic, "Processing of metals by severe plastic deformation(SPD) structure and mechanical properties respond", Metalurgija , Vol. 47, 2008, pp. 211-216.
[5] K.Bryla, J.Dutkiewicz and P.Malezewski, "Grain refinement in AZ 31 alloy processed by equal channel angular processing", Archives of Materials and Engineering,Vol. 40, 2009,pp.17-22.
[6] H. Wim, R. Sillekens Sean, R. Agnew Neale and N. Neelameggham Suveen, "Investigation of Microhardness and Microstructure of AZ31 Alloy after High-Pressure Torsion", Magnesium Technology, The Minerals, Metals and Materials, 2011.
[7] Nobuhirojsuji, Yoshihirosaito, Seong-Heelee, Yoritashi and Minamino, "Accumulative roll-bonding and other new techniques to produce bulk ultrafine grained materials", Advanced Engineering Materials, Vol. 5, 2003, pp. 338-344.
[8] R.S. Mishra, M.W.Mahoney, S.X McFadden, N.A.Mara and A.K. Mukherjee, "High strain rate superplasticity in a friction stir processed 7075 Al alloy", Scripta Mater., Vol. 42, 2003, pp.163-171.
[9] N.Saito, I. Shigematsu, T. Komaya, T. Tamaki, G. Yamauchi and M. Nakamura, "Grain refinement of 1050 aluminium alloy by friction stir processing", J. Mater Sci Lett, Vol. 20, 2001, pp. 1913-1918.
[10] M.W..Mahoney,W.H.BingetandR.S.Mishra,"MicrostructuralModification and Resultant Properties of Friction Stir Processed Cast NiAl Bronze", Mater Sci Forum, Vol. 426, 2005, pp. 2843-2853.
[11] M.L Santella, T. Engstrom, D. Storjohann and T.Y. Pan, "Effect of friction stir processing on mechanical properties of the cast aluminium alloys A319 and A356", Scripta Materialia, Vol. 53, 2005, pp.201-206.
[12] D.M.Darras, M.K.Khaishesh , F.K abu-Faraha and M.A. Omar. Friction stir processing of commercial AZ 31 magnesium alloy, Journal of materials processing technology , Vol. 191, 2007, pp. 77-81.
[13] T. A. Freeney and R.S. Mishra, "Effect of friction stir processing on microstructure and mechanical properties of cast-magnesium-rare earth alloy", Metallurgical Materials Transactions A ,Vol. 41, 2010, pp. 73-84.
[14] Y.S. Sato, A. Sasaki, A. Sugimoto, A. Honda and H. KoKawa, "Enhancement of formability in magnesium alloy AZ 31 B via friction stir processing", Materials Science Forum, Vol. 539-543, 2007, pp. 3775-3780.
[15] R. S. Mishra and Z.Y.Ma, "Friction Stir Welding and Processing", Materials Science and Engineering R, Vol. 50, 2005, pp. 1-78.