Materials Science Forum Vols. 580-582 (2008) pp 351-354
online at http://www.scientific.net

Online available since 2008/Jun/12

Effect of Probe Thread on Friction Spot Joint Strength of AZ31 Mg Alloy

Kazuhiro Nakata[1, a], Hirohisa Ikegami[1,b] and Takuya Tsumura[1,c]

[1]Joining and Welding Research Institute, Osaka University,

11-1, Mihogaoka, Ibaraki, Osaka 567-0047, Japan

[a]nakata@jwri.osaka-u.ac.jp, [b]ikegami@jwri.osaka-u.ac.jp, [c]tsumura@jwri.osaka-u.ac.jp

Keywords: Magnesium, Joining, Friction spot joining, Lap joint, Microstructure, Tensile shear strength.

Abstract. Lap joint of AZ31 Mg alloy extruded sheet can be successfully made by friction spot joining (FSJ) process. Joint strength was strongly affected by the probe thread, which increased the plastically deformed zone around a rotating probe and increased the tensile shear strength of the joint in comparison with the joint made by a thread-less probe.

Introduction

Mg alloys are expected as lightweight structural material in the automotive industry. However, fundamental details of the characteristics of the welded joint of Mg alloys, especially about recently developed welding and joining processes, have not yet been made clear. Friction spot joining (FSJ) is of much interest as the new joining process of sheet materials of car body assembly and has been already applied for aluminum alloy sheet joint instead of resistance spot welding [1-3], though there is little research works on FSJ of Mg alloy [4]. In this article, commercially available extruded AZ31 Mg alloy sheet is selected to clarify the feasibility of friction spot joining and the process parameter, especially for the probe thread to affect the joint strength.

Experimental Procedures

Fig.1 shows a schematic illustration of friction spot joining process. A rotating tool is plunged into a lap joint to the desired depth under constant tool axial down force, and then drawn out. Thus, a lap joint is made by this simple process [1]. The plunge depth of a probe was controlled by changing joining time at a constant FSJ parameter as shown in Table 1. A friction stir welding machine installed in JWRI, Osaka Univ., in which the axial down force of a tool is controllable, is used for this experiment. As a tool design, two types of the probe, with and without thread, as showed in Fig.2, were used in order to evaluate the effect of the probe thread on the lap joint formation involving the microstructure and the joint

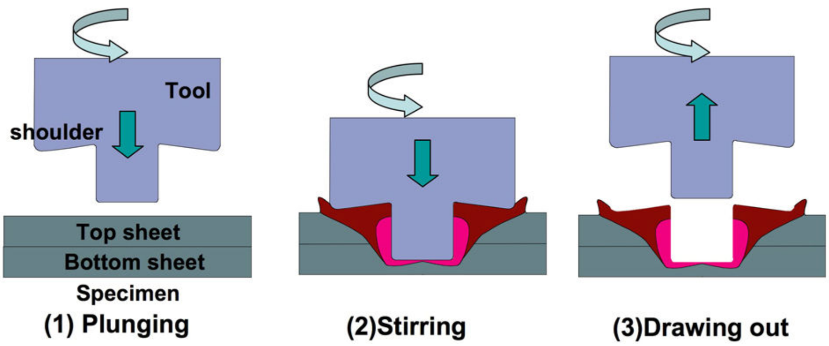
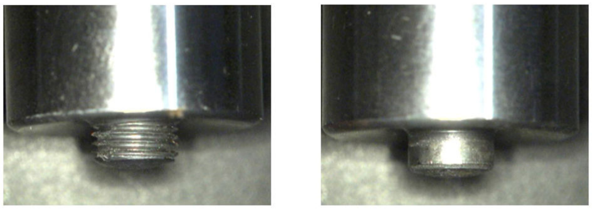


Fig.1 Schematic illustration of friction spot joining process

Table 1 FSJ parameters

Material of tool	SKD61
Diameter of shoulder	15mm
Diameter of probe	5mm/ Thread M5
Length of probe	2.4mm
Taper angle of shoulder	10 degree
Tool rotation speed	1750rpm
Down force	9.8kN
Joining time	4s ~ 9s



(a) Threaded probe (b) Thread-less probe

Fig.2 Appearances of probes used

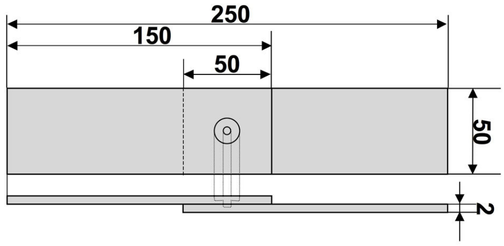


Fig.3 Lap joint for tensile shear test specimen

strength. The anticlockwise thread of M5 type was used in the clockwise direction of the tool rotation. The other tool design and dimension are same, irrespective of the thread, which were generally used for friction stir welding [5]. The tensile shear strength of FSJ joint was evaluated by using a test specimen shown in Fig.3 with as-joined conditions. The commercially available extruded sheet of AZ31 Mg alloy with a thickness of 2 mm was used for friction spot joining.

Results and Discussions

Fig.4 shows the relation between the probe plunge depth and the joining time at a constant tool axial down force. The threaded probe required longer time to plunge into the same depth than that for a thread-less probe.

Fig. 5 shows the comparison of the joint strength obtained by using different types of probe, with and without the thread, against the plunge depth at the same FSJ parameters. Tensile shear strength of the joint made by a threaded probe showed much higher strength than that of the joint made by a thread-less probe. In addition, different behaviors of the tensile shear strength against the probe plunge depth were observed. With the threaded probe the tensile shear strength showed the peak value at the adequate depth, but with the thread-less probe it increased monotonically.

For the case of threaded probe, Fig.6 (a) and (c) show the cross sections of the joint before and after tensile shear test, respectively, and Fig.6 (b) shows the closed

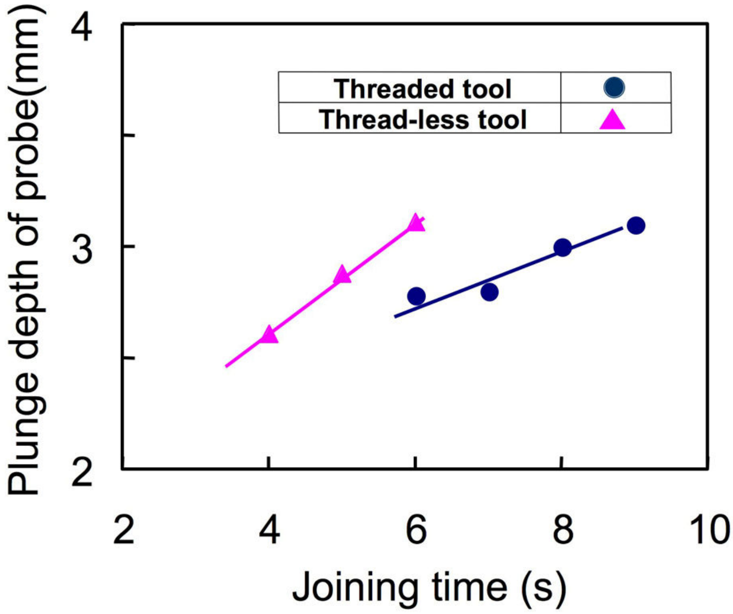


Fig.4 Relation between plunge depth of the probe and joining time

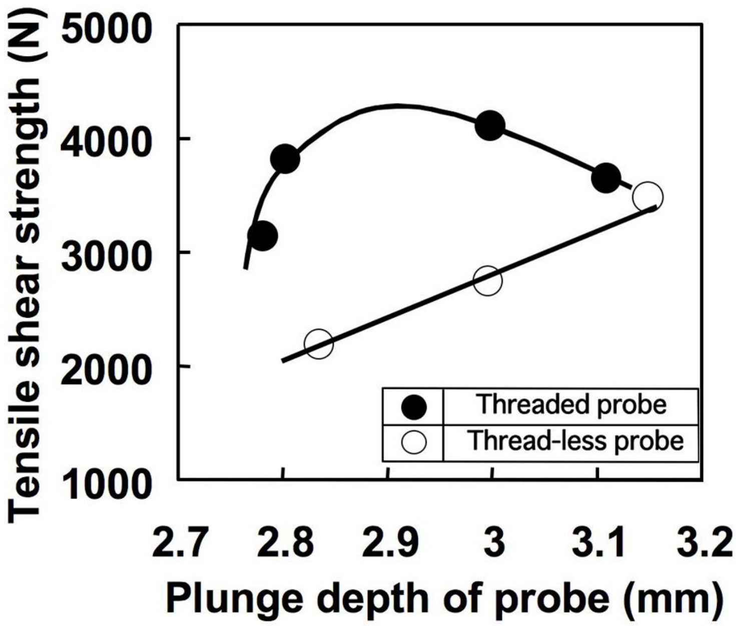


Fig.5 Relation between tensile shear strength of the FSJ joint and plunge depth of the probe

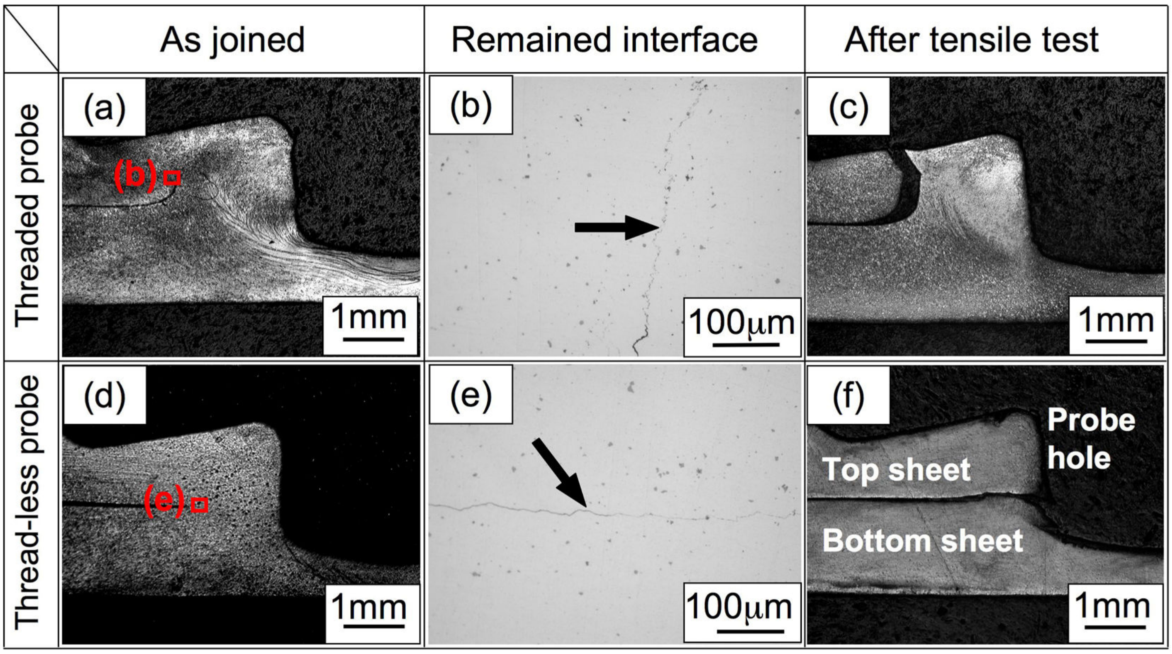


Fig.6 Cross sections of the FSJ joints; (a)-(c)with thread, (d)-(f) without thread; (a),(d)before tensile test; (c),(f)after tensile test

microstructure at a rectangle area in Fig.6 (a). Where a similar situation for the thread-less probe is shown in Fig.6 (d), (e) and (f), at almost the same plunge depth of 3.1mm. Microstructure analysis revealed that a wider plastically deformed area was made around a rotating probe by using the threaded probe, which caused the original lap joint interface to disappear. However, the "remained interface" observed in Fig.6 (b) indicates that the original interface was shifted from a horizontal direction to a vertical direction upward to the top surface of the specimen by the extruded plastic metal flow caused by plunging the probe. Thus, the fracture passed through this "remained interface" upward and finally crossed the top sheet base metal, at which the sheet thickness became thinner by contacting to the tool shoulder, as plunge depth increased. This is the reason why the tensile shear strength tended to decrease at excess plunge depth. On the contrary, by a thread-less probe the original lap joint interface still remained near the probe hole, as shown in Fig.6 (e), due to a narrow plastically deformed zone, thus the fracture passed through it in a horizontal direction and into the probe hole. The width of this narrow plastically deformed zone, however, increased with increasing the plunge depth. Thus, the tensile shear strength, by a thread-less probe, increased monotonically.

Fig.7 shows the microstructures around the probe hole at different positions. Fig.7 (a) and (d) adjacent to a probe hole are corresponding to the stir zone as in FSW; Fig.7 (b) and (e) for TMAZ, of which structures are grain-refined comparing with the base metal as in Fig.7 (c) or (f) due to the dynamic recrystallization. In addition, the structures formed by the threaded probe show much finer grains in Fig.7 (a) and many fine twin structures in Fig.7 (b), which indicate that more severe plastic deformation occurred in case of the threaded probe than thread-less probe. Consequently the thread on the probe surface promotes the plastic deformation; thus, increases the wide plastically deformed area around the probe.

Summary

Lap joint strength of friction spot joining (FSJ) of AZ31 Mg alloy sheet was evaluated by 2 different types of the probe, with and without thread. Joint strength was strongly affected by the width of the plastically deformed zone, formed around a rotating probe, in which the original joint interface between sheets disappeared. The threaded probe was effective to improve the joint

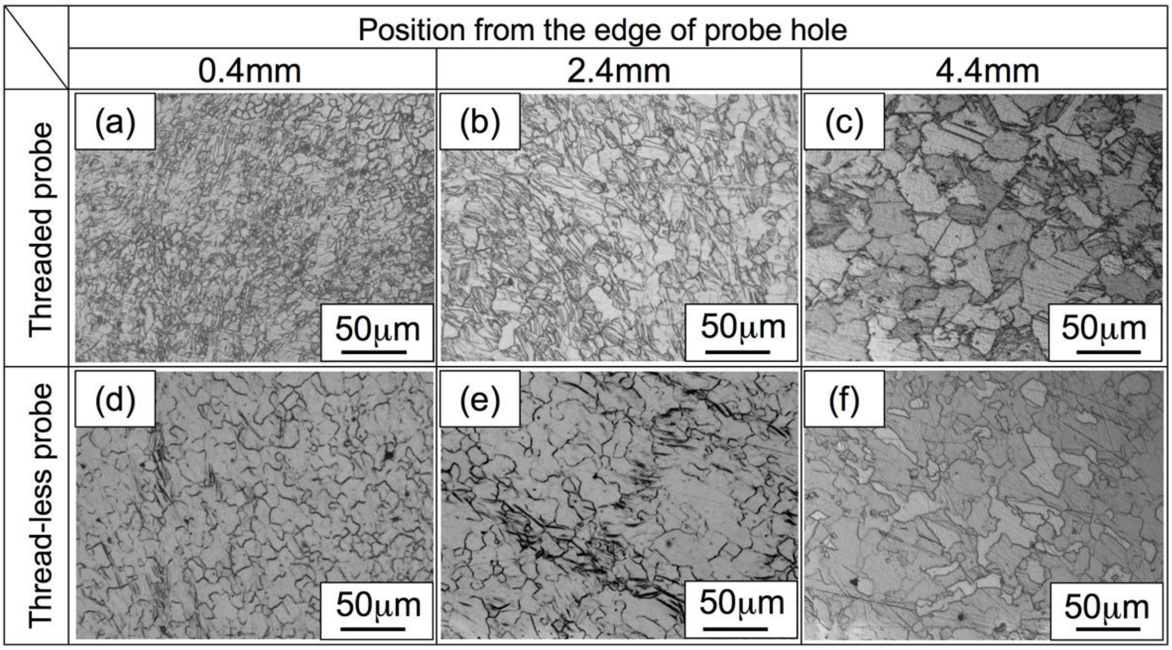


Fig.7 Microstructures around the probe hole at different positions; (a)-(c) with thread; (d)-(f) without thread

strength by promoting the plastic metal flow around a rotating probe in comparison with the thread-less probe.

References

[1] S. Koga: J. Light Metal Weld. & Construction Vol. 42 (2004), p. 523.

[2] K. Kato and R. Sakano: J. Light Metal Weld. & Construction Vol. 42 (2004), p. 532.

[3] R. Sakano, K. Murakami, K. Yamashita, T. Hyoe, M. Fujimoto, M. Inuzuka, Y. Nagao and H. Kashiki: Proc. 3rd Inter. Symp. On Friction Stir Welding, TWI, Kobe (CD-R)(2004).

[4] A. Gerlich, P. Su and T.H. North: Magnesium Technology 2005, TMS, p.383 (2005).

[5] K.Nakata, S.Inoki, Y.Nagano, T.Hashimoto, S.Johgan and M.Ushio: J. Japan Institute of Light Metals, 51(2001), p.528.

Advanced Welding and Micro Joining / Packaging for the 21st Century
doi:10.4028/0-87849-383-2
Effect of Probe Thread on Friction Spot Joint Strength of AZ31 Mg Alloy
doi:10.4028/0-87849-383-2.351