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Fiber Laser Welding of Noncombustible Magnesium Alloy

Yuji Sakai[1,a], Kazuhiro Nakata [2,b], Takuya Tsumura[2,c],Mitsuji Ueda[3,d]
Tomoyuki Ueyama [4,e],Kastuya Akamatsu[5,f]

[1]Graduate School of Engineering, Osaka University, 11-1, Mihogaoka, Ibaraki, Osaka, Japan

[2]JWRI, Osaka University, 11-1, Mihogaoka, Ibaraki, Osaka, Japan

[3]KS Technos, CO.,LTD, 2-6-54, Inadauemachi, Higashiosaka, Osaka, Japan

[4] Daihen,CO.,LTD, 5-1, Minamisenrioka, Settu, Osaka, Japan

[5]Kansai University,3-3-35, yamate-cho, suita, Osaka, Japan

[a]y_sakai@jwri.osaka-u.ac.jp, [b]nataka@jwri.osaka-u.ac.jp, [c]tsumura@jwri.osaka-u.ac.jp,

[d]mitsuji-ueda@kinkisharyo.co.jp, [e]dueyama@daihen.co.jp, [f]akamatsu@ipcku.kansai-u.ac.jp

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Abstract. Noncombustible magnesium alloy AMC602 (Mg-6mass%Al-2mass%Ca) extruded sheet of 2.0mm thickness was successfully welded using a fiber laser welding process at welding speed of 10m/min at 3kW laser power. Tensile strength of the welded joint was about 82 to 88% of that of the base metal. Vickers hardness, tensile strength and micro structural properties are also discussed.

Introduction

Magnesium alloys, like aluminum alloys, have the potential to replace steel in many applications as lightweight structural materials having high strength to weight ratio, and excellent recyclability. Therefore they are being used more and more widely in the automotive and aerospace industry in recent years than before. But on the other hand, magnesium alloys are also very active, so that flux or protective gas must be used to prevent the ignition of magnesium during melting. Hence development of advanced ignition-proof magnesium alloys has been expected. In recent years, Noncombustible Mg-Al based alloy has been developed, with Ca addition which increases the ignition temperature by 200 to 300K compared to with conventional Mg alloys[1]. Manufacturing of Mg alloys requires welding and joining procedures. Recently, among the several kinds of lasers, the focus has been on fiber laser as a welding heat source focused for a welding heat source, because fiber laser presents several benefits for industrial purposes, namely high power with low beam divergence, flexible beam delivery, low maintenance costs, high efficiency of laser generation and compact size of laser apparatus[2]. The aim of this investigation is to evaluate the weldability of noncombustible magnesium alloy AMC602 by fiber laser welding.

Experimental details

Table 1 shows the chemical compositions of noncombustible Mg alloy AMC602 of 2.0mm thickness and 120 mm width. The welding was performed by a fiber laser with argon as shielding gas, a spot focus diameter of 0.3 mm, power of 3kW and welding speed of 4 to 10mm/min to produce butt joints. Base metal (BM) of AMC602 was examined by X-ray diffractometry. Microstructures of the welded joints on traverse cross-sections were observed by optical microscopy (OM), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Analyzer (EDAX). Then tensile strength of the welded joint was evaluated by using a test specimen of JIS13B. Vickers hardness test was measured on the cross-section with a load of 0.98N, loading time of 15s; and on the compound with a load of 0.245N and loading time of 15s.

Table 1 Chemical compositions of AMC602.

Elements	Al	Zn	Mn	Fe	Si	Cu	Ni	Ca	Mg
mass(%)	5.679	<0.001	0.158	0.047	0.048	0.002	0.008	2.159	Bal.

Result and Discussions

Fig.1 shows the surface appearances on front and back side; X- ray photograph; and cross-sectional view of the butt joint of AMC602. Welding conditions include a power of 3kW and welding speeds of 4, 6, 8 and 10mm/min. On the surface, smooth and uniform joints have formed for all welding conditions. On the X-ray radiograph and cross-section, defects such as porosity and crack were not found in the joints

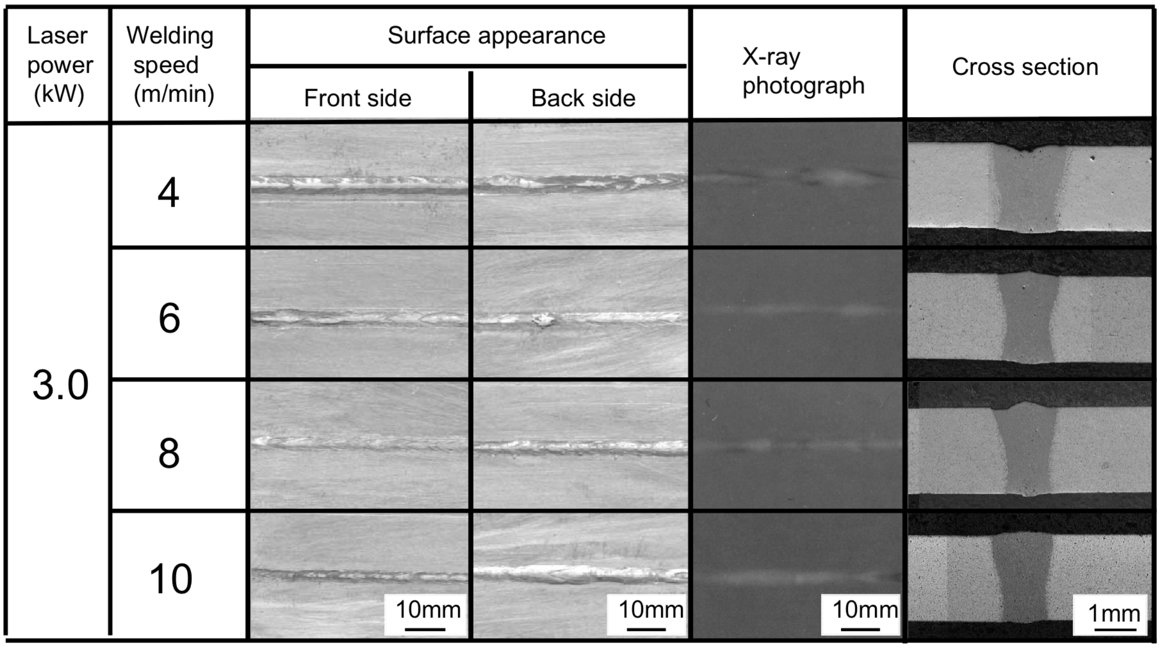

Fig.1 Fiber laser weld appearances, X- ray radiographs and cross-sections of AMC602 for different welding speeds at a constant laser power.

Fig.2 shows the OM micrographs of the cross-sectional view of the butt joint of AMC602 at 3kW-8m/min. It should be noted that the width of weld metal (WM) is very narrow, i.e. only about 1.0mm. Furthermore, there is no distinct heat affected zone (HAZ) development adjacent to the weld metal region in the cross-section. The equiaxed dendritic or cellular structures were observed in the weld metal in Fig.2(d) and some compounds which appeared in the base metal in Fig.2(b) were partially melted in the heat affected zone adjacent to the fusion boundary in Fig.2(c). From the results of X-ray diffractometry, these compounds were identified as the intermetallic compound Al_2Ca. Fig.3(a), 3(b)and 3(c) show SEM micrographs of the intermetallic compound Al_2Ca in the base metal, the heat affected zone and the weld metal, respectively. A detailed examination of Fig. 3(c) reveals that the weld metal contains no granular intermetallic compound Al_2Ca, but fine network of Al_2Ca compound along the sub-grain boundary of dendritic structure. (A) in Fig.3(b) is a partially melted compound (Al_2Ca), and was dotted along a fusion boundary. This area is called the partially melted zone [3] due to the eutectic section between Al_2Ca compound and a-Mg near 520ºC [4].

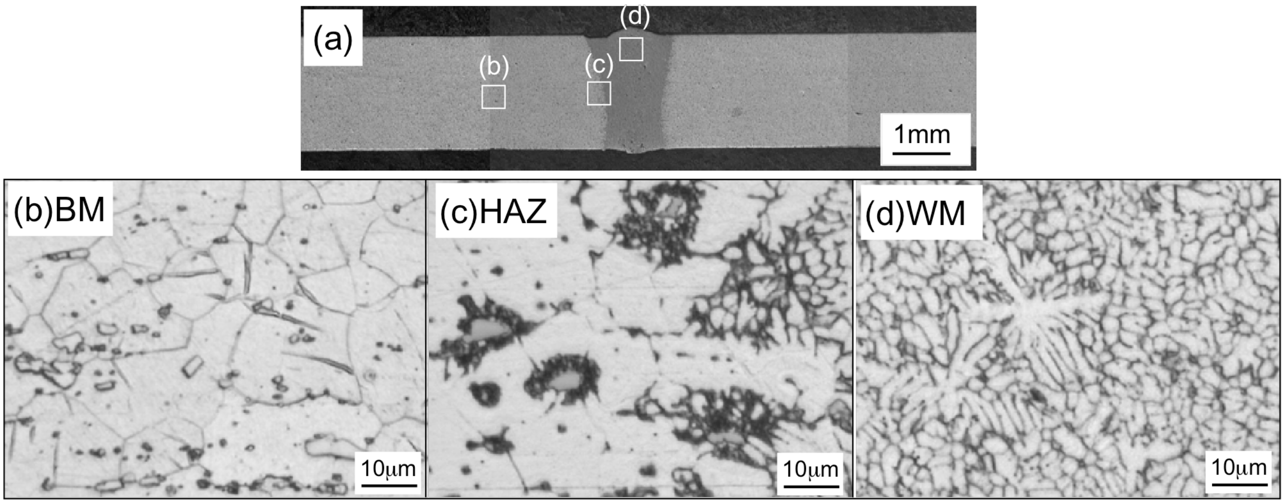

Fig.2 (a)Macro, (b)Base Metal, (c)Heat Affected Zone, (d)Weld Metal structures on cross-section of the welds; 3kW, 8m/min:

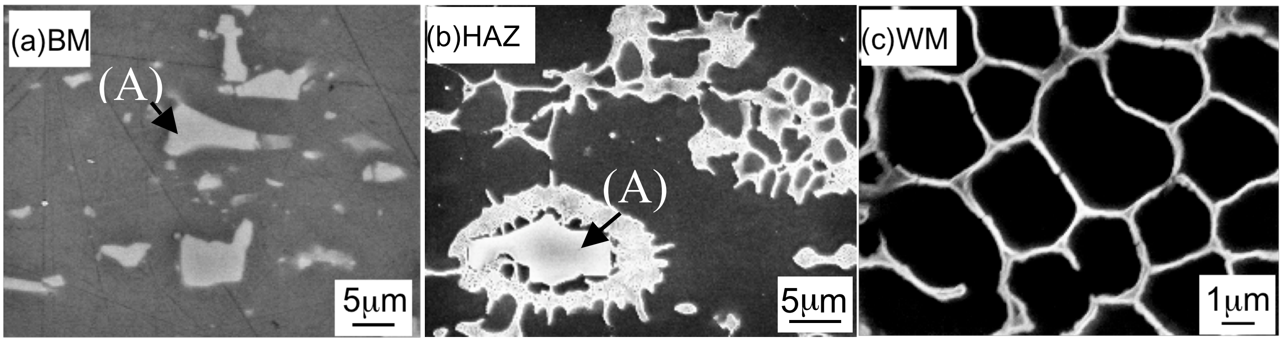

Fig.3. SEM micrographs of the intermetallic compound Al_2Ca:(a) Base Metal : (b) Heat Affected Zone : (c) Weld Metal.

Fig.4 shows Vickers hardness profile of the base metal, HAZ and weld metal at the welding speeds of 4 to 10 m/min. The hardness profile shows a sharp increase in the hardness at the weld metal from the base metal and HAZ. The hardness at the weld metal is about HV 25 higher than that at base metal. The average hardness in the weld metal is approximately HV 90 as compared to HV 65 in the base metal. The increase in the hardness of the weld metal was probably due to its fine network microstructure, with grain boundary phase of Al_2Ca compound, as shown in Fig.3(c). The hardness in

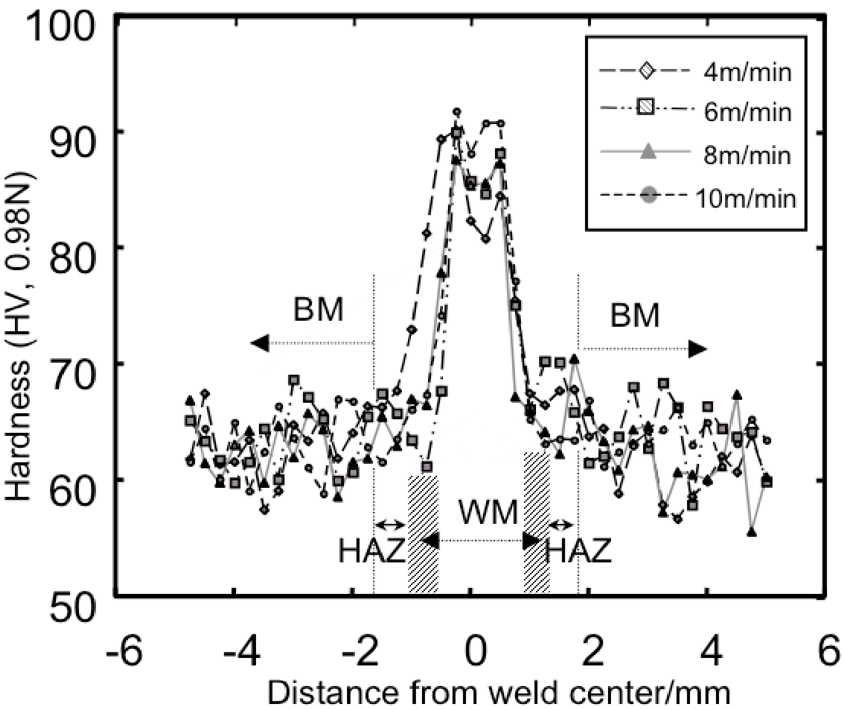

Fig. 4 Vickers hardness profiles of fiber laser welded joint of AMC602 at different welding speeds.

the weld metal increases slightly with welding speed since the rapid cooling resulted in the fine network structure of Al_2Ca compound. Fig.5 shows the tensile strengths of the welded joint as a function of the welding speed. These tensile strengths of the welds were about 82 to 88% of that of the base metal, but the elongation of the welded joint decreased to about half of that of the base metal. Fracture of the test specimen occurred along the fusion boundary.

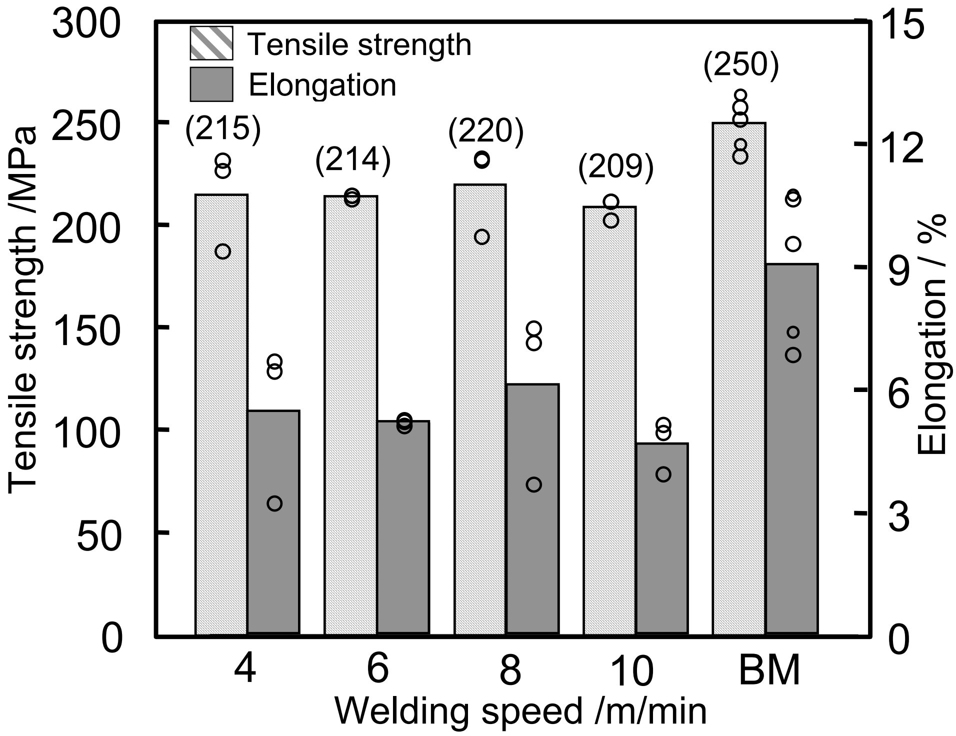

Fig. 5 Tensile test result of fiber laser welded joint of AMC602 at different welding speeds.

Summary

Weldability of noncombustible magnesium alloy AMC602 sheet by fiber laser welding was evaluated at different welding speed. There is no porosity or defect in the welded joint at the welding speed ranging from 4 to 10m/min at 3kW laser power. The microhardness of the weld metal is about HV20 to 25 higher than that of the base metal due to the fine network structure of Al2Ca along the sub-grains of the dendritic structure. Tensile strengths of the welded joint were around 209 to 220MPa that is 82 to 88% of that of the base metal. These imply that the welded joint produced by the fiber laser welding has excellent mechanical properties.

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