PAPER • OPEN ACCESS

Double fillet lap of laser welding of thin sheet AZ31B Mg alloy

To cite this article: Mahadzir Ishak and M N M Salleh 2018 *J. Phys.: Conf. Ser.* **1027** 012003

View the article online for updates and enhancements.

Double fillet lap of laser welding of thin sheet AZ31B Mg alloy

Mahadzir Ishak[*] **and M N M Salleh**

Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang

Corresponding author: mahadzir@ump.edu.my

Abstract. In this paper, we describe the experimental laser welding of thin sheet AZ31B using double fillet lap joint method. Laser welding is capable of producing high quality weld seams especially for small weld bead on thin sheet product. In this experiment, both edges for upper and lower sheets were subjected to the laser beam from the pulse wave (PW) mode of fiber laser. Welded sample were tested their joint strength by tensile-shear strength method and the fracture loads were studied. Strength for all welded samples were investigated and the effect of laser parameters on the joint strength and appearances were studied. Pulsed energy (EP) from laser process give higher effect on joint strength compared to the welding speed (WS) and angle of irradiation (AOI). Highest joint strength was possessed by sample with high EP with the same value of WS and AOI. The strength was low due to the crack defect at the centre of weld region.

1. Introduction

Joining process has become a great demand where it is important to make two or more similar or different parts to become one product with good characteristics. There are several types of joining method such as bolt and fasteners, adhesive, solder, rivet, and welding method. In all types of joining, welding gives better results especially in metal joining such as ferrous or non-ferrous metals. It is one of the methods that have been applied in manufacturing industries to joint products crucially towards metal. Manufacturing industries play an important role in term of producing new products and technologies to the people around the world. Transportation, architecture, city development, and others need manufacturing industry in order to accomplish their desired products. The application of thin sheet metals usually found in automotive, aviation, and electronic devices as an alternative of reducing weight [1, 2]. Thin sheet metals has been a growing demand in manufacturing engineering where the thickness used is below than 2 mm [3-5]. Among the metals used in industries, magnesium alloys such as AZ31B, AZ91D and AZ61 has increasing application due to the advantages; light weight metal, high-strength to weight ratio, good weldability, high electrical conductivity and high corrosion resistance [6, 7].

Application of laser in material processing is increasing since it was introduced from 1960 [8]. This contribution includes the laser welding process to join metals where this method can be used even to weld thin sheets metals. The metals to be welded are melted by means of heat from the laser beam which focused at one spot where it creates weld pool. Laser welding is unique compared to the conventional welding that have been applied in industries long before. It is unique because of its advantages as a bonding process. The advantages includes producing powerful laser beam, concentrated heat source, and allowing to obtain deep and narrow penetration depth for a high speed

process [9]. This process already becomes an important manufacturing process especially in joining metals due to its advantages as a bonding process.

As for industrial requirements, fiber laser welding is promising bigger advantages for manufacturing industry such as low cost, time saving, free maintenance and high quality production [10]. In this paper, thin sheet AZ31 was welded by fiber laser welding method with double fillet lap joint type was preferred. The objective of this work is to investigate the parameters used to achieve better weld joint in term of its strength and weld appearances.

2. Methodology/Model Description

2.1 Material

AZ31B Magnesium alloy with thickness of 0.6 mm was used in this study. The major alloying element for this material is aluminium (Al), and zinc (Zn). Metal composition was Al-2.8 %, Zn-1.2 % and Mg- balance. Before the metal subjected to the laser welding, it was cut by dimension $53 \times 20 \times 0.6$ mm. Table 1 shows the chemical compositions of AZ31B which tested with spectrometer and from previous research. Samples were polished with 180 grit sand paper in order to remove the oxide layer presented at the welding area.

Table 1. Chemical composition of AZ31B

Element	Weight, %		
Al	2.8	2.98	2.46
Zn	1.2	0.87	1.7
Mn	0.4	0.35	0.58
Si	0.02	0.016	<0.1
Cu	0.002	0.004	<0.05
Fe	0.002	0.001	<0.005
Mg	Bal.	Bal.	Bal.
Source	Spectrometer	F. Pan, et al., 2017 [2]	M. Harooni, et al., 2015 [11]

2.2 Welding Setup

Pulse wave (PW) mode was used in this experiment where the pulsed energy, EP used are 1.8, 2.0, and 2.2 J with constant pulse width and pulse repetition rate of 2 ms and 60 HZ, respectively. The angle of irradiations used is 2, 3, and 4 degrees and the welding speed used is 2, 3, and 4 mm/s. Fifteen samples were welded in this experimental work and the bond width, throat length, and penetration depth of all samples were measured and collected. Figure 1 (a) shows a low power fiber laser machine with the average power of 200 W used in this research work.

Welding jig was fabricated in order to perform the lap joint welding where the jig was made by Aluminium. Welded sample would be clamped on the welding jig where the spacer was compulsory for the lap joint sample. Arduino system was adapted to the welding rail where it controlled the movement of the stepper motor for the x-axis (welding line). Shielding gas was then attached to the laser head where the nozzle could be adjusted to the suitable angle for different welded metal as shown in Figure 1 (a) and (b) for the welding setup for the double fillet welding technique. Shielding gas used was Nitrogen (N_2) with flow rate 25 L/min.
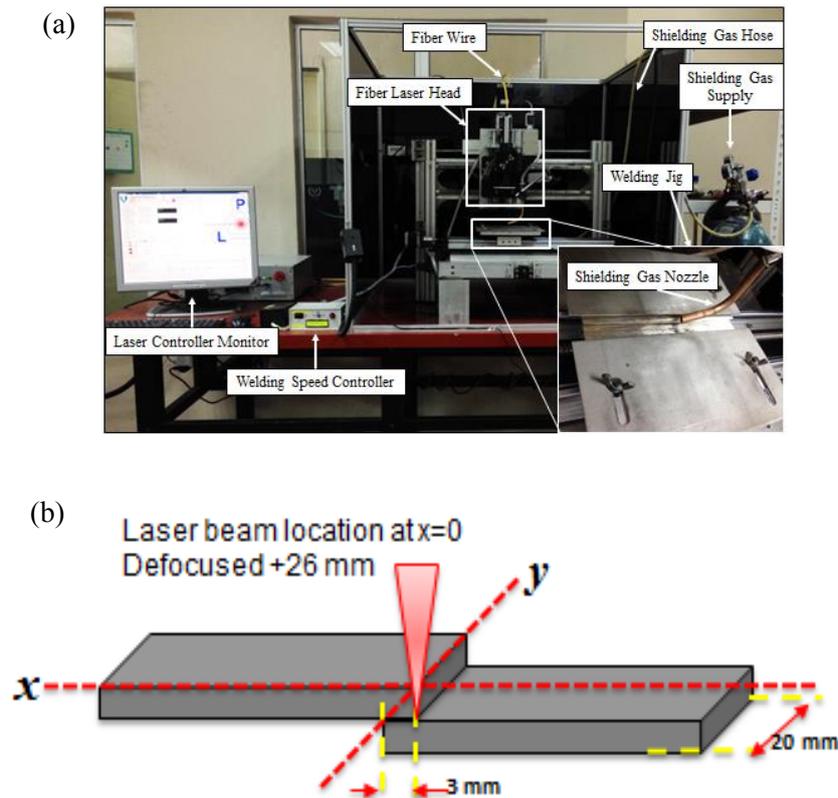
Figure 1. Double fillet lap laser welding condition (a) Complete welding setup and (b) Schematic illustration during welding

3. Result and Discussion

3.1 Verification

Laser welding experiment was carried out on thin sheet of AZ31B Mg alloys according to the number of run order as shown in Table 2. Average values of tensile-shear strength for each tested sample were tabulated where it showed the average result of fracture load values which have been conducted for all fifteen welded samples. It was observed that specimen number 1 has the lowest tensile-shear strength of 22.3 MPa with a fracture load of 101.5 N produced by Ep: 1.8 J, WS: 2 mm/s, and AOI: 3°. The joint produced by Ep: 2.0 J, WS: 2 mm/s and AOI: 2° (sample 9) achieved the highest tensile-shear strength (62.0 MPa). Sample 8 showed the second highest of shear strength (52.0 MPa) among others which was 10 MPa difference to the strength of sample 9. Sample 13 to 15 showed approximately same results of strength which was within 30 to 32 MPa. However, sample 13 possessed a slightly higher fracture load with 520 N compared to sample 14 and 15 with 426.3 N and 450 N, respectively. Figure 2 presents the bar graph in order to show the average values of fracture loads possessed by each welded sample. The error bar represents the collected values from high and low value of each sample as shown in Table 2. Based on Figure 2, it was observed that sample 9 showed the highest fracture load of 740.2 N with 62 MPa shear strength, meanwhile sample 1 showed the lowest fracture load of 101.5 N with 22.3 MPa. Based on the graph, it was observed that the welded samples possessed the fracture load mostly ranged between 400 to 600 N.

Table 2. Fracture load result according to experiment order

| Sample | EP (J) | WS (mm/s) | AOI (º) | Fracture Load (N) | | |
				Low	High	Avg
1	1.8	2	3	91.50	111.5	101.5
2	2.2	2	3	574.8	604.8	589.8
3	1.8	4	3	180.5	210.5	195.5
4	2.2	4	3	467.7	497.7	482.7
5	1.8	3	2	242.6	272.6	257.6
6	2.2	3	2	619.3	639.3	629.3
7	1.8	3	4	505.5	525.5	515.5
8	2.2	3	4	534.1	564.1	549.1
9	2.0	2	2	730.2	750.2	740.2
10	2.0	4	2	578.4	608.4	593.4
11	2.0	2	4	277.1	307.1	292.1
12	2.0	4	4	165.4	195.4	180.4
13	2.0	3	3	510.0	530.0	520.0
14	2.0	3	3	416.3	436.3	426.3
15	2.0	3	3	435.0	465.0	450.0
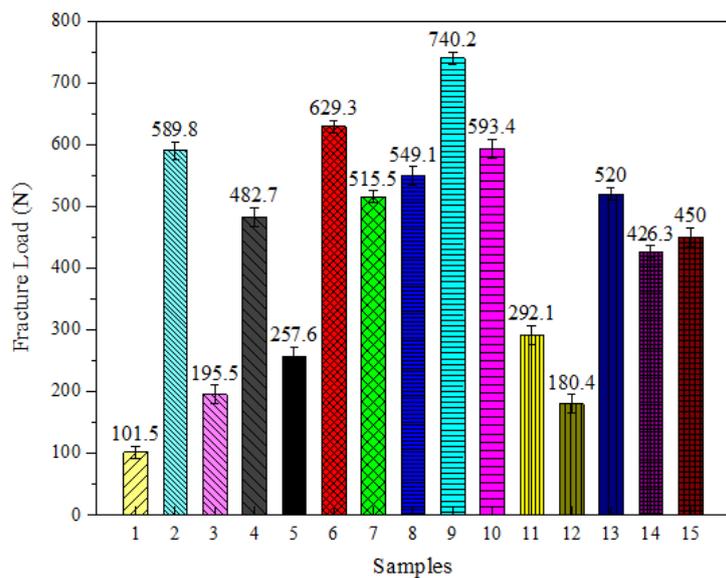
Figure 2. Average fracture load values for 15 welded samples

Sample 9 possessed good weld with less occurrence of defect compared to other samples. It was proved with the joints' strength in Table 2 where sample number 9 had the highest strength among others. Cracks occurred in most of the weld due to the hot crack which was generated when low welding speed was used. Much higher energy input caused distortion effect on the sheets which then produced higher stress concentration between the two sheets [12].

The crack in the weld bead occurred also was inevitable due to the two sheets of the welded was not clamped properly before the welding process which could present the gap between the sheets. Most of the crack defects were found at the second weld area except sample 2, 6, 9, 11, 13, 14, and 15.

Sample 13 to 15 shows approximately same weld bead for both fillets as these samples were welded using same laser parameters.

Sample number 1 was found as the lowest joint strength as the crack defect presented at the second weld region referred from Figure 4.8 (a). There was a high possibility that the crack was produced due to the solidification crack occurred after being welded using laser which created rapid cooling process in the fusion zone [12]. In addition, AZ31B consist of Zinc, Zn element which have wide melting range where it is sensitive to hot cracking [13].
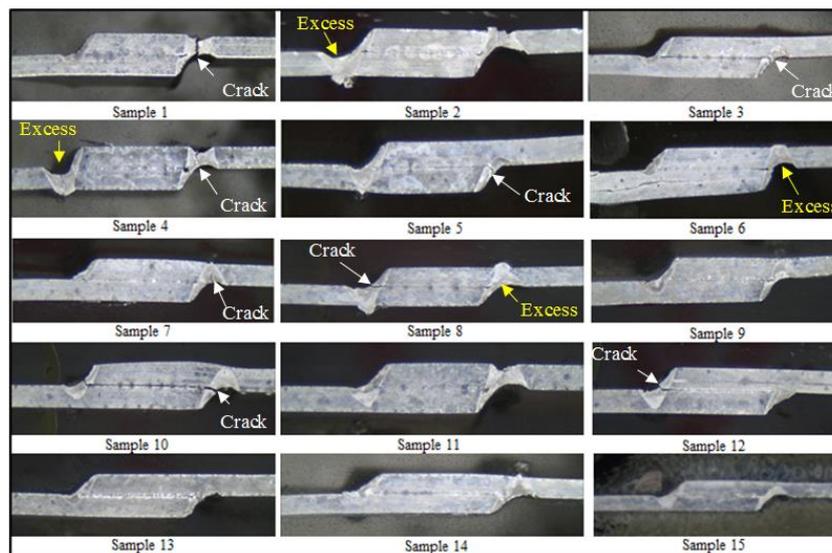
Figure 3. Macrostructure of 15 welded samples

4. **Conclusion**
From the present study, the followings can be concluded:
(a) Higher pulsed energy with same value of WS and AOI produced higher joint strength.
(b) Highest pulsed energy produced sound weld and free defects based on its appearance compared to the lower pulsed energy
(c) Pulsed energy (EP) was the most effective parameter towards joint strength

References
[1] Simoncini M and Forcellese A 2012 Effect of the welding parameters and tool configuration on micro- and macro-mechanical properties of similar and dissimilar FSWed joints in AA5754 and AZ31 thin sheets *Materials & Design* **41** 50-60
[2] Pan F, Zeng B and Jiang B 2017 Enhanced mechanical properties of AZ31B magnesium alloy thin sheets processed by on-line heating rolling *Journal of Alloys and Compounds* **693** 414-420
[3] Steglich D, Tian X, Bohlen J*, et al.* 2014 Mechanical Testing of Thin Sheet Magnesium Alloys in Biaxial Tension and Uniaxial Compression *Experimental Mechanics* **54** 1247-1258
[4] Falconnet E, Chambert J, Makich H*, et al.* 2015 Prediction of abrasive punch wear in copper alloy thin sheet blanking *Wear* **338-339** 144-154

[5]　Wu H Y, Sun P H, Zhu F J*, et al.* 2012 Tensile Properties and Shallow Pan Rapid Gas Blow Forming of Commercial Fine-grained Mg Alloy AZ31B Thin Sheet *Procedia Engineering* **36** 329-334

[6]　Tan Q, Atrens A, Mo N*, et al.* 2016 Oxidation of magnesium alloys at elevated temperatures in air: A review *Corrosion Science* **112** 734-759

[7]　Molnár P, Ostapovets A and Jäger A 2014 Reversible motion of twin boundaries in AZ31 alloy and new design of magnesium alloys as smart materials *Materials & Design* **56** 509-516

[8]　Odabaşı A, Ünlü N, Göller G*, et al.* 2010 A Study on Laser Beam Welding (LBW) Technique: Effect of Heat Input on the Microstructural Evolution of Superalloy Inconel 718 *Metallurgical and Materials Transactions A* **41** 2357-2365

[9]　Moskvitin G V, Polyakov A N and Birger E M 2013 Application of laser welding methods in industrial production *Welding International* **27** 572-580

[10]　Assunção E, Quintino L and Miranda R 2009 Comparative study of laser welding in tailor blanks for the automotive industry *The International Journal of Advanced Manufacturing Technology* **49** 123-131

[11]　Harooni M, Ma J, Carlson B*, et al.* 2015 Two-pass laser welding of AZ31B magnesium alloy *Journal of Materials Processing Technology* **216** 114-122

[12]　Ishak M, Yamasaki K and Maekawa K 2012 Laser Welding of Thin Sheet Magnesium Alloys In *Nd:YAG Lasers* InTech Open Access **2016** 135-157

[13]　Yu Z H, Yan H G, Yin X Y*, et al.* 2012 Liquation cracking in laser beam welded joint of ZK60 magnesium alloy *Transactions of Nonferrous Metals Society of China* **22** 2891-2897