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# Weldability during the laser lap welding of Al 5052 sheets

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ABSTRACT

**Purpose:** The paper presents the effect of the laser welding parameters of the laser focal position, the welding speed and the laser output power on the weldability of Al the 5052 alloy during laser lap welding.

**Design/methodology/approach:** Lap welding is conducted on an Al 5052 plate with a thickness of 1 mm. After welding, the bead surfaces and cross sections were evaluated with various laser welding parameters. The degree of porosity was also examined by X-ray transmission testing.

**Findings:** The influences of the focal point, the laser power and the welding speed on the formation of bead and on the degree of porosity were experimentally investigated. The bead quality was improved when the beam was defocused compared to when it was focused on the surface. It was found that the porosity decreased when the heat input is lowered, except when the lower plate is not melted.

**Research limitations/implications:** Various types of aluminium alloys, such as sheet, extrusion and casting types, are used industrially in diverse combinations. Therefore, it is necessary to evaluate the weldabilities of these materials. This research is limited to Al 5052 alloys at present plans are underway to expand it to various aluminium based alloys.

**Practical implications:** Automotive industries are continuously increasing their use of aluminium alloys in manufacturing. The results of this research can be referred to by the automotive industry as a basic technique.

**Originality/value:** This research shows the influence of different welding parameters on the weldability during the lap welding of Al 5052 Al alloy. The results are based on the extensive experiments.

**Keywords: Welding; Laser welding; Aluminium alloy; Lap welding**

MATERIALS MANUFACTURING AND PROCESSING

## 1. Introduction

Interest on the lightweight vehicles has increased due to industry competition related to fuel efficiency. Therefore, the use of aluminium alloys has increased as they are very strong and lightweight metal resources. Laser welding is commonly used due to its high productivity among various joining methods of aluminium alloys [1]. With the interest in aluminium welding and the development of lasing systems, various studies have been conducted regarding different types of alloys and lasers [2-12]. As the 5xxx series of aluminium alloys are non-heat-treatable types that show a high strength after the addition of a large amount of magnesium to a solid solution of aluminium, they are commonly used in auto bodies and structures in which high strength and low weight are required. However, it is reported that 5xxx series alloys are associated with the formation of pores in the weldment caused by the relatively low boiling temperature of the magnesium elements [13-16].

In this research, the weldability of an Al 5052 thin plate in the laser welding of a lap joint was investigated in experiments with various process parameters. The process parameters considered in the experiments are the position of the focal point, the laser power and the welding speed. The weldabilities were evaluated by analyzing the bead appearances, cross-sectional bead shapes and the porosities as measured by X-ray transmission testing. Weldable process ranges were recommended to achieve a satisfactory welding quality.

## 2. Experimental setup

The Al 5052 thin plate workpieces used in this research had a length of 200 mm, a width of 50 mm and a thickness of 1mm. The laser welding experiments were conducted on the lap joint of these plates. The chemical composition of the Al 5052 material is shown in Table 1. Table 2 shows the welding conditions of the experiments with fixed and variable parameters. As shown in Table 2, the incident angle of the laser is fixed at 5° (i.e. forward inclination) and shielding gas is supplied to both the top and bottom surfaces of the lap joint specimens. The parameters of interest are the focal position, the laser power and the welding speed, and their levels are 7, 3 and 7, respectively. The experiments were conducted in a full factorial experimental design. The weldability was evaluated by the internal and external bead shapes and the porosities were checked by X-ray transmission testing.

Table 1.
Chemical composition of Al 5052 alloy (weight, %)

| Si | Fe | Cu | Mg | Cr | Al |
|---|---|---|---|---|---|
| 0.08 | 0.27 | 0.01 | 2.69 | 0.18 | Bal. |

Table 2.
Welding conditions used

| | |
|---|---|
| Laser beam angle, Deg. | 5 |
| Shielding gas, Top surface | Ar 50% + He 50%, 20 l/min |
| Shielding gas, Bottom surface | Ar 100%, 10 l/min |
| Welding speed, m/min | 3, 4, 5, 6, 7, 8, 9 |
| Focal position, mm | 9, 6, 3, 0, -3, -6, -9, -12 |
| Laser output power, kW | 3.0 , 3.5, 4.0 |

## 3. Influence of the welding parameters

### 3.1. Focal position

Various bead shapes according to the position of the focal point are shown in Fig. 1. When the focal point is set on the surface, the bead appearance has low consistency. However, when using a defocused beam, the welding quality is enhanced, although the penetration depth is lowered. In the X-ray test result, as shown in Fig. 2, it is observable that the porosity rapidly increases around a defocusing length of 6 mm at which full penetration changes to partial penetration. Although the case of a 9 mm focal point position shows decreased porosity, this finding is of no consequence as the lower plate is not melted.

### 3.2. Laser output power

The influence of the laser power on the bead shape and the porosity with a fixed welding speed is shown in Fig. 3 and Fig. 4. For a lower laser power, the bead quality increases while the porosity increased. An underfill was observed when the laser power was 4 kW due to the excessive heat input.

### 3.3. Welding speed

The bead shapes and the results of X-ray transmission tests according to the welding speed with a fixed laser power and a fixed focal position are shown in Figs. 5 and 6, respectively. As is clear, the penetration depth is decreased with the increase in the welding speed; however porosity is increased. When the welding speed is faster than 7 m/min, the porosity decreases because the lower plate is not sufficiently melted. In addition, underfill resulted with a low welding speed due to the excessive heat input.

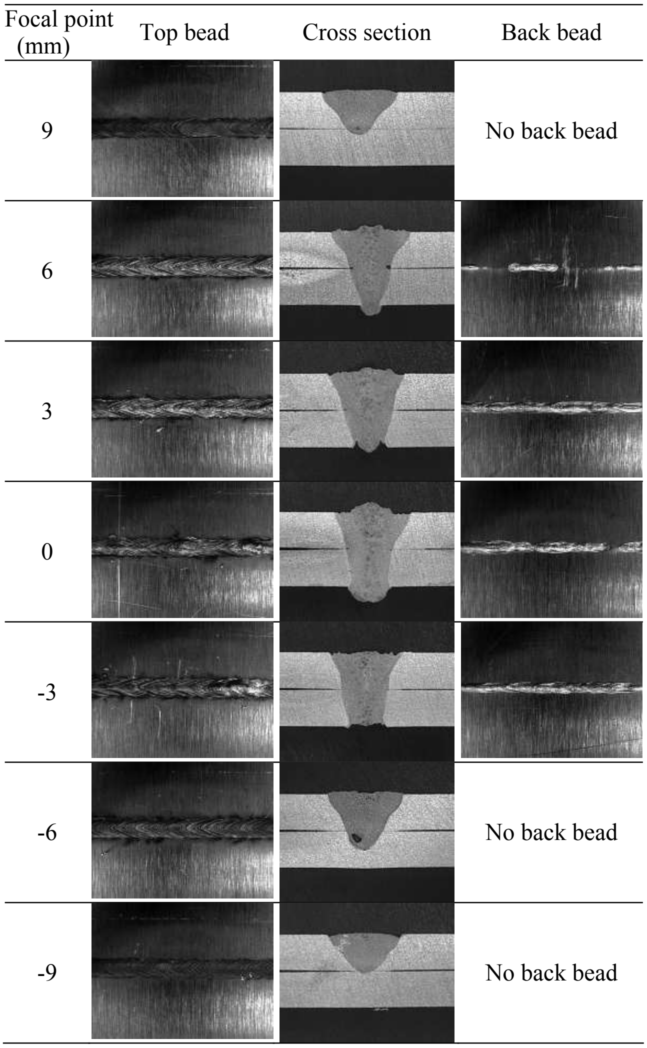



Fig. 1. Bead shapes for various focal positions (laser power: 3kW, welding speed: 6 m/min)

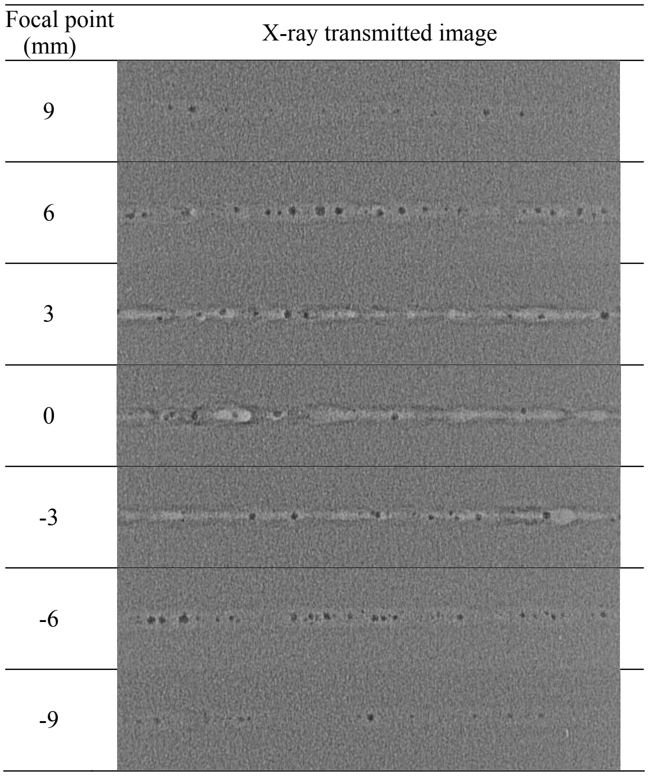



Fig. 2. X-ray transmitted images for various focal positions (laser power: 3 kW, welding speed: 6 m/min)

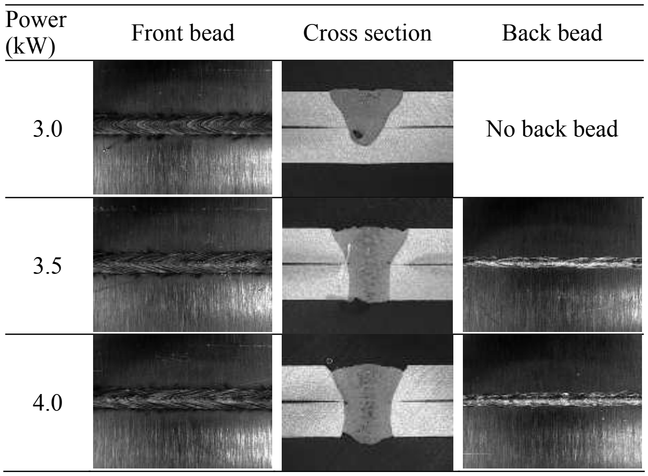



Fig. 3. Bead shapes for various laser powers (focal point: -6 mm, welding speed: 6 m/min)

## 4. Conclusions

In this research, laser lap welding experiments involving Al 5052 thin plates were conducted and the weldability levels were evaluated with various process parameters. If the heat input is sufficient, i.e.; if the beam is focused on the surface with a high

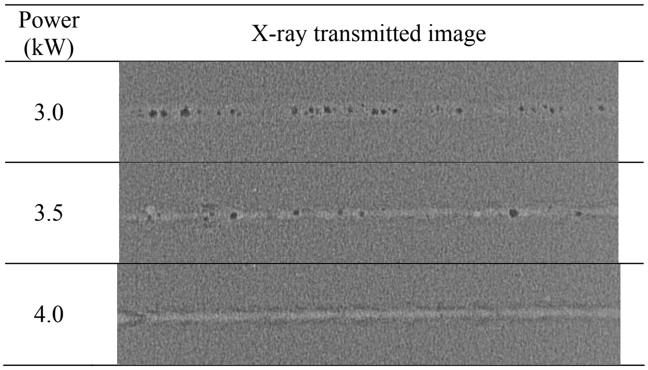



Fig. 4. X-ray transmitted images for various laser powers (focal point: -6 mm, welding speed: 6 m/min)

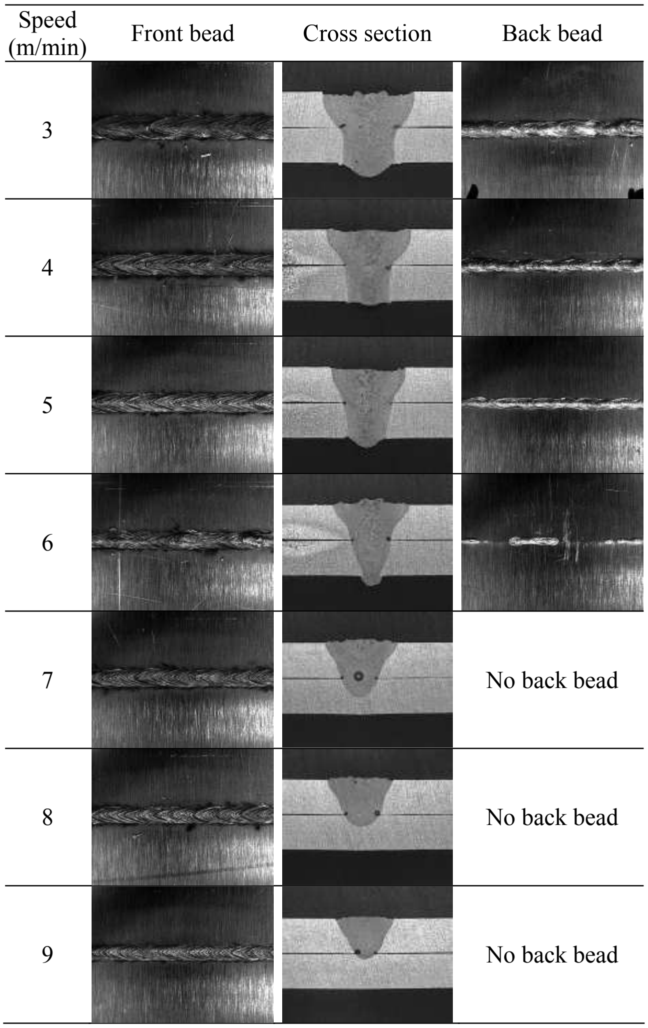



Fig. 5. Bead shapes for various welding speed (laser power: 3 kW, focal position: 6 m)

laser power and a low welding speed, full penetrations are achievable. However, it was also observed that the weld bead has low consistency and that it experienced underfill. On the other hand, if the heat input decreases, the consistency of the bead appearance increases. In this case, the porosity increases except when the lower plate is not melted. Therefore, the proper welding conditions suggested in this study are limited to cases involving lower heat input and fully penetrated condition.

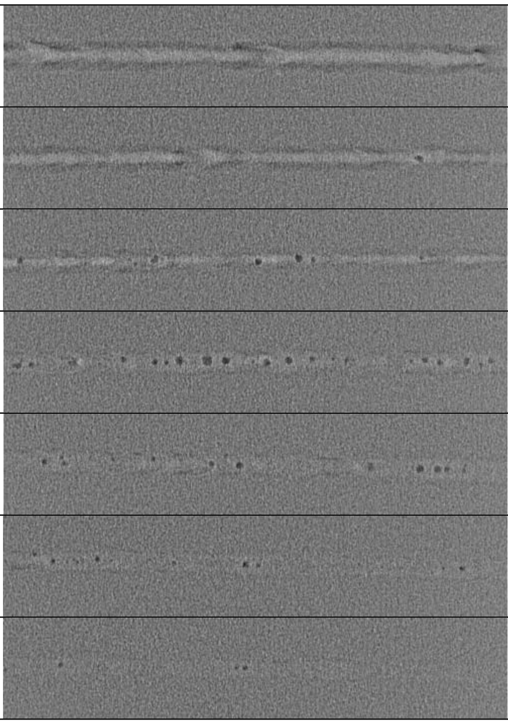
| Speed (m/min) | X-ray transmitted image |
|---|---|
| 3 |  |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |

Fig. 6. X-ray transmitted images for various focal positions speed (laser power: 3 kW, focal position: 6 m)

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