A Study on the Formation of Imperfections in CW CO_2 Laser Weld of Diamond Saw Blade

M. Shin, C. Lee, T. Kim and H. Park

Abstract

The main purpose of this study was to investigate the formation mechanisms of imperfections such as irregular humps, outer cavity and inner cavity in the laser fusion zone of diamond saw blade. Laser beam welding was conducted to join two parts of blade; mild steel shank and Fe-Co-Ni sintered tip. The variables were beam power and travel speed. The microstructure and elements distributions of specimens were analyzed with SEM, AES, EPMA and so on. It was found that these imperfections were responded to heat input. Irregular humps were reduced in 10.4~17.6kJ/m heat input range. However there were no clear evidences, which could explain the relations between humps formation and heat input. The number of outer cavity and inner cavity decreased as heat input was increased. Considering both possible defects formations mechanisms, it could be thought that outer cavity was caused by insufficient refill of keyhole, which was from rapid solidification of molten metal and fast molten metal flow to the rear keyhole wall at low heat input. More inner cavities were found near the interface of the fusion zone and sintered segment and in the bottom of the fusion zone. Inner cavity was mainly formed in the upper fusion zone at high heat input whereas was in the bottom at low heat input. Inner cavity was from trapping of coarsened preexist pores in the sintered tip and metal vapor due to rapid solidification of molten metal before the bubbles escaped.

Key Words : Diamond saw blade, CW CO_2 laser weld, Irregular humps, Cavity, Formation mechanism

1. Introduction

Diamond saw blade has been widely used for cutting concrete, asphalt, stone in construction industry[1]. This cutting tool is made by joining two parts of mild steel shank and sintered segments. Brazing has been a main fabrication process.

To develop high performance and low cost advanced saw blade, new joining processes and materials have been researched recently. As a new joining method, laser beam welding has been applied. Comparing to brazing, the laser beam welding has many advantages; a high energy density and low heat input. Therefore very little distortion and high bonding strength could be obtained. Many attempts on changing chemistry of the bond alloys of segment tips have been conducted. Fe-base tips were found to be very attractive because these tips have not only an equivalent mechanical properties to the conventionally used Co-Ni base tips but also economical competitions.

However, irregular humps, outer cavity and inner cavity which were not formed in the laser fusion zone of the diamond saw blade with Co-Ni base segments are commonly found in the diamond saw blade with Fe-base segments. Because these imperfections deteriorate not only mechanical property but also appearance. A systematic study on the behavior of defects in the laser fusion zone is strongly needed to solve the problems.

Many studies focused on the formation mechanisms of discontinuities in similar materials weld are available. But there are few studies on laser welding between dissimilar materials, especially between mild steel and powder-sintered Fe-base alloys.

The main objectives of this preliminary study are clarification of the formation of imperfections in dissimilar laser weld and optimization of the welding parameters for suppression of weld discontinuities.

2. Experimental procedures

Fig. 1 shows two components of a diamond saw blade, 1.8mm thickness mild steel shank and 2.4mm thickness Fe-base sintered tips joined by a continuous CO_2 laser. Weld tests were conducted with the various parameter combinations shown in table 1. The first welding was

M. Shin and *C. hee* : Division of Materials Science and Engineering Hanyang University, 17 Haengdang-dong, Seongdong-Gu, Seoul 133-791, Korea
E-mail : shinmh@ihanyang.ac.kr
T. Kim and *H. Park* : Research Center, Ehwa Diamond Ind. Co., Ltd. 520-2, Won-dong, Osan-City, Kyungki-Do 447-804, Korea

done at a fixed low heat input condition (3.5m/min of travel speed and 750W of beam power) and the second pass welding was made with variable conditions shown in table 1. The laser beam was focused on the top surface of the shank. The shielding gas was Ar with 80 ℓ/min flow rate.

Irregular humps and number of outer and inner cavities in the second weld were evaluated. For analysis, the specimens were cut finely and polished by 0.3㎛ diameter Al_2O_3 powders. The specimens were cleaned with acetone before etching by 6% natal for 10 sec.

The humps interval and height were evaluated by a roughness measuring instrument, surfcorder SE 40G. The number of cavity was measured by an optical microscope and image analysis system. ICP, SEM, EDS and AES were used for chemistry and microstructural evaluations.

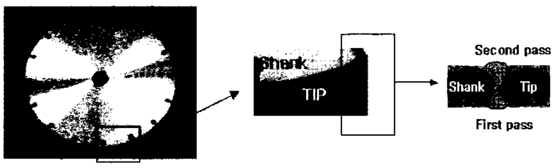

Fig. 1 Components of a diamond saw blade

Table 1 Welding parameters applied in this experiment

Beam power(W)	Travel speed(m/min)	focal point	shielding gas flow rate ,Ar
1350	1	Surface of specimen	80ℓ/min
1470	1.2		
	1.35		
1650	1.7		

3. Results and discussion

3.1 Irregular humps

Fig. 2 shows the typical appearance of outer cavity, inner cavity and irregular humps with under cut in the laser fusion zone of diamond saw blade. Humps were divided into three types such as A, B, C depending on surface roughness and are shown in Fig. 3. Both A and B types are regular humps, which can be accepted as sound bead regarding to the guarding line in actual diamond saw blade industry whereas C type is rejectable. Table 2 shows that C type was only found in the specimens welded with 1.7m/min of travel speed at 1350W beam power and 1m/min at 1650W beam power and A, B types were found in other parameter combinations.

Because it is convenient to group beam power and travel speed into one parameter, heat input. The heat input with which A, B types were formed between 10.4~17.6 kJ/m heat input range (assumed absorption efficiency was 20%). It was known that irregular humps were from the resonant oscillation of molten metal in rear keyhole[2-3]. Considering this, It is thought that resonant oscillation can be reduced between 10.4~17.6 kJ/m heat input range. However there was no evidences, which can explain the relations between heat input and oscillation. More works are needed to confirm.

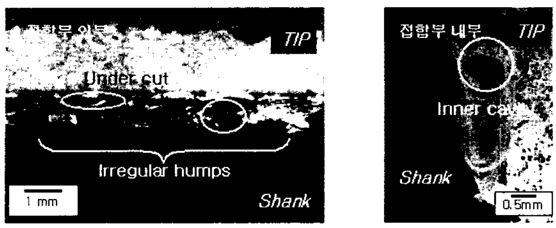

Fig. 2 Imperfections in CW CO_2 laser fusion zone of diamond saw blade

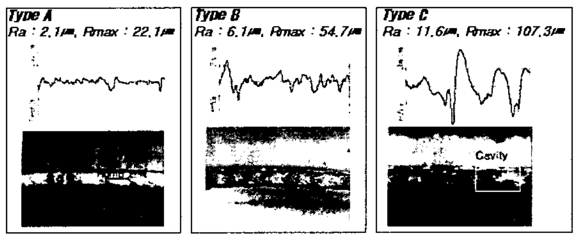

Fig. 3 Humps types in diamond saw blade fusion zone

Table 2 Humps types of welding parameters

Speed/Power	1350W	1470W	1650W
1.7m/min	C	B	B
1.35m/min	A	B	A
1.2m/min	B	B	B
1m/min	A	B	C

3.2 Cavity/Porosity

A typical appearance of outer cavity is shown in Fig 6 a. The number of outer cavities was decreased with the increase in heat input as shown in Fig. 4. As heat input was reduced, solidification rate of crown repulsed molten metal from keyhole increased and the velocity of molten metal flow to the rear part of keyhole increased[4-7]. This may have caused an insufficient refill of the keyhole and more outer cavities occurred with lower heat input. Fig. 5 shows the relations between inner cavity and heat input. Inner cavity was also reduced as the heat input increased.

From the cross section shown in Fig. 6 b, it can be observed that inner cavities formed mainly near the sintered tip side and bottom side of the fusion zone. From the longitudinal sections shown in Fig. 7, it can be noticed that inner cavities formed in the upper fusion zone at high heat input whereas formed in the bottom of fusion zone at low heat input condition. Considering these results, inner cavities mainly have formed from the preexist pores in the sintered tip and the first bead, and metal vaporization at the bottom of keyhole. These metal vapor bubbles remained as inner cavities by trapping during floating in the molten metal pool. Fe was riched in preexist pores as shown in the EDS mapping of sintered tips (Fig. 8). The preexist pore was from lack of densification caused by surface oxidation scale.

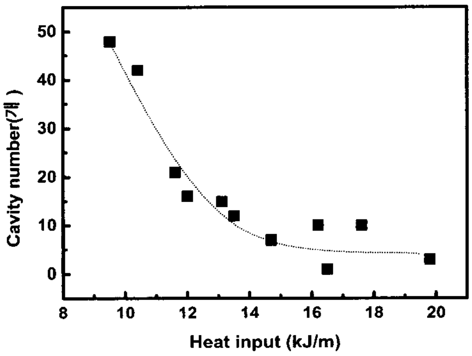

Fig. 4 Effect of heat input on outer cavity formation

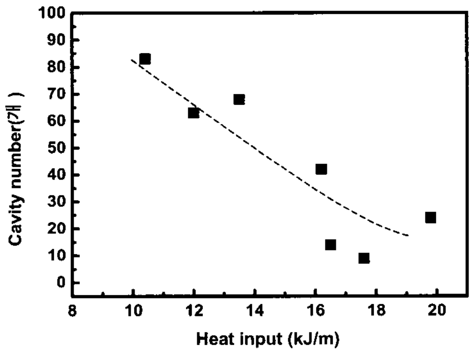

Fig. 5 Effect of heat input on inner cavity formation

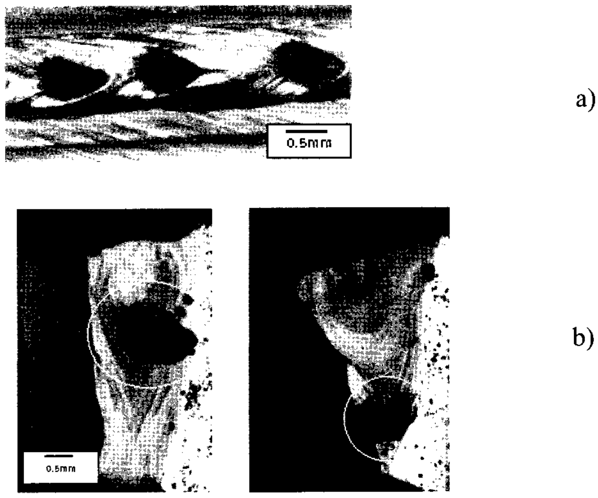

Fig. 6 Outer a), Inner b) cavities in cross section of weld

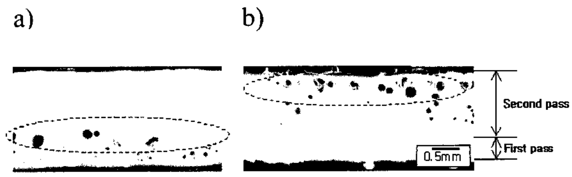

Fig. 7 Inner cavities in longitudinal section of weld
a) 1350W, 1m/min partial penetration
b) 1650W, 1.2m/min full penetration

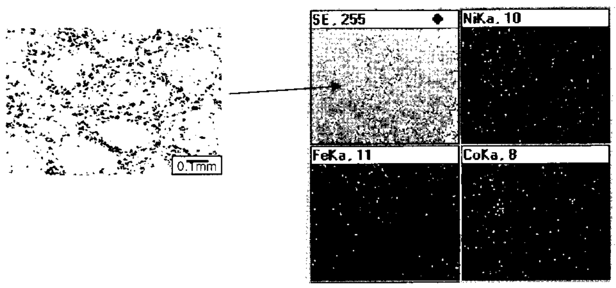

Fig. 8 EDS mapping of sintered tip

4. Conclusion

1) Irregular humps and cavities could be reduced by the control of heat input.
2) The outer cavity was caused by insufficient refill of keyhole, which was induced by high velocity of molten metal flow to the rare part of keyhole and rapid solidification of crown at low heat input condition.
3) Inner cavity source was coarsened preexist pore of sintered tip and metal vapor.

Acknowledgements

The authors would like to thank the Korean Science and Engineering Foundation for it financial support through the project 2001-30100-015-1

References

1. V. V. Borisova, S. M. Kutev and S. F. Moryaschev: *Welding Journal*, Vol. 5, No. 1 (1993), pp.56-581
2. M. Klassen, J. Skupin and G. Sepold: *lasers in material processing, Proceedings euroto series,* munich, 3097(1997), pp.137-146
3. E. Schubert, M. Klassen, I. Zerner, C. Walz, and G. Sepold: *J. of Materials processing technology,* 115 (2001), pp.2-8
4. K. Girard, J. M. jouvard and Ph. Naudy : *ICALEO* (1998), pp.168-178
5. A. Matsunawa, N. Seto, M. Mizutani and S. Katayama: *ICALEO* (1998), pp.151-159
6. J. S. Kim, T. Watanabe and Y. Yoshida : *ICALEO* (1995), pp.1011-1017
7. M. M. Chen et. al.: *ICALEO* (1998), pp.187-196