세립강 저입열 용접부의 기계적 성질

Mechanical properties of fine grained steel weldments formed with low heat input

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ABSTRACT Low heat input welding methods have been investigated in order to minimize the HAZ softening of the 600MPa grade fine grained steel weldment. The welding processes of interest were a high speed FCA welding with a multi-torch welding system, laser welding with filler feeding and hybrid laser welding. No HAZ softening was found for all the weldments formed with low heat input less than 10kJ/cm. Tensile strength of the weldments was high enough to satisfy the required value. Impact toughness of the weldments was also good even at -20°C.

1. Introduction

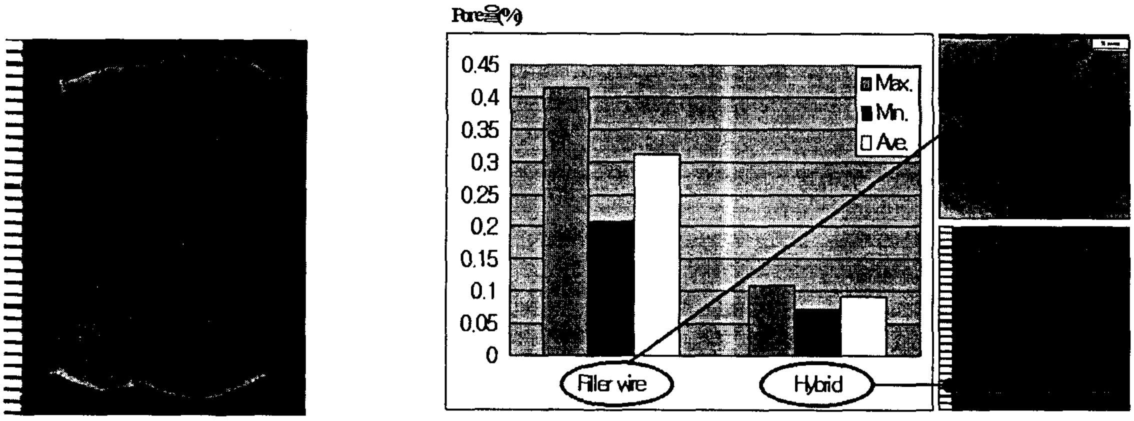
High performance structural steels characterized by high strength and toughness with good weldability have been developing in order to support the infrastructure of incoming modern society. A basic approach for developing the steel is to refine the grain size down to few μm with lean chemical composition by a controlled rolling process with/without accelerated cooling process. The developing steel is then called a fine grained steel (hereafter it is noted as FGS). Although a FGS has high strength and high toughness, its HAZ formed by a conventional arc welding process generally cannot retain the good mechanical properties of the parent metal. A feature for a conventional FGS arc weldment is the HAZ softening [1,2], which may be associated with slow cooling rate after welding. A method for minimizing the HAZ softening of the FGS weldment is to reduce the welding heat input applied. For arc welding, low heat input welding can be made with either low arc power or high speed welding.

The purpose of this study is to evaluate the mechanical properties such as tensile strength and impact toughness of thick fine grained steel weldments formed with low heat input. The welding processes of interest are a high speed FCA welding with a multi-torch welding system, laser welding with filler feeding and hybrid laser welding.

2. Experimental Procedures

The fine grained steels used were the 20mm and 25mm thick plates developed by POSCO as tensile strength of 600 MPa grade steel. Major chemical composition of the steel is 0.1C-0.25Si-1.5Mn. The tensile strength of the steel was about 650MPa. For FCA welding, double Y groove with the angle of 60° was prepared and welding speed was 1.5m/min. One welding pool method with 2 electrodes having the distance of 30mm was applied. The welding current used was about 350-420Amp and the heat input was about 9kJ/cm.

Two laser welding methods were investigated using a 5kW CO_2 laser : laser welding with filler feeding and hybrid laser welding. For a laser welding with filler feeding, three or four welding passes were made at the Y-groove with the root face of 3mm and groove angle of 16°. Autogenous laser welding was initially carried out at the root region under the power of 4 kW and welding speed of 500mm/min. Following passes were deposited by the feeding filler (ER80S) under the power of 4 kW, welding speed of 300mm/min. and filler feeding speed of 3500mm/min. For a hybrid laser welding, the welding torch of the MIG system was fixed in the same fixture as the welding head of the laser. Y-groove with the root face of 3mm and groove angle of 20° was prepared and total 5 passes were made.



(a) (b)

Fig.1 (a) Cross-sectional view of FCA weldments formed with speed of 1.5m/min, (b) Effect of laser welding method on the pore content at the weld metal and Cross-sectional view of the weldment

3. Results & Discussions

3.1 Soundness of the FGS weldment

Fig.1 shows the cross-sectional views for various FGS weldments. The FCA weldment is very sound so that no defects were found after 180° side bending tests. The laser weldment made with filler feeding reveals some pores at the weld metal but the hybrid laser weldment is sound. The pore content of the hybrid laser weld metal is only about 1/3 of that of the weld metal formed with filler feeding.

3.2 Mechanical properties

Fig.2 shows the hardness distributions of the FCA weldment formed with welding speed of 1.5m/min. All the HAZ was hardened and the hardness value of the weld metal was relatively low. Fracture occurred at the weld metal during transverse tensile test but tensile strength of the weldment was about 680 MPa. The toughness values of the weldment were higher than 100J even at –20 °C as shown in Fig.3.

Fig.4 shows the mechanical properties of the FGS laser weldment formed with filler feeding. As shown in Fig.4 (a), all the HAZ are hardened and the hardness values of the weld metal are generally higher than 300Hv. The tensile strength of the weldment was only about 630MPa due to the fracture at the weld metal. This is directly attributed to the pores formed at the weld metal. The toughness of the weldment is also good but toughness values of the weld metal shows considerable scatter in data as shown in Fig.4 (b) because of the pores unevenly distributed.

The weld metal of the hybrid laser weldment shows a relatively narrow scatter band in toughness as shown in Fig.5, compared with the weld metal formed with filler feeding. This is attributed to its lower pore content. Toughness of the hybrid laser weldment is also good even at –20°C. However it is still necessary to obtain uniform toughness value at the weld metal through modification of the hybrid laser welding condition. The hardness distribution of the hybrid laser weldment was similar to that of the laser weldment with filler feeding.

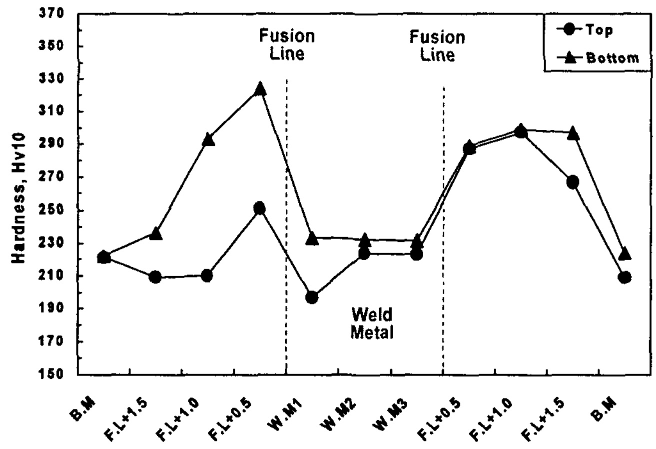


Fig. 2 Hardness distribution of the 25mm thick fine grained steel FCA weldment made with welding speed of 1.5m/min

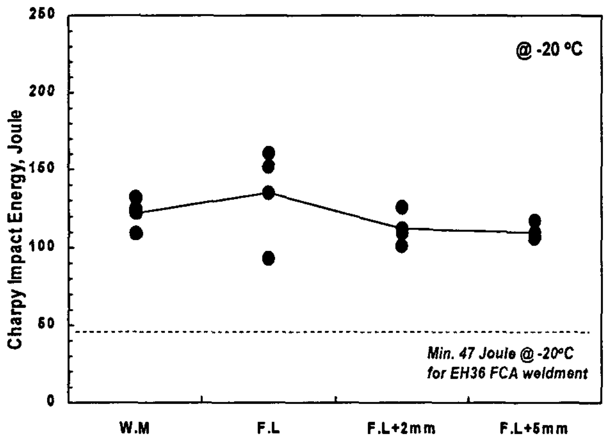


Fig. 3 Charpy impact toughness at –20°C of the 25mm thick fine grained steel FCA weldment made with welding speed of 1.5m/min

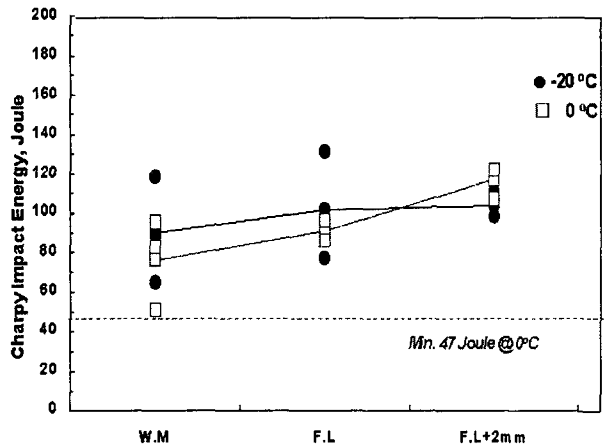


Fig.5 Charpy impact toughness at 0°C and -20 °C of the 25mm thick fine grained steel hybrid laser weldment

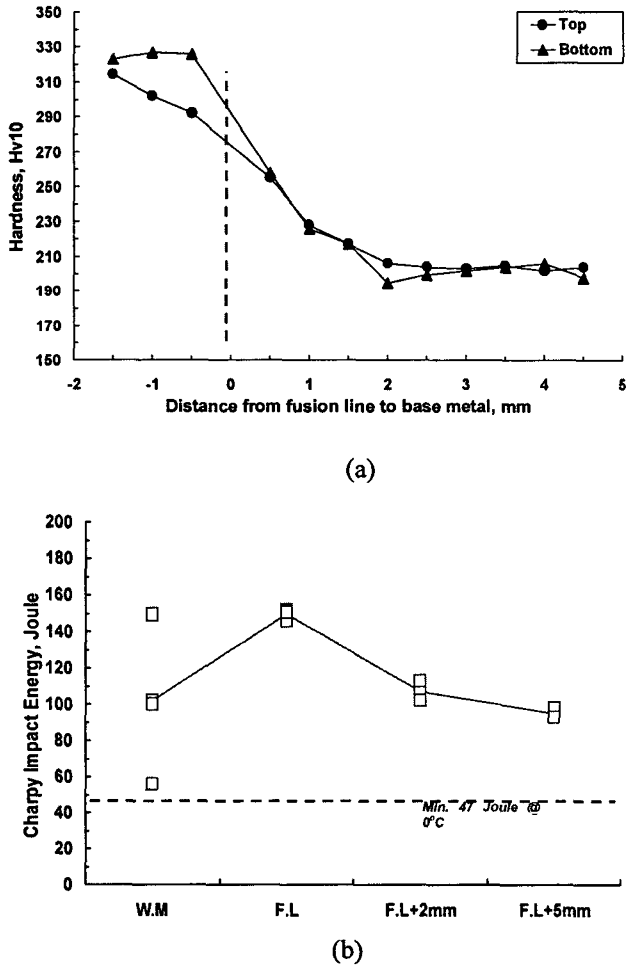


Fig. 4 Mechanical properties of the 20mm thick FGS laser weldment formed with filler feeding : (a) Hardness distribution and (b) Charpy impact toughness at 0°C of the laser weldment

4. Conclusions

For suppressing HAZ softening of thick fine grained steel weldment, a low heat input less than 10kJ/cm welding process is required. This can be made by employing either high speed welding under a conventional arc power or laser welding. Tensile strength of these weldments was high enough to satisfy the required value. Impact toughness of the weldments was also good even at -20°C.

References

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