LASER WELDING CHARACTERISTICS OF 9% NICKEL STEEL

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Abstract - This study proposes a new method of 9% Nickel steel welding that can be applied at a high speed by using laser welding technique. This method does not require the use of any filler material to solve the problem of strength reduction of 9% nickel steel weld zone and various problems arising from arc welding. In addition, experiments were performed using various welding parameters to analyze the laser welding characteristics of 9% Nickel steel used as cryogenic steel.

Index Terms - 9% Nickel Steel, Laser Welding, Filler Material, Welding Parameter.

I. INTRODUCTION

The biggest disadvantage of 9% nickel steel is that the strength of the weld after welding is lower than the strength of the base metal[1]. In order to overcome the fundamental disadvantage in which the filler material strength of the cryogenic steel is lower than the strength of the base material, this study considers the application of laser welding technology, which does not require the use of the filler material[2]. **In order to accomplish this purpose, we first observed the bead orientation according to the welding conditions during laser welding.**

Fiber laser welding experiments were conducted to compare and analyze the weld quality of 9% nickel steel and to optimize the welding process. For the experiment, a MIYACHI model ML-6950A (5 kW fiber laser welder) was used and the whole system was constructed by using MOTORMAN of YASKAWA model DX100. Fig. 3-1 shows the resonator of laser welding system, incidental material, optical system, and the jig used in the experiment..

II. EXPERIMENTAL DEVICE AND PROCESS PARAMETERS

Fiber lasers belong to the category of solid-state lasers such as Nd:YAG lasers. The laser medium is usually made of optical fiber doped with ytterbium (Yb) and the oscillation wavelength is in the range of 1,070 nm. Since the late 1990s, fiber lasers have been applied to the manufacturing industry[3]. Developed by Miyachi, the optical system used in this experiment has a spot diameter of 400 μm. The focal length is 148.8 mm, and it has a focal depth of about 6 mm

The process parameters to be considered in laser welding include the focal length, beam size, and focal depth of the optical system, which are characteristics of the optical transmission system, the nature of the laser beam itself, and the defocusing at the welding spot. However, such an optical system cannot be directly designated by the user. The optical system cannot change in real time depending on the environment, and is fixed with equipment selection. In this way, there is a part of the laser welding system that cannot be handled by the operator. However, there are conditions under which the operator must maintain the optimum condition according to the condition of the material at each welding [4]. **Fig. 1 summarizes the factors affecting laser welding.**

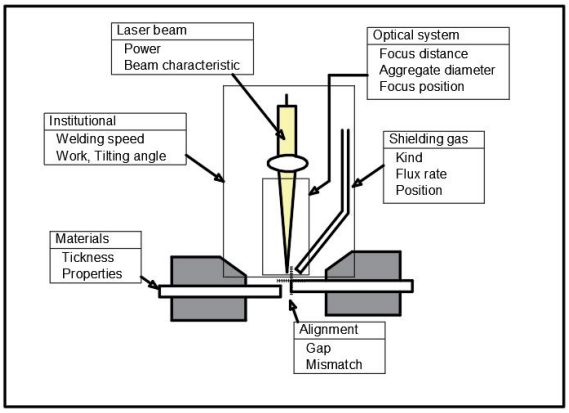


Fig. 1 Factors affecting laser welding quality

III. WELDING PARAMETERS IN LASER WELDING

In this study, three welding parameters were selected, and the reason and range of selection for each welding parameter is as follows;

(1) Laser power: Laser energy density threshold, below this value, the penetration depth is very shallow, once it reaches or exceeds this value, the penetration will be greatly improved. A plasma will be generated only when the laser power density on the workpiece exceeds the threshold value (associated with the material), which marks the stable deep penetration. If the laser power is lower than this threshold, the workpiece occurs only surface melting, i.e., welded to the stable thermal conduction type. When the laser power density is in the apertures formed in the vicinity of the critical conditions, the deep penetration and conduction welding alternately become unstable welding process, cause penetration

volatile. Welding penetration depth is directly related to the beam power density, is a function of the incident light beam power and beam focal spot. In this study, the welding power was selected from 1kW to 5kW as experimental conditions.

(2) Welding speed : Welding speed greater impact on penetration, increase the speed to make penetration shallow, but the speed is too low will lead to excessive melting of the material, workpiece burn through. So, for a certain laser power and a certain thickness of a particular material have a suitable welding speed range, and wherein the value of the corresponding speed when the maximum depth of penetration can be obtained. The welding speed used in this study is 0.3 m/m to 3 m/m. This condition was determined by the conditions under which the weld bead was formed through preliminary experiments and the minimum welding speed at which the maximum penetration depth can be secured.

(3) Defocusing: In order to maintain a sufficient power density, the focal position is essential. Changes in relative positions, the focus and the workpiece surface directly affect the weld width and penetration depth. In most laser welding applications, the defocusing is usually set below the surface of the workpiece about the desired penetration depth of 1/4. In this study, 9% nickel steel with a thickness of 15 mm was used with an optical device with a focus depth of 6 mm. And the welding conditions were selected from the range of –30 mm to + 10 mm at the defocusing based on the surface of the base material. To analyze the difference in bead geometry, it should be observed that it changes according to the defocusing. Since changing the defocusing within the focus depth of(6mm) does not cause a difference in bead geometry, this study has determined the experimental conditions to change the focal depth to a wide range of defocusing(40mm, -30mm to 10mm). The defocusing 0mm is that focus depth is located on the surface of the base material, and when the defocusing is + 10mm, the focus depth is located in a virtual space 10mm away from the surface of the base material.

The defocusing of -10 mm is located in the center of the base material. When the defocusing is –20 mm, the depth of focus is located on the bottom surface of the base material. In –30 mm, the depth of focus is located in a virtual space - 10 mm away from the bottom surface of the base material. Through preliminary experiments, it was observed that the beads were formed in five steps from –30 mm to + 10 mm, and the welding conditions were determined based on this reason.

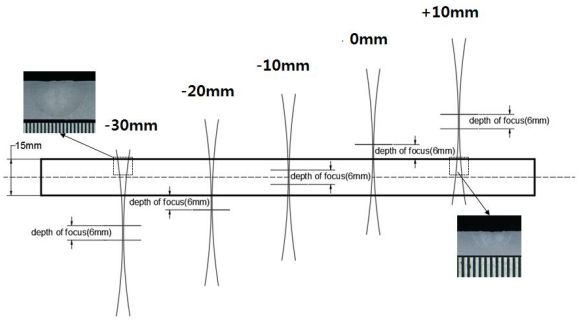


Fig. 2 Defocusing and range used as welding parameters

IV. EFFECT OF WELDING PARAMETERS

In order to derive the relationship between bead geometry and the critical parameters in laser welding, an influence analysis was performed. An effect analysis was performed on the welding power, welding speed, and the defocusing. The shape of the bead is discussed in terms of the bead height, the bead width, and the penetration depth. The effect analysis of the welding parameters is to determine which variables are efficient to control to achieve the desired bead geometry or performance.

In laser welding, laser power is one of the important control variables. It has been reported that the shape of the weld zone is controlled according to the laser power. In this study, we analyzed the influence of laser power on the three bead geometries. Fig. 3 shows that penetration depth of 9% nickel steel increases with increasing laser power at the same welding speed of 1.8 mpm and same defocusing –10mm. This result shows that laser power control is required to control the penetration depth efficiently. Furthermore, since the influence of the laser power on the width and height of the bead is small, it can be a means for independently controlling the penetration depth.

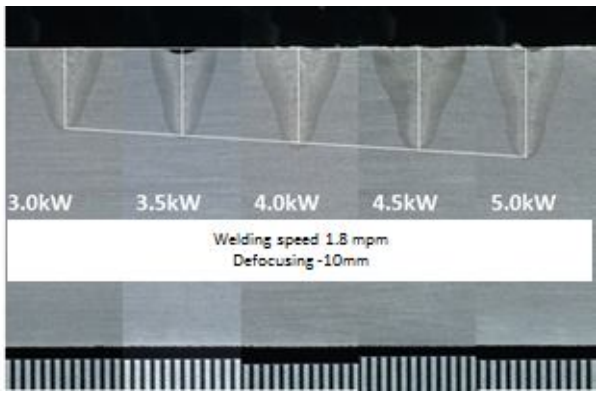


Fig. 3 Variation of penetration depth according to laser power change by macro cross-sectional analysis

In laser welding, welding speed is not only one of the most important parameters, but it also confirms that this study directly influences the width, height, and penetration depth of the geometry.

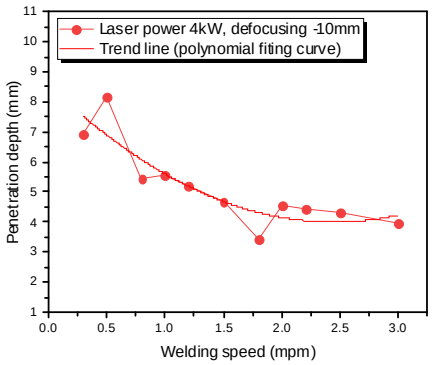


Fig. 4 Change of penetration depth with variation of welding speed

In most cases, the defocusing of the laser system is not changed frequently when the welding apparatus is determined. A short defocusing of the optical system is generally used for cutting purposes, and an optical system having a longer focal length is used for welding. By doing so, the convergence radius is increased to widen the welding line alignment tolerance and the width of the weld bead narrows more than necessary. In addition, the change of the defocusing is related to how the energy density of the focused beam is changed to further optimize the keyhole forming conditions. In this study, the influence of the defocusing on the height, width, and the penetration depth of the beads was found to be small for both materials.

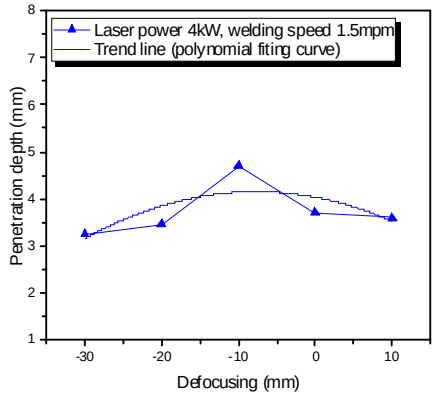


Fig. 5 Change of penetration depth with variation of defocusing

CONCLUSION

In this study, we investigated the shape of beads according to welding conditions in laser welding of 9% nickel steel. Welding conditions are welding power, welding speed, defocus. The following are the respective breakdowns.

- The higher the welding voltage and the lower the welding speed, the greater the overall bead shape, especially the bead depth. It is expected that the increase of the bead depth will be utilized in the full penetration condition in the future.

- The influence of the defocus does not greatly affect the weld bead. However, the effects should be further investigated when future production conditions are limited.

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