Study on Monitoring Method for Laser Welding Process by using UV and IR sensors

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Abstract—**This paper presents a process inspection technology for laser and laser hybrid welding processes. It proposes a quality monitoring method and the laser hybrid welding system with industrial robot for approving the welding speed and accuracy of conventional spot and laser welding systems. The laser hybrid welding process is consisted of the laser and arc welding process. The hybrid welding system has the cost efficiency of arc welding and good performance of laser welding. The laser generator, arc welding and the industrial robotic systems are consisted of laser hybrid welding systems with monitoring system. The laser hybrid welding system with robot was equipped with a laser head and arc welding gun for laser hybrid welding process. The welding joints are butt and Fillet joints. The welding specimens are made from the steel plate and aluminium plate. The quality of welding specimens is tested by observing the shape of the beads on the plate after hybrid welding. The cross-section of the welded parts is observed by using metallography method. The mechanical tensile test is carried out for analysing the performance of welding strength. The monitoring results of the plasma intensity by using UV and IR sensor are used for finding the correlation with the results of the mechanical and metallurgical test.**

Keywords—monitoring; laser; hybrid; welding;UV; IR

I. INTRODUCTION

Laser welding is one of the important technologies used in the manufacturing of automotive bodies, and the leading automotive manufacturers have replaced spot welding methods with laser welding in the process of car body assembly. The conventional spot resistance welding used in the car body assembly process has been an obstacle to car design and manufacturing due to the limited applicability and lower welding efficiency resulting from the geometry and welding characteristics of spot welding machines. As such, the automotive industry has been trying to develop new welding and joining technologies [3-5]. The laser welding technology using a high output power laser and a 6-axes robot was developed, and it is being applied to it to the field [1, 2]. In the laser welding process, it is quiet challenging to achieve high welding qualities in the curved welding surface. This is because aligning the laser beam controlled by a robot perpendicular to the curved surface is difficult. Several studies have investigated methods to improve the welding quality on curved surfaces with limited success [6, 7]. This study intends to develop a laser welding technology with a welding quality inspection capability using a robot system. In particular, it aims to apply laser hybrid welding technique employing arc welding and the quality monitoring method to address the welding quality issues on curved welding surfaces.

II. EXPERIMENTAL EQUIPMENTS

Fig. 1 shows a control block diagram and an actual photo of the proposed laser hybrid welding control system along with its illustration. It consists of a laser generator (1.6 kW fiber laser system), an industrial robot (payload of 130 kg), a MIG welder, and a laser welding head. Table 1 summarizes the core units of the system. The beam produced from the laser generator is transmitted to the welding head, which is mounted at the end of the robot's arm, via an optical fiber. The laser hybrid welding can be achieved by manipulating the axes of the robot system. To conduct a preliminary study of the weldability of the laser hybrid welding system, butt welding and fillet welding were conducted with sample steel plates and aluminum plates. The welded joints of the sample plates were then inspected and tested for tensile strength in order to obtain the optimal welding parameters. For real-time quality monitoring of the laser hybrid welding, basic experiments were conducted with a technique capable of determining the quality of welding in terms of plasma and temperature measurements. Pattern welding tests were conducted to examine the accuracy of the entire remote laser welding system. Fig. 2 shows the sequence of the monitoring process during laser welding.

TABLE I. Core units of laser hybrid welding system

Laser source	1.6kW high-power fiber laser
Laser focusing unit	Collimation, Bean expander/ Image transfer optics, Objective lens
Arc welder	MIG welder
Handling system	Industrial Robot
Workpiece device	Jig, Clamping
Position sensing, process monitoring	CCD vision, Optical emission monitoring
Main control	PC-based controller

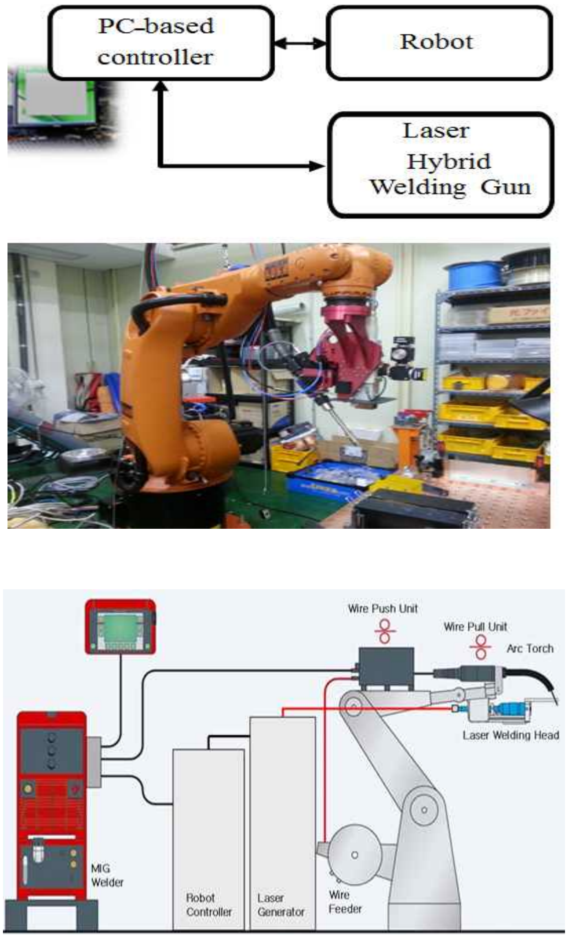


Figure 1 The robot-based laser hybrid welding system: control block diagram (top), photo (middle), and illustration (bottom).

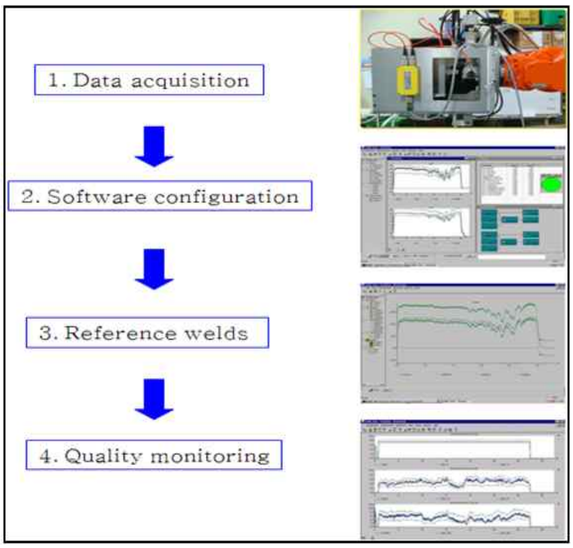


Fig. 2 Process sequence of the monitoring system.

Fig. 3 shows the PCB and the response curve of a UV sensor. Fig. 4 shows the PCB and the response curve of an IR sensor.

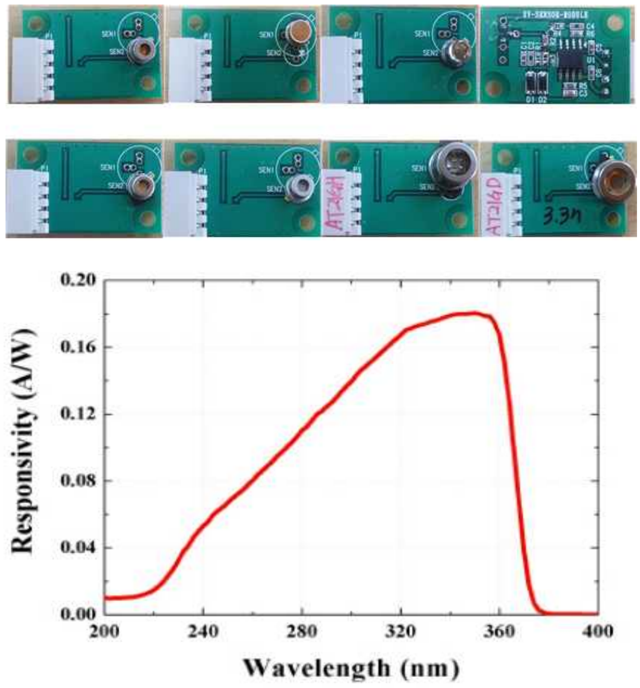


Figure 3 PCB and Response curve of UV sensor.

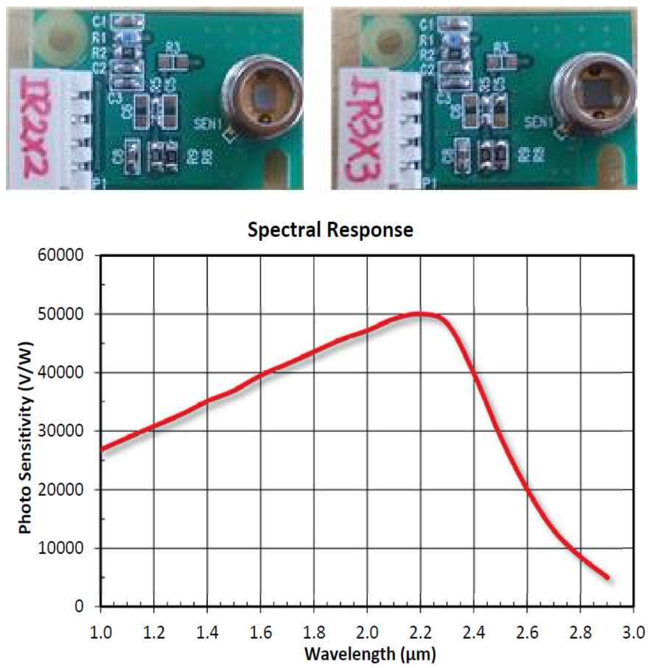
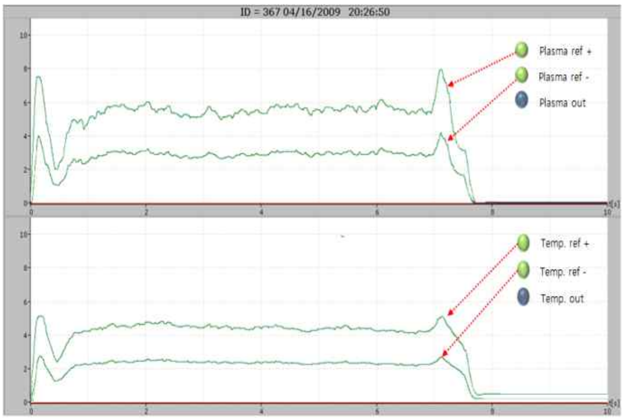


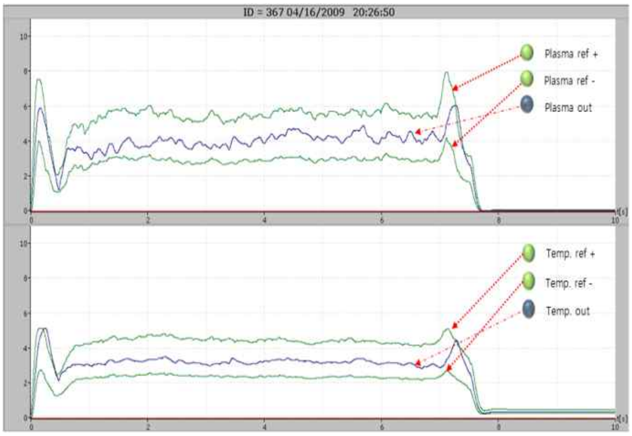
Figure 4 PCB and Response curve of IR sensor.

III. TEST RESULTS

During laser hybrid welding on a real-time-basis, basic tests were conducted to develop a technique which facilitates the evaluation of weld quality by monitoring plasma and temperature. To monitor welding quality using plasma flux intensity, the initial criteria of plasma intensity - which itself determines the critical weld quality - needs to be determined. When the plasma intensity lies between the maximum and minimum values of the reference plasma intensity envelopes, as shown Fig. 5, the weld quality can be judged to be acceptable.



(a) reference curve from results of welding test



(b) monitoring test by using reference curve

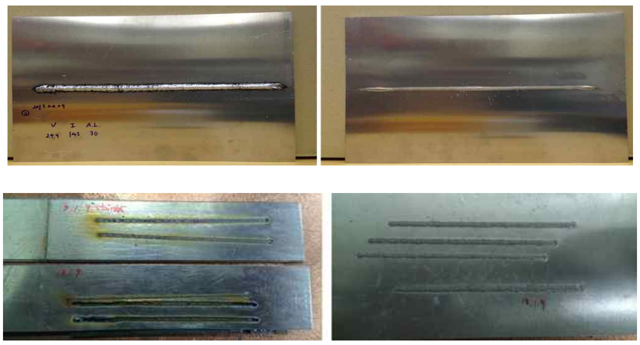

(c) welding specimens

Figure 5 The results of process monitoring during laser hybrid welding.

Fig. 6 shows the results of the tensile testing of a steel sample with butt welding with a varying power and the speed. Fig. 7 shows a cross-section of welding joints and Fig.8 shows the fracture shape of laser hybrid welding joints. Fig. 10 shows the test results of the welding quality monitoring using a laser hybrid welding on the basis of the test results of the laser welding. The fiber laser was tested from 400W to 1,600W power using UV and IR sensors. The results were obtained by scanning the steel sheet many times with the laser hybrid welding system. The plasma and temperature signals could be detected at the appropriate values, confirming that real-time-based quality monitoring can be implemented.

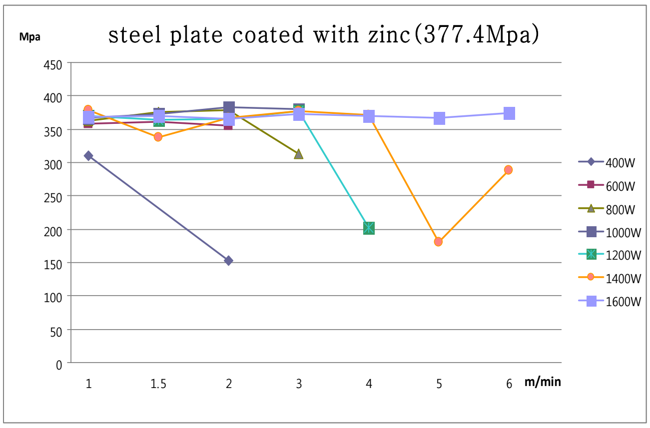


Figure 6 Results of UTM test in butt joints.

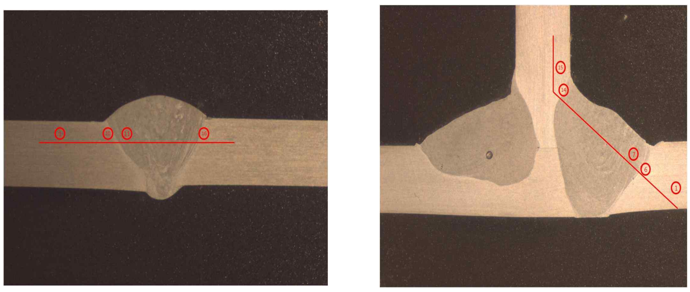
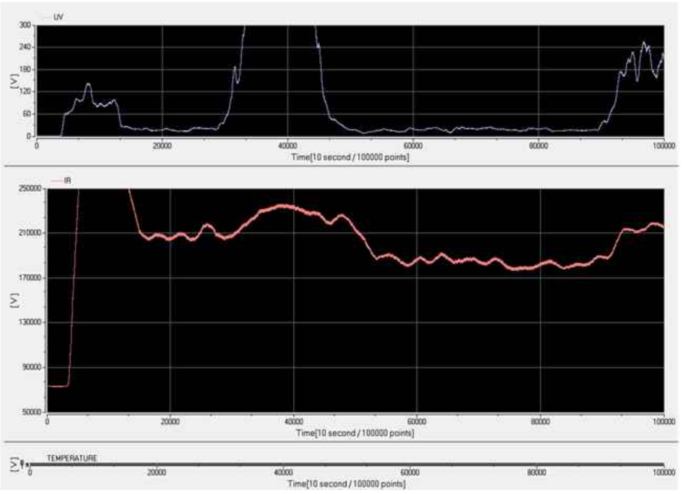

(a) butt welding (b) fillet welding

Figure 7 The cross-section of welding joints.


(a) butt welding (b) fracture shape

Figure 8 fracture shape of laser hybrid welding joints.

Figure 9 shows the results of the welding quality monitoring tests using the laser hybrid welding system with laser and arc welding. The welding conditions are on the basis of the test results of the laser and arc welding. The plasma and temperature signals are measured very well enough to inspect the quality of welding. Fig. 9 (b) shows a welding specimen with a varying weld thickness, and Fig. 9 (a) shows the welding quality monitoring results by using process monitoring method during laser hybrid welding.



(a) The results of monitoring test

(b) welding specimens with dissimilar thickness

Fig. 9 The results of process monitoring during laser hybrid welding.

IV. CONCLUSION

A laser hybrid welding system was developed by incorporating a laser welding component and an arc welding component into an industrial robot. Using the laser hybrid welding system, butt and lap welding were conducted on steel and aluminum sheets. The tensile strength of the samples was then tested to obtain the baseline or reference welding data. The laser hybrid welding tests were conducted with car body parts and the welded joints and defects were analyzed. During the laser hybrid welding, the plasma intensity signals were measured and analyzed to assist the development of a technique which enables evaluation of the quality of laser hybrid welding in real time. The monitoring technology possible to inspect the quality of welding is studied to apply the laser hybrid welding process on a real-time-basis. The plasma and temperature intensity are measured by UV and IR sensors on a real-time-basis. The laser hybrid welding tests were carried out to develop the inspection technology for welding quality by using UV and IR sensors. On the basis of the laser hybrid welding quality tests, the lap welding of galvanized steel sheets and the algorithms for evaluating the quality of laser hybrid welding will be tested in further studies.

The monitoring results of the plasma intensity by using UV and IR sensors are used for finding the correlation with the results of the mechanical and metallurgical test. The welded joints after laser hybrid welding are inspected and tested to obtain the optimal welding conditions. The quality of welding specimens is tested by observing the shape of the beads on the plate after hybrid welding. The cross-section of the welded parts is observed by using metallography method. The mechanical tensile test is carried out for analysing the performance of welding strength.

The welding conditions are on the basis of the test results of the laser and arc welding. The plasma and temperature signals are measured very well enough to inspect the quality of welding. The results of signals express welding specimens with dissimilar thickness by using process monitoring method during laser hybrid welding. This paper proposes the quality monitoring method and the laser hybrid welding system with industrial robot for approving the welding speed and accuracy of conventional spot and laser welding systems.

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