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Study on Laser Welding Process Monitoring Method

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ABSTRACT. In this paper, a study of quality monitoring technology for the laser welding was conducted. The laser welding and the industrial robotic systems were used with robot-based laser welding systems. The laser system used in this study was 1.6 kW fiber laser, while the robot system was Industrial robot (pay-load : 130 kg). The robot-based laser welding system was equipped with a laser scanner system for remote laser welding. The welding joints of steel plate and steel plate coated with zinc were butt and lapped joints. The remote laser welding system with laser scanner system is used to increase the processing speed and to improve the efficiency of processes. The welding joints of steel plate and steel plate coated with zinc were butt and lapped joints. The quality testing of the laser welding was conducted by observing the shape of the beads on the plate and the cross-section of the welded parts, analyzing the results of mechanical tension test, and monitoring the plasma intensity by using UV and IR sensor. This paper proposes the quality monitoring method and the robot-based remote laser welding system as a means of resolving the limited welding speed and accuracy of conventional laser welding systems.

Introduction. Laser welding is one of the important technologies used in the manufacturing of lighter, safer automotive bodies at a high level of productivity; to that end, the leading automotive manufacturers have replaced spot welding with laser welding in the process of car body assembly. Korean auto manufacturers are developing and applying the laser welding technology using a high output power Nd:YAG laser and a 6-axes robot [1,2]. 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].

This study was conducted to develop a remote car body laser welding technology, a welding quality inspection technique, and a robot control. In particular, due to the characteristics of laser welding - where the laser beams have to be directed perpendicularly to the welding surface - it is very difficult to instruct the robot to direct the laser beam perpendicularly on to a curved surface. Indeed, many studies have been performed to improve the speed of the robot laser welding process and the quality of welding parts [6,7]. In this study, these problems were addressed by applying the remote laser welding method and the quality monitoring method.

Experimental equipment. Figure 1 shows a schematic block diagram and the developed system of the entire remote laser welding control system. The beam from the laser generator is transmitted via an optical fiber to the welding head at the end of the robot's arm. The laser welding can be achieved by manipulating the axes of the robot system. The laser generator used was 1.6 kW fiber laser system and the robot system was the 6 axes Industrial robot of payload 130 kg. To conduct a basic study of the weldability of the remote laser welding system, butt welding and lap welding were conducted with common steel plates and galvanized plates. The weld joints were inspected and tested for tensile strength to determine the optimal welding parameters. In order to devise a technique of measuring the quality of the laser welding on a real-time-basis, basic experiments were conducted with a technique capable of determining the quality of welding by monitoring plasma and temperature.

Pattern welding tests were conducted to examine the accuracy of the entire remote laser welding system.

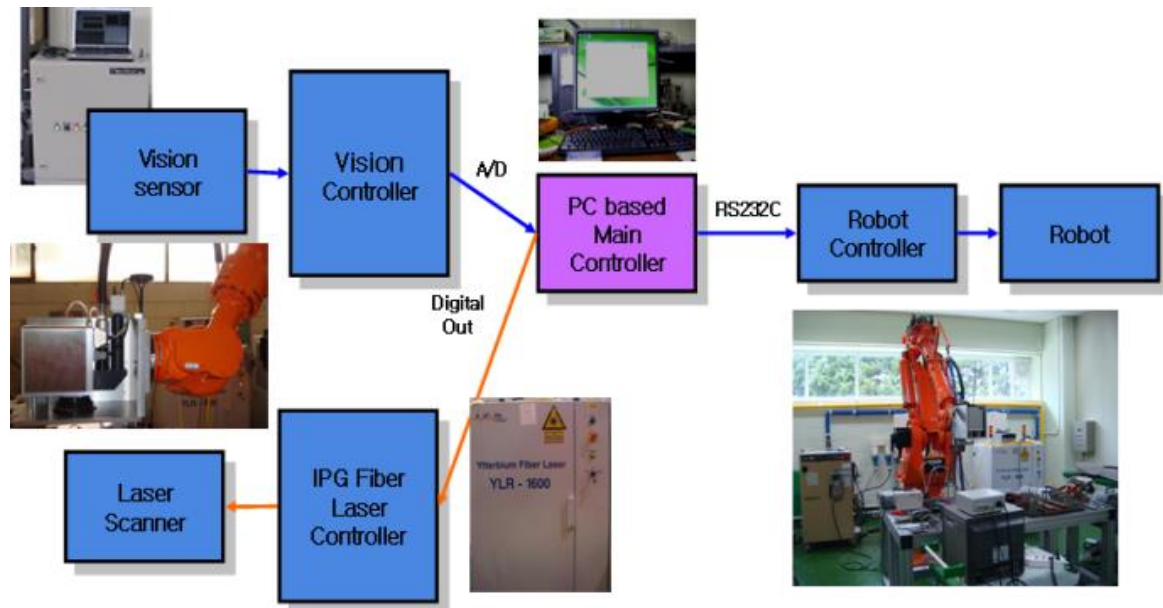


Fig. 1. The robot-based remote laser welding system.

Table 1. Core units of remote laser welding system.

Laser source	1.6kW high-power fiber laser
Focusing unit	Collimation, Beam expander/ Image transfer optics, F-theta lens
Scanning unit	XY 2 axes scanner
Handling system	6 axes Industrial Robot (payload: 130kg)
Workpiece device	Jig, Clamping
Position sensing, process monitoring	CCD vision, Optical emission monitoring
Main control	PC-based controller

Test results. Figure 2 shows the process sequence of quality monitoring system for remote laser welding. During laser 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. Tests were conducted using an Nd:YAG laser and a fiber laser. To monitor weld 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 standard range as Figure 3 (a), the weld quality can be judged to be acceptable.

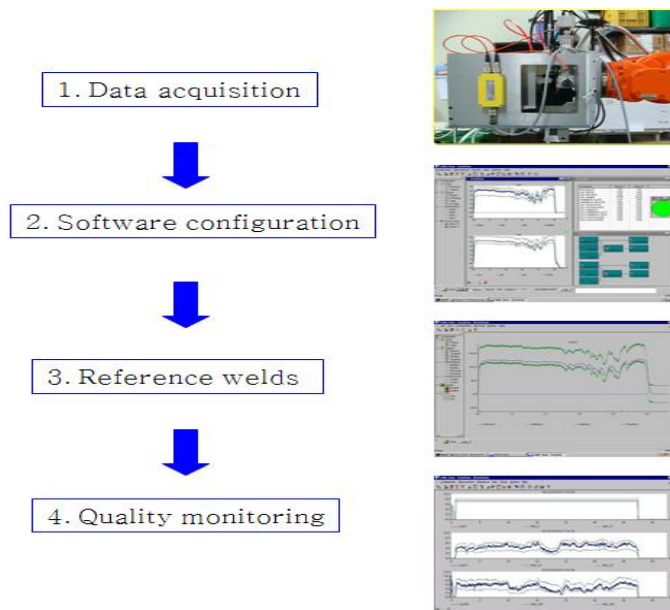


Fig. 2. Process sequence of quality monitoring system.

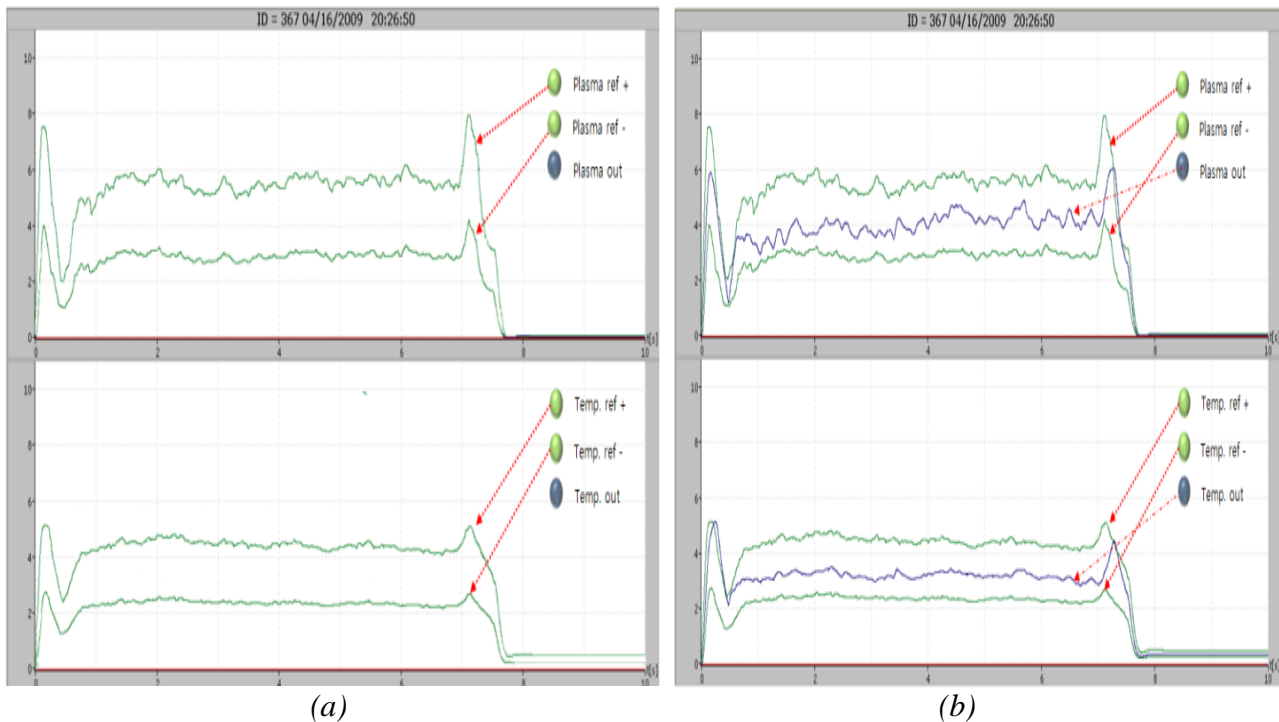


Fig. 3. The results of fiber laser quality monitoring in butt joint; (a) reference curves from results of welding test, b) monitoring test by using reference curves.

Figure 4 shows the results of plasma monitoring test. In the Nd:YAG laser tests, stainless steel specimens were welded at laser powers of 3 kW. One UV-type and two IR-type sensors were used in the tests conducted to detect plasma intensity. Three holes measuring 2 mm in diameter were machined into steel sheets to test whether it was possible to identify defective parts in which no plasma could be generated due to potential defects in the machining. In addition, steel wire measuring 2 mm in diameter was attached to the steel sheets - perpendicular to the welding direction - to test whether changes in the generation of plasma caused by changes in the laser's focal length could be detected. The applied welding conditions were laser power of 3 kW and a welding speed of 3 m/min.

Figure 5 shows the results of the welding test to find the optimal welding conditions by using a fiber laser. Figure 6 and figure 7 show the test results of the welding quality monitoring using a fiber laser on the basis of the test results of the Nd:YAG laser. The fiber laser was tested at from 400 W to 1,600 W power using UV and IR sensors. The results were obtained by scanning the steel sheet many times with the laser scanner of the remote laser welding system. The plasma and temperature signals could be detected at the appropriate values, confirming that real-time-based quality monitoring can be implemented.

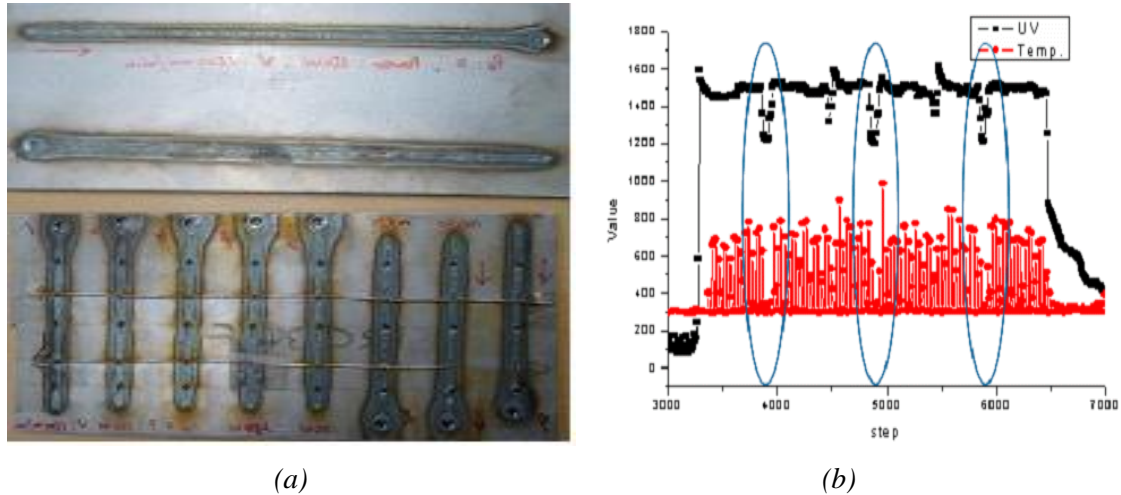


Fig. 4. The results of plasma intensity detection using an Nd:YAG laser; (a) welding specimen, (b) the graph of monitoring signal.

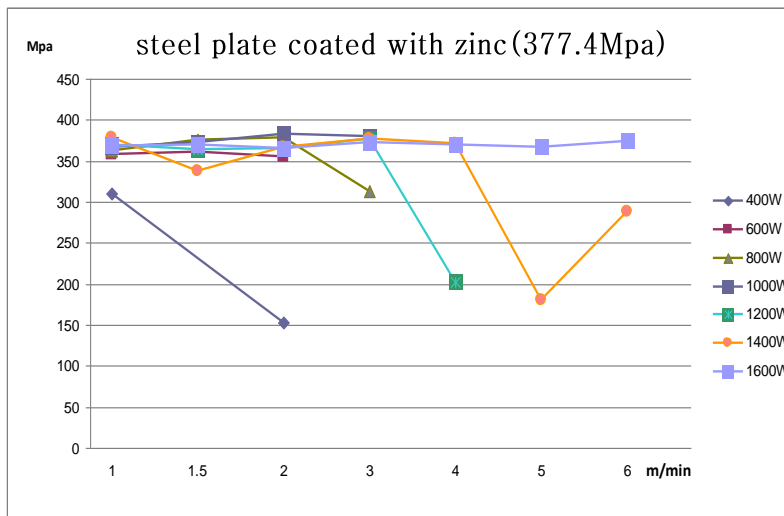


Fig. 5. Results of UTM test in butt joints (steel plate coated with zinc).

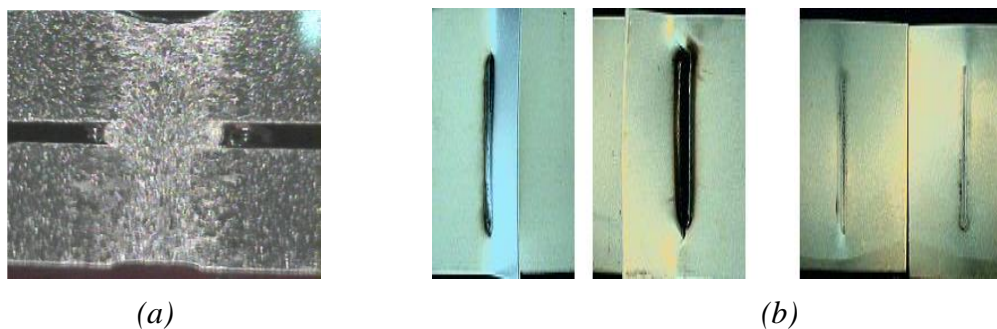
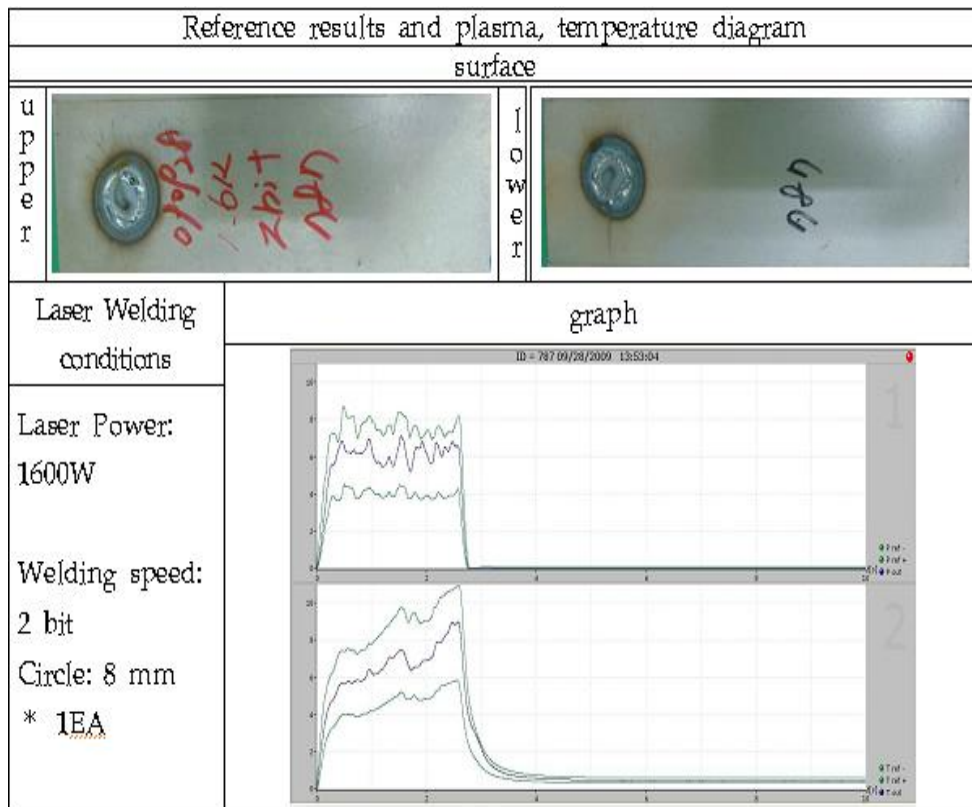
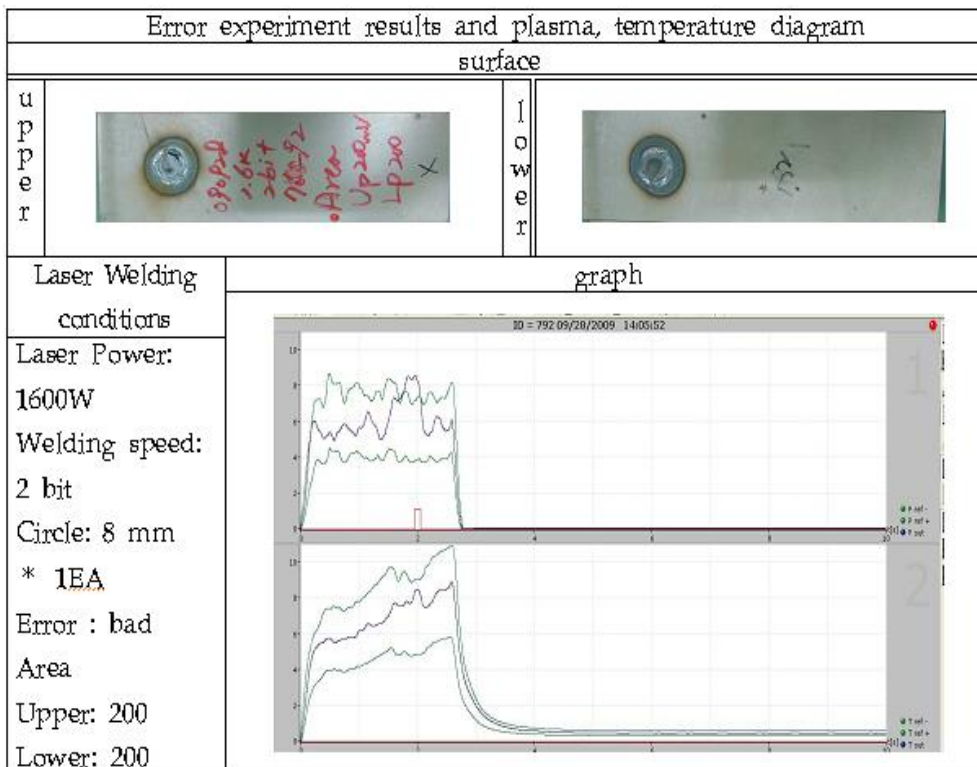


Fig. 6. The cross-sections of laser welding specimens; (a) cross-sections of lapped joints, (b) fracture shape of laser welding in lapped joints.



(a)



(b)

Fig. 7. The experimental results of quality monitoring during remote laser welding for a circle pattern ; (a) shielding gas(nitrogen), good weld, (b) no shielding gas, error.

Summary. The remote laser welding robot system was built on the basis of the interfacing between the laser system and the industrial robot system. Using the remote laser welding system, butt and lap welding of common and galvanized steel sheets were conducted and the tensile strength of the samples was tested to determine the optimal welding parameters. The remote laser pattern welding tests were conducted and the weld joints and defects were analyzed. During the laser welding, the plasma intensity signals were measured and analyzed to assist the development of a technique which enables evaluation of the quality of laser welding in real time. On the basis of the remote laser welding quality tests, the lap welding of galvanized steel sheets and the algorithms for evaluating the quality of laser welding will be tested in further studies.

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