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Study on Laser Welding Monitoring System

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Abstract: The purpose of this paper is a laser welding monitoring system designed to optimize zero defect production and process in laser welding process.In this paper, we design a laser welding monitoring system designed to optimize zero defect production and process in laser welding process. The core of the system is a high-speed thermal imaging camera with next-generation new technology that detects the infrared region (1 ~ 5μm), integrating the process, collecting 1,000 frames per second, and tracking the defect in real time.

Index Terms: CMOS camera, laser welding monitoring system, laser welding, Thermal imaging camera.

I. INTRODUCTION

ARC welding, resistance welding, laser welding and the like are generally widely used in the industrial field. ARC welding refers to the concept of EHLS including GMAW, GTAW, SAW, and plasma welding [3][8][12][13][14]. Since the characteristics of the laser are monochromatic, parallel, straight, and coherent, there are characteristics. Using these properties, it can be used for various materials including welding by high-density heat source [1][5]. It is widely used in the industrial field because it is possible to use laser as a heat source for welding, welding various materials of steel and aluminum, and alloys or heterojunctions. Such laser welding also requires quality control. In order to improve the quality of the weld, there are three methods to monitor the welding process [2, 5,6]. First, it monitors the state of the materials and systems that are welded before welding. Second, the various phenomena occurring during welding are monitored, and various phenomena occurring in laser welding are measured using sensors corresponding thereto. Third, the defect of the welded part after welding is monitored, and the shape of the contacted part and the defect due to the pore are detected through visual inspection and non-destructive inspection.

In this paper, we design a laser welding monitoring system designed to optimize zero defect production and process in laser welding process. The core of the system is integrated into the process as a high-speed thermal camera that detects medium infrared zone (1 to 5μm) to collect 1,000 frames per second of the data image and track defects in real time. The ultrahigh-speed thermal imaging camera is attached to the welding head, collecting and analyzing the thermal images of the melt pool on-line during the process, and evaluating the quality of the product in real time by the processing unit.

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II. TECHNIQUE OF LASER WELDING MONITORING

There are various phenomena such as sound, acoustic, and emission of light, image, and charge around the weld by plasma. These phenomena are measured using various sensors [4][7][8]. Of the signals generated when welding, sound or sound waves are measured using a microphone, and are related to the processing characteristics of the laser and can be easily applied to monitoring.

A method of measuring acoustic emission is a method of measuring changes in acoustic signals or stress waves caused by phase changes, keyhole fluctuations, and plasma vapor pressure fluctuations that occur during laser welding. Among the phenomena occurring in laser welding, there is a method of measuring an optical signal generated during welding. There are two main methods of measuring light in general laser welding. One method is to obtain data for a specific wavelength or a total wavelength, and it mainly uses a photodiode or a spectroscope. The other method is to monitor the laser machining process using various cameras such as CCD or CMOS camera.

In this paper, the core of the system is a high-speed thermal imaging camera that detects the infrared region (1 ~ 5μm), integrates the process, collects 1,000 frames per second, and monitors the defect in real time. In addition, the camera is attached to the welding head to collect thermal images of the melt pool on-line during the process, analyze them, and evaluate the quality of the process in real-time by the processing unit. Of course, the stored data can be used for offline analysis. Typical laser welding applications to be used in this study are CO2, Nd: YAG, diode and Yb: YAG laser sources.

III. TECHNIQUES OF MONITORING USING SMAILL THERMAL CAMERAS

The thermal camera stack used in this study is as follows.

TACHYON 1024 microCORE Camera, thermal camera:

.Optical sensor: Uncooled infrared imaging module

Detecting infrared region: MWIR (Mid Wavelength Infrared, 1.5 microns)

.Image resolution: 32x32 pixels (pixel size 135 um x 135 um)

Frame Rate: 1 kHz (1000 images per second)

.Communication: Uses USB 2.0 High-Speed (480 Mbps) or USB to Ethernet Converter

.Mechanism: (IP67 for water and dust protection)

.Power: 5 VDC, 500mA (over USB interface)

.Enclosure: Ruggedized IP67 compact mechanical enclosure

.Optical interface: CS-mount

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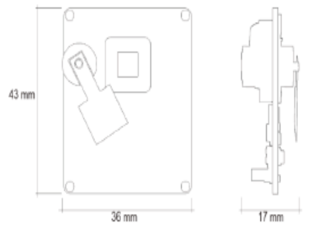

Dimensions (mm): 46 x 39 x 29

The TACHYON1024 micro CORE camera has an ultra-fast scan rate of 1 kHz frame rate and 1,000 frames per second. The TACHYON 1024 micro CORE thermal imaging camera is designed to be mounted on the welding system directly, allowing it to be installed in a small size.

Fig. 1 TACHYON 1024 micro CORE Camera, Thermal Imager

The ultrafast scan rate of 1 kHz frame rate enables real-time tracking and identification of critical parameters such as thermal distribution, thermal conductivity, holes, pores, lack of penetration, lack of fusion, and weld defects. In addition, separate light filtering is not required to remove energy radiation such as UV, VIS, etc. from the plasma.

An example of a mechanical installation of a thermal imaging camera is shown in Figure 2.

- Direct mounting on welding head using CS-mount optical interface
- Installed so that the welding process can be seen on the central axis
- Use a dichroic mirror to avoid direct laser radiation
- BS (50%): Beam splitter with a transmittance of 50%.

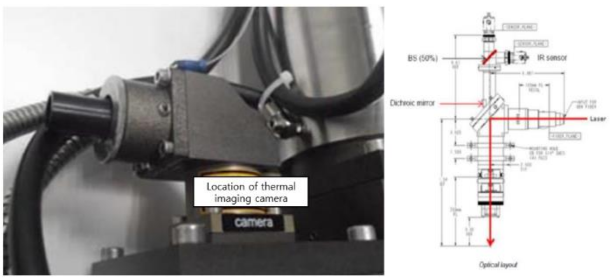

Fig. 2 CS-mount camera port in a TRUMPF Laser TruDisk BEO D70 welding head (example)

Figure 2 shows the mechanical installation of the thermal imaging camera as an example directly mounted on the welding head using the CS-mount optical interface. Here, a ichroic mirror is used to avoid the direct radiation of the laser. (BS (50%): beam splitter having a transmittance of 50%).

A. DATA ANALYSIS OF ZINC COATED STEEL SHEET PROCESS

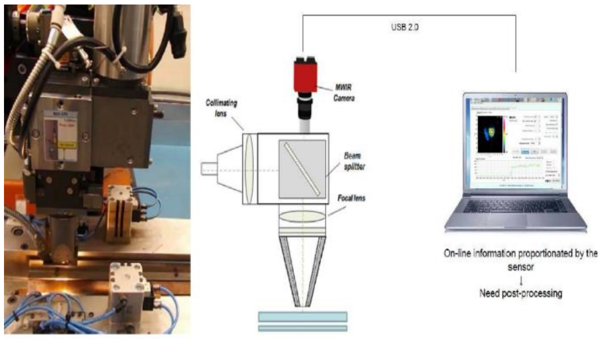

Fig. 3 CS-mount camera port in a TRUMPF Laser TruDisk BEO D70 welding head (example)

Figure 3 shows a layout with a super-fast thermal imager installed.

Two different Zinc coated steel sheets, 0.8 mm and 1.5 mm in thickness, were used, and the speed of the robot varied from 30 to 100 mm / sec. At this time, the laser power is 4.0 kW.

B. PROCESSING SOFTWARE

Real-time monitoring of the system and on-line defect tracking software

Figure 4 shows the programming and programming algorithms for defect types and analysis by collecting enough sample data from the customer's actual process and artificially creating NOK and OK situations.

Here, the core functions of the processing software are as follows.

- Real-time processing by collecting 1,000 frames per second
- Calculation and counting of on-line diagnostics and fault types
- Visualization of real-time data
- Storage of data
- Off-line analysis by loading saved data
- Labeling and Training

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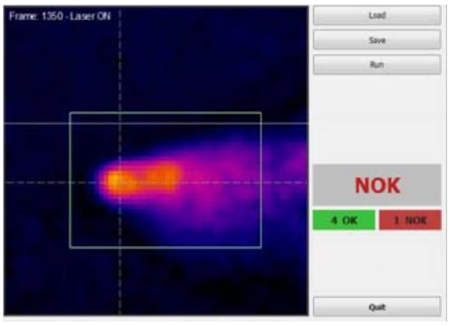
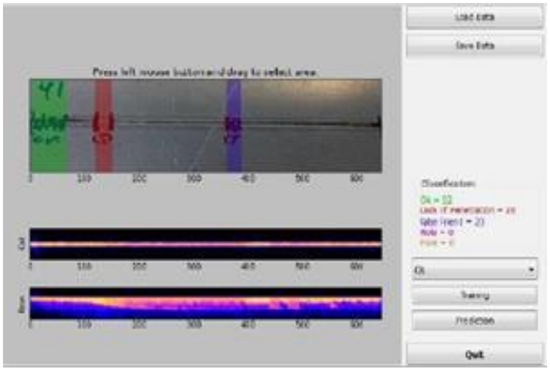


(a) Real time image of melt pool area and automatic detection of defects



(b) Training of the detection system

Fig 4. Installation type of high-speed thermal camera

Figure 4 shows the melt pool visualized in real time during the welding process. Here, the shape of the melt pool is significantly different when defects occur in the process. Raw image data collected by a high-speed thermal camera.

Fig 5. Configuration of system using thermal camera

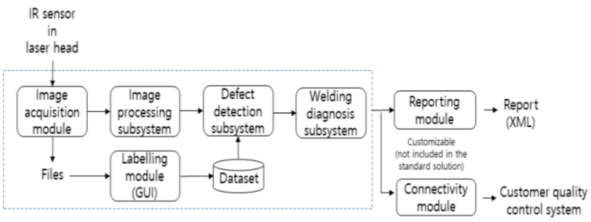


Figure 5 shows the process of the welding quality control system using the system using thermal imaging camera.

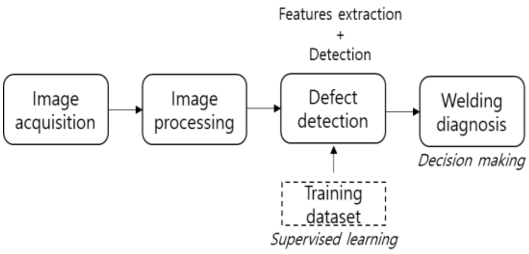


Fig 6. Laser welding process management process using thermal imaging camera

Figure 6 shows the process of a laser welding quality control system using a thermal imaging camera.

Materials	DP 600 galvanized steel
Joint	Overlap joint
Thickness sheet	0.8mm+1.5mm/1.5mm+1.5mm
Laser source	Disk laser trudisk 16002
Laser Head	BEO D70

C. TRACK DEFECTS OF THE SYSTEM APPLIED TO THE ACTUAL POCESS

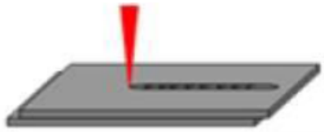


Fig 7. Process conditions

Figure 7 shows the process condition table for the defect tracking of the system applied to the actual process.

Dataset1	OK	NOK
OK	27664 (97.3%)	777 (2.7%)
NOK	35 (0.9%)	3879 (99.1%)

Fig 8. Dataset1- 32355 labeled frames

As can be seen in Figure 8, the defect tracking success rate% Dataset1-32355 labeled frames, and the defect tracking rate of 99.1%.

Dataset2	OK	NOK
OK	14349 (96.5%)	525 (3.5%)
NOK	228 (2.4%)	9359 (97.6%)

Fig 9. Dataset2- 24461 labeled frames

Figure 9 shows the defect tracking rate of Dataset2- 24461 labeled frames, 97.6%.

Due to the proven performance of the system, the OK / NOK weld classification was over 99% in overlap joints of Galvanized metal sheets (thickness 0.8mm + 1.5mm and 0.8mm + 0.8mm).

IV. CONCLUSION

This paper was designed and developed to secure the disadvantages of CO_2 welder. Disadvantages of CO_2 welder include: 1) Separate finishing process is required due to CO_2 backbone formation.

2) CO_2 backbeds can lead to poor products when assembled.

3) If CO_2 wire is not supplied, it leads to product defect.

4) Fume generation during CO2 welding causes harm to human body.

5) Separate ventilation facilities are required (investment cost increase).

6) Possibility of occurrence of leaking is relatively high, and the working speed is longer than that of SPOT welding.

In order to overcome these disadvantages, it is designed to be able to check if defects occur in the work process by monitoring the welding process. The laser welding monitoring system is designed to observe the melt pool at the center of the welding head using a very small ultra-high speed thermal imaging camera (1,000 image frame per second) without any competitors.

Image processing algorithms and high-speed image acquisition as shown in figure 4 track many types of defects (holes, pores, lack of penetration, lack of fusion, etc.).

The new high-speed thermal imaging camera, which is a new generation technology, will be applied to various welding fields in Korea, which will greatly contribute to process improvement and quality improvement.

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