High Power Laser Welder for Continuous Cold Tandem Mill*

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1 Introduction

In recent years, the number of laser welders installed in steel processing lines has increased steadily. Kawasaki Steel Corp., giving special attention to the outstanding performance of such welders in applications involving special alloys, developed and put into practical use the world's first such laser-based strip jointing technique. The technical development required for the application of laser welding to hard-to-weld materials such as silicon steels, high carbon steels, and stainless steels has made a remarkable contribution to quality improvements, yield rate, and production efficiency. This welding technique has recently been applied to the welding of not only alloy steels but also ordinary carbon steels. Further, the application of laser welders has spread to cold-rolling lines, including refining lines and pickling lines. Initially, oscillators of a low output power class[1] of 1.0 to 1.5 kW were used, but to realize high speed welding of thicker steel strips[2,3], high-output units (~10 kW) have been progressively adopted in commercial operations.

This paper describes the characteristics of a laser welder equipped with a 10-kW oscillator, which is in use at one of Kawasaki Steel's continuous cold-rolling lines.

2 Equipment Specification

Various special steels as well as ordinary steels are processed on this cold-rolling line. The line, formerly of the batch rolling type, was remodeled as a continuous line in 1988 with a view to the improvement of quality and yield rate. A high-output power laser welder was developed and installed as the type of in-line welder which would best meet the requirements of reliable welding of hard-to-weld materials, no-man control, and mass production. **Photo 1** shows the main welding unit; **Table 1** shows its specifications.

The features of the welder, which are discussed below, may be summarized as follows:

(1) Full automation.
(2) High-output, long path-distance optical transmission system.
(3) Heat treatment function.
(4) Equipment monitoring function.
(5) Short cycle time.
(6) Auxiliary weld quality evaluation function.

2.1 Full Automation

In the design of this laser welder, which would be used to weld materials of various types and sizes, not only was automation of the unit itself required, but automatic setting of welding conditions was also essential. The most important parameters with this equipment, from the viewpoint of laser welding, were: (1) butt gap distance, (2) laser beam center and focal point, (3) laser output, and (4) welding speed. These parameters were determined in advance on the basis of such requirements as by-steel-grade cutting accuracy, so as to permit on-line retrieval and automatic setting in correspondence with charging order. A function permitting

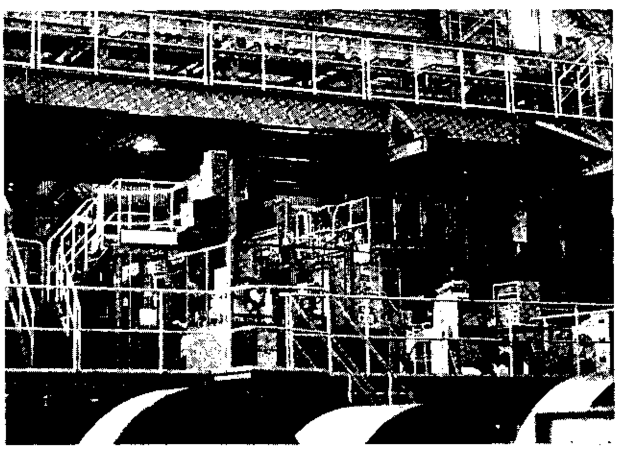

Photo 1 Appearance of high power laser welder

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Table 1 Specifications of laser welder

Material to be welded	
Kinds	Plain carbon steel, high carbon steel, stainless steel
Strip thickness	1.8~6.0mm
Strip width	600~1880mm
Rolling productivity	Max. 130 000 t/month
Laser oscillator	
Type	Unstable type, CO_2 gas laser
Output power	10kW
Optical transmisson	
Transmission route	Approx. 21m
Mirror number	7 pieces (angle remote control mechanism)
Beam gathering	Parabolic mirror (focus 254mm)
Shearing	Guillotine shear type (automatic clearance adjusting mechanism)
Post annealing device	High frequency induction heating (included in the welder)
Filler wire supply device	Wire select auto-switching
Welding pitch	Ave. 4.0min (minimum 2.0min)

the selection of the most appropriate filler wire material for the steel grade being welded and the automatic switching of filler wires was also provided.

2.2 High-Output, Long Path-Distance Optical Transmission System

2.2.1 Beam focusing by parabolic mirror

A transmission lens has conventionally been used in the laser welder focusing unit, but with laser welders in the 10 kW power range, material-related restrictions on beam intensity result in poor long-term stability. In particular, thermal deformation of the oscillator output window focuses beam energy, leading to a marked reduction in lens life. A large diameter parabolic mirror is used with this welder[4)], making possible an extension of service life.

2.2.2 Remote-controlled angle adjustment mechanism

When the distance from the oscillator to the welding station is long, a precise angle adjustment, in addition to the accurate installation of the reflecting mirror which comprises the optical transmission system, is necessary for proper alignment of the center of the beam emitted by the oscillator with the butting line. The mirror alignment operation, which hitherto required several operators, resulted in lowered operational efficiency because of the long adjustment time required with an increasing number of mirrors. With this welder, a remote-controlled angle adjustment mechanism was adopted, allowing quicker alignment.

Table 2 Specifications of post annealing device

Heating method	High frequency induction heater
Power source	Thyrister inverter
Output power	120kW
Frequency	9.9kHz
Heating zone	10mm wide×1600mm long
Heating temperature	Max. 800°C

2.3 Heat Treatment Function

In laser welding of high-carbon-bearing steels such as high carbon steels and martensitic stainless steels, rapid cooling after welding causes increased hardness and the material becomes brittle. This may cause rupture at welded joints when abrupt change occur in line tension. This welding machine incorporates a device by which welds are heated to a maximum 800°C at the welding station, contributing to a reduction in hardness and increased weld joint's strength. **Table 2** shows the specifications of the heating device.

2.4 Equipment Monitoring Function

In a high-volume continuous processing line, equipment failure can cause enormous losses. Since the laser welder is a key piece of line equipment, stable operation and the prediction of abnormalities are crucial. In this welding machine, equipment monitoring sensors are incorporated to predict abnormalities, with the aim of identifying changes in oscillator, optical transmission system, and focusing unit conditions. **Figure 1** shows a specific example.

2.5 Short Cycle Time

Conventional laser welders have not been adapted to mass production lines because their cycle time is significantly greater than that of the latest flash butt welders. With this welder, welding can be completed in as little as 48 sec with strip 3.2 mm thick and 1 000 mm wide, amply satisfying the welding pitch specification of a 2 min.

2.6 Auxiliary Weld Quality Evaluation Function

Automatic measuring instruments allowing rapid, stable on-line evaluation of the quality of laser-welds have not yet reached the stage of practical use. At present, a system is considered possible in which weld quality is evaluated by monitoring welding and equipment condition and thereby identifying aging changes from incipient values. This laser welder includes, as an auxiliary function, evaluation of weld appearance, based on weld configuration, which is shown by CRT as static images during the welding process; abnormalities are detected by measuring the cut configuration of actual butting parts and actual gap amounts using precision

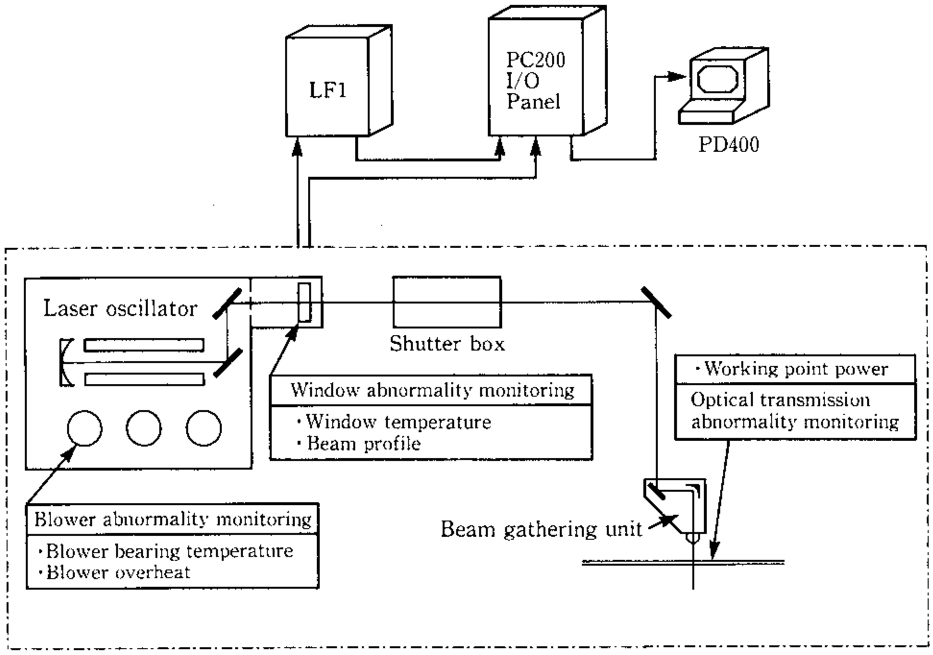

Fig. 1 Equipment monitoring items (example)

gap sensors.

3 Concluding Remarks

To date, Kawasaki Steel has applied laser welders mainly to the processing of special alloys and to middle or small scale production lines. This report describes the application of a laser welder to a mass production continuous cold-tandem-mill line, in which ordinary carbon steels account for the majority of the materials processed. The new equipment has shown outstanding results in terms of improved quality, yield rate, and productivity.

References

1) K. Ono, S. Nagasaka, M. Fujii, H. Tajika, S. Tanaka, and H. Sasaki: *Kawasaki Steel Giho*, **14**(1982)2, 173
2) Y. Kawai, M. Aihara, K. Ishii, M. Tabuchi, and H. Sasaki: *Kawasaki Steel Giho*, **16**(1984)1, 53
3) Y. Kawai, H. Nakahara, F. Yokozawa, M. Midorikawa, M. Takada, and M. Ito: *Kawasaki Steel Giho*, **16**(1987)1, 31
4) M. Ito, M. Takada, A. Kishida, F. Yanagishima, F. Yokozawa, and Y. Kawai: *Tetsu-to-Hagané*, **73**(1987)13, 306

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