CAL Entry-Side Automation

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Abstract:

To improve labor productivity, a project to automate the entry-side control room of a continuous annealing line was implemented. Traditionally, operators in the entry-side control room were responsible for "operating entry-side equipment," "monitoring the line," and "handling troubles." The challenge was to enable these tasks to be performed remotely or to automate them. First, for remote operation, additional control panels were installed to operate the entry-side equipment from the exit-side control room. By using a general-purpose sequencer to branch the PLC signals, it was made possible for our in-house group to handle the system. Next, for line monitoring, a system was set up that allows the entry-side equipment status to be monitored via network cameras, enabling the exit-side control room to monitor the situation on screens. Finally, for trouble handling, the causes of existing issues were analyzed and resolved by adjusting sensor positions and updating equipment. By implementing these measures, unmanned operation of the entry-side control room was achieved.

1. Introduction

In response to Japan's low birthrate and the retirement of the current generation of veteran operators, improvement of the labor productivity of steel works operators has become necessary. Following the concept of existing entry-side unmanned lines at continuous galvanizing lines (CGL) and other facilities, JFE Steel carried out a project to automate the entry-side control room of a continuous annealing line (CAL). This report describes the entry-side automation work, focusing on the response to technical issues.

2. Background

To achieve unmanned operation of the entry-side control room, it is necessary to implement remote operation from the exit-side control room or automation of line monitoring work and manual operation that had been performed by operators of the line entry-side control room. However, in addition to work during normal operation, manual operation or abnormal processing by the operator is required when entry-side equipment trouble occurs. Therefore, the specific work items related to line monitoring work, remote operation of the entry-side equipment and trouble prevention were identified and studied (**Table 1**).

Table 1 Entry-side unmanned items

Item	Previous tasks	After automation
Remote monitoring	Operator's visual check is required ①Coil inspection ②Sheet passage monitoring ③Weld monitoring	①Install a new cradle shear
		②Install new surveillance cameras
		③Install an additional output control panel ⇒Update the weld inspection system (PC98)
Remote operation	Operation from the entry-side control room ①Coil transport equipment ②PLC/DCS equipment	①Install an additional output control panel ⇒Update of the control system (LM7000)
		②Install an additional output control panel
Automatic operation	Welding scrap is manually transported	Install a new automatic end welding scrap conveyor
	Electrode wheel grinding and height adjustment Manual operation (twice per shift)	Automation of manual operations ⇒ Update of the welding machine control system (MELSEC A)
Trouble prevention	Automatic detection failure of coil leading edge ⇒ Manual operation (15 times per shift)	Improvement in detection accuracy ⇒ Update of the leading edge detector
	Automatic band cutting failure ⇒ Manual intervention (5 times per shift)	Change in band cutting method ⇒ Update of the band remover (MELSEC A)

First, monitoring performed by entry-side operators included inspections for abnormal coils in the coil preparation stage in order to prevent serious trouble such as in-furnace fracture, coil overturning, etc. Coils without problems were then charged on the payoff reel,

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and sheet threading was performed to a position before the welder. However, in this process, sheet passage was monitored by visual inspection to ensure that the sheet was not caught in the line.

Next, the manual operation performed at the various entry-side equipment is described. When an abnormal coil is discovered in the coil preparation stage, coil change work is performed from the operation panel of the coil conveying system. When an abnormality such as meandering or sheet warpage is discovered during threading after a coil is charged on the payoff reel, operation is switched from automatic to manual, the coil is retracted, and threading is performed again. In welding work, when the welding judgment system judges that a welding temperature abnormality or electrode pressurization error has occurred, it is necessary to repeat the welding operation at machine-side. Since welding defects due to the surface roughness of the electrode wheels may occur when a welding machine is used continuously, electrode wheel grinding is performed at set intervals, and the electrode wheel height must be adjusted after grinding. Periodic manual transportation of welding scrap to the scrap bag is also necessary.

Finally, the operations that require a manual response by the operator to prevent trouble were examined, and it was found that the tasks that occurred with a high frequency were the response to poor cutting by the band remover in the coil preparation stage (5 times/shift) and the response to coil tip detection abnormalities, which is necessary in preparation for paying out a coil after charging on the payoff reel (15 times/shift). These were factors that increased the workload on operators.

3. Remote Monitoring

A system for remote monitoring of the entry-side equipment from the exit-side control room was implemented (**Fig. 1**).

The objects of monitoring include the threading condition and welding condition of entry-side coils, the condition of coils before charging to the line, etc. To confirm printing of coil Nos. and understand the condition of equipment such as the welding scrap payout conveyor in detail, it was necessary to install a large number of cameras. However, among the problems identified during the unmanned operation trial period, the remote-monitoring monitors installed in the exit-side control room have small screens, and the number of screens is too large to check instantly. In response to these problems, the following measures were adopted.

① The number of monitor screen windows was changed from 9 to 4.

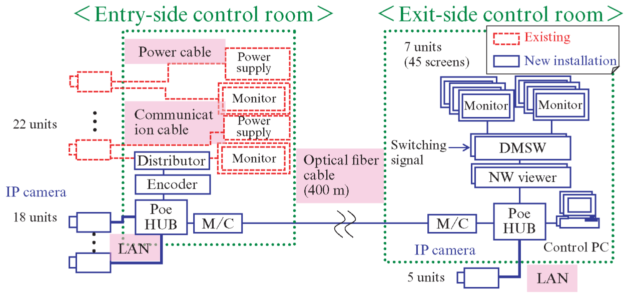


Fig. 1 Remote monitoring system

② A screen switching function using path switching signals was added.

③ The number of monitors was increased.

④ The monitor position and angle were adjusted.

Considering the large number of locations to be monitored, operational needs were addressed by displaying the necessary screens at the desired timing (i.e., the timing when it is necessary to check an operation) and adopting a screen layout with good visibility (organized in the order of the line equipment: Payoff reel ⇒ Coil dispensing equipment ⇒ Sheet shear ⇒ Welder).

When constructing the remote monitoring system, using the conventional (analog) method, it would be necessary to lay a number of coaxial transmission cables equal to the number of cameras. In addition, in this project, it was also necessary to lay cables extending over a long distance in order to monitor the entry-side equipment from the exit-side control room, and due to the large number of cameras to be installed, the high cost of construction was also a problem. Therefore, we adopted a network camera system, which made is possible to consolidate the communication cables in one optical cable. An encoder is used to convert analog signals to digital signals, making it possible to include the existing analog signals in the network and reuse the existing analog camera. Adoption of network cameras allowed power supply by PoE (Power over Ethernet), which also reduced construction costs. PoE is a technology that makes it possible to supply power from a network by using a LAN (Local Area Network) cable. Because the LAN cable used in this network consisted of 8 insulated copper wires intertwined in pairs of two each, power can be supplied by using the spare wires not used for data communication. However, the following points must be noted when selecting the equipment:

① Number of ports of the devices to be connected: There are some hubs that do not support PoE power supply.

② Power supply capacity of the hubs supporting PoE: It should be possible to cover the maximum power consumption of all connected devices.

③ Both the power supply side (hubs) and power receiving side (cameras, etc.) must be PoE compatible.

As one disadvantage of network cameras, the effect of an abnormality in the communication equipment will appear in multiple monitors. Therefore, standby units were provided for points where this is a problem. Since transmission delay was also a concern, a system that ensures a transmission speed on a level which does not adversely affect operation was constructed by providing two communication device systems and distributing the communication volume.

4. Remote Operation

To enable operation of the entry-side equipment from the exit-side control room, the various control panels of the entry-side control room (PLC (Programmable Logic Controller), DCS (Distributed Control System), entry-side conveying/welder, etc.) were added to the exit-side control room.

In adding the entry-side control panels to the exit-side control room, addition of slots for the bus signals of the entry-side main PLC was initially considered, but no empty slots were available, and further a response by the manufacturer was not possible due to suspension of manufacturer's maintenance.

Next, extension from the entry-side control room RIO (Remote I/O) to the exit-side control room by using multicore cables was studied, but in this case, an insufficient number of spare I/Os in the entry-side RIO was a concern.

Therefore, a method of signal branching using a general-purpose sequencer was studied. In this method, the sequencer is installed between the entry-side RIO and the control panel, and the sequencer performs signal branching of output signals from the PLC to transmit signals to the operation control panel in the exit-side control room (**Fig. 2**). This system was designed and implemented so that signals from both the entry-side control room and the exit-side control room are input to the sequencer, and only the signals from the control panel that currently has the operating right is output to the PLC and RIO by an operation location selection switch. This allowed JFE Steel itself to add entry-side PLC operation panels to the exit-side control room without upgrading the PLCs or changing the number of RIOs.

Next, various measures other than the addition of the control panels are described. In the existing No. 4 CAL before automation, coils were conveyed to the entry side by the coil conveying equipment and then visually inspected by the entry-side operator for coil defects such as inner diameter droop, outer circumference breakage and edge crack, and when defects were discovered, the operators took appropriate action for each defect by manual operation (**Table 2**).

To enable unmanned entry-side operation, the equipment was upgraded to allow the operators in the exit-side control room to perform coil inspections and processing of abnormalities. Coil cars were adopted as a means of conveying coils to the entry side. Focusing on the fact that the coil transport route passes near the exit-side control room, an inspection skid that enables inspection of coils near the exit-side control room was newly constructed, and a monitoring system, which allows the operator to inspect coils on a monitor in the exit-side control room, was constructed by installing a

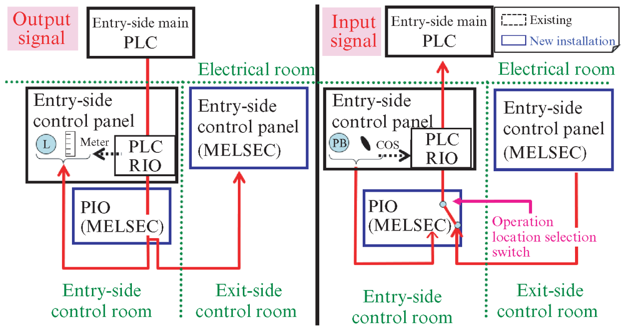
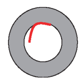
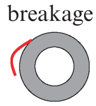
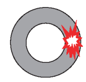
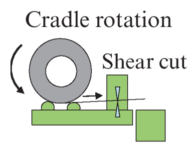
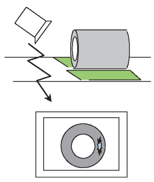


Fig. 2 Entry-side facility operation system

Table 2 Coil inspection item

Visual inspection	Inner diameter droop 	Outer circumference breakage 	Edge crack 
Operational impact	Risk of coil overturning	Unable to pass the sheet	Sheet breakage
Conventional processing	Jig loading	Cutting the folded part	Stop coil loading (Entry side operation)
Remote operation	Inner circumference tip position rotation (Cradle)	Cut the outer circumference of the coil (Shear)	Stop coil loading (Exit side operation)
Overview diagram			 Monitor in the exit-side control room

high-resolution camera on the skid.

As a result, operators in the exit-side control room can now inspect coils before transportation to the entry side and respond when detailed visual monitoring is necessary. Off-line cradle shear equipment was also newly constructed near the exit-side control room, allowing the operators to take appropriate action for defects at the exit side by removing coils with outer circumference breakage or inner diameter droop with a crane.

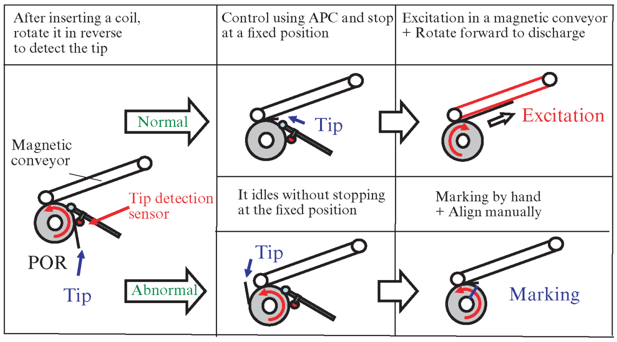


Fig. 3 Coil tip detection flow

5. Trouble Prevention

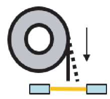
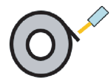
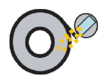
As described above, due to the poor detection rate of the existing coil tip detection sensors, it was not possible to perform APC (Automatic Preset Control) of the coil tip to a position where it could be attracted by the magnet conveyor. This led to frequent idling trouble, in which the undetected tip did not stop at the fixed position. Manual intervention by the entry-side operator was required to prevent this abnormality. Concretely, in the former operation, the operator marked the coil tip position with chalk on the coil side face before the coil was loaded on the payoff reel, and manually aligned the coil tip position when an abnormality occurred (**Fig. 3**).

The tip detection sensor was upgraded to eliminate manual operation due to failure of the coil tip detection sensor to detect the tip, which was a defect of the existing equipment. In selecting a new sensor, a comparative study of the methods adopted at various other CALs was carried out. The photoelectric sensor (PH) type is effective at lines that handle thin sheet material. However, this method was not adopted, as it was judged that tip detection accuracy would be poor due to the large sheet warpage of the materials handled by the target CAL in this project. Next, the laser rangefinder has satisfactory detection performance for thick sheet materials, but may fail to detect the coil tip of thin sheet materials. Therefore, an eddy current sensor with a proven track record at CALs handling similar sheet sizes and a wide detection range and gap interval was selected as the coil tip sensor for this upgrade (**Table 3**).

Although the detection rate improved, the eddy current sensor failed to detect the coil tip of some thin sheet materials, and thus did not eliminate manual operation.

To investigate the cause, the distance to the coil tip position output by the sensor for each coil was checked on the chart, and uniform frequency fluctuations could be seen in the sensor output. It was found that the width of this fluctuation exceeded the threshold for coil tip detection, causing repeated detection failure and overdetection, even after repeated adjustment of the threshold. This occurred because the sensor was mounted on the pinch roll, and minute vibrations of the pinch roll were superimposed on the sensor output. Various vibration measures such as increasing the pressing pressure of the pinch roll were tried, but since those measures were ineffective, other methods were studied. Observation of the sheet behavior when the coil tip was paid out revealed that, due to large sheet warpage, the coil tip rose after passing through the pinch roll, and this behavior occurred in all materials, regardless of the material thickness. Focusing on this point, misdetection was successfully eliminated by relocating the sensor position, and finally manual operation could be eliminated (**Fig. 4**).

Table 3 Comparison of coil tip detection sensors

Schematic diagram			
Measurement method	Photoelectric sensor (PH)	Laser rangefinder	Eddy current sensor
Evaluation	× Warping of the sheet	△ Thin plates cannot be detected	○ Proven track record with other equipment

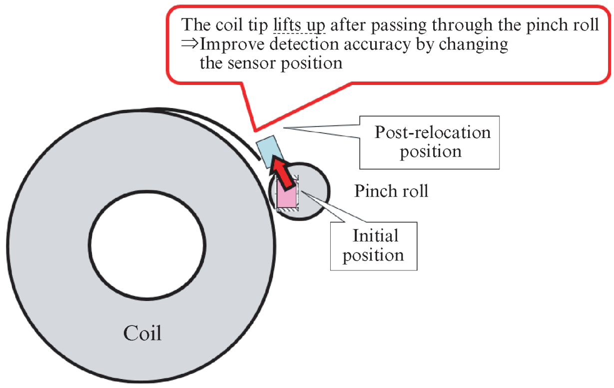


Fig. 4 Countermeasures against undetected coil tip

6. Conclusion

With the aim of achieving unmanned operation of the CAL entry-side equipment, remote monitoring and operation were accomplished and manual work to handle trouble at the entry side was eliminated. This paper described this project, focusing on the following measures:

① Remote monitoring by introduction of network cameras.
② Remote operation by use of a general-purpose sequencer.
③ Implementation of a monitoring system and installation of a new cradle shear to process abnormal coils before delivery to the entry side.
④ Improvement of the coil tip detection rate and elimination of manual operation by relocation of the coil tip detection sensor.

This project was completed without serious problems by separating the timing of equipment upgrades and the start of online operation of new functions in order to diversify potential risks. After the problem identification period and trial period, full unmanned operation of the CAL entry-side equipment was achieved, and labor-saving was achieved as originally planned.

Reference

1) Mori, T.; Inoue, T.; Egusa, K. No. 4 continuous annealing line Automation on entry side. IEEJ Technical Meeting. 2018, MZK18002, p. 5–7.

This paper is a reprint of the paper listed as reference 1), which was written by the same lead author, with partial revisions of some expressions.