UDC 621 . 77 . 06 : 621 . 771 . 252

Automated Equipment in Off-line Process of Wire Rod Production

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Abstract

There are many kinds of complex and difficult work in the manufacturing process of wire rods or in Off-line process that require humans. However, in considering the working environment and costs, it is preferred to move toward automated and unmanned operation. This paper outlines (1) Metal tug and labeling robots, (2) automation of packing, (3) automation of roll grinding, (4) automation of descaling and samples for surface flaw inspection and picking and (5) automation of sample manufacturing. These are some of the equipment that have been automated at the wire rod production sites of Nippon Steel Corporation.

1. Introduction

The wire rod manufacturing process has many auxiliary operations, such as roll grinding, preparing for inspection, and packaging, in addition to the basic manufacturing line composed of heating, rolling, coiling, inspection, and binding. Many of these auxiliary operations are complicated and difficult, and some have been targeted for mechanization but still rely on human workers.

Nippon Steel has developed and implemented technology for automating equipment accessory to wire rod mills. Of these off-line automation techniques, this article introduces: (1) an automatic metal tag stamping machine and a labeling robot at the Muroran Works; (2) automation of rod coil packaging at the Kimitsu Works; (3) automation of roll grinding at the Kamaishi Works; (4) automation of pickling of samples for defect inspection at the Kimitsu Works; and (5) automation of sample preparation at the Kamaishi Works.

2. Automatic Metal Tag Stamping Machine and Labeling Robot

The products (steel bars and rods) manufactured at the Muroran Works are shipped after metal tags for product identification and bar code labels for internal logistic control are affixed to them. These tasks were formerly done manually, increasing the cost in order to meet the needs of customers for many and varied product types in small lots, that is a characteristic of special steels. A metal tag stamping machine and a labeling robot were developed to eliminate these problems.

2.1 Automatic metal tag stamping machine

Metal tags attached to the products bear the size, standard, weight, chemical composition, and other pieces of product information. To perform the automatic stamping of the product information at high speed with high accuracy, AC servo motors were applied for X-Y table positioning, character selection and character stamping, and simultaneous control was effected by utilizing PIO with a 16-bit microprocessor unit (MPU). To shorten the cycle time, two stamping heads were adopted in place of two separate metal tag stamping machines (refer to **Fig. 1**). To prevent two metal tags from being dispensed at a time and to transfer each metal tag stably, a metal tag is vacuum held by a suction pad, pushed at the center by an air cylinder, and curled for separation from the metal tag stack in the magazine (refer to **Fig. 2**). A vacuum break valve is employed for the stable separation of the metal tag from the suction pad. The basic specifications of the metal tag stamping machine are given in **Table 1**.

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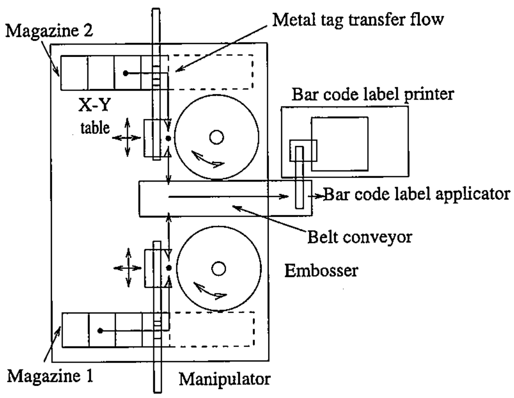

Fig. 1 Construction of metal tag stamping machine

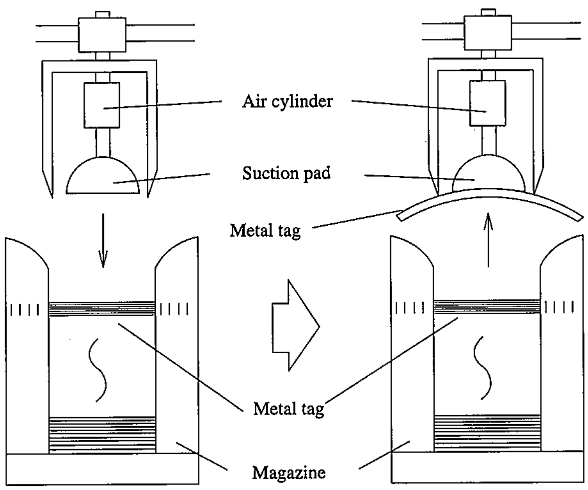

Fig. 2 Methods for dispensing and separating metal tag

Table 1 Basic specifications of metal tag stamping machine

Unit	Item	Specification
Metal tag stamping machine	Stamping device	Drum-type stamper (96-division embossing method)
	Number of characters stamped	Maximum of 107 characters/tag
	Stamping cycle time	Maximum of 20 s/tag
	Control	Multiple control by MPU and sequencer

2.2 Labeling robot

To allow labels to be affixed quickly and accurately to hoops of rod coils, an articulated robot is used for transferring the label, and a contact sensor and an image processing unit are adopted for detecting the position of the hoop (refer to **Fig. 3**). The label is peeled from the backing by vacuum holding one end and wrapping it around a roller, with the rotational speed of the roller being synchronized with the operating speed of the robot. The label is affixed to the hoop by applying the center of the label to the hoop, breaking the vacuum holding the label, and forcing the label to adhere to the hoop under compressed air pressure (refer to **Fig. 4**). These measures assure a label application success rate of 97.5%, a level of performance high enough for on-line equipment. **Table 2** shows the equipment specifications of the labeling robot.

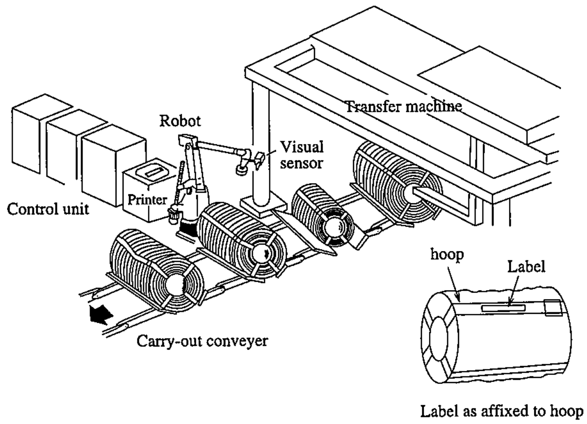

Fig. 3 Labeling robot

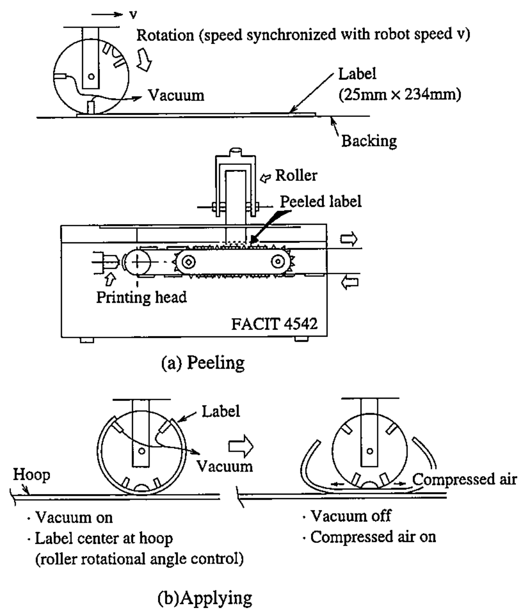

Fig. 4 Methods for peeling and applying label

Table 2 Main specifications of labeling robot

Item		Specification
Rod coil		Rod size: 5.5 to 22 mm Coil height: 600 to 1,600 mm Coil OD: 1,250 to 1,450 mm
Banding hoop		Size: 32 mm wide, 1 mm high
Label		Size: 234 mm long, 25 mm high Information printed: Order number, customer's name, coil number, and destination
Labeling robot	Robot	Type: 6-axis articulated robot Drive method: AC servo Maximum speed: 1,200 mm/s Rpeatability: ± 0.5 mm Pay load: 15 kg
	Image processor	Method: Binary black and white image processing Responsibility: ± 1%
	CCD camera	Number of pixels: 384 horizontal pixels 490 vertical pixels
	Personal computer	FC9801

2.3 Summary

The development of the automatic metal tag stamping machine and the labeling robot has made it possible to meet the needs of users for many different products in small lots and to achieve a sizable reduction in the cost. The first metal tag stamping machine was put into operation in August 1987, and five such machines are now in service for steel bars and rods. The labeling robot has been successfully working at the wire rod mill of the Muroran Works since January 1987.

3. Automation of Rod Coil Packaging

The wire rod mill of the Kimitsu Works developed automatic packaging equipment to automate the manual packaging of rods in coils and put it into operation in April 1993.

3.1 Description of automatic packaging equipment

The packaging of rod coils consists of: (1) wrapping a rod coil with protective material; (2) folding the protective material; and (3) binding the package.

3.1.1 Material wrapping unit

The packaging material wrapping unit is schematically shown in **Fig. 5**. A rod coil is longitudinally sandwiched between cylindrical jigs of a diameter slightly larger than the coil OD. The packaging material received from a packaging material feed unit is wrapped around the coil along the circumference of the cylindrical jigs. The packaging material makes one revolution around the coil about the longitudinal axis. The end of the packaging material is then taped. After the completion of wrapping, the cylindrical jigs are reduced in the OD by an OD expand/collapse mechanism and moved away from the ends of the wrapped coil.

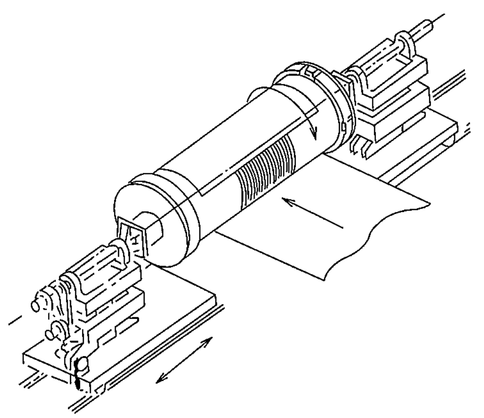

Fig. 5 Schematic of packaging material wrapping unit

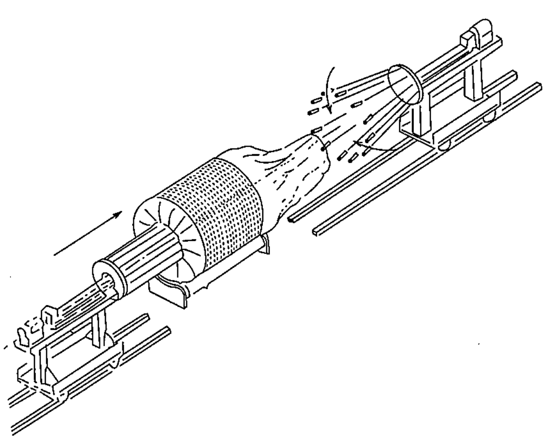

Fig. 6 Schematic of packaging material folding unit

The cylindrical jigs incorporate a mechanism to catch the end of the packaging material. The OD expand/collapse mechanism is controlled to adjust to the coil OD automatically measured beforehand. These mechanisms allow the packaging material to be tightly wrapped around the coil.

3.1.2 Material folding unit

The material folding unit is schematically shown in **Fig. 6**. The packaging material projecting from each end of the coil is folded into the coil. The open/close arms in the form of umbrella's hinged ribs are closed to press the packaging material into a smaller size and moved forward to fold the packaging material into the coil. At their forward limit, the arms are opened to push the folded material against the inside surface of the coil.

3.1.3 Package binding machine

The package binding machine is a general horizontal type. It secures the packaging material so that it does not uncover the coil in transit.

3.2 Benefits from introduction of automatic packaging equipment

The development and introduction of the automatic packaging equipment substantially reduced the number of workers employed for packaging the wire rods in coils. The automatic packaging equipment is now operated by two workers per shift. The packaging efficiency has improved by about 50% as compared with the conventional manual method.

4. Automation of Roll Grinding

Here is reported the automatic roll grinding machine introduced at the wire rod mill of the Kamaishi Works as part of its campaign to reduce the labor expended in electrochemically grinding the cemented carbide rolls of finishing stands. The automatic roll grinding machine is mainly designed for grinding the OD and grooves of cemented carbide rolls and handling the cemented carbide rolls. The overall configuration of the automatic roll grinding machine is shown in **Fig. 7**. Its main specifications are given in **Table 3**, and its automation scope is shown in **Table 4**.

The equipment features: (1) There are two vertical shafts, one for grinding the OD of rolls and the other for grinding the grooves in the rolls. They can work independently of each other. (2) A stock conveyor is installed so that up to 60 rolls can be loaded, unloaded, and ground by the machine proper in combination with a loader robot. (3) Each roll to be ground can be automatically mounted on the spindle of the machine by a purpose-built arbor. (4) There is a function for measuring and compensating for the thermal expansion of the machine bed by the heat of grinding. (5) Each roll is washed after grinding.

Pre-grinding tasks include setting the grinding wheel, the grinding conditions, and the rolls on the stock conveyor. Post-grinding tasks include removing the roll from the machine, measuring the roll diameter, checking the passes in the rolls, and marking the rolls.

A series of operations involved in grinding a roll on the automatic grinding machine is described below.

(1) Measure the amount of wear of a pass grinding wheel with a projector, and mount the pass grinding wheel on the second wheel shaft.
(2) Place the rolls to be ground on the stock conveyor, call-up a grinding program for the rolls from the NC unit, set the grinding conditions (e.g., wheel wear compensation, work number, amount of grinding, and roll diameter), and start operating the machine.
(3) The loader grabs the first of the rolls on the stock conveyor and

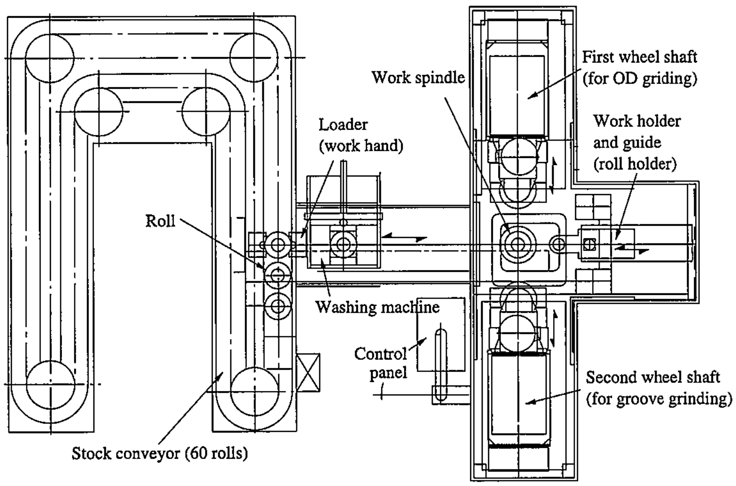

Fig. 7 Overall configuration of automatic roll grinding machine

Table 3 Main specifications of roll grinding machine

	Name	Specification
Machine proper	Work spindle	Dedicated chucks for 6-inch and 8-inch rolls, respectively
	Work holder and guide unit	Common work holder for 6-inch and 8-inch rolls
	First wheel shaft	Dedicated for flat wheel (for OD grinding)
	Second wheel shaft	Dedicated for pass wheel (for pass grinding)
	Instrument	Measuring thermal expansion of bed
Peripheral device	Loader	Work hand (payload of 30kg)
	Stock conveyer	Maximum of 60 rolls
	Washer	Nozzle water spray
	Projector	Wheel wear and vertical amount measurement

Table 4 Automation scope of roll grinding

Pre-grinding task	· Setting grinding wheel · Setting grinding conditions (e.g., wheel wear compensation, work number, amount of grinding, roll diameter) · Setting rolls on stock conveyor	Manually performed (wheel wear is measured using projector)
Automation space	· Mounting roll on spindle arbor	Roll is loadied by loader and clamped by work holder and guide unit
	· Setting at origin	NC control
	· Automatic electrochemical grinding	Two vertical shafts (for OD grinding and pass grinding)
	· Removing roll from spindle arbor	Roll is unclamped by work holder guide unit and unloaded by loader
	· Washing roll	Loader is carried by loader and washed with water
Post-grinding task	· Removing rolls from stock conveyor · Measuring roll OD, and checking roll passes · Marking rolls	Manually performed

carries it to the work spindle. Once the roll is loaded, the work holder and guide unit actuates and chucks the roll.

(4) The work spindle starts running, the first wheel shaft for OD grinding moves toward the work spindle, and electrochemically grinds the OD of the roll, leaving the amount of finish grinding. Then, the second wheel shaft for pass grinding moves toward the work spindle and electrochemically grinds the first of the passes in the roll, leaving the amount of finish grinding. When one pass is completed, the second wheel shaft moves to the next groove and electrochemically grinds it.

(5) As the machine bed thermally expands with the progress of grinding, the NC unit compensates for the thermal expansion to ensure accurate electrochemical grinding. Lastly, the automatic grinding machine mechanically finish grinds the OD and passes of the roll.

(6) When the grinding of the roll is completed, the work guide unit opens to release the roll, and the loader grabs the roll and carries it to the washer. After the roll is washed, the loader grabs and places it into a stocker.

(7) Remove the ground roll from the stocker, measure the OD of the roll, and check the passes in the roll.

Of the above series of operations, third through sixth operations are automated. The operator performs the steps (1) and (2) before grinding and the step (7) after grinding. The steps (3) to (6) are automatically carried out.

The cycle time is an average of about 35 min/roll. If 60 rolls are arranged on the stock conveyor, the automatic grinding machine can grind all of them in about 35 hours of continuous, unattended operation. As a labor-saving effect, the three-shift system of one OD grinding worker and one pass grinding worker per shift was eliminated, resulting in the elimination of six workers. The pre-grinding and post-grinding tasks to operate the automatic grinding machine are performed by operators of other work stations.

5. Automation of Sample Pickling

The shape and wire rod mill of the Kimitsu Works installed automatic sample pickling equipment to reduce the labor used for pickling rod samples for defect inspection and to improve the working improvement. The automatic sample pickling equipment started up in August 1995.

5.1 Description of automatic sample pickling equipment

When rods are rolled and coiled, a sample about 400 mm in length is cut from each end of the coil. These samples must be pickled in acid to remove their scale. Formerly, they were all manually loaded, immersed in pickling and neutralizing tanks, rinsed with water, dried in air, and unloaded. The automatic sample pickling equipment

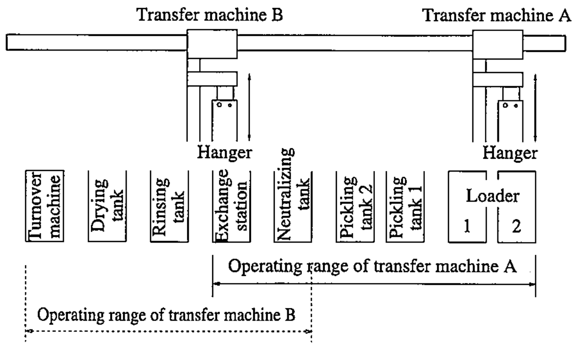

Fig. 8 Configuration of automatic sample pickling equipment

mechanizes this series of operations using a conveyor system. Its overall configuration is shown in **Fig. 8**.

5.1.1 Description of operation

The sample is placed on the hanger in the standby position of the loader at the right side of the equipment shown in Fig. 8. The hanger is moved by the transfer machine A to the pickling tank, dipped into the pickling tank, removed from the pickling tank after the specified length of time, moved to the neutralizing tank, dipped into the neutralizing tank, removed from the neutralizing tank after the specified length of time, moved to the exchange station, and transferred to the transfer machine B. The transfer machine B then treats the sample on the hanger in the rinsing and drying tanks, respectively, and carries the hanger to the turnover machine. The turnover machine turns over the hanger, removes the sample from the hanger, and sends the sample to the laboratory. The hanger is moved by the transfer machine B to the exchange station, transferred to the transfer machine A, and moved by the transfer machine A to the loader position. This completes the series of operations involved.

5.1.2 Features of component units

(1) Transfer machines A and B: Two transfer machines are installed to provide a processing capacity equivalent to the rolling efficiency of the mill. Each transfer machine has an arm to hold the suspending part of the hanger and automatically runs on the rails above the tanks.

(2) Hanger: The hanger is composed of a box to contain a sample and a shaft and gears to turn over the box, and is made of acid-resistant and heat-resistant polyvinyl chloride.

(3) Pickling tanks: The pickling tanks are equipped with hydrochloric acid and water supply piping, automatically controlled as to the hydrochloric acid concentration, and constructed of heat-resistant and acid-resistant polypropylene.

(4) Neutralizing tank: The neutralizing tank is equipped with sodium bicarbonate and water supply piping, automatically controlled as to the sodium bicarbonate concentration, and constructed of polyvinyl chloride.

(5) Rinsing and drying tanks: After a water shower, the hanger is dried in a hot-water rinsing tank. The hot-water temperature is automatically controlled to a high enough level for efficient drying. The rinsing and drying tanks are each constructed of polyvinyl chloride.

(6) Turnover machine: When the hanger reaches the turnover machine position, the gears of the turnover machine are automatically driven to turn over the hanger and to remove the sample from the hanger. The sample is sent to the laboratory.

5.2 Benefits from introduction of automatic sample pickling equipment

The introduction of the automatic sample pickling equipment reduced the number of workers required for pickling the samples and greatly improved the working environment.

6. Automation of Sample Preparation

The Kamaishi Works developed a system, called the Linkaged Automatic Processing System (LIAS), for fully automating the process of cutting a sample for metallographic examination from a curved rod, mounting it in a resin, and polishing it, which was formerly done manually. The LIAS system started its operation in April 1996 and has been contributing to the efficiency enhancement of the testing and inspection process since then. The compact layout of the LIAS system is shown in **Fig. 9**. The robot moves the sample to the respective units by changing its hand.

The features of the LIAS system are shown in **Table 5**, and the main specifications of its component units are given in **Table 6**. The honeycomb-shaped sample feed stocker and robot hand (refer to **Photo 1** and **2**, respectively) were specifically designed for the handling of curved rods, which was the largest problem. Samples were previously cut dry to shorten the cycle time. The LIAS system adopted wet cutting to eliminate heat-affected zones and to increase the cutting speed for a smaller polishing allowance. As shown in **Table 7**, the LIAS system has a sample preparation capacity about twice as large as the conventional manual process. The tablet (seal) method available as know-how at the Kamaishi Works was adopted

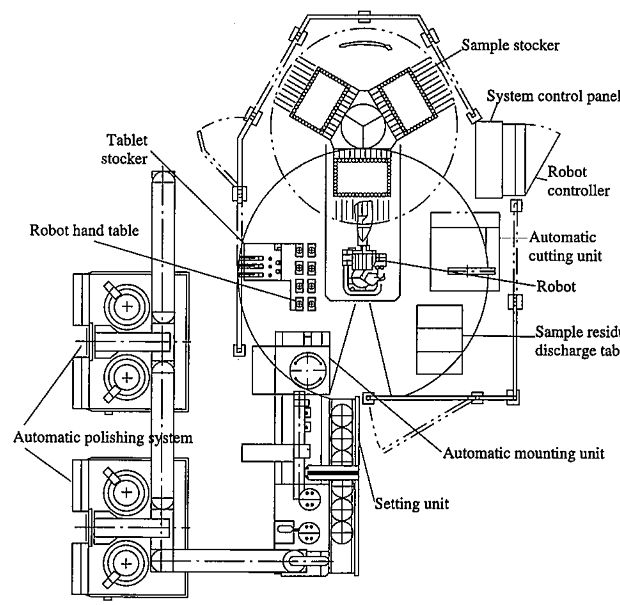

Fig. 9 Layout of LIAS system

Table 5 Features of LIAS system

(1) World's first fully automatic rod sample prepartion process
(2) Handling and supply of curved rods made possible
(3) Tablet seal method adopted for preventing samples from falling down
(4) High-speed wet cutting adopted
(5) Tracking control at instructions from host computer

Table 6 Specifications of component units

Unit	Specification
Robot	Articulated type (6 axes simultaneously controlled), 6 change hands
Sample supply stocker	190 samples, 3 surfaces (rotary type)
Automatic cutting unit	Wet type, maximum cutting diameter: 20 mm, required time: 2.5 mm/sample
Automatic mounting unit	38 mm resin mold, requied time: 8 min/mold
Marking unit	Carbon dioxide laser, maximum output: 20W
Automatic polishing unit	Setting unit: 6 molds/holder, required time: 30 min/holder

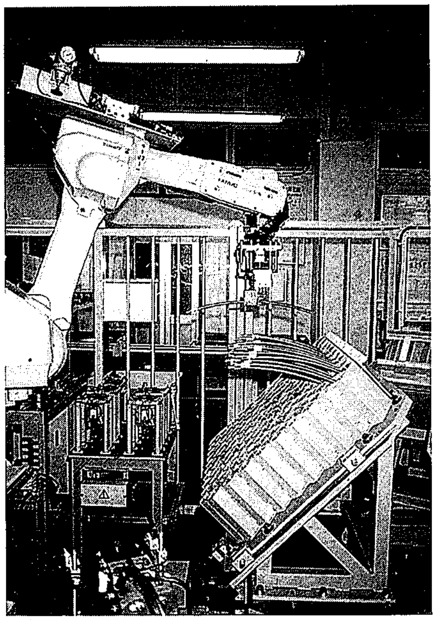

Photo 1 Sample supply stocker in LIAS system

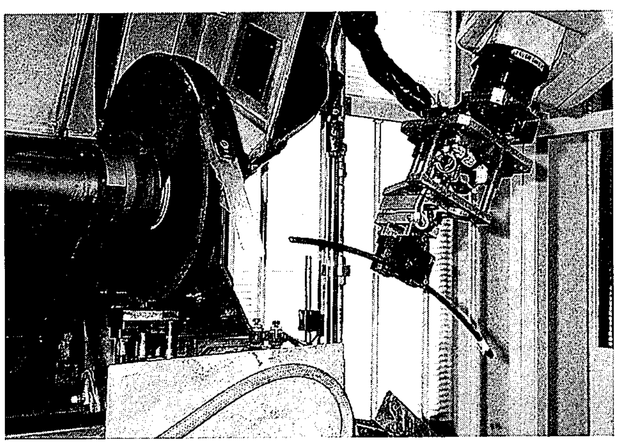

Photo 2 Hand of robot in LIAS system

Table 7 Overall sample preparation capacity of LIAS system

	LIAS system	Conventional method
Sample preparation capacity	560 samples/day (40 min/mold)	300 samples/day (100 min/mold)
Rod size range	5 to 16 mmϕ	5 to 16 mmϕ

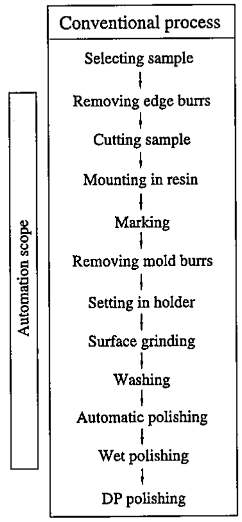

Fig. 10 Conventional sample preparation process and automation scope of LIAS system

to prevent transverse-surface samples from falling down. It is made possible to perform the tracking control of the sample preparation results at instructions from the host computer. These measures accomplished the world's first automated sample preparation process from sample selection through feed to finish polishing as shown in **Fig. 10**.

The LIAS system was developed by combining the know-how of the Kamaishi Works and its suppliers, and employing the general engineering capability of the Electronics & Information Systems Division of Nippon Steel. The Kamaishi Works is pushing ahead with the full automation of rod tensile testing and scale weight measurement to accomplish a further labor savings in the testing and inspection process.

7. Conclusions

Examples of automation techniques for equipment auxiliary to the wire rod production process have been discussed above. These pieces of automatic equipment replace manual tasks and embody the combinations of rod manufacturing technology and engineering technology. These automation efforts will be continued to improve the working environment and labor productivity.