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An Outline of New Block Mill and Its Operating Results*

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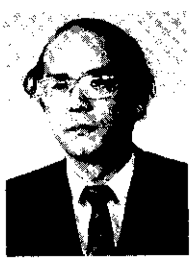

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To meet demands for higher quarlity and higher productivity of wire rods, Mizushima Works additionally installed a wire-rod finishing block mill line to the existing bar mill, and started the operation of this mill line as a new wire and bar mill in September 1984. This new plant realized the manufacture of multi-kind and multi-size products including straight bars, bars-in-coil and wire-rods using a single strand mill. For this purpose, the new plant added equipment-functions related to high-speed rolling and high-speed winding of wire rods, and introduced various kinds of process control to achieve super-high speed rolling. The entire process ranging from raw material acceptance to product delivery was under computerized control, and high-efficiency operation was realized by the mill-line automatic setting control. The operational record of the new wire-rod and bar plant for the past year was satisfactory, showing monthly average speed exceeding 100 m/s (5.5 mmϕ) and dimensional accuracy stabilized at ±0.2 mm.

1 Introduction

As a result of the recent advent of the no-twist high-speed block mill in finishing, surface quality and dimensional accuracy of wire-in-coil have been improved, and with increase in finish-rolling speed, the unit-weight of wire-in-coil is increasing.[1] At the wire-rod mill of its Mizushima Works, Kawasaki Steel advanced a revamping plan in which a new wire-rod rolling block mill line was to be installed along with the existing bar mill with the aim of ensuring stabilized production of high-grade steels. The outstanding feature of the plan was that since the block mill line would be of the full-continuous no-twist type, the facility configuration most suitable for production of high grade steels could be obtained. Since the block mill line was to perform one-strand rolling, it was necessary to increase rolling speed greatly, to the world's highest figures, and also to construct a system capable of continuous rolling of small lots of high grade steels.

Examination of the plan commenced in the fall of 1981, construction of facilities and system was begun in October 1982, and the block mill line started operation in September 1984. One year after its commissioning, the block mill line is now operating smoothly after achieving almost all targets set at the time of planning, including a rolling speed of 105 m/s for 5.5 mmϕ wire rods.

This paper describes the block mill line at the new bar and wire-rod mill in outline and reviews operation records of the facility.

2 Features of New Block Mill Line

2.1 Basic Concept

To enhance the quality of wire-rod products and improve productivity, a wire-rod finishing mill line was added to and integrated with the existing bar mill, a high-grade steel manufacturing mill using the con-

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tinuous, no-twist-type layout. Consequently, the new "bar and wire-rod" mill has become a rolling mill unprecedented worldwide, able to manufacturing products ranging from 5-mmϕ wire rods to 73-mmϕ bars in multiple type and sizes. Objectives of the plan are shown below.[2)]

(1) To achieve high productivity in wire-rod rolling by realizing super-high-speed rolling at the world's highest level.
(2) To automate the manufacturing process and the changes in manufacturing conditions in order to facilitate the rolling of multi-kind, multi-sized products.
(3) To achieve parting control at the block mill to guarantee the manufacture of higher-quality products, diversification of the Stelmor heat treatment function, non-sliding transportation, and enhancement of the quality assurance system through the use of eddy current detectors, etc.

2.2 Basic Specifications

Steels used for manufacturing bars and wire rods, types of products, steel grades, and production capacity are shown in **Table 1**.

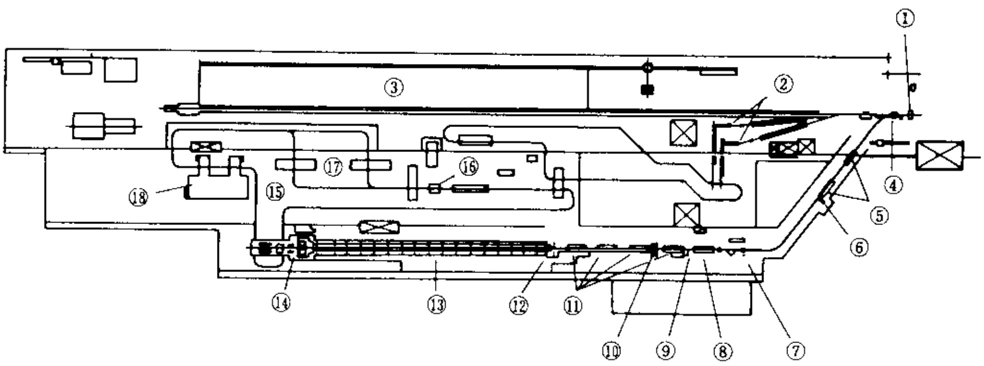
Table 1 Product specifications

Material	Carbon steel, alloy steel, stainless steel
Billet size	150 mm*W* × 150 mm*H* × 6 500 ~ 1 300 mm*L*
Billet weight	2 250 kg max.
Product size	
Wire rod	5.5–15 mmϕ
Round bar	16–73 mmϕ
Capacity	38 000 t/month

2.3 Equipment Layout

The layout of the block mill line is shown in **Fig. 1**, and features of the block mill line are enumerated below.

(1) The block mill was installed at a location adjacent to the pouring reel yard to effectively use the existing equipment and building. After overall evaluation of the costs of civil-engineering work and building construction, the mill pass level was raised about 3 m higher than that of the existing mill, and the building containing the bulk mill line became a semi-two storied structure.
(2) Since the block mill is 94 m from the existing bar mill, pinch rolls and a large looper were installed to ensure high-speed trackability of materials.
(3) The line between the block mill line and the winding equipment was made straight to ensure high-speed trackability and cooling capacity; the length of the water cooling box is 50 m.
(4) The reforming tub is of the 2-arm mandrel type, and since the coil piling head is about 9 m high, the bulk mill was made a semi-underground-structure, with the coil lifted about 3 m to the coil conveyor line installed on the building floor.
(5) For the coil conditioning equipment, the existing bar-in-coil conditioning equipment is effectively used. With a transporter connecting the existing and new conditioning equipment, inspection and binding are unified into a common operation. Also, through on-line processing all coils after rolling are put directly into storage in the warehouse without storage in the product coil stockyard.



① Bar mill
② Pouring reel
③ Cooling bed
④ Profile meter
⑤ Water spray box
⑥ Pinch roll
⑦ Shears
⑧ Block mill
⑨ Hot surface defect detector
⑩ Profile meter
⑪ Water spray box
⑫ Laying head
⑬ Stelmor conveyer
⑭ Reforming tub
⑮ Hook conveyer
⑯ Coil scale
⑰ Binder
⑱ Unloader

Fig. 1 Layout of the block mill

3 Features of Major Facilities

3.1 Existing Bar Mill Line Facilities

The existing bar mill rolls bar-in-coil ranging from 16 to 73 mmϕ and straight bars. When wire rods are rolled, this mill serves as intermediate finishing equipment. Its specifications are shown in **Table 2** and its features are enumerated below.

(1) Through the use of the walking beam furnace, it is possible to control surface decarburization and internal diffusion, and non-sliding transportation prevents scratching.

(2) Rolling with high dimensional accuracy is possible by H-V-array, continuous, no-twist rolling and tension control.

(3) Manufacture of 2-t coils using a large cross-section billet is possible.

Table 2 Bar mill line facilities

Equipment	Specifications	
Reheating furnace	Type :	Walking beam type with 4 zones
	Billet :	150 mm□ × 13 000 mm
	Capacity:	150 t/h
	Maker :	IHI
	Unit :	1
Roughing mill	Type :	Horizontal mill × 3 Vertical mill × 3
	Roll size:	H_1 & V_2 stand 550 mmϕ × 900 mm H_3 & V_4 stand 500 mmϕ × 900 mm H_5 & V_6 stand 440 mmϕ × 900 mm
	Motor :	DC 450 kW (600/1 000 rpm) × 6
	Maker :	Hitachi Zosen Corp.
	Unit :	6
Intermediate mill	Type :	Horizontal mill × 3 Vertical mill × 3
	Roll size:	400 mmϕ × 700 mm
	Motor :	H_7 & V_8 stand DC 450 kW (600/1 000 rpm) H_9 & V_{10} stand DC 600 kW (480/1 000 rpm) H_{11} & V_{12} stand DC 900 kw (480/1 000 rpm)
	Maker :	Hitachi Zozen Corp.
	Unit :	6
Finishing mill	Type :	Horizontal mill × 3 Vertical mill × 3
	Roll size:	365 mmϕ × 700 mm
	Motor :	H_{13}, H_{15} & V_{14} stand DC 1 000 kW (480/1 000 rpm) V_{16} DC 900 kW (480/1 000 rpm) H_{17} & V_{18} stand DC 1 200 kW (480/1 200 rpm)
	Maker :	Hitachi Zosen Corp.
	Unit :	6

3.2 Block Mill and Tracking Facilities

To form a wire-rod and bar combined-type mill using a single strand mill, it is essential to further improve the high-speed rolling capability of the existing block mill and to approach roll-chance-free operation in order to cope with a multi-type, multi-size product rolling. **Photo 1** shows the block mill, and its features are enumerated below.

(1) As a superhigh-speed mill, the block mill has a rolling speed of 100 m/s for 5.5-mmϕ wire rods and a rolling speed of 100 t/h for rods of 7 mmϕ or above in the converted rate of rolling-efficiency. It also has a capacity equivalent to two strands of an ordinary-type mill.

(2) The block mill is a heavy-duty-type mill which permits low-temperature rolling at an inlet material temperature of 850°C to facilitate controlled rolling.

(3) Inter-stand cooling equipment is installed to control the rolling temperature in the block mill.

(4) The block mill has the functions of shortening the period required for size changes, remote-control of roll screw-down for reduction control, and parting control.

(5) Roller guides are provided at all stands to ensure dimensional accuracy and the prevention of scratches.

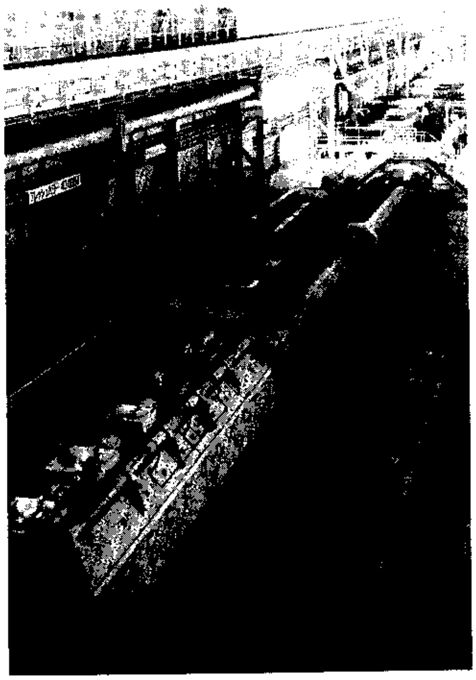


Photo 1 Block mill line

(6) To support high-speed controlled rolling, sensors are used to detect roll-neck metal temperature and load, thereby achieving adequate monitoring.

Since the block mill is also located 94 m from the existing final rolling equipment, careful consideration is given to the following points regarding tracking facilities:

(1) To ensure smooth tracking of material, pass line changes are all made in a curved line with troughs designed in arc shape, and pinch rolls are installed in the middle.
(2) The shears which trim the front and tail ends is of the stationary deflector type, in which two blades, that is, material kick-up and kick-down blades, are installed coaxially to cope with the demand for high-speed cutting when material speed reaches its 15-m/s maximum, thereby achieving stabilization of timing control. Samples can be automatically collected by changing over chutes.
(3) To ensure the quality of steel products, the curved portion of the tracking facility is provided with a guide-roller-fitted water-cooling box for trough temperature control, a descaler for removing the material-surface scale accompanying long-distance transportation, and a large looper for tension control.

Equipment specifications of the guide facilities are shown in **Table 3**.

Table 3 Block mill line facilities

Equipment	Specifications
Pinch roll ahead of block mill	Type : Air pinch type Roll size: 158 mmϕ Motor : DC 60 kW (1 900 rpm) Maker : SHI-Morgan Unit : 1
Shear	Type : Rotary type Motor : Crop shear DC 110 kW (500 rpm) Chopping shear DC 90 kW (850 rpm) Maker : SHI-Morgan Unit : 2
Block mill	Type : 10 stands on twist mill Roll size: #19～#20 stand 210 mmϕ #21～#28 stand 158 mmϕ Maker : SHI-Morgan Unit : 1
Main motor of block mill	Capacity: AC 6 000 kW (700/1 400 rpm) × 1 Control : AC-VVVF Digital ASR control Maker : Toshiba Unit : 1

3.3 Winding and Adjust-Cooling Facilities

3.3.1 Winding facilities

It is no exaggeration to say that the success or failure of realizing high-speed rolling is determined by winding facilities, and the maximum rolling speed of all wire-rod mills in operation is governed, without exception, by the winding facilities. The new block mill lines has the following features to realize high-speed, stabilized winding:

(1) To ensure high-speed guideability, the guide pipe from the block mill to the winding laying head is exclusively used for 5.5-mmϕ wire rods, and the water cooling box is provided with a self-centering mechanism to prevent pass center deviation which may occur when the water cooling box or nozzles are replaced.
(2) To ensure stabilized winding, namely, to prevent uneven cooling due to disturbance of the ring pattern and to avoid transportation problems, the following measures have been taken:
   (a) For pinch rolls, an upper and lower roll screw-down system is employed, and a precision pinch pressure control device and tensile control device for the total length of the wire rod have been developed and introduced, thereby making it possible to feed wire rods stably into the laying head.
   (b) The laying head is of a stationary type with an inclination angle of 10° to prevent vibration, and pipes are fabricated as a single piece with dimensional accuracy of within ±170 g/m to prevent deviation.
(3) To perform ring control on the non-steady portion of the rolled head and tail ends, a ring front and tail end drop position control, tail end acceleration and deceleration control, etc., have been introduced.
(4) Eddy current detectors and thickness gages are installed to carry out on-line quality assurance.

3.3.2 Adjust-cooling facilities

Quality requirements for strength, internal structure, etc., of wire-rods are being increasingly upgraded. To satisfy these requirements and cope with diversification of on-line heat treatment conditions, the cooling facilities have the following features: [3,4]

(1) Cooling capability covers a wide range, from slow cooling by adiabatic controlled cooling to rapid cooling by high-pressure impact-draft cooling.
(2) The conveyor employs a roller system which permits uniform cooling in the conveyor width direction and prevents such problems as the transported coil being caught in the conveyor.
(3) Cooling rate can be arbitrarily set by multiple division of the conveyor and blower section and by

effecting VVVF control.

In the past, cooling facilities generated a great deal of noise caused by blower operation, posing an environmental problem. In the improved facilities, all blowers are equipped with silencers. The main body is covered with soundproof lagging, and the entire blower is completely enclosed with soundproof panels, thereby significantly improving the working environment.

3.3.3 Coil storage facilities

To improve yield and rolling efficiency, two 1-ton coils are obtained by splitting a 2-ton coil into two equal halves by tub-shears while the coil is in storage. As a result, the previous "sail-down ender" system has been replaced with a 2-arm mandrel system to improve processing capacity.

(1) The time cycle, which indicates processing capacity, is 33 sec, which is converted into a rolling efficiency of 120 t/h.
(2) The tub-shears have an inclined blade to prevent cut edges from becoming excessively sharp. Also, to improve the ring-splitting function during cutting, the tub-shears employ double irises to achieve 100% on-line splitting.
(3) Very neat coil shape is obtained by trimming the coil with ring drop position control and using an eight blade nose cone.
(4) After the coil height is calculated, coil is transferred from the mandrel to the hook line, without sliding, by a transfer car equipped with an elevating mechanism, and is centered by a centering device.

Specifications of the cooling facilities are shown in **Table 4**; winding condition is shown in **Photo 2**.

Table 4 Laying head, stelmor and reforming tub line facilities

Equipment	Specifications
Pinch roll ahead of laying head	Type : Air pinch type Roll size: 158 mmφ Motor : DC 185 kW (1 800 rpm) Maker : SHI-Morgan Unit : 1
Laying head	Type : Inclined type (10°) Laying pipe: STPA 24 40 A 1 piece pipe Motor : DC 185 kW (1 350 rpm) Maker : SHI-Morgan Unit : 1
Water spray box	Type : Cooling nozzle type × 4 zones Capacity: 600 m³/h max Maker : SHI-Morgan Unit : 4 × 2
Stelmor conveyer	Type : Roller coveyer × 8 zones Blower : 250 mmAq × 1 100 m³/min × 11 Control : AC-VVVF Maker : SHI-Morgan Unit : 1
Reform tub	Type : 2 Arm mandrel Tub : Inside 900 mmφ Outside 1 350 mmφ. Shear : Swing arm shear with double irises Maker : SHI-Morgan Unit : 1

Photo 2 Laying head

3.4 Coil Finishing Facilities

In the past, although coil finishing facilities were positioned at on-line facilities, sometimes the coil stockyard was placed at the mill end and off-line conditioning of coils in process became necessary, resulting in lowering of productivity. In the new plan, coil finishing is made to be fully on-line, with all work carried out by automatic handling and processing; after rolling, the coil is immediately shipped, thus minimizing required coil storage yard space. Facility specifications are shown in **Table 5** and features of the facilities are enumerated below.

(1) To guarantee high product quality, the coil is transported from the storage yard to the delivery station, while a series of finishing works is being carried out

Table 5 Finishing line facilities

Equipment	Specifications
Conveyer	Type: Power & free Total length of P & F conveyer: 400 m Traveling speed: 18.5 m/s Number of hook: 70 Storage length: 1 950 mm Motor : 25 kW × 1 200 rpm Capacity: 100 coils/h Maker : Daifuku Unit : 2
BIC transfer	Type : Lifting car type Lift : 700 mm Motor : 2.2 kW P.C. motor Maker : Daifuku Unit : 1
Coil scale	Type : Load cell type Range : 4.0 t max Indication: 1 kg min Accuracy : ±1 kg Maker : Kawatetsu Instrument Unit : 1
Automatic binder	Type: Hoop binding Point of binding: 2.4 & 8 points Compression of coil: 10～30 t (hydraulic mandrel press) Tightening force of hoop: 200～500 kg (air motor) Binding hoop Thickness: 0.9～1.2 mm Width : 32 mm Capacity 4 points binding: 60 coils/h 8 points binding: 45 coils/h Maker: Daifuku Unit : 2
Unloader	Type: Lifting car & storing car type Lifting car Lift : 650 mm Travel: 7 990 mm Motor : 1.5 kW (P.C. motor) Storing car Capacity: 4 coils/line Number of line: 2 line/car Travel: 2 000 mm Total capacity: 100 coil/h Maker: Daifuku Unit : 2

on a non-sliding "power and free" conveyor.

(2) The new conveyor line incorporates finishing operations such as inspection and binding and is connected to the existing bar-in-coil conveyor by a transfer car, thereby optimally using existing facilities and increasing the efficiency of the finishing operation.

(3) To facilitate on-line processing, the binder employs 8-point binding and multistage pressing to make fully-automatic hoop binding possible.

3.5 Lubricating System

To eliminate roll bearing seizing problems which would obstruct high-speed rolling at the block mill, a lubrication system embodying the following concept was set up:

(1) Realization of a system which can maintain a NAS 7-class lubricating oil cleanliness.

(2) Adoption of sensors for early detection of deterioration of lubricating oil cleanliness.

Specifications of the lubricating system are shown in **Table 6**; a block diagram appears in **Fig. 2**. Main features are as follows:

(1) Tank and piping are entirely of stainless steel to prevent leakage of foreign matter from the system.

(2) Lubrication to roll bearings consists of two channels, that is, one for the bearing on the roll side and one for the drive side, to achieve optimum filtration.

(3) Prevention of entry of foreign matter from outside the system.

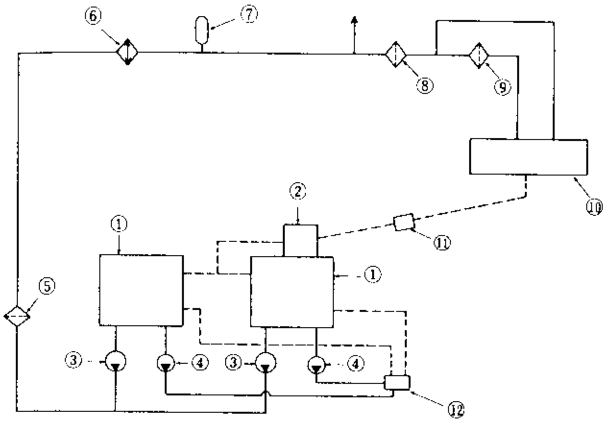
(a) The oil cellar is of a totally enclosed construction; its interior pressure is maintained at "atmospheric pressure + 10 mm H_2O" by use of a suction and discharge fan.

(b) Entry of water through the roll-neck seal is detected by a moisture meter to optimize seal replacement timing.

(c) During rolling operation, lubricating oil in the

Table 6 Lubrication system specifications

Equipment	Unit	Specifications
Tank	2	Capacity : 58 000 *l* Material : Stainless steel
Sub tank	1 1	Sub tank : 7 000 *l* Pressure tank : 2 700 *l*
Pump	2 2	Main pump : 1 100 *l*/min Sub pump : 230 *l*/min
Filter	4 2	Main filter : Nominal 20 μm Roll neck metal filter: Nominal 6 μm
Centrifuge	1	Capacity : 6 000 *l*/h



① Tank　　⑦ Pressure tank
② Sub tank　　⑧ Filter (B)
③ Pump (A)　　⑨ Filter (C)
④ Pump (B)　　⑩ Block mill
⑤ Filter (A)　　⑪ Moisture meter
⑥ Cooler　　⑫ Centrifuge

Fig. 2 Schematic diagram of lubrication system

tank is constantly processed by a centrifugal purifier.

3.6 Outline of Electrical Equipment and Process Control

Numerous new process control systems have been introduced to realize a high-efficiency, high quality process which has made possible superhigh-speed rolling in the wire-rod block mill line.[5] As fundamental principles for electrical equipment, the following major aims were set up:

(1) Construction of a high-performance, high-reliability automated operation system most suitable to superhigh-speed rolling.
(2) Construction of a highly-advanced process monitoring system aimed at high productivity and stabilized operation.
(3) Introduction of highly-developed process control taking into consideration high-quality product manufacture, and establishment of unique techniques.
(4) Introduction of a high-efficiency equipment control system taking into consideration saving on energy and labor.
(5) Implementation of a control system suitable for model preparation and quantification of wire-rod rolling.
(6) Upgrading of the level of process control, and system construction oriented towards expandability and flexibility to cope with future changes.

3.6.1 Features of electrical control system

Main features of the entire electrical control system are described below.

(1) The electrical control system is a high-performance, automatic system formed by an organic linkage of process computers, microcontrollers, and programmable display units.
(2) It is a full-scale, one-man-type operation console system equipped with programmable display units and compact console.
(3) For driving the block mill, a full-digital thyristor motor of the world's largest capacity (6 000 kW) is used.
(4) Mechanical and electrical control systems based on a tracking system for the entire process and a consolidated simulation system incorporating process computers have been introduced.
(5) A new facility-operation monitoring system has been introduced; this system takes into consideration the operation and maintenance of the entire process.

3.6.2 DDC microcontroller control system

The configuration of the DDC control system of the wirerod bulk mill line is shown in **Fig. 3**. In this control system, a single-loop network connection is formed through multiplex transfer lines by using process computers, DDC controllers, programmable display units and remote I/O units. As one feature of this system, process information and control information are both accessible through transmission channels, which greatly contributes to its highly-advanced system network architecture in fully-automatic control and process monitoring, etc.

A DDC control system is also used in the conditioning line with the same concept as in the bulk mill line.

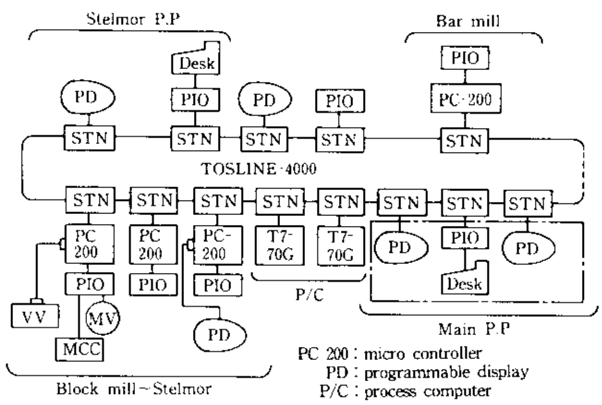


Fig. 3 Block diagram of total control system for rod mill

3.6.3 Operation and monitoring system

As a new technique in the operation and monitoring system of the rolled wire-rod bulk mill line, an opera-

Photo 3 Operation desk

tion console system has been adopted for the first time in the rolling mill. This system comprises programmable display units, a keyboard, and a simulation tracking panel; through its use, a full-scale one-man operation and monitoring system has been realized. The main operation desk of the system employing programmable display units is shown in **Photo 3**. As shown in the general block diagram of the total system given in Fig. 3, all drive systems, sensors, controllers, and the control desk are organically connected, and permit access to a great amount of information, unprecedented with conventional control desks, including not only basic information such as speed and current, but also operations of the respective facilities, sensor operations, interlock display, material flow display, and operation display for various control functions. This unit significantly contributes to labor savings in operation, monitoring, and maintenace.

Main features of the system are given below.

(1) The control desk itself is compact in size and suitable for one-man control; this has been made possible by use of numerous ingenious devices for operation control and monitoring.
(2) Operation guidance is quantified and provides full-range coverage.
(3) The configuration permits consolidated simulation incorporating mechanical and electrical control systems on the basis of the status of mechanical operation and material tracking, and makes possible easy judgment of system operation results.
(4) Not only the operational condition of the line, but also electrical facility monitoring information covering the electric control and power source systems and sensor problems, are displayed, thereby making it possible to operate and monitor the total process.

3.6.4 Main equipment drive system

The entire facility was designed with main aims of energy savings, high performance, and high reliability through use of AC equipment and digitization. In the following, the main motor drive system for the block mill line is reviewed.

The rated capacity of this motor is 6 000 kW-800/1 400 rpm, the world's highest capacity for a full-digitally-controlled thyristor motor for rolling equipment. At high speed wire-rod mills in the past, a plural DC motors connected in tandem, i.e., a 2- or 3-motor system, were used, but in the new facility, only a single thyristor motor satisfies power requirements. As a result, this single unit thyristor motor has achieved the following in comparison with conventionally used plural DC motors:

(1) A 50% reduction in the total motor length.
(2) An efficiency increase in 2% or above.
(3) A 50% saving in erection and wiring time and construction cost.

The motor control unit consists of two control boards. The control performance of the full-digitally-controlled thyristor motor is described below.

(1) Speed Setting Accuracy
A speed setting accuracy of 0.01% has been achieved, impossible with conventional analog-type control units. This accuracy of 0.01% has been realized by the use of a resolver-type speed detector with a resolution of 0.0025% and a full-digital control unit.
(2) Speed Responsiveness
In conventional DC motor systems, the total length of the motor was great, and response frequencies of the mechanical system approximated one another. Thus stabilized operation was difficult at $\omega_c = 10 \sim 12$ rad/s or above. Adoption of the thyristor motor, however, has raised the resonance frequency of the mechanical system, and the use of a digital filtering for control purposes makes possible $\omega_c = 30$ rad/s.

Through improvement in the performance of speed setting accuracy and speed responsiveness in the wire rod rolling stage, it has been possible to significantly improve various control functions affecting product quality which were conventionally performed by wire-rod rolling equipment in the past. Thus the thyristor motor control system has become essential as a block mill drive system for high speed production of high-quality wire-rods.

3.6.4 Process control

Process control in the wire-rod rolling line includes techniques for improving trackability, ring patterns, and quality/dimensional accuracy. Taking into considera-

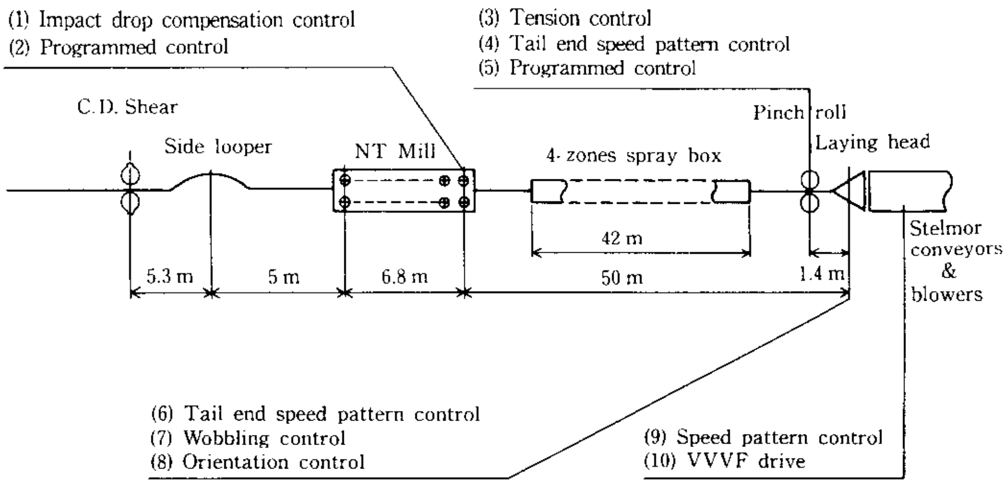


Fig. 4 Principal control of functions for rod mill

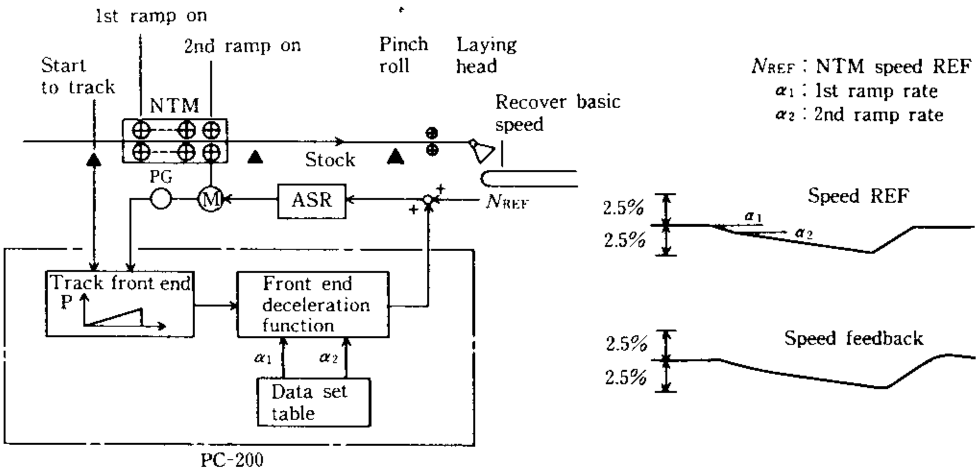


Fig. 5 Block diagram of programmed control at NTM and actual chart of speed feedback

tion achievement of the world-highest levels in speed and efficiency, efforts have been made to perfect the control mode and enhance performance. Major process control systems which have been introduced into the present block mill are shown in **Fig. 4**, with their control functions outlined below.

(1) Block Mill Programmed Control

A block diagram of this control is shown in **Fig. 5**. Trackability of the front end of the wire-rod which is to be rolled in the block mill and over the distance between the outlet side and the laying head becomes difficult in highspeed rolling.

To improve trackability, the programmed control system has the function of changing the block mill speed in a discretionary pattern, allowing the front end of the wire-rod to be given the reverse tension most suitable to threading. Through a combination of this programmed control and impact drop compensation control, trackability of the wire-rod in the block mill and in the water-cooling zone on the outlet side has been significantly improved.

(2) Pinch Roll Total Length Tension Control

A block diagram of this technology is shown in **Fig. 6**. In the past, speed control from the block mill to the pinch roll was effected by dropping control of pinch rolls. To obtain high-speed rolling of 100 m/s or above in the new block mill, measures include stabilization of the ring pattern, improvement in dimensional accuracy, and the pinch roll total length tension control system which is aimed at preventing miss-rolling.

In the control system, the set tension value is compared with a detected tension value, which has been calculated from the total load current of the pinch roll, thereby permitting stable, high-response control of the tension value applied to the wire-rod. Pinch roll total length tension control is very effective in the operation of the super high-speed

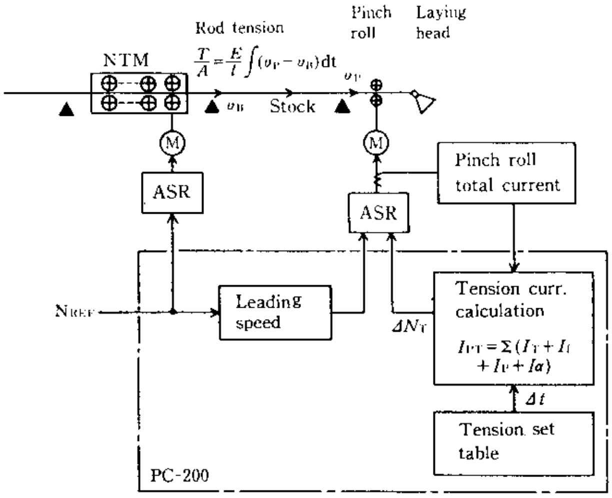


Fig. 6 Block diagram of tension control for pinch roll

block mill, and can be expected to be an indispensable control method in wire-rod block mills where increasingly high operational speeds are foreseen.

(3) Laying-Head Front and Tail End Drop Position Control

When the front or tail end of the rolled wire-rod is discharged in ring shape onto the Stelmor conveyor by the laying head, the laying head position is controlled by this method so that the front or tail end can be dropped at any desired position on the conveyor, thereby preventing problems of coil-threading obstruction occurring when the coil hits the conveyor or is caught by the conveyor.

This control uses, as bases, high-accuracy tracking signals of the wire rod tail end position and of the laying-head discharge position, and changes rotational frequency of the laying head so that the front or tail end of the wire-rod can reach the targeted laying-head discharge point, and so the control accuracy dencreases with increasing rolling speed. Through the adoption of the DDC microcontroller and full-digital drive control system as well as ingenuity in software such as equi-distance computation methods, however, it has now become possible to attain an accuracy of $\pm 20\%$ for the front or tail end drop position under conditions of 5.5 mmϕ and 100 m/s.

Beside the above, the following control modes have been used: block mill impact drop comspensation control, pinch roll front and tail end acceleration/deceleration control, pinch roll and laying head programmed control, laying-head front and tail end acceleration/deceleration control, laying-head wobbling control, Stelmor conveyor acceleration/deceleration control, and high-accuracy Stelmor blower control. All these control modes have achieved originally intended functions to cope with users' demands for improved quality and small-quiantity, multi-kind production. These demands will become stricter in the future, and the diverse functions and high performance of this control mode will demonstrate their capacities to an even fuller extent.

4 Operating Condition

The new "bar and wire-rod" mill started operation as a multi-size rolling mill unprecedented in the world for a one-stand mill in which the functions of two mills, i.e., a wire-rod mill and a bar mill, and the production of three types of products have been integrated. With both the wire-rod mill and bar mill in simultaneously operation, the block mill line commenced operation in September 1984 under a system of two shifts at the old wire-rod mill, as before, and two shifts at the new wire-rod and bar mill. In November 1984, the two shifts were upgraded to three. In February 1985, the wire and rod mill was shut down, thereby completing integration. During this time, key-person operators who had participated in the plan from the initial construction stage became the nuclei of the trial operation and operator training program, thereby realizing smooth set-up operation.

The set-up condition as well as the changes in production and rolling efficiency during the period from September 1984 to August 1985 are shown in **Fig. 7**.

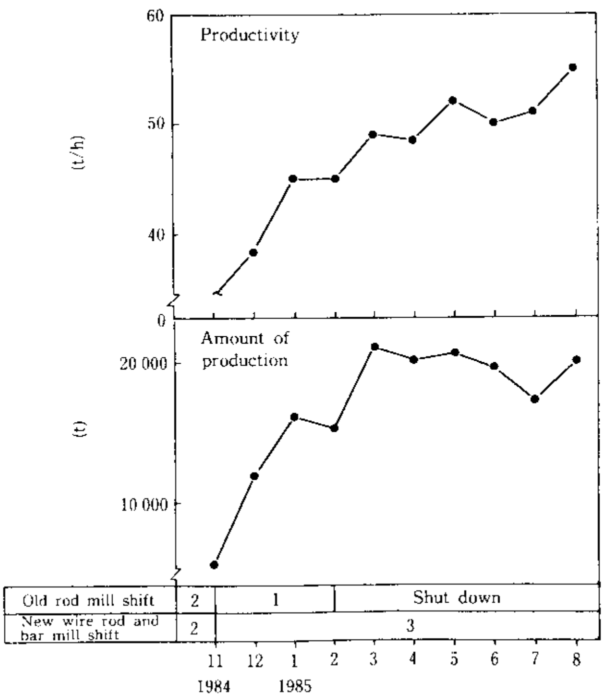


Fig. 7 Production transition

4.1 Problems during Setting-up Period

In the initial period of operation of the new block mill, problems due to high-speed rolling, an unknown at the time, were experienced together with the usual break-in period problems of new facilities. In the following, problems which arose and countermeasures taken are described:

(1) Chain-reaction problems occurred during high-speed rolling of 5.5-mmϕ wire rods, including faulty ring pattern, tub storage problems, coil stagnation on the Stelmor conveyor, and catching of transported coil. These troubles were overcome by stabilization of the ring pattern, achieved through pinch-roll pressure control, adjustment of tension control, and improvement in working accuracy of the laying pipe.

(2) For software, a timing control of 1/100 sec was required. Many problems became apparent as continuous rolling operations were performed, but were quickly corrected and stabilized by debugging and adjustments instituted as necessary.

(3) As sensors, which constitute the basis of automatic operation, non-contact sensors were extensively used in the block mill line. As a result, problems due to vibration were solved, but when production increased, heat-related problems occurred with the coil collecting device. Extensive changes in fitting methods and measures for coping with conditions in the operating environment were taken until stability was restored.

4.2 Operation Records

After one year of operation since start-up, the block mill line has attained the results originally set as targets.

(1) The monthly average rolling speed for 5.5-mmϕ wire rods reached a super-high-speed of 100 m/s, the highest in the world, in six months after start-up. Changes in monthly average rolling speed for 5.5-mmϕ wire rods are shown in **Fig. 8**.

(2) Rolling efficiency per working hour of 75 t/h has been achieved for sizes of 8-mmϕ and above, which corresponds to the capacity of conventional mills of four strands.

(3) High-quality and stabilized operation have been ensured by achieving a dimensional accuracy of ± 0.2 mm and assurance of total-length temperature control.

(4) Actual records of yield and unit fuel consumption are slightly short of original targets, but improvement on these points is continuing as operation is stabilized; the prospect of achieving these targets is good.

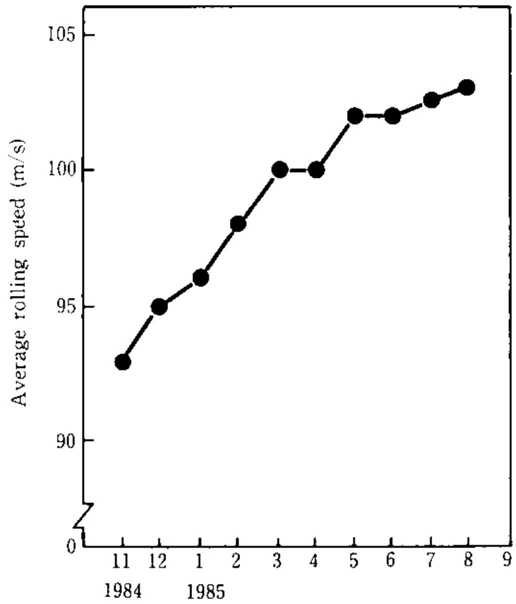


Fig. 8 Average rolling speed with 5.5 mmϕ

(5) One of the indexes showing the maintenance level is seizure problems with roll neck metal at the block mill, but no instance has occurred since commencement of operation, thereby indicating satisfactory operational condition.

5 Concluding Remark

One year has passed since the new rod and bar mill started operation as the world's first 1-strand wire rod/bar steel combined-type mill. Operation condition has been fairly smooth, although difficulties in high speed rolling and high-efficiency operation have been encountered. A system of cooperation among parties concerned has led to rapid solution of problems as they occurred, and operation as planned originally has been achieved. In the future, the authors will endeavor to upgrade the levels of facilities, systems, and operation, thereby establishing a solid system for stabilized operation.

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