Steel Industry Systems with Integrated Mechanical and Electrical Control for High-quality Production and Energy Efficiency

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OVERVIEW: The construction of new rolling equipment continues in emerging economies such as India as well as in China and South Korea. In meeting this demand, Hitachi together with Mitsubishi-Hitachi Metals Machinery, Inc., a manufacturer of rolling equipment, has supplied numerous large-scale steel industry systems that integrate machinery and electrical control to achieve high quality and highly efficient rolling in hot rolling, cold rolling, and processing line equipment. For upgrades in the Japanese steel industry aimed at improving productivity and becoming more energy efficient, the products commercialized by Hitachi include electrical control systems such as highly efficient electric motors and drives, user-friendly interfaces, and optimized control as well as energy management systems that monitor the operating status of the equipment and overall plant energy consumption to support the implementation of systems that take account of energy efficiency.

INTRODUCTION

A steady stream of new rolling equipment has been constructed around the world since the start of the 21st century driven by strong growth in the market for steel products against a background of economic growth, infrastructure development, and other factors, particularly in East Asia and other emerging economies. As a result, global raw steel production in recent years has been approximately 1.4 times what it was in 2000. On the other hand, the steel industry is notable for its heavy energy consumption and although it has undertaken a range of measures in the past to make improvements in areas like energy efficiency and product yield, the demand for further such improvements continues to strengthen in response to factors such as concern for the global environment

(a) Finishing rolling mill

(b) Control room (left) and example operation screen (right)

(c) 9,300-kW variable-speed alternating-current induction motors used to drive the finishing rolling mill

Fig. 1—Hot Rolling Equipment Supplied to Dongbu Steel Co., Ltd. in South Korea.
Operation of the finishing rolling mill (a), main control room (b), and main motors (c) at Dongbu Steel Co., Ltd. in South Korea are shown. The plant aims to achieve highly efficient rolling and high-quality production through the integration of mechanical and electrical control.

and rising raw material prices in recent years.

In addition to improvements to the quality of steel strip and reliability of operation, Hitachi is also developing rolling equipment and control technologies that can deliver benefits such as energy savings and higher rolling efficiency and supplying these to customers in Japan and overseas.

This article describes how Hitachi is integrating mechanical and electrical control to improve the efficiency of rolling equipment and achieve greater energy efficiency while expanding the scope of its activities globally.

FEATURES AND TRENDS IN STEEL INDUSTRY SYSTEMS

Steel industry systems which include rolling mills and their associated equipment, electric motors and their drivers, PLCs (programmable logic controllers), and process computers are not only very large, they also need to perform high-precision realtime control of production quality values such as strip thickness, width, and temperature. For this reason, rolling mill drives, motors, drive equipment, and other components all feature quick-response performance and the PLCs, process computers, and other systems used to control these utilize the latest computing technology available at the time[(1)].

In the field of steel industry systems, Hitachi has taken note of the demand for things like energy efficiency and efficiency improvement since the 1990s[(2)] and its developments have included rolling equipment designed for operating practices such as non-stop rolling and schedule-free rolling, equipment for achieving continuous operation, and large motors, drives and similar equipment designed for energy efficiency. In addition to seeking to improve quality, yield, and other product parameters in a controlled manner, Hitachi has also released onto the market products such as PLCs and process computers that are capable of performing the complex calculations required to achieve these objectives in realtime.

To achieve the even more efficient rolling indicated by market requirements in recent years it is necessary to investigate ways of integrating mechanical and electrical control such as using a computer to perform detailed simulations of the operation of mechanical equipment. To this end, the steel industry equipment divisions of Mitsubishi Heavy Industries, Ltd. and Hitachi, Ltd. were merged to form Mitsubishi-Hitachi Metals Machinery, Inc. (MHMM) in 2000 and since then the companies have worked together on system development for hot rolling equipment, cold rolling equipment, and other similar plant. One example of this collaboration is the hot rolling equipment installed at Dongbu Steel Co., Ltd. in South Korea in 2009 which was the first time that Hitachi has been involved in the construction of a new tandem hot rolling system outside Japan (see Fig. 1).

ACHIEVING HIGH-QUALITY ROLLING THROUGH INTEGRATION OF MECHANICAL AND ELECTRICAL CONTROL

Hot Rolling Equipment

Hot rolling requires the continuous monitoring of strip parameters such as thickness, width, and temperature to perform detailed and high precision control of the roll speed, rolling force, strip tension, crown (difference in thickness between the center and edges of the strip), and other factors. To achieve these objectives, the pair cross mill is used which has the optimum mechanical configuration in which the work rolls are crossed to provide a high level of crown correction.

On the other hand, a key point for the control of hot rolling equipment is the accurate prediction of the strip condition based on the limited information available from a small number of sensors. Important factors in achieving this are the use of simulation techniques and techniques for improving the accuracy of prediction models. Hitachi has worked with MHMM to develop a rolling and cooling simulator that combines control simulation with knowledge of the characteristics of the hot rolling equipment, physical phenomena, and other

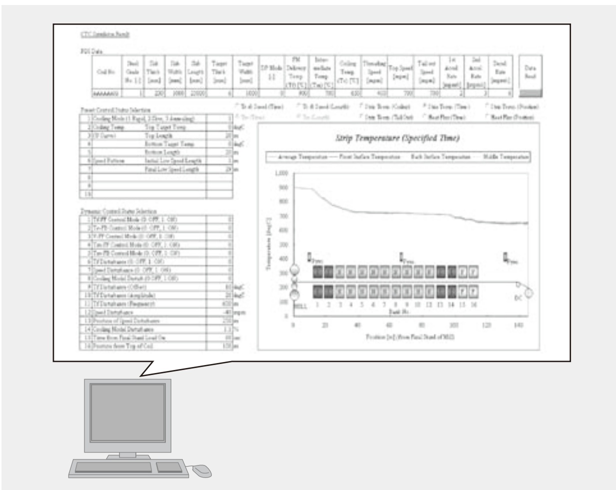


Fig. 2—Example Screen for Coiling Temperature Simulation.
Hitachi collaborated with Mitsubishi-Hitachi Metals Machinery, Inc. on the development of a rolling and cooling simulator.

factors (see Fig. 2). This simulator is used to undertake comprehensive pre-engineering of control methods and achieve highly precise control. In addition, learning control techniques are also used on the state prediction models for the rolling equipment, strip, and other parameters used in the control calculations to adapt the models automatically to match the actual rolling results.

Cold Rolling Equipment

Hitachi has had a high share of the international market for PL-TCMs (pickling line—tandem cold mills). PL-TCMs use continuous operation to achieve high efficiency, high quality, and highly reliable rolling, and Hitachi has delivered more than 15 new PL-TCMs since 2000 in collaboration with MHMM.

Another type of cold rolling equipment that can perform rolling with high efficiency is the HZ mill. The HZ mill has a 20-high configuration with separate housings and was developed for use with high-hardness materials such as magnetic steel strip and stainless steel strip which are in strong demand for use in social infrastructure (see Fig. 3). The use of separate housings improves ease of operation because it allows a large gap to be opened between the work rolls and the problem of poor mechanical rigidity that affects mills with separate housings has been minimized by optimizing the design to achieve a level of rigidity similar to monoblock designs. Also, the quick-response hydraulic roll gap system and the Double As-U (roll bending control) mechanism that has a wide shape control range are operated by a highly accurate strip thickness control system and neuro-fuzzy shape control system respectively to achieve improved quality and stable rolling operation. Demand for HZ mills has grown along with demand for magnetic steel strip, and when mills currently being built are counted, the number of plants to which HZ mills have been supplied has now reached 13.

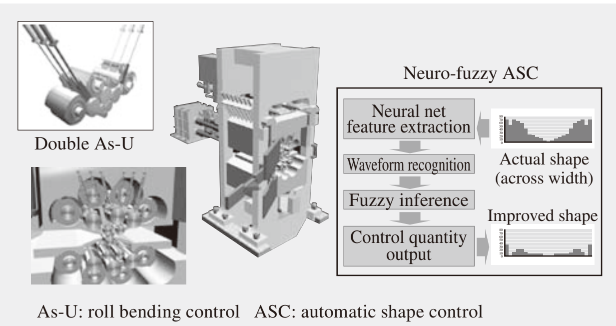


Fig. 3—Outline Diagram of HZ Mill and Concept of Neuro-fuzzy Shape Control.
High-added-value products are rolled using highly efficient equipment with improved operating characteristics.

PURSUIT OF ENERGY EFFICIENCY AND HIGHLY EFFICIENT ROLLING

A range of different initiatives are being tried in the steel industry to improve energy efficiency in various parts of the process for producing steel strip. To contribute to meeting this demand, Hitachi is working on the development of techniques for improving the energy efficiency of electrical equipment and the efficiency of production, and also on the development of energy-efficiency solution systems.

Introduction of Energy-efficient Equipment

The progressive upgrading of the main drives used to drive the rolling mills and down-coiler from DC (direct current) motors to energy-efficient AC (alternating current) motors continues. Also, high-capacity IGBT (insulated gate bipolar transistor) inverter drives are used to control the motors to achieve performance improvements and greater energy efficiency. One example is the 2009 replacement of the 5,000-kW DC motor and drive used in a roughing mill in the hot strip mill at the East Japan Works - Keihin Area of JFE Steel Corporation with an 8,000-kW variable-speed AC induction motor with a speed of 35/70 rpm, 225% (1 minute) overload rating, and one of the highest torques of any such motor in the world. Another is the planned upgrade of the motor drive for the No. 1 roughing rolling equipment at the Yawata Works hot strip mill of Nippon Steel Corporation that is scheduled for 2011.

High-voltage IGBT drives have also been used in the exhaust gas system of a steel plant where adding the variable-speed capability improves the system's energy efficiency. Energy consumption is also being reduced by using highly efficient motors with losses that are 20 to 30% lower than previous Hitachi models to drive equipment such as pumps, fans, and conveyors that are used in large numbers at steel plants combined with energy-efficient operation based on the use of inverters such as control of the number of operating units (see Fig. 4).

Technologies for Highly Efficient Rolling

The study of technologies for highly efficient production aimed at improving product yield or saving on fuel and other resources has been ongoing for a long time and many different approaches have been taken

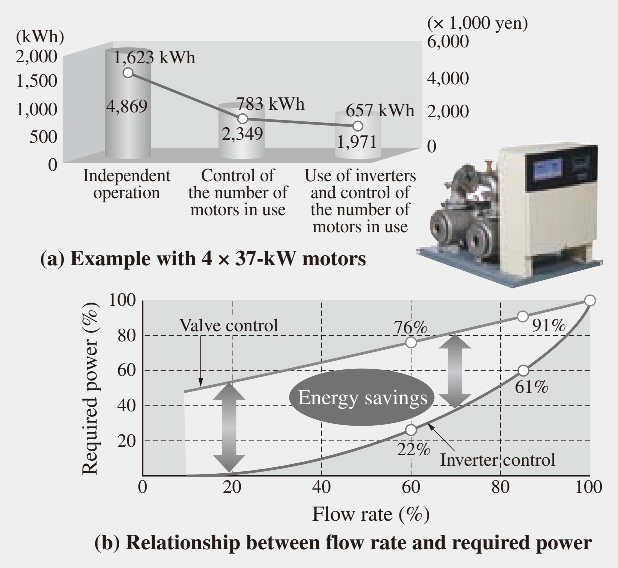


Fig. 4—Example Energy Savings Achieved Using Inverters and by Controlling the Number of Motors in Use.
Comprehensive energy savings are achieved through measures such as saving energy by controlling the number of air compressors in use (a) and the use of inverters for energy-efficient control of pumps (b).

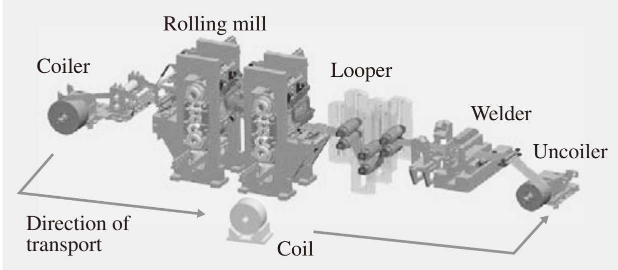


Fig. 5—Diagram of Continuous Rolling Equipment in which Coils are Transported back from Mill Exit to Mill Entry for Each Pass.
This method uses continuous operation to improve the accuracy of rolling control and thereby increase strip yield. The size of the looper unit can also be made significantly smaller by reducing the rolling speed at the welding point.

aimed at achieving these objectives.

Based on the macro-level concept that improving the yield of the cold rolling process avoids wasting the large quantities of energy used in processes upstream of cold rolling, MHMM has also developed cold rolling equipment that converts existing reversing rolling equipment into continuous rolling equipment in which coils are transported back from the mill exit to the mill entry for each pass. This not only increases production volume, it also reduces the weight proportion of off-gage material from about 3% on batch-oriented reversing rolling equipment to 1% or less. This equipment allows for a flexible system that can be adapted to the required production volume by increasing or decreasing the number of stands. It also allows a simple system configuration to be used by rolling at very low speed and high precision in the vicinity of the coil welding point which means the loopers used to buffer the coil during welding can be shrunk. Hitachi also participated in this project on a joint research basis and developed control techniques for ultra-low-speed rolling and a roll open and close technique for avoiding the welding point when necessary during rolling (see Fig. 5).

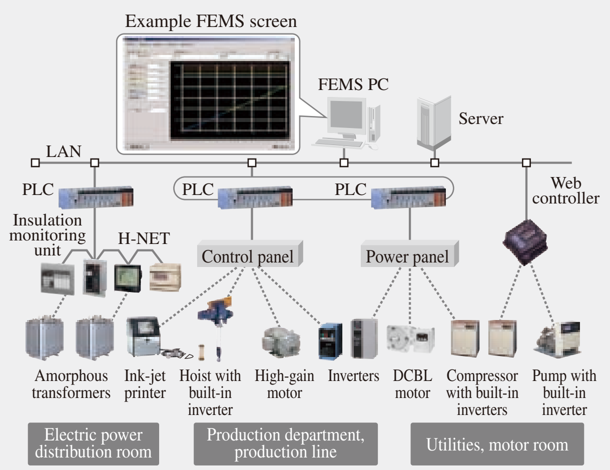
Meanwhile, a range of initiatives have been tried in different production processes aimed at using control technologies to improve production efficiency including minimum-fuel combustion control in the furnace to raise the steel to a uniform strip temperature with minimum use of fuel, rolling control to improve yield by improving the accuracy of the strip thickness, width and other parameters when rolling the head and tail ends of the strip, and coating weight control that improves the specific coating usage by applying coating to the strip uniformly. Hitachi is continuing to develop technology to satisfy the even more severe requirements of recent years which include not only reducing the cost of production but also minimizing CO_2 (carbon dioxide) emissions and other impacts on the environment.

Energy-efficiency Solution Systems

In addition to energy management techniques like those used in the past that focus on the electric power supply system, reducing energy use at a plant also requires the measurement and optimization of the operating status of individual equipment and energy usage by the overall plant. This requires a system that can perform integrated energy management of the plant. The FEMS (factory energy management system) described here not only uses the latest computer and network technology to monitor and collect plant energy use and production data in realtime in order to make energy usage visible, it also supports the construction of systems for saving energy based on the management data (see Fig. 6).

GLOBAL MARKETING OF STEEL INDUSTRY SYSTEMS

In recent years, exports, primarily to East Asia, have made up more than 60% of sales of Hitachi's products for the steel industry and Hitachi has accelerated the globalization of this business ahead



FEMS: factory energy management system PC: personal computer
LAN: local area network PLC: programmable logic controller
H-NET: monitoring system for electric power distribution and utilities
DCBL: direct current brushless

Fig. 6—Energy Management System that Supports Energy-efficiency Solutions.
This system supports the implementation of systems for improving energy efficiency by measuring the operating status of individual equipment and energy usage by the overall plant.

of its other areas of activity. As part of this, Hitachi has set up sales and production sites particularly in areas where demand has grown and is establishing an organizational structure that allows activities such as sales, manufacturing, coordination of locally supplied products, and maintenance to be handled smoothly by a local presence.

In China in April 2006, Hitachi set up Shanghai Baoli Automation & Engineering Co., Ltd., a joint-venture company with Shanghai Baosight Software Co., Ltd., a subsidiary of Shanghai Baosteel Group Corporation, to undertake design, production, sales, and post-sales service of control systems for steel plants with a particular focus on cold rolling and processing line equipment. Through this company, Hitachi aims to achieve benefits including improving cost competitiveness and expanding sales of steel plant control systems in China while increasing the proportion of domestic content in its products in China. Hitachi is also preparing for further market growth by establishing sites in South East Asia, India, and Brazil and stationing sales, engineering, and other staff in these regions.

CONCLUSIONS

This article has described how Hitachi is integrating mechanical and electrical control to improve the efficiency of rolling equipment and achieve greater energy efficiency while expanding the scope of its activities globally.

Calls to reduce greenhouse gases to help achieve a sustainable society will grow ever stronger around the world in the future. In responding to these calls, Hitachi intends to achieve the total optimization of steel industry systems in collaboration with Mitsubishi-Hitachi Metals Machinery, Inc. while also improving the efficiency of specific items of electric equipment and working toward greater efficiency in rolling through the use of control technologies.

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