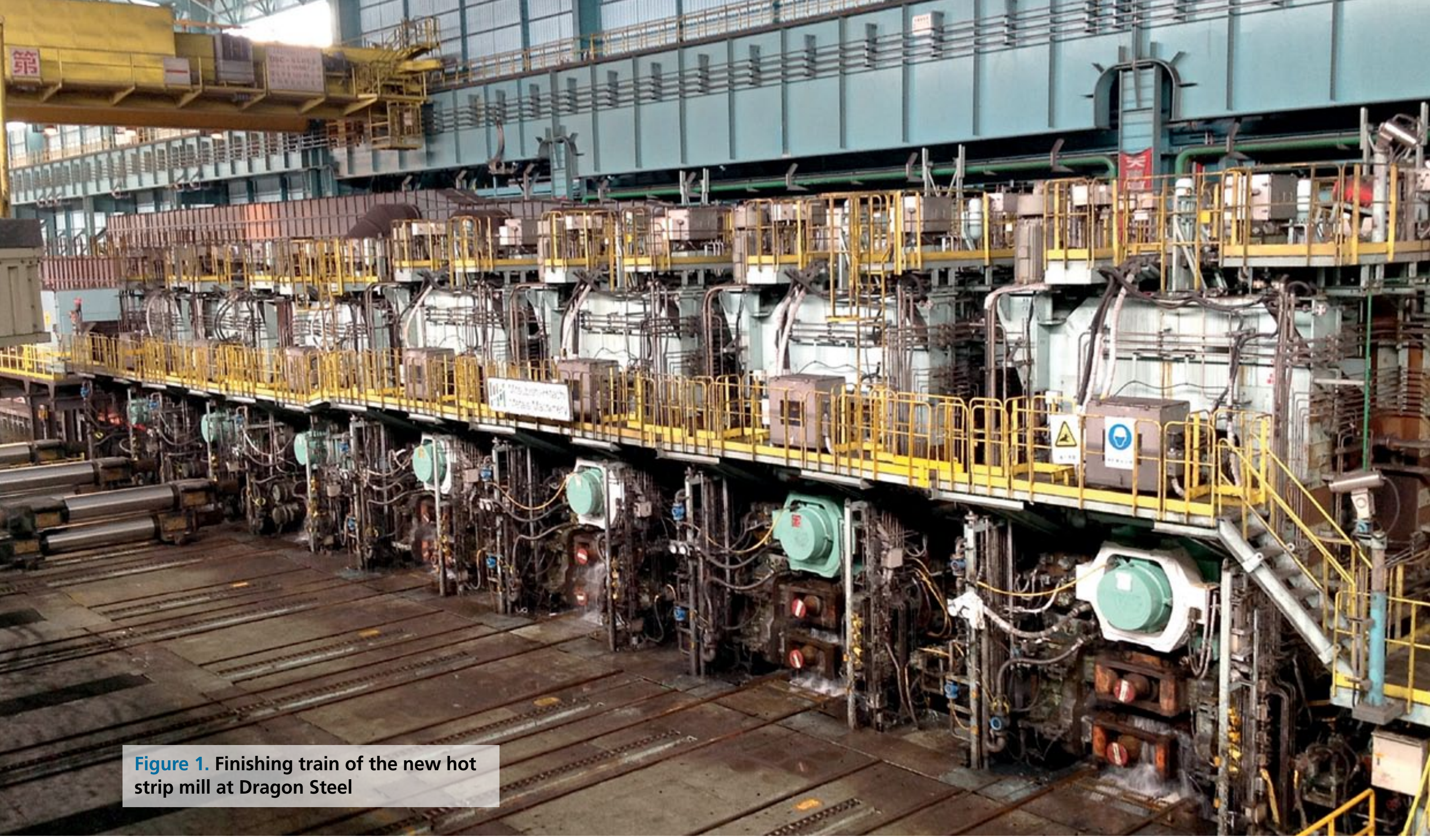

Figure 1. **Finishing train of the new hot strip mill at Dragon Steel**

Internet-PDF from „Metallurgical Plant and Technology“ 01 / 2013, pages 52 – 55

Advanced automation system for Dragon Steel's new hot strip mill

Dragon Steel Corporation, a subsidiary of China Steel Corporation, commissioned a new hot strip mill at their greenfield steel facility in Taichung, Taiwan. The new mill is capable to produce about 3 million t/year of a broad variety of high quality steel strip, including low carbon, API, IF, HSLA, BH, electric, and stainless grades.

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TMEIC®, formed from the merger of the industrial systems divisions of Toshiba and Mitsubishi-Electric, provided the drive equipment and automation system for the new hot strip mill at Dragon Steel, Taichung, Taiwan. For this very large system integration project, TMEIC responsibilities included writing the custom control and supervisory software, conducting the factory system test, supervising installation of the motors, drives and controls, and performing system commissioning. TMEIC also provided customer training and plant service support.

Hot strip mill layout

This new hot rolling mill **(figure 1)** was designed to produce strip up to 1,880 mm wide with a final thickness down to 1.2 mm. The plant comprises a two-stand reversing roughing mill with vertical edgers and a seven-stand finishing train with two downcoilers **(figure 2)**. Slabs are provided by three reheating furnaces. The main data of the mill are summarized at **table 1**.

The large 10 MW (13,400 hp) synchronous motors on the finishing mill are controlled by powerful variable frequency drives, used to start the motors and vary the speed up to a maximum of 620 rpm. The speeds of the seven drives are controlled and coordinated by the master controller so that the desired strip speed is obtained and correct tension is maintained between stands. In the rolling process, precise control of strip tension, speed, gap, roll force, and temperature is required to produce the strip.

To ensure a perfectly shaped (flat) product, the work rolls are bent and moved horizontally by electro-hydraulic actuators, as directed by the controllers.

Strip width	max. 1,880 mm
Final strip thickness	1.2 – 25.4 mm
Max. exit speed	20 m/s
Overall length of the mill	443 m

Table 1. **Main technical data of the plant**

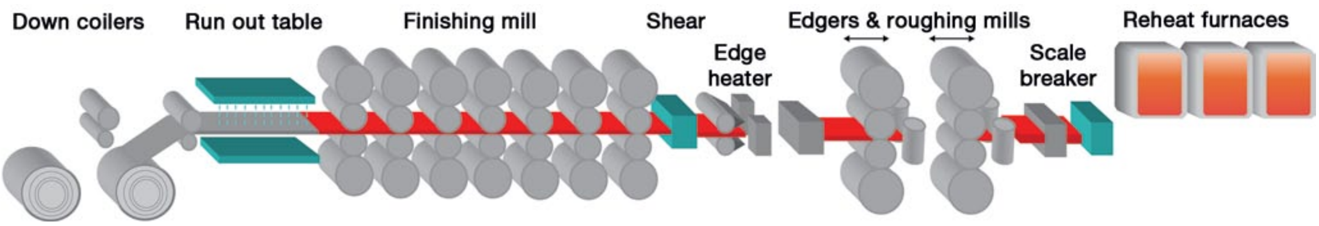

Figure 2. **Diagram of the mill, metal slabs enter at right, coils are delivered at left**

Accurate X-ray gages located at the finishing mill exit measure the thickness and profile across the width of the strip.

After exiting the mill onto the run out table, laminar water streams cool the strip at the exact rate to produce the enhanced material strength and elongation properties required. As the strip moves down the table, temperature control is critical. At the end of the table the strip enters the coiler where it is coiled for shipment.

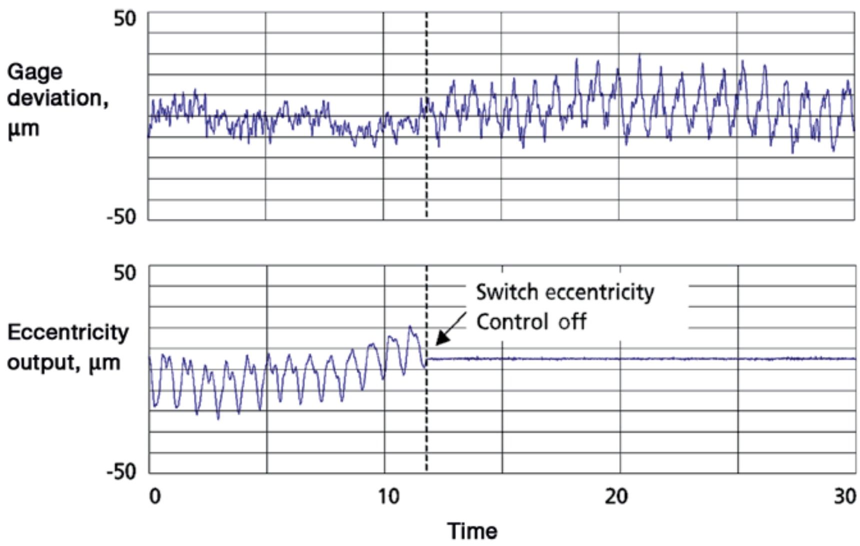

Figure 3. **Results of eccentricity control**

Hot strip mill control system

The control system includes the following important characteristics:

- open architecture,
- scalability and ease of expansion,
- simple control network communication,
- unified Level 1 and Level 2 HMI,
- structured software products and distributed computing,
- global signals and data structures definition,
- tools for process and equipment data analysis,
- ease of system maintenance.

The hierarchical automation system, developed over 50 years of steel rolling mill experience, provides advanced control allowing higher mill speeds and improved product quality. The open control architecture is based on standard controllers, computers, software, and communication interfaces, allowing easy system expansion. The Level 2 supervisory control computer uses physics-based computer process models, which supply references (setpoints) to and are tightly integrated with the Level 1 controllers. The speed of all the motors is coordinated by the controllers, which communicate with the drives over a fiber optic I/O network. To illustrate the size of the automation project, the figures of control I/O units and major components are summarized as following:

- 4,000 digital control inputs and outputs,
- 800 analogue control inputs and outputs,
- 560 variable speed AC motors,
- 18 high-power, medium voltage variable frequency AC drives (up to 13,400 HP each), comprising in total 100 MW power.

Level 1 provides direct control of the process actuators of all kinds: electrical, hydraulic and pneumatic. The drives to control electrical motors are included in this level of control, and the regulating, sequencing and equipment protection functions.

Level 1 control is performed by the Toshiba nv controller™. This is Toshiba's latest industrial controller with unsurpassed execution speed, capable of performing Boolean functions in 20 nanoseconds and word instructions in 100 nanoseconds, allowing superior machine and process control. The nv controller™ is a multitasking controller capable of executing the high priority task, a special programme requiring high-speed, at a 0.5 msec rate. Communication with the I/O modules is over a fault-tolerant fiber optic ring running at the rate of 100 Mb/s, allowing the controller to rapidly access I/O data down to a 0.1 millisecond rate.

Performed by the controllers, Level 1 accepts discrete and continuous signals from the mill sensors, and generates output signals to control motor speed, gap, roll movement, strip tension, and a host of other machine functions. Some of the major functions performed include:

- Automatic gage control (AGC) employs mass flow calculation, thickness measurement, feedforward, feedback, tension, and slip compensation.
- Supplied by the mill builder, the automatic flatness control uses advanced data filtering, parabolic flatness control, tilt control, and shape maintenance.
- Coordinated in-coil adjustments use measured and calculated values to maintain targets.
- High-speed data acquisition and tracking allows faster and more accurate control action.
- Eccentricity control dynamically reduces the effect of backup roll irregularities on thickness using fast Fourier series analysis **(figure 3)**.
- System diagnostic functions built into the engineering tools allow production delays to be quickly resolved.

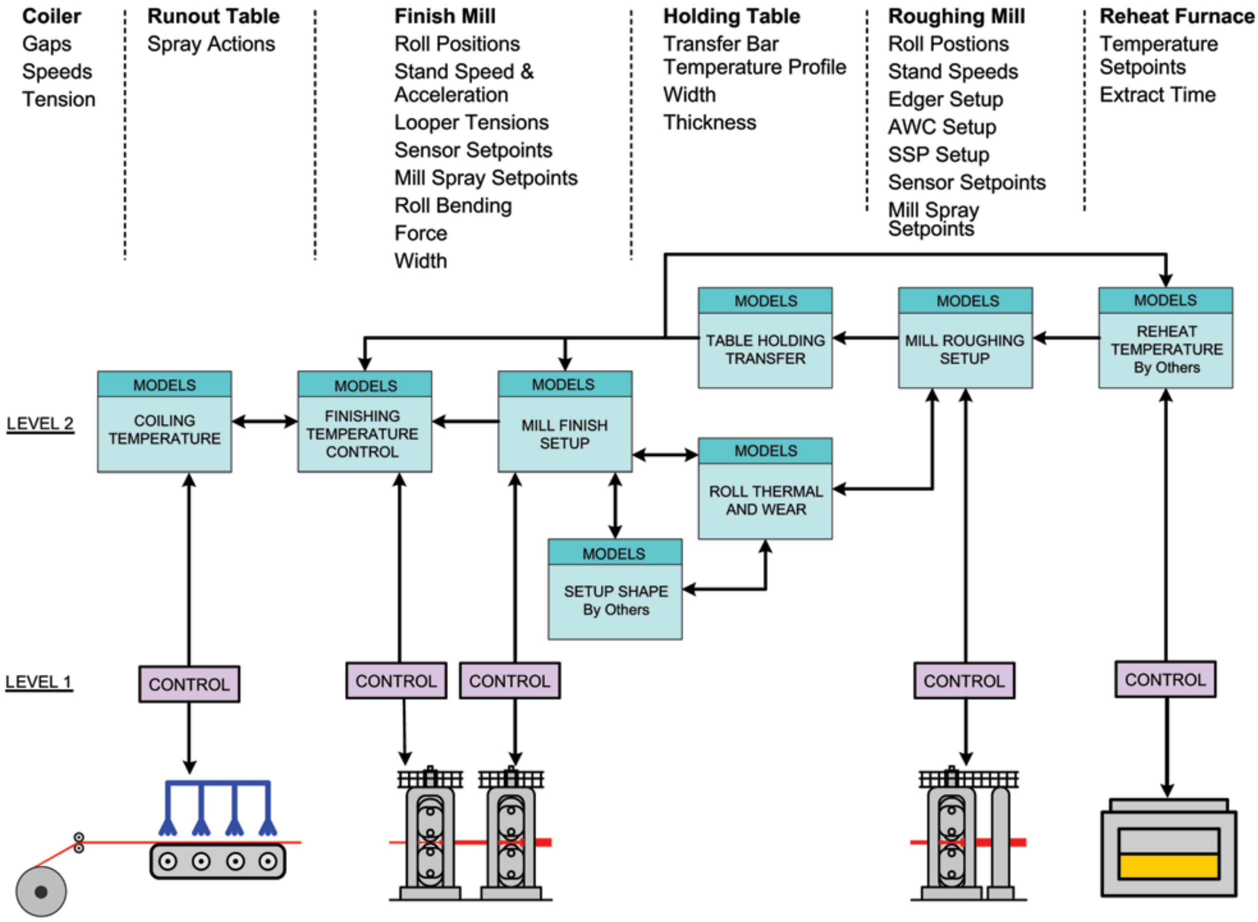

Figure 4. Level 2 models provide setup and references for the Level 1 control

Level 2 sub-system consists of two basic parts: process execution and process data storage. The process algorithms execution (supervisory) computer includes process models and Level 2 support functions (models infrastructure) software. The process data storage computer includes process data bases and necessary communication interface software. This computer, also known as the data server, contains all-important data required for process automation and process analysis, and uses Oracle™.

The databases include primary data input, process models tables, rolls' data, rolling history, and data dictionary. Due to the importance of the data servers, the hardware is based on a high class PC server, which includes cluster configuration with redundant storage, providing a "no single point failure" feature.

The trending and reporting station has the copy of the rolling history database (data transferred on manual request) for the customer's engineers to perform data analysis, statistical correlations, customized reports etc. The purpose of such separate, off-line database is to have multiple connections to this database, which will not affect the on-line performance of the data servers.

The automation system provides superior hot mill control based on Level 2 functions, including data acquisition, mill setup, product tracking, and accurate process models. TMEIC's Level 2 provides the mathematical process models and required software infrastructure for models to function. During mill operation, Level 2 supplies the Level 1 with references and receives process feedbacks for model updates and data collection. Typically, Level 2 does not include in-bar close loop control functions, except for finish temperature control and coiling temperature control models.

The **process models** are adaptive mathematical models based on the fundamental physics of the rolling process, using advanced iterative techniques such as finite element analysis to compute physical effects such as heat transfer and plastic deformation. The models generate the optimum controller setpoints to ensure production of the highest quality product. The roll bite model includes the effects of plastic deformation, roll compression, friction, and elastic release.

Some of the process models are listed below:

- force, torque, and power models with the effects of tension, slip, and friction,
- deformation resistance model with the material chemistry and work hardening effects on elongation,
- friction models with coefficients to compensate for friction variations,
- roll wear model with thermal and wear effects on roll diameter profile,
- product-dependent transfer functions for better thickness, width, and temperature control,
- roll bending and shifting (shape model supplied by the mill builder).

In figure 4, all of TMEIC's Level 2 models are listed at the top; not all of them are used on the Dragon Steel system, also the furnace control and models were not supplied by TMEIC. The models, shown in blue, provide the setup and references for the Level 1 controls shown in purple.

HMI. Providing an interface between the process control and operators,

Figure 5. **Part of the operator's pulpit**

the human machine interface (HMI) replaces traditional operator devices such as switches, pushbuttons, analog meters, etc. The PC-based HMIs process the operator's entries and send data to Level 1 and 2; they also process data from Level 1 and Level 2 and display on the terminals both as text and animated graphics.

This mill employs just one long control pulpit, so a number of video screens are used, allowing the operators to see all sections of the mill **(figure 5)**.

Conclusion

The features of this control and automation system fully meet the criteria of modern control concepts and solutions. Highly configurable software applications and open and simple architecture have brought low cost ownership and maintenance. The application of advanced rolling process modeling and control schemes has resulted in high level performance, thus providing excellent product quality. Finally, the control system has proven to be extremely reliable. As Song-Mo Lai, Dragon's assistant superintendent of the rolling mill department, comments, "Since the mill startup on April 2010, the TMEIC equipment including main motor, PLC, and drives are all running smoothly. We deeply appreciate the high stability and reliability of the TMEIC system, and the good cooperative relationship with the TMEIC project teams from the beginning." ■