New high performance flatness control system for tandem cold mills

The next generation of BFI's automatic flatness control systems has now been implemented and successfully commissioned at the tandem cold mill of Arcelor Eisenhüttenstadt(AEH). The system primarily consists of an internal model controller at the last stand, combined with entry profile feed-forward control and disturbance compensation at each stand. The results show excellent flatness performance for all strip dimensions, materials, and mill speeds.

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BFI and Arcelor Eisenhüttenstadt

Arcelor Eisenhüttenstadt (formerly EKO Stahl) is a modern integrated steel plant with highly engineered plants and technologies. In 2006, BFI delivered, installed, and commissioned an advanced flatness control system for the tandem cold mill of AEH as a part of the new automation system supplied by ABB Process Industries, Mannheim. The performance tests have been successfully conducted and an overview of the features and some performance test results are presented.

Attribute	Value
Strip width	800-1605 mm
Entry strip thickness	1.5-6.0 mm
Target strip thickness	0.4-3.0 mm
Finished coil diameter	1200-2200 mm
Coil weight	Max. 34 t
Maximum rolling force	20,000 kN
Mill capacity	1.4 Mtpa
Maximum speed	1500 m/min

Table 1 Mill design data

MILL CONFIGURATION

The tandem mill is a 4-stand 4-high mill with the design data given in Table 1. AEH has been operating the mill since 1968, and produces quality steels primarily for the automotive industry. Each stand is equipped with negative and positive work roll bending of -200/+400kN per side. A Sundwig BFI shape meter (33x50mm) is installed at the exit of the last stand for flatness measurement. Additionally, tilting and selective spray cooling (at the last stand) can be used for automatic flatness control.

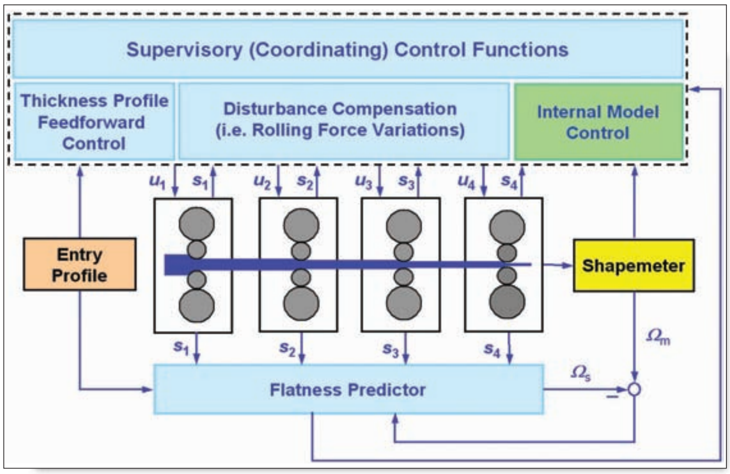


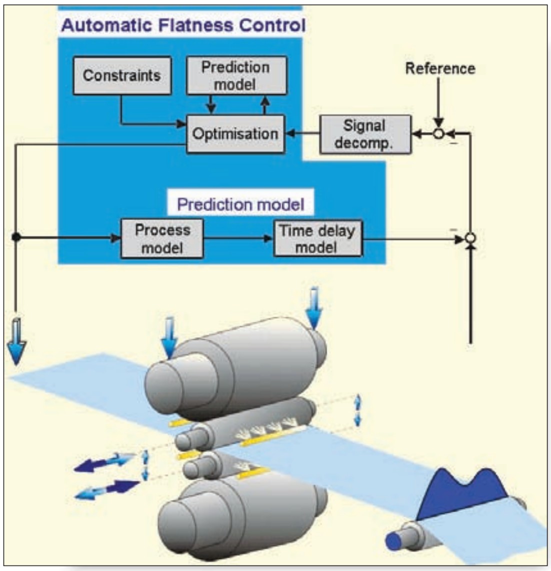
Fig.1 Structure of the flatness control system

PROJECT DESCRIPTION AND CHALLENGES

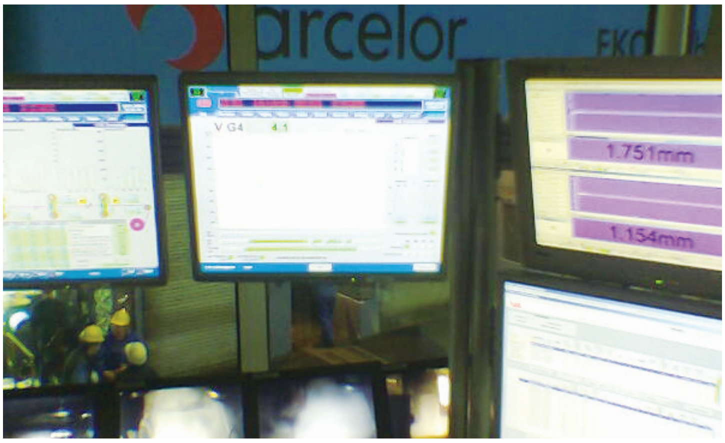
The scope of the BFI part of the project included the installation and commissioning of the flatness control system and the modification of the shape meter electronic unit to integrate measurement pre-processing and establish communication via TCP/IP with the ABB automation system.

The challenges of flatness control on that mill were to:

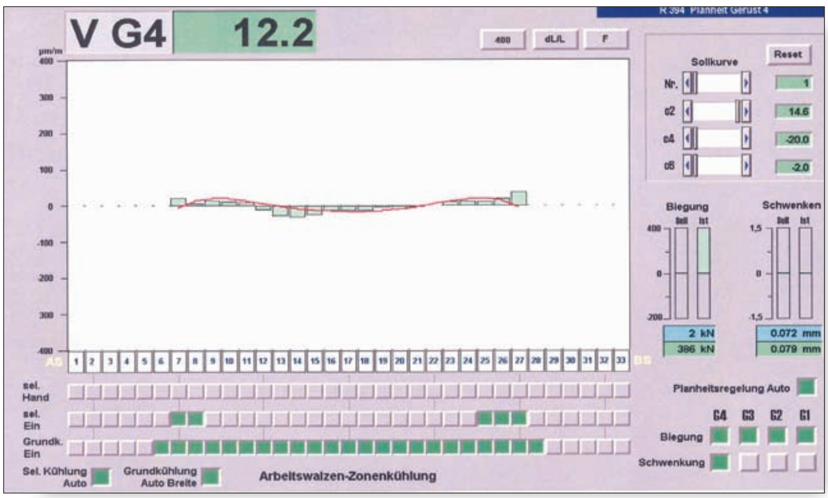
- Ensure consistent flatness performance for the wide product mix (soft to hard alloy steels, construction steels and electro-steel) over the range of strip dimensions
- Compensate for varying time delays due to the distance between roll gap and shapemeter, particularly at low speeds
- Anticipate entry profile and rolling force variations at all stands
- Guarantee tight flatness tolerances over the whole strip length, particularly for the products intended to be galvanised



Ⓐ **Fig.2 Structure of the internal flatness control model**



Ⓐ **Fig.3 Main pulpit control screens**



Ⓐ **Fig.4 Example of screen display**

CONTROL SYSTEM OVERVIEW

The new control system concept mainly consists of the following components *(see Fig. 1)*:

- Anticipation of incoming strip thickness profile deviations at the first stand by bending trims
- Compensation of the rolling force changes at all stands by bending trims
- Internal model control (IMC) at the last stand *(see Fig. 2)*, with schedule-dependent parameters. IMC provides time delay compensation and is very robust against modelling errors. Tuning is straightforward as only one parameter remains to be selected for each actuator control loop, which is very appealing in practice. The IMC is designed based on the measured flatness deviations, on-line pre-processed by Gram polynomial decomposition, thus the actual controlled variables are the polynomial coefficients.
- Flatness predictor for on-line estimation of the interstand flatness and adaptation of the transfer functions of the control system, depending on the actual mill situation
- Supervisory control level for coordinating the local controllers depending on the mill conditions and pre-selected control loops

More details on flatness controller design can be found in earlier publications **[1, 2].**

TARGET PLATFORM AND INTERFACES

The new flatness control system has been implemented on an ABB controller AC800PEC, providing maximum computation power, and is fully integrated into the new automation system, establishing communication to the other process controllers (basic controls, setup system) and to the (InTouch) HMI system via optical links and Ethernet TCP/IP, respectively.

Special attention was paid to the design of the tandem mill's main control pulpit *(see figures 3 and 4)*. Other screens, not shown here, are also provided for calibration of the shape meter and for visualisation of entry thickness profile and of the predicted interstand flatness.

All information required for the operating staff, such as reference and measured flatness, reference and actual actuator states and values, is displayed on the monitor. The operator can individually activate/disable single control loops and enter/change the reference curves for the flatness control at the control desk. Important data for quality management are sent to an IBA system.

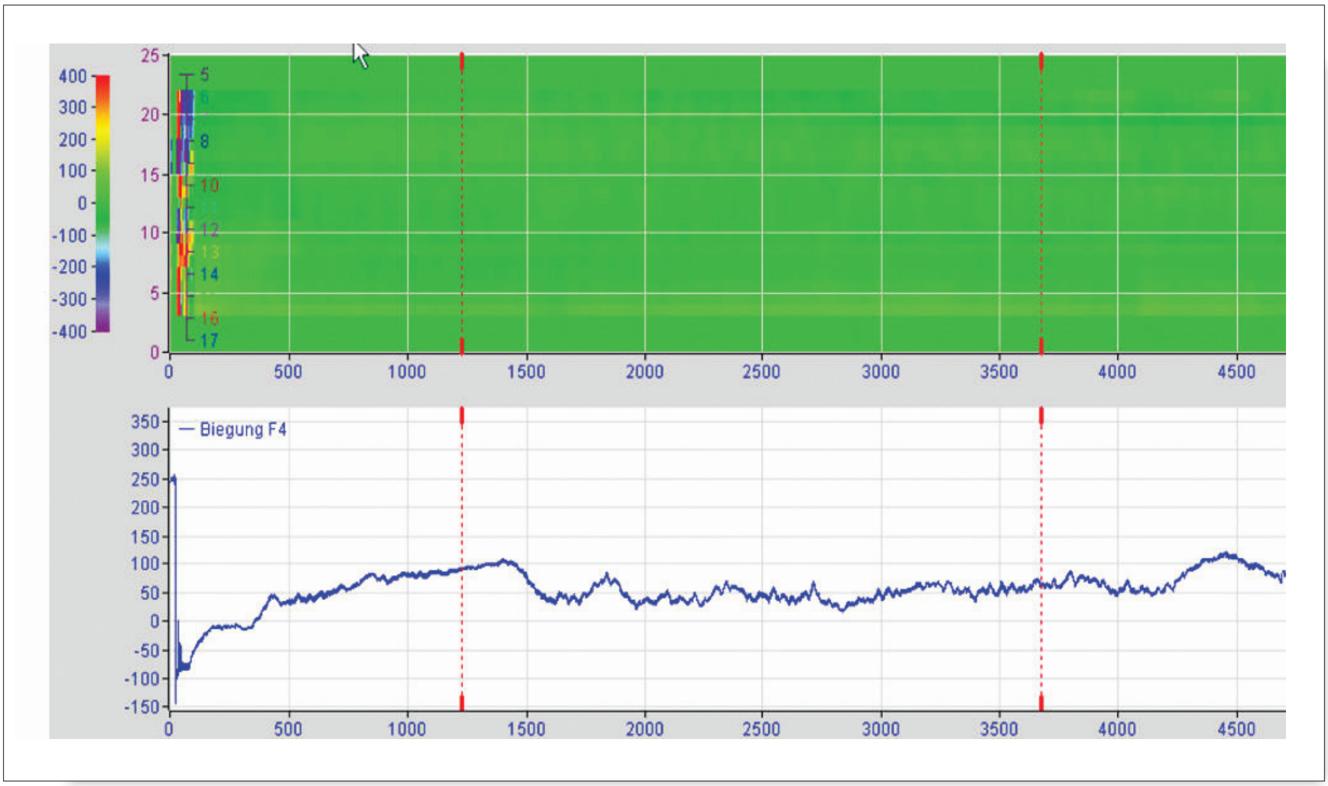


Fig.5 Typically achieved flatness control performance (top: flatness in μm/m; bottom: applied bending force [kN])

Strip width, mm	Strip thickness h4, mm		
	0.4, 0.7	0.7, 1.2	h4 ≥ 1.2
800, 1200	7.2	5.8	3.7
1200, 1500	5.6	6.0	3.4

Table 2 Typically achieved flatness performance I-units (IU)

RESULTS

Extensive preparation work allowed the flatness control system to start up after a few days. Subsequently the control system functions have been optimised to achieve the guaranteed performance values. Excellent flatness performance in the range of 4 to 7 flatness IU is delivered by the new flatness control system; (see *Table 2*). In contrast to the situation prior to the revamp, the system is operating by default in auto-mode using all actuator controls (bending at stands 1 to 3, and bending, tilting, and selective cooling at the last stand) with minimum operator trimming. *Figure 5* shows some typical results of the flatness control for thin strip.

CONCLUDING REMARKS

The successful completion of the project offers AEH the opportunity to meet highest quality demands in terms of strip flatness. The successful design, implementation and commissioning of this project represents an important example of the capability of BFI to manage a challenging project involving a new control technology as well as major modernisation activities. BFI is now working on the adaptation of the control system to other configurations, such as 6-high and cluster mills.

REFERENCES

[1] Jelali M., Müller U., Ungerer W., Wolff A., Fackert R. New system for strip flatness control during hot rolling. Millennium Steel 2002, p. 174-178.

[2] Jelali M., Wolff A., Kpper H., Schiller M. Improved flatness in EKO's tandem cold mill. La Revue de Métallurgie-CIT, October 2003, p. 987-992.

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