Recent VAI Developments in Plate Mill Automation

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From 2000 to mid-2003 VAI has received at least ten plate-mill automation projects from well known plate producers such as Rautaruukki (Raahe/Finland), Thyssen Krupp Stahl (Duisburg/Germany) and voestalpine Grobblech (Linz/ Austria), and consequently has become the market leader in this field. A key reason why VAI Automation was selected as the supplier of process models and automation systems for these projects was because of its extensive experience background in this area in addition to a number of new developments which have contributed to enhanced mill productivity and plate quality. This paper outlines several of these developments and several installation references are cited.

INTEGRATED SOLUTION APPROACH

Success in plate-mill production involves a totally integrated solution approach which comprises the use of proven and efficient mechanical and hydraulic equipment, application of advanced process control and automation systems, and in-depth operational and maintenance know-how. An overview of a comprehensive quality package offered by VAI for the modernization of plate mills is shown in Figure 1.

In addition to the installation of state-of-the-art technological control systems it is the total integration of all automation and electrical systems at all levels of automation which ensures the desired results are achieved (Figure 2). This includes not only the integration of basic equipment such as gauges and drives, but also interlocking and sequence control up to the use of a plant-wide production planning and control system.

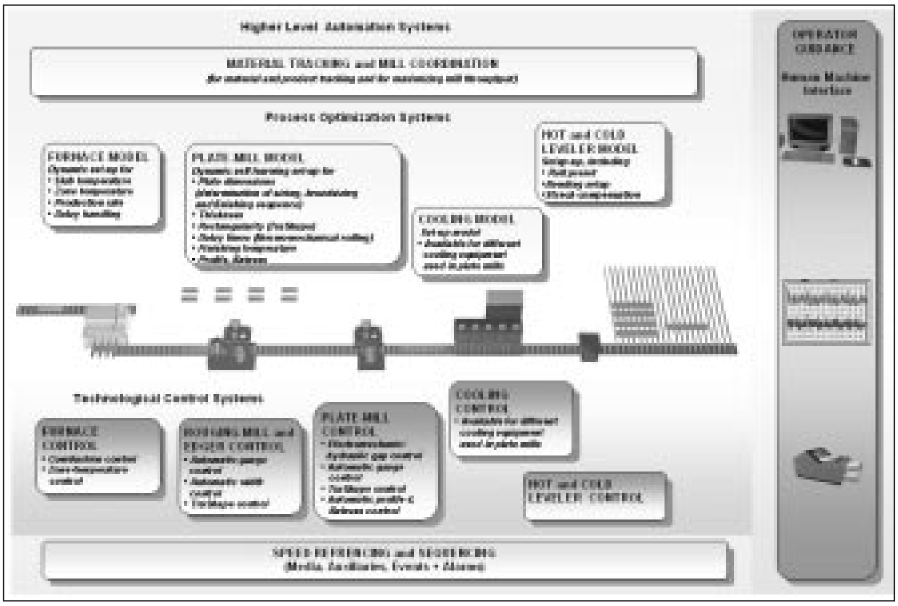
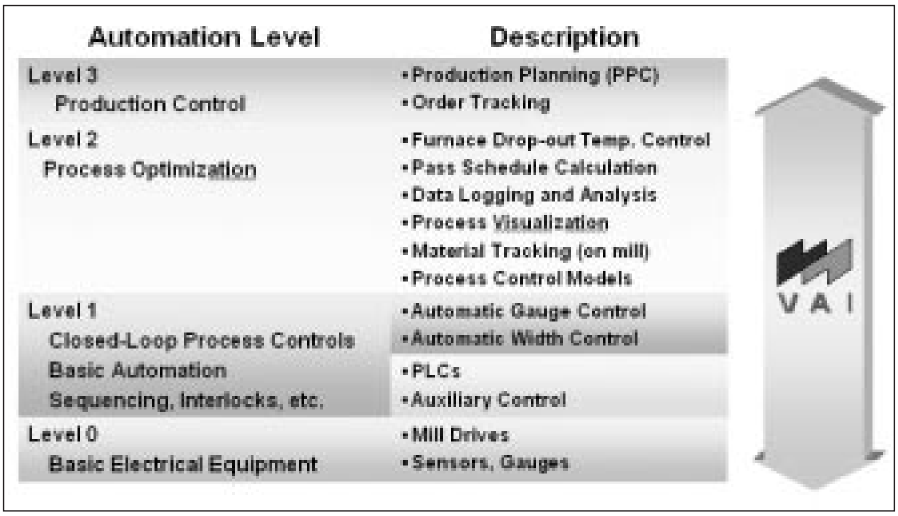


Figure 1: VAI Plate-Mill Quality Package.



Automation Level	Description
Level 3 Production Control	• Production Planning (PPC) • Order Tracking
Level 2 Process Optimization	• Furnace Drop-out Temp. Control • Pass Schedule Calculation • Data Logging and Analysis • Process Visualization • Material Tracking (on mill) • Process Control Models
Level 1 Closed-Loop Process Controls	• Automatic Gauge Control • Automatic Width Control
Basic Automation Sequencing, Interlocks, etc.	• PLCs • Auxiliary Control
Level 0 Basic Electrical Equipment	• Mill Drives • Sensors, Gauges

Figure 2: Integration of All Levels of Automation.

RECENT DEVELOPMENTS

Switch-Over Concept

During the upgrading of plate-mill automation systems interruptions in ongoing rolling operations must be kept to a minimum. Application of a so-called "switch-over concept" is sometimes carried out whereby the control functions are switched forwards and backwards between the old and new automation systems. This approach was successfully applied for the plate mill of voestalpine Grobblech and is also foreseen for Thyssen Krupp Stahl (TKS). At TKS the speed-guidance system as well as the roll-adjustment system with its corresponding Level 2 automation can be switched over using just one switch (Figure 3). When running the mill with the old equipment the process values are fed via the new Level 1 system to the new Level 2 system, where the mill model can be tuned in the offline mode.

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Accelerated Cooling Technology

VAI supplies accelerated cooling technology for the production of high-quality and high-strength plates. These are offered under the brand names of ADCO® (accelerated air-mist cooling) and MULPIC (multipurpose interrupted cooling). High-strength, uniform-quality plates mean less plate weight and thus a significantly value-added end product for producers.

Plate Leveling

The VAI pre-leveler was designed as a low cost and efficient method to obtain the correct plate entry flatness for products that are typically difficult to roll and which require accelerated cooling. Exact control of the hot-leveling operation as the final decisive step assures that the desired quality of the produced plates is achieved.

Plate Mill Set-Up Model

The set-up model is one of the decisive elements of a plate-mill automation system (Figure 4). It contributes to an optimization of the process with respect to

- Improvement of product quality parameters, especially for plates after a change of the mill conditions (roll change) or a change in the product characteristics
- Improvement of the dynamic performance and control range of the technological control loops with optimized control parameters.

The model functions are based on the exact mathematical modeling of heating, rolling and cooling as well as on the extensive and automatic adaptation of model parameters on the basis of measured values.

Roll-Force Model

Exact prediction of the roll force is one of the most essential criteria for the set-up of the rolling mill. This not only holds true for the pass schedule and thus for the drafting pattern and the number of passes, but also for many indirectly related factors. For example, the roll force influences the deformation of the roll stack and thus the results in plate flatness as well as the calculation of the required roll-bending compensation (if available).

VAI has developed a high-precision roll-force model which integrates the pressure distribution across the entire arc of the roll gap. Special attention is placed on the prediction of force for thick material, as in these cases conventional models are not sufficiently accurate.

Profile And Flatness Optimization

A certain roll-gap shape is required especially in the finishing phase to roll a perfectly flat plate. This roll-gap shape is based on the requirement that the relative profile must be kept within certain tolerances from pass to pass for the production of a flat plate.

The prerequisite for flatness optimization as described above is a model which calculates the shape of the roll gap under given load conditions. VAI has developed a new mathematical solution to the well-known problem of roll-set deformation. This model allows the online calculation of the rolling-gap contour with the precision of offline finite-element models. The simplifications commonly applied in online models in order to speed up the calculation are not required here. The new 3D finite-element model is capable of executing calculations in less than 50 ms!

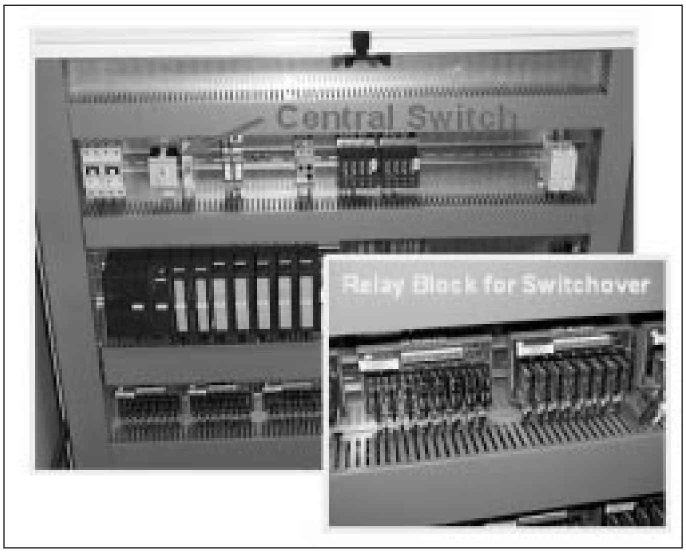

Figure 3: Automation Switch-Over Between Old and New Systems (Selection of active system by one central switch).

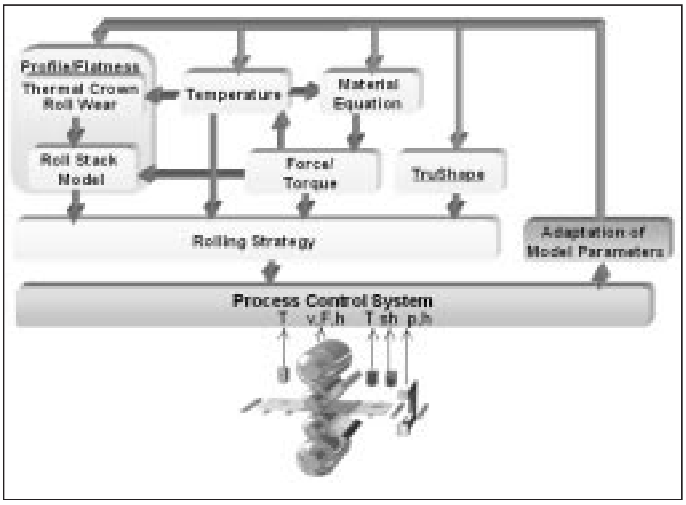

Figure 4: Plate Mill Set-up Model.

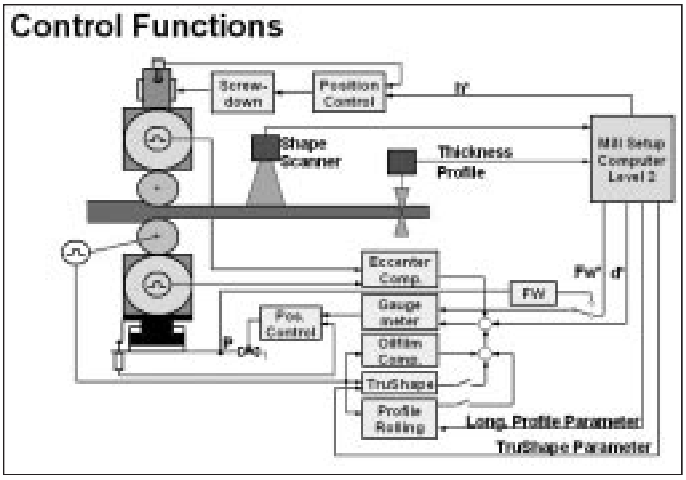

Figure 5: Schematic Diagram for Automatic Thickness Control.

Automatic Thickness Control

The Automatic Gauge Control (AGC) system controls the product thickness, irrespective of external disturbing influences, to reach a defined setpoint (Figure 5). For controlling the hydraulic roll-adjusting system a multiprocessor system is used which executes the following functions:

- Hydraulic gap control, including
  - > Position control
  - > Roll-force control
  - > Nonlinear position control for fast dynamics
- Thickness control, including
  - > Gaugemeter
  - > Gauge error update
  - > Roll eccentricity compensation.

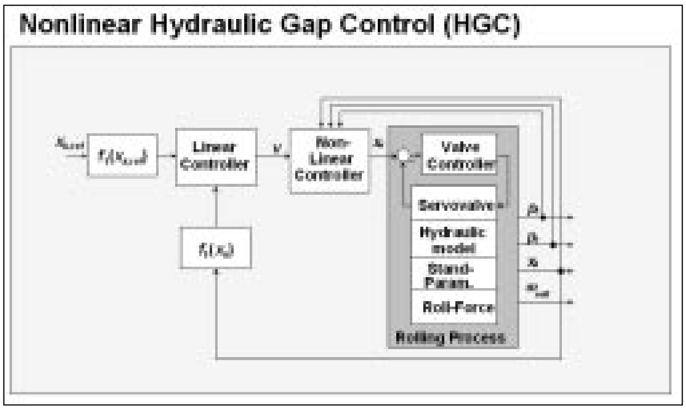

Figure 6: Schematic Diagram of Non-Linear Position-Control System.

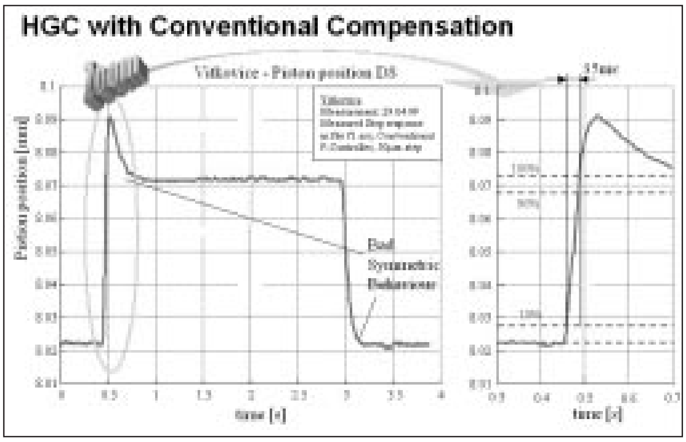

Figure 7 compares a conventional position-control system and the non-linear system. The graphs are based on measured values from a plate mill in Vitkovize, Czech Republic.

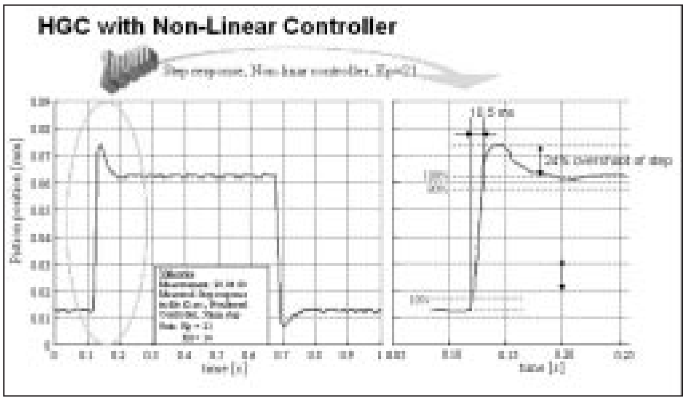

Figure 7a + 7b: Comparison of Conventional and Non-Linear Position Controller.

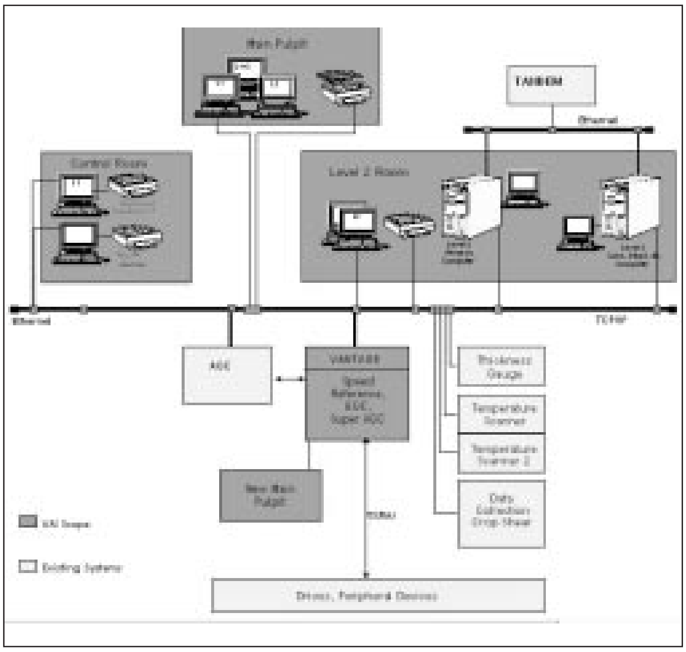

Figure 8: Automation Configuration at Thyssen Krupp Stahl, Duisburg, Germany.

The effects of mill stretch, roll deflection and roll flattening are corrected in the gaugemeter loop. In the gaugemeter branch the loaded roll gap and thus the rolled product thickness are calculated on the basis of information from the gap control positions and roll forces. Roll deflection is dependent on the roll diameter as well as on the width of the rolled product. The resulting stand stiffness may vary by up to 20% depending on the width of the rolled products.
The gaugemeter magnifies variations in the roll force resulting from roll eccentricities. Specific measures, such as creating a dead zone in the gaugemeter loop, are carried out to accommodate for roll eccentricity

Nonlinear Position Controller

The automatic gauge-control system for plate mills consists of several layers, including position control and mill-stretch compensation. Position control is the most inner control circuit that rapidly and accurately processes the position set-points, independent of whether the roll gap is open or closed. VAI has developed a non-linear position-control system in cooperation with the Christian Doppler Laboratory which is illustrated in Figure 6.

PROJECT EXAMPLES

Rautaruukki

At the Rautaruukki plate mill in Raahe, Finland a non-linear control system was implemented in a VANTAGE technological control system. This project also included the installation of pass-schedule processing and reference generation for the reversing and sequence control of the main drives and roller tables, automatic calibration of the mill stand and a new visualization system for plant operation and pass scheduling.

Thyssen Krupp Stahl

VAI is currently upgrading the automation system of the 3.9 m plate mill of Thyssen Krupp Stahl (Duisburg Hüttenheim, Germany) which comprises

- An optimized pass-schedule calculation on the basis of a three-dimensional roll-contour model
- VAI's TruShape model for enhancing the squareness of the finished plate
- The VANTAGE technological control system for electromechanical roll adjustment, feed forward AGC (Super AGC) and reference generation for main drive and roller tables
- Pass schedule processing, material tracking and sequence control for all actuators in the mill area
- Visualization system for plant operation and monitoring and pass schedule handling.

Figure 8 shows the related configuration of the new automation system, which is compatible with the existing AGC system with thickness gauge and temperature scanners.

Voestalpine Grobblech

VAI equipped the 4.2 m plate mill of voestalpine Grobblech (Linz, Austria) with a new electrical and automation system (Figure 9) that included

- An optimized pass-schedule calculation with a three-dimensional roll contour model
- The TruShape model for enhancing the squareness of the finished plate
- The VANTAGE technological control system (TCS) for electromechanical and hydraulic adjustments necessary for the control of plate thickness, shape and flatness
- Sequence control for stand, roller tables and roll changes with a central connection and indication system
- Visualization system.

Figure 9: Main Control Pulpit of Plate Mill, Voestalpine Grobblech, Linz, Austria.

Chinese Plate Mills

VAI was also awarded projects for the modernization of a number of Chinese plate mills, three for which the main mill features and scope of supply are outlined below.

CONCLUDING REMARK

The market for plates demands the highest possible product quality with respect to finished plate dimensions, plate flatness and mechanical properties. The VAI Group of companies, as the world's leading supplier of plate mills and the associated automation systems, supports producers in meeting all of the product, quality and cost targets in plate production.

Plate Mill	Angang	Wuyang	Handan
Capacity	1 Mt/a	0.5 Mt/a	0.5 Mt/a
Width	4.3 m	4.2 m	2.8 m
Main Mill Components	- 2 x Reheating furnace - Primary descaler - 1x4-high mill stand - Hot leveler - Cooling beds	- 1x Pusher-type furnace - Primary descaler - 1x4-high mill stand - Hot leveler - Cooling beds	- 2 x Reheating furnace - Primary descaler - 1x4-high mill stand - Hot leveler - Dividing shear - Cooling beds
Plate Dimensions	Thickness: 6–100 mm Width: 1,400-4,000 mm	Thickness: 6–70 mm Width: 1,400-4,000 mm	Thickness: 4–40 mm Width: 1,500–2,700 mm
Steel Grades	Carbon steel, low alloy, vessel, boiler, ship, pipe (X60–X100), containers	Carbon steel, low alloy, vessel, boiler, ship, pipe	Carbon steel, low alloy, vessel, boiler, ship, bridge
Mechanical Scope (VAI)	- New 4-high stand - Hydraulic capsules - Work-roll bending	- Upgrade of existing HGC	- Hydraulic capsules
Automation Scope (VAI)	- Level 2 - Set-up model - TCS - Level 1 mill master	- Level 2 - Set-up model - Upgrade of TCS - Level 1 mill master - Thickness gauge	- Level 2 - Set-up model - TCS - Thickness gauge

Table 1: Chinese Plate Mills.