Automation upgrade of an integrated steel works and supply of a heavy plate mill

Zhangjiagang Shagang Group has acquired an entire German integrated steel works, which has been dismantled and will be reassembled in China. VAI were contracted to provide the latest technological, process automation and optimisation solutions for the plant so that it will meet all the technological requirements for the production of high-quality flat products.

Liu Jian, Rudolf Pichler and Peter Juza
Jiangsu Shagang Group Co. and Voest Alpine Industrieanlagenbau (VAI)

The Chinese steel producer Zhangjiagang Shagang Group, currently the largest supplier of EAF-based long products in China, has decided to expand into the flat-product sector. To achieve this goal, the company acquired a German steel works, which has been dismantled and will be reassembled in China.

To enhance the performance of the existing equipment, VAI has been chosen as a partner to provide the latest technological, process automation and optimisation solutions. The scope of the automation project covers two blast furnaces, three BOF converters, one RH degasser, one continuous caster and hot-strip mill.

On the basis of the technology package proposed, a subsequent contract was then awarded to install a new plate mill.

Highlights of VAI Automation packages to be used include the VAIron closed loop expert system, substance-based BOF models, SMART/ASTC dynamic soft reduction for continuous casting, advanced set-up models and control systems for thickness and flatness for the hot-strip mill.

The optimisation process is guided and controlled by the VAI-Q Slab and the VAI-Q Strip quality assurance packages. Additionally, the production planning system Alpha-Planner and an energy management system EMS will be installed. The paper focuses on the process optimisation model highlights that will be supplied and implemented by VAI for the individual production units.

Introduction
In order to become active in the flat-product sector, Zhangjiagang Shagang Group has acquired the integrated steel plant of Westfalenhütten in Dortmund, Germany from ThyssenKrupp Stahl AG. Approximately 250,000t of plant structure and equipment from the sinter plant, blast furnaces, steelmaking facilities, casting machines and hot-strip mill had to be dismantled by the end of 2002 and all useful plant sections and components have been shipped to a new site in the Yangtze delta, near Shanghai, China to be reassembled by the end of 2004 under the supervision of Shagang.

In order to ensure that their steel expansion program will meet all modern technological requirements for the production of high-quality flat-rolled products, Shagang awarded VAI a series of revamping contracts, which include the following:
- Blast furnace
- Converter plant and twin-station ladle furnaces
- RH/T-Cas-QB degasser
- Two-strand slab casters
- Reheating furnace
- Hot-strip mill
- Production planning system – Alpha Planner
- Energy management system EMS
Automation system
One of the most important aspects of the plant modernisation is the complete revamping of the automation system in conjunction with the installation of new technological systems and process optimisation packages. Shagang decided to completely replace the old automation solutions with new state-of-the-art systems, including hardware and software, in order to guarantee the desired production and quality results. A typical system consists of a number of packages (see Figure 1).

The process information management system prepares process data and production results in a form that is suitable for evaluation by plant operators and management personnel and, most importantly, for the process models. The advanced control systems comprise components that are attributed to different levels of automation together with mechanical and/or hydraulic equipment. Packages are designed as ready-to-use upgrades for existing plants, providing immediate improvement in product quality and production yield for low investment costs.

The VAI-Q quality control package assigns production and quality-related information from the melt shop and continuous casting machine to slab segments. The information is later tracked throughout the subsequent rolling and processing stages, which contribute additional vital information. Expert systems (XPS), particularly when they are applied in a closed-loop mode, provide the best approach that is currently available for achieving fully automatic plant control without operator interaction.

VAIIron BF process optimisation
This comprises:

- Mass and heat balance models
- Burden control and distribution models
- Hearth wear calculation
- Closed loop expert system

The VAIIron blast furnace optimisation package is the first example of a third generation expert system solution that executes process changes in a closed-loop without operator interaction. This development is the latest step towards achieving optimum production of hot metal and represents the future direction of blast furnace automation. The functionality of the planned system is shown in Figure 2.

The models also provide the level 1 set points which are based on the corrective actions determined by the VAIIron expert system. Control of coke rate, burden and burden distribution, basicity and steam injection rate are simultaneously and automatically executed in a closed-loop mode to ensure stable and consistent process operation at lowest production costs.

Using the models, it has been proven that fuel rates can be significantly reduced even when using raw materials of low quality variability, and further cost savings are obtained as a result of higher productivity, reduced variability of hot metal silicon content, and reduction in energy consumption at the hot stoves.

Steel plant process optimisation
VAI has recently refined its well-proven steel plant models, which cover a wide range of steelmaking automation requirements. Figure 3 gives an overview of the models that will be installed at Shagang.

BOF converters The first and second stage charge calculations determine the required materials to be
charged into the converter, as well as the oxygen volume to be blown to achieve target steel analysis, weight and temperature. The analysis and temperature information obtained from sublance measurement is used as input to the sublance model. This provides more accurate targeting of final carbon and temperature range when compared to static calculations. The correction model calculates the necessary steps to achieve the predefined targets and the feedback model performs a recalculation of the whole process at the end of the heat treatment to allow an automatic tuning of the applied models.

**Degasser RH/T-Cas-OB** Pre-calculation at treatment start performs a simulation of the metallurgical reactions during the vacuum treatment based on the predefined process patterns. Thus, for instance, it would be pointed out at treatment start if forced decarburisation with oxygen blowing was required. The cyclic degassing model monitors the actual H, N, O and C content of the steel bath by taking into account the actual vacuum pressure and the different treatment phases. The thermal model cyclically calculates the actual steel temperature, considering thermal losses as well as the energy supplied by oxidation of different elements. If forced decarburisation or aluminum heating is required, the oxygen model determines the necessary amount of oxygen to be blown.

Finally, the metallurgical model is applied for fine adjustment of the chemical analysis and determines the cost-optimised combination of required materials. Metallurgical reactions between steel and slag are taken into account in order to reach the target analysis at the correct time.

**Continuous casting process optimisation**
VAI-Q quality assurance allows the determination of optimum production practices and guides the operators throughout the production process. Deviations from optimum production conditions are automatically detected, indicated to the production personnel and reported on quality reports.

The secondary cooling model DYNACS® and the automatic strand taper/thickness (ASTC) package for SMART® segments both actively contribute to slab quality improvement. The former avoids certain types of surface cracks that are induced by strand surface temperatures below critical. The latter calculates the optimum position of hydraulically applied ‘soft reduction’ of the strand thickness, which considerably reduces centre segregation in the slabs.

The MoldEXPERT package (see Figure 4) provides sticker breakout prevention as well as valuable...
Rolling mill process optimisation

The entire scope of functions that will substantially contribute to improved product quality and higher productivity is shown in Figure 5. The ideal combination and integration of mechanical and automation systems is of decisive importance in the modernisation of the Shagang mill. The key aspects are described below.

Non-linear hydraulic gauge control (HGC)

Automatic gauge control of a HSM consists of several control layers. The position control is the most inner control circuit and to process the position set-points as fast and accurately as possible VAI has developed a non-linear position control system in cooperation with the Christian Doppler Laboratory for Automation of Mechatronic Systems in the Steel Industry.

Roll eccentricity compensation

Any eccentricity of backup rolls results in periodic roll force fluctuations, which can seriously affect the gauge precision. The solution developed by VAI to counteract this problem is based on the identification of the roll eccentricity by means of neural networks without additional transducers.

Roll force model

The prediction of the roll force is one of the most essential criteria for the set-up of the rolling mill. VAI has developed a high precision roll force model which integrates the pressure distribution across the entire arc of the roll gap, including those areas in which relative movement occurs between the work roll and the rolled material. This is especially important when work-roll lubrication is applied.

On-line 3D finite element calculation of roll stack deformation

In order to get a flat finished strip with the target profile, a certain roll gap shape is required in each stand. VAI’s new model for the calculation of the shape of the roll gap under given load conditions allows the on-line determination of the rolling-gap contour with the precision of offline finite-element model calculations. As the deformation of the roll stack substantially contributes to roll stretch, this model is also used to calculate the required correction of the gap adjustment in order to meet the target thickness even at the strip head.

Prediction of the mechanical properties of strip with VAI-Q Strip

VAI-Q Strip is a quality control system, allowing the online prediction of the mechanical properties of the hot-rolled material. It is based on detailed physical and metallurgical modelling of the entire rolling process. Based on the
acquired process data, the microstructure of the rolled product can be precisely determined and used to calculate mechanical properties such as yield strength, tensile strength and elongation to fracture.

**New heavy plate rolling mill**
This latest project includes the installation of a 1.8Mt/yr, 5m wide heavy plate mill comprising descaler, plate mill and edger, hot leveller, cooling bed, double side trim shear, divide shear and cold leveller (see Table 1). Prior to this project only one other 5m wide plate mill was in operation in China.

**Scope of supply**
Although VAI is responsible for the complete installation of the mill, only the automation system will be described here.

**Process optimisation system**
This calculates the optimised mill set-up to ensure high accuracy of the finished plate dimensions and the technological rolling conditions, providing maximum utilisation of the plate mill and maximum yield by cutting highly rectangular plates.

To achieve these benefits the following functions will be implemented:

- Plate mill model function including rolling force and torque model, yield stress, mill stretch and temperature models, profile and flatness model, bending set-up model, TruShape model and edger set-up optimisation
- Model functions for cooling including plate segment tracking, set-point calculation, feed forward control and mill pacing
- Hot and cold leveller set-up model with on-line and off-line models
- VANTAGE technological control system with closed loop control functions for the mill and edger, including automatic width, gauge, profile and flatness control via electromechanical and hydraulic gap control for accurate dimensional tolerances
- Basic automation system including sequence and movement control for the entire mill, speed guidance, control of auxiliaries and utilities, interlocking and diagnostic, alarm and event handling, and a powerful human-machine interface (HMI) with comprehensive functionality for the operators.

Liu Jian is Executive Vice President at Jiangsu Shagang Group Co. Zhangjiagang, PR of China. Rudolf Pichler Vice President, Automation Rolling & Processing and Peter Juza General Manager, Head of Automation Proposals Iron & Steelmaking at Voest Alpine Industrieanlagenbau (VAI), Linz, Austria.