Stainless and carbon steel production via K-OBM-S

To meet increasing demand for stainless steel an 80t LD converter at TAIGANG, China, has been converted into a modern combined top and bottom blown stainless and carbon steel unit, equipped with the latest process control systems and instrumentation. Stainless steel production has increased by 350,000t/yr.

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TAIYUAN Iron and Steel Corporation (TISCO), the sole stainless steel producer in China, awarded VOEST-ALPINE Industrieanlagenbau GmbH & Co (VAI) the contract for the modification of one of the three 80t LD converters in melt shop No.2 into a modern K-OBM-S (Combined Oxygen Bottom blowing Maxhutte-Stainless) converter for carbon and stainless steel production. The objective was to increase stainless steel production of the TAIGANG group by 350,000t/yr to meet market demand and also to strengthen its leading position in China. The contract was awarded in February 2001 and included all the necessary modifications of existing auxiliary equipment and the supply of new key components, such as VAI-CON® Temp, valve stands, basic automation and process control, required to achieve desired plant capacity. Both ferritic and austenitic stainless steel grades were to be produced by applying the triplex (EAF – K-OBM-S – VOD) and duplex (EAF – K-OBM-S – LF) processes and use a high-carbon premelt based on dephosphorised hot metal.

The advantages of using a K-OBM-S converter instead of an AOD at TAIGANG are:

- Low investment by reusing existing equipment and converter shell for both carbon and stainless steel production
- Long converter lining life using liquefied petroleum gas (LPG) to protect the tuyeres
- Higher blowing intensity and therefore high productivity by combined blowing

Figure 1 shows the melt shop configuration after start-up of the new K-OBM-S converter.

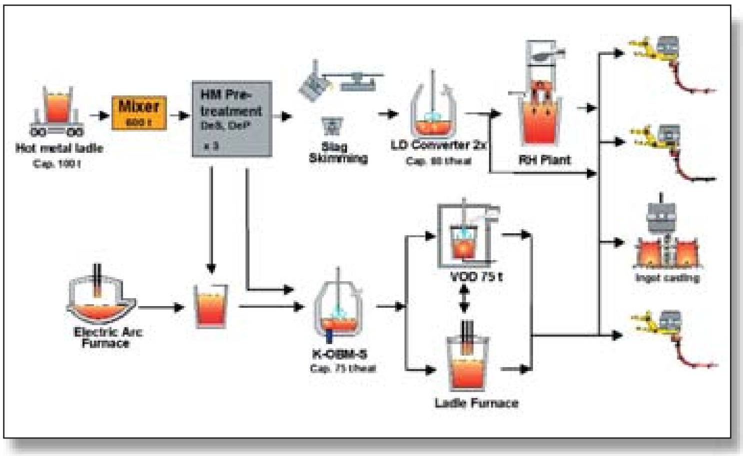

Fig.1 Plant configuration after start-up of the new K-OBM-S converter

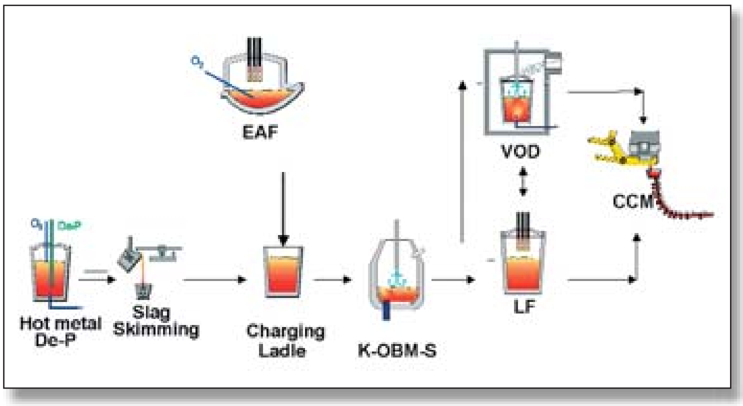

Fig.2 K-OBM-S process routes

PROCESS ROUTE AND MAIN FEATURES

Based on the required operational conditions at TAIGANG, such as productivity, argon availability and long converter refractory life, triplex is the main process route for stainless steel production (see *Figure 2*). Typically, AOD stainless steel plants use medium carbon premelt from an EAF with a typical carbon content of 1.2–1.8% and an AOD charging temperature between 1,550 and 1,600°C. However, the premelt conditions for the new K-OBM-S are characterised by high carbon contents between 3.2 and 4.8% and low temperatures between 1,260 and 1,320°C resulting from the existing blast furnaces and a small (15–30t) EAF for production of premelt. These inputs cause particular metallurgical and process control challenges.

The premelt can be provided to the converter either using only dephosphorised hot metal (~65t) or EAF premelt (15–30t) + dephosphorised hot metal (~30–50t). For ferritic grades the premelt consists of 100% dephosphorised hot metal. After mixing in the charging ladle the premelt is weighed and charged into the K-OBM-S converter by crane.

In order to fulfill the special process requirements as a main unit for the production of stainless steel at TAIGANG, the converter has a number of key features:

- Large specific volume to ensure a smooth operation without splashing
- Top lance with position control for rapid decarburisation, and CO post combustion to meet the energy demand of the process
- Combined flow and pressure single line control principle for the shroud gas to ensure optimum cooling and long tuyere life
- High blowing intensity for high productivity and ability to charge large quantities of solids into the converter
- VAI-CON Temp for continuous temperature measurement
- VAI PSS (Pneumatic Slag Stopper) to reduce carryover slag during tapping to improve down stream VOD operation
- Three operational modes on level 1 (including converter operation in computer mode) for achievement of target process conditions
- Advanced level 2 process models for heat pre-calculation and on-line process control allowing fully automated converter operation and computer controlled fulfillment of the steel quality requirements

The plant consists of a 75t converter, a top-lance system with two lance carriers, process control, a process gas valve station, a dedusting system, an additive bunker system including 12 high-level storage bins, 8 weighing bins and two discharging bins. The main technical data are summarised in *Table 1*.

CONVERTER OPERATION AND CONTROL FOR STAINLESS STEEL MAKING

The converter is initially preheated by bottom firing with LPG and the top lance prior start-up (see *Figure 3*). After charging and homogenisation of the premelt and initial sampling/temperature measurement, the process undergoes several decarburisation steps, followed by a reduction step with simultaneous desulphurisation. For each decarburisation step, target values for the carbon content and temperature of the metal bath are defined. ▷

Heat size	75t (nominal)
Inner volume with new lining	52.5m^3
Specific volume of the vessel	0.7m^3/t
Height	7,613mm
Diameter	5,200mm
Number/diameter of the tuyeres	5/16mm (inc. VAI CON Temp tuyere)
Top lance	For O_2 and inert gas, max. 200Nm^3/min
Tapping system	Tap hole, with VAI-PSS
Slag detecting system	IRIS
Temperature measurement	VAI-CON Temp

(IRIS is an optical slag detector)

Table 1 Main technical data of K-OBM-S converter at TAIGANG

Fig.3 Preheating of the K-OBM-S converter

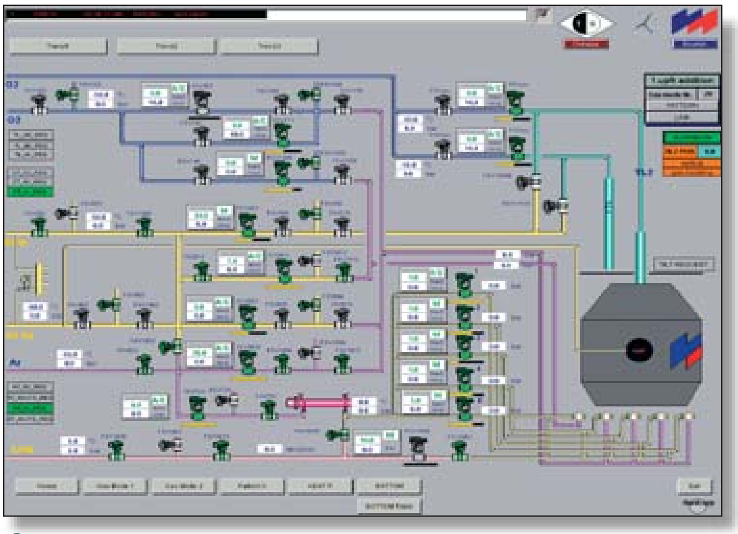

Fig.4 Level 1 blowing control screen

The main targets during the first three decarburisation steps DEC1, DEC2 and DEC3 are as follows:

- Increase the bath temperature as quickly as possible to approximately 1,680°C (usually accomplished during DEC1 and DEC2) in order to achieve a high decarburisation rate, high carbon removal efficiency and reduced Cr-oxidation
- Add the main quantity of the solid additions, such as lime, dololime, all high-C alloys (such as FeCrHC and FeMnHC) and, if required, scrap and/or Ni or Ni alloys

Combined blowing by top lance and bottom tuyeres is applied during these decarburisation steps. After DEC3 a short clean-up step is usually performed with combined blowing to minimise the build-up on the upper cone of converter. The target carbon content in the metal after the clean-up step is roughly 0.4–0.5% for both duplex and triplex process routes.

With combined top and bottom blowing a maximum total oxygen blowing rate of 240Nm^3/min is possible, however, during start-up a maximum of 180Nm^3/min was applied. The main advantages of the combined blowing technique can be summarised as follows:

- Rapid rise in temperature
- Higher decarburisation rates with high carbon removal efficiency and less Cr-oxidation
- Partial CO post combustion for improved converter heat balance
- Improved bath agitation
- Greater quantities of solid additions possible
- Shorter blowing time
- Higher productivity of the converter process

During the final decarburisation period, which, in the case of the duplex route, is usually carried out in four sub-steps (DEC_final_1 to DEC_final_4), one of the main targets is to keep the steel bath temperature within the range 1,680–1,730°C by adding slag formers and metallic cooling additions such as scrap and/or Ni or Ni alloys (Ni in case of 304 grades).

In order to avoid excessive Cr-oxidation and to decrease silicon consumption for the reduction phase, the flow ratio of oxygen and inert gas (N_2 or Ar depending on the produced steel grade) is changed during final decarburisation in steps, depending on the carbon content of steel. After the end of decarburisation a combined reduction and desulphurisation step is usually performed.

A basic level 1 automation system has been implemented in order to achieve optimum process

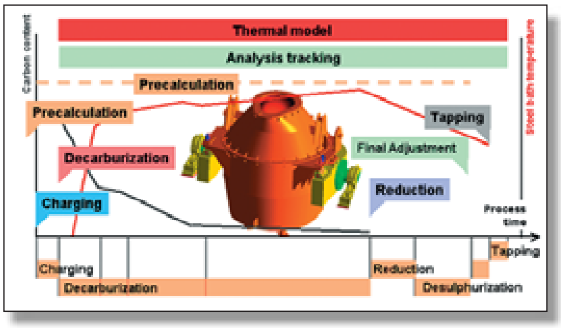

Fig.5 **Overview of stainless steel process model**

control. The system can be operated in three modes:

- Manual mode (for maintenance using manual set points)
- Automatic mode (operation with various pre-defined steps using set points calculated by level 2)
- Computer mode (fully computer controlled operation using set points calculated and continuously controlled by level 2)

The operation mode can be changed during the converter heat processing on demand, as long as the change is from upper to lower control level. *Figure 4* shows a control screen in the level 1 system.

The main advantages of the new level 2 optimisation system are:

- Increased productivity
- Minimal samples required
- Improved chemical composition and temperature of tapped steel
- Transparent process operation by data visualisation, recording and heat reporting
- On-line process control including automatic optimisation of set points
- Off-line process simulation for process optimisation and new grade development
- Operator control with graphical user interface (GUI) Windows technology
- Modular software design and object oriented software architecture for easy software modification and upgrade capability

MODEL OVERVIEW

The core component of the level 2 optimisation system is a set of on-line models supporting the metallurgical processing of the heat. The application of the implemented process models and their purpose is shown in *Figure 5*. The model calculation includes an off-line pre-calculation of the complete heat treatment from charging to tapping before start of the converter process and a cyclic on-line calculation performed during the heat. Triggered calculations such as re-blow or cooling can be carried out on operator demand or at special process events.

For each heat the model calculation is based on the standard melting practice (SMP), which is defined for each steel grade and included in the technological model database. The standard melting practice contains all the necessary basic data concerning process patterns and target product specifications for both steel and slag during heat processing. The continuous control of bath temperature and composition, as well as the calculation of other physical and chemical parameters for metal and slag during the different steps of the heat, is supported by various models, based on mathematical equations of mass and heat balance, metallurgical thermodynamics and kinetics. The model calculations describe the complete thermal, chemical and kinetic behaviour of steel and slag inside the converter for the selected (or actual) process pattern. During the process the actual state of steel and slag is calculated cyclically and displayed to the operator. Adjustments of the set points for the actual process step are made automatically in computer mode in order to reach the target values of the actual step.

The stainless steel heat pre-calculation model calculates the duration, process gas and additions (alloys and slag formers) and set points to achieve target steel and slag composition and temperature after tapping. Additional target values for the calculation are temperature and carbon content for each process step. The model allows distribution and sequencing of alloys, cooling additions and slag formers over the different process phases to achieve the required process temperature development for the heat. The calculated set points are downloaded to level 1 and are then used in automatic mode, usually without any operator involvement.

During heat processing the cyclic on-line model starts automatically. Based on the actual operational data, such as additions, blowing, steel and slag conditions and converter life time, the model determines the decarburisation process, steel bath and slag conditions (amount and compositions), and predicts the nitrogen content and the temperature of steel under consideration of the heat and mass balance and the kinetic environment.

The level 2 process model covers all standard K-OBM-S converter operation conditions, including some plant-specific items, such as 100% hot metal as premelt or chute addition of nickel plates and copper. For standard steel grades the process control can be performed in computer mode fully automated by the process model

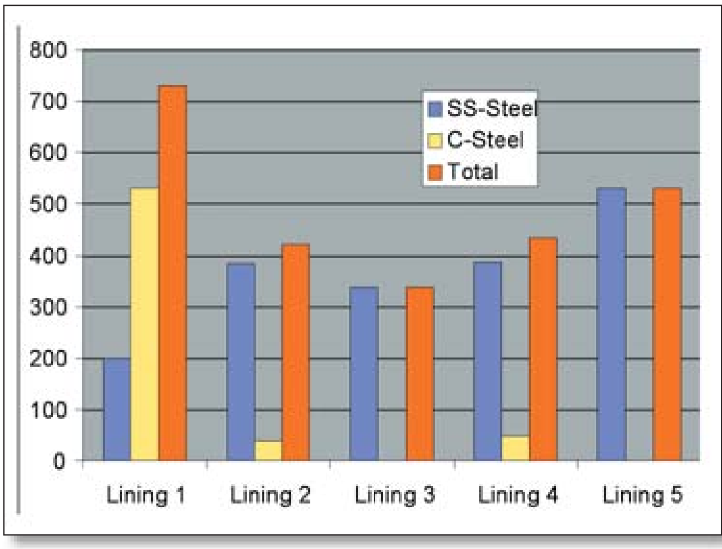

Fig.6 Converter life time performance (heats/lining) during start-up

without any sampling during the blowing process, and the heats can be tapped without waiting to receive a sample analysis after reduction.

START-UP CONDITIONS AND K-OBM-S CONVERTER PERFORMANCE

After start-up in December 2002, the K-OBM-S converter successfully underwent the function tests, machine adjustments, process optimisation and final performance tests. Since March 2003, following start-up of the new continuous casting machine, the converter has regularly produced stainless steel and the process optimisation for the whole melt shop (hot metal pretreatment, EAF, VOD and CCM) was accomplished.

In order to stabilise the entire production line the premelt condition for the converter was changed so that for ferritic grades no EAF premelt is used and all necessary solid alloys are charged into the converter. For austenite grades the EAF tap weight was minimised to reduce the EAF tap to tap time. This change of the premelt conditions meant a new challenge for process control due to the large amount of solid alloys and the higher total carbon input into the converter. After final adjustment of the process model parameters the refining process can now be controlled entirely by level 2 and for the standard grades a direct tapping after reduction could be realised. As the operation got more stable converter life increased (See *Figure 6*).

In July 2003, three months after regular operation began, the design capacity of the converter was reached. TAIGANG is the first industry application of VAI-CON Temp and was started up successfully. The performance tests on the system were carried out successfully in August 2003 and the final acceptance ▷

certificate for the K-OBM-S converter was issued on 1 September 2003.

CONCLUSIONS AND OUTLOOK

Project planning and execution were characterised by excellent and professional cooperation and a strong will to succeed. Technical and production targets were achieved. The advanced process control model, covering all special working conditions, such as high carbon content and low temperature of the premelt by using hot metal, ensures reliably high productivity and excellent quality. The newly developed VAICON Temp was implemented successfully for dynamic process control.

Following successful completion of this project TAIGANG awarded VAI new contracts for the implementation of VAICON® Quick technology for rapid converter exchange and modernisation of the existing three AOD converters and vertical slab caster of melt shop No.3 which started up early in 2004.

These projects will provide TAIGANG with the capability to provide more high quality stainless products, both for home and export markets. MS

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