INNOVATIONS FOR IMPROVED PROCESS PERFORMANCE, PLANT DESIGN AND ECONOMY IN THE STAINLESS STEEL INDUSTRY[1]

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Abstract

Increasing economic pressure and the continuing growth of worldwide capacities are leading to continuing improvements of the stainless steelmaking process and equipment. The first part of the paper describes the economic environment and main projects over the past decade comparing various plants and implemented technologies. The second part focuses on innovations and improvements of EAF technology for stainless steelmaking, and the third part highlights new technologies applied to AOD converter designs.

Key words: Stainless steel; EAF; AOD.

INOVAÇÕES PARA PERFORMANCE DE PROCESSO MELHORADO, PROJETO DE USINA E ECONOMIA NA INDÚSTRIA DE AÇO INOXIDÁVEL

Resumo

O aumento da pressão econômica e o crescimento contínuo de capacidades em todo o mundo estão levando a melhorias contínuas no processo de produção de aço inoxidável e equipamentos. A primeira parte deste trabalho descreve o ambiente econômico e os principais projetos durante a década passada comparando diversas usinas e tecnologias implementadas. A segunda parte foca as inovações e melhorias da tecnologia EAF (Forno Elétrico a Arco) para produção de aço inoxidável e a terceira parte destaca novas tecnologias aplicadas aos projetos de convertedores AOD.

Palavras-chave: Aço Inox; EAF; AOD.

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1 INTRODUCTION

The past decade brought many changes in the Stainless Steel business in many respects and was especially characterized by a huge build up of the production capacities worldwide, consolidation by mergers, co-operations and acquisitions of plants and sites by the global players.

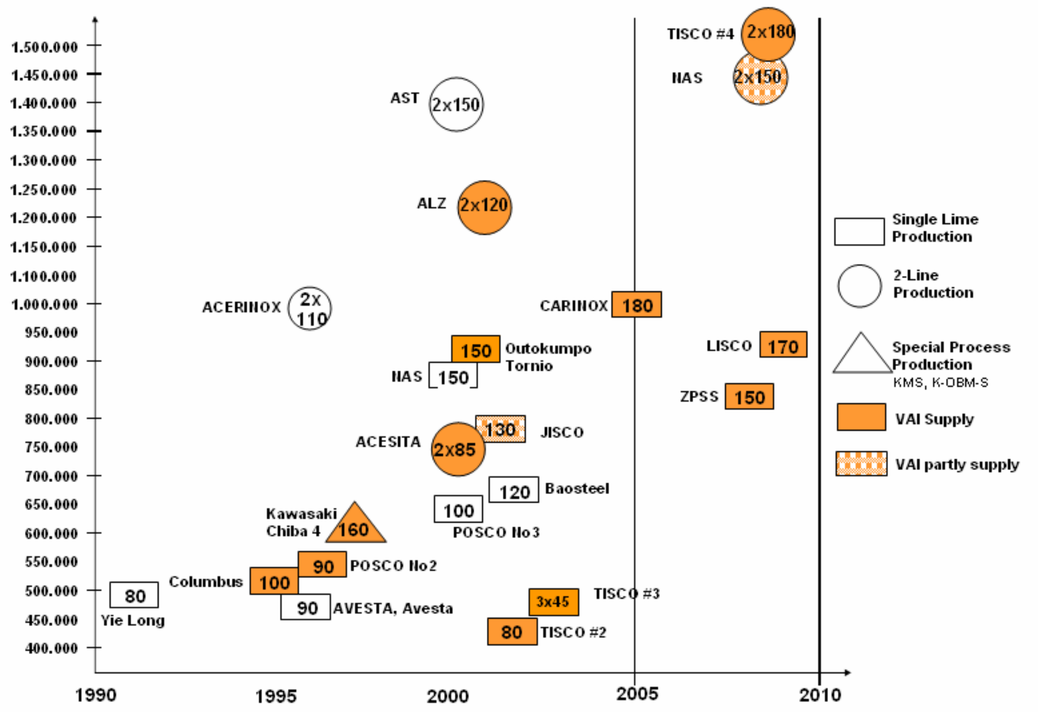


Figure 1. Stainless Steel Projects

Figure 1 shows the main projects which have been realized during the last 15 years including those that are currently under construction. Thereof SIEMENS VAI has achieved a market share of more than 50 %. The figure also shows that the size of the units became remarkably larger and the output of the plants substantially higher. Where a typical plant size in 1995 was about 500.000 tons per yer and the heat size approx.100 t, today the plants for Stainless steel flat products are designed for up to 1 million tons/year with heat sizes up to 180 t liquid tap from the AOD (CARINOX in Belgium). The reasons for this development are certainly the increased demand for stainless products with an average yearly increase of about 6% and also the requirement for a steady improvement of the cost situation of the plants. Larger heat sizes result in lower specific fixed costs and lower specific consumption.
About 60 mayor projects in Stainless steelmaking and casting have been realized by SIEMENS VAI together with its customers during the past 10 years and will be put into operation unitl 2007. Regarding capacity supply in the Stainless Steel Industry the During the last 20 years the conversion margin of cold rolled coil of steel grade 304 showed variations between approximately 500 USD/t and 1500 USD/t. The conversion margin is per definition the difference of the sales price for the product – in this case the cold rolled 304 coil - on the market and the charge material cost that means the conversion cost for the metallic charge materials to the final product of the mill. Included in this conversion margin are all specific costs for the yield loss, personnel, energy ,sales, consumables and maintenance, administration and other

overheads. In the recent years, after a period of increase after mid 2004 it seems to be that the conversion margin is shrinking again as it was between 2000 and 2004.
Shrinking conversion margins call for technologies suitable to lower the conversion costs. Innovations in this field are appreciated by the Stainless Steelmakers and SIEMENS-VAI clearly see its target to supply those innovations for its partners and customers in the industry. Some of the main activities in the field of alloyed and Stainless steelmaking shall be outlined in the following.

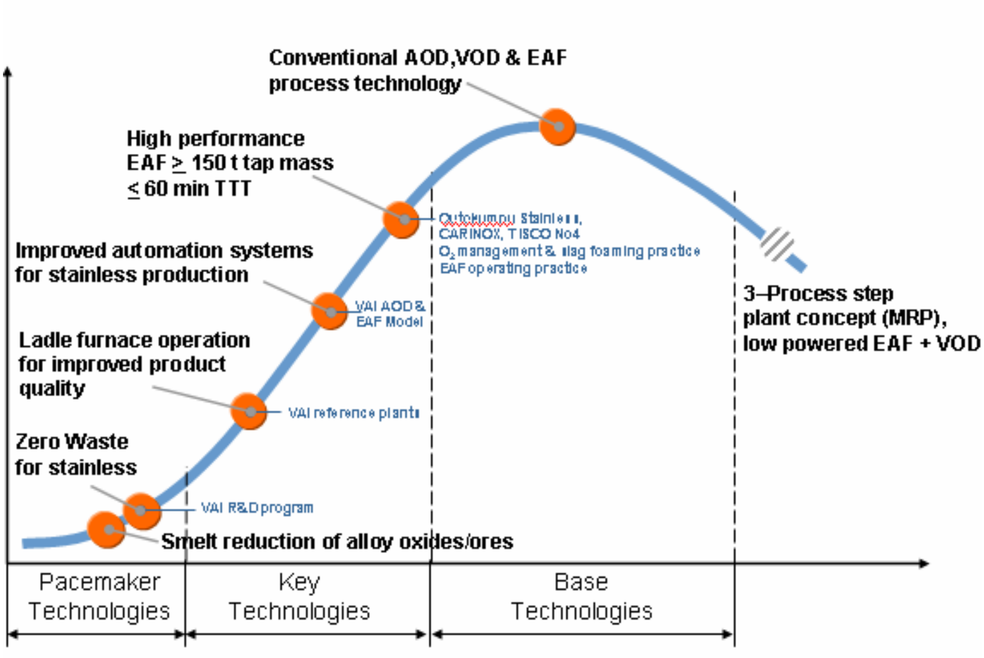


Figure 2. Technology Innovations

Figure 2 shows the main areas of technology innovations we currently see and focus on. The "Base Technologies "are the "state of the art " of Stainless Steelmaking today.
There is no substantial development any more. The so called "Key Technologies " we expect to come up strongly on the market in the near future according to the demand from the industry. A typical example shall be the high performance EAF for Stainless with a cycle time of 1 hour and 400 kWh /t specific energy consumption. For these technologies further R&D work is necessary however we have already a reference plant on industrial scale.
The following section show main Innovations in Steel Plant technologies, both for electric arc furnaces and AOD converters.

2 INNOVATION FOR EAF PERFORMANCE IMPROVEMENT

The Electric Arc Furnace (EAF) for Cr –heats is typically a melting unit. Its metallurgical tasks are few. The main issue is to provide the necessary productivity for the downstream facilities. However the O_2 usage was restricted due to the high affinity of the Cr to O_2. The target was to develop a system which allows to use more O_2 for the EAF process without oxidizing substantially more Cr than normally cannot be avoided. Another point is that the large size EAF`s for Stainless with transformers of 160 MVA apparent and appr. 115 MW temporary active power input seem to face the limits in terms of flicker and net for many projects.

	BEST	OPTIMAL	SUB - OPTIMAL	WORST
Capacity	1.65 mill t	1.0 mill t		0.2 mill t
EAF Size	165 t	100 t		35 t
MVA / t	1.11 MVA / t	0.9 MVA / t		0.35 MVA/t
Power On Time	45 min	65 min		180 min
Size AOD	180 t	110 t		75 t / no AOD
Electricity Consumption	420 kWh / t	465 kWh / t		596 kWh / t
Electrode Consumption	2.5 kg / t	3.0 kg / t		5.5 kg / t
Refractory Consumption *)	9.5 kg / t	12 kg / t		19 kg / t
Yield Loss EAF to slab	7%	9%		16%

*) EAF & AOD

Source: SMR

Figure 3. EAF Performance Comparison

The Figure 3 shows a comparison of EAF performance of three Stainless Steel producers. With the increased productivity of the AOD`s with top lances and automation systems the EAF became again the bottleneck in the production chain for Stainless Steel. Large EAF`s for C-Steel can be operated with large specific amounts of O_2 and foaming slag practice which is not feasible to the same extend for Cr-heats and cannot be compared.
To speed up the EAF the RCB Refining Combined Burner system has been adopted for Stainless melting. RCB's allow more O_2 and fossil fuel input and at the same time the RCB operation does not cause higher operation cost than the standard process.

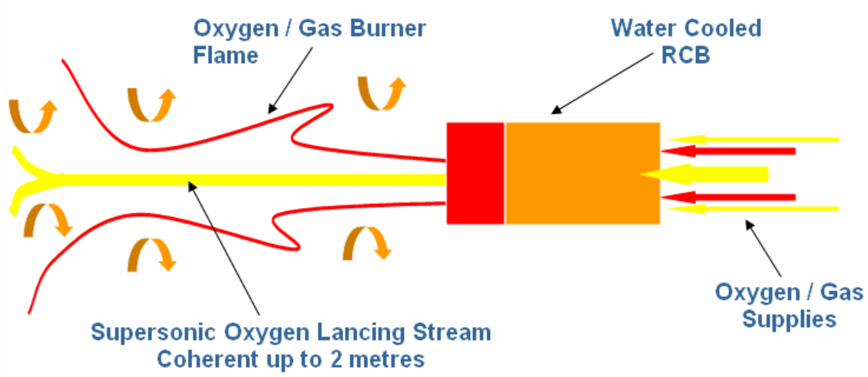


Figure 4. Principles of a Refining Combined Burner (RCB)

Figure 4 shows the RCB principle. RCB can be operated as a conventional burner as well as for refining with a compact O_2 stream blowing into the bath. In the refining operation mode the injected O_2 is shrouded by natural gas which forms a long compact coherent stream with high impulse of the O_2 on a length of at least 1,8 meters . Through a separate injection port solids, for example carbon, can be injected. Typically an injection system consists of one ore more RCB units installed in the panels as shown in Figure 5.

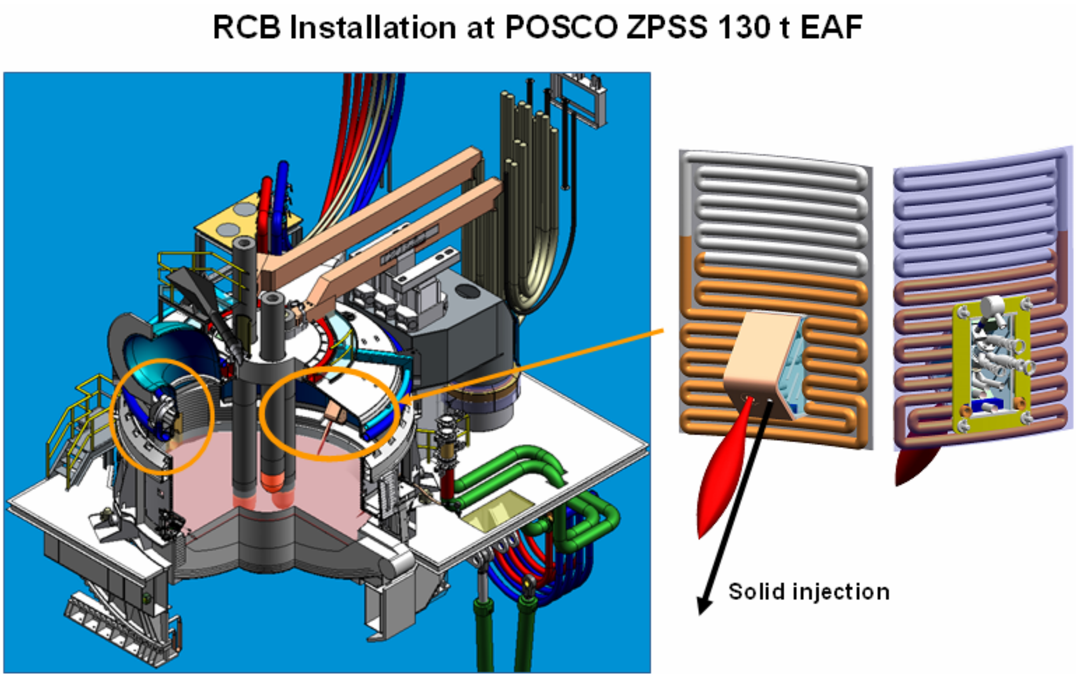


Figure 5. RCB Installation at POSCO ZPSS 130 t EAF

This Figure 5 also shows the installation of an injection system consisting of 3 RCB's in the EAF for POSCO ZPSS in China. The system shall replace the conventional wall burner and refining lances which are normally introduced through the slag door for refining.

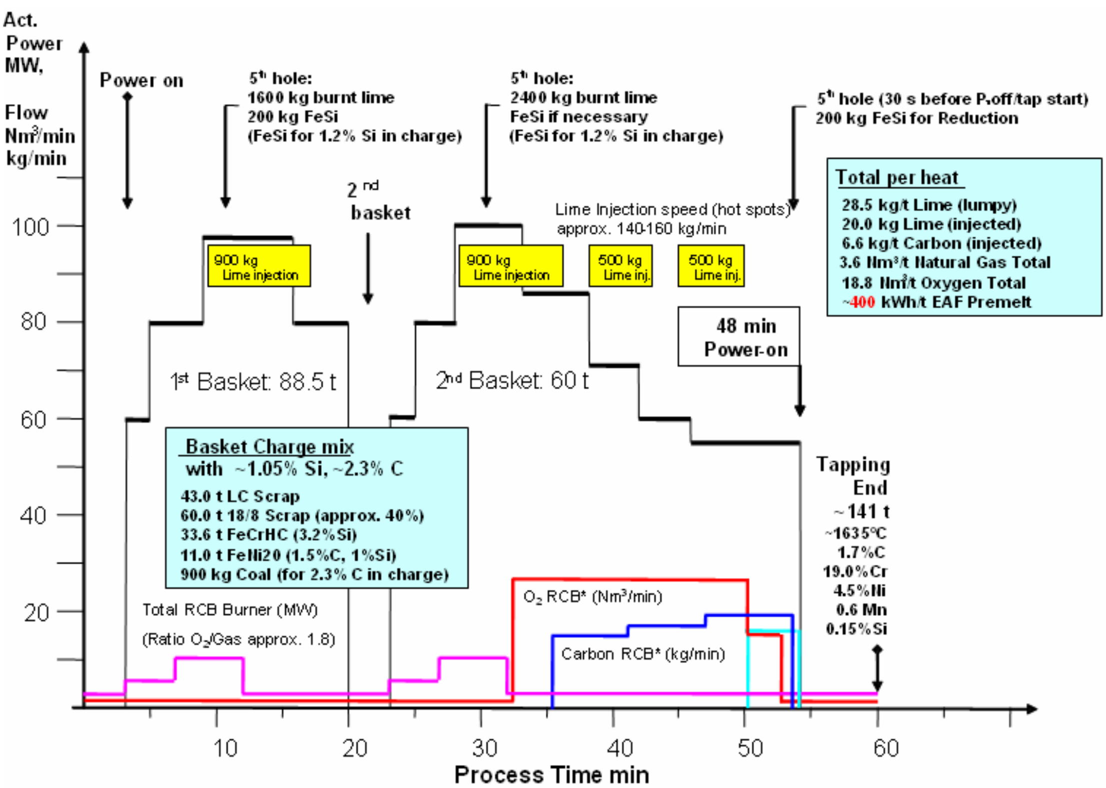


Figure 6. Typical Treatment Pattern of EAF with RCB system

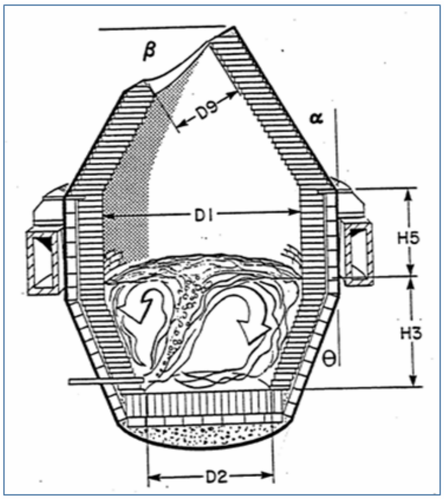
The main advantage of RCB can be summarized as follows:

- Burner and refining function with the same unit
- EAF always closed which reduces false air infiltration into the furnace and therefore off gas volume and scrap oxidation
- Higher safety and automation of the operation. No handling and observation of the operation during melting and refining by operator is necessary

Figure 6 shows a typical treatment pattern for a 140 t EAF with RCB containing all mayor procedures such as power input RCB burner and refining operation carbon injection and material addition. The target is a tap to tap time of 60 min or less and a power consumption of lower than 400 kWh/t and at the same time comparable FeSi consumption as in conventional systems with door lances.
With RCB operation, beside the improved productivity a decrease of the operational cost of more than 3 € / t steel is possible (based on European cost conditions).

3 INNOVATIONS FOR AOD PERFORMANCE IMPROVEMENT

In the following examples developments are described where a substantial improvement of the AOD performance has been achieved and can be expected. Figure 7 shows the original AOD vessel design goes back into the early days of AOD and is more than 35 years old. At that time this was considered the standard for AOD vessel design.



Important AOD Vessel Dimensions

H3…Bath Height

D2…Diameter Cylinder

D1 = 2 x H3

Upper and Lower Cone of approx. same Height

$\alpha = 30°$

$\theta = 22.5°$

Figure 7. Early AOD Vessel Design

SIEMENS VAI has supplied 20 vessels during the last decade with different vessel designs. The metallurgical results with a more flat bath design showed an improved process performance during decarburization. Figure 8 shows a comparison of 2 different large size units supplies by SIEMENS VAI.
The AOD supplied to a company in Finland is of classical AOD design with knapsack in the tuyere area whereas the other is the 180 t vessel of CARINOX. Despite the CARINOX vessel is 30 t higher in tap mass it is lower in height than the classical one. The bath height is lower than 2 m and the relation of bath diameter and bath height is approximately 2,2.

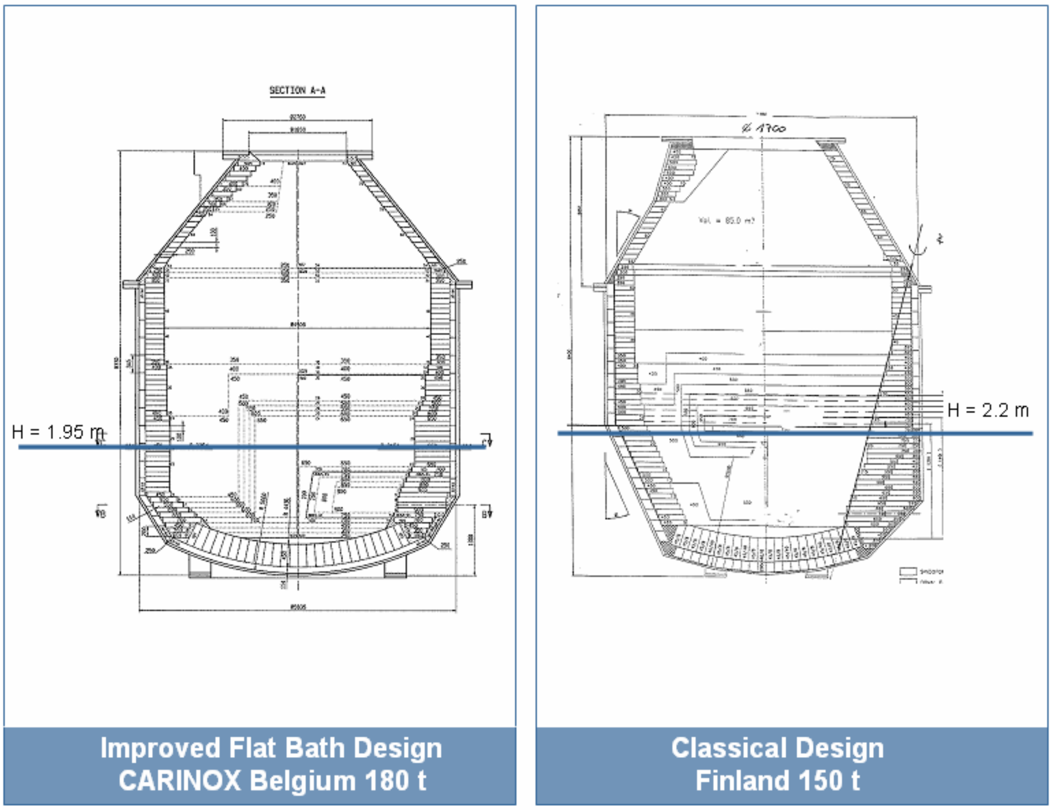


Figure 8. New AOD Vessel Designs by SIEMENS-VAI

The main effect of the new design on metallurgical performance is the lower bath height compared with the classical shape with its influence on the CO partial pressure of the gas bubbles in the bath during the decarburization. The lower CO-partial pressure influences the decarburization and improves the CRE Carbon Removal Efficiency with the following advantages of the flat bath AOD design:

- Higher CRE and lower Cr-oxidation
- Lower FeSi and flux consumption
- Lower refractory wear
- Lower gas consumption
- Shorter DEC time and higher productivity

Beside the decarburization there are some practical advantages for the refractory lining because the conventional knapsack is not applied any more:

- Easier bricking in tuyere zone
- No special bricks necessary
- Less cutting of bricks necessary during relining
- Shorter relining time and less manpower for relining required

The second example shall demonstrate that substantial improvements of AOD performance are also possible by the revamping of old existing plants. With Taiyuan Iron and Steel Corp. Taiyuan, P.R.C SIEMENS VAI realized a revamping of 3 existing 45 t small size AOD`s mainly by the installation of 3 new top lances , 3 new addition systems and a process automation (Level 2) as shown in Figure 9.

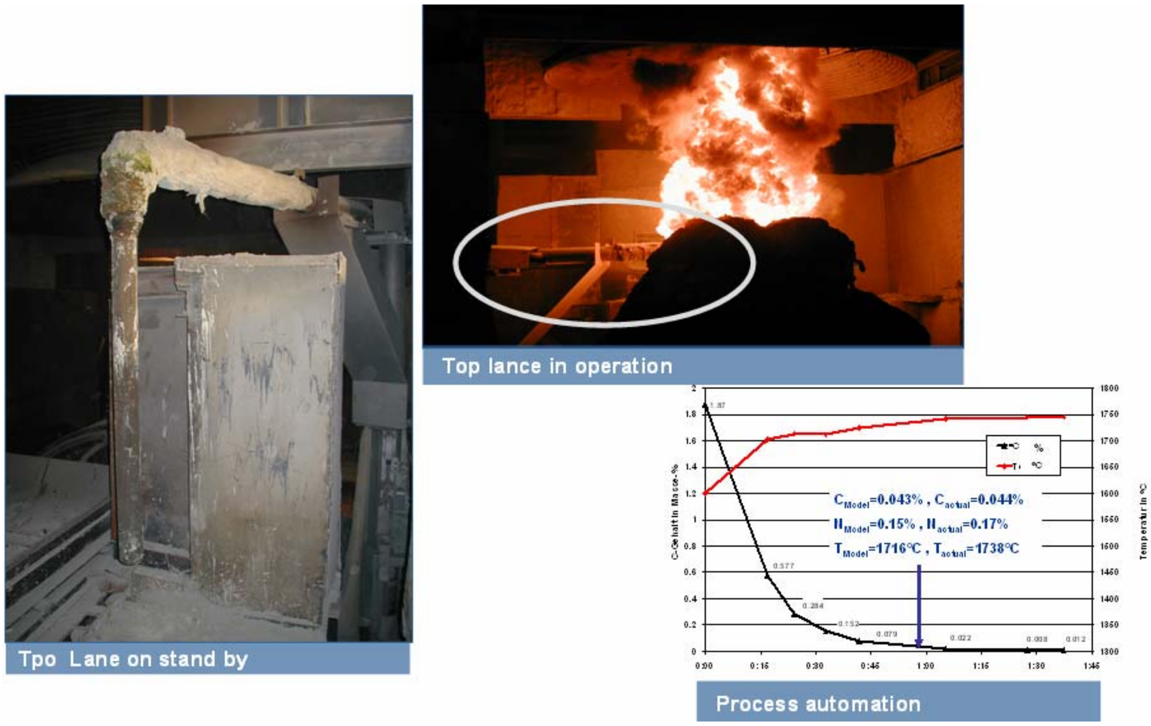


Figure 9. Taiyuan AOD Revamping – TOP Lances, Addition System and Level 2

The overall improvement of consumption and productivity were significant. On European basis the operation cost dropped by more than 6 € / t steel and the productivity increased by more than 25 % in this plant. Not regarded in this calculation is beside the productivity also the deposit cost decrease due to the fact that the improved performances caused substantially lower slag amounts by about 15 %.One additional remarkable point was the increase of the lining life of the working lining from 110 to 150 heats achieved already during the hot commissioning.

Despite all improvements in the field of refractory performance the AOD will remain the metallurgical unit with the highest refractory wear of all in the Stainless Steel meltshop because of the AOD characteristic process requirements. The vessel has to be changed after a campaign of 100-200 heats and a substantial life time increase cannot be expected in the future due to the necessary high process temperatures during decarburization.

Therefore developments for the increase of the vessel availability are of interest. The vessel exchange nowadays normally takes 1-2 hours from the end of tapping with the old lining until the new vessel can be charged. The time consuming procedures are mainly the manipulations done by hand and tools:

- Loosening and fastening of the screws for the suspension
- Disconnection and connection of the flexible hoses of the tuyeres
- Reheating of the already preheated new lining before charging

For the plant performance it would be of interest to change the vessel during two sequences of the continuous caster in a time not longer than the re-stranding time of the CCM. In this case a vessel exchange would not influence the production flow any more and would have no influence on the plant productivity any more. Therefore the task for the exchange time should not exceed 40 minutes from end of tap to charging of the newly relined AOD vessel.

VAI Siemens has investigated possibilities for this customer request. The solution could be an automatic fastening system in the trunnion ring in combination with an automatic media coupling system as shown in the Figure 10 and 11 .The system shall allow to change the vessel without manual operation by the personnel and therefore in addition to improve the safety in the plant considerably.

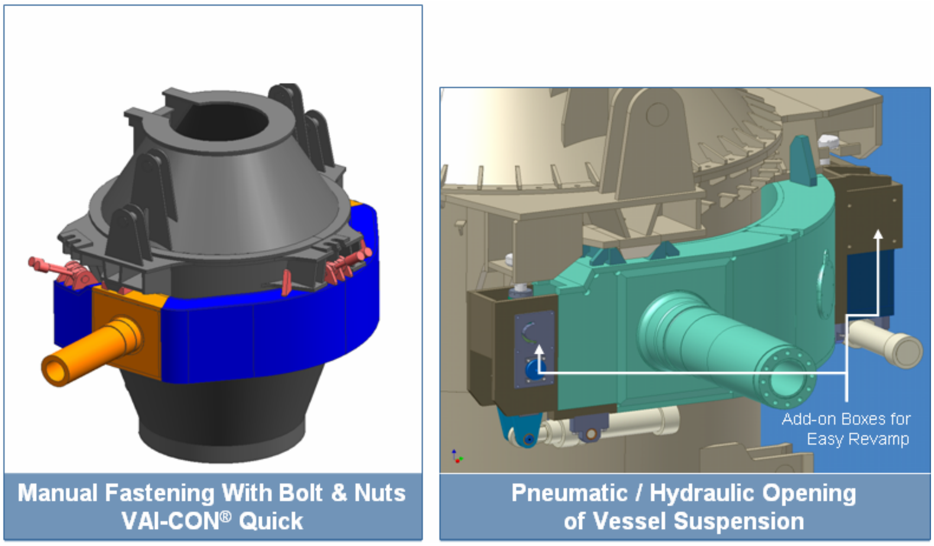


Figure 10. Comparison of Manual and Automatic Vessel Fixation System

Figure 10 shows a comparison between the conventional suspension VAI Con Quick which requires manual manipulation and the automatic system where the vessel is fixed in trunnion ring springs which can be released hydraulically or pneumatically. The opening of the fastening elements shall be performed by pressing a button in the main control room only. With this system an existing large scale converter is already in operation in Sweden. The element could be installed also at existing trunnion rings in case of revamping projects .

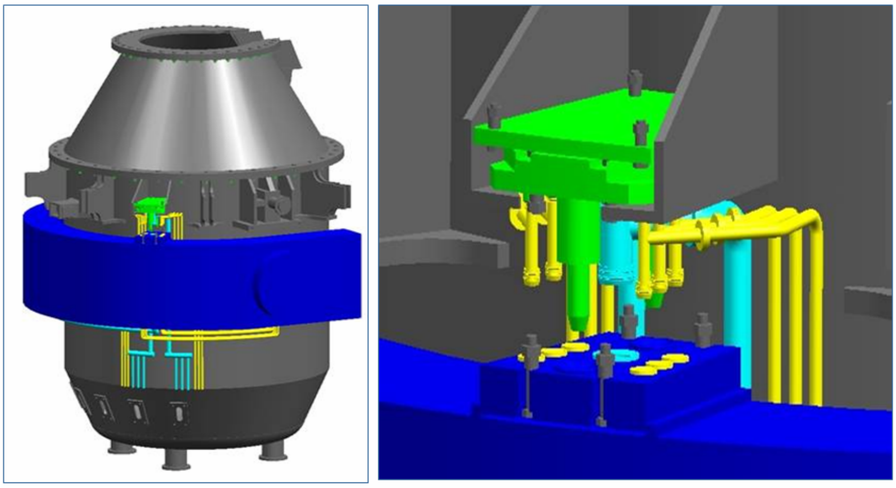


Figure 11. Automatic Gas Coupling System VAI-CON® Joint

Based on the experiences with automatic coupling systems for gases and fluids for ladle stirring plugs and top lances of converters SIEMENS VAI has developed an automatic coupling for the submerged side tuyeres and eventually a cooling water circuit for the trunnion ring. The piping and the connection of the gas supply to the tuyeres can be already done during relining and preheating of the vessel outside the trunnion ring before the vessel exchange.

Figure 11 shows the vessel exchange procedure in principle and summarized the advantages of the system. Principally when the old vessel is taken out of the trunnion ring of the vessel transfer car by crane the second already preheated vessel shall be already in stand by position with the second crane near by. The whole exchange procedure shall be so short that a reheating in the trunnion ring to charging temperature shall not be necessary any more.