Production of stainless steel has steadily risen since 1990. Traders and producers alike forecast that in 2010 some 30 million t of stainless steel will be sold.

Around 75% of all stainless steel products are flat products. Current production breaks down into 55% austenitic grades, approx. 41% ferritic and 4% other stainless steel grades.

So far, high-alloy stainless steels were overwhelmingly manufactured by the large industrialized countries, but meanwhile also smaller steel producing countries have started making these grades.

Steel producers face increasing competition on the global market.

To meet this challenge it is crucial to apply suitable techniques and process lines when producing these quality products and to achieve low production costs.

SMS Demag has developed process lines that allow for the availability of raw materials, infrastructure and energy supply so that high-quality materials can be produced at low cost.

A major factor in contributing to this approach is our permanent, close cooperation with renowned stainless steel manufacturers such as ThyssenKrupp, Arcelor, Posco, Acerinox and Yieh United.
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AOD-L CONVERTER

As a rule, stainless steel production in an AOD-L converter consists of the four phases: decarburization, reduction, desulfurization, and fine-tuning.

Decarburization involves blowing oxygen into the melt through the side nozzles and the top lance. Additionally, as the carbon content falls, inert gas is directed through the nozzles and the lance to reduce the carbon monoxide partial pressure. The mix is adjusted to the metallurgical requirements in the course of the process. Significant here is the aim of reducing the carbon content as far as possible while achieving the lowest possible level of chromium slagging. Typical final carbon contents for austenitic grades are around 0.015%.

Reduction starts when the final carbon content is reached. It serves to recover the chromium from the slag generated during the decarburization process. Experience shows that reduction recovers some 97 - 99% of the chromium.

The necessary desulfurization can be achieved by adding extra ferrosilicon and lime at the same time as homogenizing the bath with argon.

Desulfurization in the AOD-L converter guarantees sulfur concentrations of less than 0.005%.

Finally, the fine-tuning phase ensures the required steel composition and the casting temperature are achieved.

MRP-L CONVERTER

Stainless steel production in the MRP-L converter consists of two phases: decarburization and reduction.

Contrary to the AOD-L process, decarburization here already ends at approx. 0.25 - 0.35% C. (This carbon content is roughly equal to the carbon balance at normal atmosphere, a temperature of approx. 1,720° C and a chromium content of 18%.) Reduction starts as soon as the target carbon content is attained. That requires using a reduction agent such as ferrosilicon.

Rinsing with inert gas adds ferroalloys to achieve the corresponding steel analysis.

To reduce the carbon content to lower values it is necessary to decrease the CO partial pressure. This happens in the downstream VOD plant.

A corresponding reduction of the CO partial pressure in the MRP-L converter would require an increased consumption of inert gas, increasing the production costs per ton of steel.
Process lines are divided into DUPLEX lines (single-stage decarburization) and TRIPLEX lines (two-stage decarburization).

The material used in both cases can be either pig iron or scrap.

SMS Demag uses the AOD-L converter for DUPLEX lines, and the AOD-L or MRP-L converter with downstream VOD plant for TRIPLEX lines.

AOD-L – Argon oxygen decarburization with lance
MRP-L – Metal refining process with lance
DDD – Desulfurization, desiliconizing, dephosphorization
Designing the layout of a stainless steel works starts by determining the product range, the annual output and the most effective process line for these purposes. It is chiefly the material flow that dictates the arrangement of the various machine units.

ARRANGEMENT

We offer two installation options for the converter plant.

- Freestanding converter in the steel-works building
- Converter between rows of columns

Which arrangement is most suitable depends on the type of converter, the use of blow lances and sub-lances as well as the building or crane track heights.

Frequency of CONVERTER REPLACEMENT

While the service life of the fireproof lining in an MRP converter is approx. 1,200 heats (today, with slag splashing, even up to approx. 3,000), an AOD converter must be replaced after approx. 150-200 heats.

To ensure a minimum production stoppage, the complete AOD converter is usually replaced.

If the converter is installed between columns, it is replaced using a special change carriage, while freestanding converters are replaced using the crane.
Freestanding converter.

Converter between columns.
THE CONVERTERS

CONVERTER TYPES

Converter vessel shapes have in recent years changed in line with metallurgical knowledge.

Today, mainly AOD and MRP converters are used in stainless steel production.

The differences between the two converter systems are reflected in:
- the way the oxygen and/or inert gas is introduced;
- the design of the vessel;
- the reaction volume resulting from the vessel shape.

The AOD-L method involves blowing most of the oxygen for the decarburization through the side nozzles. The top lance is only used to support the process in the starting phase of decarburization.

Conversely, the MRP-L method introduces the oxygen only through the top lance. To ensure an optimal mixing of the metal bath, inert gas is injected through the converter bottom.

It is usual today for AOD converters to reach sizes of 180 t of liquid steel. Just as large are MRP converters that have also increased in size from 5 t to 170 t.

The specific volume (ratio of inner volume of the newly bricked-up converter to the total tap weight) is currently approx. 0.55 - 0.6 m³/t for AOD converters and approx. 0.6 m³/t for MRP converters.
Development of AOD converters.

CLU 1973
- Bottom blowing with oxygen-steam mix
- High chromium slag formation
- High Si consumption for reduction
- High hydrogen content

Combined blowing 1977
- Bottom and top blowing with $O_2$
- Lime injection
- Post-combustion
- Very high rate of scrap use

KMS converter 1978
- Bottom and top blowing with $O_2$
- Coal injection and/or scrap pre-heating
- Lime injection
- Post-combustion
- Very high rates of scrap use
- Large quantities of valuable offgas

MRP 1983
- High mixing energy
- Low carbon content
- Low gas content
- Very low sulfur content
- Fewer inclusions

Development of MRP converters.
Frequent replacements demand easy-to-handle converter vessels. That is why SMS Demag fits its AOD converters with a top cone attached by a flange. This makes it easier to break off the worn brickwork. It is only natural that the high temperatures generated during steel conversion cause extreme strains.

SMS Demag always uses heat-resistant steels of grades P 355 NH or P 460 NH for the vessel jacket and the trunnion ring. These materials have repeatedly proved their worth in practical operation.

**The SIDE NOZZLES of the AOD converter**

Shell-type gas nozzles are used to inject oxygen into the AOD converter. They consist essentially of a copper inner tube and a stainless steel tubular shell.

The oxygen is injected through the copper tube. There is a circular gap between the inner tube and the shell, where AR / N2 protective gas is channeled to cool the nozzle. The length of the nozzle matches the thickness of the brickwork.

Depending on the converter size, a different number of nozzles is installed. Their special arrangement and operation under corresponding pressure ensures the right volume throughput for an adequate mixing of the bath and decarburization.
The **TUYERE BRICKS** of the MRP-L converters

To achieve a homogeneous composition and even temperature in the melts, inert gas in the form of argon or nitrogen is injected into the melts through the converter bottom. It takes special tuyere bricks that are fitted in the brickwork of the converter bottom for this purpose. Here again, the number of these bricks and their arrangement depends on the converter size. Tuyere bricks are available in single or multiple-tube versions.
THE CONVERTERS

TRUNNION RING TYPES

To support the converter in the blowing position, SMS Demag uses two types of trunnion ring. What determines the version to be used is the installation situation of the converter in the blowing stand and the associated options for removing the converter.

Closed trunnion rings without water cooling are used for converter arrangements directly accessible to the crane.

Contrastingly, U-shaped, water-cooled trunnion rings are ideal for converters installed between columns. The water cooling prevents the trunnion ring from expanding due to the inevitable temperature differences between the outer and the inner flange.

FIXING TYPES

Depending on the converter design, size and installation situation, SMS Demag offers various types of fixing systems. The preferred way to fix converters in U-shaped trunnion rings is with manual-release hinged bolts. However, AOD converters in closed trunnion rings can be fixed with hinged bolts or with special SMS Demag hydraulic clamping devices.

The hydraulic clamping devices feature three trunnion pins welded to the converter and provided with special sliding blocks. These sliding blocks are inserted into the bearings on the trunnion ring and fixed in position by hydraulically driven clamps. To remove the converter, the clamps are opened and a crane lifts the vessel out of the trunnion ring.
Given that it only takes 60 minutes to change the converter, this fixing type is very popular.

MRP converters designed as replaceable converters can be fixed with tendons and load pin.
Due to the injection of process gases through the side nozzles and the resulting bath movements, extreme dynamic strains and vibrations act on the AOD converter drive.

Consequently, the tooth flanks of the drive wheels are subject to severe micro-movements with an extremely thin lubrication film, which in turn leads to early wear.

Now available is a new system for fixing the bull gear against the pinions. A toothed segment of a blocking arm engages with the teeth of the bull gear and blocks it in the blowing position. This means the forces acting on it are spread over several teeth of the bull gear, so that both the bull gear and the subsequent gear units are under less strain, minimizing wear.

Equally ingenious is the torque support of the new drive. The entire drive is supported as a riding unit on the drive journal. The reaction forces resulting from the driving torque are channeled through the housing into the torque support and from there in the form of horizontal forces into the foundations.
A converter tilting drive on the Hičkenbach shop floor.
THE LANCES

THE SUBLANCE

As a result of today’s increasing automation of the blowing process, sublances are used more and more in stainless steel production for measuring temperatures and taking samples.

The key advantage of sublances is that they precisely measure the temperature and the chemical composition of the melt prior to the start of the reduction process. The values measured indicate the degree of chromium slag formation, which is crucial to the subsequent process control.

It is no longer necessary to turn the converter to a horizontal position for temperature measurement and sample taking. This reduces the tap to tap time.

Because the point in time of sublance measurement in stainless steel production is not as important as it is in the LD process, sublances are often installed together with blowing lances on a mobile carriage.

The same opening can be used for the sublance as for the blowing lance.

THE BLOWING LANCE

Standard oxygen lances like those used for LD converters are also ideal for AOD-L and MRP-L converters. Although it was usual in the past to use almost exclusively single-hole nozzles in blowing lances for the AOD-L process, here too a trend is emerging toward multiple-hole nozzles.

The distance between the blowing lance and the bath surface is significantly greater than it is in the LD process. That means lower deposits of steel and slag on the lance so that the service life of the blowing lances is much higher than it is in the LD process.

Blowing lances for AOD-L converters are replaced on average after about 800 heats.
Blowing lance and sublance.
REPLACEMENT OPTIONS

The faster the changeover takes place, the shorter the production stoppage. We took this into account right from the start of developing our converter fixing systems. If the converter is installed in a freestanding way in the plant, the fixing is released and the crane lifts the converter out of the trunnion ring, transports it to the wrecking stand and puts it down there. Then the crane picks up the newly supplied, pre-heated converter and places it in the trunnion ring.

If the converter is installed between columns, the changing carriage is driven underneath the converter, the hinged bolts are released and the hydraulic lifting system on the changing carriage raises the converter out of the U-shaped ring and into the reach of the crane. Then the crane lifts the converter off the changing carriage and transports it to the wrecking stand.

The new converter is installed in reverse order. Subsequently, the changing carriage can either be driven to a parking bay, or the crane can pick it up and place it in a parking position.

THE VALVE STATION

The valve station controls the process gases that are injected from the sides or through the bottom of the converter. Also integrated here are the process controls for the blowing lances.
Transporting the changing carriage using the crane.

P & I diagram.

Arrangement of the control valves.

Container with complete control station.
Automation systems in modern steelworks are arranged in various levels of hierarchy. Building on a long experience in constructing steelworks, SMS Demag has developed a special automation concept.

The automation system developed for the AOD/MRP process is based on levels 0 – 1, (basis automation) for process control and visualization as well as on level 2 (technological process control system, TPCS) for optimizing the technological process.

**Basic automation**

The basic automation system uses a SCADA system. This manages, documents and visualizes plant-specific and technological data. The visualization level provides access to plant-specific data stored in the real-time database as well as to technological data stored in a relational database.

Process-related data such as

- measured values,
- process events,
- process target values from tables,
- process target values calculated from metallurgical process models

are therefore available for quick access by all connected systems.
SMS Demag automation system with integrated process tracking (tracker) and common visualization (Common HMI).

Hierarchy of the SMS Demag automation concept.

Automation structure

Production planning
Production coordination

Operator guidance
Process optimization

Process visualization
Melt tracking

Process control & Instrumentation

Other computer systems

Technological control system

Relational database system

Metallurgical process tracking

Process models

Model interface

SCADA system

Common visualization

Process tracking

Real-time database

Data transfer

Process control and instrumentation

Data transfer

SMS Demag automation system with integrated process tracking (tracker) and common visualization (Common HMI).
Technological process control system TPCS

The core of TPCS is the mathematical AOD/MRP process model developed by SMS Demag. It is based on the theory of the critical point of the decarburization reaction. The model supports extensive and fast decarburization, minimized treatment time and improved chromium slagging. That also saves reduction agents and process gases. Additionally it improves the thermal operating conditions of the converter and increases the durability of the refractory used in the converter vessel. Determining the critical point of the decarburization reaction of each melt makes it possible to forecast the process including all technological process stages.

The process forecast calculation covers the entire process technology. It starts with the pre-treatment data of the melt such as temperature, steel/slag weight, last current analysis and ends with completion of the melt.

The various treatment sequences of the melt are checked to ensure the target analysis, the required tapping temperature, the target steel weight and the planned time for transfer to the down-stream machines.

Our dynamic process model optimizes the melt treatment. Moreover it checks the chemical reactions in the melt.

The carbon and oxygen contents as well as the energy balance are determined at 10-second intervals. That is how the system uses the melt starting data to calculate the current carbon and chromium content in the bath along with the current temperature.

Exhaust gas analysis measurement helps determine the rate of decarburization from the carbon content in the exhaust gas. The basis for assessing the oxygen quantities for oxidation is provided by the oxygen balance. It is used to calculate the oxidation rate for chromium and the total chromium loss. That also applies to the elements Mn and Fe.

The main task of the process gas control function within the dynamic process control system is checking the quantity of O₂ to be introduced into the melt. This ensures that decarburization takes place under optimum thermodynamic and chemical conditions in the shortest possible time.
Optimum decarburization conditions are achieved when the oxygen throughflow at the moment of critical carbon content (critical point) is reduced in such a way that the formation of CO reaches its optimum and a sufficient reaction dynamic is maintained.

Furthermore the model determines what materials must be added to aid reduction and desulfurization as well as for alloying and to adjust the temperature. Throughout the course of treatment, the operator receives information on the calculated target values as well as the current values achieved. Then, at the end of a melt treatment, the system compiles a complete report listing all activities and consumption figures.