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SA's ferroalloy furnace technology

Renier Meyjes, Metix's MD.

A majority share of Metix, the technology leader in smelters and submerged arc furnaces in Southern Africa, has been acquired by the German-based SMS Siemag Group. *MechTech* talks to Reinier Meyjes, Metix's MD, about South Africa's niche ferroalloys furnace technology, and the attraction of a partnership with a global giant.

Pat Davies and Reinier Meyjes, the current marketing and managing directors of Johannesburg-based Metix, started working together at Samancor back in 1974. "We built an 81 MVA ferromanganese (FeMn) furnace in Meyerton in 1978. At the time the company intended to build several more, but only one was ever completed. FeMn is used in most carbon steels in the 2% range, but it seemed to be more cost effective to export the ore for processing closer to overseas steel plants than to export FeMn," Meyjes explains.

But since around 18% ferrochrome (FeCr) is required to make stainless steel, coupled to the fact that SA has the largest chromite reserves in the world, the market for FeCr smelters for local beneficiation of chromite ore has mushroomed. Participating in this growth, Metix has emerged as one of the world leaders in FeCr smelting technology, and the Southern African market leader for ferroalloy AC submerged arc furnaces. "With the SMS Siemag merger, we have also combined our reference lists," Meyjes tells *MechTech*. "And while they have hundreds more references than us, if you look at the references in the last six years, a significant percentage is ours," he adds.

Notably, Meyjes lifts out:

- The recently completed upgrading of IFM's two 66 MVA FeCr furnaces, which include new copper centre sections for the furnace roof, additional charging chutes equipped with solid copper feed chute tips, and modifications to the four furnace gas-cleaning plants.
- The up-rating of the electrode columns on two existing furnaces at Xstrata's Lion plant and the replacement of electrode columns on another two furnaces at Xstrata's Wonderkop plant.
- The upgrading of two SiMn furnaces for Mogale Alloys.
- A 600 000 tpa chromite ore pelletising and sinter plant, as part of the Tswelopele Project, being constructed for the Xstrata Merafe PSV in Rustenburg. This is the sixth chromite pre-treatment plant constructed by Metix since its formation in 2003.
- The current rebuild and upgrading of

Metix's upgrade of IFM's two 66 MVA FeCr furnaces had already enabled the company to achieve 12% of its target production cost savings by January of this year.

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goes global

a ferrochrome furnace for Zimasco in Zimbabwe.

Globally, Metix technology and design engineering is the basis for the biggest SiMn furnace in China for CYMCO, which is now in production in Jianshui. This 67,5 MVA furnace is equipped with the full range of Metix technology equipment: a set of electrodes; a furnace roof with a copper centre section; and a furnace shell with a freeze lining.

Metix has also supplied bottom electrode assemblies for SARDA in India, and is currently in the process of manufacturing electrode assemblies for four 54 MVA CaC_2 furnaces and two 36 MVA FeSi furnaces in China.

In describing Metix's modern furnace technology, Meyjes cites the recently completed IFM refit: "Energy efficiency has become more important than anything else in the furnace industry in recent times. By using less energy, you can produce more from a plant with a given installed capacity. This results in a double competitive advantage because by using less energy, the operating cost per ton also decreases proportionally," he explains.

But while improving energy efficiency is very important, another key driver is to improve the availability of the plant. Downtime kills profitability and all furnaces need to be constantly running at near to their installed capacity in order to remain competitive.

"The IFM furnaces were originally not one of our designs," says Meyjes. "The first thing we did to improve their efficiency was to improve the incoming feed of the furnace burden." In ferroalloy furnaces, the feed material (burden) is fed into the furnace through charging chutes around the electrodes at the top. The ore is heated, melted and reduced as it moves downwards. Then the molten ferroalloy and slag are tapped off via tap holes. The smelting (reduction) process gives off very hot carbon monoxide (CO) gas, which rises up though the solid material of the burden. "Typically this gas is above 1 000°C, and by transferring as much of its sensible heat as possible to the burden entering the furnace, the smelting efficiency of the whole process benefits in two ways. Firstly, less electrical energy is required to smelt the hotter burden, and secondly, less energy is transferred to the water in the scrubbing plant," he explains.

Using 3D modelling for burden profiles and CFD for gas flow analysis, the shape of the burden surface and the potential for improvement of gas flow above the burden was studied. Through this process Metix was able to determine the best arrangement and number of feed chutes into the furnace, even out the burden profile, maximise the recovery of sensible heat from the off-gas and reduce the temperature of the gas entering the scrubbing plant by several hundred degrees.

In addition, because the roof is a fully enclosed design, the CO off-gas is not combusted in the furnace. After scrubbing, it can therefore be used to generate power. IFM has installed a co-generation plant to make best use of the energy available from combusting this off-gas. It is using ten J620GS Jenbacher gas engines to recover a total of 11% of IFM's power draw. "If you don't use this gas, it would simply be vented to the atmosphere and flared after scrubbing, but every MW that you can feed back into the grid indirectly reduces the energy consumption of the furnace – "and the investment is now well into cost-effective territory," Meyjes suggests.

As an additional spin off, by reducing the temperature of the off-gas as it comes through the burden, you assist the performance of the gas scrubbing plant. Because of emissions legislation, producers are not allowed to run a furnace unless you clean the gas. "So a shut-down in the gas scrubbing plant will result in the furnace being shut down," he continues.

Metix introduced an improved design to quench the off-gas leaving the furnace. "This allows the Venturi system removing the particulate from the gas to become more effective," he says. "Typically, in the Venturi system, gas is accelerated through a narrow opening of the Venturi where it is contacted with water. The energy in the Venturi throat breaks up the water into small droplets of about the same size as the solid particles in the gas, which reduces the surface tension of the individual droplets and facilitates efficient capture of the small dust particles. If the temperature of furnace gas entering the Venturi scrubber is too high, it evaporates the small water droplets into steam, which cannot then capture small solids," he explains.

Metix's use of copper for the roof sections of closed furnaces significantly improves the cooling performance and, because welding is completely avoided, cracking and leaking is prevented.

The quencher's role is to reduce the off-gas' inlet temperature to enable the Venturi to do its job properly. The duct between the quencher and the furnace is designed to be removed for easy, safe cleaning and ducts after the quencher are kept clean by continuous water sprays. "Because IFM no longer has to regularly shut down its gas scrubbing plants to clean out dust build-up, furnace availability can be significantly improved," claims Meyjes.

But the big development for FeCr and SiMn furnaces involves closing the roof and Metix's innovative use of copper to improve the reliability of closed furnaces. "Almost all new furnaces are built with a closed roof, but we still have many that were previously built using a semi-closed roof design," Meyjes advises *MechTech*. "These are ready for upgrading, but a rebuild takes time, up to three months, and the downtime cost is a killer for such projects," he adds.

In a semi-closed furnace, air is drawn in through the sides of the furnace, which causes combustion – oxygen in the air immediately oxidises the CO into CO_2. The burnt gas and dust is then sucked through gas off-takes in the roof to a bag house. The same amount of CO_2 gas is produced by the smelting process in closed and open furnaces, but the air sucked into a semi-closed furnace changes the conditions under the roof of the furnace from reducing to oxidising. FeCr, semi-closed furnaces have fallen out of favour because of the formation of chromium-six (Cr^{+6}) compounds, which were the carcinogens at the centre of the +US$300-million class lawsuit featured in the film 'Erin Brockovich'. "There is no way to avoid the formation of Cr^{+6} in a semi-closed FeCr furnace. Cr^{+6} is particularly dangerous because it is soluble in water, so it is easily absorbed by the body either by drinking contaminated water or by breathing in Cr^{+6} in the dust," Meyjes points out.

The natural state of chromium (in chromite) is chromium-three (Cr_2O_3), which is a very stable compound. The inert properties of Cr^{+3} is why chromium is used in all stainless steels, but at temperatures above about 600°C, typical in a semi-closed furnace, chromium-six compounds (eg, CrO_3) will form. "And while a bag house might be able to capture +99% of the CrO_3 dust, the remaining chromium-six is released to atmosphere. The only way to deal with it is to dissolve it in water, for example, by means of a wet scrubber plant. Wet dust and the dissolved Cr^{+6} can then be treated to convert the Cr^{+6} back to Cr^{+3}, after which it can be safely stored in lined facilities. You cannot ever release Cr^{+6} compounds into the atmosphere without it eventually ending up in water courses when it dissolves in the rain," he warns.

In contrast, the atmosphere in a closed furnace is reducing, not oxidising. The reducing conditions inside the closed furnace prevent Cr^{+3} from being oxidised to its Cr^{+6} state. So by converting a furnace to a fully closed design there is a double benefit: you avoid forming and having to deal with Cr^{+6}; and you prevent the CO gas in the furnace from burning to CO_2, ie, you gain a combustible gas ideal for cogeneration.

While upgrading two of Hernic's furnaces to closed furnaces in 2009, Metix introduced another first-of-a-kind innovation for a FeCr furnace, a centre roof section made of copper. The section of a furnace roof between the three electrodes is the hottest part of a furnace. The heat is most intense in the area below and between the three electrodes. This area can easily see temperatures of 1 000-1 200°C. Also, a closed furnace roof is lower than a semi-closed roof design, in places less than 2,0 m to the burden level.

Strong magnetic fields exist between the furnace electrodes. To avoid unwanted electrical heating, this section is often made from non-magnetic stainless steel. "The inside of the roof is refractory lined to protect the steel, and water cooled from the outside to remove heat and prevent temperature build-up," Meyjes explains, "but due to the local harsh conditions, refractory lining eventually gets damaged and inside roof areas will become exposed causing major challenges."

Stainless steel expands much more than carbon steel and any unprotected area will experience a huge temperature differential across its typical 8,0 mm thickness. While the stainless steel material may, in the short term, be able to withstand the temperatures, it cannot withstand the expansion stresses caused by the massive temperature differential, typically hundreds of degrees. So stainless roofs tend to crack and leak soon after refractory failure, particularly at exposed welds on the inside.

"Since we had been using water cooled, solid forged copper very successfully for our pressure rings, we decided to try using it for the roof itself. In our copper roof design, the temperature differential never goes above 70°C, because of the vastly better thermal conductivity of the copper material. The transfer of heat through the roof and into the cooling water is much more efficient," he informs *MechTech*.

In addition, to avoid welding, the entire centre circle of the roof is made from a solid forged copper slab. This is then drilled to create the cooling water channels. "We fabricate these in China at a company that specialises in providing such water cooled copper panels for blast furnaces in the steel industry. They keep their techniques secret, so I don't know how they do it, but they do it well," Meyjes claims. "For example, they drill two overlapping holes to make a figure-of-eight shaped channel through 6,0 m of material with an alignment accuracy better than 1,0 mm per metre of hole depth." The purpose of the elongated (figure-eight) water channel is to allow the thickness of the copper slab to be reduced, by more than 10%, to cut down on the copper material cost.

Also, on the face inside the furnace between the cooling channels, which are typically 100 mm apart, grooves are cut into the copper. These grooves

Between the cooling channels, which are 100 mm apart, dovetails are cast into the inside surfaces of the copper and filled with refractory material. This prevents the refractory from falling off the underside of the roof and ensures that the cooling efficiency does not degrade with time.

are filled with refractory material and a dovetail shape prevents refractory from falling out. The refractory is actually not needed to protect the copper. Its purpose is to reduce unnecessary heat being taken up into the cooling water. "These roofs should never need relining. The two Hernic furnaces we upgraded in 2009 have now been running trouble-free for over two years at full capacity," Meyjes points out.

Published performance improvements at IFM as a result of Metix's recent upgrade of the company's two 66 MVA FeCr furnaces show that by January of this year, the company had already achieved 12% of its target production cost savings. Also according to IFM reports, 'The furnace rebuilds were all completed within budget and on schedule'.

"Due to the remarkable success of Metix in the local market over the past eight years, SMS Siemag is fully comfortable with the current management and structure of Metix," says SMS Siemag director for technical sales, Dr Rolf Degel. "The SMS Group has full confidence and trust in the capabilities of the Metix management team," he adds.

"We are proud to be one of the shining lights in the SMS group," concludes Meyjes. "The working relationship between Metix and the SMS Group has already proven to be mutually-beneficial, and we are looking forward to a transparent and prosperous partnership spanning decades into the future," he concludes. ❑