Three Advances in EAF Melt Shop Maintenance

By Wallace D. Huskonen

Maintenance in the electric arc furnace melt shop was a theme addressed by several speakers at the Sixth European Electric Steelmaking Conference, held concurrently with the Metec 99 trade show in Dusseldorf, Germany, June 14-15, 1999. The conference was organized by the German metallurgical association VDEh as a forum for international experts to report on new and improved processes, equipment, and technology.

Three developments discussed there have reduced maintenance effort and cost at steel mills in Europe, Mexico, and the United States. They include a new design for bottom anodes in DC furnaces, techniques for refractory maintenance, and longer-life filter media for baghouses.

Improved Filter Bag Life

Representatives from Tuscaloosa Steel and W. L. Gore & Associates reported on how high-temperature membrane filter media improved bag life in the Alabama plate producer's EAF pollution control system.

TSC began operating its EAF melt shop in October 1996. The installed air-pollution control system is composed of a 2.4 million Am^3/h (1.4 mm ACFM) reverse-air baghouse and associated fume-collection equipment and ductwork. Fumes are collected directly from the furnace shells, ladle met furnace hood, melt shop scavenger duct, and roof canopies located above the EAFs and caster turret.

Due to frequent high-temperature conditions at the baghouse, operation of the air-pollution control system had to be modified to protect the conventional low-temperature media filter bags originally installed. The baghouse was operated at higher than original design airflow rates, at times sacrificing suction pressure, to support higher levels of dilution air.

With the new high-temperature membrane filter media, required dilution air is reduced and optimal baghouse suction pressure is consistently maintained, reducing fugitive emissions. The combination of less dilution air and lower pressure drop across the bags reduces overall APC system power consumption.

The high-temperature membrane filter material shows better resistance to light spark damage, reducing the frequency of bag repairs and changes and maintenance costs.

The heart of TSC's melt shop is a twin-shell DC electric arc furnace, designed and built by MAN GHH (now part of SMS Demag Inc.) Each shell is 7.1 meters in diameter with a single 710-mm (28-in.) electrode serving both shells. The furnaces feature eccentric bottom tapping (135 mt per heat) with a 30-mt liquid heel remaining in the furnace. In addition to the heat supplied by the two 58MVA parallel transformers (116 MVA total), oxy-fuel burners are used at the door and in the EBT area. Furnace power input averages 84 MW during melting and 70 MW during refining.

A water-cooled lance with carbon foamer and supersonic carbon injection can inject up to 4,450 Nm^3/h of oxygen and up to 30 kg/mm of carbon. The furnaces can run on 100% scrap; however, TSC's goal is to use a substantial amount of DRI (up to 50%) to achieve product quality. The DRI pellets are added both with the scrap bucket and continuously via conveyors, so that each heat is produced from a single bucket charge. Tap to tap time averages less than 60 min.

The melt shop also includes a 20.5-MVA capacity ladle metallurgy furnace supplied by MAN GHH.

Liquid steel from the melt shop goes to a single-strand caster designed and built by SMS. Annual plant output is designed to be about 720,000 mtpy of coiled, cut to length, and discrete carbon steel plate.

Air Pollution Control Equipment

Like most electric arc furnace shop systems, the higher temperature gas from the furnace primary system mixes with cooler gas drawn through secondary systems. At Tuscaloosa the primary gas drawn through the direct evacuation control (DEC) system mixes with cooler gases from the ladle metallurgy furnace, the "elephant house" canopy hoods, the caster turret canopy, and a scavenger duct drawing from the very top of the melt shop building.

The system was designed for three-fan operation, but a fourth fan, originally intended to be used for backup, had to be activated to provide adequate levels of gas flow for successful emission control. At the higher gas flow, spark carry-over to the baghouse became a serious problem, with an average of 18 polyester bags showing burn holes every day. Maintenance included repair to these bags, as well as replacement.

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Conventional baghouse filtration with conventional fabrics requires that a layer of dust cake buildup in and on the filter media before full filtration takes place. Membrane surface filtration with Gore materials involves an expanded membrane structure of polytetrafluoroethylene (Teflon) applied to a fabric backing. Even submicron-sized particles must negotiate a “tortured path” to penetrate the membrane, so most particles are trapped on the surface where they can easily be removed.

Several Advantages

By taking advantage of the higher temperature capacity of Gore™ membrane/fiberglass filter media the amount of dilution air can be reduced substantially. Even at a higher DEC volume, the Gore bags are far below their 260°C limit. Previously, to avoid high-temperature damage to the polyester material, the baghouse had to operate periodically at significantly higher than original design airflow rates, sacrificing suction pressure, to attain the higher levels of dilution air. With the new high-temperature membrane filter media, less dilution air is required while maintaining consistent baghouse inlet pressure and furnace draft—thereby reducing fugitive emissions.

Since the baghouse inlet temperature is no longer limited to 135°C and pressure drop across the filter bags is lower with membrane bags, TSC is able to operate with a consistently higher DEC gas flow. This improves the shop environment since each cubic meter of DEC gas carries from 30 to 40 limes more dust than a cubic meter of secondary gas. Since gas flow from the furnace is much more stable, a higher portion of the CO can burn in the furnace. Since DEC volume is more stable, the chances for an explosion in the DEC system is significantly reduced.

TSC officials expect to realize substantial power savings after the fume-collection and baghouse systems are optimized later this year. This is because there is no need to oscillate control between pressure and temperature modes (relatively low flow and relatively high flow), and because of the lower filter drag with the high-temperature membrane filter bags. Also, the company expects to return to a three-fan operation, with one fan idle, so a planned maintenance regimen to the idle fan will be reinstituted, improving overall fan reliability.

According to Gore, with proper inspection and maintenance, the membrane/acid-resistant fiberglass fabric filter bags are expected to operate effectively for five years and longer. For sake of comparison, the original bags needed to be replaced in less than two years time. Also, TSC had to regularly repair or replace polyester bags because of spark damage and bleed through. Since TSC installed the first Gore® high-temperature membrane bags over five months ago, not one bag has failed.

New Bottom Anode Concept

Among the many requirements for an DC EAF bottom anode design, in addition to quick startup from both cold and hot conditions, and high current conduction capacity, are long campaigns between replacement shutdowns, and quick and easy maintenance.

Kjell Bergman, Danieli Centromet, Västerås, Sweden, described how his company developed a water-cooled bottom anode for a twin-electrode DC EAF, and Rogelio Gonzales, Hylsa Flat Products Div., Monterrey, Mexico, discussed the operating results of the first installation.

The design resulted from a research and development program that included theoretical calculations, simulations, and laboratory tests. It was further refined in an industrial-scale plant at the Balboa steelworks in Spain.

The 135-mt twin-electrode DC furnace built for Hylsa in Monterrey by Danieli.

The 135-metric-ton EAF with twin electrodes installed by Danieli started up in October 1998. It has an installed power of 208 MVA, and the melt shop is designed to use 100% DPI, supplied hot from the HYL reduction process using the Hylsa-developed Hytemp conveying system.

There are four water-cooled anodes embedded in the refractory lining. The anode is built with a steel upper part and a copper lower part, welded together. The copper part is tubular in cross-section, with an inner top surface machined to form fins, arranged in a spiral configuration. This ensures a high water velocity over the entire surface, and together with the contribution from the fins, results in a high heat transfer capacity.

Using 100% DRI, supplied to the furnace at 560°C, established the process parameters such as tap to tap times of 55 minutes and a maximum power of 115MW.

Projected energy consumption of 470 kWh/mt of liquid steel produced and a graphite electrode consumption of 1 kg/mt of liquid steel were reported by Danieli and Hylsa to be very close to actual results—even at the early stages of start-up.

Hylsa supported further development work at Cinvestav-Unidad Satillo, in Mexico, on an unsteady state, three-dimensional heat-conduction model to analyze the thermal conditions in three- and four-billet-type anodes for DC EAFs. The influence of operating practices and billet design characteristics were investigated. Three-billettype anodes were included in the study because Hylsa also operates a single-electrode DC furnace in Monterrey.

As a result of this additional research, several refinements in operating practice and billet design helped reduce penetration of molten steel into the refractory. One finding was that extending the water jacket deep inside the refractory bottom has a very large beneficial influence on the anode life.

Implementing these recommendations extended the life of anodes at Hylsa from an average value of 300 heats to 1,800 heats.

New Refractory Maintenance Concept

A new refractory maintenance concept to minimize EAF production costs, was presented by Karl Peter Johann, Buderus Edelstahl Werke AG, Wetzler, Germany, and Christian Wasmuht, Minteq International GmbH.

Edelstahl Buderus makes high-quality engineering steels ranging from unalloyed carbon steels for strip products to medium- and high alloy tool steels for forging. A 100-ton EBT AC electric arc furnace, with three oxygen burners and lance manipulators, provides the required output of 70 tph. An annual production of 410,000 tons is achieved by running 18 hr per day.

Maintenance of the refractory furnace lining averaged, 20 min per heat, requiring two or three people. Also, the furnace was relined an average of 12 times per year. The company undertook a program to reduce the amount of maintenance, and the cost of refractories, including brick and gunning materials.

The result was a maintenance system involving a turret, a manipulator arm, and a gunning head, and a refractory dispensing system with two 6-mt silos and two 2.5-mt high-pressure vessels. A conveying system, with quickchange valving, connects the high-pressure vessels through the manipulator turret and cantilever arm to the gunning head.

It was necessary that the manipulator could easily be operated by one person and that it could reach any point within the EAF. Another requirement was the need to feed two different refractory maintenance products (wet and dry materials) into the furnace within the shortest period of time.

The structural components were integrated onto a stable framework construction and formed a single unit. The silo and high-pressure unit counterbalance the manipulator when it is in its working position. For maintenance purposes the whole unit can be moved with one lifting operation of the charging crane. All control lines and the material supply are fixed by inline quick couplings.

The gunning head is able to reach any point within the furnace by performing a non-stop rotational movement of 360° and a simultaneous movement from the furnace center to the upper edge of the furnace panel. Inside the head there is a mixing nozzle that moistens the material with water. In order to moisten the material optimally a water pressure of 70-100 bar is required.

A special cooling technique ensures that there are no temperature restrictions for operation. This means that the maintenance process is possible immediately after tapping.

The high-pressure vessels are fed automatically with material from the corresponding silo by level measuring devices and a PLC control system. A weighing system indicates the exact weight values of the highpressure vessels so that an exact log of the material consumption per maintenance process is possible.

The system has been in use for approximately four years without major repairs. Preventive maintenance assures an availability of greater than 95%.

One-person control of the maintenance process is achieved using a radio control device. The operator uses a lever for two different movements of the gunning head (rotational movement of 360° and up and down movement of 0-120°.

With the commissioning of the equipment, and because of the special requirements that must be met in different regions of the EAF, new magnesia repair materials were developed for the short mixing times and the small mixing chamber, as well as to avoid possible segregation caused by the high conveying capacities and long routes.

Results of the New Refractory Concept

Several benefits resulted from using the new refractory maintenance concept. For example, the maximum conveying capacity of the equipment amounts to 360 kg/min, four times faster than typical in the previous practice. Maintenance times, as a result, could be limited to a maximum of 10 minutes.

The system applies the refractory materials from an optimal distance and at the correct angle to the surface, which results in reduced rebound (approximately 40% less compared with conventional gunning). During repair with dry maintenance materials, only the required spots are maintained.

The annual number of relines was reduced from 12 to seven. Furnace campaigns up to 900 heats have been reached, and campaigns of 1,000 heats are possible. Overall, the total refractory costs, which include all maintenance materials and bricks, have been reduced by 50%.

Another positive result is that the new practice is safer than the previous practice. In the view of the steelmaker, this aspect represents a decisive advantage with regard to the health of individuals and the safety at the workplace.

A connection to a PC for data processing (on-line evaluation of the quantities and consumption), as well as the possibility of coupling the equipment to a laser device measuring the residual thickness is currently in the planning phase, based on successful testing. Integrating into a data network of Edelstahl Huderus is planned to facilitate the operation of the system, and to make it more transparent. Daily production costs can then be determined online.

Measuring the residual lining thickness with the laser device is expected to allow a further reduction of refractory consumption and even full automation of the maintenance process.