WIRLD'S FIRST EAF QUANTUM*

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Abstract

The introduction of the EAF Quantum furnace by Primetals Technologies represents an important milestone in the field of electric steelmaking during the last 15 years. In this process the latent and chemical heat of the off-gas generated during a melting process in an EAF is used to pre-heat scrap in an integrated shaft prior the melting of the scrap in the vessel. Combining proven own technologies, Primetals EAF Quantum enables nearly continuous process, cutting down idle times and enhancing availability for production. The essential benefits will be shown in this Paper.

Keywords: Energy efficiency; Scrap preheating; Heat recovery; EAF; Energy saving.

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1 INTRODUCTION

In previous years, productivity was the main focus for the steel industry as the market was booming and the steel producers were output oriented. But the situation changed and the market downturn forced the industry to work on the efficiency of the equipment and the steel producers became cost oriented. Additionally, more and more countries worldwide are implementing new rules and regulations not only concerning energy efficiency and CO2 emissions but also with respect to hazardous off gas emissions.
The right approach of Primetals Technologies is the EAF Quantum.

2 BASIC CONCEPT OF EAF QUANTUM

The preheating shaft of the Quantum furnace is loaded with scrap by a tilting scrap container which is mounted on an elevator. The scrap container itself is loaded by two movable loading hoppers. The scrap charging can be operated automatically. The preheated scrap is charged into the liquid steel bath in several batches. The scrap is molten by electrical power input and oxygen injection through two top lances. The scrap charging as well as the overall process are operated automatically. The furnace shell itself can be tilted for tapping and deslagging with four cylinders while the roof and shaft are fixed. Fluxes and alloys can be added through the roof and into the ladle during tapping.

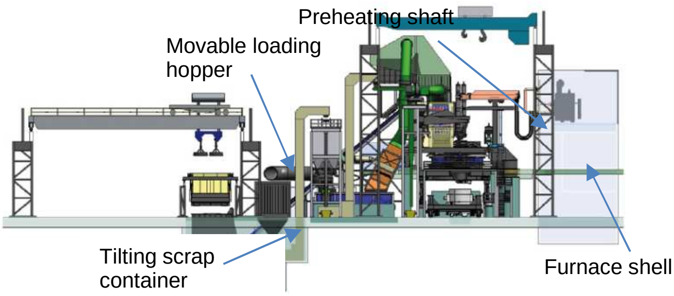

Figure 1. General view from tapping side

The off gas from the furnace and the fumes generated while charging the shaft are captured and heated up in a post-combustion system to reduce volatile organic compounds (VOC) as well as CO. The secondary fumes are captured by a canopy under the melt shop roof.

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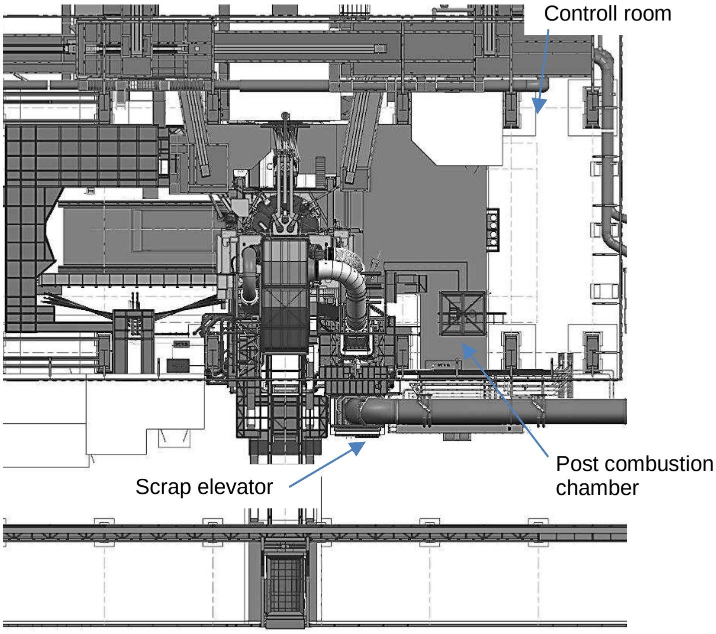

Figure 2. Layout top view

3 HIGHLY EFFICIENT SCRAP HANDLING

The new charging elevator system with container for scrap transfer from a dumping station into the furnace creates a defined and flexible charging logistic. Crane and buckets for scrap charging are not necessary. All process steps of scrap charging are fully automated.

On the scrap yard two movable hoppers are loaded with scrap directly from the scrap yard, trucks or rail cars. When one of the hoppers is filled according to the scrap specification sent by level 2, the crane driver releases the hopper which then drives automatically to the waiting position close to the elevator system.

Figure 3. Loading hoppers at the scrap yard

When the elevator system is ready, the fully automatic procedure of refilling the container is started. The hopper drives over the container and charges the scrap into it. This loading procedure is very fast and reliable. One refilling can be performed in less than 1min.

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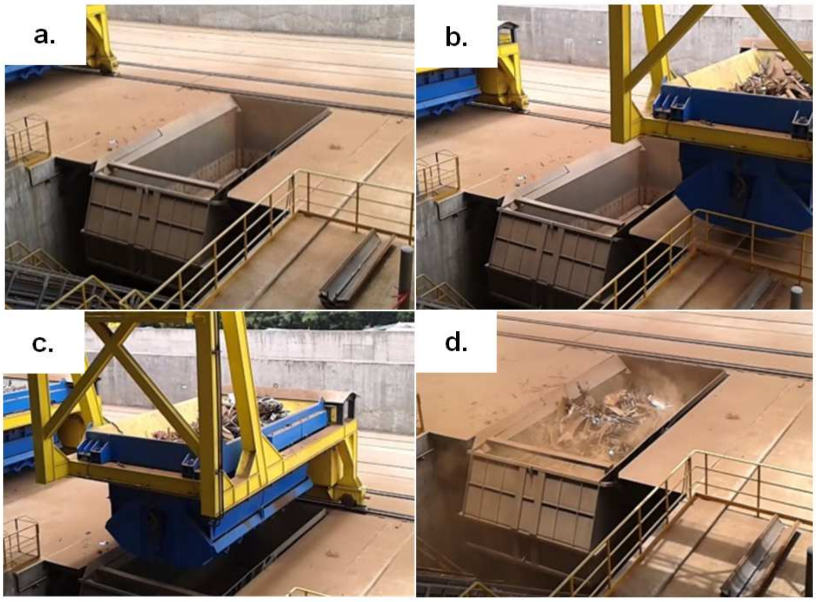

Figure 4. Intermediate loading station

Immediately after the container loading is completed, the hopper drives back to the waiting position and the filled scrap container is lifted up to the top of the preheating shaft by the inclined elevator, waiting there for shaft loading. The winch system of the elevator is equipped with two redundant ropes for safety reasons. The drive speed of 0.5 m/s of the elevator system leads to a complete charging cycle time (container moving up to charging position, opening shaft and scrap charging, container moving down in loading position) of about 5 minutes.

4 REDESIGNED PREHEATING SYSTEM

Efficient energy recovery due to 100% scrap preheating is the base for energy consumption lower than 300 kWh/t. This is realized by a trapezoidal shaped shaft design in combination with a re-designed retaining system which leads to a better scrap distribution and an improved offgas-routing for optimized heat transfer, avoiding scrap sticking and blocking inside the shaft.
After having preheated the scrap, the fingers are opened for charging by pulling the fingers out of the sidewalls of the shaft. Thanks to the new opening mechanism and a large "horse shoe" shell volume, the preheated scrap is loaded into a big liquid heel and the fingers can be closed immediately afterwards for loading and preheating the next batch of scrap. The complete finger system is placed on a sturdy fixed roof/shaft structure in order to prevent the forces coming from scrap loading going towards the water cooled parts, thus avoiding the risk of water leakages.
Operational experience shows that the finger system is reliable and that no scrap sticking to the fingers has been observed. The new fingers system enables also an easy maintenance out of the shaft.

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Figure 5. Steel rain underneath the fingers

5 PURE FLAT-BATH OPERATION AND FAST TAPPING

Melting of scrap in big liquid heel leads to pure flat bath operation with lowest flicker and supports the preheating efficiency. In combination with the Furnace Advanced Slag-free Tapping system this new furnace allows charging, tapping and taphole refilling under power on and results in highest productivity with lowest tap-to-tap time. Heat transfer from liquid heel to the preheated scrap and bath homogenization is improved by a bottom stirring system with argon. With far lower installed electrical power than a conventional furnace, the Quantum operation not only improves the productivity but also flicker generation in the respective power grids of the country, which is most important in case of weak networks.
The working profile for the process with four baskets can be seen in Figure 6.

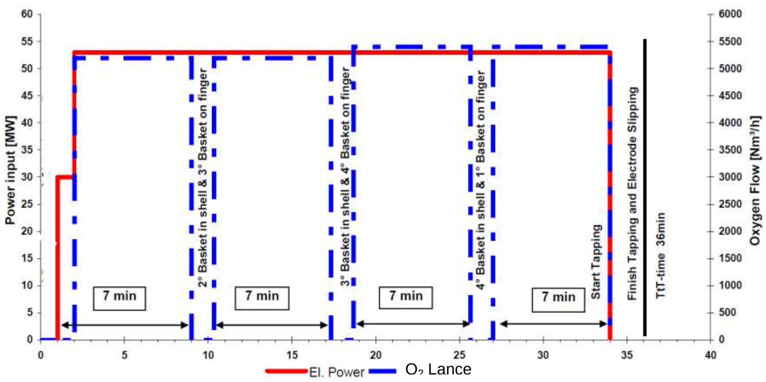

Figure 6. Operation profile with 4 baskets.

Primetals Technologies has developed the FAST system in 1999 together with Buderus Edelstahl GmbH which has been in successful operation since then. The Furnace Advanced Slag Free Tapping system allows for a more efficient use of alloying material and it improved desulphurization, which in turn enhances steel quality. With slag-free tapping, the liquid steel is purer and there are considerably lower losses in alloying material that have to be compensated for. This increases the efficiency of the alloying agents used.

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In melting and tapping operation, the horizontal channel of the FAST is closed by the liquid heel in the EAF. This ensures that no slag can penetrate the siphon and run into the ladle during tapping. When the steel bath level increases, the slag – as a result of the foaming slag process – flows through the slag door into the slag pot or clean pit. As a result, plant operators do not have to deslag and reduce the furnace's power before tapping. Deslagging is part of the continuous operation, saving both time and energy. At the end of melting process, the bath level is such that the tapping hole is sufficiently covered. The electrical energy input is kept during tapping.
The shell is designed in such way that the remaining heel is never below the highest point of the horizontal channel. This prevents slag from entering the siphon. After tapping, the bath level is lowered so that a refilling of the tapping hole under power-on is possible. This reduces power-off time as well as the number of transformer tap changes, which leads to considerably lower wear rates of the electrical equipment. The steel can be tapped earlier, as the energy input continues during tapping. The heat losses in the ladle and the temperature drop in the siphon are not higher than with conventional tapping. This extends the lifetime of refractory linings and structure materials, which are exposed to constant thermal loads. In addition, slag-free tapping increases the lifetime of the tapping hole sleeves.

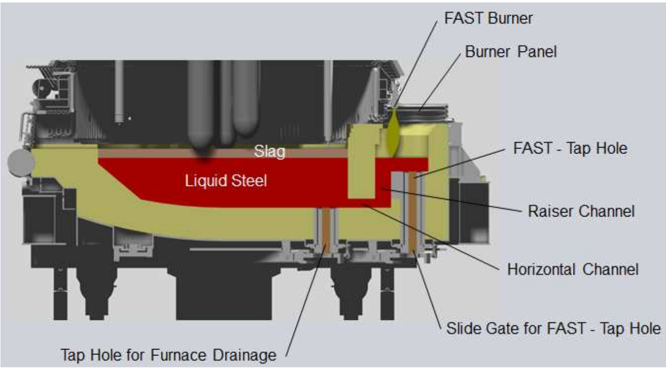

Figure 7. FAST working principle

This system, consisting of a horizontal and a vertical part, is called riser. The taphole is located in a cavity above the riser, liquid steel flows through the so called FAST tap hole. The FAST tap hole has the same function as a normal bottom tapping channel. The riser and the cavity are made of pre-assembled refractory bricks and can be maintained during a normal refractory repair. The FAST tap hole is the same type of set installed in normal bottom tapping furnaces.
To build up the FAST riser, pre-assembled refractory blocks are an economic way to build up the channel system. In case of using preformed refractory blocks to build up the FAST riser, the blocks should be stacked in the following sequence.
The main wear mechanisms for the refractory sets are due to high steel velocity in the riser inlet and onto separation wall during tapping as shown on next picture.
The steel flow characteristics for a Furnace Advanced Slag Free Tapping system were investigated by using computational fluid dynamics (CFD) simulations for a large variety of channel geometries. The maximum steel velocity and velocity gradients at the channel entry and the pressure differences at the channel walls were significantly decreased indicating a lower tendency for wear at the channel entry area and, therefore, an increased lifetime.

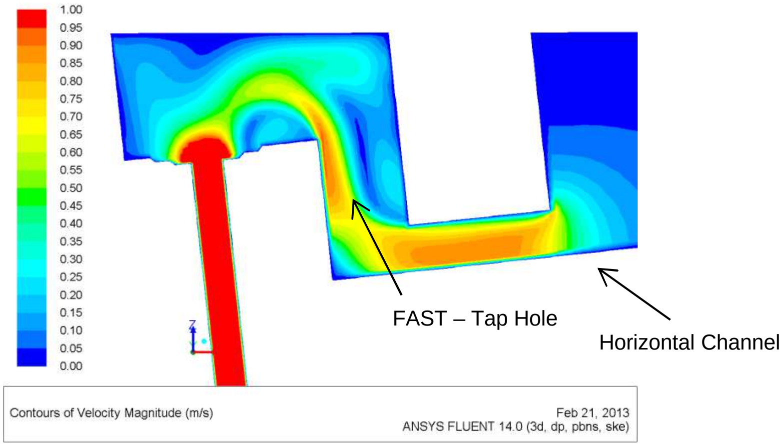

Figure 8. Calculated steel velocity (m/s) in vertical cross section through the FAST system

Results have shown that the CFD optimized FAST design significantly decreases inlet wear. As a result, the operating conditions are more stable over the entire tap lifetime. In addition, the lifetime of refractory blocks is further increased by the optimized lining thickness and reduced wear at the inlet area.

6 FURNACE MOVEMENTS

As the shaft structure and roof are fixed installed, the shell has to be manipulated for tapping and deslagging (if required). This is realized in a manner that the shell is sitting on base frame with cylinders and guides, allowing the shell to be tilted in both directions –tapping and slag side.
By lowering all 4 cylinders it is possible at any time to place the furnace shells onto the transfer car and move the full furnace out in maintenance position. It improves furnace maintenance as well as enables a quick shell exchange. All media and sensors are connected via quick connectors so that it becomes easier to exchange the vessel every ~250 heats than changing the tap hole refractory in hot conditions. Thus furnace availability for production is drastically enhanced.
The gantry with the electrode lifting system and the two oxygen and carbon lances are not tilting, but only swinging out for electrode slipping and fast roof center piece exchange. Heavy stress from furnace tilting like the gantry at the conventional EAF with all its consequences on support and bearing, high current cables, etc. is not required.

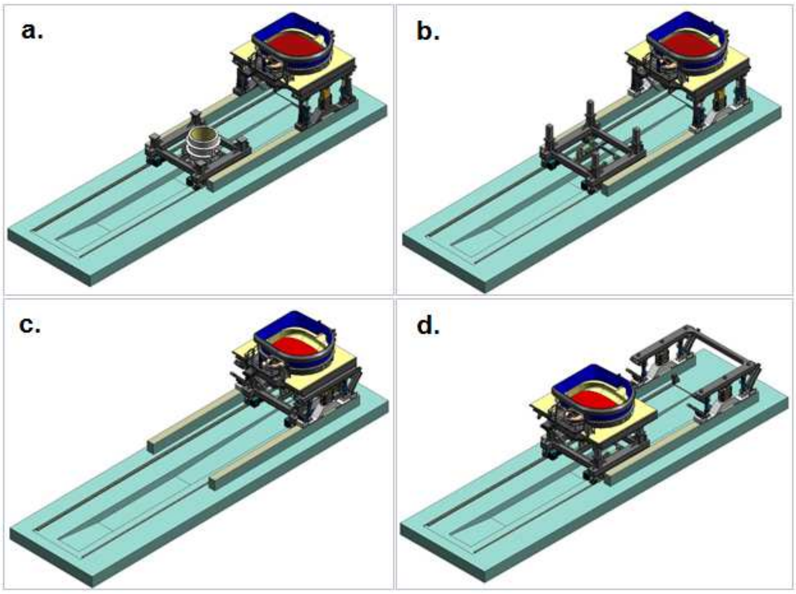

Figure 9. (a) Ladle car with ladle ;(b) Ladle car before shell change; (c) Ladle car with shell in pick up position; (d) Ladle car with shell in maintenance position

The transfer car is acting as tapping car as well as shell transfer car. The sequence of shell exchange is shown in the Figures 11. In order to pick up the shell from the frame, the car has to be placed into the exchange position, underneath the shell. The shell will be lowered by means of the cylinder and guide system. When sitting on the car, the shell is free and can be moved outside the furnace area for refractory maintenance or shell exchange.

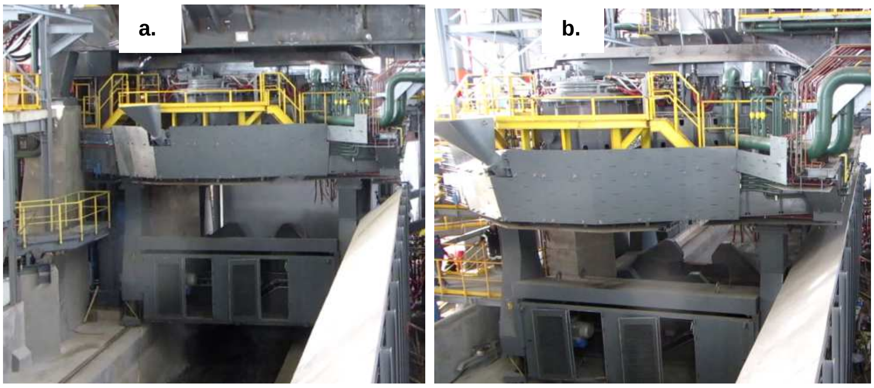

Figure 10. (a) Ladle car in shell change position; (b) Ladle car with shell in maintenance position

In order to prepare the furnace for restart, the shell can be loaded with remaining liquid steel or scrap prior moving to the operating position. Once again in operating position, the cylinder and guide system are moved up and then connect the base frame with the shell.

7 PERFORMANCE PARAMETERS

In the following tables, the main technical data with corresponding consumption figures are shown. The EAF Quantum is flexible to melt various kinds of scrap densities still keeping high productivity paired with low conversion cost. The low electrical energy consumption and the extremely low natural gas and oxygen input figures represent benchmark values for EAFs.

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100 % Scrap operation	Unit	Standard EAF	Finger Shaft Furnace	Quantum EAF
		AVERAGE		
Tapping weight	tons	100	100	100
Transformer capacity	MVA	100	100	80
Consumptions (per ton of liquid steel)				
Electricity	kWh/t	370-390	330-350	280-300
Electrodes	kg/t	1,4	1,2	0,9
Natural gas incl. PC	Nm³/t	5,2	12	4,4
Total oxygen	Nm³/t	29	30	25
Performance				
Metallic yield	%	87	89	91
Power-on time	min	43	39	33
Power-off time	min	12	10	3
Tap to tap time	min	55	49	36
Productivity	t/h	109	122	167

Figure 11. Consumption figures and performance of different furnace types

As soon as the operating team became accustomed to the new equipment, which was much more productive and sophisticated than the previous EAF, production output increased continuously. The outstanding figures underline the performance capability of the equipment and the excellent teamwork at Talleres y Aceros S.A. de C.V. (Tyasa). Overall productivity is expected to reach an average hourly minimum of 150 t/h.

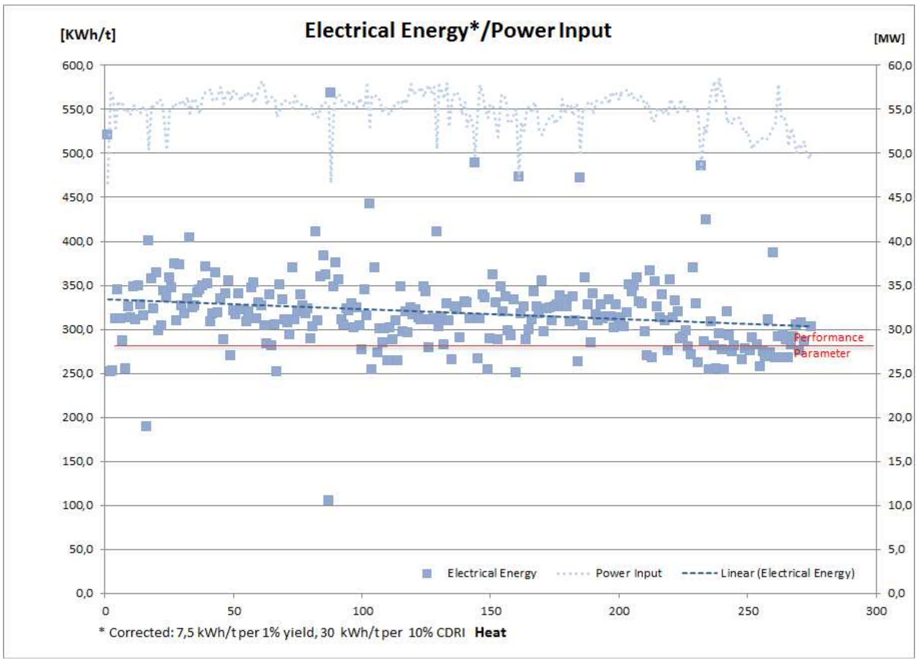

Figure 12. EAF Quantum Electrical Energy Consumption

8 ENVIRONMENT AROUND THE FURNACE

Environment condition around the furnace area is improved compared to a conventional EAF. In case of EAF Quantum, scrap is charged through the shaft and it is not necessary to open the roof, which reduces dust around the furnace. Dust emissions in the offgas are also considerably reduced with less than 12 kg/t, about half of the dust generated by a conventional furnace, because the shaft is always full of scrap and filters the offgas.

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Noise around the furnace is significantly reduced because of constantly operation under flat bath and foamy slag conditions. Figure 15 shows comparison of noise level measurement between a typical conventional furnace and EAF Quantum. The main noise sources in the steelworks are the electric arc furnaces. The noise radiated by a conventional electric arc furnace is extremely intense during the melting, especially at the first bucket and becomes moderate at the refining. An electric arc furnace has the noisiest level at the beginning of the melting, when the electric arcs are very unstable, taking into consideration the arc ignitions and blow-outs on the solid iron scrap. Therefore, only a change in the way of process can solve the problem. The main solution is to operate the furnace in flat bath conditions as long as possible. A low individual sound pressure level enclosing of the furnace, brings the advantage of protecting the workers on the furnace platform as well as in the furnace control room and in the workshop without any additional measures.

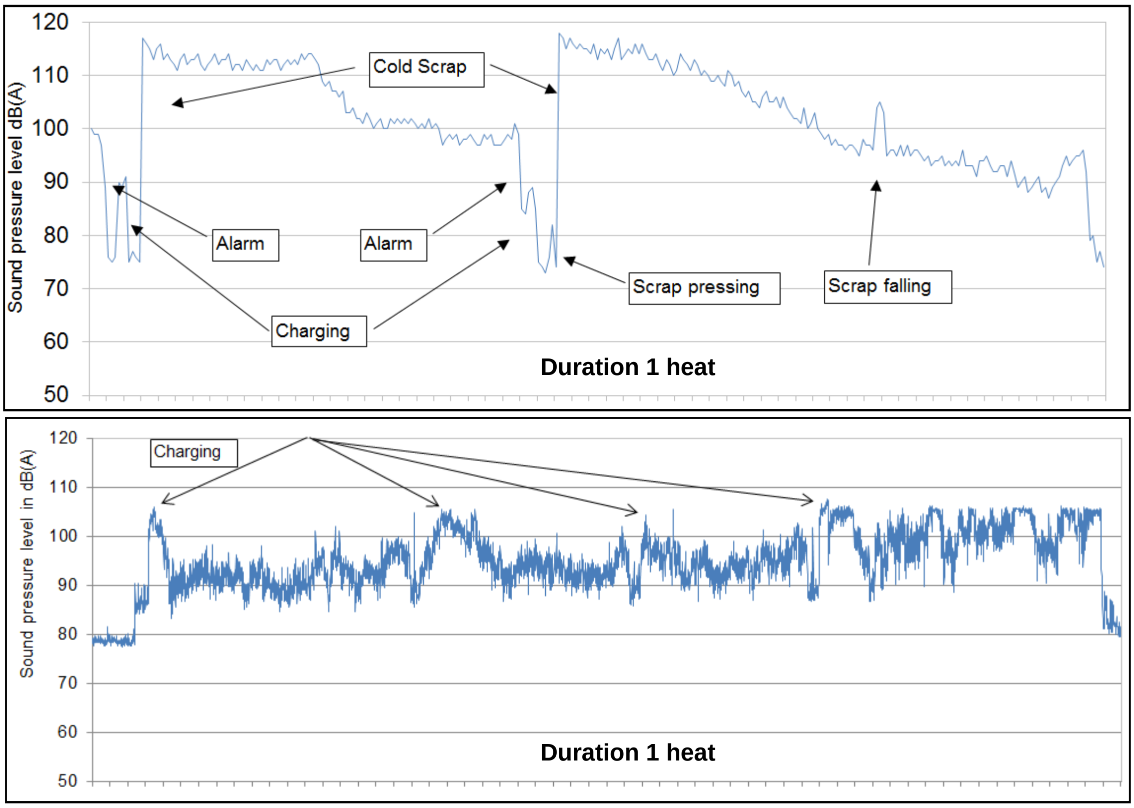

Figure 13. (a) Sound pressure level conventional EAF; (b) Sound pressure level EAF Quantum, reduction of 8 dB(A)

There are several reasons why the noise output diminishes from an EAF Quantum compared to a conventional EAF. In the first few minutes of scrap melting from a conventional furnace the noise is highest, recording 5 m from the furnace shell and 45 degrees to the slag door (standardized). If the furnace operates on liquid steel, the noise decreases significantly. Openings within the furnace have a noticeable effect on the sound emission. Because of an open slag door or an open roof, the sound emission increase. Furthermore, the melting progress of a conventional EAF through a heat, as the arcs, descend through bore-in, they become more distant from the openings in and around the roof.

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The average sound pressure level for an EAF Quantum is 94 dB(A). The measured reductions of acoustic power outside the furnace during a heat are of the order of 8 dB(A), compared to a conventional EAF.

9 PEOPLE MAKE THE DIFFERENCE

Competitive electric steelmaking requires that the melt shop is operated efficiently with respect to production output and energy consumption. Advanced equipment and systems in combination with rigid maintenance practices, of course, are a prerequisite for this. However, it is ultimately that the people who operate the equipment and control the processes are the true key to Talleres y Aceros S.A. de C.V. (Tyasa) continuous productivity improvements. Their dedication to excellence in steelmaking is the most important factor for success.

10 CONCLUSION

For Tyasa's new compact steelmaking plant in Ixtaczoquitlan in the Mexican state of Veracruz, Primetals Technologies supplied a Quantum electric arc furnace with a tapping weight of 100 tons, as well as secondary steelmaking facilities. These include a 100 ton twin ladle furnace and a 100 ton twin vacuum degassing plant. The plant has a capacity of around 1.2 million tons of low, medium and high carbon steels per annum. The steel it produces is cast on a six-strand combi caster into billets with cross-sections ranging from 130x130 to 200x200 millimeters, as well as beam blanks and rounds. The new plant will enable Tyasa not only to increase its production capacity substantially but also to widen its range of products.
The key component of the compact steelmaking plant is the EAF Quantum electric arc furnace newly developed by Primetals Technologies. This combines proven shaft furnace technology elements with a new scrap charging process, an efficient preheating system, a new tilting concept for the lower shell and an optimized tapping system. The furnace allows tap-to-tap times of down to 36 minutes. The electricity consumption of just 280 kilowatt-hours per ton is considerably lower than that of a conventional electric arc furnace. This, in combination with the lower consumption of electrodes and oxygen, gives a total advantage in the specific conversion cost of about 20%. Total CO2 emissions can also be reduced up to 30% per ton of crude steel in comparison to conventional electric arc furnaces.
The introduction of the EAF Quantum furnace by Primetals Technologies represents an important milestone in the field of electric steelmaking during the last 15 years. In this process the latent and chemical heat of the off-gas generated during a melting process in an EAF is used to pre-heat scrap in an integrated shaft prior the melting of the scrap in the vessel. Combining proven own technologies, Primetals EAF Quantum enables nearly continuous process, cutting down idle times and enhancing availability for production. The essential benefits are:

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Energy / resources

- Energy consumption < 300 kWh/t
- No burner power
- Reduced flicker and network disturbances
- Pure flat bath operation

Environment

- Dust emission reduction based on revolutionary offgas treatment
- Improved furnace tightness
- 20% reduced CO_2 emissions
- Lowest noise emissions
- Smaller footprint

Efficiency

- 100% scrap preheating
- Reduced power installation
- Melting of scrap in liquid steel
- Tap-to tap time of 36 min
- Electrode consumption < 0.9 kg/t

Safety

- Minimized furnace movements
- No bucket for scrap loading
- Full fledged automation concept applicable

Figure 14. EAF Quantum essential benefits

Additionally, safety improvements can be claimed due to the possibility of full automation and no crane movements in the furnace area which reduces danger from moving loads.

Figure 15. EAF Quantum top view

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11 ABBREVIATIONS

FAST	furnace advanced slagfree tapping system
EAF	electric arc furnace
min.	minute
CFD	computational fluid dynamics
DRI	direct reduced iron
HBI	hot briquetted iron

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