Jumbo size 420t twin DC FastArc® EAF at Tokyo Steel

The recently commissioned 420t capacity twin DC, ultra-high power EAF equipped with Consteel® at Tokyo Steel is the world’s largest electric arc furnace. It has a yearly production of 2.6Mt and features the most advanced technologies to combine ultra-high power demand and power network stability.

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A single, 420t capacity twin DC, ultra-high power EAF equipped with the Consteel® system successfully started in June 2010 at the Tokyo Steel, Tahara plant in Japan (see Figures 1 & 2). This jumbo sized EAF is the largest ever built and was designed to achieve a yearly production of 2.6Mt at 360t/h. It is extremely efficient in terms of operating costs due to low manpower and low energy demands.

The layout of the meltshop was designed to minimise infrastructure investment and achieve extremely efficient operations through optimum use of space via a single bay design (see Figure 3). The furnace is fed continuously via the Consteel® system, as a result of the exclusive agreement between Danieli and Tenova.

The construction of a single, high-capacity EAF is in line with the trend in recent years of increasing meltshop sizes to achieve greater productivity and efficiency, with limited investment in order not to affect margins with high fixed and variable costs. The most advanced technologies have been employed, due to the need for fast processing in a large EAF including an ultra-high power supply, which is particularly critical in this case because of the weak network available.

The plant also includes secondary metallurgy equipment comprising a 300t ladle furnace (LF) equipped with two ladle cars, and a vacuum degasser (VD) with twin tanks and twin covers, connected to a 700kg/h ejector pump needed to achieve the required steel quality (low and ultra-low carbon for hot rolled coils) in a short cycle time. A powerful fume treatment plant comprising a 3.3Mm³/h double bag house of the reverse cleaning type is also installed. All the equipment is controlled and optimised by a fully integrated automation system and Tokyo Steel has specifically developed an automatic charging system that feeds the scrap from the shipyard to Consteel.

**EAF FEATURES**

The achievement of 2.6Mt/y productivity with a single EAF is a major technological advance, which has required
excellent design in order to supply ultra-high power (up to 175MW), while limiting the level of disturbances even with the weak network available and, at the same time, to obtain bath homogenisation and final product quality with a short tap-to-tap time.

The design consists of a full platform, split shell furnace, 9.7m shell diameter, with continuous scrap charging and twin DC power supply technology. The 420t EAF is designed to tap 300t of liquid steel and keep 120t of hot heel. Such a large hot heel is designed to enhance the melting rate of continuous scrap fed by Consteel in combination with the twin DC technologies.

*Figure 4* shows a productivity comparison between Consteel twin DC technology and a conventional AC EAF (two bucket charge). About four minutes power-off is saved due to the absence of bucket charging, and power-on is reduced by about two minutes, thanks to a better ratio between average and maximum applied power.

With a conventional two bucket AC EAF, in order to reach the extremely high value of 175MW, power ramp-up in the boring phases would require about two to three minutes for each bucket, during which time average power would be half of the maximum. Continuous scrap charging (with the presence of a molten metal heel that ensures quick scrap melting throughout the process) and twin DC supply (with full control of current between anodes and reduced network disturbances) makes it possible to employ very high power from the beginning of the process, with stable arc conditions.

The high efficiency of a twin DC furnace is because the arc converges between the two electrodes and the scrap is fed towards the arc convergence area, achieving the best melting efficiency. The formation of the desired slag composition and consistency throughout the process is achieved by adding slag builders continuously from the fifth hole. The melting of the charged slag builders is very rapid, since the feeding is directed close to the arc-converging and oxygen injection areas. As a result, power is employed very efficiently – on average, 95% of maximum power, with a melting rate equal to 2.1t/h/MW. Moreover, continuous scrap charging results in improved meltshop logistics and less noise and electrical network disturbances.

**ULTRA HIGH POWER SUPPLY**

The requirements in terms of low electrical disturbances, due to the presence of a weak network (Apparent short circuit power = 1,700 MVA) has been solved by means of the twin DC technology. The EAF has been designed with the two cathodes and four water-cooled bottom anodes, each with the capacity to operate up to 70kA. The design, compared to a single cathode design, provides extremely high power, carrying a total 280kA with smaller electrode
diameter, and reducing the network disturbances. The main technical features of the equipment for DC power supply (see Figure 5) are:

- Primary voltage: 33kV
- Transformers: 4 x (2 x 32MVA)
- AC / DC converters: 8 x 35kA
- Reactors: 8 x 350μH
- Operating current: 4 x 70kA
- Operating voltage: 600V
- Cathode diameter: 76mm

Maximum flexibility in power regulation is reached by individual control of current conduction and distribution between each of the four anodes. The particular design of the water-cooled bottom anodes (see Figure 6) means that standard refractory materials can be used. Anode cooling is located inside the refractory and, together with the full control of anode conditions in terms of water flow, temperature and pressure, ensures low thermal stress for refractory and electrical insulation, thus increasing life and safety of the installed components. This design also makes it possible to perform intermediate repairs to the anode refractory, prolonging the anode life.

**MECHANICAL DESIGN**

The EAF has a full platform design, which allows compact installation, limited erection and civil works execution time. The electrode masts and thrust bearing position means that shorter electrode arms can be designed, with higher mechanical rigidity and better electrode regulation performance.

The tilting platform design is based on three rockers, providing better operational stability on the bearing area. The rocker misalignment with the furnace ensures safe back-tilting. Innovative water-cooled panels (see Figure 7; Danieli patent) are installed, based on an advanced design resulting from numerical analysis of temperature profiles. This particular design, made up of double tube layers, lowers the risk of breakage, increasing panel life (experienced already more than 20,000 heats in other plants) and safety of operation. Most of all, a significant decrease in energy consumption is reached, due to radiation losses, which are 25% less when compared to conventional panels.

**CHEMICAL ENERGY ARRANGEMENT**

Due to the high melting rate required and the large bath dimensions, Danieli has developed a special design for oxygen and carbon injectors (see Figure 8).

This optimum injector distribution and installation arrangement ensures a good stirring pattern, homogeneous liquid steel temperature and fast decarburisation. In particular, the injection of carbon close to the oxygen
enhances its reactivity and hence improves foaming slag efficiency, which is of great importance in this kind of flat bath process to increase arc coverage and heat transfer rate to the melt, and to protect walls, refractories and panels from thermal stress. Supersonic oxygen and carbon lances are automatically introduced into the furnace through the door by a ‘Parpi’ manipulator, which can be moved towards the melt, promoting injection efficiency, mainly during the initial phase, with a very low bath level.

The oxygen jets and carbon pipes are installed inside water-cooled copper bulged boxes (see Figure 9), which provides proper injector protection, reduces the distance between the injector tips and liquid steel, and improves the refractory life under the injector.

To reduce the power-off time, automatic sampling equipment provides continuous information on bath temperature and chemical composition (see Figure 10). Table 1 shows the number and flow rate of the injectors.

### MELTING PROFILES

The presence of a molten metal heel and the absence of scrap, made possible by the Consteel® technology, and the reliability of twin DC supply, enable high power to be used from the very early stages of the process with limited network disturbances as (see Figure 11).

The highest scrap feeding rate (9t/min), power (175MW) and oxygen flow rate (15,000Nm³/h) are reached after only four minutes of power-on time. Carbon injection is gradually raised in order to achieve an optimum balance between electrical and chemical energy and homogeneous CO bubble generation in every phase of the process. This, together with injection of slag builders via the fifth hole, ensures adequate slag foaming and therefore a highly efficient transfer of heat from the arc to the bath.

### AUTOMATION SYSTEM

All operations are controlled and optimised by an innovative and fully integrated automation system, in order to minimise operator intervention, achieve a high repeatability of results and reduce power-off time. The automation system covers both equipment control (Level 1) and process control (Level 2), and is based on state-of-the-art hardware and software platforms, while the application software is the well-proven Danieli automation package, the result of over 40 years’ experience in the steelpaking field.

The automation system includes functions and equipment for:
- Resource management, with ladle tracking, equipment life tracking and consumption accounting
- Production control, with heat scheduling, heat tracking, operator’s guide and reporting
- Full set of process models for EAF, LF and VD/VOD
Integrated operator interface for Level 2 and Level 1 (HMI) functions
- Danieli Automation HiREG® enhanced electrode regulator for EAF and LF
- PLCs for equipment control
- Communication with laboratory and Level 3 production management system

The electrode control package HiREG® and hydraulic system design guarantee very fast response time, enhancing the average power to the melt.

The online monitoring and recording of process data for subsequent analysis also improves the knowledge of arc behaviour, which is particularly important considering the extremely high power input. Full control of all electrical and chemical furnace parameters is provided, with working points being automatically varied according to the process phases, guaranteeing high repeatability of furnace performance in terms of steel quality and energy consumption.

As the Consteel is charged automatically, in order to control the level of scrap inside the Consteel, Danieli Automation developed an innovative monitoring system, based on laser technology, which reports scrap levels step-by-step along the conveyor. The meltshop is also provided with an integrated material handling system (IMHS). The various computers/PLCs are integrated in fibre optic, ring-type backbone networks: the switches are connected to the two ends of the backbone, thus allowing communication to take place at one end, even in the cases when the network at the other end is at fault.

For system engineering and maintenance, a full set of tools is provided, including:
- Danieli Automation FDA-Fast Data Analyser unit
- TeleService remote access and support

In addition, MOREIntelligence, a complete data analysis software platform, offers a totally new scenario for process data analysis for steelmaking plants, including:
- Real-time data collection from all the production areas, directly from the Level 2 databases. Data are stored in a multidimensional array, also known as a ‘hypercube’.
- Synchronisation, normalisation and multi-dimensional analysis of the process data collected
- Easy user access via standard web browser
- Reports and analysis tools for the main process parameters

MECHATRONIC PACKAGES
The demanding requirements for high productivity require minimum power-off time, and this has been achieved by installing reliable mechatronic systems. These have also increased operator safety, avoiding direct exposure to the
process and allowing remote control from the main control room, even if located far from EAF. These systems are:

- **MOTANK robot (see Figure 12)**: this is of sturdy design and makes it possible to keep the slag door clean during power-on time, safely and consistently.

- **Automatic tapping system** which includes:
  - Infrared camera for fast and reliable remote detection of slag in tapping stream, avoiding slag carryover into the ladle (see Figure 13)
  - High-resolution camera for remote EBT control and automatic tap hole sand refilling system

**OPERATING RESULTS**

Furnace commissioning was completed in June 2010. The reliability of mechanical and electrical equipment, as well as simplification of operations due to efficient automation system, has made it possible to reach relevant and consistent performances after one month from the first heat. Table 2 shows the main operating values obtained. Ultra-high power is being supplied without introducing disturbances to the network. This allows high and stable power input throughout the process, as shown in Figure 14.

**SECONDARY METALLURGY**

Final steel quality for all grades (medium, low and ultra-low carbon for hot rolled coils) is achieved at the LF and VD. The LF has a 45MVA transformer, which enables a maximum power supply of 32MW, with a heating rate of 3.3 °C/min, and an automatic feeding system and sampling equipment for efficient operation. It has an inert roof design (see Figure 15) that provides a neutral pressure inside the furnace via a pressure damper regulating the draft on secondary hood suction line. Consequently, air infiltration is strongly reduced and the following benefits are obtained:

- Reduced electrode oxidation
- Reduced oxidation of the slag, which results in lower FeO and oxygen content in the steel
- Reduced hydrogen and nitrogen pick up from the furnace atmosphere

The vacuum system, obtained by means of a four-stage steam ejector pump with water ring pumps as a backing stage, is capable of providing 700kg/h of suction capacity at 0.5torr, ensuring a pump-down time to 0.5torr in less than 5.5 minutes. Twin tanks, with switchable suction line, allow high operational flexibility and the possibility of positioning two ladles at the same time. An oxygen lance has also been provided, and will give the flexibility to produce ultra-low carbon grades, providing the required decarburisation.

**FUME TREATMENT PLANT**

An extremely powerful fume treatment plant has been
provided (see Figure 16) in order to fulfil the strict environmental requirements. The plant processes a total flow of 3.3Mm³/h of fumes, of which 0.4MNm³/h are from primary suction. Fumes are filtered in a double bag house, with a reverse air type cleaning system. This provides a low air-to-cloth ratio, resulting in a long bag life. An axial cyclone, acting as spark arrester, is installed in front of bag houses in order to protect the bags from damage related to sparks coming from the EAF.

**CONCLUSIONS**

The new jumbo-sized twin DC EAF at Tokyo Steel’s Tahara plant is successfully operating and is representative of the recent market trend towards increased focus on meltshop productivity, efficiency and quality steel for flat product production. The furnace is the largest ever built, with a 420t capacity, and state-of-the-art technology (Consteel® and Twin DC) has been applied to obtain from the maximum power available (175MW), the highest possible productivity with limited disturbances to the weak existing network (SSC = 1,700MVA).

Process efficiency is reached through optimal design of chemical energy configuration and the implementation of an innovative and fully integrated automation system. The latest, innovative mechatronic packages are employed in order to reduce power-off time, increasing safety and efficiency of operations. The EAF, even in its learning curve phase, already has demonstrated a very positive trend in terms of productivity and efficiency, and our expectation is to very quickly obtain the performance parameters.

**Table 2 Main contract and early operating data**

(Charge mix: 100% scrap and charging capacity up to 9t/min)

<table>
<thead>
<tr>
<th>Units</th>
<th>Contract</th>
<th>1 month after start up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapped steel</td>
<td>t</td>
<td>300</td>
</tr>
<tr>
<td>Charged steel</td>
<td>t</td>
<td>319</td>
</tr>
<tr>
<td>Tap-to-tap time</td>
<td>min</td>
<td>50</td>
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<tr>
<td>Power-on time</td>
<td>min</td>
<td>42</td>
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<tr>
<td>Productivity</td>
<td>t/h</td>
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<td>Electric energy consumption</td>
<td>kWh/tls</td>
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<tr>
<td>Oxygen consumption</td>
<td>Nm³/tls</td>
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<tr>
<td>Injected carbon consumption</td>
<td>Kg/tls</td>
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<tr>
<td>Electrode consumption</td>
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<tr>
<td>Tapping temperature</td>
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</tbody>
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