THE MOST ADVANCED POWER SAVING TECHNOLOGY IN EAF INTRODUCTION TO ECOARC™

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Summary
JP Steel Plantech Co. (hereinafter referred to as “SPCO”) has developed “ECOARC™”, a high efficiency EAF having the most advanced energy recovery and environmentally conscious technology in the Mini-Mill industry. ECOARC™ uses high temperature exhaust gas for preheating scrap charged into “shaft type” pre-heating chamber attached directly to the furnace shell. In addition, the gas is used to treat unwanted chemicals from the waste gas in a combustion chamber with very little use of extra fuel. Only ECOARC™ has these features because of its high level air tightness to prevent air infiltration into the scrap preheating shaft and the furnace.
Six ECOARC™ have already been put into commercial operation in Japan, South Korea and Thailand which have achieved approx. 30 % reduction of energy. In this paper, the method of improving energy efficiency by the utilization of waste heat is described and ECOARC™ under commercial operation are introduced.

Key Words
EAF, ECOARC™, Electric Arc Furnace, High Efficiency, Scrap Preheating, Power Saving, Off Gas Treatment

1. Introduction

1-1. Outline of ECOARC™ system
Figure 1 shows the concept diagram of ECOARC™. It consists of a melting furnace along with a preheating shaft. The preheating shaft is rigidly connected to the melting furnace. The rigidly connected shaft for preventing air infiltration is one of the most important features. As the connection is tight, there is no air infiltration into the preheating shaft. Also, gap between panels etc. in the melting furnace is minimized and semi-air tight configuration is realized. As another mechanical feature of ECOARC™ it has no mechanism to hold charged scrap in the shaft such as a “Finger”. As a result, scrap at the bottom of the shaft is always in contact with the molten steel in the melting furnace. During operation, scrap is fed to the furnace from the top of the shaft. Accordingly, except cold start, the melting process goes under so-called flat bath condition. Even in super heating and tapping periods, the shaft keeps certain amount of the scrap for preheating. In ECOARC™, scrap is supplied semi-continuously, approx. 10 –13 times a heat. Because of its price and high preheat efficiency; it is more economical to use as much light scrap as possible within the constraints of metallurgical requirements. As a matter of course, turnings, can bundle and large scrap are also used. In addition, low bulk density scrap and highly combustible scrap such as automobile soft bundle can be easily utilized. Practically, there is no limitation of scrap in commercial operation.

1-2. Off gas treatment system
Figure 2 shows the flow of off gas from the preheating shaft. By using CO gas contained in the off gas, it is possible to avoid the generation of harmful chemicals with a little amount of extra fuel. Because in ECOARC™, the oxidation degree ($OD=CO_2/\{CO+CO_2\}$) of the off gas from the preheating shaft is controlled from 60 to 70%. The gas with such composition burns by itself. In the combustion chamber located downstream of the preheating shaft, the off gas is maintained at a temperature high enough to decompose dioxins. After combustion, the gas is rapidly cooled by spray water in the cooling chamber to prevent the re-composition of dioxins. Through this process, ECOARC™ has achieved dioxins degree less than 0.5 ng-TEQ/m^3N required by the Japanese regulations for new electric arc furnaces. ECOARC™ can provide better treatments for harmful chemicals with lower cost.

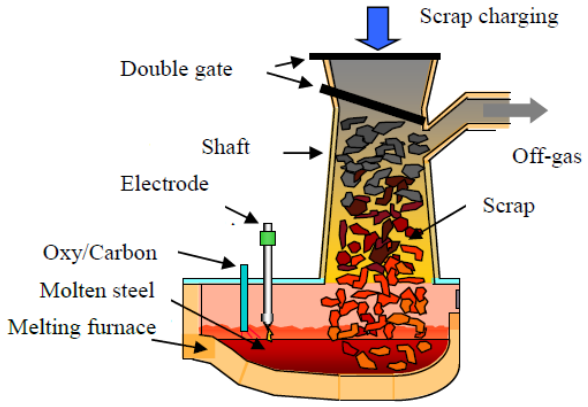

Figure 1: Concept diagram of ECOARC™

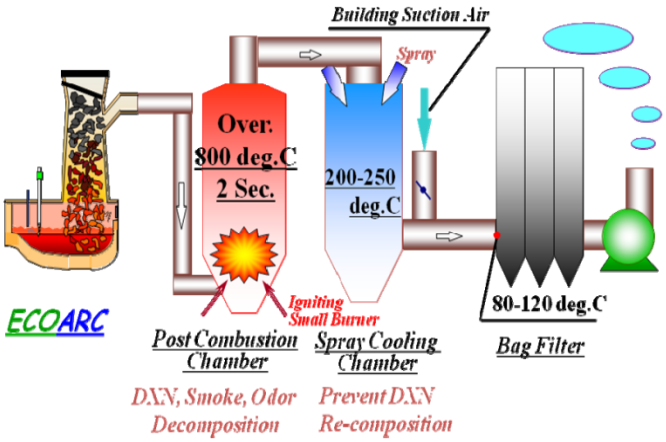

Figure 2: Outline of ECOARC™ process

2. Merits

Table 1 shows merits of ECOARC™ compared with conventional EAF.

2-1. High efficiency

Generally, in addition to heat recovery in the shaft, shaft type furnaces have some advantage to cut down a certain level of heat losses, because it is not necessary to open a roof for scrap charge. SPCO has developed ECOARC™ to take full advantage of the shaft-type furnace.

In fact, data obtained through the commercial operation shows that power consumption of 210 kWh/t (t represents metric tons of tapped steel in this paper) can be achieved with specific oxygen consumption of 33 m^3N/t.

In the ECOARC™ process, high temperature CO and CO_2 gas directly contacts the scrap at the bottom of the shaft without scrap hold mechanism like “Finger”. Therefore, scrap is always in contact with molten steel at the bottom of the shaft. Both heat recovery from off gas to scrap and molten steel to scrap is maximized because it is free from a heat loss to undesirable mechanical component. In addition, O_2 injection is not limited by the off gas temperature because there is no “Finger” possibly damaged by heat load from high temperature off gas. Increasing latitude for O_2 usage has great impact on the electric power consumption.

It also means ECOARC™ is free from troubles and maintenance difficulties related to “Finger” such as sticking between “Finger” and preheated scrap, water leakage of “Finger”, etc.

2-2. Off gas oxidation degree control

Air tightness to avoid incoming air into the furnace and preheating shaft is also necessary to achieve lower power consumption.

If the shaft and melting furnace are “not” connected directly, certain gap exists between the scrap preheating shaft and the melting furnace. This gap causes air infiltration resulting in excess oxidation of scrap and lower off gas temperature in the preheating shaft. Both the prevention of air infiltration and the off gas oxidation degree control are required for stable preheating. Keeping off gas with high CO concentration and low O_2 concentration is needed for stable combustion of the exhaust gas. Because of high and inhomogeneous O_2 concentration in off gas, other processes which have lower air tightness tend to create uncontrollable burning of off gas.

Until today, a number of shaft-type furnaces were proposed as concept models and some of them have actually been commercialized. However, in other processes, the melting furnace and the preheating shaft are separated so as to tilt the melting furnace by itself. With such a considerable gap, the Oxidation Degree of off gas can easily reach 1.0 and not only scrap over oxidation but also scrap melt down adhesion often occurs. Those problems have been reported by other suppliers’ papers. Therefore, at the standpoint of air tightness, it seems that separated-shaft furnaces have some difficulties in stable and efficient operation because of excess oxidation. Lower temperature air-mixed off gas may limit the power consumption level to 280 kWh/t. In these reasons, SPCO has adopted connected-type preheating shaft for ECOARC™.

2-3. “All time” flat bath air tightness process

In the ECOARC™, once operation starts, the melting and heating process continuously proceeds under flat bath condition. Therefore benefits of flat bath operation can be fully used. Notable benefits are listed below.

a) Decrease of nitrogen content in molten steel

Submerged arc can be easily achieved with sufficient level of slag in the melting furnace. As the arc is always covered in the slag, an atmospheric nitrogen invasion into the molten steel is decreased. According to our customer’s report, nitrogen content in molten steel decreased by 10 ppm in comparison with a conventional furnace.

b) Decrease of electrode consumption

With the continuous flat bath operation, there is no scrap bore-in period like a conventional furnace. Therefore, the occasion of electrode breakage by scrap cave-in is decreased, and the arc becomes stable as arcing takes place between molten steel and electrodes. For these reasons, electrode consumption can be decreased. One of our customers has reported the following value in AC ECOARC™. This value is far below that of conventional furnaces.

Electrode consumption (AC); 0.75 kg /t

c) Improvement in tapping yield

In ECOARC™, oxygen is always blown into molten steel by flat bath operation. In other words, there is not so-called scrap cutting work by oxygen lance. From this aspect, generation of excess FeO is avoided compared to the conventional EAF. The air tight shaft also contributes to avoid oxidation of charged scrap. As a result, the tapping yield is improved. Tapping yield improvement by around 1.0 – 1.5 % has been reported.

d) Lower dust generation & higher Zn condensation in the dust

Because of flat bath operation with submerged arc, and scrap charging without opening the roof and a dust adsorption removal effect in the shaft, quantity of dust emission decreases. As a consequence, an operation result, equal or less than around 50 %, has been reported after conversion from a conventional furnace. In addition, Zn condensation in the dust becomes higher, because vapored Zn is captured by the scrap layer in the shaft. For the EAF dust, higher Zn concentration means higher transaction price. Then, total dust processing cost decreases and tapping yield improves. Environment inside the meltshop building is also kept clean in comparison with the conventional furnace.

e) Improvement in power supply system

Due to flat bath operation, there is no large fluctuation of power input as seen in a conventional scrap melting furnace. It is possible to keep high power factor, low flicker and low higher harmonics throughout a heat. Therefore, the electric facilities necessary to meet power quality regulation such as SVC, higher harmonics filter, etc., can be drastically reduced. Figure.3 and Figure.4 are comparison of higher harmonics distortion for one heat between a conventional furnace and an ECOARC™. In addition, Figure.5 shows flicker measurement value in ECOARC™. From these measurements, it is easy to understand that the ECOARC™ has a great advantage on the supplied power quality.

f) Lower noise

Noise during the operation is largely reduced by ECOARC™ because of flat bath operation with sufficient foamy slag and no scrap charging from top of the furnace. Figure.6 and Figure.7 are the results of noise level measurement at the time of operation of a conventional furnace and an ECOARC™ with the same productivity. In the conventional furnace, the noise level more than approximately 100 dB was recorded in the melting period. On the other hand, the noise level in ECOARC™ was always less than 100 dB and around 90 -95 dB in average.

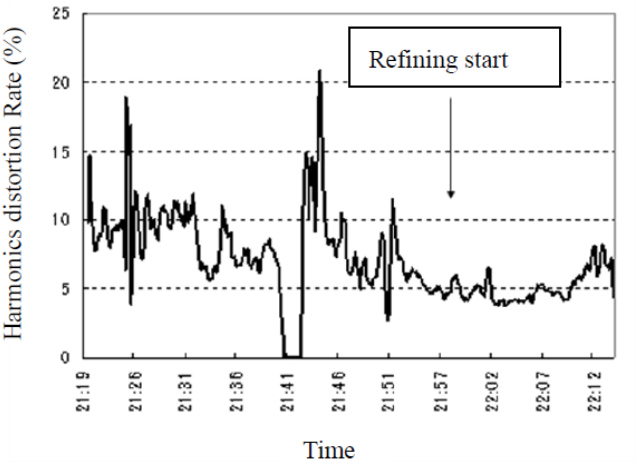

Figure 3: Harmonics distortion of conventional EAF

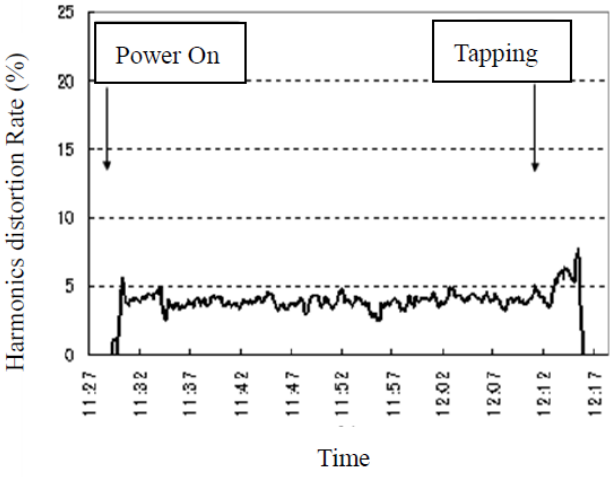

Figure 4: Harmonics distortion of ECOARC™

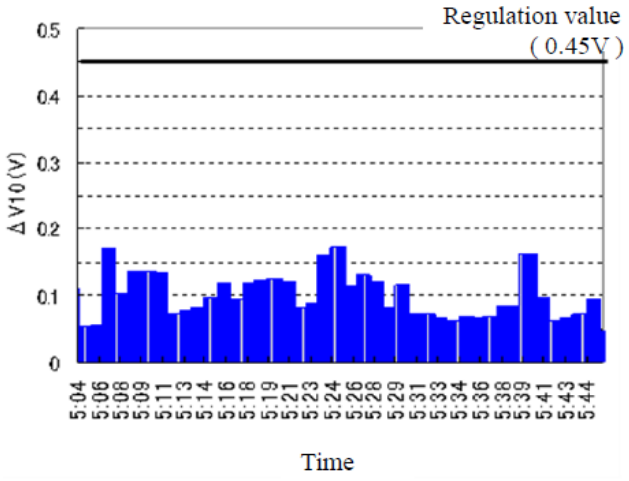

Figure 5: Flicker measurement value in ECOARC™

2-4. High efficiency Off gas treatment system

In the conventional furnace, large size burners are installed in the combustion chamber to thermally decompose pollutants. With strict regulation, the fuel cost becomes too high to ignore. In ECOARC™, CO gas from the melting furnace is mixed and burned at a temperature more than 800 degree Celsius in the combustion chamber, then the causative agent of white smoke, odor and dioxins are decomposed. Only a very little fuel of the burners to ignite the CO gas is used. By semi-air tightness, infiltration air to the melting furnace and the shaft is minimized. Then, off gas volume of ECOARC™ is much less than a conventional furnace and it is about 60% compared to a conventional furnace with the same productivity. Therefore off gas becomes high temperature only by self-burning of presented CO gas. The problems of pollutant such as white smoke/odor in conventional preheat systems also have been solved in ECOARC™ by these processes. Commercial ECOARC™ have cleared the regulation value of Dioxins in each country. Pursuit of the preheat efficiency and restraint of the pollutants were contradicting problems. However, innovative ECOARC™ technology can now provide a solution for the both contradicting demands.

2-5. Highly sophisticated control system

ECOARC™ is also equipped with high level sophisticated control system. Almost all operation tasks are automated including scrap blend instruction, scrap handling, sub material blend instruction and handling, etc. The operator in pulpit can control the ECOARC™ through the seamless control stations including HMI and level 2 with helpful guidance systems. Figure 8 shows an example. It is used for keeping appropriate balance between the volume of charged scrap and the input power.

Merits of ECOARC™ compared with Conventional EAF	
Power consumption	−100 ~ 150 kWh/t
N_2 content in molten steel	−10 ppm
Electrode consumption	−40 ~ 50 %
Tapping yield	+ 1.0 ~1.5 %
Dust generation	−50 %
Flicker	−50 %
Noise	−10 dB
Productivity	+ 20 ~ 60 %

Table 1: Merits of ECOARC™

3. Commercial Application

Table 2 shows the main specification of the six commercially operating ECOARC™. Three of them are green field and the rest three are renewing project. As shown in Table 2, ECOARC™ has wide range on the tapping size, and can handle the worldwide scrap.

Here, the 5th ECOARC™ project in Thailand is shown as an example .The project was planned with an aim to improve the EAF performance and environmental condition of the surrounding area with a minimum shutdown period for revamping the old conventional furnace into ECOARC™ with its auxiliary equipment, direct fume suction system and scrap handling system. Concurrently, reuse of the existing meltshop facilities as much as possible, in order to minimize capital expenditure was another important task.

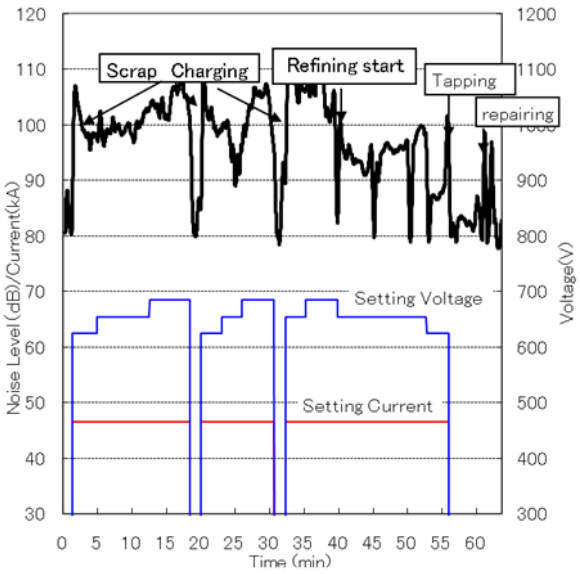

Figure 6: Noise level of conventional EAF

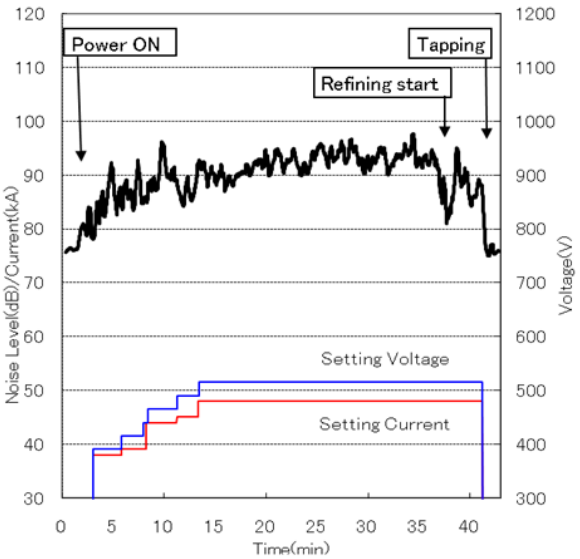

Figure 7: Noise level of ECOARC™

The improvement target figures were cleared just within two months after the hot-run. Regarding the maximum reuse of the existing meltshop facility, no modification of the overhead crane and meltshop building were necessary though ECOARC™ has a vertical shaft and scrap charging method from the top of the shaft. In addition, the existing main power system including the furnace transformer, electrode arms, the building fume suction system with bag filters, the water treatment system and some other auxiliary facilities were all reused. In fact, SPCO can engineer ECOARC™ system as the best suited solution for all customers.

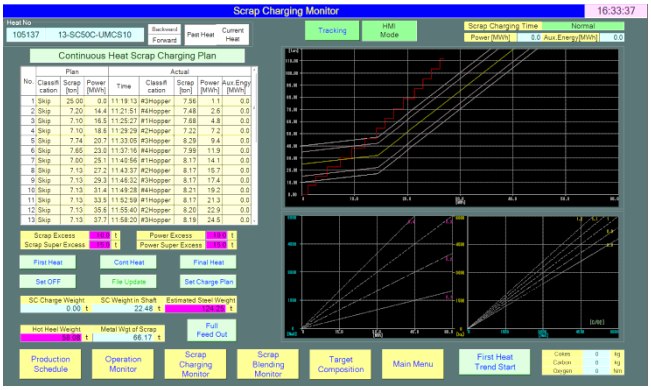

Figure 8: Scrap charging guidance

4. Conclusion

SPCO has developed most advanced arc furnace "ECOARC™" based on totally new ideas, which are

a) Preheating shaft directly attached to the melting furnace.
b) Keeping the shaft fully filled with scrap throughout a heat to preheat it continuously for maximizing energy efficiency.
c) Scrap and molten steel co-existing for efficient heat transfer.

Through the stable operation of the first commercial plant, SPCO has confirmed that power consumption 210kWh/t is achievable. In addition, 2nd to 6th ECOARC™ are operating smoothly and they keep updating their operation records. It is notable that the largest 6th ECOARC™ also successfully started up in the end of 2014.
Production cost and the recent environmental measures are contradicting issues for EAF application. ECOARC™ is the best solution for saving production costs and developing more eco-friendly iron and steel industry.

NO	1	2	3	4	5	6
Startup year	2001	2005	2008	2010	2012	2014
Country	Japan	Japan	Japan	Korea	Thailand	Japan
Heat size	70 ton	140 ton	130 ton	120 ton	70 ton	200 ton
Furnace Type	AC	AC	AC	AC	AC	AC
Trans Capacity	41 MVA (Reuse)	88 MVA (Reuse)	75 MVA (New)	80 MVA (New)	50MVA (Reuse)	115MVA (New)
Electrode	20 in	24 in	24 in	22 in	22 in	28 in
Product	D-Bar	H-beam, FB, Angle	Rod/Wire For Automobile	D-Bar	D-Bar Billet	Long Products, D-Bar

Table 2: Main specification of commercial ECOARC™