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CISDI-GREEN EAF *

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Abstract
The CISDI-GreenEAF innovatively applies the top-side-chute for charging for improving the cold zone of electric-arc furnace (EAF) requiring preheating scrap. It can greatly reduce the operating power consumption during EAF melting by combined use of fume for preheating scrap. The enclosed charging mode and specially-designed structure contribute to less emission of dust and fume during charging while enhancing the metal yield. Thanks to the extraordinary fume temperature control at scrap preheating procedure and fume quenching technology as developed by CISDI, for restraining the regeneration of dioxin.
Keywords: steelmaking, EAF, scrap preheating, dioxin.

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1 Foreword

It's a common pursuit of global steel industry for developing the eco-friendly and energy-conservation electric-arc furnace (EAF), known as or nicknamed as green EAF. To achieve the set target of saving energy and reducing emission, bettering environment and enhancing productivity, the green EAF should hinge on the suited technologies of energy-conservation, environmental protection, automation control and intelligence.

The EAF using fume for preheating scrap emerged in 1990s represented the substantial progress of EAF steelmaking in saving energy, as typical as the Finger Shaft, CONSTEEL and COSS. Those different models of scrap preheating could indeed reduce the power consumptions in melting and enhance the productivity, however, still came across hard issues. For instance, on one hand, there remains the charging cold zone; it would impair the arc thermal efficiency inside the electric furnace and evenness of bath temperature (could improve by stirring); on the other, the consolidated scrap preheating applications have brought about the serious harm to environment, more dioxin in the discharged fume from the EAF using scrap preheating technology, compared with the old-model EAF without scrap preheating. It's against the backdrop of ever-growing attention to environmental protection by the governments and increasingly stringent regulations and policies concerned. The discharge of dioxin from EAF steelmaking has been put under strict control as stipulated in the new environmental laws and regulations in many place. In China, application of scrap-preheating EAF with out fume quenching cooler (control of dioxin) will be restricted.

Another bottleneck worthy of attention is the requirement on acceptable specification of scrap size in charge and maintenance of scrap preheating equipment. China's Shagang and Anyang Steel gave negative feedback in this regard where the scrap-preheating EAFs were operated. That has become one of the major obstacles for promoting the scrap preheating technology in EAF on China's mainland.

CISDI has committed to earnest and enormous studies and researches for approaching the issues in EAF technological development. To that end, CISDI-GreenEAF came into being, independently developed by CISDI characteristic of energy-conservation and eco-friendliness. It's unique in design of top-side-chute for charging, completely different from all the other models of scrap-preheating EAFs. Specifically, it charges the scrap close to arc by taking use of the horizontal velocity of scarp inside of the chute; in so doing, the cold zone of scrap-preheating EAF can be improved to a large extent [1].

CISDI-GreenEAF relies on the technological synergy of scrap preheating for saving energy, environment-friendly production, equipment reliability, and automation control. The key technologies hereof are:

1) EAF enclosed charging;
2) Scrap being preheated by fume in penetrated way;

3) Fume temperature control and regulation after preheating scrap;
4) Fume insulation and quenching after preheating scrap;
5) EAF top-side-chute for charging;
6) Highly-reliable automatic charging system;
7) Highly-efficient and energy-saving DMI-AC electrode regulation system;
8) Flat bath melting;

2 Technological Highlights of CISDI-GreenEAF

2.1 EAF Enclosed Charging Technology

The dedusting structure is designed with opening control to minimize the overflow of dust and fume from the charging process and solve the issue of a large amount of heat dissipation that occurs to the furnace requiring opening lid for charging. The enclosed charging technology can lessen discharge of dust in production while the metal yield will have increased by 1~2 percent. Less dust discharge from this procedure is also conducive to decreasing the required dust extraction volume of the whole workshop, thus saving the investment of related dedusting fan equipment to some degree.

The CISDI-GreenEAF charging technology reduces the additional auxiliary time and avoids energy consumption due to lid-opening charging; reduces the lid and electrode movements, relieving the equipment maintenance work.

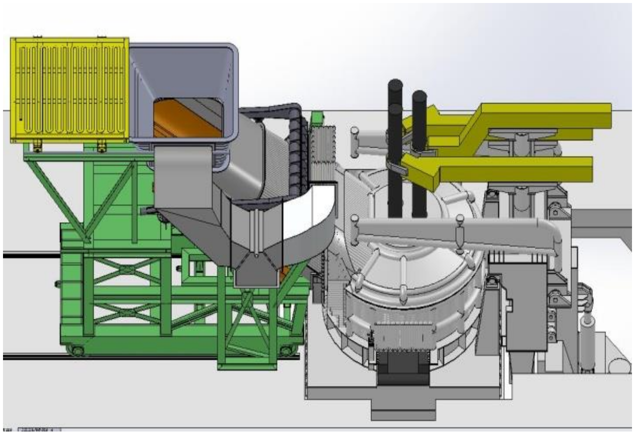

Figure 1. CISDI-GreenEAF

2.2 Automatic Charging Technology

The CISDI-GreenEAF is designed with the ramp titling skip for automatic charging instead of charging by crane. The charging duty is realized by multiple small batches, normally 4~5 batches per feeding. Supported by the EAF large hot heel and scrap preheating operation, the fully automatic charging technology can alleviate the impact on power grid in melting and shorten the tap-to-tap cycle. The ramp tilting skip acts mechanically in reliable manner and in need of minor maintenance.

2.3 Melting Cold Zone Improvement Technology

The melting cold zone is primarily caused by the accumulated materials at one side. The top-side-chute charging technology can improve that situation by controlling the material falling points during enclosed charging process, thus creating more uniform heating of arc and enhancing the heating efficiency.

2.4 Penetration Scrap Preheating Technology

For the top-side-chute charging, it's considered installing an adjustable rake door (or called a barrier) apart from the interface between scrap preheating room and furnace proper. Such a rake door can separate scrap or control material falling. During charging, the rake door is closed to stop the scrap within the preheating room; in the meanwhile, the fume passes through the rake door via the seal cover and penetrates the scrap in the preheating room, gaining sound preheating effect and energy-saving purpose.

2.5 Dioxin Control Technology

The CISDI-GreenEAF applies the selective split-flow fume for preheating scrap. The split-flow dedusting piping is regulated and the flow proportion of dedusting main controlled. In this way, the fume temperature after preheating the scrap can be accurately controlled [2]; when the mixed fume temperature has met the requirement and keep a few seconds, the fume enters the quenching cooler for rapid cooling, which can suppress the secondary synthesis of dioxin in fume cooling process.

It's refrained from fume after-burning or needs only slight after-burning for inhibiting re-generation of dioxin. The fume quenching helps save energy and lower cost in dioxin control.

2.6 DMI-AC Electrode Regulation System

The DMI-AC electrode regulation system developed by CISDI applies the intelligent dynamic control and energy input optimized target control, and plays the function of automatic regulation of optimum working point. It can improve the electric energy utilization ratio and keep the EAF's electric performance at best. The electric response time of the DMI-AC electrode regulation system is shorter than (<) 60ms, a remarkable advancement in arcing stability. By virtue of the peculiar busbar balance design and high-power supply technology, the current fluctuation ratio during the period of electrode inserting to bottom can be controlled lower than (<) 33% and that during the melting-down period controlled lower than (<) 14%.

The DMI-AC electrode regulation system is developed with electrode saver protection hardware detection and electrode slip measurement functions, able to reduce the probability of electrode breakage during melting process.

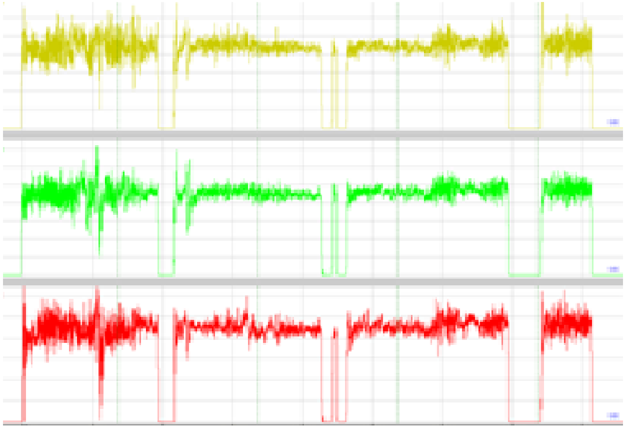

Figure 2. Working Effect of Electrode Regulation System (as recorded at a certain EAF site)

3 Considerations

3.1 Design Basis of CISDI-GreenEAF

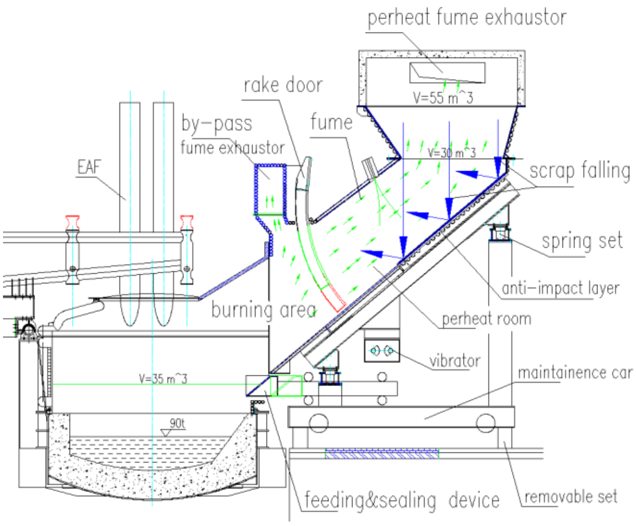

Figure 3. Structure Sketch of CISDI-GreenEAF

The top-side-chute charging technology bears the key to CISDI-GreenEAF technological development. The proper inclination for scrap to fall along the chute was explored in the tests of scrap cold chute. The chute is designed with a structure of gradual widening and gradual elevating; the chute itself is inclined too. The preheating room is built a smooth surface. The scrap falls down from the spatial height at a certain horizontal velocity, which makes the scrap at the bath move to the center of EAF. By this way, the cold zone issue inside of the furnace can be improved.

After preheating, since the scrap presents bigger static friction coefficient, it should pay attention to controlling the scrap preheating temperature at the preheating tank, so that the scrap can be avoided from sticking with preheating tank due to overheat. To remove that significant risk, it invents a dual-flue to have a good control of the scrap preheating temperature. Besides, by understanding the scrap distribution at the preheating room and the flow direction of fume, it can make a judgment that the scrap at the bottom of preheating tank is positioned at a relatively low-temperature zone. It provides a favorable condition for the scrap to fall along the chute.

The rake door swings in a curved track, decreasing the probability of scrap being intertwined with the rake, becoming more acceptable at the scrap specification. And the rake door can be completely withdrawn from the top of preheating room, not posing obstacle to scrap movement at all. However, in case of scrap sticking and unsmooth charging, the dedicated auxiliary vibration conveyor can enforce a large-inclination vibration activity to help convey the material.

3.2 Improvement on Equipment Reliability of CISDI-GreenEAF

The top-side-chute charging technology benefits the higher reliability of equipment. The chute itself is inclined and unites with the rake door nearby the EAF proper to compose the scrap preheating room. The rake door is actually the weakest part in the entire preheating equipment structures because it has to be exposed to the severest working conditions, withstanding the high temperature and impact. Nonetheless, by using the chute receiving the material from the external basket, the falling height of scrap is reduced, so is the scrap's gravitational potential energy. To escape from direct impact of the scrap, the chute charging inlet is designed with its vertical projection in shunt from the rake door, as shown in Figure.3.

Some other measures are taken to further upgrade the equipment reliability:

1) The vibrating section is specially designed for further reducing impact of the falling material onto the chute;
2) Materials are internally collided with each other since they are changed the course of movement by impacting on the chute, thus further depleting their impact energy onto the chute bottom;
3) The weak section of chute subject to impact is installed with wear-resistant bars which can be replaced;
4) The rake door is added with spring set for protecting it from being seriously impacted;
5) The rake can be partially pulled out during chute charging so as to mitigate the heat duty of rake and save the heat loss by rake's cooling water.

Moreover, the charging operation is optimized; small batches are charged by multiple times, and the light and medium-weight materials are charged first and the heavy materials put in the middle part of the stock column; in so doing, the related equipment can suffer less impacts and become more reliable in operation.

3.3 Concept of CISDI-GreenEAF on Efficient Use of Fume and Control of Dioxin

One of the important aspects to study of CISDI-GreenEAF lies in how to make a highly efficient use of the sensible heat of the fume generated from the EAF melting process, with a peak temperature range of 1,400~1,800℃. In CISDI's design, the excess heat of fume gets the best use to preheat scrap, a direct means to save the EAF's electric energy input. From the perspective of energy balance, it's known that if the input heat energy for scrap preheating is converted to the electric energy, it will get positive benefit in view of the thermal efficiency of EAF system itself. Concretely speaking, for instance, when the 40kWh/t heat energy is brought in EAF by scrap preheating, it can be converted to about 50kWh/t electric energy input by electrodes, which can be saved in real sense. Hereby, the scrap preheating technology should be taken as a priority for energy saving as it is.

Just as all coins have two sides, the existent EAF with scrap preheating imposes great challenge of dioxin on the environment control. At present, it can resort to fume quenching to suppress generation of the dioxin in the discharged fume.

The low-temperature fume vented from scrap preheating procedure is re-heated by natural gas or gas at the after-burner up to 850~900℃; staying at the reheated temperature for at least 3s, the dioxin in the fume can be completely decomposed; then, the high-temperature fume is quenched at the quenching tower to below the range of 200~250℃; the rapid cooling can arrest regeneration of the dioxin.

As a matter of fact, the volume and temperature of fume in the EAF tap-to-tap cycle are not stable, the scrap size, temperature and permeability and other boundary conditions are hardly defined, and the equipment operation consumes heat energy. To that end, the temperature of discharged fume from EAF with conventional scrap preheating cannot be kept in a stable range; the temperature of after-burnt fume would generally rise, unable to be accurately controlled. In other words, the energy loss from fume after-burning and quenching is understood as an encroachment of the saved electric energy mostly from the scrap preheating [3] [4]. That underscores the study on how to make a cost-effective control of fume temperature downstream scrap preheating. In the light of analysis on energy balance, large capacity of hot heel operation and multiple small batches charging can result in relatively stable and continuous fume volume and desired temperature. The fume at temperature range of 1,400~1,800℃ dropping to 900℃ can still contribute the sensible heat of 500℃ and beyond, which is generously recovered for preheating scrap. In this way, it accommodates both energy saving and environmental protection.

The CISDI-GreenEAF holds the unique design of a chute for preheating, letting the fume penetrate the scrap at the preheating room, fulfilling the highly-efficient direct recovery of that energy. The melting power consumption of an EAF can reach 320~340kWh/t. However, the CISDI-GreenEAF will reduce the power consumption to 300~320kWh/t if the mixed fume temperature is controlled at 800℃ for degrading the fume temperature control requirement of dioxin suppression, or the higher chemical energy is introduced or larger hot heel operation conducted.

3.4 Dioxin Control Scheme of CISDI-GreenEAF

The CISDI-GreenEAF takes its structural advantage in realizing fume temperature control during scrap preheating. The scrap preheating room is composed partly by the chute structure which is connected closely with the top side of the EAF. On the top of preheating room is a preheat fume exhauster (namely, the main dedusting side); in the front of preheating room is the bypass fume exhauster (namely, the bypass dedusting side). The whole preheater's both exhausters converge to a tee valve, and the fume is mixed in the piping downstream that tee valve. Either of the fume routes can be selected for switch-off by the tee valve. The opening of the tee valve can be made step-less regulation.

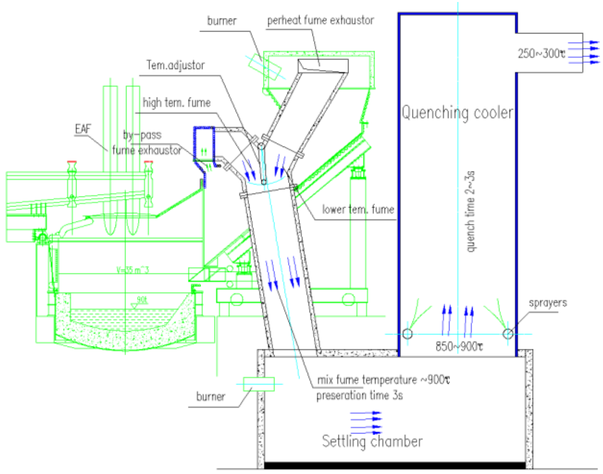

Figure 4. Dioxin Control of CISDI-GreenEAF

The discharged fume is duly fired with mixed gas in front of the preheating room, and then divided into two parts, one part of high-temperature fume passing through the bypass fume exhauster and the other penetrating the preheating room and preheating scrap. Both parts are mixed at the fume tee valve; the flow rates of both flues are controlled by the tee valve according to the measurement of mixed fume temperature. The fume temperature with dynamic control as discharged is kept in the range of 850~900℃, followed by the fume quenching procedure for holding back dioxin regeneration. Seen from the above analysis, the CISDI-GreenEAF hits the targets of both energy saving and environmental protection.

The CISDI-GreenEAF also takes the lead in applying flat bath and large hot heel operation technology (hot heel reaching up to 50%~100%). It is useful for producing the stable and continuous volumes of fume at the required temperature, and facilitates the stable control of fume temperature downstream the scrap preheating. When the fume falls far short or fails to reach the desired temperature, the tee valve at the main dedusting side can be closed; at that moment, no scrap is preheated and little dioxin possible for generating. Under the circumstances, only a small volume of fume needs after-burning or even none for raising the temperature of fume.

4 CONCLUSION

The CISDI-GreenEAF innovates in using the top-side-chute charging system. It does improve the equipment reliability and inherent cold zone of the EAF with scrap preheating system. The unique design of chute preheating complies with the rule of fume flow field distribution, and gains a good preheating efficiency while remarkably saving the melting power consumption. The enclosed charging system combining the fume exhauster structure and opening control ensures to minimize the overflow of dust and fume during charging while enhancing the metal yield. In terms of control of dioxin generation, the CISDI-GreenEAF contains its own suppression technology at scrap preheating procedure and exerts the fume quenching technology for putting an end to its generating source. The innovative DMI-AC electrode regulation system performs well in fast electric response and automatic adjustment of optimum working point, playing its due role in enhancing the utilization ratio of electric energy.

In conclusion, the CISDI-GreenEAF characteristic of energy-conservation and eco-friendliness will be an ideal electric furnace model for bringing about melting cost effectiveness and sustainable competitiveness for the steel enterprises.

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