EFFECTIVE USAGE OF SOLID WASTE IN STEEL PLANT

BY

DONG-HAI LI *, ZHI LI, LEI LUO, HAI-QUAN YONG, BAO-LONG LUO

SYNOPSIS:

With the significant growth of steel yield, more and more solid waste are generated in steelworks, which usually don’t get effective usage. This not only inevitably results in wasting of resource, but also pollutes the environment seriously. Hence, this paper particularly focuses on the iron-containing solid waste in steelworks, and introduces several disposal processes, respectively, including rotary hearth furnace, cold-bonded pellet and homogenization. Finally, a concept of comprehensive disposal platform with the abilities of centralized management and classified treatment was put forward to realize the optimized reutilization and green renewable development.

Keywords: solid waste; iron-containing dust and sludge; resource recycling; rotary hearth furnace; cold briquette; homogenization;

* Engineer of Solid Waste Disposal and Environmental Control Division, CISDI Group Co., Ltd, Chongqing, China
1. Introduction

In recent decades, enormous amount of solid waste were produced by the iron and steel enterprises with the drastically increase of the world’s steel production capacity, which not only causes great negative impact on the environment protection and resource saving, but also restricts the further development of the steelworks reversely. Therefore, it is great significant to recycle the solid waste more efficiently and economically for the steelworks.

The solid waste in steelworks are produced constantly in every process, such as smelting slag (blast furnace slag, steelmaking slag), iron-containing dust and sludge (including stockyard, coking, sintering, ironmaking, steelmaking and rolling etc.), steel scrap, and so on. The output of solid waste is about sixty percent of the steel yield (every steelwork may has difference situation due to its individual raw materials, production process and dedusting technologies). Take a Chinese ten-million-ton integrated steelwork as example, the solid waste output and utilization ways were shown in Table 1. Wherein, the iron-containing dust and sludge and slags are main two kind of solid waste. The slags can be almost 100% reused as high iron contained material or construction material after processing. As for the iron-containing dust and sludge, which is a good kind of iron mine deposit; however, because of the existence of volatile such as Zn, alkalis etc., it is difficult to recycle by sintering directly, which can certainly bring cyclic accumulation in the blast furnace and cause severe damage to the lining and worsen the production. Therefore, large amount of iron-containing dust and sludge with high zinc are stocked or sell out, which not only cause secondary pollution, but also waste the valuable elements. Under this circumstance, it is very necessary to disposal the iron-containing dust and sludge systemically and effectively, on their basic characteristics.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Name</th>
<th>Output</th>
<th>Utilization way</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Stockyard dust</td>
<td>75</td>
<td>Self-circulation in the unit</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Sintering and pelletizing dust</td>
<td>240</td>
<td>Self-circulation in the unit or export</td>
</tr>
<tr>
<td>3</td>
<td>Iron containing dust and sludge</td>
<td>Blast Furnace dust/sludge</td>
<td>330</td>
<td>high zinc iron containing dust sludge stockpiled and exported, other self-circulation in the unit or export</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Converter dust/sludge</td>
<td>460</td>
<td>Self-circulation in the plant or export</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Electric furnace dust</td>
<td>7.5</td>
<td>Sub-contractor</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>scale</td>
<td>150</td>
<td>Self-circulation in the plant</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Coking dust</td>
<td>75</td>
<td>Self-circulation in the plant or export</td>
</tr>
<tr>
<td>8</td>
<td>slags</td>
<td>Blast furnace slag</td>
<td>3,085</td>
<td>Export after water quenching</td>
</tr>
</tbody>
</table>
2. Recycling technologies of iron-containing dust and sludge

Because of the complexity of iron-containing dust and sludge, it is impossible to dispose of them in only one way. In consideration of the differences of the zinc content and the demands for products, it is proposed to treat the waste in combined ways. On behalf of decreasing the enrichment of zinc in the blast furnace, the BF dust or sludge and EAF dust with high zinc content can be recycled after dezincification by the rotary hearth furnace. The LT dust or OG sludge etc. from steelmaking process can be briquetted as uniform pellets and return to converter as coolant, forming a short circular process economically and environmentally. And for the rest iron-containing dust and sludge with low zinc can be homogenized before being reutilized by sintering.

2.1 Rotary Hearth Furnace (RHF) Technology

(1) Technic Process

The rotary hearth furnace (RHF) technology belongs to coal-based directed reduction process, which is typically shown as Fig.2. After mixing of the iron-containing and zinc-containing dust or sludge with reducing agent and binder in accordance with certain proportion, the mixture will be pelletized by disc pelletizer or roller pressure machine; then the proper pellets can be achieved after screening and drying; afterwards, the green pellets should be reduced in the RHF during nearly 20~30 minutes under 1250°C ~1300°C and reducing atmosphere. The oxides of iron and zinc will be quickly reduced by the carbon inside the pellets; then the zinc will be vaporized and flow into exhaust gas and reoxidized as ZnO powder, which can be recycled by filter bags; meanwhile, the iron element will be existed as metallic state mostly in the pellets, which are known as the direct reduction iron (DRI). After being discharged from the furnace, the DRI should be cooled below 200°C, so as to avoiding reoxidation and transporting easily to customers such as BF or converter.
(2) Key Technologies

1) Pelletization methods

As a result of various kinds of raw materials and dedusting process in different steelworks, large differences of physical and chemical properties will be presented between the dust and sludge for RHF treatment, such as the chemical composition, particle size, wettability, adhesion etc. At present, there are two main methods for pelletization. The disc pelletizer is suitable for the fine particles with good wettability, but usually has a fluctuant yield and quality, which is against the production stability. Whereas, the pelletization with roller pressure machine is more adaptable for a wide range of materials and can produce higher strengthened green pellets, however, the high expenditure of binder will probably increase the production cost. Therefore, overall consideration must be taken into particularly on the basis of actual situation, before choosing a proper pelletization method.

2) Carbon-bearing pellets self-reduction controlling system

The required reduction time for carbon-bearing pellets in the furnace is approximately 20~30 minutes, which is so quickly to complete the reduction with the co-existence of combustion, gas flow and heat transfer, that is nearly impossible to keep pace with the adjustment of the upstream process. Moreover, because of the weak association with each procedure, the traditional controlling method is mainly up to the experience of operators. Hence, it is necessary to establish an expert system to control the whole process more predictably and accurately, which should be based on the big data analysis of core process parameters, operation rules and product qualities.
3) Heat recovery and purification of exhaust gas

The exhaust gas will take a large part of heat away from the furnace due to its limitation of low thermal efficiency, in the meantime, the by-product zinc powder will be also carried off. Therefore, a heat boiler and a bag filter are necessary to recovery the waste heat and purify the exhaust gas. However, because of the dust and sludge also contain a lot of volatile elements such as K, Na, Cl, Pb etc., which are inevitably vaporized into the gas and easily lead to blocking and corrosion of the boiler tube bundle and filter bags. It is essential to own anti-blocking and anti-corrosion design for the exhaust system. According to the experience, the gas temperature must be lowered below 650°C in several seconds so as to avoiding melting and sticking to the boiler tube bundle and weaken the chlorine corrosion effectively, besides, combined clean facilities in sequential are also indispensable to clear the tube bundle. As for the bag filter, the key point is to prevent the moisture absorption, especially in the surface of flue, bags and hoppers, which calls for strict temperature controlling and proper bag material with additional protection measures.

4) Core equipment design

Objectively, it is not yet long enough for the developing and application of RHF technology, and there are lack of mature and reliable equipment suppliers. Moreover, because the working conditions are extremely complicated and harsh, the advanced core equipment design ability is essential for the whole process.

- Stable and reasonable furnace—as mentioned above, for the sake of appropriate reduction conditions, especially a uniform temperature field and precise atmosphere, and in consideration of the low thermal efficiency, it is crucial to design the furnace with energy-saving combustion system and good thermal insulating property. Furthermore, good slag erosion resistance is also needed to prevent the formation of low-melting phase between the refractory and dust in the exhaust gas with Zn and alkalis.

- Economic and durable discharging equipment—The DRI pellets are discharged by a screw discharger with shaft, blades and so on, under a continuous high temperature. Besides, the DRI pellets have heavy abrasiveness and can easily cause wear and tear. Therefore, it is very import to optimize the screw parameters, materials and cooling system as far as possible.

- Quick and reliable cooling equipment—The DRI pellets with high iron content can arrive as high as 1200°C after reduction and discharging from the furnace, which must be lowered below 200°C with special anti-oxidation measures so as to avoiding reoxidation and
transporting conveniently. Meanwhile, in view of the heavy abrasion between the DRI pellets and the cooling equipment, a particular inner structure design is vital to balance the cooling effect and abrasion degree.

2.2 Cold bonded pellet technology

Cold-bonded pellet technology means that the dust and sludge are shaped by a pressure machine after mixing with binder, and the product are uniform green pellets which would have high intensity after drying or curing. This process is extremely favorable for the treatment of steelmaking waste since the product can directly return the converter as cooling agent and slag-making material, and this can form a well simple and short circular process with low cost and flexible production. Besides, the pellets are also good for the converter steelmaking which are shown as follows

![Figure 2 A typical cold-bonded process](image)

(1) The cold-bonded pellets have good cooling effect and slag-forming ability because of high content of iron oxide, which can shorten the production cycle and improve the productivity.

(2) Due to the existence of CaO, less consumption of lime is possible and high slag basicity can be achieved in the initial stage, which is beneficial for the longevity of lining and oxygen lance.

(3) One can decrease or even substitute various kind of slag materials such as lime, iron ore and scrap etc., and greatly simplifying the operation process.

(4) The cold-bonded pellet technology can significantly improve the circular utilization of solid waste with high efficient recovery of ferrum and calcium, and greatly reduce the waste
emission. Which not only solves the dust and sludge pollution, but also obtains great economic and environmental values.

2.3 Homogenization Technology

Homogenization technology is mainly used to deal with iron-containing dust and sludge with low-zinc or even no zinc to produce blending materials for sintering. This kind of dust and sludge usually have very complex physicochemical properties and s, which is impossible to return sintering directly as iron-bearing materials. Thus, it is very necessary to mix them together to have uniform and stable properties.

Advantages of homogenization technology are listed as follows.

(1) Modifying the sludge which are difficult to store and transport;

(2) Making the dust and sludge having homogeneous chemical composition and moisture, which can be good iron-bearing materials.

3. Engineering application

According to the enterprises’ situation, the above processes can not only be constructed and operated independently, but also can be integrated for systematical management. Take a new constructed steelwork as example. By setting up a comprehensive disposal center, all the iron-containing waste can be precisely managed and properly treated; meanwhile, the DRI pellets, cold-bonded pellets and blending materials etc. can be produced for ironmaking and steelmaking.

<table>
<thead>
<tr>
<th>No.</th>
<th>Process name</th>
<th>Capacity(t/a)</th>
<th>Handling waste</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RHF process</td>
<td>200,000 (200,000 reserved)</td>
<td>BF dust, Coking dust, OG sludge, etc.</td>
<td>DRI pellets</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Metallization ratio≥70%; Dezincification ratio≥85%)</td>
</tr>
<tr>
<td>2</td>
<td>Cold-bonded pellet process</td>
<td>200,000t/a</td>
<td>OG sludge, steelmaking dust etc.</td>
<td>Cold-bonded pellets</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Compressive strengthen ≥ 700N)</td>
</tr>
<tr>
<td>3</td>
<td>Homogeneous process</td>
<td>800,000</td>
<td>Ironmaking dust, steelmaking dust, etc.</td>
<td>Blending materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Moisture 10%-12%)</td>
</tr>
<tr>
<td>4</td>
<td>others</td>
<td>200,000</td>
<td>scale, etc.</td>
<td>Iron-bearing mine</td>
</tr>
</tbody>
</table>

Table 2 A iron-containing waste disposal center in a steelplant

4. Prospect

Because of the differences of raw materials and numerous production units, various kinds of iron-containing waste are produced with different properties, which are difficult to deal with.
Moreover, most enterprises are generally lack of specialized and scaled management, and not form a sustainable and effective supervision system yet. It is gradually unable to meet the need of green circular development for the ironmaking and steelmaking enterprises. So, a reliable way to handle the dust and sludge systematically with minor influence on the current production, is especially necessary from the perspective of the whole ironmaking and steelmaking process.

According to establish a comprehensive disposal platform, all kinds of iron-containing waste will be managed centrally, and different technologies will be systematically integrated to realize the total recycling of waste in specialized and scaled methods. Which is not only beneficial for the cost reducing, but also favorable for the pollution controlling, and finally promote the long-term development of steel industry.