A PRACTICE OF FERROALLOY PRODUCTION IN AN "ENVIRONMENT-FRIENDLY AND RECYCLING" WAY

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ABSTRACT

The ferroalloys industry has generated historically substantial solid waste. The accumulated waste causes serious problems to the environment. However, it is possible to transform the solid waste into an environment-friendly resource to serve the human being. Consequently, the construction of plants that are "environment-friendly" and that accommodate "recycling" has become a target of most ferroalloy producers in the world to ensure sustainable development.

This paper introduces the practice of Shanxi Jiaocheng Yiwang Ferroalloys Works, the biggest manganese metal producer in China, in the development of an "environment-friendly and recycling" process. The process includes power generation using coal gangue, waste from local coal mines; hollow bricks manufacture using slag and fly ash from the power station; cement production using slag from ferroalloy smelting; recovery of ferrous and non-ferrous elements in the dust from the furnace gas cleaning system; application of silica dust in construction and so on. The final objective of the plant is to realize zero discharge of solid waste.

The profit of the "environment-friendly and recycling" process compensates in part for the operational expense of the environment facilities.

1. INTRODUCTION

Great amount of wasted material is generated by industries and has caused tremendous harm to both the environment and ecology. The development of science and technology has made it possible to transform the waste into new resources to benefit human beings. In fact, zero discharge of waste materials in many industries becomes true. The construction of pollution free and recycling plants is the target of sustainable development of ferroalloy industry in all countries of the world.

Excessive ferroalloy production has been a problem for many years in the international market. The industry has to reduce its production cost in order to survive in the competitive market. Currently ferroalloy production capacity in China is more than 7 million t/a. The production capacity of manganese metal is over 300 000 t/a, of which 90% is in the form of manganese flake. The production of electrolytic manganese flake in China relies on the abundant lean ore reserves and local hydroelectricity supply. The production of smelted manganese metal, however, requires high quality manganese ore and consistent power supply. More and more ferroalloy producers in the world realize that the ferroalloy industry would not survive unless it consolidates with the upstream industry, like the mining and the power industries.

Shanxi Jiaocheng Yiwang Ferroalloy Works is the largest manganese metal producer in China. It consists of a power plant, smelting plants and a hollow block plant. Yiwang Ferroalloys Works has gained extensive experiences in the practices of environment protection and material recycling. The whole production process becomes pollution-free, with the emphasis on recycling.

These initiatives include:

- Power generation from coal gangue, which supply power for ferroalloy production;
- Preheating of manganese ore in a rotary kiln and hot charging;
- Ferroalloy production in submerged arc furnaces, as well as in refining furnaces;
- Hot metal treatment to recover manganese from the molten slag;
- Briquetting and recycling of manganese dust fines;
- Lead recovery from manganese ore;
- Hollow block manufacturing using fly ash and slag.

The application of the novel processes and the recycling process have not only reduced the production cost, but have also saved energy and optimized the utilization of resources. Zero discharge of waste materials has become a reality in the production process.

2. EXPLOITATION OF ENERGY RESOURCES

Power supply exerts influences on the ferroalloy market to a considerable extent. With the development of the national economy the Chinese power industry has been growing very rapidly. However, the power supply in many places in China is still tight. The power generation in South China varies with seasons, where hydropower is dominant. The ferroalloy production there has been conditioned in dry season.

On the other hand, the economy in East China has become more developed than the economy in West China. The power supply in the West China is relatively abundant. Consequently, a tremendous amount of electric power is transmitted from West to East China.

The power supply to many ferroalloy plants in China is restricted in peak hours and in the dry season. The government restricts the installation of the power generators less than 50,000 kW in order to keep the utilization of energy efficient. However, the installations of power stations that utilize waste materials and secondary energy, such as coal gangue power stations, has been encouraged. Several incentives including exemption of income tax and value adding tax are given to this kind of projects.

Coal gangue is a waste material in the coal production process, with 200 million tons of gangue is discharged from coal mines each year in China. This waste overlays 1,400 hectares of land that causes numerous problems to the environment and the ecology. The government has encouraged the protection of farmland and the utilization of gangue in industry. However, so far only 15% of the accumulated gangue is consumed in industry due to various technical problems.

The area where Yiwang Ferroalloys Works is located is rich in gangue disposal. There are more than 20 coal washing plants in the surrounding area, with 500,000 t of coal gangue that is produced each year. It overlays a great deal of land and causes significant pollution. The gangue is a potential resource of energy with a heat value that ranges from 7,000 to 13,000 kJ/kg.

During 2000 a gangue power station of two 6,000 kW power generators was completed in Yiwang Ferroalloy Works. This power station consumes 200,000 t/a of coal gangue, resulting in a power generation of 100,000 MWh/a. In addition it supplies 40 t/h of steam to local heating system. Generally, the cost of the power generated in the Gangue Power Station compares to one third of the power tariff of the national power network only. The overall power consumption of LC FeMn and manganese metal is around 7,000 kWh/t. The cost of power consumption contributes to nearly 30% of the production cost. The installation of the power station has considerably enhanced the competitive nature of our product in the market. Besides, since the installation of the gangue power station the supply of our products to the market has no longer been dictated by power supply.

3. IMPROVEMENT OF HEAT EFFICIENCY IN THE SMELTING PROCESS

3.1 Potential of heat efficiency improvement in the ferroalloy industry

Ferroalloy production is a high energy consuming industry. Ferroalloy smelting not only consumes great amounts of electric energy but also consumes a great deal of chemical energy in the form of coal and coke. The metal, slag and furnace gas generated in the process, leave the furnace carrying a lot of sensible heat energy. It is considerably advantageous to be able to use the latent energy of the materials in the process.

3.2 Preheating of manganese ore

Preheating of manganese ore in a rotary kiln is applied in the process of HC FeMn production at YiWang Ferroalloys Works. Manganese ores contain a certain amount of combined moisture and adhesive water. The moisture in manganese ores ranges from 2% to 10% or even higher in the rainy season. At elevated temperatures a great amount of CO_2 and H_2O gas is released from manganese ore, descending to the hearth in the smelting process. It is troublesome when an ore with high moisture is charged to the furnace. Not only does it consume a great deal of coke but it also causes slagging and “blowing” problems. Serious “blowing” incidents may damage equipment and cause injury to operators around furnaces, resulting in hot stoppages of the furnaces.

The benefits of ore preheating and hot charging are as follows:

- Utilizing cheaper energy to heat charge materials in order to reduce the power consumption;
- Reducing the risk of furnace “blowing”;
- Improving the furnace efficiency.

As a result the specific power consumption is reduced by 10%. Consequently, the output of the furnace is increased by 10%.

3.3 Ladle treatment and hot charging

The Chinese ferroalloy industry has developed a variety of techniques to improve the heat efficiency of smelting processes, especially in the refining process. The basic principle of the process is based on the utilization of the latent heats of hot metal and slag, as well as the chemical potentials of the materials. The process consists of two stages. The first stage is the ladle treatment of hot metal and slag. The second stage is hot charging. Yiwang Ferroalloys Works applies this process in LC FeMn and manganese metal smelting.

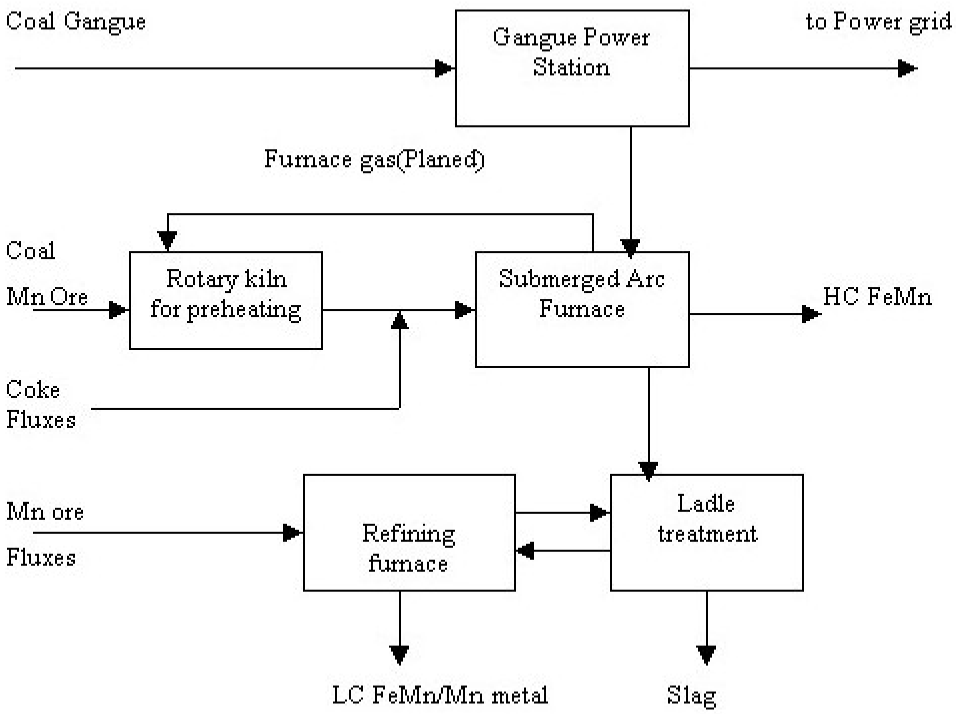

Figure 1. Energy structure system in Yiwang Ferroalloys Works.

The process innovation has substantially improved the heat efficiency and the power consumption. The production results indicated that around 30% of the power consumption in the refining process was reduced. Figure 1 shows the integral energy structure of Yiwang Ferroalloys.

4. RESOURCE RECYCLING AND ENVIRONMENT PROTECTION

4.1 Improvement of manganese yield in production

China is short in manganese reserve, especially in high grade manganese ore. The average Mn content in the local ore is only 30%. The annual manganese ore production in China is 5 - 6 million t/a. It is substantially less than the local demand for manganese consumption in iron and steel production. China imports more than 2 million tons of manganese ore each year. Yiwang Ferroalloys imports 40,000 t/a of manganese ore. The proportion of manganese ore in ferromanganese production cost is approximately 40%. Manganese has been considered as a valuable commodity in our plant and a great deal of attention is paid to the improvement of manganese yield in the production process.

In order to reduce the pollution caused by the gaseous emissions, bag filters have been installed on all furnaces and inside raw material treatment facilities. Each year a significant tonnage of manganese dust fines are recovered via the environment protection system. Table 1 shows the dust recovery of the facilities.

Table 1. Distribution of manganese dust recovery.

Origin	FeMn Furnaces	Refining Furnace	Rotary Kiln
Output t/a	1,300	400	1,500

Manganese emission in smelting plants is detrimental to human health. The exposure to manganese is a risk for the development of neurological illnesses. On the other hand, manganese dust fines is a useful resource of manganese. Table 2 shows the chemistry of these fines. The particle size of the fines is too small to be used directly in the smelting process. Many plants dispose the dust as waste material. We have developed an agglomeration process for the dust fines.

Currently, 100% of the fines is recovered and smelted in the process. As a result the overall yield of manganese in the process is enhanced by 3%. This increased recovery of the manganese units helps to compensate for the costs of the dust cleaning system. The installation of bag houses at all the furnaces greatly reduced manganese exposure at Yiwang Ferroalloys.

Table 2. Chemistry of manganese dust, %.

Chemistry	Mn	SiO_2	CaO	Al_2O_3	MgO
HC FeMn, %	~32	~10	~6	~6	~2
Refining, %	~18	~5	~43	~3	~1

The following innovations were introduced in our ferromanganese production process:

- Ladle treatment technique where hot metal with a high silicon content and molten slag with a high manganese content is mixed outside of the furnace. As a result the residual content of the manganese in the waste slag is as low as 3 – 5%.
- The hoods of the furnaces were modified as such to avoid the loss of dust and to reduce the amount of flue gas.
- Metal particle recovery. A lot of scrap metal is generated by the finishing operations on the final ferroalloy products and by the metal separation from the slag. All the scrap is recycled in the process.

4.2 Utilization of waste solid materials

The solid waste in Yiwang Ferroalloys consists of slag and fly ash. The particle size of fly ash is extremely small. In windy weather these fines are deposited all over the plant and its surroundings, causing serious pollution to the environment. The composition of fly ash is shown in Table 5.

Another problem caused by the solid waste is that the disposal of fly ash and slag cover a significant portion of farmland. It is estimated that there is 14,000 hectares of land in China covered by 700 million tons of fly ash. The disposal of large quantities of waste material creates a lot of problems in the ecology and the environment. The annual disposal of slag and fly ash is shown in Table 3.

Table 3. Annual disposal of solid waste in Yiwang Ferroalloys.

Solid waste	Fly ash	Boiler slag	Ferroalloy slag
Amount, t/a	~ 50,000	~ 20,000	~ 60,000

The government has paid attention to the pollution control of solid waste disposal. Preference has been given to the projects such as recycling of waste materials. Incentives by the government include the exemption of value-added tax, the exemption of income tax in the initial 5 years and the exemption of import tax on the technical facilities.

4.2.1 Utilization of ferroalloy slag

The manganese content in the slag is extremely low after the ladle treatment. Though this slag is a waste product for the ferroalloy industry, it is regarded as a resource for the construction material industry.
Table 4 shows the chemistry of the waste slag discarded from ferromanganese/manganese metal production.

Table 4. Chemistry of manganese slag disposal.

Term	Mn	SiO_2	CaO	Al_2O_3	MgO
%	< 5	~ 42	~ 43	~ 6	~ 3

Water granulation is used during slag treatment. After the treatment all the granules are transported to the adjacent cement works. The cement production process has proved that slag is very useful as a blending material.

4.2.2 Manufacturing of hollow blocks

Though China is an agricultural country, the average area of farmland relative to the population, is lower than that of the rest of the world. With the development of the national economy the area utilized for construction has increased. Among the utilized land, considerable area is used for the manufacturing of bricks. There are 120,000 brick manufacturing plants, occupying 420,000 hectare of land. These plants consume 1,430 million tons of clay each year.

The extravagant consumption of resources has brought serious problems in the ecology and the environment. For this reason the central government restricts the use of clay bricks in the 170 major cities and encourages utilization of construction materials, produced from waste.

There is some residual carbon in the fly ash, which is available for the block sintering process. The chemistry of the fly ash is shown in Table 5.

Table 5. Chemistry of fly ash.

	Ignition loss	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	TiO_2	K_2O	Na_2O
%	24.48	38.03	6.48	26.62	0.79	0.59	0.60	1.18	0.67	0.45

The construction of a hollow block manufacturing line started in 2002. Fly ash and slag are used as the raw materials for hollow block production. The flow chart of the process is shown in Figure 2.

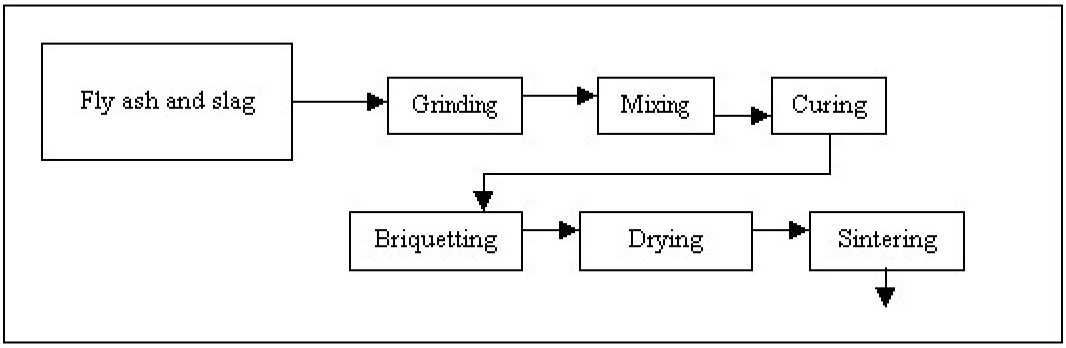

Figure 2. Flow chart of hollow block manufacture.

The advantage of the hollow block lies in its low thermal conductivity of 0.454W/m^2K, that is 60% of the thermal conductivity of the clay bricks only. It is estimated that 30% of heat energy is saved by using fly ash and slag. This is beneficial in reducing the heat loss of houses in winter. Another advantage of the hollow blocks is the lower volume specific weight. The weight of a wall constructed with the hollow blocks may be reduced by 420 kg/m^2 (Weight per construction area).

The production capacity of the plant is 60 million blocks per annum. The plant consumes 53,000 t/a of fly ash and 23,000 t/a of slag. The construction of the plant didn't only substantially reduce the pollution of solid waste, but it has also changed the product structure, which is beneficial to the sustainable development of our company.

4.3 Pb Recovery in smelting

The manganese ore from local mines contains a certain amount of lead. Some lead enters the metal during smelting and contaminates the product and occasionally results in the lead content being beyond the specification. Table 6 shows the chemistry of the local manganese ore. A technique of lead recovery was developed at plant scale and a novel device was installed in the smelting furnace. As a result, huge quantities of lead are recovered by smelting each year.

Table 6. Composition of lead bearing manganese ore.

Chemistry	Mn	Fe	SiO_2	CaO	P	Pb
%	32	7	25	8	0.05	0.7

The quality of the product has been improved since the recovery technique was developed. It is also beneficial to resource conservation.

Figure 3 shows the material flow chart of Yiwang Ferroalloys Works.

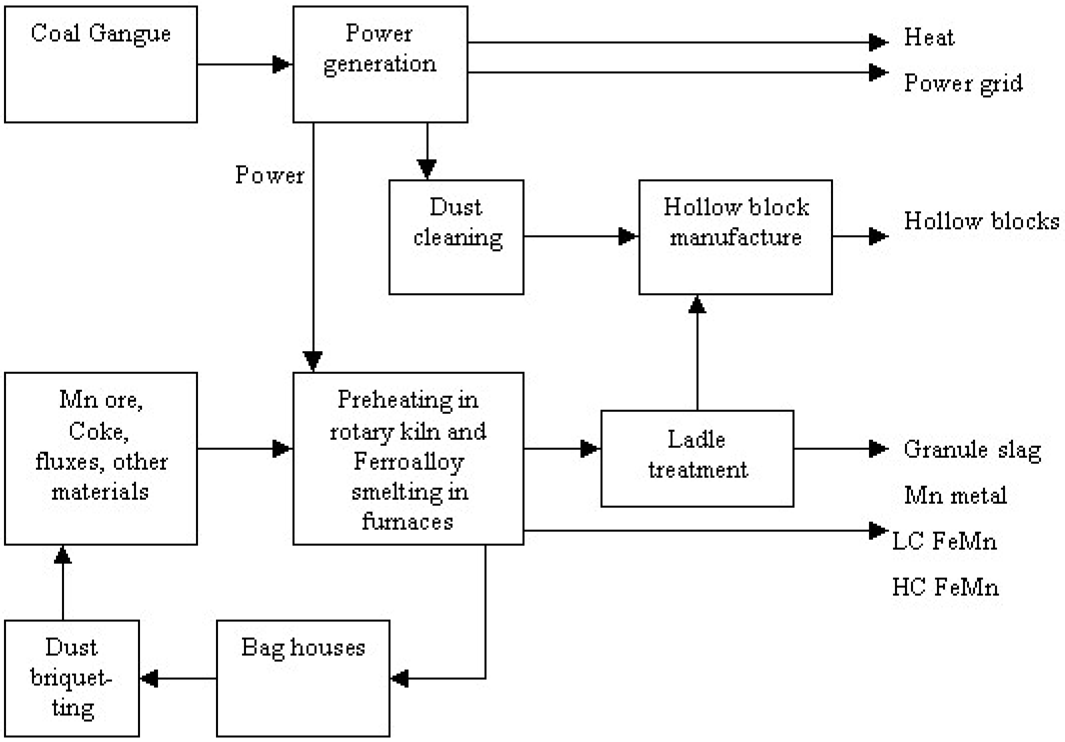

Figure 3. Materials flow chart in Yiwang Ferroalloys.

5. CONCLUSIONS

- The solid waste generated by the ferroalloy industry is a potential resource for the sustainable development of the national economy. The operation at Yiwang Ferroalloys Works indicated that the recycling of waste material is beneficial to the development of the ferroalloy industry.
- The use of the latent heat of molten slag and hot metal improves the energy efficiency of the ferroalloy smelting process.
- Manganese emissions in smelting plants is detrimental to human health. The installation of bag houses in furnaces greatly reduces manganese exposure. The recovery of Mn dust is helpful to improve Mn yield of the smelting process.
- Utilization of fly ash and slag in the manufacturing of construction materials greatly reduces the disposal of solid waste from the power and the ferroalloy industries.
- The profit of the “environment-friendly and recycling” process compensates in part for the operating expense of the environment facilities. The recycling of waste materials has considerably enhanced the competitive ability of our products in the market.