Application of Waste Heat Recovery Energy Saving Technology in Reform of UHP-EAF

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Abstract. The furnace waste heat of a company's existing 4 × 100t ultra-high-power electric arc furnaces is not used and discharged directly of the situation has been unable to meet the national energy-saving emission reduction requirements, and also affected their own competitiveness and sustainable development. In order to make full use of the waste heat of the electric arc furnace, this paper presents an the energy-saving transformation program of using the new heat pipe boiler on the existing ultra-high-power electric arc furnaces for recovering the waste heat of flue gas. The results show that after the implementation of the project can save energy equivalent to 42,349 tons of standard coal. The flue gas waste heat is fully utilized and dust emission concentration is accorded with the standard of Chinese environmental protection, which have achieved good results.

1. Introduction
Iron and steel industry as an important pillar industry of the national economy. It provides basic raw materials also consume a lot of energy at the same time. According to statistics, China's annual output of steel is more than 600 million and energy consumption accounts for about 15% of the total energy consumption [1]-[5], but the energy efficiency is only 30%-50% [6]. The effective use of energy has become the key to China's economic development. The Iron and steel enterprises have a wealth of waste heat resources. A lot of waste heat generated in the production process is an important secondary energy. With the waste heat resources gradually being taken seriously, the waste heat recovery technology has been applied to steel industry. It is of great significance for conserving resources, improving environment quality, enhancing economic efficiency, realizing the circulation and optimal allocation of resources and sustainable development [7]. This article takes the example of a company intends to build an energy-saving technological transformation project of waste heat for four 100-ton steelmaking ultra-high-power electric arc furnaces to analyze and introduce.

2. Process status and problems
Iron and steel company has reached an annual output of 2.33 million tons of steel, steel plate 1.86 million tons of production scale, rolling system of industrial kiln, the annual consumption of about
150,000 tons of heavy oil. There are four VD (vacuum degassing) furnaces, supporting the installation of three fast gas boilers, fuel for natural gas. According to the statistics, a ton of steel's consumption of steam is 0.19GJ. According to an annual output of 4 million tons of steel production, consumption of steam is 80GJ. Figure 1 is no waste heat utilization of the furnace dust removal system process, the waste heat produced by waste production in turn through the settlement room, water-cooled flue, cooler, booster fan into the mixing chamber and from the roof catchment and the lid of the flue gas Mixed int→o the dust collector, through the fan discharge.

![Diagram](image)

**Figure 1.** No waste heat utilization of the furnace dust removal system process

In recent years, although some of the enterprises in the fuel heating furnace for some transformations, because the fuel industry furnace process is simple, heavy oil burning directly in the kiln, resulting in heavy oil consumption (burning is not complete, low thermal efficiency), combustion products pollution of the environment, the degree of automation is not high enough, the labor intensity and the quality of heat treatment is not stable and some drawbacks difficult to overcome. At present, four 100t ultra-high power electric furnace flue gas waste heat is not carried out directly and discharged, electric furnace smelting generated in a large number of flue gas heat can not be recycled. At the same time, with the increase of the electric furnace steelmaking equipment production capacity, molten iron into the amount and oxygen intensity, the dust removal capacity of electric dust removal system is also weakened.

3. **Transformation program**

3.1. **Overview of the program**

In view of the current four 100t ultra-high-power electric arc furnaces generated flue gas waste heat is not used and discharged directly of the situation, we decided to add a waste heat recovery system to make full use of electric furnace flue gas waste heat. Because the medium in heat pipe through the phase change heat transfer, the heat pipe has good heat transfer performance, high efficiency and it can maximize the efficient use of waste heat. Based on the above advantages, we decided to use heat pipe waste heat boiler for the four sets of electric furnaces. After analysis and research, replacing the water-cooled flue and cooler with heat pipe heat exchanger, then the high temperature flue gas can be used by the waste heat utilization system into high temperature and high pressure steam to meet the daily life and production needs.

3.2. **Waste heat utilization system process**
According to 100t electric furnace waste heat process parameters and the use of requirements, there are waste heat utilization of the furnace dust removal system and furnace waste heat utilization process shown in Figure 2, Figure 3. The heat pipe heat exchanger in Figure 2 replaces the water-cooled flue and cooler of Figure 1. The industrial water in Figure 3 after the softening of water into the deaerator, and then pressurized by the pressurized water pump into the hot water preheater, after preheating into the heat pipe steam generator, in addition to the absorption of heat to vaporize the steam into steam, And finally through the heat collector outward delivery.

![Figure 2. Waste heat utilization of the furnace dust removal system process](image)

![Figure 3. Main diagram of waste heat utilization process of electric furnace](image)

3.3. Program feasibility analysis

3.3.1. System features

- The use of heat pipe will be fully separated from the hot water circulation system and the
flue gas heat fluid, optimizing the working environment of the heat transfer element.

- The heat pipe elements in the equipment are independent of each other, and the hot and cold medium is subjected to secondary wall heat transfer. The fluid is not interlocked and does not affect the continuous and stable operation of the system when one or more heat pipes are damaged. At the same time, water, steam will not be due to heat pipe damage into the hot fluid.

- Designed to adjust the heat transfer area at both ends of the heat pipe can effectively adjust and control the wall temperature, to prevent low temperature acid dew point corrosion.

- The heat transfer process of the system belongs to the natural circulation, does not need any external power drive, the operation is simple, the maintenance is convenient, the work is reliable, the failure rate is low.

3.3.2. Advantages of heat pipe economizer

Table 1. Comparison between heat pipe economizer and cast iron economizer

| Project                | Unit          | Heat pipe type | Cast iron type |
|------------------------|---------------|----------------|----------------|
| Flue gas inlet temp.   | ℃             | 250            | 250            |
| Flue gas outlet temp.  | ℃             | 190            | 190            |
| Feed water inlet temp. | ℃             | 20             | 20             |
| Water supply outlet temp | ℃         | 50             | 50             |
| Flue gas volume flow   | N·m³/h        | 2988           | 2988           |
| Gas volume flow        | t/h           | 2.2            | 2.2            |
| Minimum wall temp.     | ℃             | 136            | 35             |
| Heat recovery          | kW            | 78             | 78             |
| Flue gas pressure drop | Pa            | 38             | 98             |
| Unit volume of heated area | m²/m³ | 106.12         | 35.89          |
| Dimensions             | mm            | 1670×450×250   | 1350×600×700   |
| Total capacity         | m³            | 0.188          | 0.608          |
| Total quality          | kg            | 320            | 720            |

As can be seen from Table 1, the same conditions of the heat pipe economizer and cast iron economizer in the following areas are quite different:

- Heat transfer system. Heat pipe economizer heat transfer strength of cast iron economizer 7.45 times, K heat pipe: K cast iron = 145.3: 19.5 = 7.45: 1;
• Minimum wall temperature. Heat pipe economizer for the 135 °C, while the cast iron economizer only 35 °C, a difference of 100 °C;
• Smoke side pressure drop. Heat pipe economizer for the 38Pa, cast iron economizer for 98Pa;
• The volume of heat transfer per unit volume. Heat pipe economizer for the cast iron economizer 29.6 times;
• Total capacity. Heat pipe economizer compact structure, the total volume of cast iron economizer 1/3;
• Total quality. Heat pipe economizer less metal consumption, the total weight less than cast iron economizer 1/2.

In summary, the use of heat pipe economizer for boiler flue gas waste heat recovery, whether it is advanced technology or work reliability, service life and other aspects are significantly better than the traditional cast iron economizer.

3.3.3. Heat pipe waste heat boiler

Heat pipe waste heat boiler application heat pipe as a heat transfer element, absorb the higher temperature of the flue gas waste heat used to produce steam, the steam generated can enter the steam pipe network. The kind of waste heat utilization form, has the following performance characteristics:

• Has a super heat characteristics: heat transfer efficiency, strength, energy saving effect is remarkable;
• Heat pipe completely isolated heat and cold source, will not produce hot and cold fluid blending;
• Flue gas side for the tube outside the heat transfer, ash easy;
• Start the fast, the adaptability of the load fluctuations, generators or thermal oil furnace load in the range of 30% to 100% change, can produce steam;
• Stable operation, long service life;
• Easy to install, not limited by the installation location, without changing the original process system, structural design and location layout is very flexible;
• Short investment payback period.

Heat pipe heat exchanger as a new and efficient energy-saving equipment, in the steel, petrochemical and other industries have been widely used in waste heat recovery. Which can effectively recover the use of production or equipment in the process of running a variety of sensible exhaust gas, both to enable enterprises to obtain significant economic benefits, but also reduce pollutant emissions, to achieve energy saving, the dual purpose of protecting the environment. Therefore, the project selected advanced heat pipe waste heat recovery equipment to recover ultra-high power electric furnace emissions of waste heat.

4. Transformation effect

4.1. Energy saving evaluation

After the implementation of the project to save energy for the four ultra-high-power electric furnaces configuration of the four waste heat boilers recovery of steam, each waste heat boiler steam production is 14 t / h, steam pressure 1Mpa. After the implementation of the project to increase the energy consumption for electricity consumption, the new power facilities, the average effective power of 2094kw. According to the actual operation of steel-making electric furnace, it takes the actual
operation of the project for 330 days, 24 hours a day running. In this calculation, the standard coal coefficient of steam is 0.10857 tce / t steam, and the standard coal coefficient is 0.350 tce / k.kwh.

Energy saving accounting (yearly):
- 4 sets of waste heat boiler recovery steam folding coal = 4 × 14 × 0.10857 × 24 × 330 = 48153 tce.
- the new power equipment consumption discounted standard coal = 2094 × 0.35 × 24 × 330 × 10–3 = 5804 tce.
- after the implementation of the project the actual energy savings of coal:
  
  Year Actual Energy Saving = New Recycled Energy– New Energy Consumption = 48153–5804 = 42349 tce.

After the implementation of this project, the annual savings of energy equals to 42,300 tons of standard coal, waste heat boiler has replaced the company’s original three natural gas boilers. After the system has been run, the heat has reached the use of high-temperature flue gas to produce steam for VD vacuum furnace production and other domestic use of steam targets, and after using the new technology of utilizing flue gas waste heat, the original VD vacuum furnace using natural gas boiler as a spare to save a lot of fuel costs, reducing production costs.

4.2. Economic feasibility analysis
The total investment of the project is 62.6458 million yuan. After the implementation of the project, the annual energy savings will be 4.2349 million tons, being calculated at 570 yuan/ton, it can save 2413.89 yuan, the payback period is 5.93 years. The profitability of the project will meet the requirements. The set of financing options can be accepted. From the financial point of view of the technical program evaluation, the project is feasible. Projects can produce significant economic results, suggesting owners to take a positive investment strategy.

4.3. Environmental evaluation
The dust of the project first uses waste heat boiler to remove dust, and then uses the bag to do dust collection, the received dust, ash are all back to the company’s internal production system to recycle iron, etc. It will not cause the environmental pollution.
Under normal production conditions, the amount of industrial waste water produced is less, standard discharge or recycling make a little impact on the environment: the neutralizing treatment of acid and alkali wastewater of chemical water treatment station is being done in the neutralization pond, discharging standards.

5. Conclusion
Through the 4 × 100t ultra-high power furnaces flue gas waste heat utilization of energy-saving technological transformation to waste heat boiler to replace the company’s original natural gas boiler, while after using advanced heat pipe waste heat boiler technology, energy-saving technological transformation the exhaust heat is fully utilized. The new 4 sets of waste heat boilers can save a total of 4.2349 million tons per year. At the same time, the implementation of the project makes smoke (powder) dust and CO₂ emissions decreasing significantly, not only significantly reduce energy consumption, improve enterprise product quality, increase business income, promote the healthy and sustainable development of enterprises, but also in line with national industrial policy, helping to ease
the government energy supply and energy project construction pressure. It also has a more realistic significance to reduce the waste gas pollution protection environment.

6. References

[1] Chen T, Chen Y, Chen L and Hu Q 2012 J. The implementation of contract energy management problems and related recommendations. Construction Economy 1 67-69

[2] He W D and Zhang K 2013 J. Decomposition Analysis of Influencing Factors of Carbon Emission in China’s Iron and Steel Industry. Journal of Industrial Technological Economics 1 3-10

[3] Dong H Z, Xue H F, Song L H and Zhang Q 2009 J. Analysis on the variable factors of Energy Consumption Intensity in Iron and Steel Industry. Science Research Management 3 132-138

[4] Lin B Q and Liu J H 2001 J. Estimating Coal Production Peak and Trends of Coal Imports in China. Energy Policy 1 512-519

[5] Zhang X and Feng J X 2013 J. Latest advancement of energy performance contracting (EPC) and discussion on its development in industrial sector. Energy for Metallurgical Industry 6 3-6

[6] Zhang M 2015 J. Waste heat recovery technology in the steel industry application and energy saving potential analysis. Resource conservation and environmental protection 8 8-9

[7] Yang W B, Chen Z L and Kong L B 2001 J. Recycling technical discussion and effect analysis for the waste heat of the flue gas from electrical furnace. Energy for Metallurgical Industry 1 47-48