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Key Technology and Application of Ultra-low Emission Transformation of Sintering Tail Dust Removal

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Abstract:

With the implementation of ultra-low emission policy in iron and steel industry, the original dust removal system of sintering machine tail can no longer meet the environmental protection requirements and emission standards, and it is in urgent need of transformation and upgrade. In this paper, the tail dust removal system of No.1 265 m^2 sintering machine of Echeng iron and Steel Co., Ltd. was reformed by applying the key technologies of ultra-low emission transformation of sintering machine tail dust removal, such as annular cooling unloading smoke exhaust technology, tail closed top suction smoke exhaust technology, dust removal point optimization, dust removal pipe network system optimization design, purification facility optimization and integration. After the transformation, the working dust concentration and organized emission dust concentration are less than 0.5 $mg•m^{-3}$ and 5 $mg•m^{-3}$ respectively. The dust removal system has achieved double standards of dust emission concentration. At the same time, the annual particulate matter emission is reduced by 17 t, the annual material loss is reduced by 130 t, the system operation energy consumption is reduced by 43%, and the annual comprehensive operation cost is reduced by 3.45 million yuan, realizing good economic and environmental benefits.

Keywords: *Sintering machine, Tail gas, Ultra-low emission, Energy-saving optimization, Engineering reform.*

Sintering is one of the most important links in iron and steel smelting process. The sintering process refers to that: raw materials such as concentrate powder, limestone and lime are mixed with fuels such as pulverized coke and anthracite according to a certain proportion, then distributed at the head of the sintering machine. After ignition, the powder is sintered into blocks, and then crushed naturally by its own gravity from the tail of the sintering machine. After that, the blocks are crushed by a single-roll crusher, screened by a chute, and cooled by a circular cooler; finally, the cooled sinter is screened by the whole

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grain, and sent to the sintering product warehouse through a belt, waiting for the blast furnace ironmaking process [1]. Sintering flue gas is mainly divided into sintering machine head flue gas and sintering machine tail flue gas. The pollutants in sintering machine tail flue gas are mainly particles generated in the dumping bin, ring cooler and finished ore transfer belt of sintering machine tail, mainly showing as follows: 1) High flue gas temperature and high dust concentration. The temperature of dust flue gas produced by sintering tail is generally 80℃-200℃, and the dust concentration is 5 $g \cdot m^{-3}$ -15 $g \cdot m^{-3}$. Tail gas has a large amount of recovery, high iron content and high recovery value; 2) Paroxysmal smoke. A lot of paroxysmal smoke and dust will be produced whenever the sintering trolleys turn down and pour. There are many problems in the original dust removal system of sintering machine tail gas: the structure of the trap hood had poor effect on high-temperature dust collection, and the unorganized emission of dust was serious. The air volume of the dust removal pipe network was unbalanced. The overall air volume of the system is often high, but the dust collection effect is poor, resulting in a great deal of waste. Due to the large and unstable dust concentration, high flue gas temperature, and the particularity of physical and chemical properties of dust, corona blocking and cathode wire prickling and balling of electrostatic dust remover often occur, which leads to the decrease of dust removal efficiency and even the emission concentration exceeding the standard[2].

In April, 2019, the Ministry of Ecology and Environment together with relevant ministries and commissions, researched and released *the Opinions on Promoting the Implementation of Ultra-low Emission in Iron and Steel Industry*, which requires that the emission of particulate matter from sintering machine tail gas be less than 10 $mg \cdot m^{-3}$. At the same time, *the Opinions* also raises requirements for unorganized emission control measures, which comprehensively strengthens the unorganized emission control of material storage, transportation and production process. On the premise of ensuring production safety, effective measures such as sealing shall be taken to effectively improve the collection rate of waste gas. There shall be no visible smoke and dust escaping from the dust producing point and workshop [3].

To meet the ultra-low emission requirements of the iron and steel industry and the needs of the environmental protection level and equipment upgrading to the enterprises, this paper aims at a large amount of high-temperature smoke and dust generated in the tail of sintering machine in Echeng iron and Steel Co., Ltd. Through the key technologies of ultra-low emission transformation of sintering machine tail dust removal, such as annular cooling unloading smoke exhaust technology, tail closed top suction smoke exhaust technology, dust removal point optimization, dust removal pipe network system optimization design, purification facilities optimization integration the dust concentration achieve double standards of working environment and the dust removal system[4].

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I. KEY TECHNOLOGIES OF ULTRA-LOW EMISSION TRANSFORMATION OF SINTERING MACHINE TAIL DUST REMOVAL

1.1 Exhaust Technology and Optimization Design of Sintering Machine Tail Workshop

1.1.1 Annular cooling unloading smoke exhaust technology

The unloading hood of the ring cooler is located at the tail of the ring cooler. During the unloading process, the sinter falls from the platform of the trolley to the conveying belt at the unloading position, and a large amount of smoke and dust will be generated in the process. The original dust removal hood is simply covered on the trolley. The quadrangular structure and the layout of the upper and both sides of the exhaust vents lead to obvious outdoor air suction, poor smoke and dust trapping effect and high dust concentration in the operation site. Therefore, it is urgent to improve the structure of the discharge hood of the circular cooler, strengthen the effect of dust collection and reduce the dust pollution in the working environment [5].

According to the actual field measurement and engineering experience, in order to get closer to the dust source, improve the trapping efficiency of the trapping port, reduce the mixing of wild wind and the overall air volume, and at the same time make the best use of the original dust removal hood and pipeline to reduce the transformation amount, it is planned to adopt the upper and lower split hood close to the shape of the circular cooler trolley as the structure of the tail discharge hood of the circular cooler. The previous structure and the upper and lower split hood structure are modeled, as shown in Fig 1.

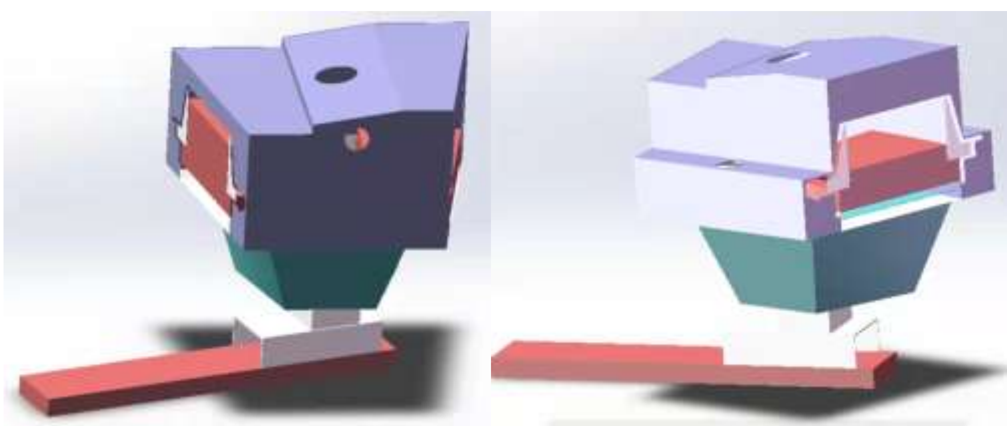

Fig 1: previous structural model (left) and the structural model of the upper and lower split hood (right) of the discharge hood of the circular cooler

According to the structural features, the model is segmented, and the grid is divided by locally encrypted unstructured grid, as shown in Fig 2. The quality of the grid is about 0.82, and the number of

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grids is about 1 million. The second-order k-ε equation algorithm commonly used in fluid mechanics is adopted in the calculation, and all inlets are set with free pressure inlets. To compare the control effects of dust removal hoods with two structures on the air flow at both ends of the trap, the dust removal air volume is set to be 130,000 $m^3 \cdot h^{-1}$. Case1 is the previous structure, and Case2 is the upper and lower split hood structure.

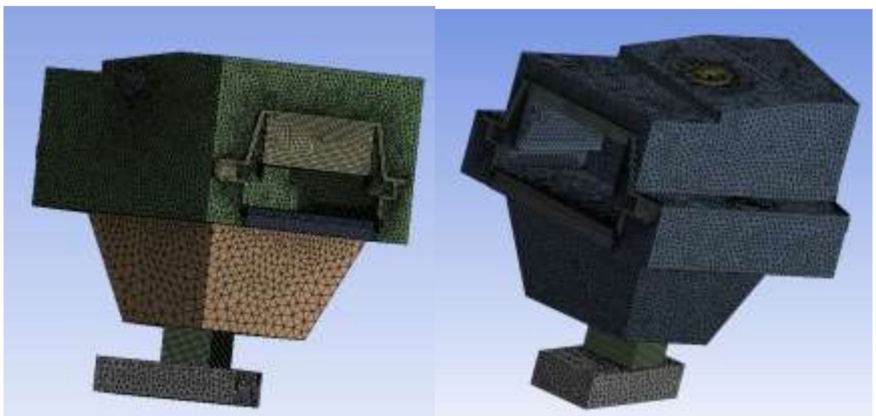

Fig 2: grid division of discharge hood of circular cooler

As shown in Fig 3, comparing the xy cross-sectional flow fields of Case1 and Case 2, we can see that in the form of split hood, the lower part of the model has faster overall airflow velocity, more uniform flow field distribution and better overall control effect. The air volume at both ends of the trapping port is increased, and the trapping efficiency is increased by 12%, so the upper and lower split hood structure has more advantages.

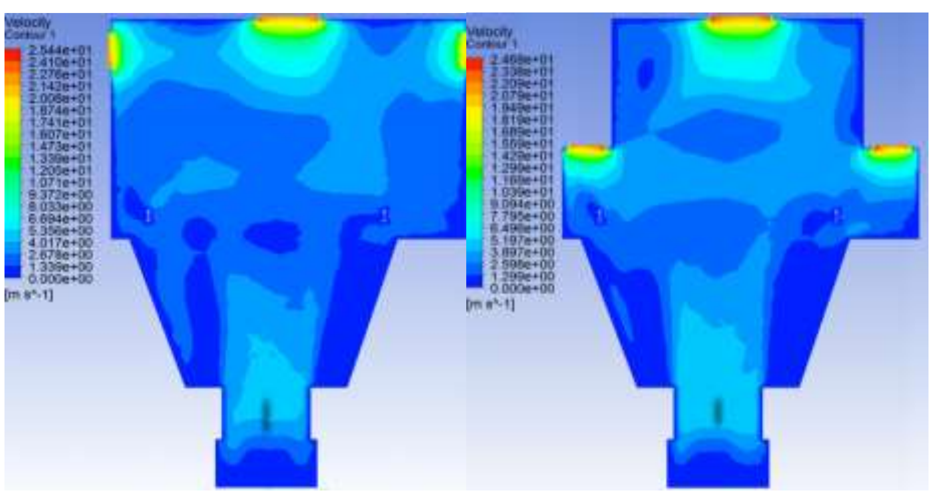

Fig 3: the velocity nephogram of xy section of Case1 (left) and Case2 (right) at z=0

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Under the condition of upper and lower split hood structure, the total air volume is optimized. When the total air volume of Case3 is set at 110,000$m^3 \cdot h^{-1}$, it can ensure that the lower pumping force and capture rate are basically unchanged, only reduced by about 3%, but the total exhaust air volume is reduced by 15%, the air leakage rate is reduced by 11%, and the capture rate is increased by 9%, which effectively reduces the system energy consumption. The numerical simulation results are shown in Table I.

TABLE I. Numerical simulation results

Name	Simulation results		
	Case1	Case2	Case3
Dust removal air volume	130000 $m^3 \cdot h^{-1}$	130000 $m^3 \cdot h^{-1}$	110000 $m^3 \cdot h^{-1}$
Air leakage rate (Base on Case1)	100%	87%	89%
Trapping efficiency (Base on Case1)	100%	112%	97%

1.1.2 Tail closed top suction smoke exhaust technology

To avoid hoisting in the workshop, the original organic tail hood adopts the side-rear suction. A large number of paroxysmal high-temperature smoke generated by the dumping box at the tail of sintering machine rises rapidly, with obvious thermal expansion effect, and the positive pressure in the hood is serious. Even if the suction air volume is increased, the side-back suction method still has poor effect on capturing this high-temperature smoke and dust, and some smoke and dust can only be discharged from the hood mouth and the hood gap under the positive pressure, resulting in unorganized emission pollution. Therefore, it is urgent to reform the structure of the tail hood, adopt a reasonable way of back top suction to conform to the flow direction of high-temperature smoke and dust, and improve the trapping efficiency.

According to the characteristics of pulse radiation flow and the emission characteristics of high-temperature smoke and dust from sintering tail, the tail side suction exhaust hood is buffered and expanded, and transformed into a tail closed top suction exhaust hood. As shown in Fig 4, through numerical simulation, it is found that after the transformation, the overall airflow velocity under the dust hood increases, and the average wind speed on the cross section increases by 24% compared with that before the transformation. And the smoke can better follow the airflow to the dust removal pipeline. The actual project operation shows that the modified tail closed top suction hood can better comply with the upward dispersion characteristics of high-temperature smoke, improve the capture efficiency, reduce the unorganized smoke emission, and basically eliminate the escape of smoke.

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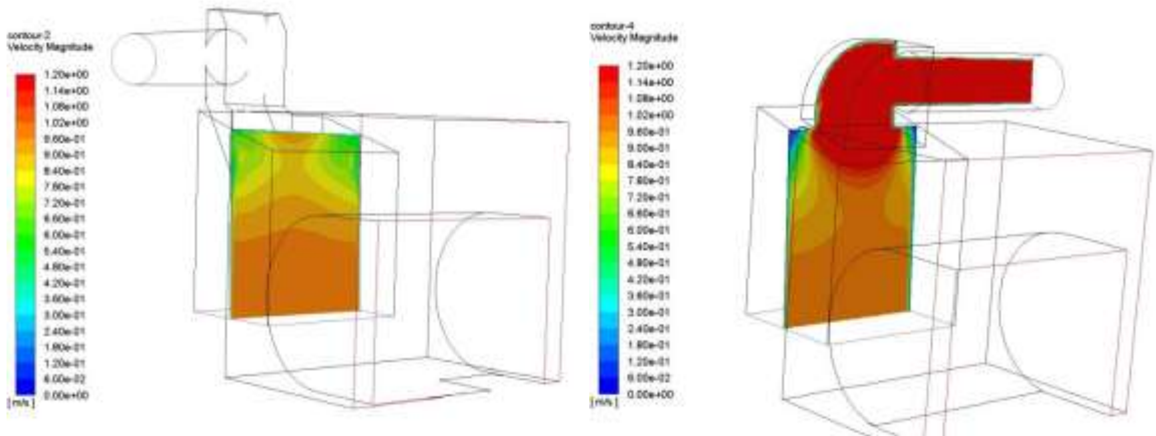

Fig 4: cross sectional velocity nephogram under tail capture hood before (left) and after (right) reconstruction

1.2 Dust Removal Point Optimization

1) The dust removal point of the blanking funnel of the single-roll crusher is optimized. This dust removal point has high gas temperature and large dust content. Due to the unreasonable design of the original dust-removing hood, the dust removal effect is poor. As shown in Fig 5, the high-temperature smoke and dust at this point can be effectively controlled by reasonably changing the position of dust hood and matching the air volume between dust hoods.

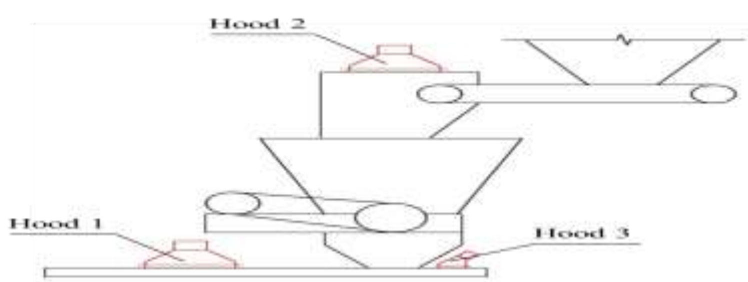

Fig 5: optimization of dust removal point of single-roll crusher

2) There is a height difference between the feeding belt and the receiving belt, and the dust generated by falling during the transportation and transfer of materials will affect the surrounding environment, resulting in unorganized discharge. Therefore, the optimal design of the trapping hood on the head of the feeding belt and the receiving belt adopts the "three-hood type" trapping method, as shown in Fig 6. Among it, Hood1 is the main trapping hood, and its air volume is 3-4 times that of Hood2 and Hood3. However, when transporting high-temperature materials, the smoke dust has obvious rising effect due to

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high temperature, and the air volume ratio between Hood1 and Hood2 can be appropriately adjusted to improve the trapping effect. This design can effectively reduce the air volume, balance the air volume of dust removal points, improve the collection efficiency, and effectively reduce the working dust.

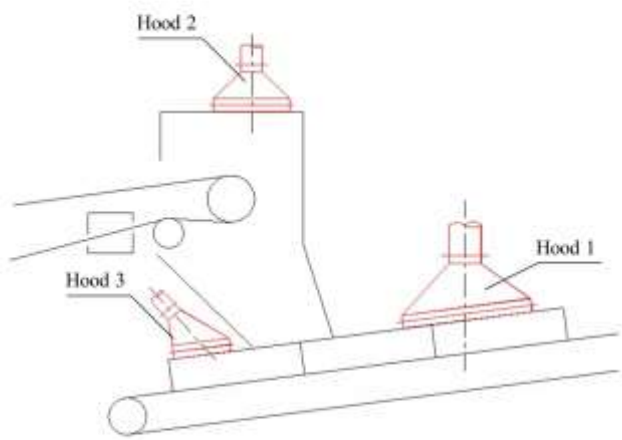

Fig 6: "three-hood type" belt transfer dust collection design

1.3 Optimization Design of Dust Removal Pipe Network System

Most of the dust removal points of the original organic tail dust removal system have no valves, and the air volume of each dust removal point cannot be adjusted. After long-term operation, the demand and supply of each dust removal point cannot completely match. Therefore, during the renovation, on the premise of ensuring the constant wind speed of the air duct in front of the dust remover, wear-resistant valves are added at each dust removal point to adjust the air volume of each branch pipe and dust removal point, so as to meet the air volume demand of each dust removal point. At the same time, due to the high content of iron in the particles in the sintering machine tail gas, to prevent the control valve from being worn through by high-speed particles, a ceramic tile should be added in the control valve to meet the high requirements of the high-temperature flue gas of the sintering machine tail for wear resistance in this project.

1.4 Optimization and Integration of Purification Facilities

To meet the requirements of ultra-low emission of flue gas, it is vitally important to choose the end dust removal and purification equipment, and it is a consensus in the industry to use bag filter for dust removal of sintering machine tail gas. In view of the fact that the original electrostatic precipitator cannot be shut down for a long time for technical transformation, the following engineering transformation methods can be adopted according to the characteristics and production conditions of sintering machine tail gas [6-8].

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1) Purification process of spark catcher + bag filter + high temperature filter material

With the implementation of ultra-low emission in the iron and steel industry and the release of relevant national policies, it has gradually become the consensus in the industry to use bag filter for dust removal of sintering tail gas. Due to the fluctuation of sintering process, the instantaneous flue gas temperature of sintering machine tail will be too high and molten particles will enter the dust removal pipeline. Therefore, adding spark arrester can effectively prevent the ignition of cloth bags and prolong the service life of cloth bag dust collectors. The system has stable operation, good emission effect and mature management experience [9].

At the same time, the filter material is the key of bag filter. There are many filter materials for bag filter on the market, which are used in different working conditions. Filter material can be divided into ultra-high temperature filter media, high temperature filter media, medium temperature filter media, normal temperature filter media, etc. Different technological processes in the iron and steel industry have different requirements for filter materials. The sintering flue gas is about 150 ℃-230 ℃, so high-temperature filter materials are generally used. At present, the commonly used high-temperature filter materials mainly include Metamax, P84, PPS, PTFE and glass fiber.

The post-treatment technology of spark catcher + bag filter + high-temperature filter material can well adapt to the characteristics of flue gas under sintering conditions. The average concentration of particulate matter emission from the purified flue gas is 4.7 $mg \cdot m^{-3}$, far lower than the ultra-low emission standard of 10 $mg \cdot m^{-3}$[10].

2) Changing the ash conveying mode to pneumatic ash conveying

Due to the sealing problem of the original mechanical ash conveying mode, during the operation of the scraper, part of the dust rises and comes out from the gaps such as the observation hole, resulting in unorganized emission pollution. Therefore, the pneumatic ash conveying mode can effectively reduce the unorganized emission.

II. RENOVATION OF DUST REMOVAL SYSTEM OF SINTERING MACHINE TAIL

2.1 Introduction of the Original System

There are two sets of 265 m^2 sintering machines in Echeng iron and Steel Co., Ltd. ironmaking plant, with an annual output of 5.5 million tons, and two sets of tail dust removal systems. This paper introduces the technical transformation project of dust removal system at the tail of No.1 sintering machine. The relevant parameters of the original tail dust removal system of No.1 sintering machine are shown in Table II. The original designed air volume is 850,000$m^3 \cdot h^{-1}$, and the actual operating air volume is about

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760,000 $m^3 \cdot h^{-1}$. The dust removal equipment is a class 4 electrostatic dust remover, and the ash conveying method is mechanical ash conveying. The concentration of particulate matter in the discharged flue gas is 8.20 $mg \cdot m^{-3}$, and that in the post is 1.33 $mg \cdot m^{-3}$. The working environment is poor [11].

TABLE II. Related parameters of original organic tail dust removal system

Name	Parameter
Design air volume	850,000 $m^3 \cdot h^{-1}$
Actual operating air volume	760,000 $m^3 \cdot h^{-1}$
Electrostatic dust remover	4 Stages
Fan	948,500 $m^3 \cdot h^{-1}$×4820 Pa×730 rpm×2000 kW
Ash conveying mode	Mechanical ash conveying
Particulate matter concentration in exhaust flue gas	8.20 $mg \cdot m^{-3}$
Working particle concentration	1.33 $mg \cdot m^{-3}$

According to the field survey, the problems of the tail dust removal system of No.1 sintering machine are as follows:

1) The original dust cover design is unreasonable, the original design air volume is too large, the actual operation air leakage rate is high, the capture efficiency is low, the high-temperature smoke and dust of some posts cannot be effectively controlled, and the dust concentration of posts does not meet the standard.

2) Most dust removal points lack valves, and the original dust removal pipe network cannot adjust the air volume, resulting in uneven air volume distribution of each branch pipe, unable to distribute the air volume according to the original design value, high pipe network resistance and high operation energy consumption. Unreasonable control measures or even no dust removal facilities are provided in some dust producing points, causing dust pollution out of control in some posts, such as finished product warehouse, 1DL batching room slot, TL-15 belt corridor, landing mine loading point, etc.

2.2 Effect after Transformation

The project adopts innovative technologies of ultra-low emission of high-temperature smoke and dust at the tail of sintering machine, such as optimization of capture hood, optimization of dust removal pipe network and optimization of high-temperature smoke and dust purification facilities, to transform the old

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dust removal system at the tail of sintering machine. According to the third-party detection, the particle concentration of the reformed dust removal system is 4.7 $mg \cdot m^{-3}$, and the dust concentration of three positions is less than 0.5 $mg \cdot m^{-3}$, which is superior to the current national ultra-low emission standards and health standards. The annual particle emission is reduced by 17 t. The annual material loss is reduced by 130 t. The system operation energy consumption is reduced by 43%, and the annual operation cost is reduced by 3.45 million yuan. Economic comparison of before and after transformation is shown in Table III.

TABLE III. Economic comparison of before and after transformation

Project	Unit	Before transformation	After transformation	Comparison (%)
Design air volume	10,000 $m^3 \cdot h^{-1}$	85	60	-29
Operating air volume	10,000 $m^3 \cdot h^{-1}$	76	43	-43
Annual operating cost	Operating power (kw)	1265	695	-45
	Annual power consumption (10,000 kwh)	1063	584	-45
	Annual power consumption fee (10,000 yuan)	563	309	-45
	Compressed air consumption (10,000 m^3)	25	164	550
	Maintenance cost of pneumatic ash conveying (10,000 yuan)	4	25	550
	Annual electricity cost (10,000 yuan)	567	334	-41
	Personnel comprehensive management cost (10,000 yuan)	256	144	-44
	Total (10,000 yuan)	823	478	-42
Annual particulate emission	Organized (t)	20	3	-86
	Material loss (t)	200	70	-65

Note: The annual operation time is calculated at 8400h, and the depreciation cost is not included [12].

III. CONCLUSION

To meet the requirements of ultra-low emission of flue gas from sintering machine tail, this demonstration project is technically reformed on the basis of the design capability of the original dust removal system. Innovative technologies of high-temperature dust collection and purification applied to the key technologies of ultra-low emission of tail dust removal of sintering machine include: annular cooling unloading smoke exhaust technology, tail closed top suction smoke exhaust technology, dust

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removal point optimization, dust removal pipe network system optimization design, purification facilities optimization integration, etc..

Through the application practice of the above new technologies, the particle concentration of sintering machine tail gas after transformation is 4.7 $mg \cdot m^{-3}$, which meets the ultra-low emission requirements of sintering machine tail gas. After the transformation, the working dust concentration is less than 0.5 $mg \cdot m^{-3}$, which is better than the current national ultra-low emission standard and health standard, effectively controls the unorganized emission and ensures the working environment. At the same time, the exhaust air volume of the capture hood is greatly optimized, the capture efficiency of local high-temperature smoke and dust is improved, the air volume of the dust removal system is reasonably distributed, and the treatment air volume of the fan and dust collector is reduced, so as to significantly reduce the system operation energy consumption while ensuring that the working dust concentration and the smoke and dust emission concentration of the dust removal system meet the double standards.

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