Development and Application of Internal Circulating Water-cooled Electromagnetic Separator

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Abstract. For dusty and explosive use environment, especially in coal mines, mostly self-cooled and water-cooled electromagnetic iron separators are used. This article introduces the application of water cooling internal circulation technology to electromagnetic separator equipment for the first time, the advantages and disadvantages of the three cooling methods as well as the development process and application prospects of the internal circulating water-cooled electromagnetic separator are introduced and analyzed respectively.

1. Introduction
At present, in power plants, chemical plants, coal mines and other dusty and explosive production sites, iron removal is required to protect the main equipment and product quality of the industry. In these industries, if iron parts are not removed in time, it will directly affect the normal operation of downstream equipment. Iron separators on the market with different cooling types are used in different occasions. For the dusty and explosive use environment, mostly self-cooled and water-cooled electromagnetic iron separators are used. However, these electromagnetic separators with the two cooling methods have their own differences and defects in terms of use occasions and use efficiency. The self-cooling electromagnetic separator is large in size, high in manufacturing cost, and difficult to dissipate heat. The heat inside the water-cooled electromagnetic separator cannot be transferred out through the water, and the cooling effect is not obvious, which causes the temperature rise of the separator to be too high, which reduces the field strength of the separator, and the efficiency of iron removal is low. The advantages and disadvantages of the three cooling methods are described below:

2. Self-Cooling Electromagnetic Separator
Self-cooling electromagnetic iron remover is the most widely used magnetoelectric iron remover. The electromagnetic coil in the equipment directly uses single wire with an insulating layer, and heat sinks are welded around the equipment for natural cooling. This method has simple structure and convenient maintenance, and is widely used in cement plants, power plants and other fields. As higher and higher magnetic field strength is required, it is gradually difficult for the self-cooling electromagnetic separators to meet the requirements. The reason is that the more coils, the greater the heat generation. This structure is difficult for the coils to dissipate heat, which affects the strength of the electromagnetic field of the equipment, resulting in unsatisfactory sorting effects.
3. Water-Cooled Electromagnetic Separator
Based on the fact that the magnetic field strength of the self-cooling electromagnetic separator cannot be further improved, water-cooled iron removal equipment has been developed. The electromagnetic coil in this type of equipment adopts a method of single hollow wire and water cooling. This method has simple structure and convenient maintenance. As the intensity of the magnetic field increases, it is gradually difficult for the water-cooled coil to meet the requirements. When the water passes through hollow wire, it will inevitably cause scaling on the inner wall of the wire, which will affect the heat dissipation of the coil and ultimately affect the selection effect by affecting the strength of the electromagnetic field.

4. Internal Circulation Water-Cooled Electromagnetic Separator
As the country puts forward higher safety requirements for equipment in a dusty and explosive environment, although the first two types can meet the safety requirements, they cannot meet the requirements of customers. In order to meet the above two points, a new technology is introduced, the internal circulation water-cooled electromagnetic iron separator. The structure is simple, the safety is good, and the design structure of the coil and the circulating airway system is unique. The air passage structure and the welding is simple, the cooling effect is good, the temperature rise is low, the cost is low, the weight is light, the energy consumption is low, no pollution, easy to maintain, and cost-effective.

4.1. Structure
As shown in Figure 1, the internal circulation water-cooled electromagnetic iron separator is mainly composed of magnet body, coil, air chamber, annular blower, magnetic yoke, air chamber support, the heat exchanger, drying device, lifting lug and other major components. For inner wire winding of the coil, every 2 to 5 layers of wires form a group. An insulating plate is added between the groups, divided into several groups in the radial direction, and a certain gap is formed between the groups for heat dissipation. There is an air outlet at the top of the air chamber, and all other surroundings are sealed. There is an air chamber on the upper part of the magnet body. Annular blower and circulating heat exchanger are connected with magnet body, coil and drying device to form an internal circulating air cooling system. The internal circulation water-cooled annular blower is connected to the air chamber and installed above the iron separator, and a heat exchanger is installed at the rear. The cooled air enters the cavity in the coil through the drying device and the magnet through the air passage to form an internal circulation.

Figure 1. Structure diagram of internal circulating water-cooled electromagnetic separator
1—magnet; 2—coil; 3—air chamber; 4—annular blower; 5—magnetic yoke; 6—air chamber support; 7—heat exchanger; 8—drying device; 9—lifting lug
4.2. Working Principle
After the internal circulation water-cooled electromagnetic separator is started, the hot air generated by the coil is sent to the heat exchanger box through the annular blower, the cooled water is dried by the drying device, and the dried air is returned to the inside of the magnet through the air outlet. It forms an omni-directional internal circulation, internal air circulation, external water cooling, and no communication between internal and external. Excessive water is discharged from the outlet valve. To achieve the function of rapid cooling of the coil, so as to meet the performance requirements of the iron separator. (as shown in Figure 2)

Figure 2. Working principle diagram of internal circulating water-cooled electromagnetic separator

4.3. Main Innovations and Key Technologies
Different from the traditional electromagnetic separator, the internal circulation water-cooled electromagnetic separator has the following innovations: technically, the cooling method adopts air medium, which is pollution-free, and the manufacturing process is simple. At present, this equipment has not been produced by the major domestic and foreign iron separator manufacturers, and it is still the first of its kind.

At present, other structures and cooling methods have disadvantages, such as high temperature, pollution, unsuitable for dusty environment, low work efficiency and unsuitable for specific environment. Therefore, the "internal circulating water-cooled electromagnetic iron separator" has the leading technology among similar iron removing equipment and has obvious advantages.

(1) In terms of cooling device selection, the internal circulation water-cooled electromagnetic separator adopts a annular blower to forcibly suck the hot air in the magnet, and send it to the heat exchanger for sufficient heat exchange and cooling, and then send the cooled air back to the magnet, realizing the circulating and cooling in the iron separator. The structure is simple, the hot air in the magnet flows smoothly, the heat exchange and cooling effect is good, the external air does not directly contact with the internal electromagnetic coil, dust is avoided, and the life of the iron separator is prolonged.

(2) Regarding the structure of the electromagnetic coil, in order to facilitate the smooth passage of hot air, when the electromagnetic coil is wound, it is distributed in several groups on the geometric center. There is a certain gap between the groups to form an air passage. And there is a certain distance between the outer diameter of the electromagnetic coil and the inside of the magnet housing.

(3) The magnet and internal air duct are unique in design. The stable performance of the whole machine, the heat dissipation of the electromagnetic coil, and the level of temperature rise not only depend on the type and size of the cooler, but also on the design of the heat dissipation channel of the electromagnetic coil. In the selection of the air duct path, there is no short-circuit phenomenon of wind current. The air duct design of the machine is unique, which realizes the omni-directional air flow
without dead angles, eliminates the phenomenon of no local high temperature, and achieves the temperature balance of the whole machine, so that the iron remover has a good iron removal effect.

(4) In addition, the internal circulation water-cooled electromagnetic separator uses air as the cooling medium, which not only saves resources, but is also environmentally friendly and pollution-free.

4.4. Application Effect

In order to verify the iron removal performance, temperature rise, power consumption, equipment quality and cost performance of the internal circulation water-cooled electromagnetic separator, a comparative trial was carried out between a conventional (RCDSB-12T1) water-cooled electromagnetic separator and a (RCDNB-12T1) internal circulation water-cooled electromagnetic separator. The operation results in a coal mine in Shandong show that under the same suspension height and the same electromagnetic field iron removal efficiency, the internal circulation water-cooled electromagnetic separator RCDNB-12T1 saves 10 kWh of electricity per hour compared to the water-cooled RCDSB-12T1. If calculated based on 20 hours of operation per day and 360 days in a year, the annual electricity consumption can be saved by 72,000 kWh, and the electricity consumption expenditure can be saved by 72,000 yuan. At the same time, resources are saved, equipment utilization is improved, maintenance costs are reduced, and equipment runs smoothly.

Table 1. Comparison of the operation effect of RCDSB-12T1 water-cooled electromagnetic separator and RCDNB-12T1 internal circulation water-cooled electromagnetic separator

| Model content       | Electromagnetic power (kw) | Media consumption | Equipment temperature rise | Equipment maintenance fee (Ten thousand yuan) | Service life (year) | Running result                  | Manufacturing process complexity                  |
|---------------------|-----------------------------|-------------------|----------------------------|-----------------------------------------------|---------------------|---------------------------------|-----------------------------------------------|
| RCDSB-12T1          | 25                          | Treat scale once a year | 60°C                       | 1.2                                          | 10                  | Good iron removal performance   | Anti-leakage, high welding technology requirements |
| RCDNB-12T1          | 15                          | air               | 50°C                       | 0.5                                          | 12                  | Good iron removal performance   | Low welding technology requirements             |

5. Conclusion

The test comparison shows that the internal circulation water-cooled electromagnetic iron remover does not require other media, has no pollution, low power consumption, and low failure rate. Based on the conventional electromagnetic iron remover, this equipment makes full use of technical advantages and has made innovative exploration and improvement. In some harsh places, it can replace oil-cooled, air-cooled, water-cooled and self-cooled electromagnetic separators. With the vigorous requirements of national environmental protection policies and technological progress, green and environmentally-friendly precise iron removal equipment has become an inevitable trend of development. In the future, internal circulation water-cooled electromagnetic iron removers have broad development prospects.

6. References

[1] Dai Huixin, Hao Xianyao, Zhao Zhiqiang. The application status and development direction of iron remover J. Metal Mine, 2007 (9): 90-93.
[2] Liu Zheng. The application of iron remover in export coal processing J. Coal Quality Technology, 2003(4): 24-26.
[3] Wang Lijuan, Zhang Chaoda, Zhong Senlin. Development of a multi-stage high-efficiency ceramic glass raw material iron removal machine[J]. Modern Mining, 2016(6):259.
[4] Zeng Zhenglin, Jiang Qinglei, Niu Linlin, Liu Yanfei. Cooling method and characteristics of
electromagnetic separator coil[J]. Modern Mining. 2019(08)

[5] Song Yumin. The choice of heat dissipation mode of port super electromagnetic iron remover[J]. Port loading and unloading. 2012(06)

[6] Zheng Qiurong. Application and selection analysis of electromagnetic separator in coal conveying system of thermal power plant[J]. Electromechanical Information. 2013(15)

[7] Yin Jiangping, Wang Lei. Use of circulating oil-cooled electromagnetic separator[J]. Port loading and unloading. 2012, (04)

[8] Li Jiachuan. Research and application of built-in heat exchange electromagnetic separator[J]. Coal preparation technology, 2007[3]

[9] Guo Zhonghua, Guo Meisheng, Li Hongxu. Comparison of cooling methods of explosion-proof super electromagnetic separators for mines[J]. Coal Processing and Comprehensive Utilization. 2012(06)

[10] Cai Junlin. Talk about the use of imported electromagnetic separators[J]. Coal Quality Technology, 1997(03)