Research Progress and Development Trend of Permanent Magnetic Separators in China and Abroad

YUFENG LI AND FENGTAO YANG

ABSTRACT

Magnetic separation is an integral part of mineral separation, and separator performance is the key factor in the process of magnetic separation. With the increasing development of constantly updated magnetic materials and magnetic separation process, for the development of the permanent magnetism and large-scale direction start separator, and solve the low grade, fine granularity, weak magnetic the mineral beneficiation opens up a new path. Permanent magnetic separator has the advantages of saving energy consumption, simple structure, convenient operation and maintenance, the advantages of lighter and stable performance, compared with the same type of electromagnetic separator has a more broad prospects for development. This article reviews the characteristics and research on permanent magnetic separator at home and abroad, analyzes the main problems of permanent magnetic separator at home and abroad and its development trend.

INTRODUCTION

Magnetic separation are magnetic mineral particles that happened in inhomogeneous magnetic field by using magnetic force, to achieve a dressing method of non-magnetic particles and magnetic particles separation and widely application in ferrous metal ore, nonferrous and rare metal and non-metallic mineral removing iron. 80% of iron ore resources in China need to separate by magnetic [1]. How to improve the efficiency of magnetic separation, achieve the iron ore to the maximize recovery of at present the magnetic separation industry to solve important problems. As the main equipment and the carrier of the magnetic separation, its performance is determined by the efficiency of magnetic separation [2].

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Magnetic separator is mainly used for magnetic mineral separation, removal of iron and non-metallic tailings recycling, it has been widely used in many fields both in China and abroad. It can be divided into electromagnetic separator and magnetic separator. In electromagnetic separator, electromagnet need to consume large amounts of electricity to produce high strength magnetic field, while the heat coil needs the cooling. It is heavy and complicated, also have control components and many fault points. But the permanent magnetic separator which used permanent magnet materials do not need energy and cooling system, it has the advantages of simple structure, convenient operation and maintenance, has the advantages of stable performance and save energy consumption, it has more development prospects broad than the same type of electromagnetic separator. With the increasingly development of magnetic materials updated constantly and magnetic separation process, the permanent magnetic separator become more fine and automatic, giving the suggestion to solve the problem of low grade, fine granularity, weak magnetic. According to the separation of the medium, magnetic field strength, structural characteristics, magnetic field types and other standards, permanent magnetic separator can be divided into different types [3], the classification results can be see in table 1.

RESEARCH PROGRESS OF PERMANENT MAGNETIC SEPARATORS IN FOREIGN COUNTRIES

In the early period of seventeenth Century, it was found that ferromagnetic impurities are removed from the crushed minerals by using the permanent magnets. However, the early permanent magnet whose magnetic energy product is low, so the application in magnetic separation equipment is less. Since the 20 century in 60s, with the large-scale application of permanent ferrite magnetic materials and magnetic body technology, weak magnetic field selection of equipment become the permanent magnetization gradually. In the 20 century in 70s, permanent magnetic separator is acquired importance by foreign scholars, and reported the first paper on permanent magnetic separator literature in 1974, then in 1989, the first cylinder type developed abroad for field strength as high as 0.5T permanent magnetic separator, in 1990s, as department of magnetic circuit more deeply, the second generation of cylinder type magnetic separator magnetic field intensity increased to 0.7T [4].
<table>
<thead>
<tr>
<th>Type of magnetic separator</th>
<th>Magnetic field strength</th>
<th>Characteristic</th>
<th>Application</th>
<th>Research and development enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent magnetic drum</td>
<td>160mT–450mT</td>
<td>The structure is simple, the installation is convenient, has already realized the series and scale production. High magnetic field strength, processing capacity, the production of volatility and the adaptability of the selection effect is good, and so on.</td>
<td>Mainly used for iron ore stone before roughing. And non-metal removal.</td>
<td>American Eriez Corporation</td>
</tr>
<tr>
<td>Permanent magnetic drum type magnetic separator</td>
<td>250mT</td>
<td>With strong magnetic roller as the core processing, saving energy, high magnetic field strength, the magnetic field gradient is larger.</td>
<td>Mainly used for the separation of weak magnetic minerals.</td>
<td>American Eriez corporation, Japan TOWA company</td>
</tr>
<tr>
<td>Permanent magnetic roller type magnetic separator</td>
<td>1400mT–2000mT</td>
<td>Don’t need the excitation electric energy, light weight, stable operation, high field intensity, large capacity, high magnetic field intensity, energy saving etc.</td>
<td>It is mainly used for the separation of non-metallic iron removal and weak magnetic minerals as well as fine particle materials.</td>
<td>South Africa, the United States Inprosys company</td>
</tr>
<tr>
<td>Permanent magnet high gradient magnetic separator</td>
<td>600mT</td>
<td>Don’t need the excitation electric energy, light weight, stable operation, high field intensity, large capacity, high magnetic field intensity, energy saving etc.</td>
<td>It is mainly used for the separation of non-metallic iron removal and weak magnetic minerals as well as fine particle materials.</td>
<td>Japan mining resources research, American Bateman Corporation</td>
</tr>
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</table>

In recent years, with the research of permanent magnetic separator maturity and high performance permanent magnetic materials, foreign countries have achieved rapid development in the development of permanent magnetic separator, permanent magnetic separator has been widely used in many fields. In order to meet the actual needs of the modern society of industrial production, magnetic separation equipment tends to be large in the scale, the structure has gradually diversified in the control mode of program automatic control and monitoring gradually. The permanent magnetic separator for the practical application of industrial production, as the rapid development of the body material, machining precision and magnetic properties of magnetic materials, and because the body has simple, stable performance, energy saving, advantages of installation which easy to use, the permanent magnetic drum and permanent magnetic separator two permanent magnetic separator, which used in the mining industry, electric power, coal, paper and other fields has been widely used. Performance permanent magnetic material developed successfully accelerated the permanent magnetic separator. Typical permanent magnetic separator have permanent magnetic drum, permanent magnetic drum magnetic separator, permanent magnetic series type strong magnetic separator with permanent magnet high gradient magnetic separator [5-8] foreign typical permanent magnetic separator details are shown in Table 2.
## TABLE 3. CLASSIFICATION OF PERMANENT MAGNETIC SEPARATORS IN CHINA.

<table>
<thead>
<tr>
<th>Type of magnetic separator</th>
<th>magnetic field strength</th>
<th>medium</th>
<th>Characteristic application</th>
<th>Research and development enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak magnetic field</td>
<td>0.2T</td>
<td>Permanent magnetic material, neodymium iron boron and ferrite composite</td>
<td>Closed magnetic system, magnetic field strength and magnetic force are not high, increasing the magnetic bag angle and sorting chamber, to the ore tank with a mixing device, a small amount of treatment.</td>
<td>Maanshan Institute of Mining Research; Beijing General Research Institute of mining and metallurgy; Baotou Inner Mongolia steel plant Beijing mining and Metallurgy</td>
</tr>
<tr>
<td>Medium magnetic field</td>
<td>0.4T</td>
<td>Rare earth permanent magnet and ferrite material</td>
<td>Open magnetic system, stable performance, high depth of magnetic field, the magnetic system is composed of the main magnetic pole and auxiliary pole, the auxiliary pole clip in the gap between the main magnetic pole.</td>
<td>Sorting iron ore, non-metallic minerals in addition to iron and tailings recovery, as well as coarse particles of weak magnetic minerals primaries and sweeps.</td>
</tr>
<tr>
<td>Strong magnetic field</td>
<td>0.6T</td>
<td>Neodymium iron boron and iron magnetic medium composite</td>
<td>Closed magnetic system, the magnetic system using a single layer of a certain shape of the magnetic poles and the original magnetic poles of the closed circuit, or the relative magnetic poles are equipped with a special shape of the ferromagnetic medium of the magnetic system.</td>
<td>Mainly used for selection and separation of fine materials.</td>
</tr>
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TABLE 4. RESEARCH AND COMPARISON OF PERMANENT MAGNETIC SEPARATORS AT HOME AND ABROAD.

<table>
<thead>
<tr>
<th>project</th>
<th>abroad</th>
<th>domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study time</td>
<td>Early start</td>
<td>Late star</td>
</tr>
<tr>
<td>Application status</td>
<td>Development and application of mineral separation technology in the field of export</td>
<td>used for the separation of mineral purification, sewage treatment</td>
</tr>
<tr>
<td>Research focus</td>
<td>Research focuses on the mechanism</td>
<td>Research focuses on the application</td>
</tr>
<tr>
<td>Development trend</td>
<td>Large scale and series</td>
<td>Series and diversification</td>
</tr>
</tbody>
</table>

80% of iron ore resources in China need to separate by magnetic. As the main equipment and the carrier of the magnetic separation, its performance is determined by the efficiency of magnetic separation. Therefore, many domestic machinery research departments have to look into the development and improvement of magnetic separator. At present, the domestic permanent magnetic separator have many types, according to the magnetic field strength and magnetic strength can be divided into the weak magnetic field of permanent magnetic separator (magnetic field intensity $H=80-120kA/m$) and a strong magnetic field permanent magnetic separator (the magnetic field intensity $H=800-1600kA/m$). Domestic classification of permanent magnetic separator are shown in Table 3.

By visible, in China and abroad, research organizations and experts and scholars in the field of permanent magnetic separator do a lot of research work, great progress has been made. According to the research, from the time, application, research points and development trend are contrasted, specific conditions are shown in Table 4 shows.

THE MAIN PROBLEMS AND DEVELOPMENT TREND OF PERMANENT MAGNETIC SEPARATOR

Major problem

With the deepening research of theory and production practice of the research, although the permanent magnetic separator was produced a lot of products, there are a lot of problems permanent with magnetic separator at present.

(1) Magnetic system design was the main content of the permanent magnetic separator, its structure was related to the field intensity, the leakage of magnetic flux, the energy consumption and other technical parameters, which affected the stand or fall of separation index. Magnetic system structure design was unreasonable, poor selectivity and different degree of magnetic flux leakage of magnetic department, was currently one of the main problems of permanent magnetic separator.

(2) The permanent magnetic material of the permanent magnetic separator were ndfeb and ferrite at present, its high magnetic was a processing and manufacturing requirements, Assembly was difficult, and the background magnetic field was not easy to adjust, sometimes it resulted in the lackage of separation space, the narrow of the capacity.

(3) Compared with the electromagnetic separator, the overall research of permanent magnetic separator was less, compared with those of other theoretical study, the permanent magnet magnetic separator in experiment and production practice in the research was quite insufficient.
Development Trend

In recent years, with the development of high-performance permanent magnet materials research at inland and abroad, the equipment industrialization and the traditional permanent magnetic separator magnetic system and the body structure optimization, improvement and perfect constantly, it speed up the process of permanent magnet magnetic separation equipment, it gradually replaced solenoid magnetic separation equipment. At the same time, with the domestic and foreign mining enterprises in the introduction of automatic control technology and monitoring technology, the degree of automation of mining enterprises was higher, and the magnetic separation equipment in the field of magnetic mineral separation accuracy requirement was becoming higher. Therefore, the development of permanent magnetic separator existed the following development trends.

1) The exquisite of the equipment
   To meet the need of actual mineral magnetic separation production in mining enterprises, with the continually expand the scale of equipment, magnetic separator equipment manufacturer, it payed more attention to the refinement of a magnetic separator equipment design.

2) The renewal of the equipment
   With the development of social science and technology, the emergence of high-energy permanent magnet materials, precision machining technology, the continuous improvement of assembly technology and the continuous improvement of the automation control technology and promotion, and combining the actual requirement of mining production, which resulted in the update of the speed of magnetic separation equipment.

3) The automation of equipment
   With the social development of automation technology, the costs of labors increased gradually, the needs of the production of the mine enterprise automation, it put forward to higher requirements on the technology of magnetic separation of machine automation.

CONCLUSION

(1) In recent years, with the development of high-performance permanent magnet materials research at inland and abroad, the equipment industrialization and the optimization and improvement of the traditional permanent magnetic separator magnetic system, it speed up the process of permanent magnet magnetic separation equipment and gradually replaced solenoid magnetic separation equipment.

(2) Compared with electromagnetic separator, permanent magnetic separator had great advantage in the aspect of saving energy and reducing consumption, but it was still in the theoretical and experimental research stage, the distance was larger from large-scale industrial application.

(3) With the development of high performance magnetic materials, the further development of new type of magnetic separator, in order to achieve the best benefit, it was important to optimize the structure of magnetic system, expand the application field of permanent magnet magnetic separation machine.
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14. Chen Jiansheng, Yang Gang, the current situation and development trend of the magnetic separator (a) [J]. mining machinery, 2009, 37 (17): 75-79.