Optimization for blast furnace slag dry cooling granulation device

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Abstract. Since the large accumulation amount of blast furnace slag (BFS) with recycling value, it has become a hot topic for recovery utilization. Compared with the existing various BFS granulation process, the dry granulation process can promote the use of blast furnace granulated slag as cement substitute and concrete admixtures. Our research group developed a novel dry cooling granulation experiment device to treat BFS. However, there are still some problems to be solved. The purpose of this research is to improve the cooling and granulation efficiency of the existing dry type cooling equipment. This topic uses the FLUENT simulation software to study the impact of the number of air inlet on the cooling effect of the device. The simulation result is that the device possessing eight air inlets can increase the number of hot and cold gas exchanged, resulting in a better cooling effect. According to the power consumption, LCA analysis was carried out on the cooling granulation process. The results show that the device equipped eight air inlets not only improved the original equipment cooling granulation effect, but also increased resource utilization ratio, realized energy-saving and emission reduction.

Keywords: blast furnace slag; dry granulation; numerical simulation; cooling; material life cycle assessment

1. Introduction

Due to the accumulation of large amount of BFS and recycling value, so the slag recycling has become a hot issue. Dry granulation method can retrieve high quality in BFS sensible heat, no consumption of fresh water, which can effectively reduce environmental pollution, high content of amorphous phase particles and slag dry granulation can be obtained. The group's research and development of BFS granulation device can satisfy the cooling effect of BFS particle, but there are still many problems. The aim of this paper is to improve the dry granulation equipment. In the process of dry cooling granulation of BFS, the uniformity of the internal wind field has a great influence on the cooling effect [1,2]. The existing equipment uses the cooling fan to the cold air through an air inlet into the equipment inside. After the experiment, it is found that the cooling is not uniform and the wind field is messy when it is cooled. So it is necessary to research the influence of the number of air inlets on flow field distribution.

In this paper, the influence of different air inlet on the cooling effect is resolved. Using the method of numerical simulation can reduce the unnecessary experiment, which can effectively guide the
transformation of the equipment. CFD is an important technology to study heat transfer, multiphase flow and chemical reaction. Fluent software was used to numerically simulate the cooling effect of cooling granulating equipment of BFS [3,4]. Our research conclusion will provide the superior experimental parameters for subsequent experiments.

2. Experimental

2.1. Geometric model building

The research group made a good effect of the equipment, which mainly includes the cylinder, the axis of rotation, the rotor blades, inlets, outlet and inlets blast furnace slag. Granulating device is composed of a fan blade rotating shaft, motor, used for liquid slag centrifugal granulation for fine particles. The device has the advantages that the water resource is not consumed, and the heat energy can be recovered efficiently, which is beneficial to the energy saving and environmental protection. The granulation principle is that the slag is crushed and granulated under the action of blade shearing, and then the natural wind is used for cooling.

![Figure 1. Simplify equipment diagram](image)

According to the main parts in the process of experiment, the three-dimensional model is shown in figure 1. Its size same as the actual size, that is, the tube high 80cm, the diameter of 54cm.

2.2. The mesh of geometry model

After the three-dimensional model is established, the STEP file is imported into ICEM. Using ICEM to divide the model into unstructured tetrahedral hybrid mesh. It can automatically form Pyramid grid transition between the tetrahedral and hexahedral mesh [5].

![Figure 2. Model mesh established by ICEM](image)

On account of the use of agitator models, the sliding mesh method that only had one static coordinate system was adopted to calculation. The computational domain was divided into two parts, the movement area of blades and the static area. The accuracy of the moving area is higher than that of the static area. ICEM could deal with the division of local grid, and different region had different grid
size [6]. The grid is divided into the model as shown in figure 2(a). Without affecting the accuracy of
the calculation, the tetrahedral unstructured mesh is transformed into a polyhedral mesh to reduce the
number of mesh [7], and the transformation results are shown in figure 2(b). This can speed up the
simulation calculation speed while reducing the occupation of computer memory.

2.3. Experiment parameter setting
In the previous research, the research group has made numerical simulation of the number of air intake
without adding the blast furnace slag. The conclusion is that the total air volume is constant, when the
machine owns 8 air inlets, both the wind velocity near the air outlets and the inner flow field are
considered to be the most stable distribution. However, after adding the BFS, the actual cooling effect
still need to be further verified. So we simulate the different number of air inlet, and then compare the
cooling effect of the number of different air inlet. As shown in figure 3.

![Figure 3. Different air inlet quantity setting](image)

In order to make the results contrast, in addition to the number of the air inlet, the other parameters
are consistent. Set the slag temperature to 1500 degrees, the speed is 1200rpm, the step size is set to 1-e6, and the patch method is used to quickly fill the blast furnace slag, and the total air volume Q is the
same.

3. Results and discussion

3.1. Analysis of numerical simulation results

![Figure 4. Internal flow field when t=0.0002s](image)

After setting the parameters, initialize and start the calculation, and then import the results into post
CFD [8]. The temperature field distribution is shown in the following diagram. The left picture is the
temperature field under the number of air inlet. The right picture is the temperature field under the eight air inlet.

Figure 4 shows the results when \( t=0.0002 \)s. The initial temperature field distribution is equivalent to the initial temperature of the device. The two internal flow field is the same.

**Figure 5.** Internal flow field when \( t=1.5 \)s

Figure 5 shows the results when \( t=1.5 \)s. From the left figure, the BFS cooling effect is pool, and there is accumulation phenomenon. This phenomenon has a serious impact on the cooling and granulation of the BFS [9]. From the right figure, the BFS is cooled sufficiently, the bottom of the BFS is basically at low temperature.
Figure 6. Internal flow field when t=2.5s/3.5s/6s

Figure 6 shows the results when t=2.5s, t=3.5s, t=6s. When the device has eight air inlet, the internal temperature field distribution is very symmetrical, and multiple vortex are formed. While the device has one air inlet, only form one vortex above the air inlet[10]. In contrast, the device has eight air inlet can increase the number of hot and cold gas exchange, resulting in a better cooling effect. The cooling time of the BFS can be obtained from the internal fluid image. Under the preset volume, the cooling time of an air inlet is about 6.3 seconds. And the cooling time of eight air inlet is about 3.7 seconds.

3.2. Analysis of LCA results

LCA is an effective tool for sustainable environmental management. Due to the high energy consumption and high pollution characteristics in the construction industry [11], it is necessary to guide and analyze the construction industry in our country by using the method of LCA.

Most of the energy consumption of dry granulation machine in the laboratory is electric energy. Due to the air inlet of the cooling device is reformed. The cooling effect is improved, and the cooling time becomes shorter. Cooling device and other mechanical parts remain unchanged. And keep the same air volume when cooling. So we can calculate the different power consumption according to the difference of time to analyze the energy consumption of the granulation process before and after the transformation of equipment. The data of environmental pollution release of electricity producing is shown in table 1.

| Reduced environmental load(ELU) | Equivalent to standard coal[kg] | Discharge[kg] |
|--------------------------------|--------------------------------|---------------|
|                               | CO₂   | CO   | CₓHᵧ   | NOₓ   | SO₂   |
| 1                              | 0.404 | 0.938| 0.000040| 0.000072| 0.0051| 0.00112|
| Total:                         |       |      |         |        |       | 1.29378ELU |

From the figure 6 we can find that the cooling time of one air inlet is about 6.3 seconds and the cooling time of eight air inlet is about 3.7 seconds. The cooling granulation time of an air inlet is about 1.7 times compared with that of the eight air inlet devices. Compared with the original equipment, both the energy consumption and discharge of pollutants of the optimized equipment are all decreased by 1/3. The largest emissions of CO₂ as an example.

The rated power of the cooling fan used by the equipment is 1 KW. When the volume of BFS is V. Assuming the eight outlet of the equipment cooling BFS takes t hours. It can be deduced that one outlet of the equipment cooling these BFS takes 1.7t hours. Binding the table data can be known that using the eight outlet of the equipment cooling these BFS will emit 0.94t kg of carbon dioxide. While
using one outlet of the equipment cooling these BFS will emit 1.59t kg of carbon dioxide. If we want to cool a large number of BFS, we will get a very alarming figure. This is just an estimated value, in order to get accurate data, further experiments and analysis are needed.

The LCA results show that the device equipped with eight air inlets not only improved the original equipment cooling granulation effect, but also increased resource utilization ratio, realized energy-saving and emission reduction.

4. Conclusion
Through the analysis of the simulation results and the LCA data, we can get the following conclusions:

When the total air volume was constant, the numbers of inlets impacted the internal flow field. By simulating the change of temperature field inside the system, it is found that the equipment has 8 air inlets, which can increase the exchange frequency of hot and cold gas and produce better cooling effect. And it can reduce the phenomenon of the accumulation of material at the bottom.

By using the LCA data of the existing electric energy, it is estimated that the energy consumption and discharge of pollutants of the optimized equipment are all decreased about 1/3, which can effectively promote the industrialization of equipment applications.

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