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Research on Separation and Extraction Technology and Device of Metal Meltdowns in Fire Scene

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Abstract. Small metal meltdown at the fire scene is one of the main physical evidence used by the fire department in the investigation of the cause of the fire. The mixture of metal meltdown and fire scene residue is mainly composed of steel, copper, aluminum, plastic, and burned carbides. According to magnetic roller structure, the magnetic field distribution and particles in the process of separating force and motion analysis and calculation, design the fire scene molten metal fall separator, according to the orthogonal experiment to discuss the separation of different parameters under the effects of the parameters on the separation and through discussing the separation efficiency of parameter under this experiment device of optimal parameter setting and the optimal picking area design. The sorting machine overcomes the shortcomings of low efficiency and easy omission in the past, which completely rely on manual screening of melted objects in the fire scene, and greatly improves the efficiency and accuracy of fire investigation.

Keywords. Fire investigation, evidence, eddy, copper beads, extraction technology

1. Introduction

The main work of fire investigation is to find out the cause of fire. Fire site investigation is one of the core work of fire accident investigation and plays a decisive role in fire accident investigation. Material evidence of fire trace is the traces and objects that prove the occurrence, development and spread of fire and the cause of fire. Among the types of fire evidence, material evidence is one of the most powerful evidence.

Due to its relatively stable nature and strong design ability, metal meltdowns in fire are one of the key objects in the investigation of fire cause. In a lot of fire scene, however, because of the molten metal at the scene of the fire fall colors and shapes of objects with the scene of the fire non-metallic residues of color and shape are very similar, this manual sorting method of sorting efficiency and sorting accuracy is not high, greatly increasing the difficulty the extraction of fire trace material evidence, reduces the extraction rate of trace evidence.

The traditional manual sorting method is time-consuming and laborious, and the efficiency and accuracy are not high, so it is urgent to solve it by technical means [1].

2. Theoretical Analysis

The main separation methods for small metal meltdowns in fire scene are gravity separation and eddy current separation. The experimental results show that eddy current separation method is more advantageous. To study eddy current separation technology for metal meltdowns, mathematical analysis will be based on the basic equation of electromagnetic field, namely Maxwell's equation [2].

2.1. Eddy Current Separation

In 1998, Delft University of Technology in the Netherlands studied the basic principle of eddy current separation, and its mechanical model of eddy current separation was also cited by most scholars later [3]. When a non-magnetic metal particle passes through a changing magnetic field, an alternating eddy current will be generated inside the particle. The alternating eddy current will generate a magnetic field with a new direction change around the particle, and the two magnetic fields will repel each other in opposite directions, which is called eddy force. The process of separating mixed materials by eddy current force is called eddy current separation, and the eddy current separator is designed based on this principle [4]. The separator is mainly composed of magnetic roller and feeding system, and the magnetic roller is composed of permanent magnet, according to the N-S-N pole around the rotating shaft in turn. Schematic diagram of common eddy current separator and eddy current sorting process are shown in figure 1.

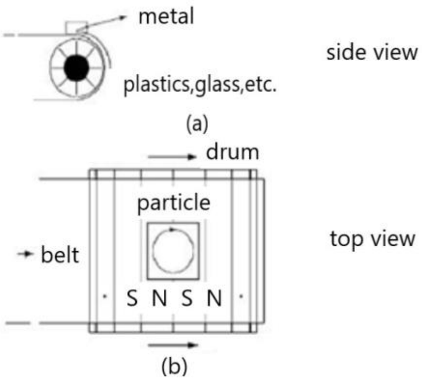

Figure 1. Schematic diagram of eddy current separator and its process.

2.2. Theoretical Calculation

The metal meltdowns at the fire site are regarded as a magnetic pole with changing magnetic field direction, which repels the magnetic roller. The repulsive force between the two is called eddy current force. The direction of eddy current force generated in eddy current separation is always radially outward along the line between particle and magnetic roller axis. The eddy current force increases with the decrease of the distance between the non-magnetic metal particles and the magnetic roller.

3. Experimental Analysis

Since the particle diameter of metal meltdown in the fire scene is mostly in the range of 0.5mm-2mm, and it is difficult to prepare particles with a diameter of 0.5mm, brass beads with diameters of 1mm, 1.5mm and 2mm were selected for experimental study in this experiment.

3.1. Experimental Verification

For the eddy current separation device of fire metal meltdowns in this experiment, the conveyor belt speed and magnetic roller speed are set in groups by means of manual feeding near the conveyor belt. The rated speed of the conveyor belt of the experimental device is 0.9m/s, and the rated speed of the magnetic roller is 4000rpm. Combined with the simulated motion track and horizontal drop distance, the experimental parameters are shown in table 1.

The actual drop distance of copper beads was measured experimentally, and compared with the calculated results; the correctness of calculation was verified. The diameter of 2mm copper beads was used in the experiment. The conveyor belt velocity v=0.6m/s and magnetic roller speed ω=3500rpm were used to measure the coordinates of four track points and the horizontal drop distance D during the copper beads' movement, so as to determine the accuracy of the trajectory curve calculated above. During the measurement of the experimental path, the origin of the coordinates was set as the intersection point between the central axis of the magnetic roller and the table top, the vertical upward direction was the positive direction of the Y axis, and the horizontal right direction was the positive direction of X. A piece of white paper is placed vertically at x1=66, x2=75, x3=86 and X4 =105mm respectively, and the corresponding Y value is recorded. Then a piece of white paper is spread on the table top in the material receiving area to record the horizontal drop distance D of the copper beads.

As shown in figure 2, the diameter of 2 mm copper beads into colorless, lubricating oil, after being set good magnetic roller conveyor belt speed and rotational speed, placed on a piece of white paper on the vertical position 1 (x1 = 66 mm), from feeding, in turn, slowly pour into the prepared copper hundred grain of bead for all thrown backward, remove the position 1 in white paper, according to mark record y1 its vertical height.

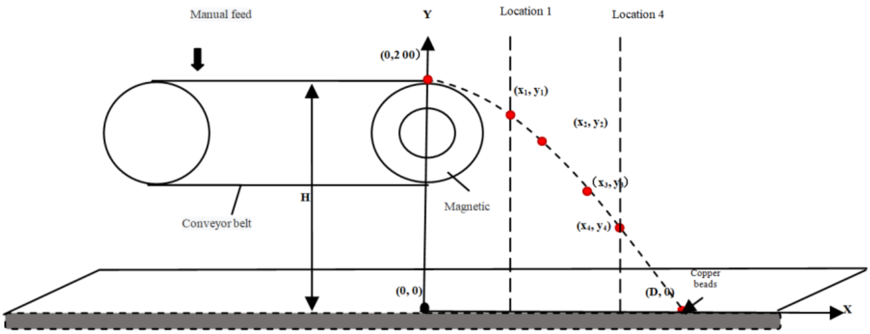

Figure 2. Schematic diagram of verification experiment measurement.

Table 1. List of this design experiment.

Copper bead diameter (mm)	1		2		3	
Speed	Conveyor belt speed (m/s)	Magnetic roller speed (rpm)	Conveyor belt speed (m/s)	Magnetic roller speed (rpm)	Conveyor belt speed (m/s)	Magnetic roller speed (rpm)
Parameters	0.5	3000-4000	0.5	3000-4000	0.5	3000-4000
	0.6	3000-4000	0.6	3000-4000	0.6	3000-4000
	0.7	3000-4000	0.7	3000-4000	0.7	3000-4000

Then place a piece of white paper in position 2, 3 and 4 respectively, and record the vertical height Y value of each position according to the above method. Then lay a piece of white paper at the level y=0, conduct the experiment according to the above method, and record the horizontal distance D of particles dropping. Finally, the six-point coordinates (0,200), (x1,y1), (x2,y2), (x3,y3), (x4,y4) and (D,0) of the copper beads during the separation process under this parameter were sorted out, and the movement trajectory curve under this parameter was fitted by using the six points above.

3.2. Result Analysis

3.2.1. Influence of Conveyor Belt Velocity V on Dropping Distance of Copper Beads

For copper beads of different sizes, the horizontal throwing distance D increases with the increase of conveyor belt velocity V. The horizontal throwing distance results of copper beads with a diameter of 2mm are analyzed in figure 3.

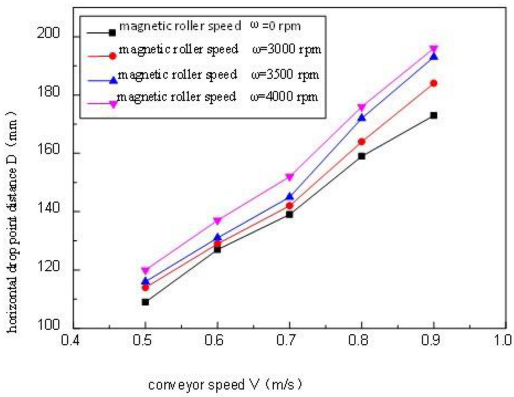

Figure 3. Horizontal drop distance of copper beads with diameter different V.

According to the figure, when V is constant, the horizontal throwing distance D increases with the increase of magnetic roller speed ω. When ω is constant, the horizontal throw distance D increases with the increase of v.

3.2.2. Influence of Particle Size D on Dropping Distance of Copper Beads

The dropping experiments of copper beads with different particle sizes were carried out. The results are shown in figure 3. According to the figure, for copper beads with diameters of 1 and 2mm, when v and ω are constant, the horizontal throwing distance D increases with the increase of D. For copper beads with diameters of 4 and 5mm, when v and ω are constant, the horizontal throw distance D decreases with the increase of D. The main reason is that when D is too large, the eddy current force received when it is close to the magnetic roller cannot be regarded as a vertical magnetic field approximately. It has a component of horizontal and backward force, which reduces the initial horizontal velocity of the drop and the horizontal distance of the drop.

According to the figure, for copper beads with diameters of 1 and 2mm, when v and ω are constant, the horizontal throwing distance D increases with the increase of D.

3.2.3. Influence of Magnetic Roller Speed ω on Dropping Distance of Copper Beads

Horizontal dropping experiments are carried out on copper beads with diameters of 2mm and 5mm. The results are shown in figure 4. For copper beads with diameters of 1 and 2mm, the horizontal throwing distance D increases with the increase of ω. For copper beads with diameters of 4 and 5mm, the horizontal throw distance D decreases with the increase of ω. This is because the increase of ω will increase the eddy current force on the copper beads. For copper beads with diameters of 1, 2 and 3mm, the greater the eddy current force, the greater the horizontal drop distance D will be.

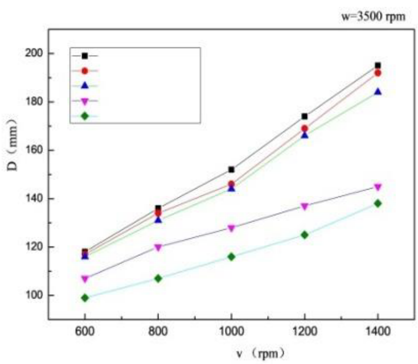

Figure 4. Horizontal drop distance of copper beads with different diameters.

4. Conclusion

Based on the theoretical basis of eddy current technology, the influence of eddy current force on particles and velocity and acceleration in parabolic motion is mainly studied. The factors affecting eddy current force on particles in sorting are magnetic roller structure, transmission speed and magnetic roller speed. The velocity and acceleration in the process of particle separation and discarding have an important relationship with eddy current force, gravity force and conveyor belt velocity. Comprehensive analysis shows that: under the condition of fixed magnetic roller structure, the factors affecting the horizontal discarding distance of metal melt mainly include conveyor belt velocity, particle size and magnetic roller speed. Design the separator suitable for the separation of metal meltdowns in the fire site, and according to the magnetic roller structure of the designed separator, the distribution of magnetic field and the analysis and calculation of the force and movement of particles in the separation process, the suitable experimental parameters and experimental scheme are obtained. According to the orthogonal separation experiment under different parameters, the influence of various parameters (conveyor belt speed, magnetic roller speed and particle size, etc.) on the separation effect is discussed, and by discussing the separation efficiency under various parameters, the optimal parameter setting and optimal material receiving area design of the experimental device are obtained. The separator to overcome the past completely by hand screen of the scene of the fire melt leave inefficient, the shortcomings of easy omission, it is not only suitable for laboratory, and more convenient to use the fire investigators at the scene of the fire and to provide a solid and strong combat weapons fire investigators, rewritten the history of the scene of the fire melt falling object extraction.

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