Preliminary study on rapid screening technology of small non-ferrous metal residues in explosive devices

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Abstract. The remnants of explosive devices contain copper, aluminium, tin and other non-ferrous metals, which often play a key role in the detection of explosive cases. Therefore, compared with the remnants of explosive devices made of plastic and other materials, the discovery and extraction of non-ferrous metals remains is particularly important in the field investigation of explosive cases, especially the small non-ferrous metal remains that are difficult to be found by the naked eyes. It is necessary to study new techniques and methods for the discovery and extraction of residues. In this study, the automatic screening technology of small non-ferrous metal residues in explosive devices is analysed. Through the comparative analysis of various separation and extraction technologies, it is believed that electromagnetic separation technology is expected to be used in the rapid screening of small non-ferrous metal residues in explosive devices.

1. Introduction

In recent years, the explosion caused by fire accidents, terrorist activities and violent crimes is still one of the major disasters in the world. Explosion cases often cause casualties, huge property losses, and extremely bad social impact, seriously endangering national stability and unity, and social stability. In these explosion cases, the explosive device is usually composed of metal or plastic switches, remote control receivers, timers, metal wires and other key components, which are distributed in the explosion site in the form of fragments under the action of explosion. The effective use of technical means to quickly discover and extract the explosive remnants of these explosive devices plays an important role in the reconstruction analysis of explosive devices, the characterization of criminals' behaviour and the provision of characteristic case solving information [1-3]. For fire accidents, with the joint efforts of several generations, China has established the identification and analysis methods of electrical fire physical evidence, such as macro method, metallographic method, composition analysis method, micro morphology method and comprehensive identification method, to assist in the analysis of the causes of electrical fire [4-9], and developed a fire scene electrical molten debris rapid screening machine to assist in the extraction of electrical fire debris evidence [10]. However, for the effective extraction of small non-ferrous metal residues in explosive device, the current means are still difficult to meet the needs of actual application.
2. Problem Analysis

2.1. Discovery and extraction of explosive device remains is the basis of case investigation

Explosive devices are usually composed of explosives, initiators, control components, containers, fillers and auxiliary materials, which are the main tools for criminals to commit crimes in explosive cases. The explosive devices of different cases have different characteristics, which can not only effectively reflect the criminal behavior characteristics of criminals, but also carry the biological characteristics of criminals and the source characteristics of components on the explosive device components. Therefore, the detection and extraction of explosive device remains is the basis of case detection in the investigation of explosion scene.

For example, in the 2011 serial explosion at the gate of Shanxi Provincial Party Committee, the special investigation team quickly extracted a large number of explosive device remnants at the explosion site, quickly rebuilt the explosive device, and tested the DNA of criminals from multiple explosive device remnants. In 2014, the "1.13" casino explosion case in Kaili city, Guizhou Province, was solved through the explosion fragments of remote control receiver of explosive device found at the scene of the explosion, so as to realize the "finding people by objects" material evidence. The Yunnan Qiaojia explosion case was also solved through the mobile phone explosion fragments found at the scene, etc. For such cases, the explosive device remains are not only the important carrier of the material evidence clues, but also the most important court evidence after the case is solved.

2.2. It is difficult to meet the new needs of rapid detection of explosive cases by traditional explosive device residue extraction technology

It is an important work to find and extract the physical evidence of the explosion scene in the field investigation of explosion cases. The buildings around the explosion scene are damaged and collapsed due to the explosion, and the explosives thrown out are scattered in different areas of the explosion scene, mixed with the surrounding environment, resulting in a large number of persons to clean and screen the explosion scene. In the explosion site, the explosive remnants are very small under the action of explosion, and the flying range is large, especially in the ruins, bushes, green belts, lawns, it is very difficult to find and extract. The traditional method of explosive device residue screening mainly adopts the combination of manual and expert screening, which has the following characteristics:

2.2.1. Huge workload, easy to cause material evidence omission and missing. The traditional method of domestic explosion scene investigation standard is to spend a lot of manpower to find and identify through cleaning, water cleaning, sieve, visual observation and other ways to obtain effective physical evidence. However, the explosion site often has a large area of damage, large area of investigation, and a lot of on-site interferences and garbage. In the screening process of on-site physical evidence, due to the huge workload and high repeatability, it is easy to cause the loss of key physical evidence and secondary damage, which affects the efficiency of case detection and the final litigation work.
2.2.2. Rely heavily on the expertise of field inspectors. There are many kinds of key components and different structures of explosive device. When it is under the action of explosion, the whole structure will be damaged and split into some or local fragments, and the shape and material will change under the action of high temperature of explosion. Whether it can be effectively and quickly found and screened from the mixed dust and soil in the explosion site has strong technical requirements for the field inspection technicians. However, due to the small number of explosive cases and the different cognition level of the fragments of explosive device components, it is easy to omit and eliminate the effective physical evidence in the process of extraction and screening of explosive device remnants due to the lack of recognition and wrong cognition, which makes the case detection more difficult.

2.3. The development of new technology provides a new means for the rapid discovery and screening of explosive remnants.

The contradiction between the demand for rapid disposal of major explosion, terrorism cases and the complexity of physical evidence at the scene of explosion crime requires the establishment of fast and effective on-site inspection equipment to provide technical support for rapid discovery and extraction of physical evidence at the scene of explosion, timely output of various physical evidence information and accurate investigation. Explosive remnants rapid screening equipment is a very important technical means and equipment in explosive scene inspection equipment. It is of great significance to
change the status quo of the blank field special equipment used for explosive remnants rapid screening in explosive scene, improve the efficiency of on-site inspection, and eliminate the fear of difficulties in the face of large-scale on-site material evidence screening.

3. Analysis of separation and extraction methods of non-ferrous and non-metallic particles
Analysis of the separation and extraction method of non-ferrous metal and non-metallic particles due to the complexity of the actual explosion scene, the non-ferrous metal residues from the explosion scene will be mixed in a large number of residual ashes, dust, residual chemical products or explosives, and non-metallic mixtures such as liquid sand. Therefore, it is necessary to select appropriate separation methods to extract the molten metal which can be used as the evidence of explosion from a large number of non-metallic residues. The separation methods of non-ferrous metal and non-metallic particles mainly include: gravity separation, high-voltage electrostatic separation, eddy current separation, flotation, etc. The following mainly analyses the above separation methods from the aspects of principle, device and application, and selects the most suitable method to separate and extract 1-5 mm non-ferrous metal residues from the mixture of non-metallic residues and sandstone by comparison.

3.1. Gravity separation
Gravity separation method, the difference of settling velocity of different density materials in the moving medium leads to different movement states (direction, velocity, acceleration and motion track), which makes metal and nonmetal separate. According to the different separation media, there are mainly two kinds of separation media, one is air separation the other is hydraulic separation.

3.1.1. Air separation. Air separation is to use air as separation medium. Under the action of airflow and mechanical vibration, the materials to be separated are separated according to the density and particle size. The basic method of separation using air as separation medium is: feed raw materials to the inclined, fixed or movable porous surface, and promote particle suspension by intermittent or continuous upward airflow, and promote stratification according to density difference, or separate according to density (particle size) in vertical updraft or horizontal air flow.

3.1.2. Hydraulic separation. Hydraulic separation methods, is also known as wet heavy medium separation. Usually, the medium with density greater than water is called heavy medium, which is a solid-liquid two-phase dispersion system composed of high-density solid particles (heavy substance) and water. In order to effectively carry out the separation process, the heavy medium that needs to be used has the advantages of high density, low viscosity, good chemical stability, non-toxic, non-corrosive, easy to recover and regenerate. The operation of hydraulic separation equipment is simple and the cost is low. However, it needs water, heavy liquid or heavy suspension for separation, which consumes a lot of energy. At the same time, heavy metals in wastewater and waste liquid have secondary pollution to the environment.

3.2. Floatable separation
Floatation separation method is a method of separation and extraction which uses different physical and chemical properties of material surface to separate substances. More commonly used in industry is foam flotation, in which a substance selectively attaches to an air bubble and then rises to the surface of a solution to separate the useful substance from the useless. Flotation method is generally only suitable for material separation with particle size ranging from 0.01 mm to 0.5mm.

3.3. Electromagnetic separation
Electromagnetic separation technique for separating metals from nonmetals based on differences in their electrical conductivity. Electromagnetic separation follows two important laws of physics: electromagnetic induction and Bisa's law, that is, an alternating magnetic field with time always gives
rise to an alternating electric field; a magnetic field is induced in a current-carrying conductor. When the non-magnetic metal particles pass through the magnetic field of the magnetic roller, alternating electromagnetic currents will occur inside the particles, and the alternating electromagnetic currents will produce a magnetic field changing in the opposite direction around the particles. The magnetic field of the magnetic roller and the induced magnetic field inside the particles repel each other, and this repulsive action is electromagnetic current force, seen in Figure 3.

Figure 3. Abbreviated drawing of electromagnetic separation.

4. Comparative analysis of metal and non-metal separation methods
Analysis of the separation and extraction method of non-ferrous metal and non-metallic particles due to the complexity of the actual explosion scene, the non-ferrous metal residues from the explosion scene will be mixed in a large number of residual ashes, dust, residual chemical products or explosives, and non-metallic mixtures such as liquid sand. Therefore, it is necessary to select appropriate separation methods to extract the metallic residues which can be used as the evidence of explosion from a large number of non-metallic residues. The separation methods of non-ferrous metal and non-metallic particles mainly include: gravity separation, Floatable separation, electromagnetic separation, etc. The following mainly analyses the above separation methods from the aspects of principle, device and application, and selects the most suitable method to separate and extract 1-5mm non-ferrous metal residues from the mixture of non-metallic residues and sandstone by comparison.

Among the metal and non-metal separation methods described above, air separation has high requirements on the size and shape of the separated materials, which is not suitable for the separation of complex residues in the fire scene; the hydraulic separation uses the density difference of the solution for separation, which will cause corrosion and characterization damage to the material evidence, and is hard to be used; the flotation process is relatively complex, and the separation of materials is suitable the particle size range in 0.01mm-0.5mm, and the main metal objects at the explosion site are copper (aluminium) beads with particle size of 1 mm-5 mm and segmented objects. Therefore, flotation method is not suitable for separating and extracting small non-ferrous metal residues from explosive devices. Based on the above analysis, the resistivity of metals (mainly copper) is less than $1 \times 10^{-7}$ ohm, while that of non-metallic impurities is more than $1 \times 10^{-5}$ ohm. Therefore, the electromagnetic separation method can be used to separate the small non-ferrous metal residues of explosive devices.

5. Summary
This paper mainly analyses the rapid screening technology of small non-ferrous metal residues of explosive devices at this stage, analyses and compares the feasibility of gravity separation, high-voltage electrostatic separation, buoyancy separation, eddy current separation and other separation and
extraction methods applied to the rapid screening of small non-ferrous metal residues of explosive devices. Through the analysis, it is concluded that vortex separation is more suitable.

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