Journal of Innovation and Development
ISSN: 2958-4752 | Vol. 10, No. 1, 2025

Research on the Application of Neutron Detection in The Identification of The Effectiveness of Munitions

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Abstract: The identification of the effectiveness of munitions faces many challenges today, such as problems in detection speed, accuracy and adaptability to complex environments. Neutron detection technology, characterized by non-invasiveness and high sensitivity, can provide an effective solution to these problems. Neutron detection technology is used for munitions effectiveness identification, and the application scenarios include battlefield assessment, storage security and many other fields. One of its major benefits is the ability to assess the status and accuracy of munitions in real time. This study systematically analyzes and explores the advantages and limitations of neutron detection technology in identifying the effectiveness of munitions, gives theoretical support to the practical application of neutron detection technology in identifying the effectiveness of munitions, and also points out the direction of future research.

Keywords: Neutron detection, munitions, validity.

1. Introduction

Neutron detection technology, as an advanced means of detection, centers on the understanding of the mechanism of neutron-matter interaction. Neutrons are not electrically charged, and when they pass through matter, they can interact with protons or neutrons in the nucleus. This interaction involves elastic scattering, as well as inelastic scattering, absorption reactions and other complex physical processes. An in-depth study of the propagation and scattering characteristics of neutrons in different materials can reveal information about the internal microstructure of the material and allow efficient identification of equipment, munitions and explosives.

In specific applications, neutron detection technology relies on the design of the detector and the choice of materials to optimize the sensitivity and selectivity of neutron detection. For example, the use of deuterated polymers (Polyethylene) or lithium-aluminum alloys (LiAl) as target materials for neutron sources can be a good way to improve the detection of low-energy neutrons. This is due to the high content of hydrogen or lithium atoms in these materials, and the probability of an elastic scattering event when neutrons hit these atoms is higher. By analyzing the change in neutron energy during scattering, the composition and physical properties of the material under test can be inferred.

Neutron detection technology is a science and technology with a wide range of applications. In the civilian field, it has been used in many fields, such as industry, petroleum, geology and agriculture, and its applicability has been increasingly emphasized. In recent years, in the military field, especially in recognizing the effectiveness of munitions, its importance has become more and more obvious. Specifically, the high accuracy and sensitivity of Neutron Detection (ND) and its non-intrusive analytical capabilities make it an ideal tool for assessing the condition and performance of munitions in the military domain [1]. In complex battlefield environments such as Counter-terrorism, the application of this technology is critical. It reduces the risk of misuse, improves operational efficiency, and provides a reliable technical basis for military decision-making. At the same time, it can save the cost of equipment maintenance, accelerate the turnover efficiency of military materials, and enhance the military readiness. The effective use of neutron detection can promote the modernization of equipment technology and improve the country's security and protection capabilities.

2. Realities of Munitions Effectiveness Recognition

Equipment Ammunition is an article of ordnance containing gunpowder, explosives or other charges which, when exploded, can destroy or injure a target or perform other tactical tasks. It includes firearms, artillery shells, grenades, rifle grenades, aerial bombs, rockets, missiles, torpedoes, depth charges, mines, landmines, blasting cartridges, blasting kits, blasters, etc., as well as ceremonial artillery shells, police shells, hunting shells, and shells for shooting sports, which are used for non-military purposes. Against the background of the current rapid development of science and technology, the identification of the effectiveness of munitions has gradually become an important topic in modern military applied research. The identification of effectiveness in this field has an impact on the overall combat capability of the army, and is also directly related to whether the battlefield decision-making is accurate and timely. At present, the actual situation of munitions effectiveness identification is diverse and complex, which involves the comprehensive application of traditional detection means and modern high-tech means.

2.1. Limited means of detection and inadequate response to complex situations

There are many types of munitions with different properties, and with the continuous progress of science and technology, the emergence of new types of munitions and explosives has brought great challenges to the detection work. Traditional detection means such as appearance inspection, X-ray imaging [2], etc., in the face of some special ammunition or specially treated explosives, it is often difficult to accurately determine its internal composition and state. For example, for the equipment ammunition in the daily ammunition storage room, the management personnel mainly rely on the

appearance inspection and the implementation of the daily system to judge whether the quantity is sufficient and whether the performance is intact. However, this method is highly subjective, making it difficult to ensure the accuracy of the judgment, and thus prone to miscalculation, leading to accidents during the use of ammunition, resulting in potential casualties and property losses. In the case of munitions in good condition, their internal composition may have changed as a result of prolonged storage, environmental factors, etc., and purely cosmetic inspections are unable to detect these internal changes, thus leading to the misuse of munitions with hidden dangers. Another example is that for chemical weapons abandoned by Japan in China that have been corroded and deformed, as well as smuggled explosives that have been skillfully concealed, traditional inspection means are often beyond their capabilities and are difficult to effectively identify, which brings great difficulties to the subsequent processing work. The identification of the effectiveness of traditional munitions used to rely mainly on physical detection and performance testing. This method has accumulated a lot of experience in the use, but also has certain limitations. Like using the density method (Density Method) or vibration inspection method (Vibration Inspection) to assess the integrity and functional effectiveness of the munition, it is easy to be interfered by external environmental factors, the test results will be unstable. Therefore, traditional methods generally require a combination of several parameters to be evaluated. However, the results obtained, although of some reference value, often lack systematicity and accuracy.

2.2. Lack of targeted testing to achieve accurate identification

Different types of munitions and explosives have different chemical compositions and physical properties, and therefore require targeted detection for accurate identification. In military applications, the identification of the effectiveness of munitions is subject to complex environmental variables, such as temperature, humidity and atmospheric pressure. These variables affect both the effectiveness of the detection method and the long-term storage and safety of the munitions.

However, current detection technologies are still inadequate in terms of targeting. On the one hand, although some detection technologies are able to detect the presence of ammunition or explosives, they are unable to accurately determine their specific types and properties; on the other hand, for certain special types of ammunition or explosives, such as drugs containing special chemical compositions or new types of explosive devices, existing detection technologies may not be able to carry out effective identification at all. The lack of such targeted detection undoubtedly increases the security risks and disposal difficulties. For example, the performance of a certain type of rocket may decline in extreme weather, a situation that is usually difficult to fully detect by a single traditional means of detection alone. Therefore, the neutron detection and environmental monitoring technology to integrate the composite research is particularly important.

2.3. Inefficient testing to meet rapid response needs

In military conflicts, counter-terrorism operations and other emergencies, the rapid and accurate detection of equipment, ammunition and explosives is crucial. However, current detection technologies are still deficient in terms of efficiency. On the one hand, some detection means need to consume a lot of time and human and material resources, such as chemical analysis, physical tests, etc., which is difficult to meet the demand for rapid response; on the other hand, even with efficient detection technology, professional operators and complex equipment support are needed, which may be difficult to realize in some remote areas or battlefield emergencies. Therefore, improving detection efficiency and shortening detection time has become one of the urgent problems to be solved at present.

The reality of the identification of the effectiveness of munitions presents a tendency to combine traditional detection with modern scientific and technological means. In this context, the introduction of neutron detection technology points to a new direction for improving the accuracy and reliability of detection. In future research, more reliance will be placed on the construction of a comprehensive technology platform to comprehensively improve munitions management and combat effectiveness.

3. Application of Neutron Detection Technology in The Identification of The Effectiveness of Munitions

3.1. Application of neutron detection technology

The principle of neutron detection of munitions is as follows: through the use of a neutron source to irradiate the object to be tested, the neutron interacts with the nucleus, generating transient γ-rays and inelastic scattered γ-rays, and determining the main elemental components of the munitions, N, O, C and H, as well as the relevant elements, C, and the characteristic γ-rays of other trace elements (e.g., Nitrogen: 5.1MeV, Carbon: 4.4MeV, Oxygen: 6.1 MeV, Hydrogen: 2.2 MeV), which are solved using computer software to determine the content and proportions of N, O, C and H for munitions effectiveness identification. Over the past few decades, great progress has been made in the detection technology of explosives, mines and other munitions, and many technical solutions have been proposed. According to the characteristics of the neutron source used and the detection method [3], the neutron activation analysis technology for the detection of munitions is mainly classified into the thermal neutron method (TNA), the fast neutron method (FNA), the pulsed fast neutron method (PFNA), the combination of the pulsed fast neutron and thermal neutron method (PFTNA), instantaneous gamma neutron activation analysis (PGNAA) and so on.

This technology uses neutron-matter interactions to identify the composition and structural properties of the material inside munitions, and to assess their effectiveness. Neutron detection can be used in a number of scenarios, such as rapid identification of suspect munitions on the battlefield, assessment of the condition of old munitions during inventory management, and quality control during the manufacturing process of munitions. In these scenarios, neutron detection is highly sensitive and can penetrate through multiple layers of material without damaging the object being detected. 2007, Wang Bairong and others from Beijing Chemical Defense Command and Engineering College proposed to build a chemical weapons detection system based on PNGAA technology. The principle is to recognize chemical weapons

by detecting Cl elements. The combination of this system and the X-ray detection method can greatly improve the speed and credibility of chemical weapons detection. In 2009, the Nuclear Chemistry Research Department of the Korea Atomic Energy Research Center [4] identified a series of material samples by using the transient gamma spectra of the materials as well as the elemental component content data. Explosives and non-explosives were distinguished by the content of major elements.

3.2. Advantages of neutron detection technology

The key to identifying the effectiveness of munitions is to accurately assess the performance, condition and safety of the munitions. Traditional methods of identifying the effectiveness of munitions rely on X-ray, ultrasonic detection and chemical analysis. However, these methods have many limitations when dealing with complex or closed structures, such as insufficient detection accuracy, time-consuming, and high environmental requirements [5]. When inspecting military materiel, traditional X-ray imaging techniques can cause signal attenuation and image distortion due to the complexity of the thickness and composition of the equipment material, whereas neutron detectors have a greater ability to penetrate metal casings and can accurately identify the effectiveness of the internal munitions and associated features. With the traditional detection methods (such as X-ray imaging, γ-ray detection) compared to the neutron detection by virtue of its own unique physical properties, well overcome these shortcomings, in terms of sensitivity and accuracy, can make the munitions identification efficiency greatly improved. In terms of sensitivity, neutron detection of some materials, especially compounds with high hydrogen content, the response ability is super strong, neutrons can be with hydrogen atoms for effective elastic scattering. As a result, when detecting hydrogen-containing explosives and other related components, the false positive rate is also dramatically reduced. In contrast, conventional methods often have difficulty recognizing these materials, and there is a risk of misdiagnosis or missed detection.

Literature studies have shown that neutron detection technology, when used to identify the effectiveness of munitions, can accurately identify the intrinsic composition and physical state of munitions based on the principle of nuclear reaction. This technology can recognize the type, age and storage conditions of munitions, and is also more sensitive in identifying vulnerable materials and potential chemical breakdown. For example, when testing the effectiveness of a particular type of munition, the use of Neutron Reflectometry and Reactive Focusing can identify the location and extent of internal corrosion to accurately determine whether it is safe to continue using it [6].

A comparative study of neutron detection technology and munitions effectiveness identification was carried out in an attempt to reveal the deep-rooted mechanism of the interaction between the two. In the future, with the development of new materials and the innovation of imaging technology, neutron detection technology is expected to achieve more significant results in the identification of the effectiveness of munitions, thus promoting the modernization of military equipment. Therefore, in order to realize a more scientific and effective means of ammunition identification, it is urgent to invest more resources and efforts in the research and application of neutron detection technology, with a view to improving its practical application and building a more solid foundation for the equipment safety defense. The neutron detection technology has been widely used in the field of ammunition identification.

Table 1. Comparative analysis of neutron detection techniques and equipment for munitions effectiveness identification

Detection Methods	vantage	drawbacks
Traditional detection methods	more mature Relatively low cost of technology Highly demanding operating environment	Insufficient detection accuracy
Neutron detection technology	Highly penetrating and recognizes structurally complex munitions High recognition sensitivity	Requires special security measures

3.3. Limitations of neutron detection technology

The potential for neutron detection technology to be used to identify the effectiveness of munitions is significant, although the limitations should not be underestimated. The equipment and systems used for neutron detection are complex and generally require in-depth knowledge and expertise in high-energy physics, which significantly increases the cost of operator training. For example, in practical use scenarios, the selection of neutron detectors and the corresponding data acquisition and processing techniques require operators to have a solid level of specialized knowledge, which, to a certain extent, restricts their wide application.

A major obstacle to the diffusion of neutron detection technology is the investment in equipment and maintenance costs. Today, detection systems based on the neutron scattering principle are usually very expensive, and a lot of money has to be invested in subsequent maintenance and calibration. This economic burden makes it difficult to introduce and apply this advanced technology when budgets are limited. The concentrated supply of neutron detectors on the market limits the possibilities for technological advances and cost reductions, which in the long run may affect their market competitiveness.

Another important limitation of neutron detection technology is the problem of environmental adaptability. The performance of neutron detection equipment may be drastically reduced in different environments, such as high temperature, high humidity or strong radiation environments, the sensitivity and accuracy of detectors will be significantly affected. This not only increases the uncertainty of the equipment in a given application context, but also limits the diversification of the technology.

4. Future Prospects

Neutron detection technology is used to identify the effectiveness of munitions, and the prospects and practical

value are quite remarkable. With high sensitivity and strong penetration ability, neutron detection can overcome the limitations of traditional detection means in complex environments and accurately analyze the internal composition of munitions, which has attracted much attention and has been widely applied in modern warfare and military equipment maintenance. In practical applications, attention must be paid to the impact of technological advances on its future development. After the introduction of Artificial Intelligence (AI) and Big Data Analysis (BDA) technologies, the level of automation of munitions effectiveness identification has become higher [7], and the ability of data processing and decision support has become significantly stronger. The combination of neutron detection and cutting-edge technological tools such as data mining and machine learning has been continuously optimized with great potential. This shift has made it possible to mine and analyze large amounts of historical data. During this time, researchers have been able to both conduct real-time monitoring and predict future use by building mathematical models to simulate the performance of munitions under different conditions. With these challenges on the horizon, future research will have to be centered around solving these problems. With continued efforts and technological innovation, it is foreseeable that the scope of application of neutron detection technology will certainly continue to expand, leading to the development of munitions effectiveness identification in the direction of greater precision and efficiency. This is not only the succession of existing technologies and breakthroughs, but also for national security, military equipment modernization process actively help. In general, science and technology continue to progress, the relevant research is also increasingly in-depth, neutron detection technology in recognizing the effectiveness of munitions in the importance of more prominent, has a wide range of potential applications and good prospects for development. Under the continuous exploration and innovation, this technology can provide more effective detection means for the military field in the future, to ensure national security and peace and stability.

References

[1] TANG Ya-jun, JIA Wen-bao, HEI Da-qian, LI Jia-tong, CHENG Can, CAI Ping-kun, SUN Ai-yun, ZHAO Dong, HU Qiang. Research on the Identification of Chemical Research on the Identification of Chemical Weapon Based on PGNAA Technology[J]. Spectroscopy and Spectral Analysis, 2019, 39(12): 3653(in chinese).

[2] Wells K ,Bradley D .A review of X-ray explosives detection techniques for checked baggage[J].Applied Radiation and Isotopes, 2012,70(8):1729-1746.

[3] Bucher,, B. et al. Assessment of the associated particle technique with high-resolution gamma-ray spectroscopy for in-field identification of chemical warfare agents and explosives[J].NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND assorted equipment, 2022, 1032.

[4] Im,,Hee-Jung et al.Classification of materials for explosives from prompt gamma spectra by using principal component analysis [J]. APPLIED RADIATION AND isotopes, 2009, 67(7-8):1458-1462.

[5] Ginacarlo, Nebbia, Juergen et al. Detection of buried landmines and hidden explosives using neutron, x-ray and gamma-ray probes [J]. Europhysics News, 2005.

[6] A.,M.,Reda.Design of an explosive detection system to investigate the luggage of aircraft passenger based on neutron-gamma technique [J]. International Journal of Physical Sciences, 2015, 10(18):528-536.

[7] Rahmani,,Faezeh et al.Landmine-identification system based on the detection of scattered neutrons: a feasibility study [J]. RADIATION PHYSICS AND CHEMISTRY,2022,199.