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A LINEAR SHAPED CHARGE NEUTRON RADIOGRAPHY PRECISE DETECTION SCHEME

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ABSTRACT

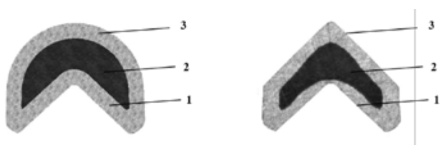
Neutron radiography was researched to detect the linear density of explosive in linear shaped charge (LSC), to determine its distribution uniformity and defective. The clear images of some samples were obtained by neutron radiography, and were processed to obtain the linear density of inner explosive. The defectives such as sparseness, discontinuity and cavity were shown clearly in the images. The method, with more intuitive and more reliable results, is more direct and simpler than existing quality testing methods for LSC, and most important, the method is a non-destructive one. This new method is of significance to the precise test of LSC and its application in precise blasting; in addition, it could be used in quality test of cord type explosive device.

Keywords: *Neutron Radiography, Linear Shaped Charge, Non-Destructive Testing*

1. INTRODUCTION

The Linear Shaped Charge (LSC) is a kind of cord type explosive devices, which transfers explosives energy to metal liner and makes it format high velocity jet to cut objects by using Munroe Effect. Because of its high energy density and strong orientability, LSC is widely applied in many fields such as large steel structures disintegration, offshore drilling platforms demolition, wreck salvage, aerial bomb destroyed and etc.

The common LSC are generally divided into U-type and V-type, their structures are shown in Figure 1. The material of LSC's sheath and liner are lead-antimony alloy (lead of 98.5% -97.5% and antimony 1.5 % -2.5%), its wall thickness depending on the model, and its built-in explosives usually are RDX. The Drawing-Stretching process is commonly used in LSC manufacture. To begin with, a lead-antimony alloy tube, with consistent wall thickness, is filled with RDX, and then after drawing and stretching several times, the tube is reached desired wall thickness, and finally formed through mold. This process may sometimes cause the density uneven or intermittent of the explosive in the axial direction (see Figure 1, perpendicular to the direction of the screen).



1. Liner 2. Explosive 3. Sheath
Figure 1: The Structure Diagram Of LSC

A large number of studies have shown that, the main factors affecting LSC's cutting ability include explosive performance and shape, liner materials, blasting height, detonating method, etc. Explosives, as the energy provider, are the main factor that affects cutting ability. In order to improve the cutting ability, high detonation pressure explosives should be selected and the charge density should be increased as far as possible. If the charge density is uneven or intermittent, it would seriously affect the cutting effect, and even lead to cutting failure. In some special occasions such as multistage rocket separation and aircrew emergency escape, the safety of personnel and equipment should be guaranteed as well as the cutting result, which means the charge density and its distribution must be precisely controlled. Therefore, the detections of LSC's charge linear density uniformity and other structural defects are particularly important.

1.1 Overview on Existing LSC Detection Method

Cutting Method and Dissolution Method are two methods mainly used in LSC quality inspection. In the Cutting Method, two samples are taken from both ends of a LSC, then cut open to remove the charge and weighed. The charge's weight divided by the length of the samples comes to the linear charge density. In the Dissolution method, the samples are taken in the same way, after weighing samples are soaked in acetone to dissolve the charge contained in, then weighed again when they are dry and clean. The different between the two weights divided by the length of the sample comes to linear charge density. Generally, the Dissolution

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Method has high precision than the Dissolution Method. However, both methods are destructive detection and can only measure the average linear density of the samples, which means these methods just judge whether the linear density meet the design requirements, but fail to determine the uniformity of the linear density of the samples, let alone the intermittent of the charge.

1.2. Advantage of Neutron Radiography in Detecting LSC

X-ray is an important means to carry out non-destructive testing. But the strong attenuation effect of lead-antimony alloy to X-ray, make it very difficult to carry out non-destructive testing by the X-ray technology.

Neutron radiography is based on the basic principles that neutrons will decay through the objects. When using a neutron beam irradiation to the sample, the neutrons interact with the sample's nuclei. The cross sections of neutron scattering and absorption varied in different nuclides, result in an intensity and spatial distribution change of transmission neutron, and this change closely relates to the nature of the sample material (component elements, density, cavity, etc.). As a result, the transmitted neutron beam contains the information of samples interior composition and structure. With neutron detection technology and space imaging technology, the information of samples interior material can be obtained, such as spatial distribution, density changes, and various defects, etc. Heavy elements, such as lead, bismuth, uranium, etc., have a very small neutron mass absorption coefficient, while the lighter elements, such as hydrogen, carbon, nitrogen, oxygen, etc., have a large one. The difference between them is about three orders of magnitude. Therefore, neutron radiography can detect the light elements material wrapped with heavy elements material. To LSC, with a lead-antimony alloy sheath and containing explosives RDX $(CH_2NNO_2)_3$, neutron radiography is directly applicable.

For the reasons above, this thesis tries to use neutron radiography to take the nondestructive test on the linear charge density of LSC.

2. EXPERIMENTS

The experiments were carried out on a 49-2 pool-type light water reactor of the China Institute of Atomic Energy (CIAE). The level pore opening of the reactor is 15cm in diameter and 2.9m away from the reactor core; the thermal neutron flux of the reactor is $2*10^7$ n/cm^{2}s. The experimental setup is shown in Figure 2. Samples of LSC were fixed in 1 mm thick aluminum plate and vertically placed 1m away from the level pore opening. The ZnS (Gd) converter screen was placed close to the aluminum plate; behind the conversion screen there was a mirror that was at a 45-degree angle with the direction of the beam reflecting the fluorescence to digital camera lens.

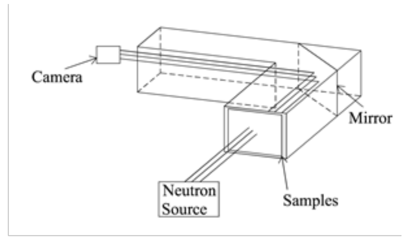

Figure 2: The Diagram Of Neutron Radiography Device

According to the project actual needs, 18 samples of LSC, 7.5 cm in length, were selected, among which there were 3 samples with a linear density of 6 g/m, 12 samples with a linear density of 22 g/m, 3 samples with a linear density of 25g/m. In order to carefully study the uniformity of density, samples was artificially set with defects, such as intermittent, the metal impurities (wire), and non-metallic impurities (glass fragments) and etc.

After the experiment apparatus set, using the pre-placed light-emitting device in the edge of the conversion screen to adjust the camera parameters, a clear image of the light-emitting device was obtained. The conversion screen was located in the same plane with the light-emitting device, and therefore, camera could also clearly capture the image on the conversion screen. Open the reactor level channel control valve to start the neutron radiography experiments. The background image without any sample was taken first, followed by images with samples batches placed.

3. DATA PROCESSING

According to neutron radiography image processing method described in references, a professional image processing program package was applied to analysis the experiment image. First, remove the background of each sample images with the background image. Figure 3 is the image of Sample No. 4 (S4) off background, from which it could be noticed that the neutron radiography produced a very clear image of the inner explosive of the sample.

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Figure 3: The Off-Background Result Picture Of S4

Then, these images were greyed and sliced along the length direction in the units of image pixel; with the gray values of all of the pixels in each slice, the linear charge density and its distribution could be calculated. All the results are shown in Figure 4 - Figure 11.

4. EXPERIMENT RESULTS AND ANALYSIS

4.1. Results on Samples with Linear Density of 6g/m

Figure 4 is the result of samples with nominal linear density of 6g/m. The relative linear density of S1, S2, and S18 are respectively 20.64, 20.18, and 20.08, their variance are respectively 1.15, 1.83, and 2.36. The result shows that the linear density uniformity of S1 is superior to the other two samples.

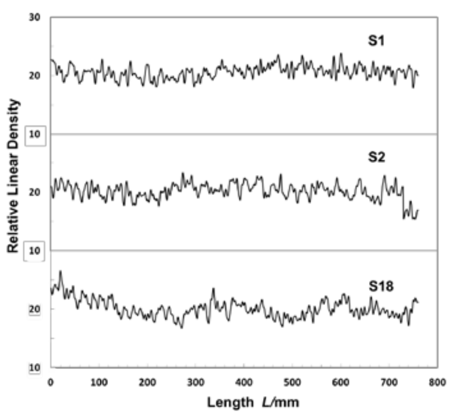

Figure 4: The Relative Linear Density Distribution Of Samples With Linear Density Of 6 G/M

4.2. Results on Samples with Linear Density of 22g/m

Figure 5 is the result of samples with nominal linear density of 22g/m. The relative linear density of S7, S9, S10, and S14 are respectively 25.79, 25.95, 25.17, and 20.36. S14 has the lowest relative linear density value among all the samples, which means it contains less explosive and fail to comply with the nominal value. The variance of S7, S9, and S10 are respectively 1.15, 1.83, and 2.36. The result shows that the linear density uniformity of S10 is superior to the other two samples. It may be noted that there is a singular point in S14 may be the result of flawed experiment equipment.

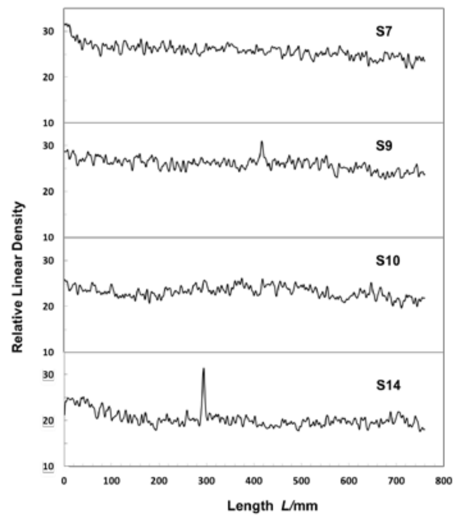

Figure 5: The Relative Linear Density Distribution Of Samples With Linear Density Of 22 G/M

4.3. Results on Samples with Linear Density of 25g/m

Figure 6 is the result of samples with nominal linear density of 25g/m. The average relative linear density of S15 and S16 are respectively 31.25 and 32.04, their variance are respectively 2.20 and 4.82. Apparently， S15 has a better linear density uniformity.

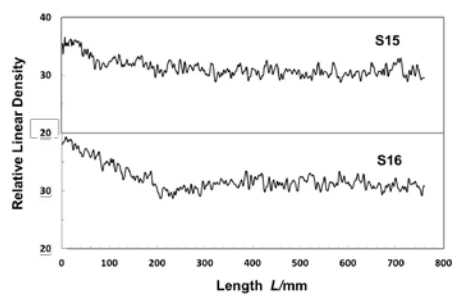

Figure 6: The Relative Linear Density Distribution Of Samples With Linear Density Of 25 G/M

4.4. Results on Explosive with Point-like Defects

Figure 7 is the result of S4 and S13; both samples are set with point-like defects in explosive. There are 3 point-like defects in explosive of S4 (3 1mm diameter holes), two of them located in sheath, the other is located in liner. All of the three holes can clearly be seen from the results, and accurately displayed the location and depth of the hole in the surface of the sample. Two holes are located in liner of S13 without touching explosive section. However, the liner defects lead to a tiny explosive leak that influent the linear density; the results clearly reflect this.

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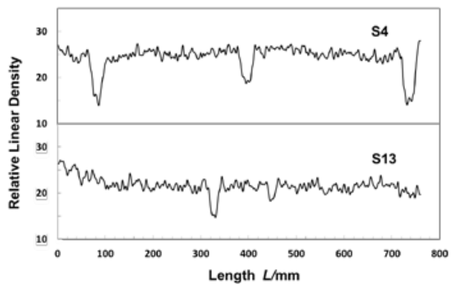

Figure 7: The Relative Linear Density Distribution Of Samples With Point-Like Defects

4.5. Results on Explosive with Linear Defects

Figure 8 is the result of S6 which is set with linear defects in explosive, which is a 1.5mm long empty stripe; the results clearly reflect this.

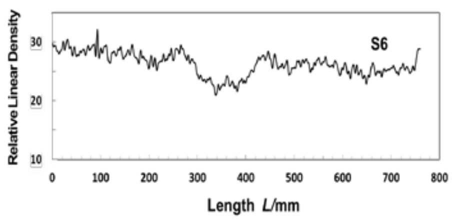

Figure 8: The Relative Linear Density Distribution Of Samples With Linear Defects

4.6. Results on Explosive with Planar Defects

Figure 9 is the result of S5 which is set with planar defects in explosive, which is a cross section of 2mm thickness; the results clearly reflect this.

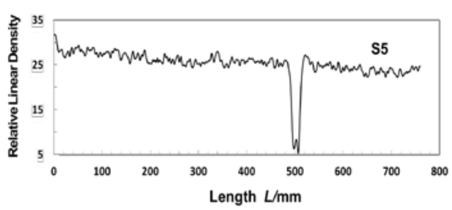

Figure 9: The Data Processing Result Of Samples With Planar Defects

4.7. Results on Explosive with Empty Ends

Figure 10 is the result of S3 and S17; both samples have an empty end in explosive, 1.5mm and 5mm respectively. The results clearly reflect the change of explosive and precisely indicate the region without it. This result and the results on planar defects provide a reliable method to judge whether there is an intermission in a LSC.

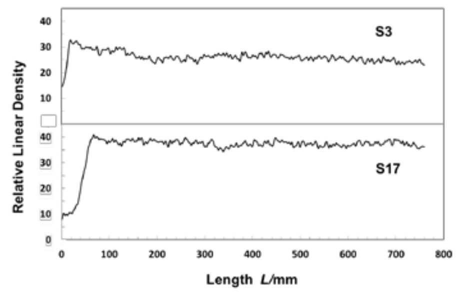

Figure 10: The Relative Linear Density Distribution Of Samples With An Empty End

4.8. Results on Explosive with Impurities

Figure 11 is the result of S11 and S12; S11 has metal impurities (wire) in it, and S12 has non-metallic impurities (glass fragments) in it. The results clearly reflect the change of explosive but fail to detect the kind and shape of the impurities.

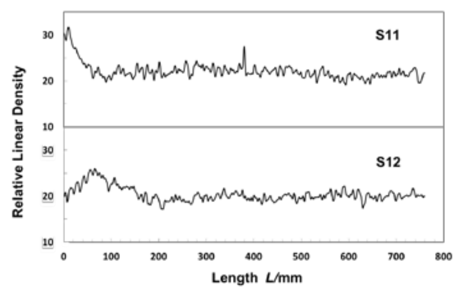

Figure 11: The Relative Linear Density Distribution Of Samples With Impurities

5. CONCLUSION

In this experiment, neutron radiography combined with image processing technology is applied to take non-destructive test of internal explosive of LSC. From neutron radiographic images obtained from the experiment, the inner explosive distribution of samples can be clearly distinguished. With further image processing, an intuitive explosive linear density distribution curve can be obtained and used for the quantitative analysis of charge uniformity. The explosive defects like heterogeneous, intermission and cavity are presented through data processing, which offers a reliable way to choose the qualified LSC. However, this method can barely distinguish the impurities in explosive.

Experiments indicate that the neutron radiography precise detection technology is an ideal non-destructive testing means to LSC. The technology is a good way to overcome the deficiency of current detection method. Results of this technology are intuitive, reliable and precise. With this technology, the quality of LSC can be

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more accurately controlled and the cutting failure of LSC can be avoided. Meanwhile, this technology can be widely used in accurate detection of other cord type explosive devices.

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