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Research on Feature Extraction Technology of Weld Defect Signal based on Wavelet Packet Transform

Liqiang Hu, Haili Jia, Zhaohua Liu, Yadong Zheng, Mingke Wang

Tianjin University of Technology and Education, Tianjin, China

Abstract

Aiming at the identification and classification of weld defect signals of LPG spherical tanks, a wavelet packet transform signal analysis method is proposed to extract characteristic energy of weld defect echo signals. In this paper, ultrasonic phased array module is used to detect weld defects of prefabricated Q345R steel, and Daubechies18 wavelet packet is selected as the optimal basis to extract multi-scale spatial energy features of echo signals. Experiments show that the low-frequency energy values of the five types of defects are quite different. The ultrasonic reflected wave signals of different defects detected by the ultrasonic phased array can be processed by data and used as the basis for subsequent defect classification. The obvious feature difference proves that the method is very effective.

Keywords

LPG spherical tank; Phased array detection; Wavelet packet transform; Daubechies18; Feature extraction.

1. INTRODUCTION

The development of social economy and technological level has driven the continuous progress of the chemical industry. In the chemical industry, liquefied petroleum gas (LPG) is widely used as fuel and raw material, and its storage has become a key focus of the chemical industry. When storing liquefied petroleum gas, due to the long welding seam of the spherical tank, it will be squeezed and corroded by the high-pressure liquefied petroleum gas, resulting in defects. The defects will affect the mechanical properties of the welded seam of the LPG spherical tank, and at the same time make its plastic toughness worse. Affect social security and personnel safety. When inspecting the internal weld defects of the spherical tank, scaffolding needs to be set up inside, and then the welds are polished, and finally the inspectors hold the inspection equipment for inspection. After the inspection is completed, the inspector needs certain map analysis ability and inspection experience to determine whether the inspection result is a defect and conduct a qualitative analysis of the defect. This will not only be affected by experience, but also lead to missed judgments and misjudgments. Therefore, in ultrasonic testing, the accurate analysis of defect types has not yet been completely resolved. The main reason is that the echo signal of ultrasonic defects is a typical transient signal. The frequency spectrum obtained by traditional analysis methods cannot reflect at the same time[1]. The feature information such as the position of the signal mutation in the time domain and the corresponding frequency, and the feature extraction and selection of the defect echo signal are the prerequisites of the defect classification, so the quality of the feature extraction method directly affects the correctness and reliability of the defect classification.

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2. PRINCIPLE OF WAVELET PACKET TRANSFORM

The ultrasonic phased array is used to detect the weld defects of the LPG spherical tank, and the obtained A-scan signal is a non-stationary signal. When inspecting a workpiece, after the ultrasonic encounters a defect, the reflected wave frequency changes, and the probe center modulates the reflected signal into an echo signal according to the frequency modulation. Only when the frequency domain and time domain parts of the echo signal are analyzed at the same time, can the echo signal be accurately measured. The defect echo signal of the workpiece is analyzed by wavelet packet transform. After wavelet packet decomposition, the signal in each scale space can provide the time-frequency local information of the original signal, especially the composition information of the signal on different frequency bands. In addition, the nature of the echo signal can be characterized by its wavelet packet coefficient. The larger the wavelet packet coefficient, the more signal energy it carries. The wavelet packet transform has a kind of "concentration" ability, which can concentrate the energy of the signal on a few coefficients in the wavelet packet transform domain. If the signal energy on different spatial scales is solved, and the energy on the decomposition scale with larger wavelet packet coefficient is selected and arranged in the order of scale, feature vectors can be formed for subsequent identification. This is the basic principle of extracting multi-scale spatial energy features of signals based on wavelet packet decomposition.

Wavelet packet transform has the characteristics of high time-frequency resolution and multi-resolution analysis, and is suitable for analysis and processing of transient signals. After wavelet packet decomposition, local time-frequency information can be provided. The local time-frequency information of the original signal can be collected from the detail signal and the smooth signal. The information composition of the reconstructed signal can be provided by the detail and smooth signal in each frequency band. In this paper, the wavelet packet decomposition method is used to decompose the weld defect echo signal into different scales. Through statistical analysis of the energy on each scale, the characteristic energy in the typical frequency band is selected to form a characteristic vector reflecting the defect echo signal. Related experimental research and verification.

3. DEFECT SIGNAL FEATURE ENERGY EXTRACTION METHOD

The defect echo A-scan signal undergoes wavelet packet transformation, and the collected signal is decomposed in three layers, and the signal is reconstructed for each node, and then 8 frequency band energy features from low frequency to high frequency are extracted as characteristic signals, as shown in Fig 1.

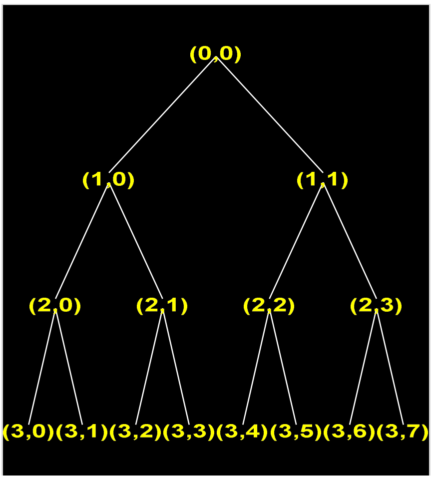

Fig 1. Exploded diagram of three-layer wavelet packet

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Decompose and reconstruct the defective signal, extract the signal decomposed by wavelet packet in the third layer frequency band, the signal will be disordered, because after high frequency filtering, the frequency spectrum of the sampled signal has to be changed once, and the order of the frequency spectrum needs to be re-arranged . The reconstructed signal redistributed according to a certain rule is recorded as $S_{3i}(i=0,1,\cdots 7)$. S is the original signal, $S_{3i}(i=0,1,\cdots 7)$ is the reconstructed signal of each node. It can be known that the sum of each node is equal to the original signal, then:

$$S=\sum_{i=0}^{7} S_{3i} \tag{1}$$

After wavelet packet decomposition, local time-frequency information can be provided. The local time-frequency information of the original signal can be collected from the detail signal and the smooth signal. The information composition of the reconstructed signal can be provided by the detail and smooth signal in each frequency band. Wavelet packet analysis is based on wavelet analysis and extends and expands wavelet analysis to obtain more detailed and accurate signal reconstruction and analysis. The signal is decomposed by the wavelet packet. In the wavelet transform, the increase of the scale will cause the spectrum window to become wider, and the spectrum window will be further narrowed. In this way, the optimal signal base or time-frequency window can be obtained.

Because the input signal is a non-stationary signal, the output signal is also a non-stationary signal, suppose the energy corresponding to $S_{3i}(i=0,1,\cdots 7)$ is $E_{3i}(i=0,1,\cdots 7)$, then there is a formula:

$$E_{3i}=\int\left|S_{3i}(t)\right|^{2} d_{t}=\sum_{k=1}^{n}\left|x_{ik}\right|^{2} \tag{2}$$

Among them, A represents the amplitude of signal B.

When there is a problem in the system, it will affect the feature vector construction and change the energy in each frequency band. Therefore, the construction of the feature vector is based on the frequency band energy, and the formula of the feature vector T is obtained as follows:

$$T=\left[E_{30}/E, E_{31}/E, \cdots, E_{37}/E\right] \tag{3}$$

In the formula: $E=\sqrt{\sum_{i=0}^{7}\left|E_{3i}\right|^{2}}$.

4. EXPERIMENTAL DATA COLLECTION OF WELD DEFECTS

LPG spherical tanks are generally made of 07Cr2AlMoR, 13MnNiMoR, Q345R and Q370R. This experimental equipment uses the Shantou Ultrasonic CTS-PA22S phased array module to detect prefabricated Q345R steel weld defects. The detection probe is GW-PA061903010, the

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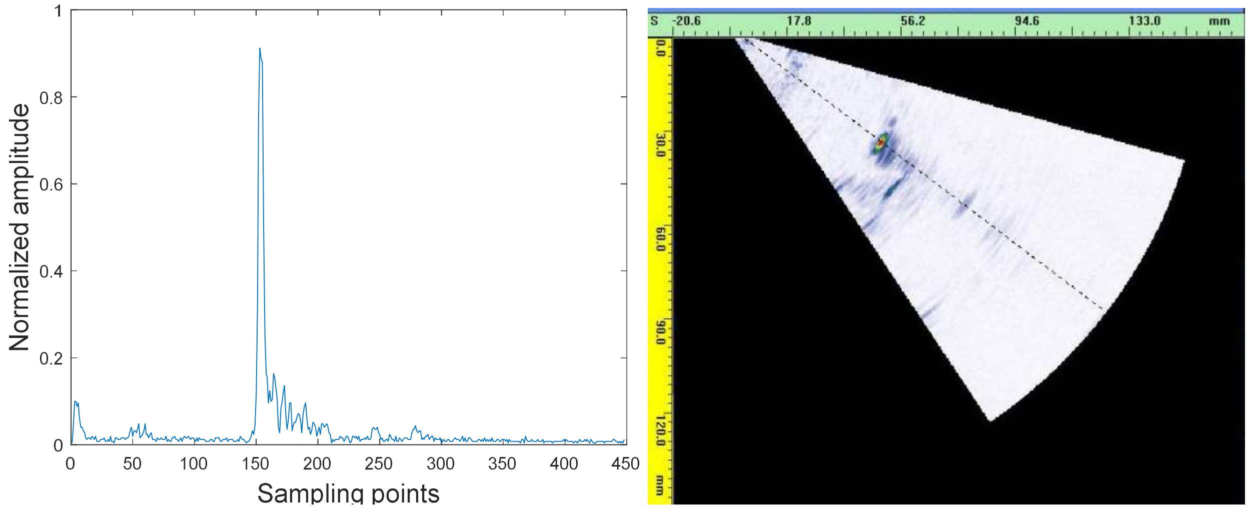
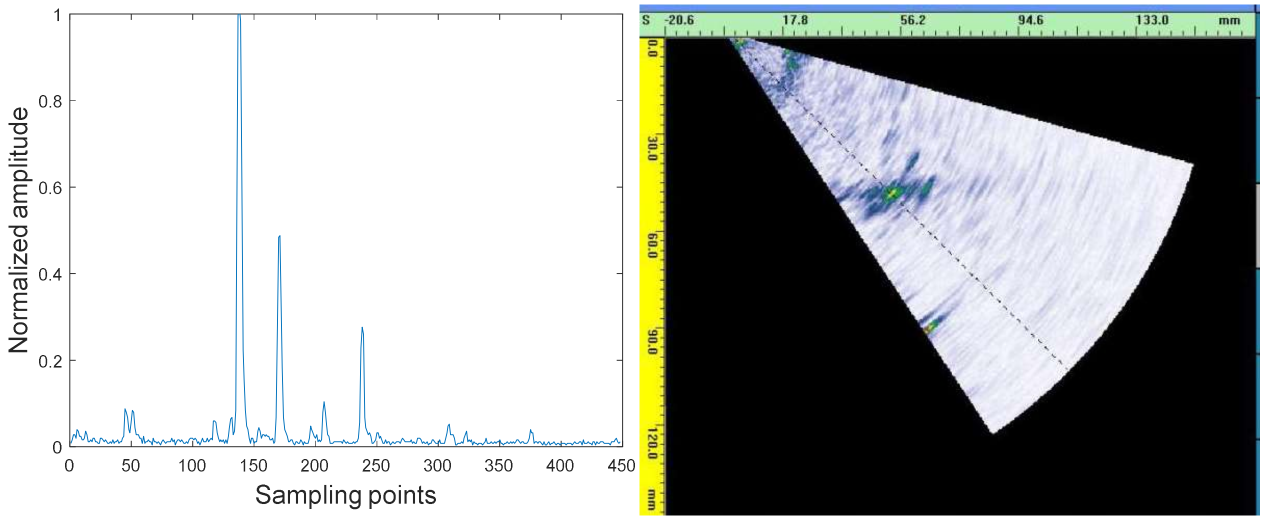
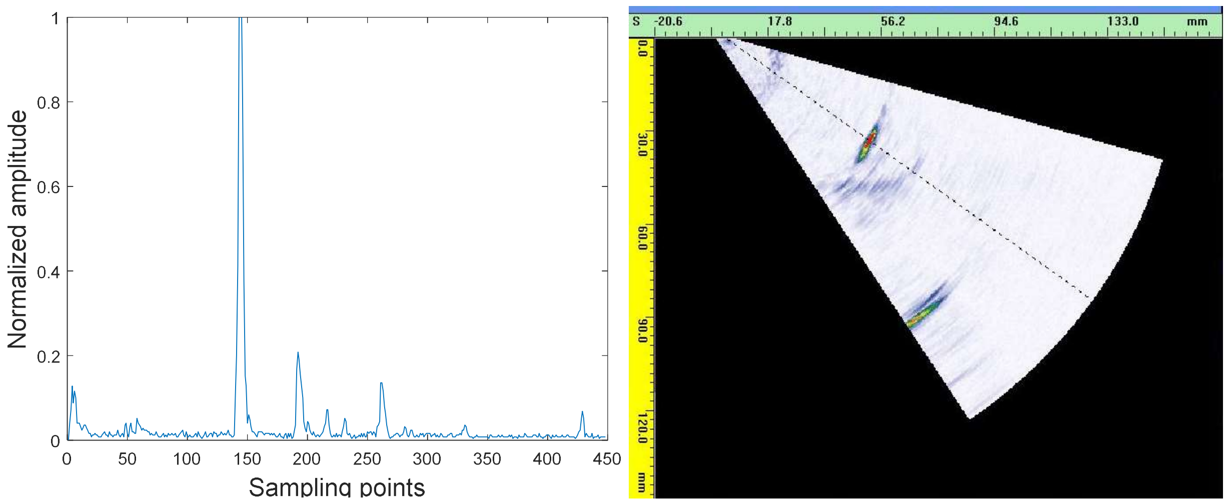
number of chips is 16, the center frequency is 2.5MHz, and the probe is installed on the GW-PA05-IH wedge. On the upper side, installing wedges can prevent the probe surface from wearing. The equipment has high detection sensitivity, can store data at any time, and combine with Matlab for defect signal analysis.



(a) A-scan and S-scan of Crack



(b) A-scan and S-scan of Not penetrated



(c) A-scan and S-scan of Not fused

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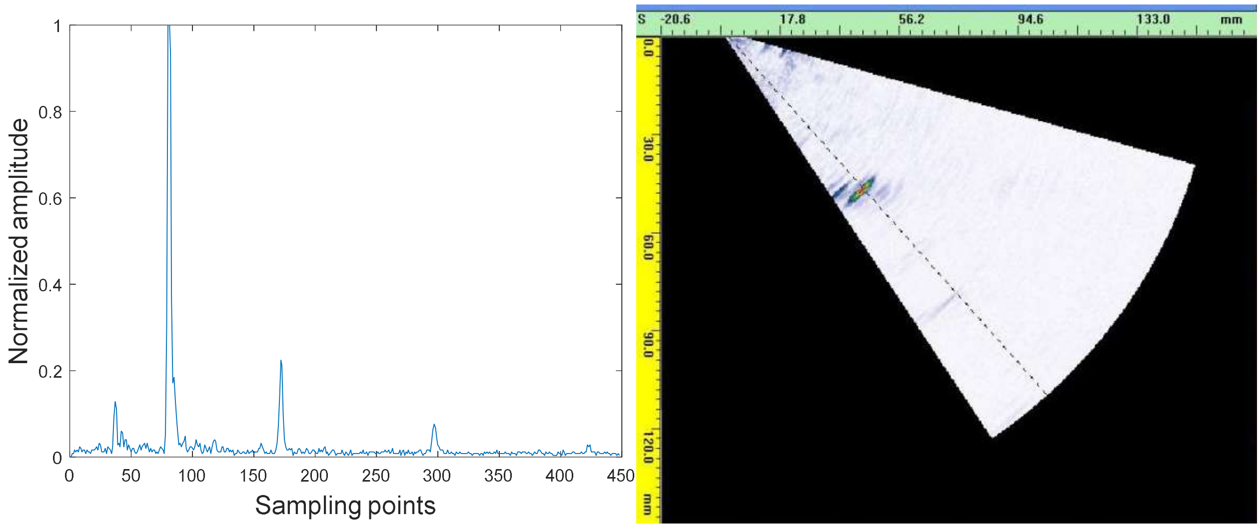
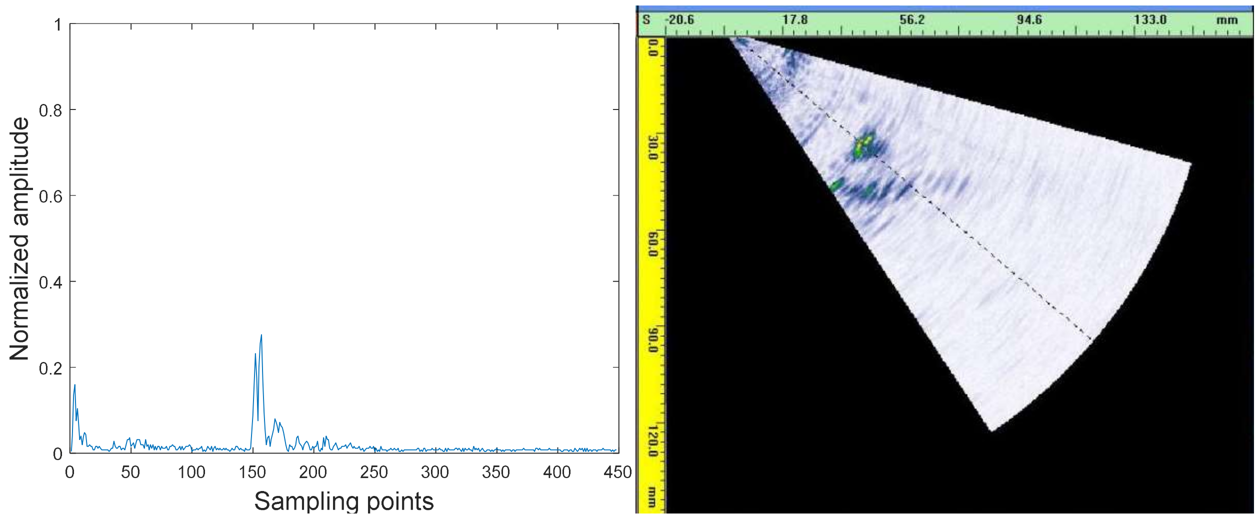


(d) A-scan and S-scan of Slag



(e) A-scan and S-scan of Stoma

Fig 2. Scanning diagram of ultrasonic phased array detection

When testing, place the direction of the probe and the weld line perpendicular to each other. At this time, the scanning direction of the probe is parallel to the direction of the weld line. The coupling agent between the probe and the contact surface adopts oil coupling. The view display mode is A Scan and fan sweep mode. As shown in Fig 2, (a) is a crack scan, (b) is a scan without penetration, (c) is a scan without fusion, (d) is a scan with slag, and (e) is a scan with a hole. The experiment tested a total of 300 sets of data, 60 sets of each defect.

5. FEATURE EXTRACTION OF ECHO A-SCAN SIGNAL

According to the ultrasonic defect echo A-scan signal, the multi-scale spatial energy feature extraction is carried out. In this paper, Daubechies18 wavelet packet is selected as the optimal basis, and the measured signal is decomposed on three scales of wavelet packet.

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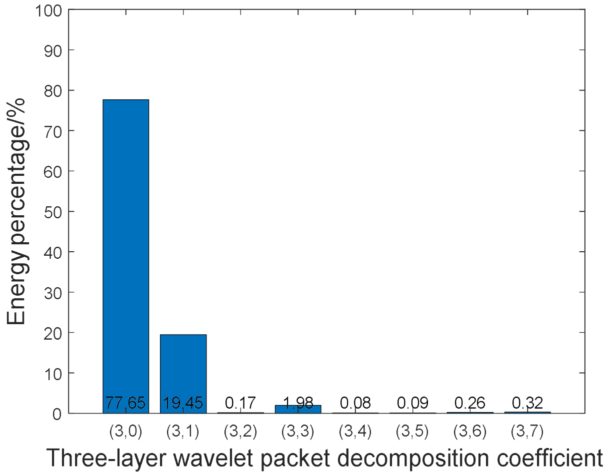
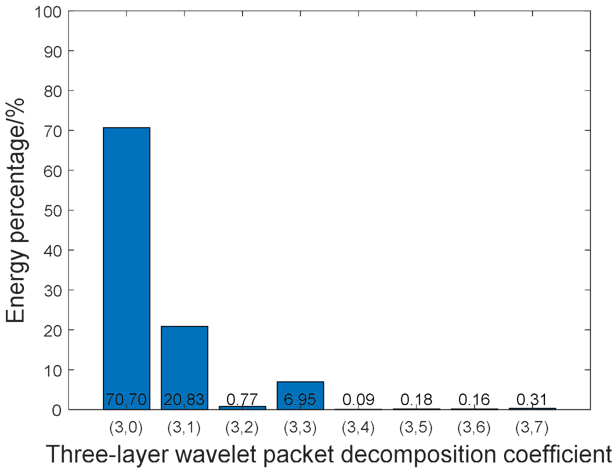
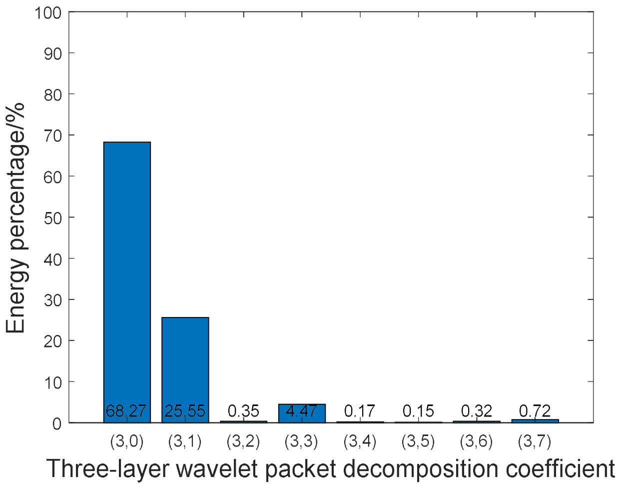


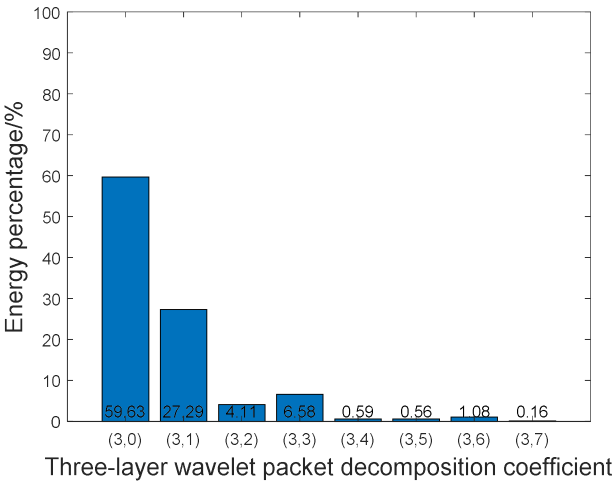
(a)Defect energy ratio of Crack



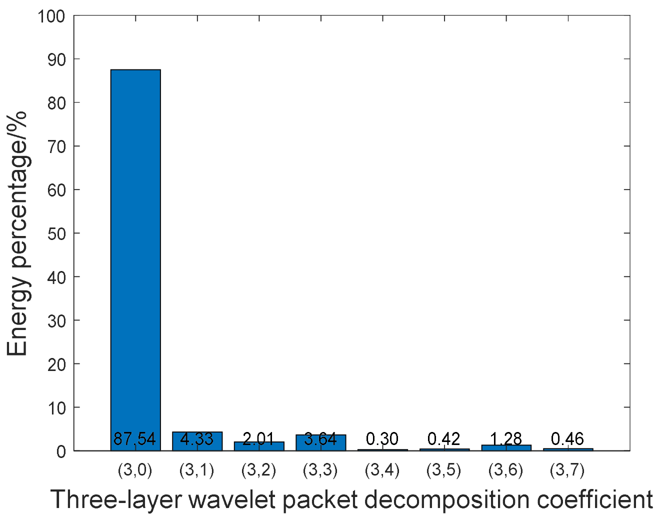
(b)Defect energy ratio of Not penetrated



(c)Defect energy ratio of Not fused



(d)Defect energy ratio of Slag



(e)Defect energy ratio of Stoma

Fig 3. Histogram of characteristic energy spectrum of weld defect A-scan signal

The characteristic energy spectrum histogram extracted from the measured five kinds of weld defect echo signals after wavelet packet decomposition is shown in Fig 3. It can be seen

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from the figure that the high-frequency characteristic energy ratios of the five types of defects have little difference, but the low-frequency band energy values are quite different. According to the results of wavelet packet decomposition, for the pore (3,0) node, the energy ratio is higher than 86%, for the crack defect (3,0) node, the energy ratio is about 79%, and the slag inclusion defect (3,0) node, the energy ratio of the node is about 62%, and the energy ratio of the non-fusion defect and the non-penetration defect node is not much different. According to the above research and analysis results, the ultrasonic reflected wave signals of different defects detected by the ultrasonic phased array can be processed by data and used as the basis for subsequent defect classification.

6. SUMMARY

Based on the wavelet packet transform signal processing method, this paper selects the dB18 wavelet basis as the optimal wavelet basis for wavelet packet decomposition, and extracts the characteristic energy of the ultrasonic A-scan signal of weld defects. From the characteristic extraction diagram, you can see the amplitude of different defects There is a big difference between the values. For low-frequency nodes, the relationship between the energy of various defects is: the energy of inclusion<the energy of unfused<the energy of incomplete welding<the energy of cracks<the energy ratio of pores, The obvious feature difference proves that the method is very effective.

ACKNOWLEDGEMENTS

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