17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

Acoustic Emission Testing of The Shell 0f Electromagnetic Valve

guozhen XU [1], yiwei CHEN [1], zhihua CAO [2]

Shanghai Institute of Space Power -sources

Tel:+021-64852789 Fax:021-64852015 E-mail:sisip@sisip.cn

ABSTRACT

As the control valve of the propulsion system engine, the electromagnetic valve play an important role in attitude and orbit control for spacecraft. While the leak of the electromagnetic valve has always been the main cause of the failure of the propulsion system. Due to the shell's complex structure as well as many seam weld on it, the normal NDT is unfit to check out some small cracks and micro-welding defects of the electromagnetic valve.

In this paper, the specific way of detection for the valve shell with the help of acoustic emission has been introduced. Especially, we would major describe transducer arrangement, parameter setting and waveform data analysis, etc.. We analyze some relevant technological problems, such as how to improve the defection location precision of small-sized valve shell, also we test and verify the phenomena of micro leakage of the shell by other detection means and hold further discussion about the testing results.

This paper summarizes the function of the acoustic emission in the problem of micro-leakage of the shell of the electromagnetic valve, therefore providing us with acoustic emission proof of the quality control of valve and the wide application of this new testing way.

KEYWORDS acoustic emission，valve，weld，leak

1. Testing Purpose

Valve is the precise component of propulsion subsystem with complex structure and special-required property and wide varieties. At present, there are more than 90 valves in the propulsion subsystem of "Shenzhou" aircraft propulsion cabin, including 56 electromagnetic valves, 18 self- locking valves, 6 electric storm valves, as well as pressure release valves, safety valves and inflation valves etc. After many whole system experiments, valve was found to be one of the component which fault comes into being most easily. So the quality of valve is the key problem in the study of aircraft propulsion subsystem.

In various faults of valve, the leak of valve shell is the primary problem in valve quality control. At present, various valves are all welded structures. It is stipulated by American Astronavigation Bureau that the leakage of the valve in aircraft should be less than 1×10^{-6} cm^3/s (standard) helium and the leakage of the valve in carrier rocket should be less than 1×10^{-4} cm^3/s (standard) helium. Though the helium mass spectrometer was used, by which the minimum leakage of $1\times10^{-12}cm^3/s$ could be detected, faults caused by the leakage of valve shells came into being in the development and ground test of the valve. And the valve shells were often the ones qualified by helium mass spectrometer .It was found by the dissection of shells and metal graphic analysis of flaw cross-sections, that leakage was caused by the spreading of the minute welding cracks in valve shell and the minute flaws in the base material when they were stressed, especially in the valve shells which were welded with the components of different materials. The difference of the welding properties of different materials made the welded parts higher probability of minute cracks than the products welded with same materials. Due to the shell's complex structure, normal nondestructive testing (NDT) methods are difficult to get effective results because of their limitation. As a testing method for dynamic testing, acoustic emission (AE) can be employed to control the quality of the valve shells, because it has no requirement for the geometry of the parts inspected and integral testing can be carried out.

2. Testing method

2.1 Testing condition

A valve shell usually consists of 5~7components including input connect, up split magnetic ring, magneto conductive ring, down split magnetic ring and base plate etc. Figure 1 shows its typical structure. The internal diameter of valve shell is usually 30~40mm.Input connect magneto conductive ring and shell base plate are made of Cr17NiTi soft magnetic alloy while up split magnetic ring and down split magnetic ring are made of 1Cr18Ni9Ti stainless steel. The shells are composed of components by vacuum electron beam welding.

MISTRAS2001 AE testing instrument made by American Physical Acoustic Company was used. Double-probe one-divisional linear location method was adopted; one end of a valve shell was sealed up with plug and the other was connected with tube mouth. Testing instrument worked at 4.5PaNz(The designed working pressure was 3.5MPa) and the pressure was kept for 10 minutes. AE probe was properly fixed in the machined plane of the plug and tube mouth. Proper couplant was used to insure good coupling between thread connection and probe. Testing scope was the whole body of the shell, and attention was paid to the welds.

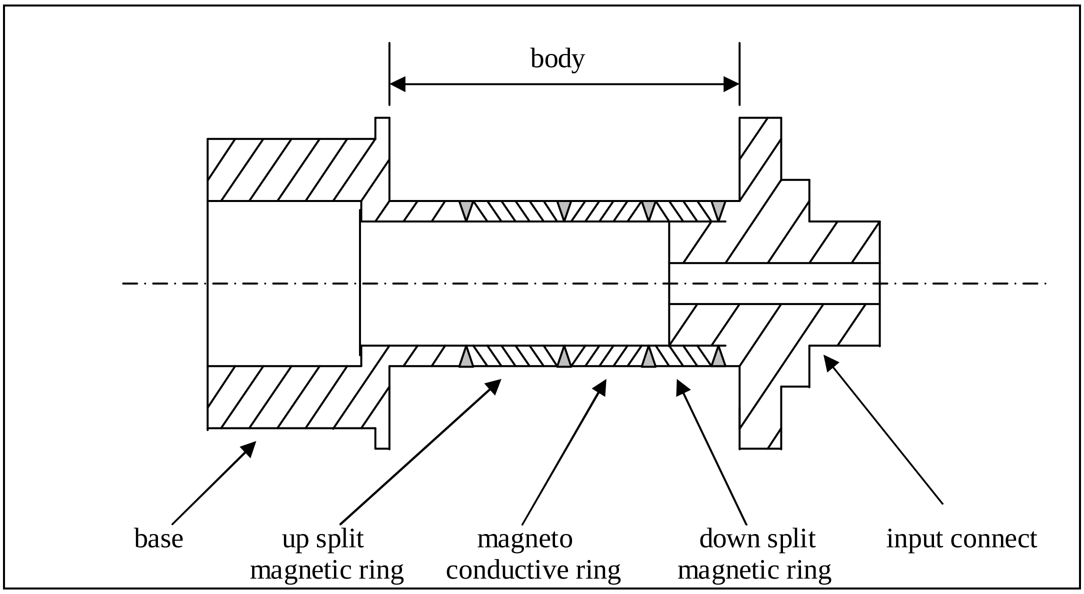


Fig 1 Structure of valve shell

2.2 Setting testing parameters

Table 1 shows the specific parameters of AE test:

Table 1: The setting of the AE testing parameters

parameter	threshold	gain		Time parameter			filter	
	(dB)	Pre-gain (dB)	Main amplifier (dB)	PDT (us)	HDT (us)	HLT (us)	Low-pass (kHz)	High-Pass (kHz)
value	40	40	30	500	1000	2000	100	400

2.3 Analysis and evaluation of the testing result

As testing result is evaluated on the basis of the grade of AE source, to evaluate the testing value accurately, the effect of the noise source should be distinguished first.

Noise is mainly classified as two types according to the occurring factors. One is electromagnetic noise, another is mechanical noise.

Electromagnetic noise usually comes from the disturbance of the electric network, such as the instantaneous changes of voltage and electric current caused by the power starting and motor's sudden running etc. These signals are easily distinguished according to their location

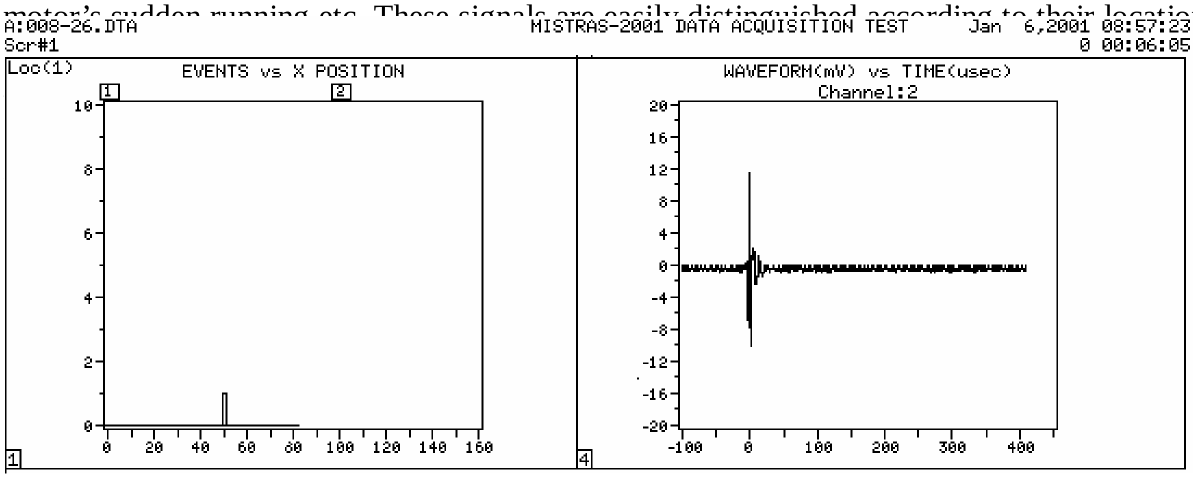


Fig2:Typical location of the electric disturbance   Fig3:Typical wave of the electric disturbance

The cause of mechanical noise is very complex. It mainly comes from the two aspects as follows: One is the AE signal from the relative mechanical slipping of the thread structure coupling. These noise signals can be recognized according to the location figure. They mainly engendered at the initial stage of applying and maintaining pressure. For the valve shell's thread structures are at the two ends outside the shell body, the noise signals can be distinguished according to their location in the figure with the precondition of insuring the location accuracy and avoiding the effect of the reflected waves' overlapping .As figure 4 shows, the acoustic signals are outside the shell's body. But because of the sound waves' overlapping, varied characters including waveform and amplitude should be synthetically thought over besides the location. Figure 5 shows the waveform with overlapping.

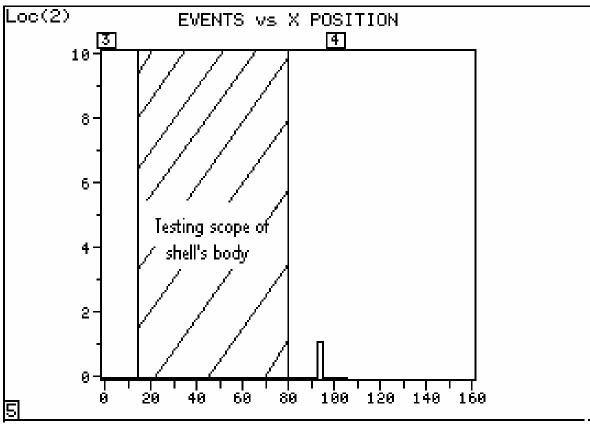


Fig4:Location of the mechanical noise in the whorl

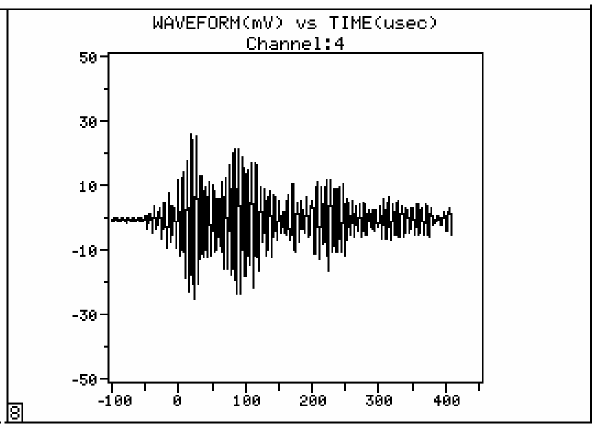


Fig 5:Typical wave overlapping

The other cause is the fluid friction noise which is mainly the friction between the air and the cavity of the valve shell when pressurizing as well as the small leak caused by the two ends' bad sealing. If pressurizing fast, nitrogen fluid can stimulate stress waves in the cavity because of its small diameter. And when reach threshold, these stress waves can form noise signals which are continuous ones similar to leak signals. So we can easily distinguish the two kinds of signals by the waveform showed as Fig 6.

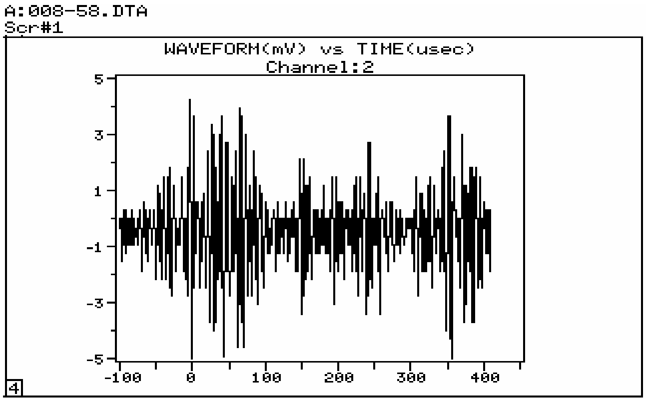
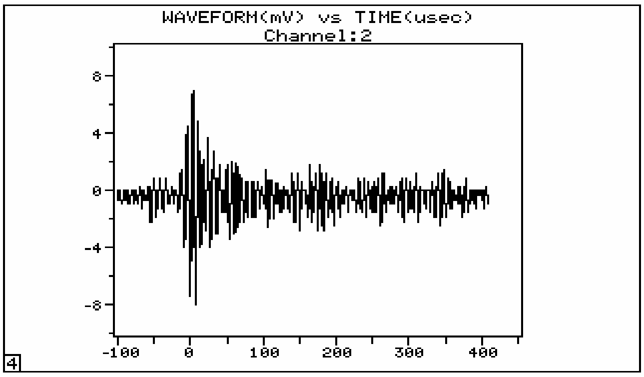


Fig6:Typical continuous signal wave of friction and leak

After picking out the noise signal, we can analyze and evaluate flaws according to the valid signal characteristic value. Fig 7 shows the typical wave feature of the flaw's sudden spreading.

Fig7:Typial sudden spreading wave of flaw



AE source grade is classified on the basis of its strength and activity. Activity is classified as strong activity, activity and weak activity according to the event count in the testing scope during applying and maintaining pressure. Strength is classified as high strength、middle strength and low strength according to the average elastic energy released by the AE event(Table 2 and Table 3).

Table 2 Classifying of the AE source's strength

Grade of source's strength	Strength of source E
High strength	E>80dB
Middle strength	60dB≤ E≤ 80db
Low strength	E<60db

Table 3 Classifying of the AE source's activity

Grade of source's activity	Activity
Strong activity	Event count>2
activity	2≥ event count>1
Weak activity	Event count≤ 1

Table 4 Classifying of the AE's synthesized grade

Activity grade / Strength grade	Strong activity	activity	Weak activity
High strength	A	A	A
Middle strength	A	A	B
Low strength	A	B	C

Synthesizing the activity and strength grades, the AE source can be classified as grade A, grade B and grade C shown in Table 4.

According to the synthetic evaluation grades, AE signal source of the detected components can be disposed consulting Table 5.

Table 5 The evaluated method of AE test

Source grade	Deposing plan
A	Can't employ to the delivering product and the test running product
B	Can't employ to the delivering product, can employ to the test running product
C	Synthesizing the result of helium test, can employ to the delivering product

2.4 Discussion and analysis

When testing various types of valve shells by AE, two problems should be discussed and analyzed.

One is the location accuracy. It plays an important role in AE testing of valve shells.First, the precondition of avoiding mechanical noise of thread is accurate location. Second, accurate location helps us to determine where flaw is located, in the weld or in shell's body. So it is conducive to repair and to the elimination of flaws. Last, it is helpful to carry out directive leak detection with helium mass spectrometer. One-division linear location and principle of time difference location were used in AE testing of valve shells. But since the effect of the objective factors such as the wave speeds (The valve shell was made of two kinds of materials), and components' shapes (The whole shell has complicated shapes) etc, it is difficult to insure the accuracy. It was determined by comparisons and simulated experiment that relative location method was effective to solve the problems, by which the position of a flaw AE source was determined by the relative position of the simulated source under the same condition.

Before AE testing, we located leads at the two sides of the valve shell respectively to simulate source (Fig 8 and Fig 9). The same condition (same leads and breaking models) should be insured in location. In order to avoiding the location errors resulted from the acoustic wave overlapping in small components, attention should be paid attention to signal amplitude and fracture waveforms. After the positioning of simulative source, the position of a flaw can be determined from formula (1).

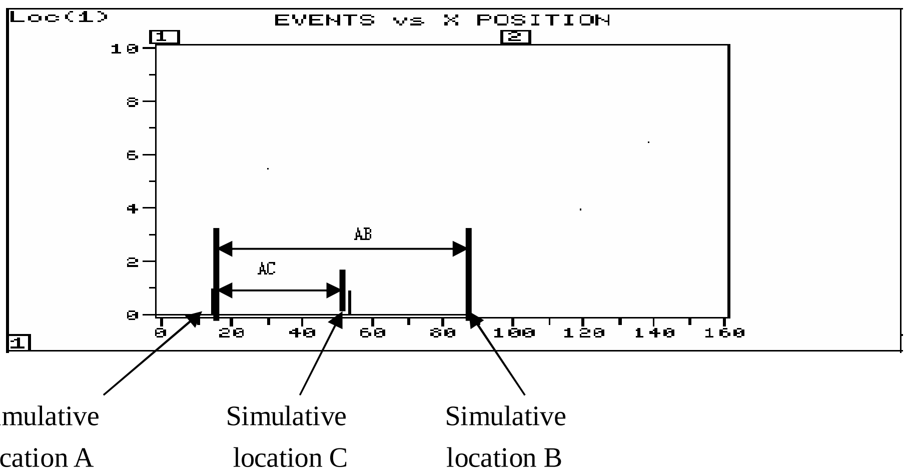


Fig8:Sketech map of the flaw position

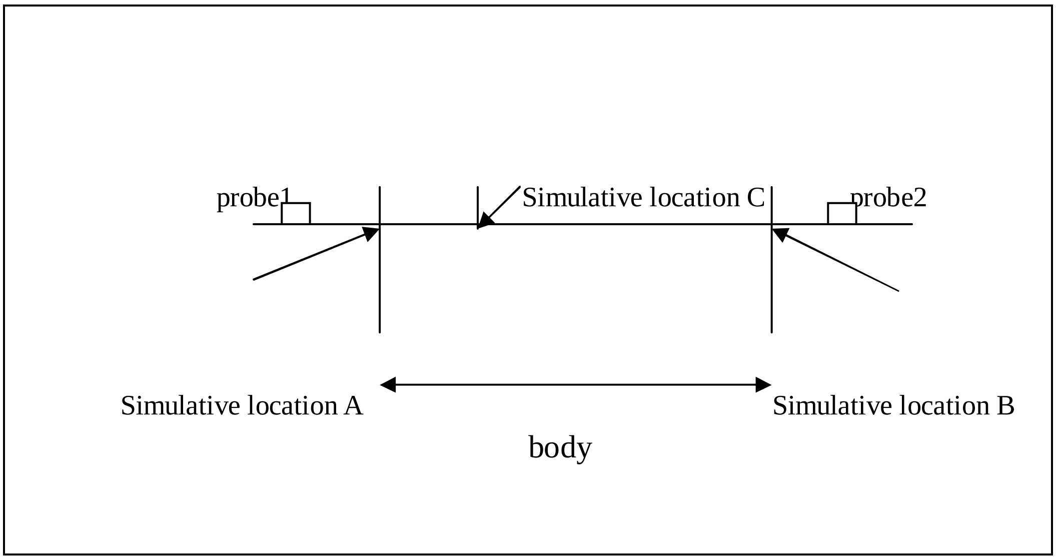


Fig9: Location of the flaw's AE

$$|AX|=|AC|/|AB| \times L \quad (1)$$

Where |AX|: the distance of the flaw position relative to the simulative position A

|AC|: the distance between flaw position C and the simulative position A in the location figure of flaw AE signal

|AB|: the distance between simulative positions A and B in the location figure of flaw AE signal

L: the real length of the valve shell's body

The advantage of the relative location method avoided the repeated location by regulating the sound velocities to insure the absolute accuracy of the simulative positioning.

The other problem is minute leaks. In AE experiment, we found a phenomenon that a leak spot was found in air-tight test with bubble method in valve shell which did exist when applying and maintaining pressure. And there were 4 bubbles per minute. So we AE experiment again with higher pressure and lower threshold, and didn't find AE signal of defect. Then we tried to test by comparing the slopes of the cumulated ringing counter at the states of normal pressure and applied pressure. First, we decreased the threshold properly to 20dB, wrote down the cures of accumulated ringing counters relative to time at the normal pressure. Then we increased the pressure and wrote down the curves under the same condition of the other factors. After that we compared the two curves and analyzed the changes of the slopes. If there was relatively apparent change, there was AE signal accumulation of which the amplitudes were very low at the increased pressure. Analyzing in theory, the AE signals of leakage were continuous waveforms and had no high amplitude as the sudden signals of the crack spreading. When the leaking speed was very low, the amplitude of AE waveform was very low. And as the shell's wall was very thin, the overlapping effect of AE signals was very weak. So the AE signals of the minute leakage in the valve shells were submerged in the background noise of AE instrument which were difficult to distinguish. Testing capability could be relatively increased by comparing the slopes of the accumulated ringing counter. In the experiment, the leakage spot of 8 bubbles per minute detected out by bubble method was found by comparing method under the same condition. Namely, the testing sensitivity of AE is not high for the small components. So the combination of AE testing and the leak detection with helium mass spectrometer will insure the quality of the valve shells.

3. Conclusion

(1) The activity of the flaws in the valve shells can be evaluated by AE test, which will be an offset to the traditional NDT methods. And the detectivity of the dangerous active flaws can be improved.

(2) Though AE testing is highly sensitive to the crack spreading signals in the valve shells, it is less sensitive to the minute leakage. So AE testing should be used with the help of helium mass spectrometer to insure the quality of the valve shells.

(3) The application of AE testing is limited by various factors such as theory study, standard formulating and equipment development etc. We will work hard continuously to promote the wider application of the AE testing.

Reference:

[1] Guoqiu Liu PRENCIPLE OF LIQUID ROCKET ENGLISH(M) 1993.465