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Application of a Weak Signal Processing Method on Cable Non-destructive Testing

Jie Sun, Fei Zhu, Wen Sun*

Jiangsu Fasten Material Analysis and Testing Co., Ltd, Jiangsu, China

*Corresponding author e-mail: 41329150@qq.com

Abstract. A weak signal processing method is used to distinguish the defect signal while signal-to-noise ratio is small, and the application in cable non-destructive testing so that can find the tiny defects in the cables. For the signal noise obeys the normal distribution in time domain which is symmetrically distributed on both sides of the real value. The signal noise could cancel each other after accumulating. while the real signal does not obey the normal distribution and could be amplified after time accumulating. A weak signal processing method is designed to collect weak signals multiple times under timing control, and accumulate the collected signal sequence strictly according to the time line. The accumulation of weak signals could effectively amplify the real signal without amplifying the noise, so that the weak signal generated by the tiny defects could be clearly distinguished. The application of weak signal processing method could greatly improve the accuracy of cable non-destructive testing.

1. Introduction

There are several kinds of non-destructive testing methods and instruments, and pulse reflection type ultrasonic flaw detector is most widely used [1]. In the transmission path of ultrasonic signal, the defect or discontinuity of material will cause the inconsistency of acoustic impedance. Ultrasonic signal or bundle will reflect at the interface of two different acoustic impedance [2], and judge the location of defect by the reflected signal.

In the cable non-destructive testing, the amplitude of echo signal is dependent on the defect size. The echo signal of larger defects can be easily identified but the smaller echo signal so weak that even submerged in noise. The reflected signal should be amplified to distinguish the defect and noise. However, the traditional amplify method will both enlarge the defect signal and noise so that the signal-to-noise ratio is still small [3]. A weak signal accumulating processing method of cable non-destructive testing is designed to solve the problem of small signal-to-noise ratio, and would find the reflected signal caused by tiny defect in cable.

2. Cable non-destructive testing system

The cable non-destructive testing system collects weak signals several times under the precise time sequence control, and accumulates the collected signal sequence strictly according to time line. Because the signal noise obeys the normal distribution and symmetrically distributed on both sides of the real value which will cancel each other after accumulating. But the defect signal does not obey the normal distribution and the amplitude will enlarge by accumulating [4]. Therefore, the weak signal processing

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method effective enlarge the defect signal without the noise, and find the tiny defect of weak reflected signal.

The cable non-destructive testing system is mainly composed of MCU, time line generate port, signal input/output port and data output port, are shown in Fig. 1.

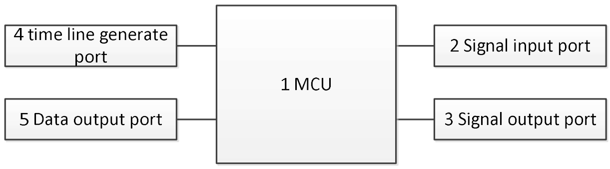

Figure 1. Hardware design of cable non-destructive testing system

3. Weak signal processing

The weak signal processing method of cable non-destructive testing is mainly produced by the precise time line control. With several signal generation, signal sequence acquisition, accumulation, normalization and other steps under strict time sequence control, can effectively amplify weak signals of tiny defect without amplifying noise.

The probability density function of normal distribution is:

$$\mathrm{p}(x)=\frac{1}{\sqrt{2\pi}\sigma}\exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\} \tag{1}$$

And the distribution function is:

$$\mathrm{F}(x)=\frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{x}\exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\}dx \tag{2}$$

Where, μ is the mean value, σ is the standard deviation.

Because the noise obeys the normal distribution, the M times accumulated value tends to ME(x).

$$\mathrm{E}(x)=\frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{+\infty}x\exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\}dx \tag{3}$$

According to the principle of normal distribution, E(x)=μ, therefore:

$$\mathrm{S}_{\mathrm{T_1}}=\mathrm{F}_{(1)\mathrm{T_n}}+\mathrm{F}_{(2)\mathrm{T_n}}+\ldots+\mathrm{F}_{(\mathrm{M})\mathrm{T_n}}\approx M\mu \tag{4}$$

Then, the S distribution function is obtained by M matrix addition.

$$\mathrm{S}_{[\mathrm{T_1\,T_2}\cdots\mathrm{T_n}]}=\begin{bmatrix}F_{(1)T_1} & \cdots & F_{(1)T_n}\\ \vdots & \ddots & \vdots\\ F_{(M)T_1} & \cdots & F_{(M)T_n}\end{bmatrix} \tag{5}$$

Then the matrix values are normalized. If the detected signal of a certain time T_h is not noise, and the value dose not obey normal distribution, the value $\mathrm{S}_{\mathrm{T_n}}$ will amplify with the increase of M.

$$S_{[T_1\,T_2\cdots T_n]} = [M\mu \quad \cdots \quad M\mu] \tag{6}$$

The signal process flow chart is shown in Fig. 2, and the signal processing steps are:

(1) A time line is generated which serves as a timing benchmark for the entire process.

(2) At time T_1, the transmitting pulse signal is generated and waits for 50ms.

(3) At time intervals, the echo signal sequence is collected and saved as (F_1, F_2, ...F_n).

(4) Repeat (2) and (3) M times to get M group signal sequence $(F_1, F_2, ...F_n)_1$~$(F_1, F_2, ...F_n)_M$.

(5) The M group signal sequence is added to get result sequence. And the result sequence is normalized to get the final result sequence data.

(6) The final result sequence is output and displayed as echo curve which is convenient for testers to judge the result.

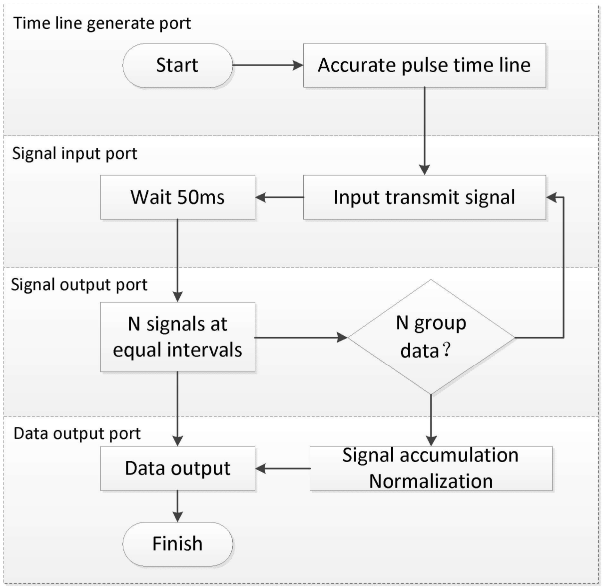

Figure 2. Weak signal processing flow chart

4. Experiments

An original reflect signal of cable non-destructive testing is shown is Fig. 3. The experimental signals with M coefficients of 10, 50, 100 and 1000 for cable non-destructive testing are also collected and shown in Fig. 4~Fig. 7. The amplitude signal and noise of each results are list in Table 1. The experimental data show that the weak signal processing method can effectively amplify the defect signal without amplifying the noise, which can easily distinguish the weak signal caused by tiny internal defects and greatly improved the accuracy of non-destructive testing.

Table 1. Signal processing of different coefficients

Number	M coefficient	Signal amplitude	Noise amplitude	Signal-to-noise ratio
1	1	25	20	1.25
2	10	100	50	2.00
3	50	350	60	5.80
4	100	650	70	9.20
5	1000	5400	200	27.00

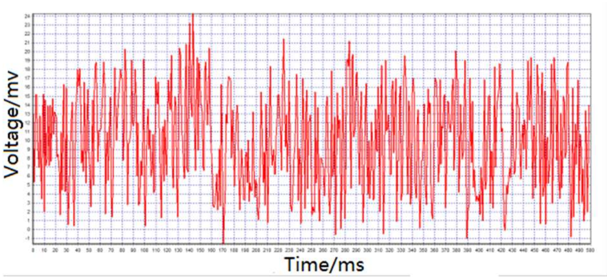

Figure 3. Original signal of cable non-destructive testing

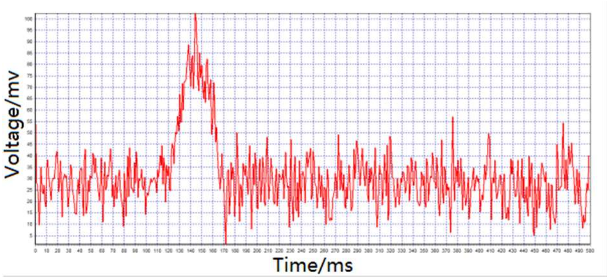

Figure 4. Processed signal with a coefficient 10

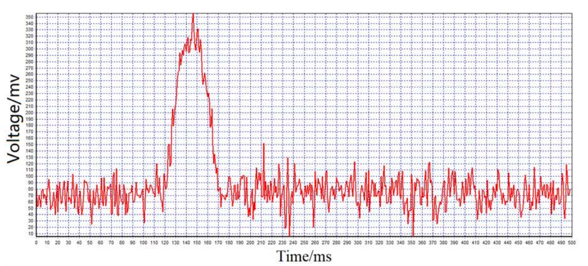

Figure 5. Processed signal with a coefficient 50

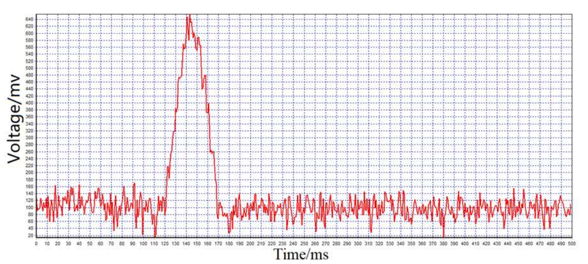

Figure 6. Processed signal with a coefficient 100

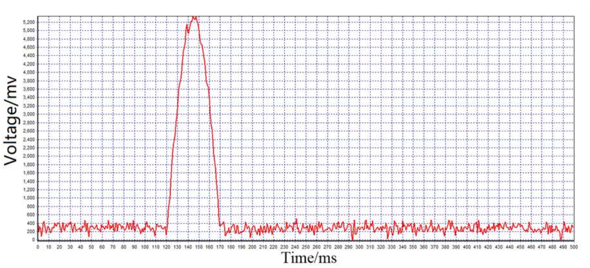

Figure 7. Processed signal with a coefficient 1000

5. Conclusion

A weak signal processing method is applicated on cable nondestructive testing. By collecting weak signals several times and accumulated under precise timing control, the real signals caused by defect is amplified without amplifying the noise.

The application of weak signal processing method on cable nondestructive testing can effectively accuracy and capability to find tiny defects.

Acknowledgments

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