Application of Logarithmic Amplifier in Ultrasonic Testing of Nuclear Power Plant Pipe Weld

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1. Introduction

Since the first report on inter-granular stress corrosion cracking (IGSCC) in primary loop recirculation piping of boiling water reactor (BWR) in the 1970s, the nuclear power industry has made every effort to develop the methods for IGSCC detection and sizing using the ultrasonic examination. By the manual ultrasonic examination, inspector identify IGSCC and the neighboring geometry echoes by observing waveforms, dynamic signal characteristics and its location. For the depth sizing of IGSCC, the crack tip diffraction technique is demonstrated to be reliable. The most difficult part of IGSCC depth sizing by the tip diffraction technique is to discriminate the faint tip echo from the other noise echoes originated in the weld metal[1]. It is often necessary in UT applications to display very small signals and very large signals on the same screen. The more common amplifier is the "Linear Amplifier", which is limited in being able to instantaneously display a very small signal and very large signal on the same display scale. Though linear amps normally allow to see 32dB of dynamic range at once, "Logarithmic Amplifiers" or "Log Amps" can help provide a wider range 80-96dB. [2]

This paper evaluates the possibilities of application in piping weld inspection in nuclear power plant.

2. Methods and Results

2.1 Basic concept of Log amplification design

Fig. 1 is the basic concept of designing a log amp. Each stage will provide a fixed gain as well as a saturation limit. This limit of each stage always gives a fixed contribution to the sum portion before the final result. This kind of behavior can provide the non-linear behavior a log amp needs, as no matter how high the input value is for one stage the output of an individual stage will always be limited at some point.

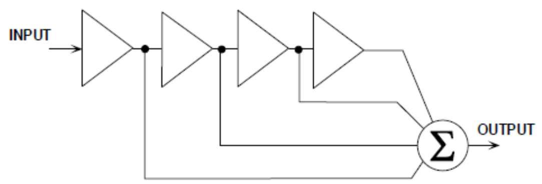

Fig.1 Basic concept of log amp design

The logarithmic amplifier ultrasonic system has the capability to amplify the received signals following a logarithmic curve. This is done by analogue circuits before digitalization of the signal. This means that small signals are amplified more than large signals allowing acquiring with a large dynamic range: very small and very large signals can be recorded at the same time with a fixed gain setting (0 dB).

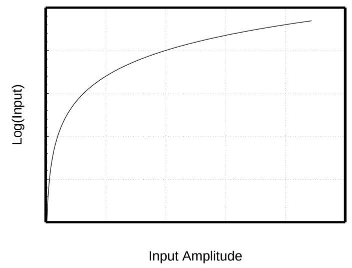

Fig. 2 Log output amplitude plotting vs. input

2.2 Test System and Specimen

To compare the ultrasonic imaging capabilities of a linear amplifier and a logarithmic amplifier the µTomoscan system was selected. It is equipped with a linear amplifier and a logarithmic amplifier.

The test conditions for the experiment are as follows:

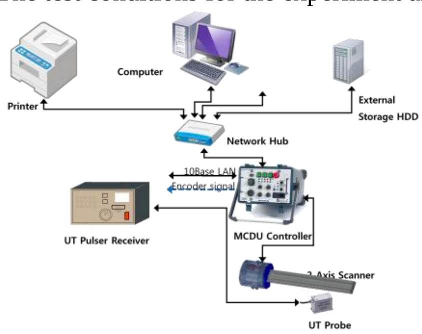

Fig. 2 Configuration of ultrasonic test system

A steel block made of stainless 304 austenitic material which containing a side drill hole, is used as test specimen. A broadband 2.25 MHz frequency and 12.5 mm(0.5") in diameter with 45 degree shear wave were used for the experiment.

2.3 Test Conditions and Procedure

The experiment is performed by two types of amplifier scale. One is linear scan and the other is logarithmic scale. The automatic ultrasonic test system is scanned for side drilled hole on both conditions.

The linear scale experiment is performed fixed gain at 30 dB.

2.4 Result and Discussion

Fig. 3 shows the acquired A-scan waves form of the side drilled hole at linear scale. The amplitude of reflected signal is 64.7 % of full screen height.

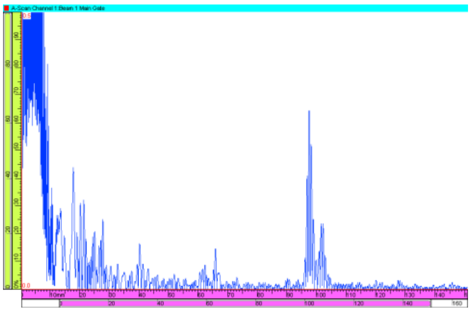

Fig. 3 Ultrasonic signal from the side drilled hole at linear scale

Fig. 4 shows the logarithmic scale ultrasonic signal from the side drilled. As shown in this figure, we can't discriminate the characteristics of side drilled hole signal. Therefore it should convert to linear scale form log scale.

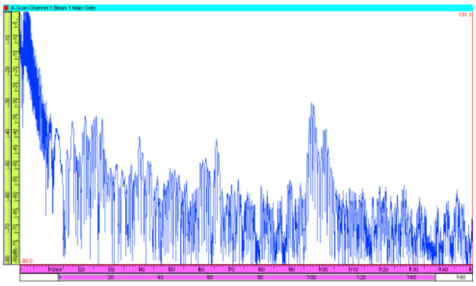

Fig. 4 Original ultrasonic signal from the side drilled hole at logarithmic scale

The converted signal has wide range of dynamic gain. To compare the amplitude difference between the converted logarithmic signal and linear signal, the software gain increased to 25 dB same level as the linear scale signal. Fig. 5 shows converted and increased gain ultrasonic signal. In this signal, the peak of reflected signal was measured. The resulted amplitude value is 66.2% full screen height.

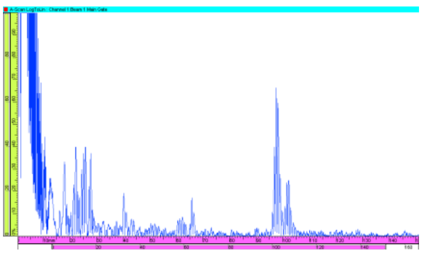

Fig. 5 Converted ultrasonic signal at 25 dB gain.

There is only 2% difference in amplitude comparison. It shows excellent repeatability between linear and logarithmic scale signal. However, we can change the ultrasonic gain at the range of 0~ 96 dB. This is very effective in ultrasonic signal analysis aspect. The UT analyst can change the gain as he wish without re-inspection. In the conventional linear scale technique, if the analyst wants to increase or decrease the signal amplitude, he should perform the whole inspection again. Some of ultrasonic analysis software offer software gain but the signal noise also increased as same rate. This means the S/N ratio is fixed in this case. However, the ultrasonic signal acquired by logarithmic amplitude shows better S/N ratio compared with linear scale data.

To evaluate the flaw response in actual application the ultrasonic signal was obtained from fatigue crack embedded in pipe weld. The acquired signal was converted to log scale and signal analysis was performed to characterize the flaw. By changing the signal amplitude with range of 0 to 90 dB, the analyst can have more information about the dynamic response of signal. The analyst has no limitation changing the gain without re-inspection. Fig. 6 shows the result of changing the gain after convert log signal.

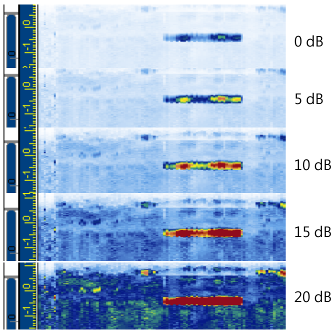

Fig. 6 Ultrasonic c-scan image changes by increasing gain

3. Conclusions

In this study, the effectiveness of the logarithmic amplifier with A-scan and C-scan signal is evaluated experimentally. Consequently, we propose the following results.

1. The logarithmic amplifier inspection shows more S/N ratio compared with conventional linear scale inspection.
2. The signals converted from the logarithmic scale are very helpful to interpret the characteristics of reflectors.
3. Crack tip echoes can be easily identified when using linear amplifiers. Because the diffracted tip echo signal can be adjusted according to the S/N ratio of interested signal
4. By adapting logarithmic amplifier in field inspection, it can offer more latitude in signal analysis by adjusting the range of signal gain.

REFERENCES

[1] Toshihiko Sasahara and Hirotsugu Inoue, Application of Logarithmic Amplifier to Ultrasonic Imaging. 17th WCNDT pp. 25-28 October 2008.
[2] EPRI, Proceedings: 5th Piping and Bolting Inspection Conference, TP-110136, pp. 21~24, 1999