Performance Comparison of Automated Ultrasonic Testing Systems

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1. Introduction

The nondestructive examinations including ultrasonic testing and eddy current testing are used for the in-service inspection in the nuclear power plant. Ultrasonic testing is widely used to ensure the integrity of the components, such as piping welds, in the nuclear power plant. The automated ultrasonic testing is able to yield more reliable consequences than the manual ultrasonic testing. Korea Electric Power Research Institute (KEPRI) developed the automated ultrasonic testing instrument, K-AUT (tentative name), for the in-service inspection of the nuclear power plant. The performance of K-AUT system was compared with the Intraspect™ system which is currently being used for the inspection of piping welds in the nuclear power plant. Eleven piping specimens with sixteen flaws were used in this analysis. The 45°, 60°, and 70° probes of 2.25 ㎒ were used for data acquisition. Two qualified analysts participated in the evaluation of data acquired by both of Intraspect™ and K-AUT system and their length-sizing results were analyzed. This study shows that the K-AUT system gives smaller RMSE (Root Mean Square Error) and larger Z-value in the standard normal distribution than the Intraspect™ system.

2. Automated Ultrasonic Testing System

The automated ultrasonic testing(AUT) system is composed of four parts of pulser/receiver, motor drive unit, scanner/sensor and display unit as shown in Fig. 1. Among these units, the pulser/receiver is the most important part which influences the signal quality.

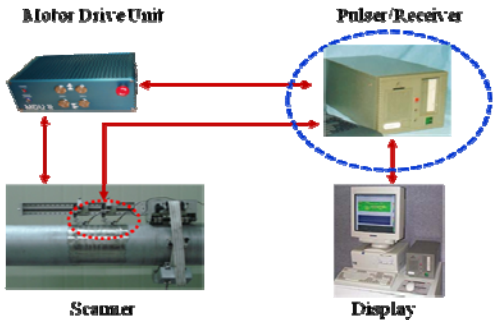

Fig. 1. Automated Ultrasonic Testing System

The ultrasonic pulser and receiver play a very important role in the automated ultrasonic testing system, for example, generation of analog signal and analog to digital converting[1]. The essential variables such as pulse type, bandwidth and linearity of amplifier should be considered in designing the AUT system. The design specification of ultrasonic pulser/receiver module of the K-AUT system is listed in Table 1 and the block diagram is shown in Fig. 2. Analog data are converted to digital by the analog to digital converter (ADC) module of the K-AUT system which has the ability of 200 ㎒ sampling rate and 12-bit resolution. The pulser and receiver module of the K-AUT system have eight channels, respectively, in order to correspond to 8-channel ADC module[2]. The multi-layered printed circuit boards (PCBs) were designed and manufactured for the noise reduction. In the K-AUT system, the PCB of pulser is configured by four layers and receiver six layers. The volume of the K-AUT system was minimized through the removal or change of many electronic chips on the PCBs.

Table 1. Design Specification of K-AUT System

Pulser	
Pulse Type	square wave
Rise Time (10% to 90%)	15nS (20nS max)
Available Pulse Voltage	400V (custom)
Pulse Width	25nS~10nS (step: 25nS)
Mode	pulse-echo, through-transmission
Pulse Repetition Rate	0~100kHz
External Trigger Input	TTL/CMOS compatible
Receiver	
Bandwidth	0.1MHz~35MHz
Phase	inverting
Gain Selection	-20dB~60dB(10/1/0.1dB step)
High Pass Filter	none/1/100/300K/1 MHz
Low Pass Filter	none/5/10/20/35 MHz
Max Signal Output	±1.5V peak terminated in 50ohms
Input Impedance	500 ohms
Output Impedance	50 ohms

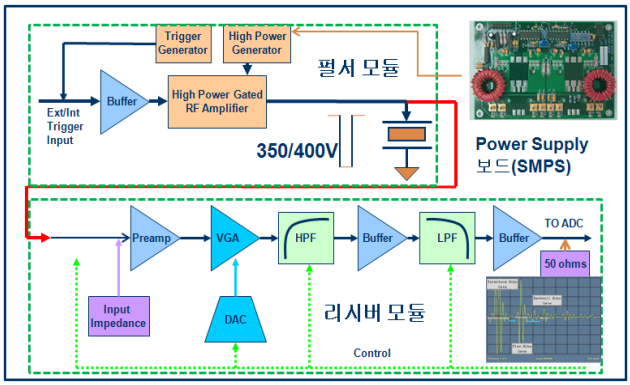

Fig. 2. Block Diagram of Pulser/Receiver

3. Performance Comparison

Performance between the K-AUT and Intraspect™ system was compared in this study. Eleven piping specimens with sixteen flaws were used to acquire ultrasonic signals. The 45°, 60°, and 70° probes of 2.25 ㎒ were used for data acquisition. The illustration of data acquisition and ultrasonic signals by K-AUT system are shown in Fig. 3 and Fig. 4, respectively. As shown in Fig. 4, multi document interface (MDI) was adopted in the K-AUT system for the convenience of data analysis. This allows the window to display different signals of the same location simultaneously.

Fig. 3. Data Acquisition using K-AUT System

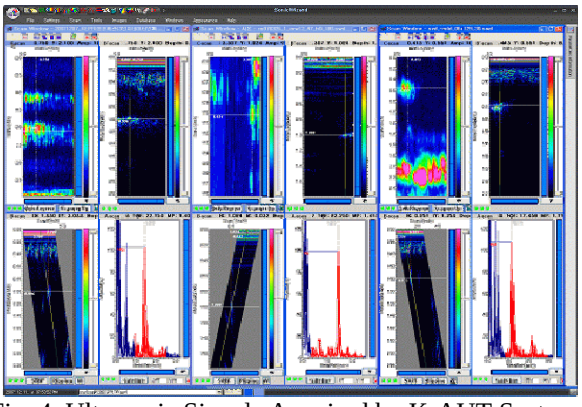

Fig. 4. Ultrasonic Signals Acquired by K-AUT System

Two qualified analysts participated in data evaluation and the length-sizing results were used to produce the RMSE and Z-value in the standard normal distribution. The data by the Intraspect™ system followed the normal distribution whereas the data by the K-AUT system followed the exponential distribution from the normality test. The RMSE value was 12.55 ㎜ for the Intraspect™, whereas 8.66 ㎜ for the K-AUT. The Z-values in the standard normal distribution were 0.79 for the Intraspect™ and 1.22 for the K-AUT as shown in Fig. 5 and Fig. 6. The value of the upper spec limit in the 6-sigma analysis tool is 0.75 inch (19.05 ㎜) which is qualification requirement of Korean Performance Demonstration (KPD) for the ultrasonic testing.

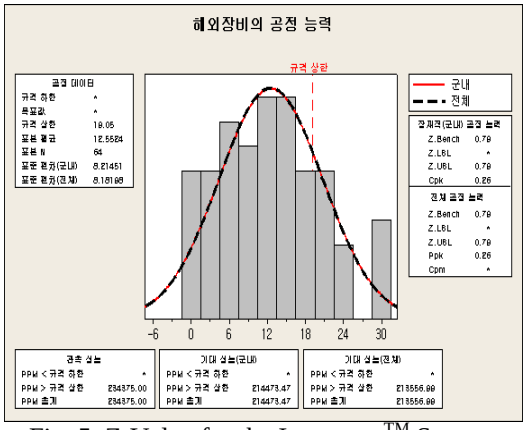

Fig. 5. Z-Value for the Intraspect™ System

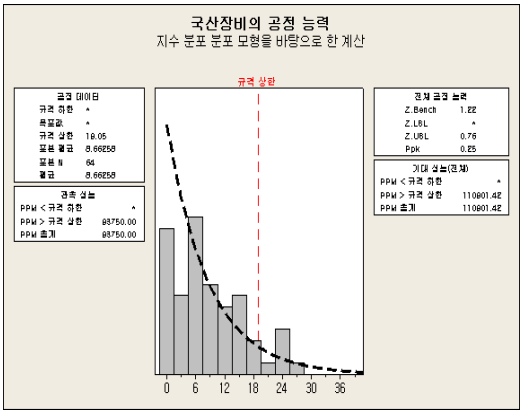

Fig. 6. Z-Value for the K-AUT System

4. Conclusion

Korea Electric Power Research Institute developed the K-AUT system for automated ultrasonic testing in the nuclear power plant. The performance of length-sizing between the K-AUT system and Intraspect™ which is currently being used in the domestic nuclear power plant was analyzed in this study. The results show that the RMSE and Z-value in the standard normal distribution of the K-AUT system were 8.66 ㎜ and 1.22, respectively, whereas 12.55 ㎜ and 0.79, respectively, for the Intraspect™.

REFERENCES

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[2] H. J. Lee, et al. “Development of Korean-model of Inservice Inspection Technology for NPP Components”, Ministry of Education, Science & Technology, R-2007-3-012-01, 2009.