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THE CURRENT STATUS OF PERFORMANCE DEMONSTRATION PROGRAM IN TAIWAN

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ABSTRACT

The Institute of Nuclear Energy Research is holding an ultrasonic testing (UT) performance demonstration (PD) program for the nondestructive testing crew in nuclear power plants. This program is for qualifying personnel's manual detection skills on stainless steel piping and carbon steel piping welds. Artificial flaws embedded in welds comprise two types of circumferential and axial ones. Examinees are required to detect and size flaw lengths. Statistical analyses, including accuracy rates, detection rates and relative sizing errors, are made over examinees' detection data. Based upon eighteen examinees' output in six PD sessions, the overall accuracy rate is about 90%, with stainless steel and carbon steel piping yielding similar results. The length sizing errors, however, depend on piping materials and flaw orientations. The statistical results can provide both regulatory authorities and utilities with a conservative evaluation of the confidence level of realistic UT results in nuclear power plants.

Keywords: performance demonstration, ultrasonic, piping weld

1. INTRODUCTION

The piping weld ultrasonic testing performance demonstration held by the Institute of Nuclear Energy Research (INER) follows the ASME Section XI, Appendix VIII for nuclear power plant (NPP) nondestructive testing (NDT) workers. Qualified examinees are given certificates with a valid date to ensure their skill. Until June 2004, INER has held 6 PD sections since October 2002 for totally 18 NPP workers with 3 workers each time. During the 4-day PD section, the examinees perform UT skill on steel piping specimens to detect and size artificial flaws (Figure 1). The test pieces are made of carbon steel and stainless steel with both circumferential and axial thermal fatigue cracks. Each examinee should decide if the designated region contains flaws first, and then evaluate flaw orientation and length. A corner of test pieces storage room is shown as Figure 2. Each examinee is given 6 stainless steel piping specimens and 3 carbon steel piping specimens of different diameters and artificial flaws. There are 18 designated testing regions on 6 stainless steel piping specimens, including 6 regions that contain flaws while the others contain no flaw. There are 9 designated testing regions on 3 carbon steel piping specimens, including 3 regions that contain flaws while the others contain no flaw. The qualification criterion is to find out all flaws in stainless steel piping welds with at most one erroneous call in no-flaw region, subjecting to the condition that the difference between the actual and estimated flaw length cannot exceed 1 inch. The examinees who pass the stainless steel piping welds UT PD had to also give all correct calls on carbon steel piping welds to qualify. Ten out of eighteen examines were qualified in totally 6 PD sections, resulting in 55.6% qualification rate. The PD results are analyzed below as a conservative evaluation of the examinees' UT skill on steel piping welds.

Fig. 1 A shot of a progressing performance demonstration testing session

Fig. 2 A corner of test pieces storage room

2. RESULTS FOR UT PD ANALYSIS

The following analyses include those on accuracy rate, detection rate and circumferential flaw sizing error.

2.1 Detection Accuracy

The definition of accuracy rate is the probability of judging correctly the existence or non-existence of flaws and the existing flaw's orientation (circumferential or axial), even though the sizing error exceeds 1 inch. Among 324 testing results on stainless steel piping welds, 34 misjudgments were made, resulting in an accuracy rate of 89.5%. Among 162 testing results on carbon steel piping welds, 14 misjudgments were made, resulting in an accuracy rate of 91.4%. The total accuracy rate is 90.1% regardless of piping material. The analyzed results are summarized in Table 1a.

Table 1a Accuracy rate analysis*

Material	Correct Calls	Incorrect Calls	Accuracy Rate	Total Accuracy Rate
Stainless Steel	290	34	89.5%	90.1%
Carbon Steel	148	14	91.4%	

*Correctly judge the existence or non-existence of flaws and their orientations (circumferential or axial)

The definition of detection rate is the probability that finds out the existing flaws, regardless of sizing error or misjudgment in flawless regions. For stainless steel, the detection rates of circumferential and axial flaws are 90.5% (i.e. out of 10 existing circumferential flaws 9 are found) and 75.0% respectively. For carbon steel, the detection rates of circumferential and axial flaws are 90.5% and 77.8% respectively. The detection rates of circumferential and axial flaws regardless of piping material are 90.5% and 76.2% respectively. The detection rate is 86.9% as a whole. The analyzed results are summarized in Table 1b.

Table 1b Detection rate analysis*

Flaw Orientation / Material	Circumferential	Axial
Stainless Steel	90.5%	75.0%
Carbon Steel	90.5%	77.8%
Regardless of Material	90.5%	76.2%
Total Detection Rate	86.9%	

*The probability to find out existing flaws

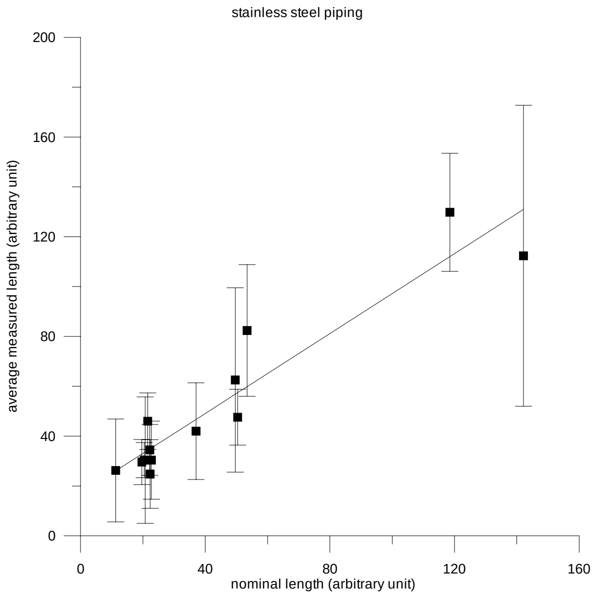
2.2 Circumferential Flaw Length Sizing

Since it is difficult to estimate axial flaw length, the analyses are only focused on circumferential flaw length estimation. The original data group did not exclude those results with sizing error exceeding 1 inch, but the outlier in the data group was eliminated. The definition of uncertainty U is that, with 95% confidence level, the actual length falls in the $L \pm U$ interval, where L is the average measured flaw length. The uncertainty U is an extended uncertainty in statistics, which equals standard uncertainty multiplying extension coefficient. The extension coefficient is determined from effective degree of freedom and t-distribution table (Fang et al, 2003). The data of the actual flaw lengths are provided from specimen manufacturers. The linear regression of the test results is shown in Figure 3, which indicates good linear correlation between estimated and actual flaw lengths while the uncertainties vary significantly for each data point.

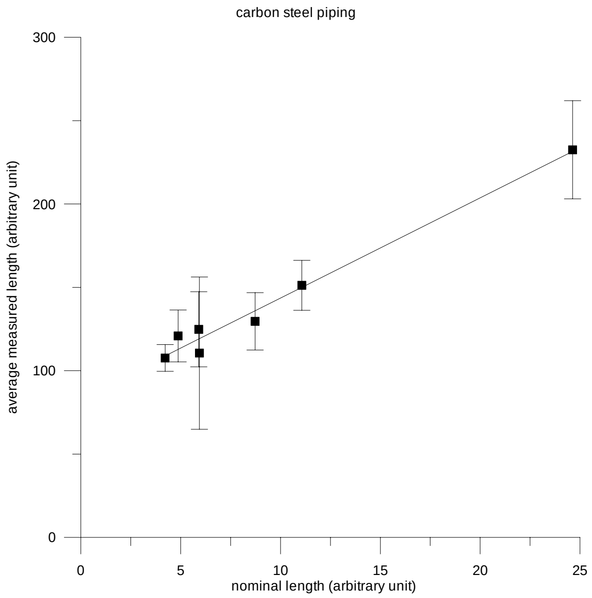
Relative error of each flaw length is calculated as |average estimated length-actual length|/actual length×100%. Analysis of variance (Lee et al, 2003) is then applied to the average of calculated relative errors. The average relative errors for stainless steel piping, carbon steel piping and all piping regardless of material are 53.9±7.2 %, 36.9±6.2 % and 48.3±5.2 % respectively. Considering the testing results of qualified examinees only, the average relative errors for stainless steel piping, carbon steel piping and all piping regardless of material are 46.8±8.5%, 26.8±4.8 % and 40.1±5.7 % respectively. The analysis results above are summarized in Table 2, from which differences are observed in relative errors of sizing between all examinees and qualified examinees.

Table 2 Relative errors of circumferential flaw length sizing

Examinees / Material	All Examinees	Qualified Examinees
Stainless Steel	53.9 ± 7.2 %	46.8 ± 8.5 %
Carbon Steel	36.9 ± 6.2 %	26.8 ± 4.8 %
Regardless of Material	48.3 ± 5.2 %	40.1 ± 5.7 %



(a) Stainless steel piping welds



(b) Carbon steel piping welds

Fig. 3 Linear regression results of circumferential flaw length sizing for (a) stainless steel piping welds; and (b) carbon steel piping welds

3. CONCLUSION

According to the analysis above, both the accuracy rate and the detection rate for stainless steel and carbon steel piping welds are similar, with the results for carbon steel being a little better. These figures agree with the general trend, since carbon steel is acoustically more detectable than stainless steel. The detection rate of axial flaws is expectedly lower than that of circumferential flaws. The results of flaw length sizing for carbon steel piping are better than those for stainless steel piping. The conclusions above are based on the data collected from PD examinees. Although all examinees are qualified UT level II examiners, not all of them work particularly on UT tasks in the NPP. The skill of some examinees may not be as good as that of the normal UT crew. Therefore, each analysis result is viewed as a conservative one. In other words, the performance of the UT crew in the NPP should be better than the analyzed results. The statistical results can provide both regulatory authorities and utilities with a baseline of the confidence level of realistic UT results in nuclear power plants. The analyzed results will get closer to reality when more data are collected from the future PD sections.

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