THE STATUS OF PERFORMANCE DEMONSTRATION IN TAIWAN

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Abstract: The nuclear authority in Taiwan adopts the ASME Code Section XI, Appendix VIII as a mandatory requirement for the in-service inspection of importance nuclear components. To fulfill this requirement, the ultrasonic testing (UT) Level II of nuclear power plants have to go abroad for the qualification of performance demonstration (PD) hosted by the EPRI, USA. It is time consuming and costs much money. In order to set up domestic PD capability, this project planned and purchased test pieces, prepared qualification procedures and arranged examination site. A prototype PD system for carbon steel piping weld and stainless steel piping weld manual UT has been established from 2002. Until January 2004, five PD qualification sections have been held. The detection accuracy and uncertainty of flaw length sizing of UT were calculated according to the data provided by the examinees. Based on the available data, the flaw detection accuracy was about 89% for both stainless steel and carbon steel. However, the uncertainty of flaw length sizing varied with test piece material and flaw orientation. This analysis can be a reference for related organizations to gain more insight information of UT results

Introduction: The piping weld ultrasonic testing performance demonstration held by the Institute of Nuclear Energy Research (INER) in Taiwan follows the ASME Section XI, Appendix VIII for nuclear power plant (NPP) nondestructive testing (NDT) workers. Qualified examinee is given a certificate with valid date to ensure their skill. Until January 2004, INER has held 5 PD sections since October 2002 for totally 15 NPP workers, with 3 workers each time. During the 4-day PD section, the examinees performed manual UT skill on steel piping specimens to detect and size the length artificial flaws (Figure 1). The test pieces are made of carbon steel and stainless steel with both circumferential and axial flaws, known as 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 was given 6 stainless steel piping specimens and 3 carbon steel piping specimens of different diameters and artificial flaws. There were 18 designated testing regions on 6 stainless steel piping specimens, including 6 regions that contain flaws while the others contain no flaw. There were 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 welds with at most one erroneous call in no flaw region, subjecting to the condition that the difference between actual and estimated flaw length cannot exceed 1 inch. The examinees who passed the stainless steel piping welds UT PD and also made right judgments of all designated regions in the mentioned carbon steel piping specimens, were also qualified the carbon steel piping weld PD. 8 out of 15 examinees were qualified in totally 5 PD sections, resulting in 53% qualification rate. The PD results are analysed below as a conservative evaluation of the examinees' UT skill on steel piping welds.

Results for UT PD analysis: The following analysis includes those on accuracy rate, detection rate and circumferential flaw length sizing error.

3.1 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 exceeding 1 inch. Among 270 testing results on stainless steel piping welds, 29 misjudgements were made, resulting in an accuracy rate of 89.3%. Among 135 testing results on carbon steel piping welds, 13 misjudgements were made, resulting in an accuracy rate of 90.4%. The total accuracy rate is 89.6% regardless of piping material.

The definition of detection rate is the probability that finds out the existing flaws, regardless of length sizing error or misjudgement in flawless regions. For stainless steel, the detection rates of circumferential and axial flaws are 90.0% (i.e. 9 out of 10 existing circumferential flaws are found) and 75.0% respectively. For carbon steel, the detection rates of circumferential and axial flaws are 91.4% and 66.7% respectively. The detection rates of circumferential and axial flaws regardless of piping material are 90.5% and 71.4% respectively. The detection rate is 85.7% as a whole. The analysed results are summarized in Table 1.

3.2 Circumferential flaw length sizing error:

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 excluded. 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. U is so called extended uncertainty in statistics, which equals standard uncertainty times extension coefficient. The extension coefficient is decided by effective degree of freedom and t-distribution table [1]. The actual flaw lengths are provided by 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 [2] 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 51.5±7.1 %, 32.2±4.5 % and 45.0±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 48.2±10.5%, 29.7±5.5 % and 41.6±7.1 % respectively. The analysis results above are summarized in Table 2. It shows the differences of relative errors of sizing between all examinees and passed examinees are not obvious.

Discussion: The quality of performance demonstration should be improved if more specimens are available. Some piping specimens of this project contain many flaws, therefore it is difficult to select the regions where contain no flaw. If the no flaw region near a flaw, even with required distance between them, it might cause a false call. In order to improve the PD quality, this project is planning to prepare more piping specimens, both stainless and carbon steel, and more axial flaws to increase the number of designated testing regions.

Conclusions: According to the analysis above, both the accuracy rate and the detection rate for stainless steel and carbon steel piping welds are similar. 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 results mentioned above are based on the data collected from PD examinees. Although all examinees are qualified UT level II examiners, not all of them work on UT tasks specifically in NPP. The skill of some examinees may not be as good as that of the UT crew. Therefore, the analysis result is viewed as a conservative one. In other words, the performance of the UT crew of NPP should be above the analysed result. The analysed result will be closer to reality when more data are collected from the future PD sections.

References:

[1] "ISO GUM measurement uncertainty and statistical application seminar (Basic)" handout, Center for Measurement Standards - Industrial Technology Research Institute, Hsinchu, Taiwan, 2003.

[2] "ISO GUM measurement uncertainty and statistical application seminar (Advanced)" handout, Center for Measurement Standards - Industrial Technology Research Institute, Hsinchu, Taiwan, 2003.

Table 1a Detection accuracy* analysis

Material	Correct Calls	Incorrect Calls	Accuracy	Total Accuracy
Stainless Steel	241	29	89.3%	89.6%
Carbon Steel	122	13	90.4%	

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

Table 1b Detection rate* analysis

Material \ Flaw Orientation	Circumferential	Axial
Stainless Steel	90%	75%
Carbon Steel	91.4%	66.7%
Regardless of Material	90.5%	71.4%
Total Detection Rate	85.7%	

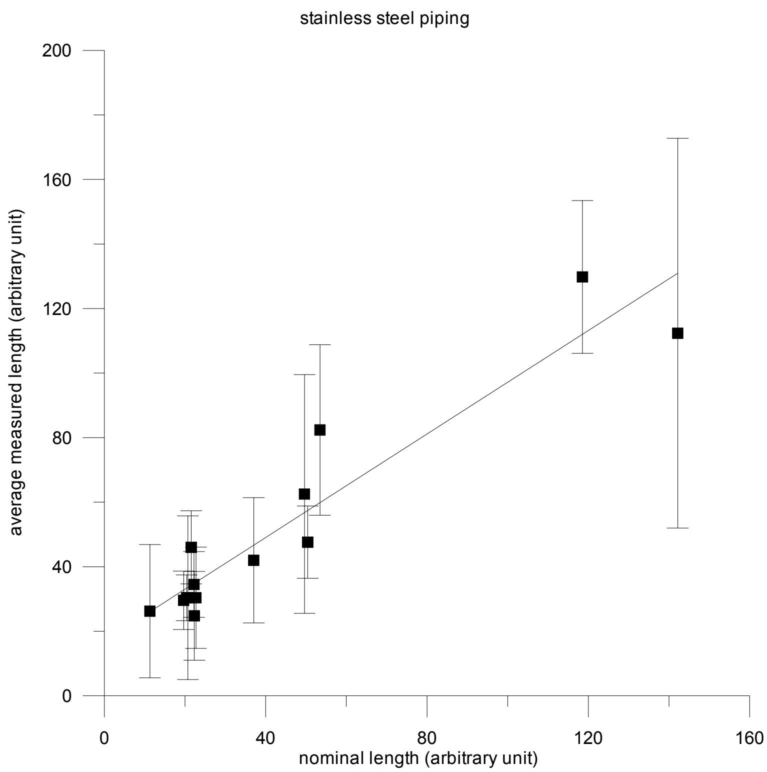
*The probability to find out existing flaw

Table 2 Circumferential flaw length sizing error analysis

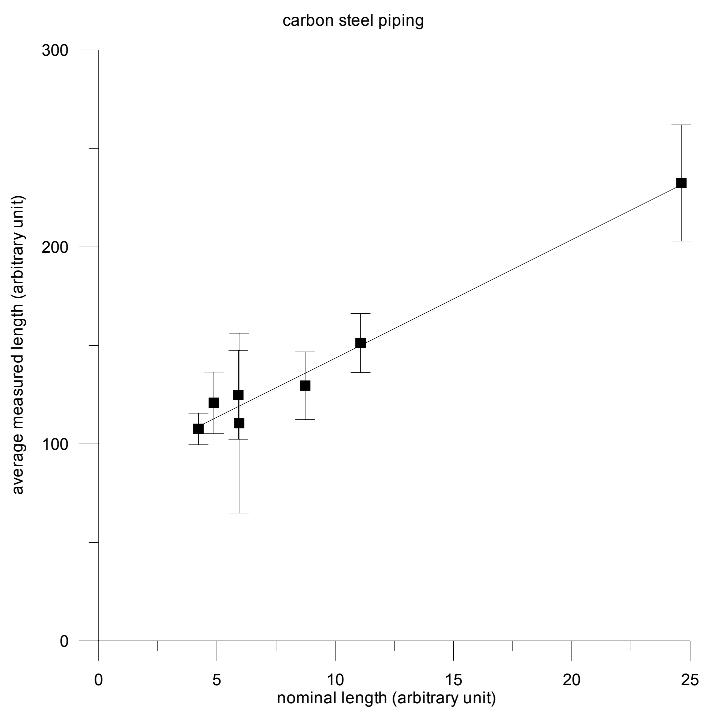
Material \ Examinees	Qualified Examinees	All Examinees
Stainless Steel	48.2 ± 10.5 %	51.5 ± 7.1 %
Carbon Steel	29.7 ± 5.5 %	32.2 ± 4.5 %
Regardless of Material	41.6 ± 7.1 %	45.0 ± 5.2 %

Figure 1 Performance demonstration room

Figure 2 Test pieces storage room



(a) Stainless steel piping specimens



(b) Carbon steel piping specimens

Figure 3 Circumferential flaw length sizing linear regression results