Ultrasonic Examination of RPV, RCP Studs in NPP by Performance Demonstration

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1. Introduction

Bolting degradation problems are a major concern in the nuclear power industry. Incidents of bolting degradation and failure related to primary coolant pressure boundary applications have been reported since 1970. More demanding requirements have been added to the American Society of Mechanical Engineers (ASME) Code[1], requiring performance demonstrations of the examination process and personnel. Several ultrasonic examination techniques exist. However, their capabilities vary depending on the application and are dependent on the examination personnel, equipment selection, and calibration.

In this paper, the bore probe technique was conducted on three different type stud ranging in diameter from 4.31 ~ 6.0 inches and in length from 36.4 ~ 73.31 inches. The studs used in experiments were identical to some of those currently used in nuclear power plants. Ultrasonic examinations were performed using a range of probe angles and frequencies to determine their relative effect on discontinuity detection.

2. Requirement for Ultrasonic Examination

Examination requirements are defined in ASME Section XI, Table IWB-2500-1, Examination category B-G-1, Pressure retaining bolting greater than 2 inches in diameter and Table IWC-2500-1, Examination category C-D, Pressure retaining bolting greater than 2 inches in diameter. Section XI requires only that the portion of the stud or bolt that is under load be volumetrically examined. Ultrasonic examination is typically the volumetric examination used.

Also, from April 2004 Performance demonstration for the piping and stud/bolt are implemented in Korea. ASME Section XI, Appendix VIII, Supplement 8 defines the material, size and scan surface requirements for qualification specimen. The notches used in specimen are required on the outside threaded surface and the inner bore hole surface of bored studs with maximum depths and reflective areas as specified below.

Table 1. Maximum notch dimensions

Bolt, Stud Size	Depth (inches)	Reflective Area ($inch^2$)
Greater than 4″ in Dia.	0.157	0.059
Less than 4″ in Dia.	0.107	0.027

Specimen identification and notch locations shall be obscured so as to maintain a “blind test”. The notch axial location correlation shall be ±1/2 inches or ±5% of the bolt or stud length, whichever is greater.

Examination procedures, equipment, and personnel are qualified for detection when each qualification notch has been detected and its response equals or exceeds the reporting criteria specified in the procedure. The notch response shall have a minimum peak signal to peak noise ratio of 2:1

2.2 Ultrasonic Examination Technique

Before the performance demonstration start, ISI vendors have their own procedure to examine the stud and bolt[2,3,4]. The table 2 shows the different essential variables.

Table 2. Difference in ultrasonic examination

Vendor / Variables	A company	B company	C company
Frequency (MHz)	2.25	2.25 or 5	5
Angle for shear wave	60°	60°	60°
Angle for surface wave	N/A	88°	88°
Scanning velocity	6″/sec	6″/sec	Demo

From the start of KPD in 2004 April, ultrasonic examination for piping, bolt and stud must be demonstrated for their performance. The qualified procedure by performance demonstration uses 70° shear wave for outer perimeter examination and OD creeping wave(ODCR) for bore surface examination[5]. Scan speed shall not exceed 3 inches examination surface per second. Examination frequencies are fixed in the procedure but the table attached to the procedure shows the frequencies that can be used by the ultrasonic instruments.

3. Results of Experiments

Examination for external surface discontinuities are conducted with shear-wave probes from the bore, transmitting ultrasonic energy toward the outside surface on three different types. The signal presentation from one of the types is compared.

Figure 1 shows a signal presentation of stud threads obtained with a 60° shear wave bore probe and Figure

2 shows signal obtained with a 70° shear wave bore probe. The 70 probe has a more distinct thread signal pattern change and the axial radial beam width can be increased by using a higher probe angle. So examination coverage can be increased and the chance to detect the flaw is also increased. Signal obtained from each probe has shadow effect because the notch signal hides the signal from the next thread signal.

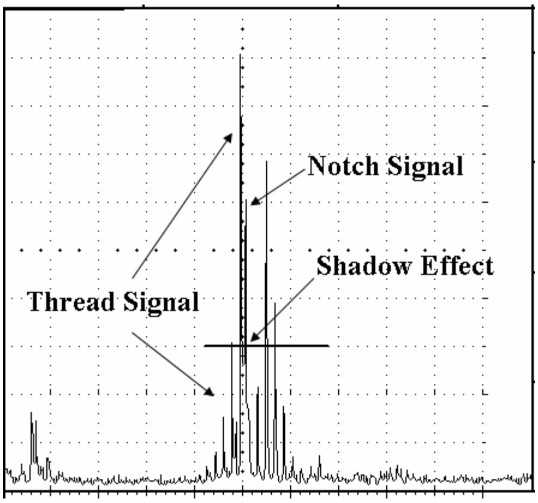

Figure 1. Signal presentation obtained from stud thread and outside notch using 5MHz 60° shear wave bore probe

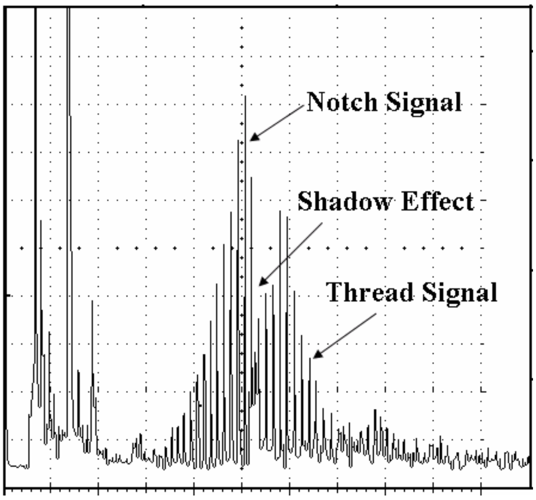

Figure 2. Signal presentation obtained from stud thread and outside notch using 5MHz 70° shear wave bore probe

Examination of the bore surface is achieved with either a dual element creeping wave or a high angle shear wave probe. Figure 3 shows a signal presentation obtained from a bore surface using 2.25MHz high angle shear wave probe and Figure 4 shows a signal presentation obtained from 5MHz creeping wave. The notch signal obtained from 2.25MHz is not clear compared to signal from 5MHz. This is due to frequency and the fact that high angle surface wave is easily dampened and do not travel far in water. So Creeping Wave can detect the signal from the flaw earlier than high angle surface wave and the possibility to detect the flaw is also increased.

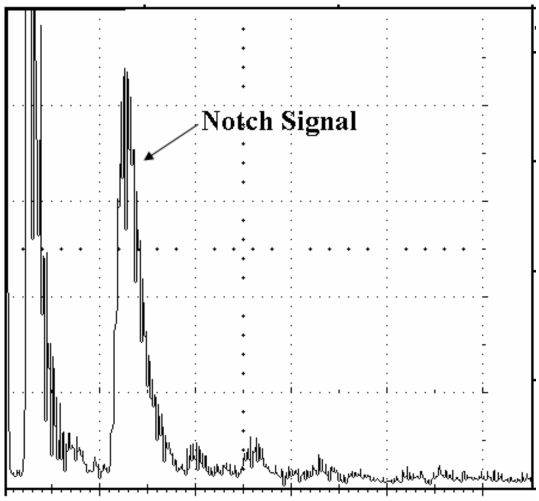

Figure 3. Signal presentation obtained from bore notch using 2.25MHz 88° high angle shear wave bore probe

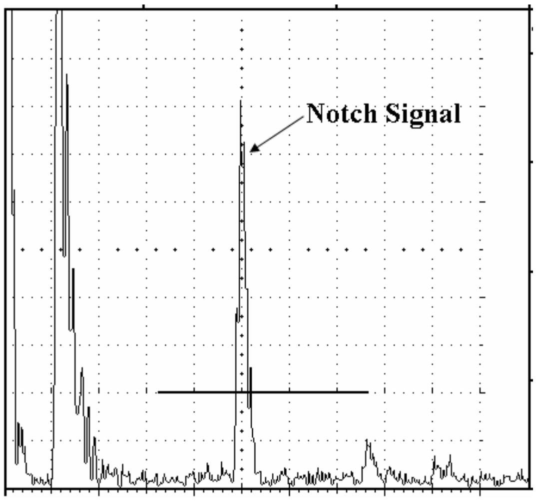

Figure 4. Signal presentation obtained from bore notch using 5MHz ODCR probe

4. Conclusion

For the stud evaluated, a 70° shear wave bore probe and ODCR bore probe are better than 60° shear wave bore probe and high angle shear wave probe in detecting outside notch or flaw signal and inside notch for each.

REFERENCES

[1] ASME B&PV Code Section XI, "Rule for In-service Inspection of Nuclear Power Plant Component" 1995 Edition & 1996 Addenda

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[3] "Manual Ultrasonic Examination of Studs and Bolts from the Bore" Rev. 0, KAITEC, 1997

[4] "Manual Ultrasonic Examination of Studs and Bolts from the Bore" Rev. 4, SAEAN, 2001

[5] "Generic Procedure for Ultrasonic Examination of Studs and Bolts from the Bore" Rev. 0, Korean Performance Demonstration, 2004