NDE Round Robin Test Results on Cast Austenitic Stainless Steels

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1. Introduction

Cast Austenitic Stainless Steel (CASS) has been widely used for reactor coolant piping applications in Westinghouse designed Pressurized Water Reactors (PWRs), and are used for reactor coolant pump and valve pressure boundary applications in Nuclear Power Plants (NPPs).

While CASS are designated as austenitic materials, they are duplex austenitic-ferritic alloys, with ferrite typically in the 10 to 25 % range. Their corrosion and embrittlement properties depend strongly on the ferrite content. Service experience with CASS in PWR reactor coolant system service is excellent. However, there is increasing pressure to continue to improve the inspection systems and to ensure the integrity of aging CASS piping system due to such concerns as the inspection of mitigated Alloy 82/182 welds to CASS components.

CASS material is difficult to inspect using Non-destructive Examination (NDE) including Ultrasonic Testing (UT). So, there are many initiatives to solve these NDE problems in CASS materials. Korea Institute of Nuclear Safety (KINS) also participated in the Regional Cooperative Project-2 (RCOP-2) whose objective was to evaluated NDE reliability through NDE Round Robin Tests (RRT) of CASS piping.

2. Application and Compositions of CASS

Typical nuclear power plant (NPP) applications and material grades of CASS are shown in Table 1.

Table. 1. Spreadsheet of grouped parts information of nuclear power plant[1)]

Material Grades	Application in NPPs
CF8	Reactor coolant pump casings
CF8A	Reactor coolant and auxiliary system piping Reactor coolant pump casings Reactor coolant valve bodies and fittings
CF8M	Reactor coolant and auxiliary system piping Reactor coolant pump casings Reactor coolant valve bodies and fittings

Typical composition limits of CASS are shown in Table 2.

Table 2. Specified Compositions of Typical Cast Austenitic Stainless Steels (wt%)[2,3)]

Name, UNS No.	C	Mn	Si	Cr	Ni	P	S	Mo
Type CF8, Type CF8A	0.08	1.50	2.00	18.0 - 21.0	8.0 - 11.0	0.04	0.04	0.50
Type CF8M	0.08	1.50	1.50	18.0 - 21.0	9.0 - 12.0	0.04	0.04	2.0 - 3.0
Type CF3, Type CF3A	0.03	1.50	2.00	17.0 - 21.0	8.0 - 12.0	0.04	0.04	0.50
Type CF3M, Type CF3MA	0.03	1.50	2.00	17.0 - 21.0	9.0 - 13.0	0.04	0.04	2.0 - 3.0

3. CASS Inspection Requirements

CASS material used in PWR primary piping systems has had an incident-free service record for almost 40 years.

The American Society of Mechanical Engineers (ASME) In-Service Inspection (ISI) qualification requirements are found in ASME Boiler and Pressure Vessel Code (BPVC), Section XI, Appendix VIII. Supplement 9 of Appendix VIII which concerns CASS inspections has been in course of preparation since 1989. Until the qualification requirements are developed the plants must follow the requirements found in Section XI, Appendix III.

Appendix III contains prescriptive requirements for performing non-qualified ultrasonic examination (UT) of vessel and piping welds.

The Appendix III techniques are amplitude based techniques and are not considered the best available UT methods for successful CASS exams.

In 1997 the Section XI Task Group on Austenitic Stainless Steel Inspections was established to resolve the issues concerning CASS inspections and to propose Code actions to complete Appendix VIII supplement 9.

Recently the Task Group has initiated a significant action regarding for Appendix III supplemental requirements for UT exams of CASS piping welds.

The Appendix III supplemental requirements will call for specific equipment and exam parameters that have been shown to provide the best and most reliable exam results currently available for CASS material. The Appendix III rules will serve as interim best practice requirements for CASS inspections while the Appendix VIII requirements are being developed.

4. NDE Research on CASS

With respect to CASS NDE research, Korea Institute of Nuclear Safety (KINS) participated in the Regional Cooperative Project-2 (RCOP-2). This multi-national program involved utility, vendor, and regulatory organizations from Korea, Japan, and China. The objective was to evaluated NDE reliability through NDE Round Robin Tests (RRT) of CASS piping. The three-year program began in early 2007 and was completed in early 2010.

The inspection techniques and RRT results of three Korean teams are shown in Table 3 and 4.

Table 3. Inspection Techniques used in CASS NDE RRT

	Team A	Team B	Team C	
Technique	Phased Array(PA)	PA	Conventional UT	PA
Equipment	Tomoscan III	Omni scan	Instra Spect	Omni scan
Probe	Pitch-Catch (P-C)	P-C	35°/45°	P-C
Frequency	1.5MHz	1.5MHz	0.5MHz	0.5MHz, 0.7MHz
Scan Mech.	Manual	Manual	Automatic	Automatic
Length Sizing	Full dB Drop	Full dB Drop	Full dB Drop	Full dB Drop

Table 4. Flaw Detection Results of CASS NDE RRT

No	Sample ID	The Number of Flaws (ea)	Detection Rates of Teams (%)			
			A	B	C-Con. UT	C-PA
1	Chinese	16	31	38	19	44
2	Japanese 1	8	38	63	100	88
3	Japanese 2	3	100	100	100	100
4	Korean 1	5	100	100	100	100
5	Korean 2	3	67	100	100	100
Sum		35	74	80	84	86

Based on the RRT results, it has been concluded that low frequency phased-array probes provide the best results when inspecting CASS material. Statistical analysis of the data is ongoing.

5. Conclusions

CASS material used in PWR primary piping systems has had an incident-free service record for almost 40 years. CASS was selected for these installations based on such factors as its relative cost, corrosion resistance, and ease of welding.

However, CASS material is difficult to inspect using Ultrasonic Testing (UT) and is susceptible to thermal aging embrittlement. Furthermore, CASS components are in safety significant locations in reactor pressure boundary.

According to the RRT results, low frequency phased-array probes show the best performance when inspecting CASS material. We are now performing the statistical analysis considering the flaw types of each specimen.

REFERENCES

[1] T. Lian, Primary System Corrosion Research Program : EPRI Materials Degradation Matrix, Revision 2, EPRI MRP-1020987, August 2010.
[2] ASME/ASTM SA/A 351, “Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts”
[3] ASME/ASTM SA/A 451, “Specification for Centrifugally Cast Austenitic Steel for High-Temperature Service”