Study on the Transition Temperature Shift of Reactor Pressure Vessel Materials in Surveillance tests of Korea

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1. Introduction

A nuclear power plant, especially pressurized water reactor (PWR), has a beltline region of a reactor pressure vessel (RPV), and that is subject to embrittlement because of the exposure to neutrons [1]. The irradiation embitterment of RPV materials is evaluated from the change in transition temperature shift (TTS) and upper shelf energy (USE) of the Charpy V-notch specimens in the surveillance program. In order to confirm the safety of the reactor, the change of TTS and USE should satisfy the regulatory guide of the power plant [2].

In this study, the 30 ft-lb transition temperature shift results of Korean PWR surveillance data has been analyzed and the trend of the TTS change was investigated using Regulatory Guide 1.99 revision 2 (RG1.99/2) and the improved TTS model of USNRC. The difference between the model and Korea PWR TTS data was also discussed.

2. Methods and Results

2.1 Data base

The 20 power plants include PWR and BWR are operating now in Korea. The 12 PWR power plants have the surveillance test reports; Kori 1-4, Yonggwang 1-4, Ulchin 1-4. The report was prepared following the 10CFR part 50.61 [3] and USNRC Regulatory Guide DG-1053. The main information of the power plant was summarized in table 1.

Table I: RPV materials of Korean PWR

Plant ID	Plant design	Test #	Materials	Product
KR 1	Westinghouse	5	SA508 Gr2 Cl1	forging
KR 2	Westinghouse	5	SA533 Type B	plate
KR 3	Westinghouse	5	SA533 Type B	plate
KR4	Westinghouse	5	SA533 Type B	plate
YG 1	Westinghouse	5	SA533 Type B	plate
YG 2	Westinghouse	5	SA533 Type B	plate
YG 3	OPR1000	1	SA508 Gr3 Cl1	forging
YG 4	OPR1000	1	SA508 Gr3 Cl1	forging
UC 1	Framatome	4	SA508 Gr3 Cl1	forging
UC 2	Framatome	4	SA508 Gr3 Cl1	forging
UC 3	OPR1000	1	SA508 Gr3 Cl1	forging
UC 4	OPR1000	1	SA508 Gr3 Cl1	forging

2.2 TTS vs. irradiation fluence

Figure 1 shows the TTS vs. irradiation fluence in Kori 1 plant. The TTS was calculated using the 30 ft-lb transition temperature shift from Charpy impact energy-temperature tests. The data include the base metal specimens with longitudinal (L-T) and transverse (T-L) direction as well as the welds with transverse direction. The solid line represents calculated TTS value using RG1.99/2. The TTS model uses the chemistry factor (CF) and that is calculated from the regression of the surveillance data of Kori 1 plant [4,5].

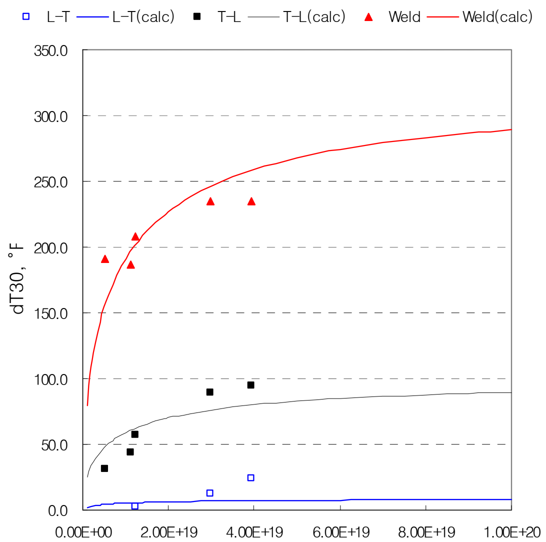
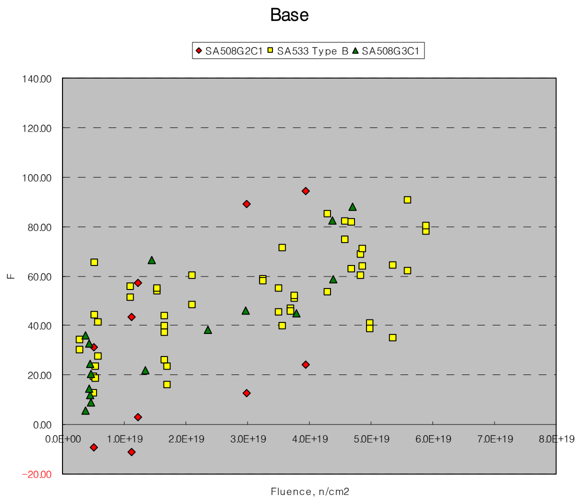


Fig. 1. Plot of the 30 ft-lb TTS vs. neutron fluence (E > 1 MeV). L-T and T-L represents the direction of the specimen of base metal.

Kori 1 plant used the SA508 Grade 2 Class 1 forgings for RPV and Mn-Mo-Ni filler wire and Linde 80 flux for welds. Lind 80 flux had been used for the submerged-arc welding of RPV in 1970 and it was reported as a primary cause of irradiation embrittlement of RPV. Figure 1 shows the trend clearly. The welds data shows very large TTS over that of the base metals. It is because of the high Cu composition over ~0.2 wt%, almost 5-10 times of the Cu composition of base metals. Regarding the specimen direction, T-L direction specimens showed larger TTS. The other plant TTS results were also analyzed.

2.3 Trend of TTS with neutron fluence

Figure 2 shows the base metals and welds TTS versus neutron fluence of the 12 PWR power plants. The data points are categorized by the materials of the plants.



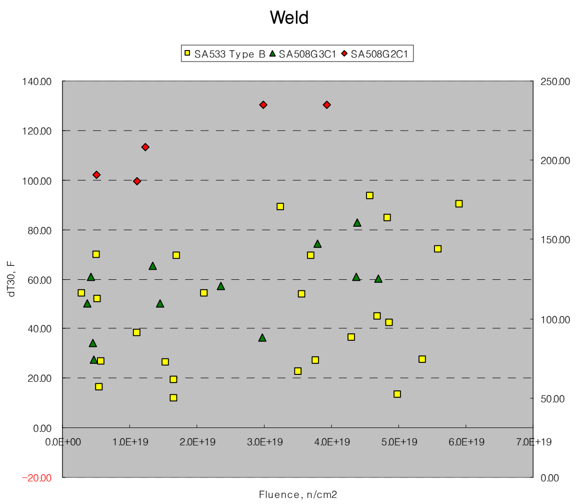


Fig. 2. Plats of TTSs indexed at 30 ft-lb vs. neutron fluence for (a) base (forging/plate) metals and (b) weld.

The general trend of increasing TTS with fluence was observed in fig. 2(a). Especially TTS of SA533 and SA508 Gr.3 were more pronounced. There are some scattered data in SA508 Gr. 3 at the low fluence. This is because the only first surveillance test was carried out during operating and TTS data were limited. The weld results are very scattered points and hard to assess a correlation between TTS and fluence.

3. Summaries

The embrittlement correlation for reactor pressure vessel steels was analyzed with a viewpoint of TTS models including Regulatory guides of US. The surveillance data of Korean PWR RPV showed that the base metals are closely related with neutron fluence, but it was hard to find the correlation of welds. The TTS data were compared with the TTS models from USNRC and that analysis provided insight into the difference of RPV TTS between US and Korea.

REFERENCES

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