Experimental study on irradiation embrittlement of 2 ¼ Cr – 1 Mo steel for reactor pressure vessels

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FRAMATOME has considered the use of 2 ¼ Cr – 1 Mo steel type for the RPV of PWRs. This steel grade indeed features some important advantages with respect to the commonly used RPV steel grade type SA 508 Gr 3 Cl 1 (or 16MND5 in French RCC-M code classification). In particular its fracture toughness transition temperature is lower for equivalent condition of application (i.e. similar tensile properties and similar thickness) and it appears to be less prone to embrittlement under irradiation conditions typical of PWR RPV.

This paper shows experimental results of a recent irradiation campaign conducted on a 2 ¼ Cr – 1 Mo forging, and on a weld (including the weld metal and the heat affected zone). Irradiation exposure was conducted in OSIRIS test reactor at 288°C up to a fluence of 6.22×10^{19} n/cm² (E > 1 MeV). Mechanical testing was performed before and after irradiation, including tensile tests, Charpy impact tests, and fracture toughness tests.

The results of the present study are analyzed and compared to unpublished results of irradiation embrittlement, generated on various 2 ¼ Cr – 1 Mo steel (base metals and welds) after irradiation in OSIRIS reactor for a fluence level in the range of $3.2 – 3.6 \times 10^{19}$ and $6.2 – 7.3 \times 10^{19}$ n/cm² (E > 1 MeV), and in production PWR surveillance capsules for a fluence of ~2.5×10^{19} n/cm² (E > 1 MeV). Comparison is also made with commonly accepted embrittlement formulas for 16MND5 steel, and it is shown that the embrittlement sensitivity of 2 ¼ Cr – 1 Mo is less than that of 16MND5.