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EFFECT OF IRRADIATION TEMPERATURE ON VOID FORMATION IN COLD WORKED TYPE 316 STAINLESS STEEL

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Experimental results indicate that the effect of irradiation temperature on void formation in neutron irradiated cold worked Type 316 stainless steel is significantly different from that in solution treated steel. The difference appears to be related to the thermal instability of the cold worked microstructure.

The irradiation temperatures and neutron fluences for which voids were either absent or present in 20 to 27% cold worked Type 316 stainless steel samples are mapped in Figure 1. The figure shows that in this material, void formation occurs in two distinct irradiation temperature regions. To avoid the problem of evaluating possible stress effects and other environmental factors peculiar to fuel pin cladding, only data from samples irradiated under stress free conditions are included.

At moderate fluences, two maxima in the swelling-temperature curve for cold worked Type 316 steel arise due to a superposition of the normal temperature dependence associated with void formation, as in the solution treated material, and the temperature dependence for recovery of the cold worked microstructure. For low temperature irradiation, voids and Frank faulted loops are produced in the cold worked Type 316 stainless steel. Voids are produced in a manner similar to that in, but at a lower rate than, solution treated steels. At higher temperatures, the defect supersaturation decreases because of the increased thermal equilibrium vacancy concentration and defect mobility while the sink density (dislocation, and/or Frank loops) remains high. However, the void nucleation rate is critically dependent upon defect

supersaturation. Hence, void nucleation rate in the cold worked steel should decrease rapidly with increasing temperature and results in the suppression of void formation in this intermediate region.

At still higher irradiation temperatures, the cold worked microstructure becomes thermally unstable. The dislocation density decreases due to mutual annihilation of mobile dislocations. At these higher irradiation temperatures voids are preferentially formed in localized regions which have had substantial dislocation recovery. Finally, at the highest irradiation temperatures, void formation is suppressed irrespective of the microstructure--even in solution treated steel.

There are two major conclusions from the present study:

1. The irradiation temperature dependence of cold worked Type 316 stainless steel is different from that of the solution treated steel and from that of the previously reported empirical swelling equation for cold worked steel.[1] This difference in temperature dependence may be important in the analysis of the distortion of fast reactor core components.
2. The difference in the temperature dependence of void formation is related to the thermal instability, or recovery kinetics, of the cold worked microstructure. In this regard, the swelling of cold worked stainless steel due to high energy particle bombardment[2-4] must be critically evaluated as to its use for simulating fast reactor induced void formation in cold worked materials.

References

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IRRADIATION CONDITIONS FOR VOID FORMATION

COLD WORKED TYPE 316 STAINLESS STEEL