Determining Tensile Behavior of Irradiated Steel by Instrumented Indentation

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Structural materials for fusion applications are exposed to multiple loadings. Apart from mechanical forces and high temperatures, there is a strong neutron exposition which leads to a significant change of mechanical properties. This radiation damage is examined by irradiation and by post-irradiation experiments. Those experiments are limited in space and highly expensive per tested volume. Here, the instrumented indentation offers valuable information, as for instance an already tested charpy impact specimen or small volumes and coatings might be subjected to multiple indentation tests.

A modified commercial indentation device is installed in a hot cell of a Fusion Materials Laboratory. In combination with a neural network based analysis method, it allows identifying the material parameters of a unified viscoplasticity model with nonlinear isotropic and kinematic hardening from small specimens. Thus, the Young’s modulus, the true stress-strain curve, and the viscous properties responsible for creep/relaxation at room temperature can be obtained. Material properties are obtained as well by instrumented indentation as by conventional tensile experiments, and it is shown that results from both methods are in good accordance. Material properties for ferritic-martensitic steels like EUROFER 97 are presented in unirradiated condition and after irradiation up to 2.4 and 15 dpa at temperatures between 250 and 450°C.

The examined materials exhibit clear embrittlement and hardening after irradiation, which is dependent on the irradiation dose and on the irradiation temperature. There are strong changes in yield strength and in ultimate tensile strength. They can be determined by both methods, tensile and indentation test, in good accordance. In addition, the indentation test as a non-destructive test offers the possibility to test the same specimen before and after applying post-irradiation annealing treatments.

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