MACHINE LEARNING FOR NON-DESTRUCTIVE ESTIMATION OF NEUTRON-INDUCED EMBRITTLEMENT OF REACTOR PRESSURE VESSEL STEEL

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The reactor pressure vessel (RPV) of a nuclear power plant is a large thick-walled container made of low alloy steel. During service, the RPV wall is exposed to high levels of neutron and gamma radiation from the reactor core. The neutron radiation interacts with atoms of the RPV, causing microstructural changes and embrittlement of the steel. Currently, the embrittlement is monitored destructively using surveillance campaigns. Several mechanical material parameters, such as the ductile-brittle transition temperature (DBTT), are measured. The DBTT can be measured using the ISO-standard Charpy pendulum impact test [1] with an approximate accuracy of 10 °C . The number of surveillance specimens in the reactor is limited, thus restricting the potential monitored operating lifetime. Therefore, a non-destructive method to estimate the embrittlement is required.

In this study, 157 irradiated and non-irradiated Charpy specimens [1] manufactured from six different steel alloys used in RPVs (18MND5-W, 22NiMoCr37, A508-B, 15Kh2NMFA, HSST-03 and A508-Cl2) were measured. The measurements included determining several non-destructively measurable electric, magnetic and elastic parameters. The applied non-destructive methods were Direct Current-Reversal Potential Drop (resistivity) [2], 3MA (eddy current impedance loop shape) [3], TEP (Seebeck Coefficient) [4], MIRBE (Barkhausen noise) [5], MAT (magnetic hysteresis loop shape) [5] and sound velocity. After the non-destructive measurements, the DBTT was determined destructively using the ISO-standard method [1].

Several different regression algorithms, including neural network regression and support vector regression, were applied to the data. The algorithms were implemented with TensorFlow and scikit-learn using Python 3.7. With these algorithms, it was possible to estimate the DBTT with the mean absolute error smaller than 20 °C. Based on the results, the method can be seen as a potential candidate for estimating neutron-induced embrittlement non-destructively.

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