A New Methodology for Developing Charpy Impact Data Trend Curves

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INTRODUCTION

A new methodology that incorporates the chemical compositions into the Charpy trend curve was developed. The purpose of this new fitting procedure is to generate a new multi-space topography that can properly reflect the inhomogeneneity of the surveillance materials, and utilize this multi-space trend surface to link and to project the surveillance test results to that of reactor pressure vessel steels.

SURVEILLANCE CHARPY TEST DATA

Currently, the Charpy impact test data are widely used by industry and regulatory agencies to monitor the reactor pressure vessel (RPV) degradation during service. In general, the impact energy of the Charpy impact test samples from RPV surveillance capsules depends on irradiation temperature (T), neutron fluence, and chemical compositions and material history of the test samples, which can be described as below.

$$E = f(\,T,\ \varphi t,\ Cu,\ Ni,\ Microstructure, ...)$$

Mean fluence and irradiation time are generally used for data from the same capsule; and RPV materials, such as base, weld and HAZ, are categorized within separate groups; thus, the impact of microstructure factor can be minimized. Therefore, the formulation of the impact energy for a Charpy impact data set from one surveillance capsule can be further simplified and written as follows:

$$E = f(\,T,\ Cu,\ Ni,\ ..)$$

Proposed New Fitting Function with Consideration of the Chemistry Variability

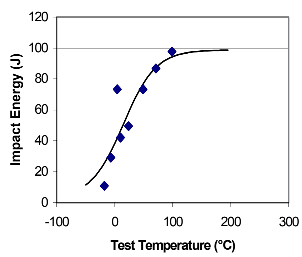
In order to consider the chemical variability of the surveillance test samples, a new fitting procedure that incorporates the chemical composition into the governing equation was developed. The formula for the impact energy as a function of test temperature (*T*), and copper and nickel (or plus other chemistry, such as P, Mn, etc.) can be written as follows:

$$E = \left\{ A + B * Tanh\left[\frac{T - T_0 / f_1}{C / f_2}\right] \right\} * f_3 + f_4$$

where f_i , i =1,4 are functions of chemical composition for Cu and Ni content, and *A, B, C,* and T_0 are fitting parameters. This new fitting procedure provides a new multi-dimension topography that can properly reflect the inhomogeneity of the surveillance materials.

Results of the Proposed Fitting Procedures

The weld Charpy data, with heat_id = WDR301 listed in the Embrittlement Data Base (EDB) [1], from surveillance capsule 18 of Dresden Unit 3 nuclear power plant were used for this feasibility study. The new fitting procedure achieves a reduction in uncertainty of predicted impact energy by 27%, compared to that of the conventional hyperbolic tangent fit procedure, which are illustrated in Figs. 1.



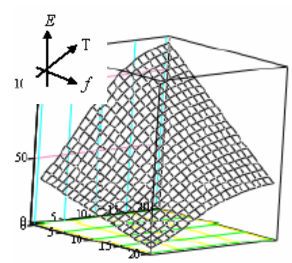


Fig. 1 Conventional Charpy curve fit (left); a multi-dimension topography was generated based on new approach (right), where the third axis represents the integrated formulation of the chemistry composition functions, f_i.

CONCLUSION

Based on the constructed multi-space topography, as illustrated in Fig. 1, one can substitute the target chemistry into integrated composition functions, f_i , to determine the projected trend curve. This new procedure not only provides an expedient way to properly reflect the inhomogeneity of the surveillance materials, but also provides a link between the surveillance materials and reactor pressure vessel materials. Thus, it is envisioned to be useful in assisting research on displacement per atom (dpa) attenuation through the RPV wall.

REFERENCES

[1] J.A. Wang, Embrittlement Data Base (EDB), Version 1, NUREG/CR-6506 (ORNL/TM-13327), U.S. Nuclear Regulatory Commission, August 1997.