Options for Using an ASTM E900-15-Style Function to Represent Trends in Domestic RPV Surveillance Data

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Between 2010 and 2015 the American Society of Testing and Materials (ASTM) developed a new embrittlement trend curve (ETC) to represent trends in a large international collection of reactor pressure vessel (RPV) surveillance data. This work was concluded in 2015 and resulted in an update to the ASTM Standard E900. In this paper we explore options for using an E900-15 style fitting function to represent trends in surveillance data collected from Japanese nuclear power plants.

Keywords: Reactor pressure vessel, neutron embrittlement, trend curve modeling.

1. Background

Nuclear reactor pressure vessel (RPV) structural integrity management relies on the ability to forecast future embrittlement states of the RPV. This ability is typically provided by a surveillance program (which provides data for plant-specific materials) as well as an embrittlement trend curve, or ETC, (which makes predictions of Charpy transition temperature shift as a function of composition and exposure variables). In Japan, JEAC4201 [1] describes the requirements for the surveillance program and provides an ETC appropriate for application to Japanese nuclear power plants (NPPs).

Until about eight years ago the ETCs developed and/or used by national regulatory bodies and consensus codes and standards organizations had been developed on a national basis using data sets from a single country (e.g., JEAC-4201 in Japan, either Regulatory Guide 1.99 [2] or ASTM E900 [3] in the USA, the FIM/FIS formulae in France [4], and so on). This practice was followed despite the fact that, with the exception of ex-Soviet / Russian designs, most light-water reactors used in (for example) Japan, South Korea, Taiwan, Europe, and the United States employed similar designs having similar exposure conditions and similar steel compositions. Between 2010 and 2015 the American Society of Testing and Materials (ASTM) Subcommittee E10.02 on the *Behavior and Use of Nuclear Structural Materials* employed a new approach, which attempted to use surveillance data from 13 countries (Brazil, Belgium, France, Germany, Italy, Japan, Mexico, The Netherlands, South Korea, Sweden, Switzerland, Taiwan, and the United States) to calibrate a ETC [5]. This effort resulted in the E900-15 standard [3], which was finalized in 2015. While the ASTM E900-15 ETC relies to some extent on physical insights concerning embrittlement mechanisms (e.g., it includes two terms, one depending on copper that saturates at high fluence, the other independent of copper and increasing in proportion to (approximately) the square-root of fluence) it is for the most part an empirical representation of the data used in its calibration. By comparison the JEAC4201 ETC provides a closer tie to the underlying embrittlement mechanisms through a series of differential equations, but nevertheless still relies on calibration to the Japanese surveillance data set.

2. Objectives

The objectives of this paper are (1) to compare how well the JEAC4201 and E900-15 ETCs represent the Japanese surveillance data, and (2) to assess the possibility of using the more empirical approach of E900-15 to represent the Japanese surveillance data.

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3. Comparison of JEAC4201 to E900-15 Predictions

Figure 1 assesses the statistical significance of the trends in prediction errors for both the JEAC4201 and E900-15 equations when applied to the current Japanese surveillance data set. The axis on this radar plot gives the value of Student's T-statistic, values over 2 are considered statistically significant. Not surprisingly JEAC4201 provides a better representation of the data to which it was calibrated than does E900-15. The presentation on this topic will include further assessments, including the application of both ETCs to a data set that includes data from international surveillance programs but is restricted to the ranges of variables seen in Japanese NPPs.

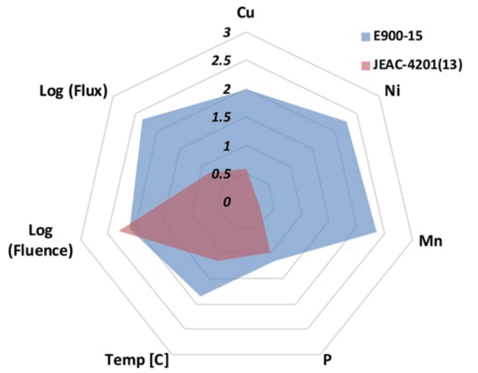

Fig. 1 Comparison of trends in prediction errors when E900-15 and JEAC4201 is applied to prediction of surveillance data from Japan.

4. Calibration of E900-15 to only Japanese Surveillance Data

Figure 2 compares the range of composition variables in Japanese surveillance (blue) versus the international surveillance data set compiled by ASTM (green). Initial attempts to calibrate a E900-15 type of equation to only the Japanese surveillance data has been complicated by the limited range of composition variables relative to that present in the international database and, therefore, used by the ASTM effort. For example, E900-15 includes a term that saturates at higher copper values (above 0.28 weight percent). The fortunate absence of high copper data from Japanese NPPs makes it impossible to calibrate this term. The presentation on this topic will include a more detailed assessment of options to use the more empirical approach of E900-15 to represent the Japanese surveillance data.

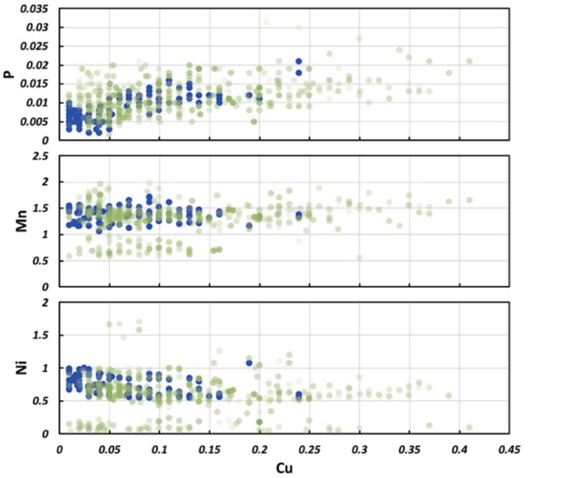

Fig. 2 Comparison the range of composition variables in Japanese surveillance (blue) versus the international surveillance data set compiled by ASTM (green).

References

[1] Japan Electric Association, 2013, JEAC4201-2007(2013 addendum), "Methods for Surveillance Tests for Structural Materials of Nuclear Reactors

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