ASME STANDARDS TECHNOLOGY, LLC

STP-PT-094

DETERMINATION OF STRESS STRAIN CURVES OF 304, 304L, 316, 316L FOR STRAIN-BASED DESIGN CRITERIA

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ABSTRACT

True stress-strain curves up to final fracture (flow curves) are used for the assessment of materials behavior and determine the acceptability of Spent Nuclear Fuel (SNF) containers. To cover possible damage events like dropping of containers, several conditions must be considered. Different temperatures covering the effect of loads with high radioactivity and low ambient temperatures during loading and transport of such containers determine the required material properties. Austenitic steels like 304, 304L, 316, 316L show a tendency for strain-induced martensitic transformation at low temperatures which needs specific consideration. Strain rates are also important when dropping events are considered. In this report, true stress strain curves were determined in a true strain range from 0 to 100 percent. Up to Ultimate Tensile Strength (UTS), a Ramberg-Osgood type of analysis using strain at UTS was employed. Temperature dependence of UTS and yield stress (YS) was determined from experimental data and ASME Sect II Table D, Y-1 and U values. The stress-strain behavior at higher strains was determined on the basis of measured tangent moduli. Effects of strain rate were assessed with the Cowper-Symonds relation. A set of curves for temperatures ranging from -20°F to 600°F was developed.

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1 INTRODUCTION

True stress-strain curves up to final fracture (flow curves) are used for the assessment of materials behavior and determine the acceptability of Spent Nuclear Fuel (SNF) containers as a result of energy-limited events. This is required for determination of deformation and containment in case of transportation accidents (see goals of Task Group in Appendix A). The results presented in this report are limited to 304/304L and 316/316L.

Due to decay heat coming from the SNF and temperature conditions on the outside of the container, temperature must also be considered. In the case of dropping of containers, strain-rate dependence must also be considered. Due to the differences in behavior of the various cask components resulting from the material property assumptions, minimum and maximum design curves are needed. For example, the reason for the maximum design line is the fact that this curve can result in a condition where stress concentrations can be responsible for high local stresses. Similarly, the minimum curve may predict higher deformations of components which may lead to a change in load path. The design curves should be connected to YS and UTS in the Section II, Part D tables. These complex requirements for design lines require the following clarifications:

- What is an appropriate stress-strain curve parametrization?
- How do those curves look between UTS and final fracture?
- What are maximum YS and UTS assuming that the minimum curve is defined by YS and UTS given in ASME Section II, Part D tables?
- What is the role of temperature (taking into consideration that at low temperatures strain-induced martensite can occur)?
- What is the role of high strain rates?

Based on these questions, minimum and maximum design curves were developed where:

- Minimum curves are based on minimum YS and UTS (IID) at temperature.
- Maximum curves are based on maximum YS and UTS (IID modified) at temperature and high strain rates.

The considerations are based on experimental data from Idaho National Laboratory (INL) [1], Keith Morton (INL) private communication 2015, and data from the Nuclear Regulatory Commission (NRC) private communication 2015.