STP-NU-041

UPDATE AND IMPROVE SUBSECTION NH – ALTERNATIVE SIMPLIFIED CREEP-FATIGUE DESIGN METHODS

ASME STANDARDS TECHNOLOGY, LLC

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Date of Issuance: March 31, 2011

This report was prepared as an account of work sponsored by the U.S. Department of Energy (DOE) and the ASME Standards Technology, LLC (ASME ST-LLC).

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ISBN No. 978-0-7918-3364-3

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FOREWORD

This document is the result of work resulting from Cooperative Agreement DE-FC07-05ID14712 between the U.S. Department of Energy (DOE) and ASME Standards Technology, LLC (ASME ST-LLC) for the Generation IV (Gen IV) Reactor Materials Project. The objective of the project is to provide technical information necessary to update and expand appropriate ASME materials, construction and design codes for application in future Gen IV nuclear reactor systems that operate at elevated temperatures. The scope of work is divided into specific areas that are tied to the Generation IV Reactors Integrated Materials Technology Program Plan. This report is the result of work performed under Task 10 titled "Update and Improve Subsection NH – Alternative Simplified Creep-Fatigue Design Methods."

ASME ST-LLC has introduced the results of the project into the ASME volunteer standards committees developing new code rules for Generation IV nuclear reactors. The project deliverables are expected to become vital references for the committees and serve as important technical bases for new rules. These new rules will be developed under ASME's voluntary consensus process, which requires balance of interest, openness, consensus and due process. Through the course of the project, ASME ST-LLC has involved key stakeholders from industry and government to help ensure that the technical direction of the research supports the anticipated codes and standards needs. This directed approach and early stakeholder involvement is expected to result in consensus building that will ultimately expedite the standards development process as well as commercialization of the technology.

ASME has been involved in nuclear codes and standards since 1956. The Society created Section III of the Boiler and Pressure Vessel Code, which addresses nuclear reactor technology, in 1963. ASME Standards promote safety, reliability and component interchangeability in mechanical systems.

Established in 1880, the American Society of Mechanical Engineers (ASME) is a professional not-for-profit organization with more than 127,000 members promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety, and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org for more information.

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EXECUTIVE SUMMARY

Five newly proposed promising creep-fatigue evaluation methods were investigated. Those are 1) modified ductility exhaustion method, 2) strain range separation method, 3) approach for pressure vessel application, 4) hybrid method of time fraction and ductility exhaustion, and 5) simplified model test approach.

The outlines of those methods are presented first, and predictability of experimental results of these methods is demonstrated using the creep-fatigue data collected in STP-NU-013 [2] and STP-NU-018 [3]. All the methods (except the simplified model test approach which is not ready for application) predicted experimental results fairly accurately. On the other hand, predicted creep-fatigue life in long-term regions showed considerable differences among the methodologies. These differences come from the concepts each method is based on.

All the new methods investigated in this report have advantages over the currently employed time fraction rule and offer technical insights that should be thought much of in the improvement of creep-fatigue evaluation procedures.

The main points of the modified ductility exhaustion method, the strain range separation method, the approach for pressure vessel application and the hybrid method can be reflected in the improvement of the current time fraction rule. The simplified model test approach would offer a whole new advantage including robustness and simplicity which are definitely attractive but this approach is yet to be validated for implementation at this point.

Therefore, this report recommends the following two steps as a course of improvement of NH based on newly proposed creep-fatigue evaluation methodologies. The first step is to modify the current approach by incorporating the partial advantages the new methods offer, and the second step is to replace the current method by the simplified model test approach when it has become technically mature enough.

The recommendations are basically in line with the work scope of the Task Force on Creep-Fatigue of the Subgroup on Elevated Temperature Design of the Standards Committee of the ASME Boiler and Pressure Vessel Committee Section III.

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1 INTRODUCTION

STP-NU-018 [3] investigated existing creep-fatigue rules to improve the provisions on creep-fatigue evaluation of Mod.9Cr-1Mo steel in Subsection NH of ASME Boiler and Pressure Vessel Code Section III [1]. All the rules investigated were based on the time fraction rules.

This report investigates newly proposed creep-fatigue evaluation methods that have not been employed in exiting codes and procedures, using the data on Mod.9Cr-1Mo steel collected in STP-NU-018 [3]. This report selected the following five promising methods, all of which are more or less different from the conventional time fraction method, for the investigation:

- Modified Ductility Exhaustion Method (MDEM)
- Strain Range Separation Method (SRSM)
- Approach for Pressure Vessel Applications (APVA)
- Hybrid Method of Time Fraction and Ductility Exhaustion (Hybrid)
- Simplified Model Approach (SMT).

This report describes the outline and the predictability of experimental results of the above methods, potential to deploying the methods to NH is investigated from the viewpoints of required database, extrapolation strategy and applicability to structural design which is more complex than predicting material test results. Also mentioned is the impact to the provisions of Subsection NH when these methods were to be implemented replacing the current provisions.

This report deals with Mod.9Cr-1Mo steel only. However, it is to be noted that other materials such as 316 stainless steels including low-carbon nitrogen added versions and Alloy 800H are also of interest for the development of New Generation Nuclear Plants.