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CREEP-FATIGUE DATA AND EXISTING EVALUATION PROCEDURES FOR GRADE 91 AND HASTELLOY XR

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CREEP-FATIGUE DATA AND EXISTING EVALUATION PROCEDURES FOR GRADE 91 AND HASTELLOY XR

Prepared by:

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FOREWORD

This report describes the results of investigation on Task 5 of DOE/ASME Materials Project based on a contract between ASME Standards Technology, LLC (ASME ST-LLC) and Japan Atomic Energy Agency (JAEA). Task 5 is to collect available creep-fatigue data and study existing creep-fatigue evaluation procedures for Grade 91 steel and Hastelloy XR. Part I of this report is devoted to Grade 91 steel. Part II of this report is devoted to Hastelloy XR.

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EXECUTIVE SUMMARY

This report describes the results of investigation on Task 5 of DOE/ASME Materials Project based on a contract between ASME Standards Technology, LLC (ASME ST-LLC) and Japan Atomic Energy Agency (JAEA). Task 5 is to collect available creep-fatigue data and study existing creep-fatigue evaluation procedures for Grade 91 steel and Hastelloy XR. Part I of this report is devoted to Grade 91 steel. Existing creep-fatigue data were collected (Appendix A) and analyzed from the viewpoints of establishing a creep-fatigue procedure for VHTR design. A fair amount of creep-fatigue data has been obtained and creep-fatigue phenomena have been clarified to develop design standards mainly for fast breeder reactors. Following this, existing creep-fatigue procedures were studied and it was clarified that the creep-fatigue evaluation procedure of the ASME-NH has a lot of conservatisms and they were analyzed in detail from the viewpoints of the evaluation of creep damage of material. Based on the above studies, suggestions to improve the ASME-NH procedure along with necessary research and development items were presented. Part II of this report is devoted to Hastelloy XR. Existing creep-fatigue data used for development of the high temperature structural design guideline for High Temperature Gas-cooled Reactor (HTGR) were collected. Creep-fatigue evaluation procedure in the design guideline and its application to design of the intermediate heat exchanger (IHX) for High Temperature Engineering Test Reactor (HTTR) was described. Finally, some necessary research and development items in relation to creep-fatigue evaluation for Gen IV and VHTR reactors were presented.

PART I

GRADE 91

1 COLLECTION OF AVAILABLE DATA

1.1 Outline of Collected Data

Data obtained in various organizations such as Japan Atomic Energy Agency (JAEA), Electric Power Research Institute (EPRI), Oak Ridge National Laboratory (ORNL), Central Research Institute of Power Industry in Japan (CRIEPI), National Institute of Material Science in Japan (NIMS) and the University of Tokyo were collected from available sources as listed in Table 1 Data collected include 205 creep data, 281 fatigue data and 78 creep-fatigue data. Product forms include plate, forgings and pipe. Chemical compositions available in the data sources are summarized in Table 2. Most of the data are considered to have been obtained for the application to the development of fast breeder reactors.

1.2 Evaluation of Collected Data

Collected data were evaluated in terms of creep properties, fatigue properties and creep-fatigue properties. Details are described below.

1.2.1 Creep Properties

(a) General trend

Creep rupture life is shown in Figure 1. All the collected data showed a uniform trend and there were no data that showed obvious discrepancy compared to other data.

(b) Environmental effect in sodium

In Figure 1, data in sodium are plotted for comparison at a temperature range from 450 to 600˚C. Although creep rupture time was slightly longer in sodium at 600˚C, basically it was same both in air and sodium environments, and environmental effects due to sodium were not observed.

1.2.2 Fatigue Properties

(a) General trend

Fatigue life is plotted against total strain range in Figure 2 to Figure 7. All the collected data were obtained under completely reversed strain controlled conditions using uniaxial push-pull specimens. Along with the experimental data, an average trend derived from the DDS procedure (See Reference. Outline of the procedure is shown in Chapter 2 of this report.) by substituting safety margins from design curves are shown in the figures. In general, fatigue life showed clear strain rate dependency. As strain rate becomes slower, fatigue life becomes shorter. EPRI data showed shorter fatigue life at 550˚C but the reason is not clear.

(b) Effect of thermal aging

In Figure 5, available data with thermal aging at 550˚C are plotted. As far as these data are concerned, no effect of thermal aging on fatigue life was observed.

(c) Effect of environment

From Figure 3 to Figure 6, it is shown that fatigue life in sodium is obviously longer than that in air. This trend is the same for a vacuum environment but the difference is more pronounced in a vacuum than in sodium as shown in Figure 6. The difference of fatigue life in air and vacuum environments is as much as an order of magnitude. This is attributed to the fact that oxidation of test specimens is negligible in vacuum.