Proceedings of the 2008 International ASME Pressure Vessels & Piping Conference
July 27-31, 2008, Chicago, Illinois, USA

PVP2008 - 61917

TEMPERATURE DEPENDENCE OF REACTOR WATER ENVIRONMENTAL FATIGUE EFFECTS ON CARBON, LOW ALLOY AND AUSTENITIC STAINLESS STEELS

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ABSTRACT

Recent studies of the environmental fatigue data for carbon, low alloy and austenitic stainless steels have shown that reactor water effects are significantly less deleterious as temperatures are reduced below 350 °C (662 °F). At temperatures below 150 °C (302 °F) the reduction in life due to reactor water environmental effects is less than a factor of 2, and the existing ASME Code Section III fatigue design curves for air can be used. The latter include a factor of 20 on cycles whereas the ASME Subgroup on Fatigue Strength (SGFS) has determined that a factor of 10 should be used on the mean failure curves which include reactor water effects. These factors account for scatter in the data, surface finish effects, size effects, and environmental effects.

Reactor water environmental degradation dependence on temperature is determined using variations of the statistical models developed by Chopra and Shack, Higuchi, Iiada, Asada, Nakamura, Van Der Sluys, Yukawa, Mehta, Leax and Gosselin, References [1 through 22]. Comparisons of the resulting proposed environmental fatigue design criteria with reactor water environmental fatigue data are made. These comparisons show that the Code factors of 2 and 20 on stress and cycles are maintained for air environments, and the 2 and 10 Code factors are maintained for the reactor water environments. Environmental fatigue criteria are given for both worst case strain rates and for arbitrary strain rates. These design criteria do not require the designer to consider sequence of loading, hold times, transient rates, and other operating details which may change during 60 years of plant operation.

INTRODUCTION

Environmental fatigue data for carbon, low alloy and austenitic stainless steels studied by ANL and SGFS have shown that reactor water effects are significantly less deleterious as temperatures are reduced below 350°C (662°F). At temperatures below 150°C (302°F), the reduction in life due to reactor water environmental effects is less than the environmental factor of 2 on life used in the existing fatigue design curves for air. The latter include a total factor of 20 on cycles whereas a factor of 10 is used on the mean failure curves which include reactor water effects. These factors account for scatter in the data, surface finish effects, size effects and environmental effects.

Chopra and Shack (References [1 through 9]) developed statistical models of the temperature dependence of the environmental fatigue properties between 150°C and 350°C. These models use a linear relationship between (Ln N) and temperature in this range, per Figures (1) and (2), except that their relation for austenitic materials uses an upper limit of 325°C. The latter limit was apparently used because no tests were conducted above that temperature. While the difference is small, we found that the correlation with all of the austenitic data is improved when an upper limit of 350°C is used for austenitic materials in lieu of ANL's 325°C. This makes the general trend equation of the temperature correction the same for carbon, low alloy and austenitic materials. Of course, the fatigue lives for austenitic materials are quite different than for ferritic steels. The resulting temperature dependence is given by Equation (1) in terms of °C: