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MEMORANDUM FOR: E. G. Case, Acting Director
Office of Nuclear Reactor Regulation

Robert B. Minogue, Director
Office of Standards Development

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER - #13 - RESIDUAL STRESSES IN WELDS

Introduction

The purpose of this Research Information Letter is to transmit to NRR a verified model for predicting residual stresses resulting from the girth-butt welding of pipes and the estimation of residual stresses resulting from weld repairs of vessels. This model was developed by Battelle Columbus Laboratory under the sponsorship of RES and can be used as needed in licensing reviews and standards development.

Background

Residual stresses due to welding have been of concern in safety analyses for LWR primary system components. Residual stresses arise from the differences in temperatures due to the cooling of the deposited weld metal and the heating and cooling of the neighboring base metal. Subsequent weld passes also contribute to residual stresses by reheating and remelting metal. The heat input, weld speed, weld rod size, weld metal and base metal properties, and the mechanical restraint of the structure all have an influence on the residual stresses. Ordinarily these stresses are relieved by a postweld stress relief treatment, but for most welds made in the field, this treatment is not possible. Residual stresses can be quite high, reaching and even exceeding yield stress levels. The subsequent addition of operating stresses produces localized stress levels that could be excessively high. Such conditions of localized high stress increase the tendency for crack initiation to occur. Thus, it is important that some method be available to measure or estimate the residual stresses in welded components for LWRs.

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Results

Analytical methods have been developed and validated at Battelle Columbus Laboratories to determine residual stresses in girth-butt type welds due to the weld-joining process. A computer code AXISOL has been developed to predict residual weld stresses in girth-butt welds in pressure vessels and pipes. Validation of the procedure has been accomplished by comparison of predicted results with residual stresses obtained through measurements made on four different pipes with three different pipe diameters and in a weld repair of the 6-inch-thick, 39-inch-diameter HSST intermediate test vessel. The computer model predicts the actual residual stress levels well and, more importantly, the predictions accurately describe the compression-to-tension changes in residual stress in going from the base metal on one side of the weld, through the weld metal, and to the base metal on the other side of the weld. Comparisons between predictions and measured values agreed well for both the inside and outside of the pipes. Details of the computer code and results of the validation comparisons are presented in the enclosure.

Evaluation

The results of this program have been reviewed by the NRC Vessel Integrity Research Review Group, and by the staff of the HSST Program at Oak Ridge. It is the consensus of these experts that the calculations and measurements have been most carefully done and, thus, represent the best method for prediction of residual weld stresses. Furthermore, the code has been shown to be capable of predicting residual weld stresses in small diameter (4.5 inches) pipes as well as thick section pressure vessels which required the modeling of some 1000 weld passes in a 6-inch-deep pressure vessel weld repair. The procedure is versatile enough that both NRC and EPRI plan to use it as an aid in directing research in improving weld practices for reduction of weld stresses thereby enhancing the quality of fabricated products.

This model could be used in the licensing process to aid in the evaluating of cracking that has occurred in girth-butt welds in piping. It should also prove to be useful in any safety evaluation of proposed repairs by weld buildup in nozzle corner regions after cracks have been removed, and in vessel weld repairs.

Attachments

The results of the study in which the model was developed and verified are described in the final report, "Residual Stresses in Girth-Butt Welds in Pipes and Pressure Vessels," prepared for the U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research under Contract No. AT(49-24)-0293, Task 1, August 1977, currently in

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publication. This report is summarized in the enclosure, "Evaluation of Method for Predicting Residual Stresses in Girth-Butt Welds." A paper describing the model and comparisons with laboratory measurements for residual stresses has been accepted for presentation at the American Society of Mechanical Engineers Winter Annual Meeting held November 27 to December 2, 1977, in Atlanta, Georgia. The paper is entitled, "A Finite Element Model for Residual Stresses in Girth-Butt Welded Pipes," by E. F. Rybicki, D. W. Schmueser, R. B. Stonesifer, J. J. Groom, and H. W. Mishler.

Original Signed by
Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosure: as stated

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