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Effects of geometry and combined loading on steady-state creep stresses in welded branches

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ABSTRACT

In our previous paper, it was found that the mis-match effect in creep on steady-state stresses within the weld metal for a large bore branch junction could be uniquely quantified by the mis-match factor defined as a function of the creep stress exponent and the ratio of creep constants for the base and weld materials. Furthermore ratios of section-averaged (effective and maximum principal) stresses for the mis-matched case to those for the even-matched case were linearly dependent on the mis-match factor. Above results were obtained for a specific branch geometry under single loading. This paper extends our previous analysis to other branch geometries and to combined loading. It is found that above conclusions can be applied to general branch components under combined loading.

1. Introduction

Creep life assessment of welded branch vessels is important in structural integrity assessment of components operating at elevated temperatures [2–4]. A proper assessment requires accurate determination of stress distributions from inelastic analyses. As such inelastic stress analyses should include not only detailed geometrical configurations but also different elastic-plastic-creep properties of all constituents (such as base and weld metals). Due to complexities involved, only a few published papers can be found in the literature [5,6]. In our previous work [1], steady-state creep stress distributions within the weld metal in a large bore welded branch component (Fig. 1a) were reported, based on extensive three-dimensional (3-D) elastic-creep finite element (FE) analyses. The branch was modeled by two materials, the base metal and weld metal, which were characterized by idealized power law creep laws with the same creep exponent. For systematic analyses, the creep stress exponent and constants for the base and weld metal were systematically varied to simulate under-matching, even-matching and over-matching conditions in creep. To quantify the effect of mis-match in creep, the mis-match factor was introduced, as a function of the creep stress exponent and the ratio of creep constants for the base and weld materials. Furthermore various loading conditions were considered to see the effect of the loading mode. Two important findings can be summarized as follows. The first one was that steady-state stresses within the weld metal could be uniquely characterized by the mis-match factor. It was also found that ratios of averaged (effective and maximum principal) stresses within the weld metal for the mis-matched case to those for the even-matched case were linearly dependent on the mis-match factor, implying that the weld redistribution factor[2] that is used in the R5 procedures [7] to estimate creep rupture life of welded components could be deduced from the mis-match factor in creep and the loading mode.

Although findings in our previous paper were useful in creep life assessment of welded branch components, the results were obtained for one particular geometry (the large bore branch component) under single loading (although various loading modes were considered). For more concrete conclusions, other branch junction geometries and combined loading need to be considered, which is the topic of this technical note.

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[2] The weld redistribution factor is used to account for stress redistribution between the material zones in a weldment as a result of differences in their creep deformation properties.

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