EFFECT OF RESIDUAL STRESSES ON FATIGUE CRACK PROPAGATION AT ROOM TEMPERATURE IN A FERRITIC-AUSTENITIC WELDED JOINT

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INTRODUCTION

Ferritic-austenitic welded joints are often found in nuclear reactors where the largest components are made with low alloy steels and piping with stainless steels. These junctions, difficult to obtain, are subjected to special service loadings due to the presence of dissimular materials.

The analysis of the in-service behaviour of these weldments require detailed knowledge of their fatigue properties and in particular the fatigue crack propagation behaviour.

The heterogeneous properties and structures of the different materials involved in the joint constitution (base metals : A 533 B ferritic steel and 316 L austenitic steel, welded metal : 308 L type steel) induce a complex behaviour of this type of junction.

The aim of this paper is to show that crack growth rate can be strongly changed at the proximity of the materials interface and that these changes can be explained for their most important part by taking into account the residual stresses in the joint.

FATIGUE CRACK PROPAGATION RESULTS

Fatigue crack propagation tests have been carried out with CT specimens (B = 20 mm, W = 100 mm), using R = 0.15.

Two propagation directions are used. In the first case named case A, crack propagates from the ferritic steel, trough the ferritic-weld interface. In case B, crack propagates in the weld, in a direction paralel to the interfaces.

Case A results show an important decrease of the crack propagation rate when the crack tip approachs the interface. This effect can always be observed even when the crack propagates in the weld metal (FIG. 3).

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Case B results exhibit also a decrease of the propagation rate but smaller than thess observed in case A (FIG. 4).

To explain these facts, we assume that important residual stress fields exist inside the specimens.

RESIDUAL STRESSES MEASUREMENTS

Residual stresses measurements are performed using a hole drilling method modified to allow determination of non-uniform stress field. The most important hypothesis used here is the existence of a special function called transmissibility function, which connects the measured deformations during drilling to the residual stresses at a given depth.

High level of compression longitudinal stresses which are acting in case A propagation are observed near the ferritic-austenitic boundary (up to - 350 MPa) (FIG. 1). To take into account this internal stress field, we suggest to calculate residual stress intensity factors K_{ress} derived by weight function methods (Buchelet, Bueckner, Chell). FIG. 2 shows the K_{ress} distribution when using the Chell method. The same approach is made in case B crack propagation.

INTERPRETATION

When crack propagates, the effective stress intensity factor range ΔK_{eff} is given by :

$$\Delta K_{eff} = K_{max.}^{appl.} - | K_{res} |$$

Where $K_{max.}^{appl.}$ is the maximum stress intensity factor due only to the mechanical loading of the specimen.

This relation is based on the following hypothesis : when the minimal stress intensity factor value is negative ($K_{min}^{appl.} - K_{res} < 0$), we assume that it is equal to zero.

New plots using ΔK_{eff} are shown in FIG. 3 for case A propagation and FIG. 4 for case B propagation. The solid ligne represents the classical Paris'law for the corresponding material (A 533 for case A and austenitic welded metal for case B). We can verify that when residual stresses are taken into account by using a residual stress intensity factor, the crack growth relation ($\frac{da}{dn}$, ΔK_{eff}) in heterogeneous weldments, is very close to those obtain separatly on each different materials.

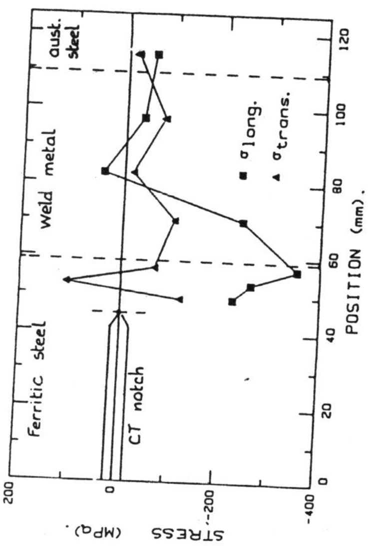

FIG. 1 - RESIDUAL STRESSES EVOLUTION (CT SPECIMEN)

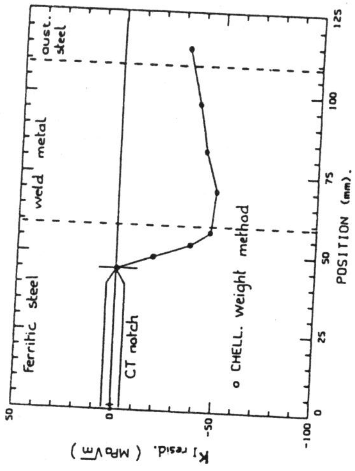

FIG. 2 - K_{Iresid} EVOLUTION (CT SPECIMEN)

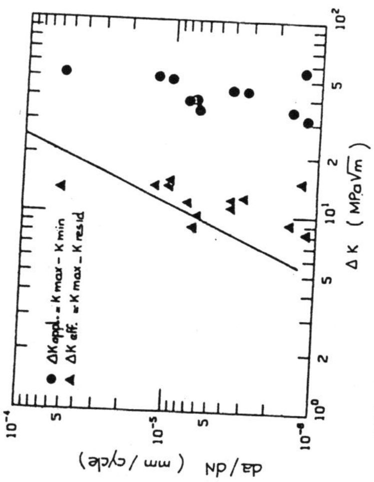

FIG. 3 - CRACK PROPAGATION RESULTS IN THE FERRITIC STEEL OF THE JOINT

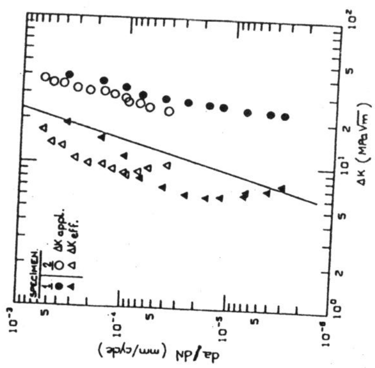

FIG. 4 - CRACK PROPAGATION RESULTS IN THE WELD METAL OF THE JOINT