Study of the effects of fatigue crack closure under negative load ratio

Contrat CIFRE Framatome

Description of the subject

In the framework of the life extension of power plants or the design of new projects such as Hinkley Point C in the UK, fatigue propagation studies are receiving increasing interest. The loadings leading to crack propagation are mainly related to thermal shocks which vary over time. Significant mechanical loads are periodically superimposed to these loadings, corresponding to the proof tests imposed by the regulation authorities. Currently these sequences of cycles are taken into account in a penalizing way by maximizing the combination of different situations in an unrealistic way and do not take into account the effects of load histories.

An extensive R&D work was therefore initiated by FRAMATOME to improve the fatigue crack propagation models currently used for variable loadings. One of the key issues for this will first be to control the crack closure effects for the loading conditions of interest.

These effects can be different, depending on whether one is interested in thermal loadings whose load ratio may be negative or mechanical loading where the load ratio is positive.

Historically, the fatigue crack propagation equations have been determined on the basis of tests carried out on standard CT (Compact Tension) type specimens. The grip system of these specimens using pin loading actually limits the studies to tensile loadings and does not allow to investigate fatigue loadings with a negative load ratio.

On the other hand, this type of specimen requires a significant crack representing on the order of 50% of the specimen ligament and is not representative of shallow defect in thick structures.

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In order to improve the understanding of fatigue crack closure phenomena, it is proposed to rely on the experimental developments carried out by Paul Cussac as part of his thesis.

P. Cussac has shown that tests on a cylindrical fatigue specimen with a surface defect can be used to determine the Paris law of a given material.

As this type of test is not subjected to the same loading constraints as CT specimens, it can be used for both positive and negative load ratios. It therefore constitutes an interesting alternative to the test on a CT specimen to determine the effects of the load ratio on crack closure.

The subject of the proposed thesis is based on the comparison of the fatigue propagation and the closing effects for the tests on the 2 types of test specimens for the loads with a positive load ratio. This comparison will involve both carrying out tests on the 2 types of test specimens and setting up dedicated instrumentation to observe the closure. At the same time, simulation work with finite element software will make it possible to analyze the tests on this fatigue specimen and to deepen the comparison between the 2 geometries.

In a second phase, the study can be extended to negative load ratios on the geometry proposed by P. Cussac where specific crack closure effects to these charges will be demonstrated. In this case also, the experimental study will be supported by modeling.

The study will first focus on 304L austenitic stainless steel type which has a low yield strength, and will then be completed by the study of a different material such as 18MnD5 steel. As the closure effects are partly due to plasticity effects, the study of a second material with a relatively high yield strength will be considered to extend the conclusions previously achieved.

Proposal of experimental program:

Fatigue tests on a CT specimen:

- On 304L with different load ratios - 2 to 3 tests
- On 18MnD5 - 1 retiming test

Tensile-compression fatigue tests:

- On 304L - 2 to 3 tests with positive load report + 5 tests for the 2nd part

- On 18MnD5 - 4 tests at different load ratios.

Profile of the candidate: The candidate must hold a Masters or an Engineering degree, ideally in materials mechanics. Knowledge of metal alloys and the numerical simulation of their mechanical behavior would be an asset. A very good level of English is also required.

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