Influence of a microstructure gradient on crack propagation in railway axles

M.A. FAHAM[1a], J.F. Witz[1], A. Tandjaoui[1], J. Hosdez[1] and N. Limodin[1]

[1]Univ. Lille, CNRS, Centrale Lille, UMR 9013 - LaMcube - Laboratoire de Mécanique, Multiphysique, Multiéchelle, F-59000 Lille, France

[a]mohamed-amine.faham@centralelille.fr

Abstract. The study of crack propagation in railway components, especially axles, is of great importance. The ferrito-pearlitic steels used for the manufacture of these railway components can have a different microstructure from the surface of the component to the bulk, which leads us to study the influence of a microstructure gradient on crack propagation. A constant stress intensity factor amplitude ΔK test is used to keep the experimental conditions as constant as possible in order to study the effect of a single variable, the microstructure, on fatigue crack propagation[1].

Introduction

The Single Edge Notch Tension (SENT) specimen used presents a microstructure size gradient across its entire width. This study uses fracture mechanics principles, Digital Image Correlation (DIC) and Finite Element Method (FEM) to evaluate the crack length, Stress Intensity Factor (SIF) and plastic zone at the crack tip. Tests were performed at constant ΔK thanks to the "Load shedding" technique [2] where the loading is adapted according to the crack length in order to keep ΔK as constant as possible; analytical formulas were used to link the crack length to the SIF[3]. The use of this technique requires the implementation of a control chain for the testing machine controlled by a means of real-time crack length measurement, in this case the "DCPD" electrical crack length following technique[4, 5].

Results

A constant ΔK test should lead to a crack length versus number of cycles curve which, theoretically, should increase linearly in the presence of homogeneous microstructure. Fig.1 shows that this is not the case for the test performed on specimen taken from the axle surface presenting a microstructure gradient. The variation of the crack growth rate was studied as a function of the percentages of ferrite and pearlite, the size of the pearlite nodules and the proeutectoid ferrite grains, and the branching and bifurcation of the crack in several zones along the propagation path.

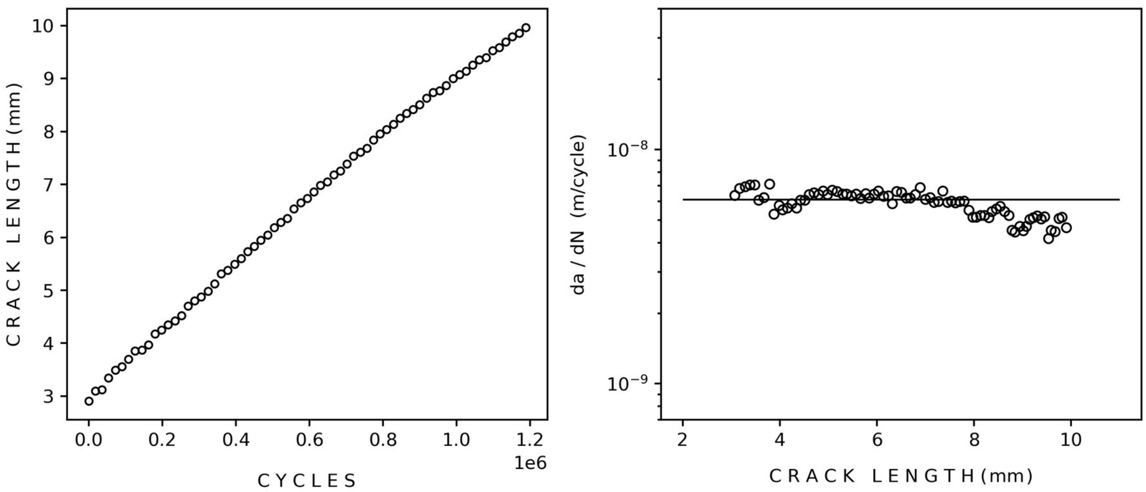

Figure1 : Crack length evolution (left) and crack growth rate (right) for a constant ΔK test

Bifurcations and multi-branching of the crack lead to a decrease of the propagation rate locally. The variation of the percentages of ferrite and pearlite and their respective sizes also affects this crack growth rate. Indeed, the ferrite-pearlite interface acts as a barrier to crack propagation, and several bifurcations occur in the pearlite nodules, which explains the local deceleration of the crack in these regions. Moreover, it was found that the crack path also influences the crack growth rate.

Conclusion

In a constant stress intensity factor amplitude test, it was observed that cracks experience local slowing, which is attributed to the bifurcation and multi-branching of the crack. Moreover, the crack growth rate is also influenced by the size of the microstructural constituents. These findings highlight the complexity of crack propagation and the need for a thorough understanding of the underlying mechanisms.

References

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