DETERMINATION OF FATIGUE CRACK GROWTH IN EPOXY RESINS USING EXPERIMENTS AND SIMULATION

J. Roger[1,2], A. Zimmermann[1], D. Coutellier[2]

[1] Robert Bosch GmbH, Corporate Research and Advance Engineering,
Department Plastics Engineering, Postfach 1131, D-71301 Waiblingen
e-mail: julien.roger@de.bosch.com, andre.zimmermann@de.bosch.com
[2] LAMIH, UMR CNRS 8530
Université de Valenciennes et du Hainaut Cambrésis, F-59313 Valenciennes cedex 9
e-mail: daniel.coutellier@univ-valenciennes.fr

ABSTRACT

Stress or strain concentration due to material inhomogeneity, product design or external loading leads to crack nucleation and propagation. A powerful tool to characterise a material within the framework of fracture mechanics is the fatigue crack growth analysis. The development of experimental and numerical methods leads to the prediction of crack propagation in mechanical structures. These techniques, which were previously established for metals, are extended to epoxy resins in the present study.

The fatigue crack growth analysis is based on experimental results performed with simple specimens. A cyclic traction loading is applied on a compact tension (CT) specimen with a constant amplitude and a fixed stress ratio. During the test, the crack length is measured with an optical system. Finally, material parameters are extracted in accordance with the Paris law. The evaluated Paris exponent m has a high value compared to metallic materials.

The second part of this work consists in validating a numerical fatigue crack growth model. A finite element model of the CT specimen is generated. The experimental fatigue crack growth parameters are implemented as input data. With the help of the software Zencrack, a 3D crack propagation is simulated by a sequential approach, in which the crack length is updated step by step. A suitable correlation is found between experiments and simulation.

KEYWORDS: fatigue, crack growth rate, data extraction, FE model, epoxy resins

INTRODUCTION

The fatigue crack growth analysis is based on experiments performed with simple specimens, like CT specimens. Material parameters are extracted with the help of phenomenological solutions, the most well-known being the Paris law. Consequently, the implementation of these data in numerical models enables the prediction of crack growth process and lifetime for complex structures.

For the continuum mechanics analysis of a crack, it is useful to distinguish three basic modes for a crack extension: opening, sliding and tearing mode (resp. mode I, II and III). Of the three modes, the first is by far the most critical to crack propagation in highly brittle solids. This is documented by the tendency for a brittle crack to seek an orientation that minimises the shear loading [1]. From this statement, the study will focus on opening mode of crack propagation. The stress distribution in the vicinity of crack tip is described with the help of Linear Elastic Fracture Mechanics (LEFM). The solution proposed by Irwin [2] for the opening mode of crack extension (or mode I) introduces the stress intensity factor K:

$$\sigma = \left(K \big/ \sqrt{\pi a}\right) Y \qquad \text{Eq. 1}$$