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# Predicting fatigue crack initiation in fibre metal laminates based on metal fatigue test data

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**Abstract**

A methodology is presented to predict the cycles to crack initiation in a notched fibre metal laminate subjected to cyclic loading. The methodology contains four steps. First, the far-field metal layer stress cycle is obtained using classical laminate theory. Second, the peak stress cycle is estimated from a combination of a handbook solution for the stress concentration factor in a finite isotropic plate, and analytical solutions for the stress concentration for equal situations in infinitely large plates. The third step is to adapt the amplitude of the peak stress cycle to the characteristics of S-N data for monolithic material from the literature to allow for the cycles to initiation to be read from the S-N curve for each metal layer.

In contrast to what can be found hitherto in the literature about predicting the cycles to fatigue crack initiation in fibre metal laminates, the authors of this paper leave no obscurities but rather attempt to bring understanding of the complete path from situation to prediction.

Test results from the literature for Glare 4B-3/2-0.3 have been replicated using the aforementioned methodology. It is shown that it can accurately predict the number of cycles to crack initiation, although the S-N data that is used for the predictions dictates the obtained accuracy. The closer the stress cycle value of the S-N data is to the value of the case analysed, the higher the accuracy obtained. Such a trend was not observed for the stress concentration factor of the S-N curves used, although a choice for S-N data with a different stress concentration factor can cause a significant change in precision. The method is also shown to work for several other fibre metal laminates.

*Keywords:* fibre metal laminates, fatigue, crack initiation, prediction

## 1. Introduction

Fibre metal laminates (FMLs) owe their popularity mainly to their better specific fatigue resistance in comparison to their monolithic aluminium counterparts [1]. Fatigue can be split in two phases. First, the fatigue crack initiation (FCI) phase occurs, which is dominated by material surface conditions owing to the small dimensions of the damage. In the second phase, the damage grows to a larger size and fatigue resistance depends on bulk material parameters rather than the surface [2]. The improved fatigue resistance of FMLs is attributed to its fibre layers which bridge fatigue cracks that appear in the metal layers due to repetitive loading [3]. This work focuses on the crack initiation phase.

If full use is to be made from the fatigue resisting capability of FMLs, it is of vital importance that the amount of load cycles the material is able to survive can be accurately predicted. Although many different methods already exist to describe the fatigue crack growth behaviour of FMLs [4, 5], the literature about models that predict FCI in FMLs is rather limited. Currently, a complete description of a method that can predict this number of cycles with a sufficient precision is still lacking. Homan takes the first step towards a prediction model with his proposition to compare the number of cycles to crack initiation for Glare to that for monolithic aluminium by looking at the stress levels in the metal layers rather than the net section stress of the FML [6]. The subsequent use of this stress to get to a prediction of cycles to crack initiation, however, is left untreated. Homan and Schra mention that the presence of residual stress in notched FMLs makes the stress concentration factor (SCF) depend on applied load [7], but no information is given on which SCF should be used to characterise the peak stress cycle in comparison to S-N data. No details are given, moreover, about the selection of one of the many stress ratios that can be computed for an FML, for similar purpose. Chang *et al.* connect Homan's reasoning to two different models to create an S-N curve for a notched monolithic specimen to allow for a prediction of cycles to crack initiation of FMLs [8, 9]. Their explana-

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