Accepted Manuscript

Probabilistic approaches to fatigue with special emphasis on initiation from inclusions

André Pineau, Stephen D. Antolovich

PII: S0142-1123(16)30268-7
DOI: http://dx.doi.org/10.1016/j.ijfatigue.2016.09.002
Reference: JIJF 4066

To appear in: *International Journal of Fatigue*

Received Date: 30 August 2016
Revised Date: 2 September 2016
Accepted Date: 6 September 2016

Please cite this article as: Pineau, A., Antolovich, S.D., Probabilistic approaches to fatigue with special emphasis on initiation from inclusions, *International Journal of Fatigue* (2016), doi: http://dx.doi.org/10.1016/j.ijfatigue.2016.09.002

Probabilistic approaches to fatigue with special emphasis on initiation from inclusions

André Pineau[1] and Stephen D. Antolovich[2*]

[1]Centre des Matériaux, Mines ParisTech, B.P. 87, 91003 Evry Cedex, France
andre.pineau@ensmp.fr
[2] Georgia Institute of Technology, Atlanta, Georgia, 30332-2920, USA
& Washington State University, Pullman, WA 99164-2920, USA, stevea@gatech.edu

*Corresponding author

Abstract

Existing methods for computing the life of critical components in jet engines, such as disks, are based on determining the design allowable forcing function (e.g. stress, strain). This is done by subtracting six standard deviations from the mean of the property in question. For example, if a stress amplitude-based criterion is used, then the design allowable life is given by:

$$N_a^{design} = N_a^{mean} - n\sigma_a^{std\ dev}$$

where:

N_a^{design} = the safe operating design life at a given nominal stress amplitude, σ_a^{nom}

N_a^{mean} = the mean life at the nominal stress amplitude

$\sigma_a^{std\ dev}$ = the experimentally measured standard deviation in life from the mean at the nominal stress amplitude.

n = the number of standard deviations or "knock down" from the mean life that will produce an acceptable safe operating life. In the aerospace industry, this value traditionally was 3 but now "6σ" has become common and even the norm.

This means that those factors which affect the dispersion of results in the High Cycle Fatigue (HCF) and Very High Cycle Fatigue (VHCF) regimes must be well understood and controlled in order to allow higher operating stresses or, conversely, longer lives at a given operating stress.

The fatigue resistance of metallic materials suffers from a number of uncertainties, in particular the dispersion associated with variance in microstructure and a component size effect (i.e. scale effect). At low stresses and longer lives, such dispersions are particularly troublesome since small variations in microstructure, for example, can produce large dispersions or uncertainties in life. An understanding of the life-limiting tail of the defect distribution is crucial for modelling and predicting minimum safe operating fatigue lives.

This paper concentrates on the two problems of microstructural variance and on the effect of component or specimen size in introducing uncertainty. In the first part, an attempt is made to summarize the micromechanisms of crack initiation by the formation of intrusions / extrusions along the slip bands in pure metals. This is an attempt to develop microstructural elements which are necessary to model the dispersion in fatigue life. While these features are, for the most part, illustrated by using recent results published on Ni-based and Fe-Ni based superalloys, the procedures are applicable to a wide range of other classes of alloys.