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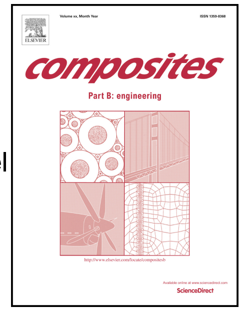

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Estimating fatigue reliability of structural components via a Birnbaum-Saunders model with stress dependent parameters from accelerated life data☆

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Abstract
In this paper, the interest is in estimating the fatigue life distribution of highly reliable structural components from data obtained via accelerated life tests. These tests consist in subjecting the products of interest to stress levels more severe than those encountered in normal use. This forces the considered products to fail more quickly and allows collecting failure data in a reasonably short amount of time. Estimates of the product's reliability at normal use conditions are then extrapolated from accelerated failure data by adopting proper models. The model proposed in this paper generalizes a model which is widely applied in literature to analyze accelerated fatigue life data. In fact, as the abovementioned standard model it relies on two very classical assumptions, namely: a) the test conditions affect the lifetime distribution parameters, and not its form, and b) the fatigue life at each considered stress level follows a Birnbaum-Saunders distribution. On the other side, differently from the standard model, in which only the scale parameter depends on the stress conditions, the proposed model assumes that both the parameters of the Birnbaum-Saunders distribution possibly depend on the stress. The model is applied to a real set of accelerated fatigue failure data. Model parameters are estimated via the maximum likelihood method. The estimate of the reliability function at normal use conditions is extrapolated from the accelerated data. It is shown that the proposed Birnbaum-Saunders based model, in which both scale and shape parameters depend on the stress conditions, fits the considered data better than the model usually adopted in literature. Differences, among results provided by the two considered alternative models, are highlighted and discussed. Finally two graphical strategies are proposed that allow judging the goodness of fit of the proposed model in absolute terms.

Keywords: Fatigue; Statistical properties/methods; Accelerated life testing; Birnbaum-Saunders Distribution; Stress dependent scale and shape parameter; Maximum likelihood estimation.

1. INTRODUCTION

Fatigue is one of the main causes of failure for mechanical components and structural systems. This damage mechanism manifests itself through the appearance and propagation of a crack inside the material, which the component is made up. Fatigue is caused by cyclic stresses that are below the ultimate tensile stress, or even the yield stress of the material. Indeed, the name "fatigue" suggests the idea that due to loading cycles a material becomes "tired" and fails at a stress level that is below its nominal strength. The fact that the original nominal strength is not exceeded and that the only warning sign of an imminent failure is a crack, which is often hard to see, makes fatigue an especially dangerous phenomenon.
Fatigue was first observed in metallic materials subjected to repeated alteration of a mechanical stress [1,2-5], nonetheless, different cyclic stresses (e.g., mechanical vibrations, temperature, electric voltage, etc.) can be considered, depending on the application and on the features of the components of interest. In modern materials, like carbon fibrous composites, fatigue is the effect of intangible "stress concentrations" factors inside the material [6], [7], and [8]. Design of high-reliability components involves the study and the use of innovative materials, which are able to ensure high-performance in terms of resistance to fatigue (i.e. very long useful life) [9, 10]. Assessing reliability of these high reliability components is a challenging task. In fact, collecting life data under normal use conditions would require many years [11,12]. Thus, accelerated life tests (ALTs) are usually adopted in order obtaining failure data in a reasonably short amount of time [13-15]. ALTs consist in testing products under

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