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# On the growth of cracks from etch pits and the scatter associated with them under a miniTWIST spectrum

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**Abstract:**
This paper examines the growth of cracks from small naturally occurring discontinuities in AA7050-T7451 coupons tested under a miniTWIST load spectrum. A markerband is inserted in the spectrum to aid in Quantitative Fractography. The resulting crack growth curve is reasonably exponential in nature, which indicates that crack growth under combat aircraft spectra and civil aircraft transport spectra is similar. It is also shown that the Hartman-Schijve crack growth equation can be used to compute the crack growth histories and account for the scatter seen in the various tests by allowing for small changes in the value of $\Delta K_{thr}$.

*Keywords:* Aircraft sustainment, etch pits, fatigue crack growth, lead cracks, fatigue variability

## 1. Introduction

Traditional total crack life predictions make use of the Linear Elastic Fracture Mechanics (LEFM) principles, in which standard material growth rate data is obtained from long cracks, typically via the ASTM method outlined in E647-13a. Several crack growth models have been developed over the years which predict early fatigue crack growth using the United States Air Force (USAF) Damage Tolerance (DT) method. In this method, fatigue crack growth behaviour is derived from a) back extrapolation of variable amplitude (VA) long crack growth data or b) VA growth curves derived from long crack constant amplitude (CA) data, with both methods using analytical models tuned to long crack growth behaviour [1]. However, to study fatigue crack growth in aircraft structures it is important to look at both long and short (small[†]) crack behaviour [2] since a majority of the life of these components lies in the short crack regime. Observations from numerous studies [3-5] have indicated that fatigue crack growth behaviour of short cracks differs from the expectations based on long crack behaviour in a non-conservative manner.

For this reason, the Defence Science and Technology (DST) Group and Royal Australian Air Force (RAAF) approach to the management of fatigue crack growth uses the Lead Crack Concept [1] which states that:

i. Crack growth initiates from small, naturally occurring defects or discontinuities, such as inclusions and pits, which have dimensions that are equivalent to a fatigue crack-like size typically about 10µm in depth.

ii. Crack growth essentially starts from the day that the aircraft enters service.

iii. The shape of the crack growth versus flight hours curve can be approximated by a near-exponential crack growth curve.

Differences in the behaviour of short cracks and long cracks can be attributed to several distinguishing characteristics of short cracks. One of these is that there is a large plastic zone at the crack tip of a short crack with respect to the length of the crack, which violates one of the conditions necessary for analysis in terms of LEFM. Another characteristic is that the level of crack closure is in a state of transition as the crack changes from a short to a long crack [7].

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[†] While short and small may be used interchangeably, small cracks are those where all the dimensions are small whereas short cracks sometimes refer to cracks with only one small in plane dimension such short through section cracks [30]. Here short is referring to cracks that are small in dimensions.