Fatigue crack growth approach for fleet monitoring

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Aircraft, and especially military ones, are subjected to unpredictable variable amplitude loadings. Fighter aircraft structures are essentially sized by operational loads that vary widely according to the missions flown by the aircraft (combat, cruising, training, airshow display). For safety reasons, it is necessary to be able to estimate each aircraft's actual fatigue "consumption" relative to its potential. For this purpose, most French military aircraft are equipped with load monitoring systems (flight parameter recorder, g-counters and others acquisition systems). These systems give direct or indirect access to in-service loads.

The data are regularly processed for each aircraft throughout its lifetime. The cumulative fatigue damage is calculated at various points of the structure pointed out as being critical as a result of the full-scale fatigue test. This information enables the Armed Forces to optimize the fleet management in terms of structures potential. Also, for fleet life-extension purposes and usage predictions, the use of more precise damage and crack growth prediction models is a major concern.

Military aircraft were historically designed with a safe life philosophy, that is to say designed to demonstrate their entire lifetime with no damage. However, due to fatigue life extensions and their associated tests, cracks may be detected. The initiation models are yet insufficient to cover the entire lifetime. In order to maintain the operational capability as well as the design safety margins, the technical authority introduced the damage tolerance philosophy: cracks are allowed below a given size provided propagation process is well known (slow, stable, predictable). This change of philosophy opens prospects in terms of crack propagation control. Indeed, new and more effective monitoring methods are developed.

Systems currently in operation on the French Air Force Mirage 2000D and Rafale enable the acquisition of large number of parameters and thus advanced monitoring methods. The use of this information gives access to continuous parameters such as g-accelerations, roll, pitch ... This data associated with crack growth models such as PREFFAS or ONERA could provide information about the propagation phase if any life extension of these Aircraft requires crack monitoring. The airframe potential consumption during the operational life can thus be estimated by combining initiation and propagation models.

Studies are conducted concerning the use of both initiation and propagation models to control the airframe potential consumption. For the aircraft equipped with g-counters with no temporal data, only initiation models can be used to control the crack propagation. The prediction qualities of this method are analyzed.

Initiation models enable to control the processing damage. In the case of aircraft with temporal flight parameters recorders, the initiation model is based on a unit damage matrix. In practice, the monitoring systems data are treated to know the real load sequence applied to the critical structural points. This load sequence is then used to perform a rainflow counting. The result gives a matrix that has to be multiplied by the unit damage matrix to determine the damage. Thus, the cumulative damage law is linear. As a consequence, the damage law is linear too.

In the case of aircraft equipped with g-counters (with no temporal data), the cumulative damage law is linear too but it is necessary to build an acceleration usage spectrum with the cumulative number of occurrences vs g-level, then to extrapolate and to discretize it. The discretization gives elementary damage by referencing to Wöhler curves or abacus. The total damage is then obtained by cumulating all elementary damages multiplied by their number of occurrences.

Furthermore, propagation models are investigated for the fleet providing temporal data. At this stage, experiments were carried out on CT samples and are ongoing on a more realistic geometry close to a spar one.

In the future, investigations will be carried out to extend the conclusions made on aircraft equipped with flight parameter recorder to aircraft only equipped with g-counters. It means adding a system to build spectrum using the g-counters output. This point needs further research in order to take load history into account in the propagation process.

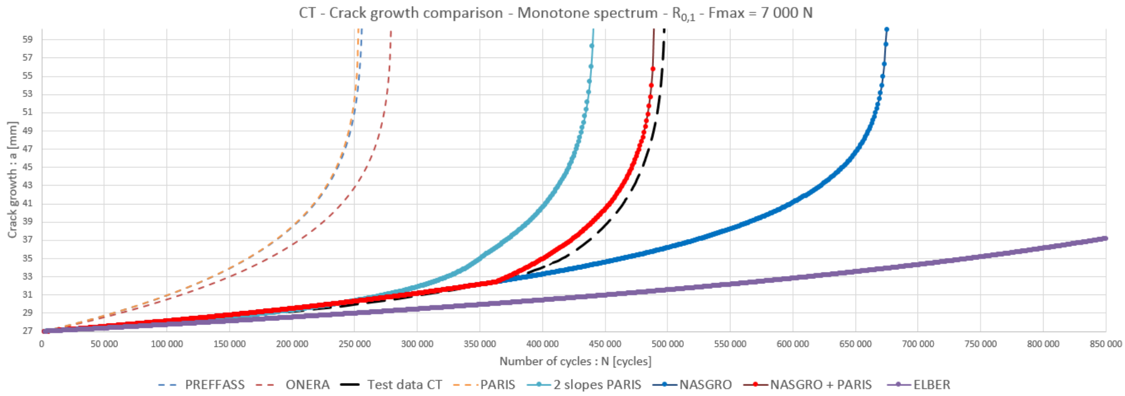

Figure 1 : Crack growth correlations on CT coupons

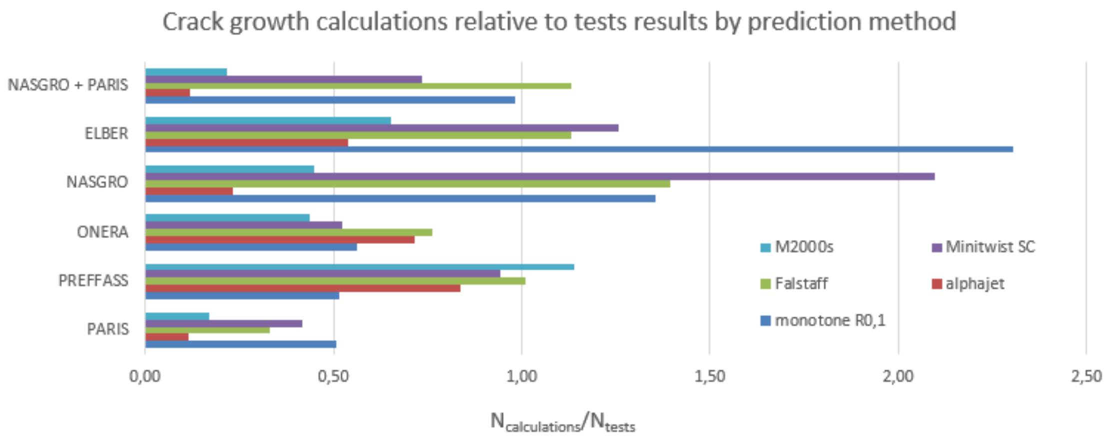

Figure 2 : Crack growth calculations relative to test results by prediction method

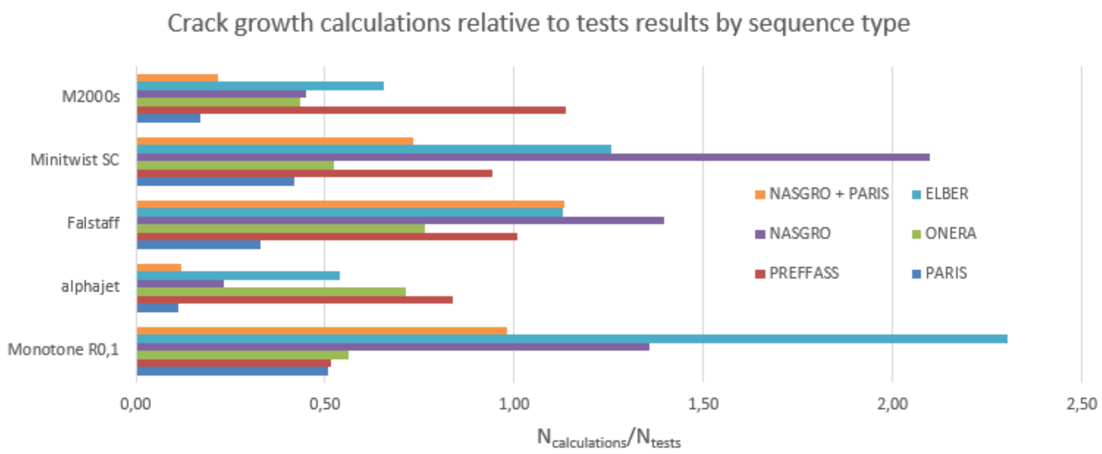

Figure 3 : Crack growth calculations relative to test results by sequence type

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