Enhanced Model for Describing Total Fatigue Rate Curve Considering Stress Ratio Effects

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Abstract: An enhanced fatigue crack growth model is proposed to approximate fatigue crack growth rate in all three regions of fatigue rate curve. The model uses Collipriest’s crack driving force for accounting stress ratio effect on fatigue crack growth. Seven fatigue crack growth models, namely Priddle, Mcevily, Weertman, Collipriest, Broek, Walker and Forman are examined. Performance of the crack driving force of these models in depicting stress ratio effects in fatigue crack growth rate is evaluated by fitting a lowess curve in transformed FCG data. Non-uniform B-spline is used to describe fatigue rate curve which allows local movements of the fatigue crack growth data that can be matched well in the vicinity without extending their effects to distant parts of the curve. Experimental FCG data of Al 2024 T351 from literature are used for validation of the model.

Key words: fatigue crack growth, stress ratio effects, crack driving force, lowess curve, B-spline.

1. INTRODUCTION
During the last five decades, a lot of research effort has been focused on fatigue crack growth prediction models. The most successful and popular has been Paris’ relation (Paris and Erdogan 1963), which is based on the applied stress intensity range, $\Delta K_{appl}$, as the only governing parameter for fatigue crack growth (FCG). One of the fundamental problems concerning the Paris expression is its ineffectiveness for quantification of the stress ratio effects. The Paris equation prompted widespread research aiming at possible improvements of its original form and at the analytical modeling of fatigue crack growth and its various aspects. Numerous models have been suggested in literature to account for the R effect, the popular among them are crack closure models (Garrett and Knott 1977; Elber 1971) and residual compressive stresses models (Kujawski and Ellyin 1972; Klesnil and Lukas 1972). Closure models use the stress intensity factor for crack opening load, $K_{op}$, as one of the parameters to depict crack growth which has to be determined from experiments (Kujawski 2001; Sun et al. 2014) gave relation between fatigue strength and stress ratio for two specimen of same material and same fatigue life. Many researchers used an extra parameter the maximum stress intensity factor, $K_{max}$ with applied stress intensity range, $\Delta K_{appl}$ to explain stress ratio effects (Sadananda and Vasudevan 1993; Sadananda and Vasudevan 1997; Kujawski 2001; Noroozi et al. 2007). However, the validity of these concepts is still limited to the specimen type, testing conditions and material used in the experiments. Empirical and semi empirical relations which are modification of Paris’ relation which account for stress ratio effects are easiest to handle and can predict fatigue crack growth rate to a fair accuracy. A crack growth model should be able to portray stress ratio effect on fatigue crack growth rate, (FCGr) and other very important trait for an FCG model is that it should also be capable of accommodating local movements of the crack growth data.

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