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NUMERICAL ANALYSIS OF MULTIAXIAL LOW CYCLE FATIGUE OF NOTCHED SPECIMENS MADE BY STAINLESS STEEL 316L UNDER NON-PROPORTIONAL LOADING

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Abstract: This study analyzes notched specimens made of stainless steel 316L which undergo low cycle fatigue. The specimens were already tested with three different types of load paths and the results were carried out in terms of fatigue life and hardness. The geometries involved feature four types of stress concentration factors. From the pictures of the cracked specimens, the crack initiation spot was detected to be moved from the notch tip. This work evaluates the value and position of local parameters of strain and stress by means of a sophisticated finite element method analysis which described the real material behavior. Other than comparing the crack initiation spot found in the numerical analysis with the one observed in the tests, the model allowed to summarize the fatigue life in a narrow scatter band, giving a reliable design tool and a faithful interpretation of the phenomena involved in this type of load cycle.

1. Introduction

Many components in industrial applications are subjected to low cycle fatigue with a load that is non-proportional (the direction of the principal stress changes during the cycle). Fatigue life of materials which undergo to such conditions has been evaluated following pioneering works, based on the concept of critical plane [1] or based on energy which however tend to return an overestimation in fatigue life for non-proportional loading. For a better evaluation of this conditions, a model was proposed by Itoh *et. al* [2]. This model takes into account of the gravity of non-proportional loading and the additional hardening occurring in the material due to this type of cycle. Successively, the model was also extended to notched specimen by involving the stress concentration factor referred to the net section ($K_{t,n}$). By observing the tested specimens, the fracture was detected moved from the notch tip, suggesting that the employment of the stress concentration factor doesn`t reflect the real behavior of the cracking process. This paper reanalyzes the experimental tests by means of a sophisticated FEM analysis, trying to obtain the local parameter of stress and strain on the notched specimens and understanding the cause of this gap of distance between the notch tip and the crack initiation spot.

2. Results

Starting from the cyclic curves of the material for the push-pull (proportional) and circle test (non-proportional), a set of 100 cyclic curves has been obtained thanks to a process of best fitting (Figure 1a). These curves between push pull and circle have been assigned on the specimen modeled on the software ANSYS®, following the percentage variation of the shear

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stress to simulate the real behavior of the material (Figure 1b), characterized by a value of hardness that decreases from the notch tip to the axis, as obtained with hardness tests previously conducted on the tested specimens. Finally, the finite element model has been loaded with a static pressure. The value of maximum strain is moved from the notch tip (Figure 2a), by a quantity that decreases as the stress concentration factor increases, as shown in the pictures. A new factor has been calculated (K`) as the ratio between stress at the maximum strain point and the nominal stress, defining a new stress concentration factor which replaced $K_{t,n}$ in the Itoh-Sakane model, returning a narrower scatter band compared to the original model. (Figure 2b).

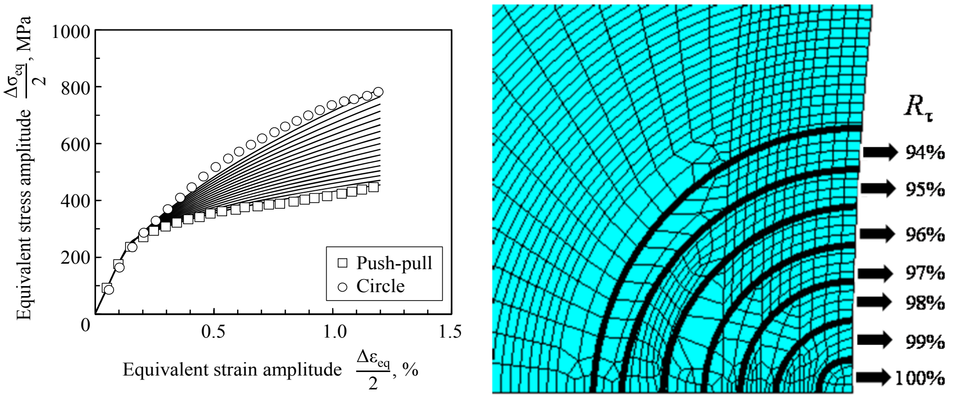

Figure 1. Curves between push-pull and circle (a) and *a*reas to which a curve was assigned following R_t (shear stress percentage value) (b)

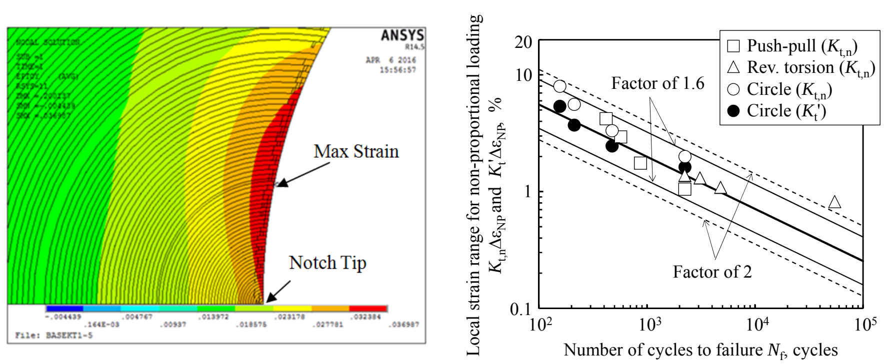

Figure 3. Contour plot of strain (a) and application of K` in the original Itoh-Sakane Model (b)

3. Conclusions

The model allowed to understand the cause of the crack initiation spot detected in the experimental tests because of a more faithful interpretation of the real behavior of the material during this load cycle. This accurate reproduction of the material allowed also to modify a model and improving its results, giving a more accurate prediction of fatigue life.

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