Multiaxial Fatigue Life Assessment of Adhesive Materials Based on Critical Plane Technique: **Strain-Based Approaches**

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Introduction

A few studies have been conducted by researchers on the multiaxial fatigue life assessment of bonded joints based on critical planes approaches. The purpose of this work is therefore to perform a rigorous evaluation of the commonly applied multiaxial fatigue critical plane criteria. Different critical plane strain-based multiaxial fatigue models including, Kandil-Brown-Miller, Fatemi-Socie, Smith-Watson-Topper and Chen et al. have been evaluated and compared using experimental fatigue loading tests obtained using Arcan joints available in the literature.

Joint geometries

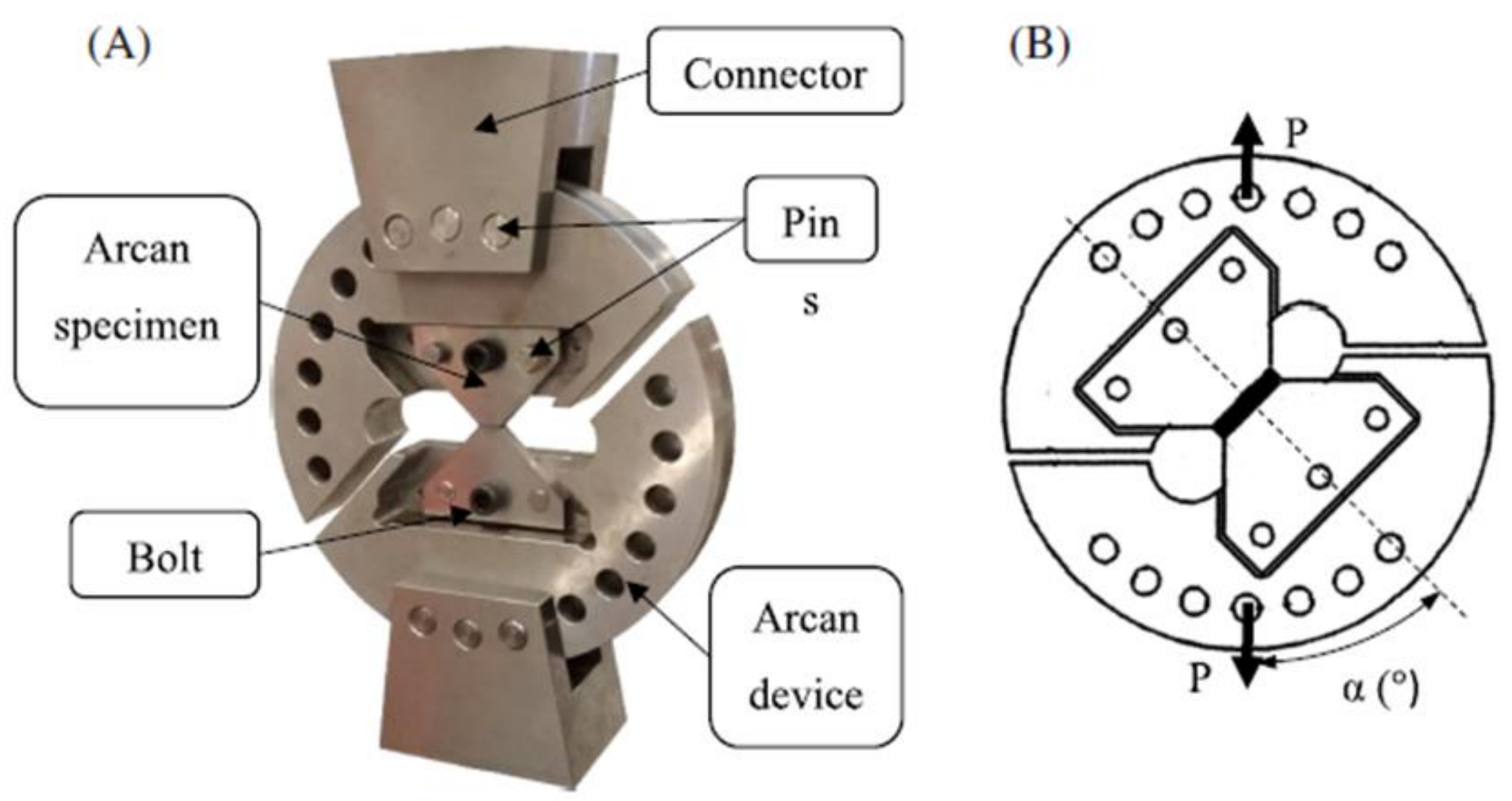

Figure 1 - (A) Arcan apparatus; (B) load angle definition

Critical plane-based multiaxial fatigue models

- Kandil, Brown and Miller (1973) introduced the first critical plane approach for multiaxial low-cycle fatigue:

$$\frac{\Delta\gamma_{max}}{2} + S\Delta\varepsilon_n = A\frac{\sigma_f' - 2\sigma_{n,m}}{E}\left(2N_f\right)^b + B\varepsilon_f'\left(2N_f\right)^c \qquad (1)$$

- Fatemi and Socie (1988) proposed the following expression:

$$\frac{\Delta\gamma_{max}}{2}\left(1 + k\frac{\sigma_{n,max}}{\sigma_y}\right) = \frac{\tau_{f'}}{G}\left(2N_f\right)^{b_0} + \gamma_{f'}\left(2N_f\right)^{c_0} \qquad (2)$$

The critical plane is the plane where $(\Delta\gamma_{max}/2)(1 + k\sigma_{n,max}/2)$is most extreme,$\left((\Delta\gamma_{max}/2)(1 + k\sigma_{n,max}/2)\right)_{max}$.

- Smith, Watson and Topper parameter (1987):

$$\frac{\Delta\varepsilon_{n,max}}{2}\sigma_{n,max} = \frac{{\sigma'_f}^2}{E}\left(2N_f\right)^{2b} + \sigma_f'\varepsilon'_f\left(2N_f\right)^{b+c} \qquad (3)$$

- Chen et al. (1999) proposed two criteria:

$$\Delta\varepsilon_n\Delta\sigma_n + \Delta\gamma_{ns}\Delta\tau_{ns} = 4\frac{{\sigma'_f}^2}{E}\left(2N_f\right)^{2b} + 4\sigma_f'\varepsilon'_f\left(2N_f\right)^{b+c} \qquad (4)$$

$$\Delta\gamma_{ns}\Delta\tau_{ns} + \Delta\varepsilon_n\Delta\sigma_n = 4\frac{{\tau'_f}^2}{E}\left(2N_f\right)^{2b_0} + 4\tau_f'\gamma_{f'}\left(2N_f\right)^{b_0+c_0} \qquad (5)$$

For mode I crack, the critical plane is the plane of maximum normal strain range $\Delta\varepsilon_n$ and with mode II crack, the critical plane is the plane of maximum shear strain range $\Delta\gamma_{ns}$.

Discussion

The models of Kandil-Brown-Miller and Smith-Watson-Topper show excellent correlations between experimental and numerical data for mode II loading conditions but, the results is not satisfactory for mode I and mixed mode. Fatemi-Socie fatigue model is more conservatives than the other models. All the considered multiaxial fatigue models overestimated the fatigue life for pure mode I loading conditions.

Evaluation results

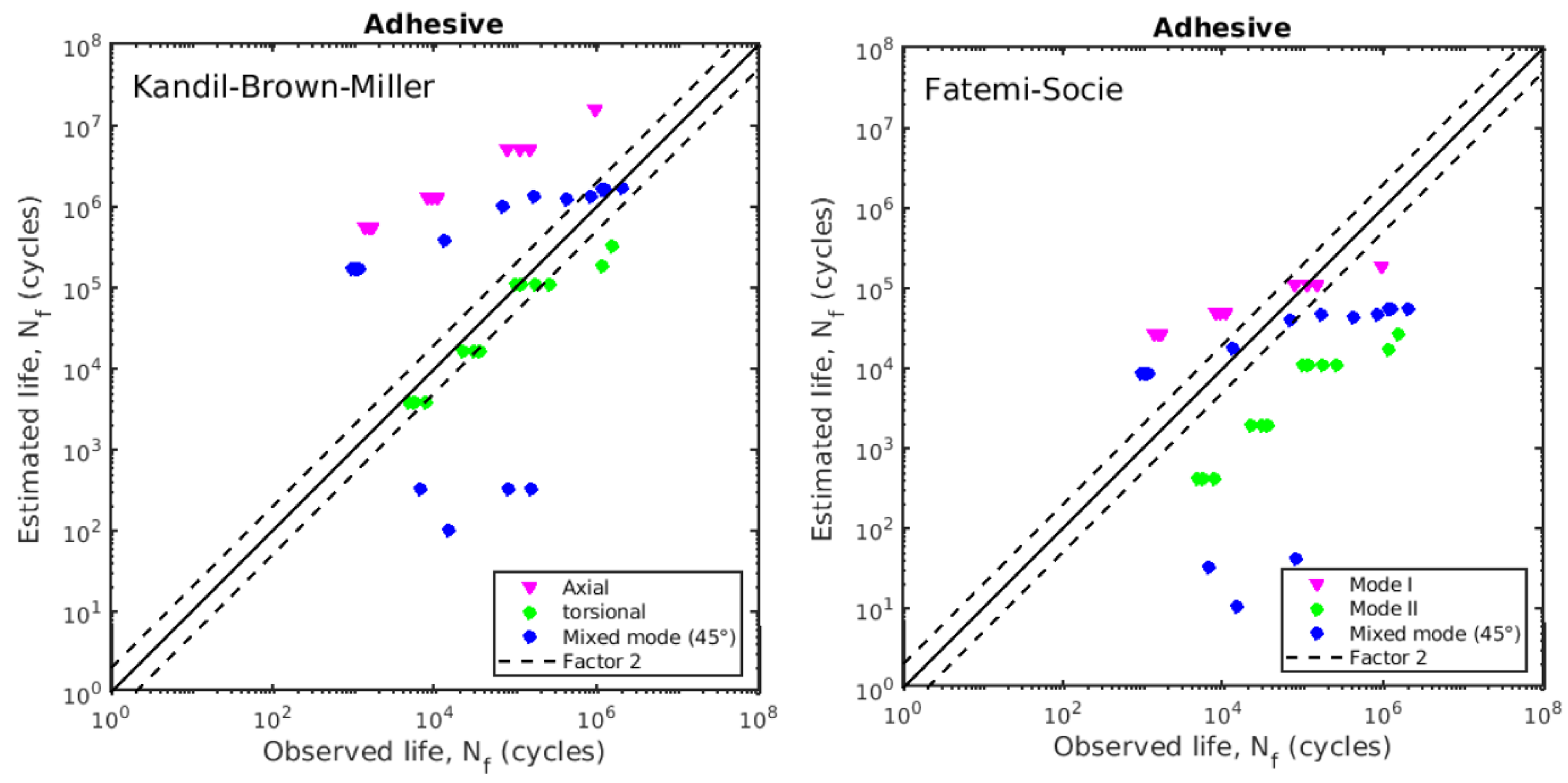

Figure 2 –Comparison between observed and estimated lives for the Kandil-Brown-Miller and Fatemi - Socie parameters.

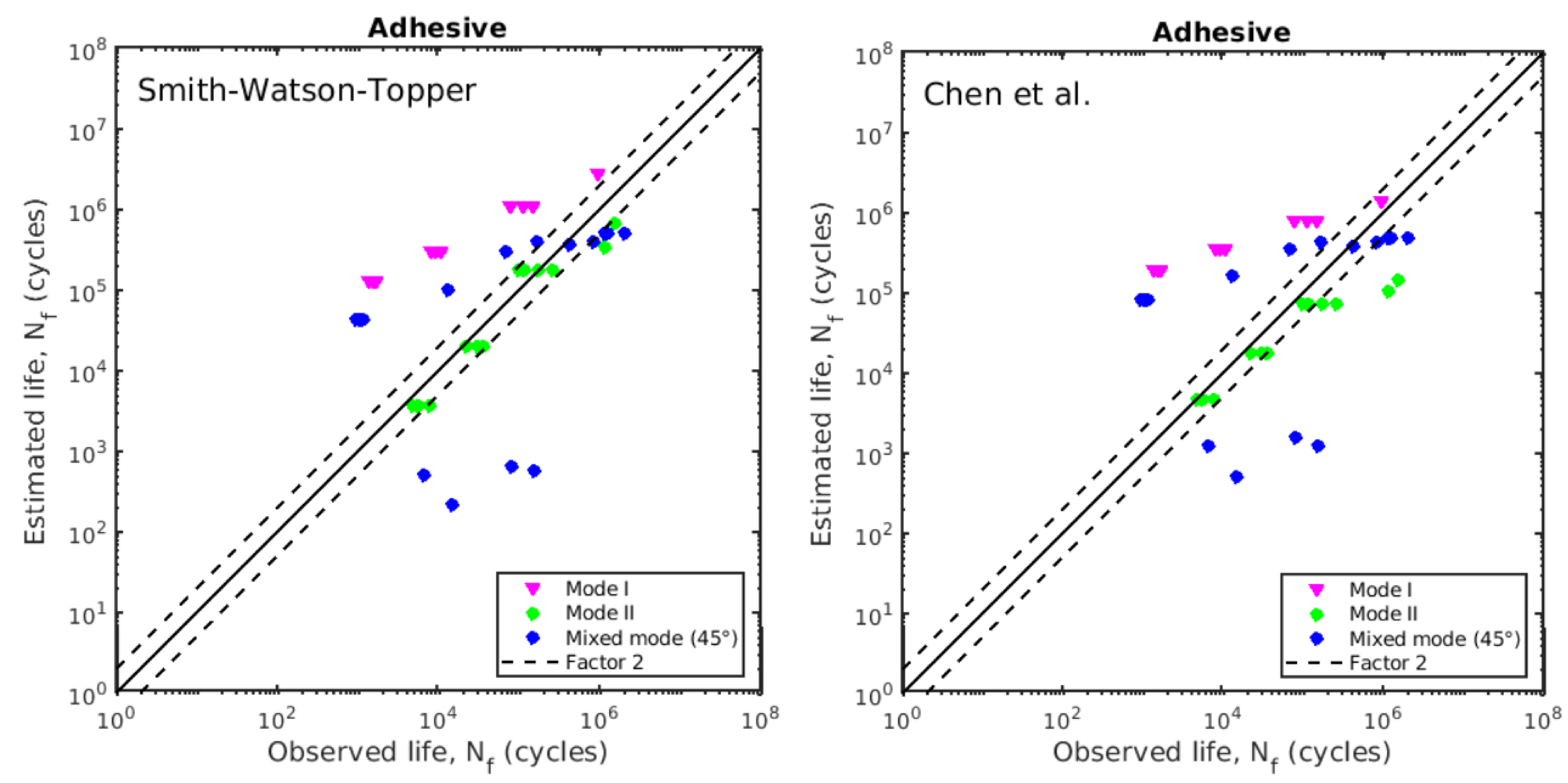

Figure 3 – Comparison between observed and estimated lives for the Smith-Watson-Topper and Chen et al. models.

Conclusions

Kandil-Brown-Miller, Smith-Watson-Topper, and Chen et al. criteria are better critical plane models among the studied models to estimate the fatigue life in mode II (pure shear) loading conditions, while Fatemi and Socie criterion is suggested to estimate the fatigue lives of mode I and mixed mode stress states.

References

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[2] Fatemi, A. and Shamsei, N., 2011. "Multiaxial fatigue: An overview and some approximation models for life estimation". Int. J. Fatigue. 33:948-58. 5.

[3] Chen, X., Xu, S. and Huang, D. (1999). A critical plane-strain energy density criterion for multiaxial low-cycle fatigue life under non-proportional loading. Fatigue of Engineering Materials and Structures 22, 679–686. .