# Multiaxial Fatigue Life Assessment of Adhesive Materials Based on Critical Plane Technique: Stress-Based Approachg

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## Introduction

Many studies have been conducted to understand and predict the fatigue behaviour of adhesive joints under multiaxial loads. However, a few studies have analyzed adhesive joints under multiaxial loads based on the critical planes approach. The purpose of this work is to perform a rigorous evaluation of commonly applied multiaxial fatigue critical plane criteria. Different critical plane stress-based multiaxial models including Findley, McDiarmid, Sines, and Crossland were evaluated and compared using Arcan joints and single lap joints (SLJ) fatigue results available in the literature.

## Joint geometries

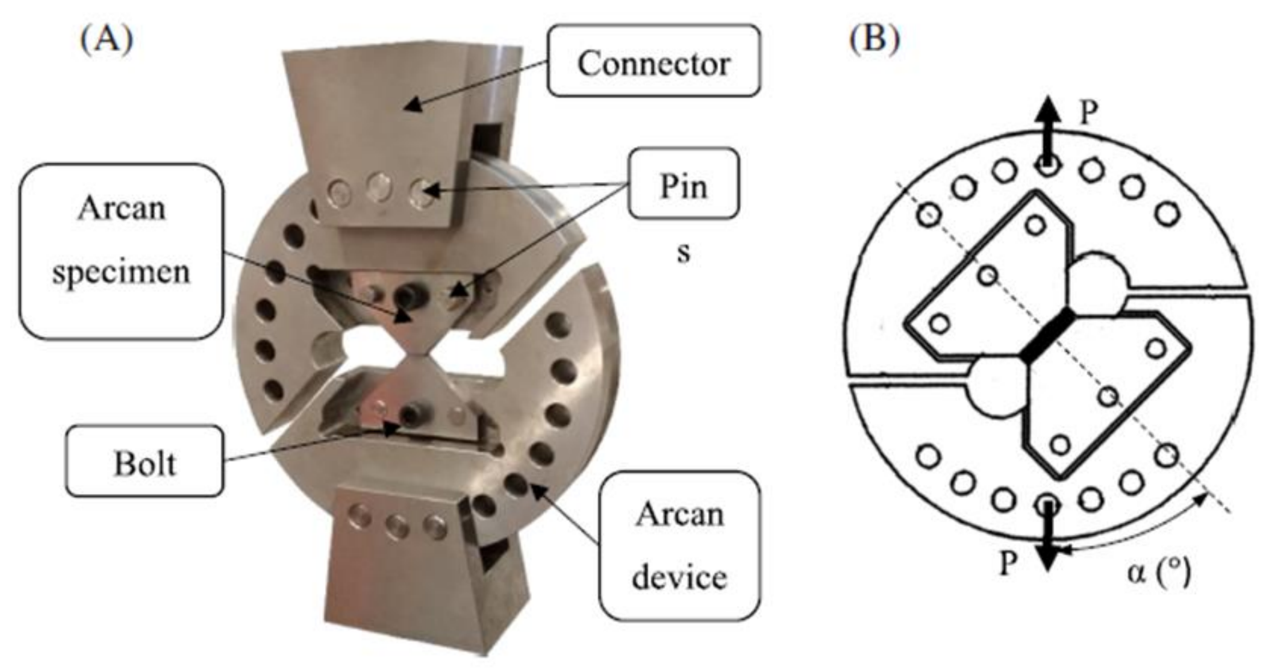


**Figure 1** - (A) Arcan apparatus; (B) load angle definition (Castro Sousa et al., 2020).

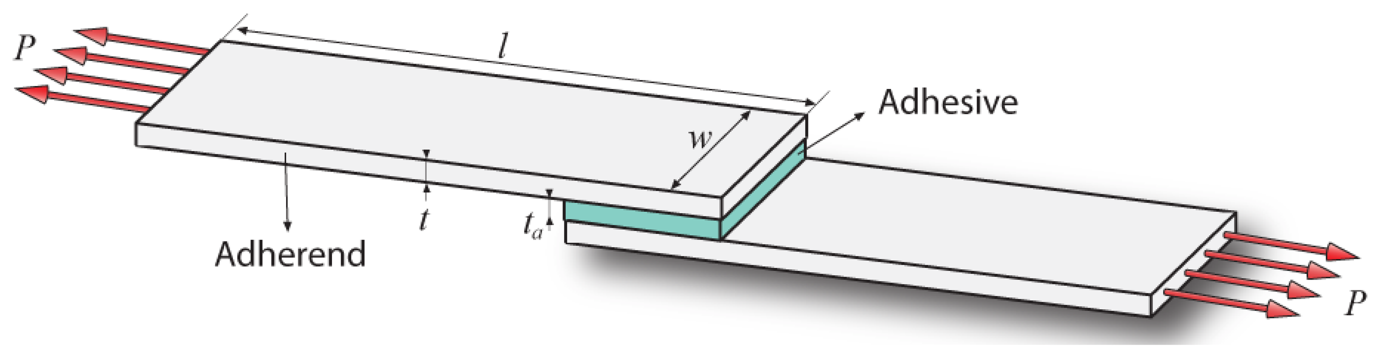


**Figure 2** - Three dimensional single lap joint (Çalik,2016).

## Critical plane-based multiaxial fatigue models

Findley (1957) introduced the first critical plane approach for stress-based multiaxial high-cycle fatigue.

- Findley model is expressed as follows:

$$\tau_a + k_F\sigma_{n,max} = \tau_f'(2N_f)^{b_0} \qquad (1)$$

The critical plane is the plane where $\tau_a + k\sigma_{n,max}$ is most extreme, $(\tau_a + k\sigma_{n,max})_{max}$.

- McDiarmid (1994) proposed the following expression:

$$\tau_a + k_{Mc}\sigma_{n,max} = \tau_f'(2N_f)^{b_0} \qquad (2)$$

The critical plane is the plane where $\tau_a$ is most extreme,$(\tau_a)_{max}$ .

- Sines (1959) developed a critical plane theory based on equivalent stress state approach:

$$\tau_{oct,a} + k_S\sigma_{h,mean} = \tau_f'(2N_f)^{b_0} \qquad (3)$$

The critical plane is the one where the octahedral shear stress amplitude $(\tau_{oct,a})$ achieves the maximum value, $(\tau_{oct,a})_{max}$.

- Crossland (1956) proposed a criterion very similar to that of Sines, disagreeing only as to the influence of hydrostatic stress:

$$\tau_{oct,a} + k_C\sigma_{h,max} = \tau_f'(2N_f)^{b_0} \qquad (4)$$

The critical plane is the one where the octahedral shear stress amplitude $(\tau_{oct,a})$ achieves the maximum value, $(\tau_{oct,a})_{max}$.

## Discussion

Based on the results it was found that except for the Findley model which is less precise, the other three models worked well on fitting the multiaxial fatigue behaviour of joints with mode I and mode II loading conditions. For mode mixed, the overall correlation produced by the four considered models was satisfactory.
Findley, McDiarmid, and Crossland criteria are more accurate than Sines criterion in predicting fatigue lives of single lap joints tests.

## Fatigue models evaluation results

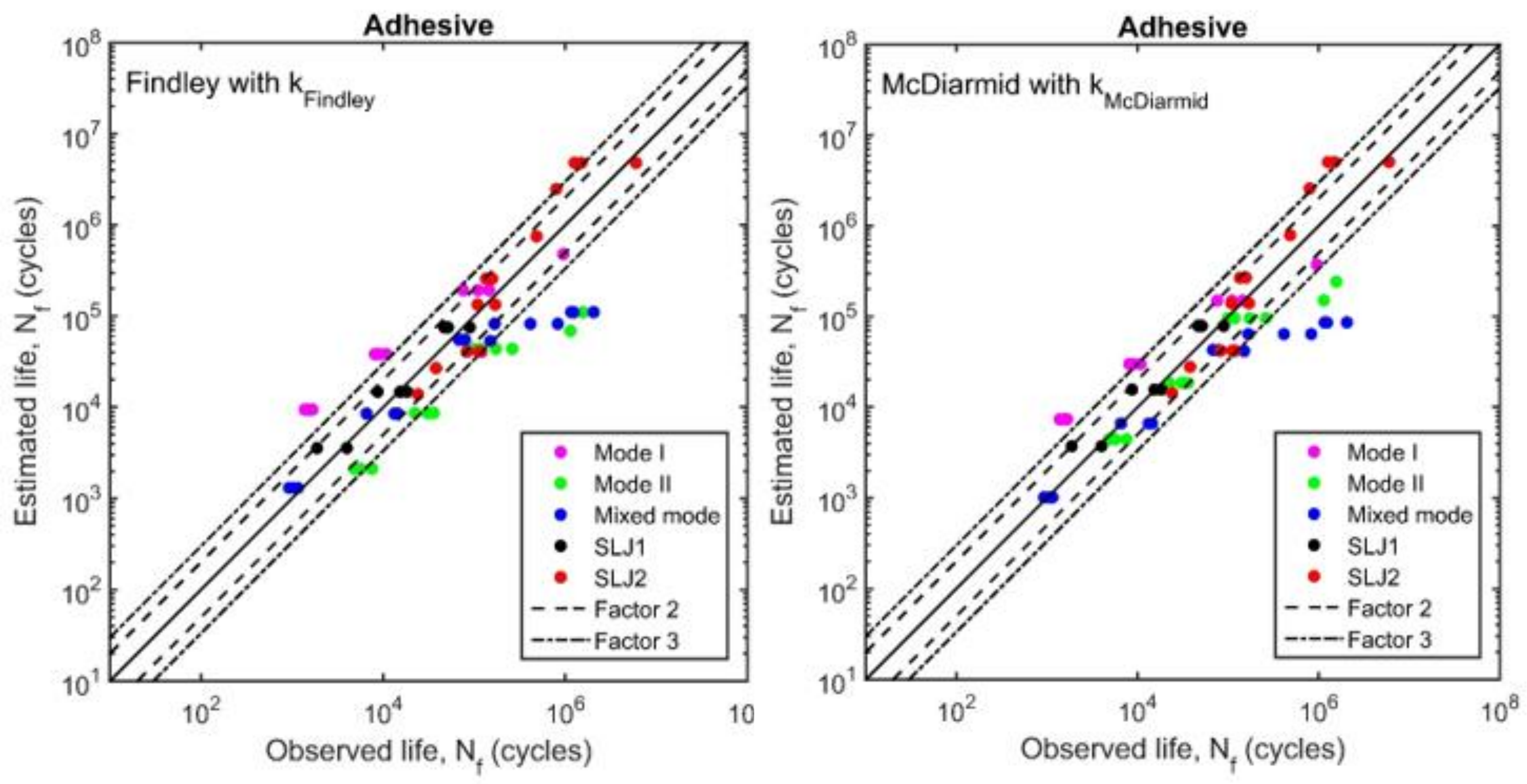


**Figure 3** –Comparison between observed and estimated lives for the Findley and McDiarmid parameters.

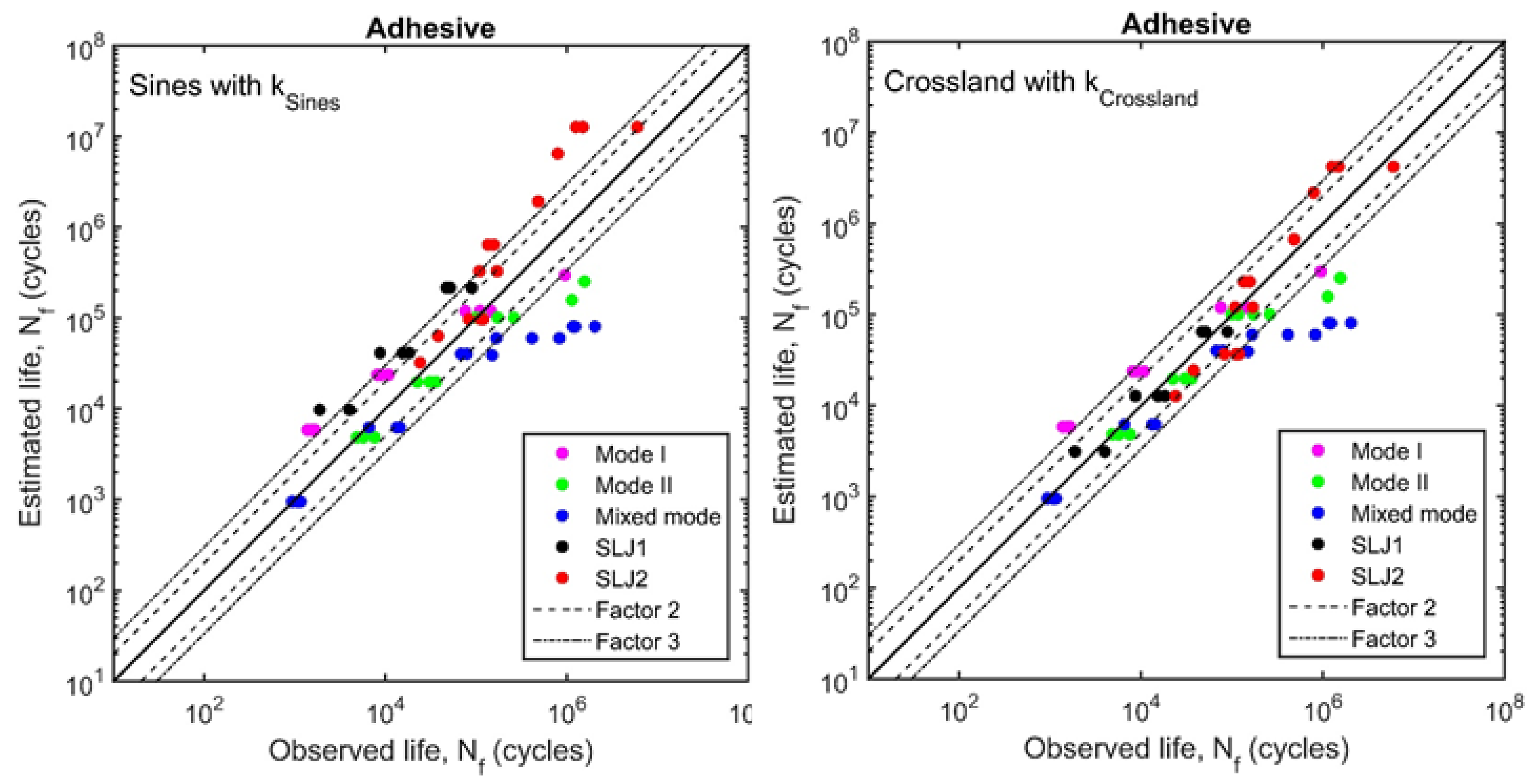


**Figure 4** – Comparison between observed and estimated lives for the Sines and Crossland models.

## Conclusions

McDiarmid and Crossland criterions are more precise critical plane models to be used to estimate the fatigue life of the joints. While Sines criterion can be used to estimate the fatigue life joints subjected to pure Modes I and II conditions. Findley criterion can be used to estimate the fatigue life of Mixed Mode and single lap joints loads.

## References

[1] Findley, W.N., Fatigue of metals under combinations of stresses, Transactions of A.S.M.E., vol. 79, 1957, p. 1337-1348.
[2] McDiarmid, D.L., A shear stress based critical-plane criterion for multiaxial fatigue failure for design and life prediction, Fatigue & Fracture of Engineering Materials & Structures, vol. 17, no. 12, 1994, p. 1475-1485.
[3] Sines, G., Behavior of metals under complex static and alternating stresses, Metal Fatigue, McGraw-Hill, New York, 1959, p. 145-169.