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ELASTO-PLASTIC FINITE ELEMENT STUDIES OF FATIGUE CRACK SHIELDING IN MULTI-LAYERED SYSTEMS

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ABSTRACT

Multi-layered systems used in automotive plain bearings show complex patterns of crack growth under service conditions. The studied architecture consists of a steel backing (1.8 mm), a compliant pure-aluminum interlayer (0.04 mm) and a lining of medium-strength aluminum alloy (0.38 mm). Previous experimental studies [1] with flat strip specimens of identical architecture under three point bending indicated similar crack propagation patterns despite the absence of mixed mode loading.

The investigation of propagating cracks under large scale yielding is carried out using finite element (FE) analyses and the damage tolerance approach. Quasi-static analyses based on a multi linear isotropic hardening material model were applied to estimate the state of stress around the crack tip and the crack driving force (CDF) parameter for straight and deflected cracks. The crack tip opening displacement (CTOD) was here adopted as CDF and estimated along crack paths whose direction was predicted using the maximum tangential strain (MTSN) criterion. The CTOD and MTSN were evaluated from a blunted crack tip model with a refined mesh which is better suited to simulate the extensive plastic deformations in this area, as shown in Figure 1. Elongated elements in the radial direction with a size of 12 nm were used to estimate the CDF and direction of growth. Initial attempts to address this problem using quarter-point elements leaded to convergence problems and greatly deformed elements when the crack tip was positioned in the interlayer and loads equivalent to one fourth of the experiment's value was applied.

Shielding and anti-shielding trends match well previous results based on *J*-integral calculations [2] despite the use of a different CDF parameter for single tip cracks that approach to mechanically mismatched layers. The applied load generated different extents of plasticity near the crack tip that caused shielding and anti-shielding to occur closer to the layer interfaces when compared to simulation where lower loads were applied, as shown in Figure 2 where results for a bi-layer model are also plotted for comparing the effects of different architectures.

Shielding is considered to be responsible for crack bifurcation. The analyses related to this scenario show two main effects: firstly, the blocked plastic zone by the stiffer layer and secondly, a stress increment in the steel caused by the presence of the cracks. The predicted crack paths, shown in Figure 3, correlated well to experimental observations.

In conclusion, the application of the FE analyses and the damage tolerance approach provide the means to assess the service life of components that undergo large scale yielding.

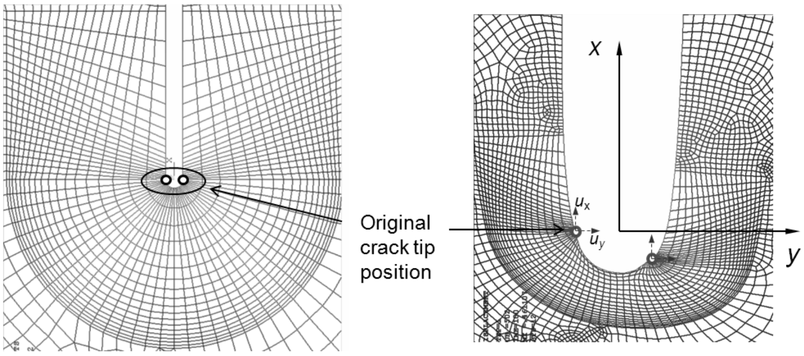

Figure 1. Undeformed and deformed crack tip mesh (Scale 1:1).

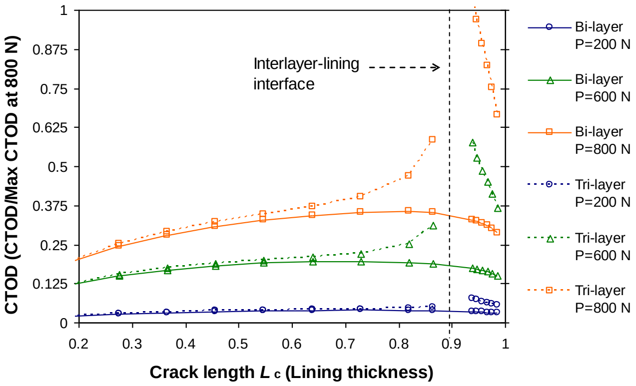

Figure 2. Evolution of CDF with crack length at different loads (Presenting only P=200, 600 and 800 N for clarity).

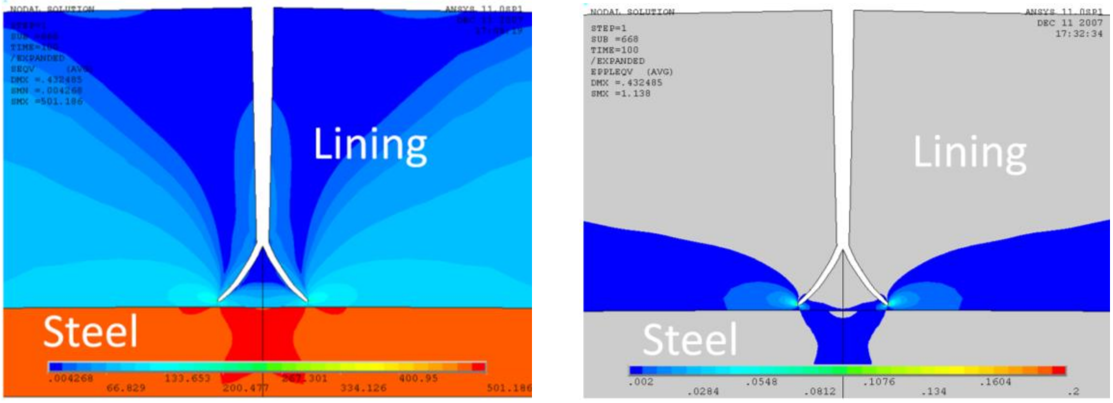

Figure 3. Mises stress (left) and plastic strain (right) for bi-layer architecture at 800 n when crack tip reaches the interface.

REFERENCES

1. Ali, M., *Microstructural modelling of fatigue in layered bearing architectures*, in *School of Engineering Sciences*. 2007, University of Southampton: Southampton. p. 275.
2. Suresh, S., Y. Sugimura, and E.K. Tschegg, *Growth of a Fatigue Crack Approaching a Perpendicularly Oriented Bimaterial Interface*. Scripta Metallurgica et Materialia, 1992. **27**: p. 1189-1194.