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

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ABSTRACT

The focus of this paper are multi-layered systems used in automotive plain bearings showing 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 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. Initially, the zone around the crack tip was modeled using quarter-point elements; this however led to convergence problems and highly distorted elements at a fraction of the experimentally applied load when the crack tip was located within the more compliant interlayer. The blunted crack tip model with a refined mesh was found to be much better suited to simulate the extensive plastic deformations in this area, Elongated elements in the radial direction with a minimum size of 12 nm were used as shown in Figure 1. This modeling led to reliable evaluation of both CTOD and MTSN.

Shielding and anti-shielding trends were detected for single tip cracks that approach mechanically mismatched layers. Such predictions agree well with previous results based on *J*-integral calculations [2] despite the use of a different CDF parameter. At higher applied loads plasticity extends to steel and this brings shielding and anti-shielding closer to the layer interface as shown in Figure 2 for a bi-layer model. The results for the tri-layer model are also plotted in the same figure for comparing the behaviour of different architectures.

The numerically predicted shielding can also explain the experimentally observed crack bifurcation. The analyses simulating this scenario show two main effects: firstly, the plastic zone blocked by the stiffer layer and secondly, an increase stress intensity in

steel caused by the presence of the cracks. The predicted crack paths, shown in Figure 3, are well correlated to experimental observations.

In conclusion, the developed two-dimensional finite element models, combined with a suitably formulated damage tolerance approach are promising analysis tools for assessing the service life of multi-layered systems that undergo large scale yielding.

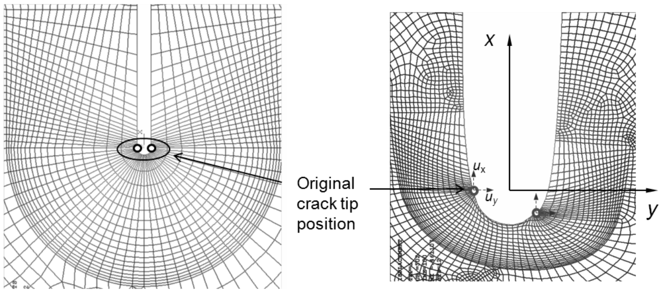

Figure 1. Undeformed and deformed crack tip mesh (Scale 1:1).

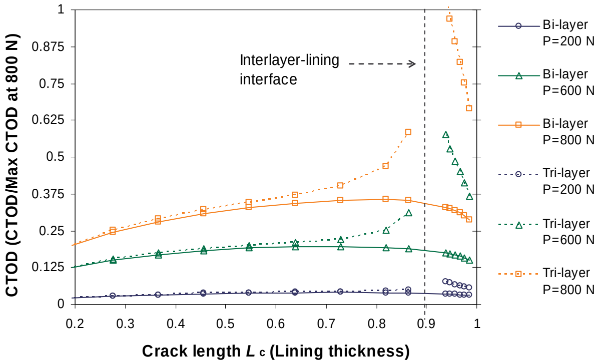

Figure 2. Evolution of CDF with crack length at different loads (Presenting only P=200, 600 and 800 N for clarity).

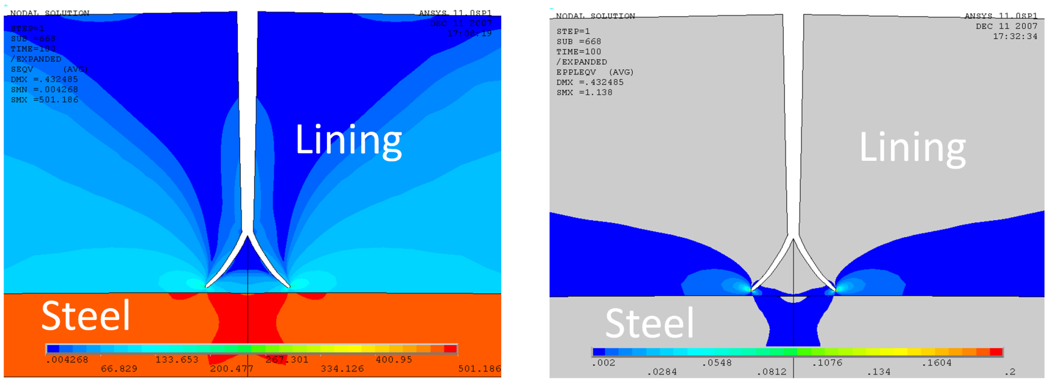

Figure 3. Mises stress (left) and plastic strain (right) for bi-layer architecture at 800 n when crack tip reaches the interface.

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