Fatigue Crack Growth in FMLs with MSD Scenario

**Background**
Multiple-site damage (MSD) is usually characterised as the presence of multiple collinear cracks in one structural element. Mechanically fastened joints are especially susceptible to MSD as there are three stress raising contributions, such as open hole, pin loading and secondary bending. See Fig 1. MSD is a great concern for aircraft structural integrity. Fiber Metal Laminates is a kind of damage tolerant hybrid structure due to its well known fiber bridging mechanism. One variant Glare has been used as fuselage material on A380. For the sake of aviation safety, it is also imperative to study fatigue crack growth in FMLs with MSD scenario.

**Methodology**
The essential concept to develop the prediction model is to idealize the effect of adjacent cracks on a single crack as local reduction in effective stiffness. The general approach is base on linear elastic fracture mechanics in conjunction with the principle of superposition and displacement compatibility.

**Research Objective**
To propose a fatigue crack growth prediction method for FMLs with MSD.

**A first step validation**
The local reduction in effective stiffness is achieved with artificial notches in a FML panel. A prediction model is developed and validated using experimental data on Glare panels.

\[ \sigma_{\text{net}} = \frac{\sigma_{\text{remote}}}{\sqrt{1 - \left( \frac{a}{l} \right)^2}} \]

**K due to far-field load and load redistribution**
The stress distribution in FMLs ahead of the crack tip can be expressed as

\[ K = \int \sigma(x) dx \]

**K due to bridging mechanism**
The displacement compatibility between cracked metal layers and bridging fibers is used to calculate bridging stress.

**Validation Results**
- The modelling method provides good prediction.
- The crack acceleration is adequately captured by the proposed modelling method.
- It is the first step that attends to address MSD in FMLs, the correlation indicates that capturing load redistribution due to MSD cracks could be a promising way to tackle MSD in FMLs.

**Scientific questions to be answered**
- In real MSD scenario, should the stiffness reduction ahead of the crack tip and that behind the crack tip both be considered when calculate the stress intensity factor of an asymmetric crack tip?
- If secondary bending is also present in MSD condition, can the combination of this presented model and slant crack growth model developed by Greg Wilson be feasible to determine the crack growth rates?

**Publications**
-W. Wang, R.C. Alderliesten, R. Benedictus, (2014) "On the development of a prediction methodology for crack growth in Fibre Metal Laminates with MSD scenario", 11th International fatigue congress

**Figures**
Fig 1. Three stress raising contributions in joints
Fig 2. FMLs in Aviation Application
Fig 3. Illustration of load redistribution due to reduction in effective stiffness
Fig 4. Decomposition of K and far-field load
Fig 5. Illustration of stress distribution at cracked section
Fig 6. Illustration of displacement compatibility
Fig 7a. Crack growth rate for Glare 3 under 140MPa
Fig 7b. Crack growth rate for Glare 3 under 120MPa