Geometry and length scale selection in material patterned interfaces

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Abstract

Interfaces represent in many cases the weakest material region. They can be found at multiple material scales. Thus, the tuning of material interfaces to augment fracture resistance has been long related to materials development. In particular, the modification of the interface topology has been suggested as one of the responsible mechanism for interface improvement (Song et al. Materials Science and Engineering: A , 2010, Yigit & Hector, Trans.Asme, 2000).

This research propose a novel approach in which morphological modifications of the interfaces (e.g. geometrical patterns) at different scales can be used to induce significant changes in the macroscopic material mechanical properties. A series of combined computational/ experimental analysis through a set of design guidelines are used to discuss the main material properties and geometrical parameters which rule such material enhancement.

Goal

The goal of this project is to find design guidelines which connects interface patterning at multiple scales with material fracture resistance improvement .

In particular, the main ***research objectives*** of this project are:

1. Develop computational models to study the effect of patterned crack propagation along interfaces based on shape and size aspect ratio.
2. Define an effective metrics for the characterization of crack resistance in patterned interfaces.
3. Study the role of the patterned geometry and length scale on finite and infinite material systems for homogeneous and heterogeneous material interfaces.

Research Method

Simple models are generated to capture the basic mechanics of the material system and more physics is added progressively to increase model complexity:

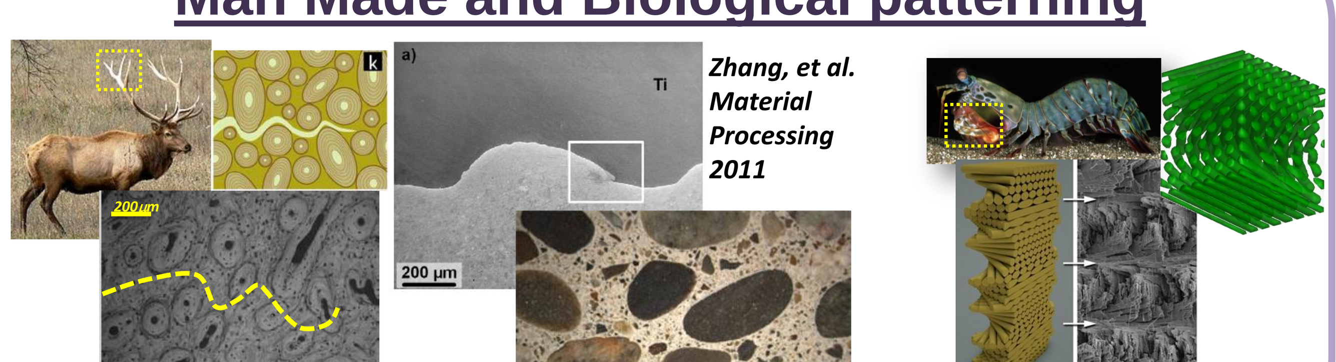
(a) Brittle patterned sinusoidal interfaces are modeled within solid homogeneous and infinite elastic materials .

(b) Non linear material behavior is introduced to capture the interface brittle-ductile transition.

(c) Experiments are used to introduce characteristics dimensions to the system and capture a effective fracture metrics in correlation to simulations

(d) Based on previous results, a extension to material heterogeneous interface models are developed.

Man Made and Biological patterning



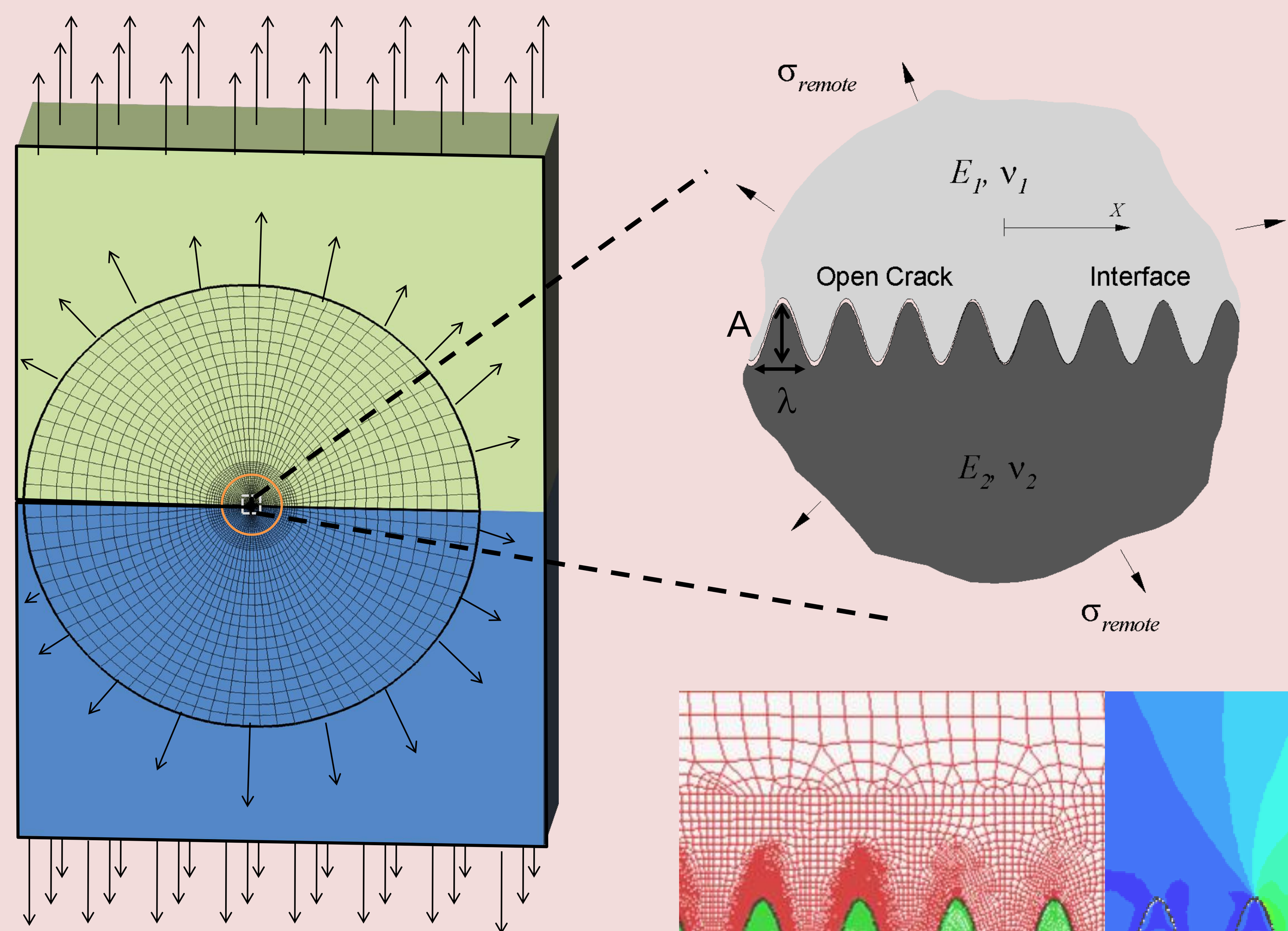
M.E. Launey et al., Biomaterialia, 2010

Weaver J., Science, 2012

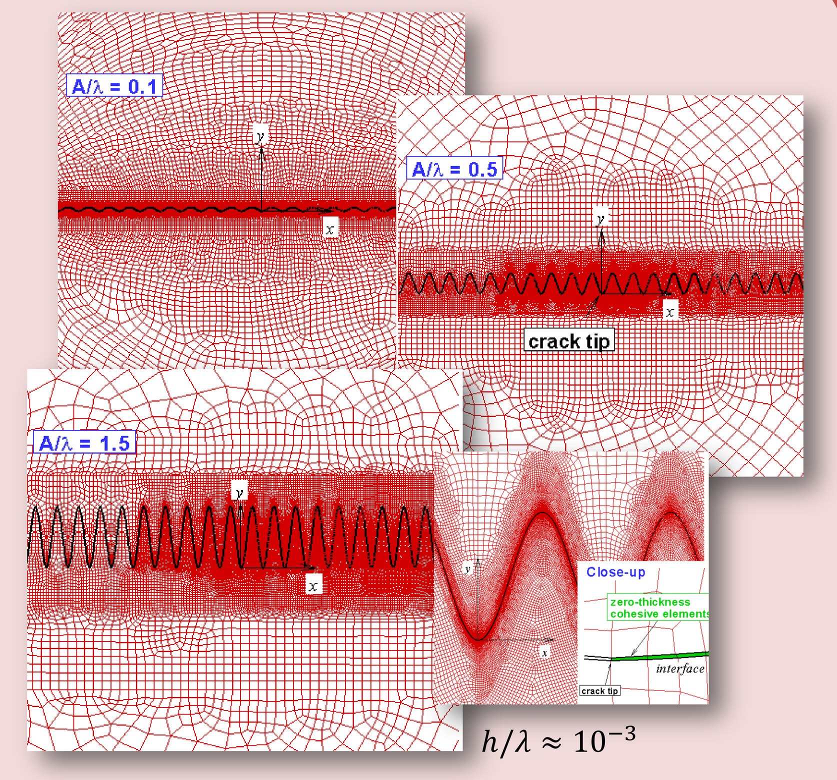
Acknowledgements: Dr. Louis Hector, General Motors
NSF Multiscale Computational Modeling of Cementitious Materials.
International US-POLAND Workshop. October 18-19, 2012, Cracow, Poland.

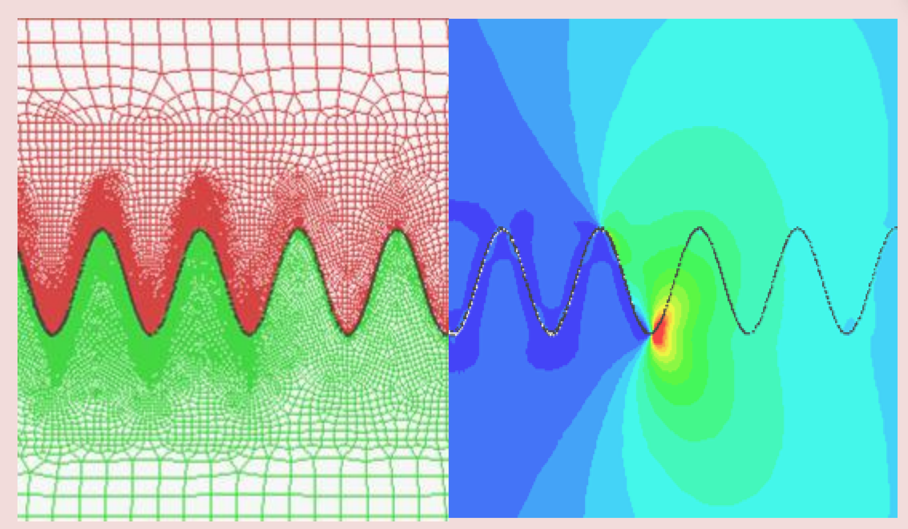
Computational Multi-Scale Material Modeling Laboratory

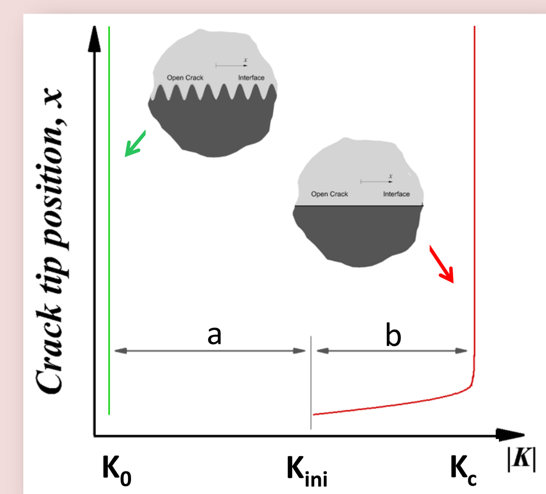
Computational Analysis



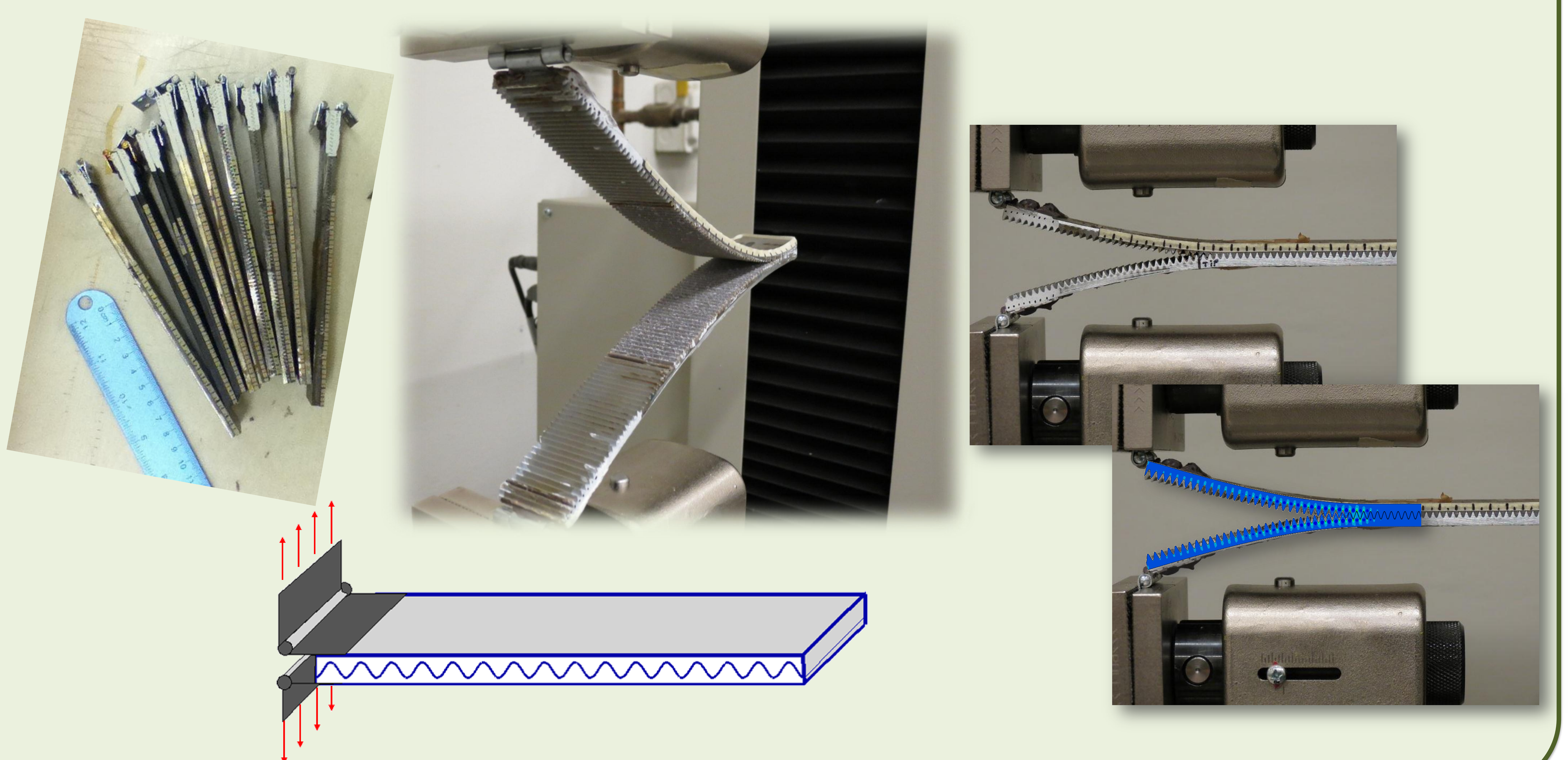
...more on this work



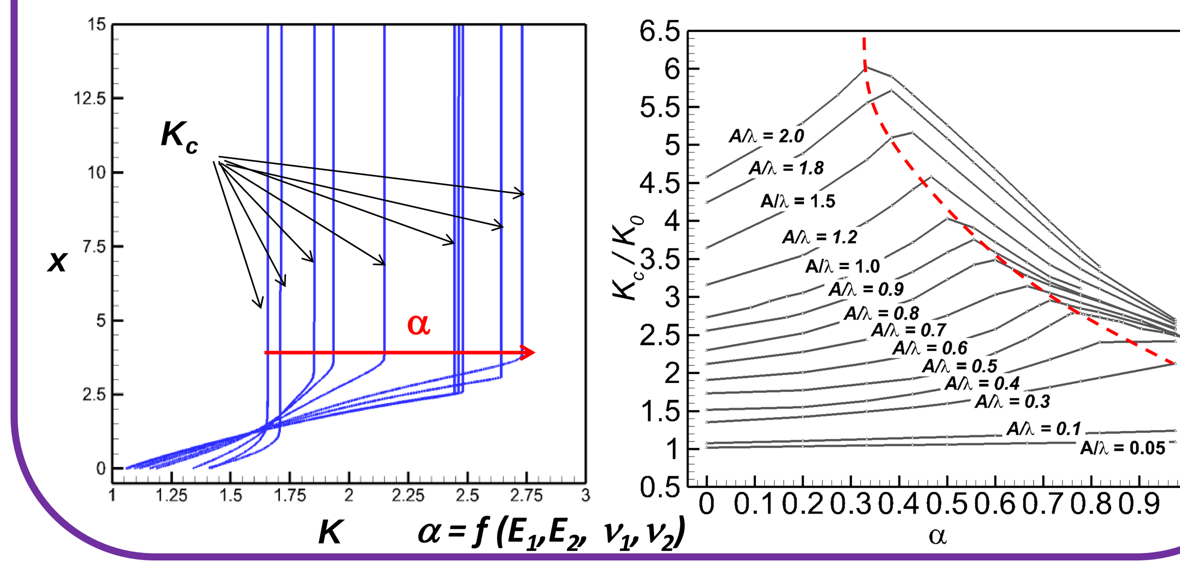




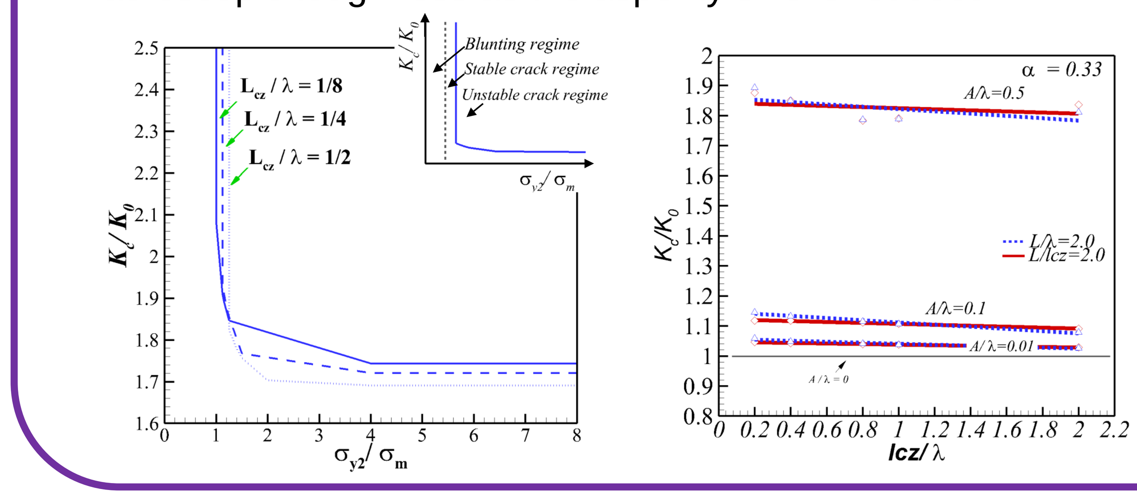
Experimental Analysis



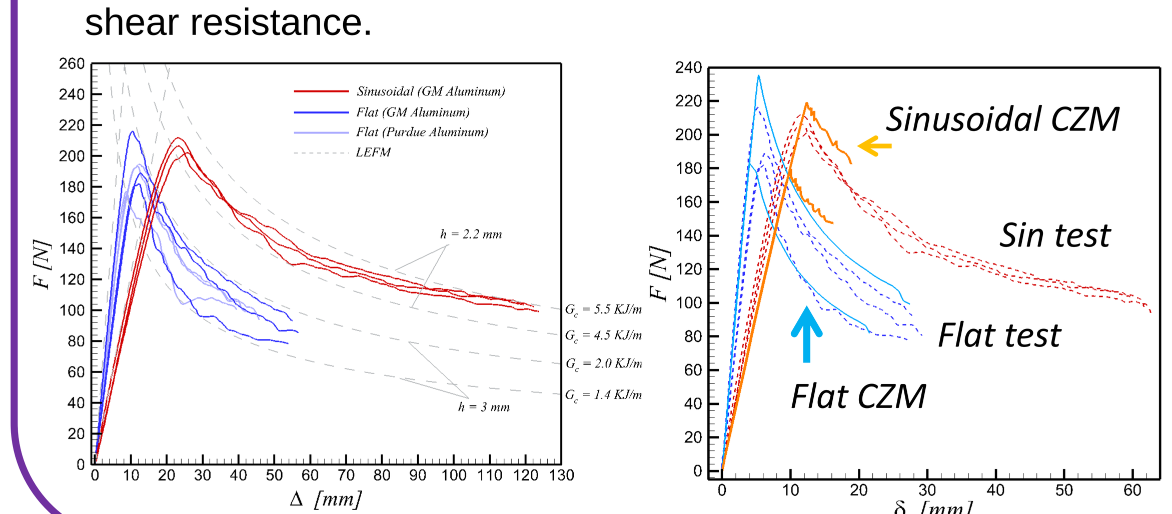
Pattern Aspect ratio: The aspect ratio contributes to the crack growth behavior. When $\alpha<\alpha_{crit}$ continuous crack growth predominates. When $\alpha>\alpha_{crit}$ discontinuous crack growth predominates. The limit within this domains is characterized by a α_{crit} . The maximum K_c/K_o is delimited by α_{crit} .



Size Effects: when dissipation is allowed in the solid materials, the computational model predicts a increase in the macroscopic toughness as the asperity size is reduced



Towards a patterned interface metrics: experiments predict fracture toughness enhancement. The change in the fracture toughness is intrinsic to the interface pattern and not the adhesive shear resistance.



What's next?