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Testing and phase-field modeling of fracture in Al_2O_3/Cr and Al_2O_3/AlSi12 metal-matrix composites under quasi-static and dynamic loads

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Metal-ceramic composites represent advanced materials that combine the hardness of ceramics with the strength and toughness of metals, resulting in high stiffness, wear resistance, and thermal properties. They find applications as structural materials in the aerospace, automotive, and energy sectors, where they are often subjected to severe quasi-static and dynamic loads. Employing phase-field modeling to homogenized domains characterized by effective mechanical properties serves as a solution to avoid the computational costs and limitations associated with modeling real microstructures in metal-ceramic composites. However, determining the appropriate length scale parameter is crucial for successful implementation.

Following [1], this study aims to propose an experimental approach for establishing a physically meaningful length scale parameter in the phase-field modeling of quasi-static and dynamic fracture in metal-ceramic composites with brittle or ductile matrices. To accomplish this objective, a series of quasi-static and dynamic fracture tests are performed at room temperature using a 50J instrumented impact pendulum. The tests involve three-point bending on mode I and mixed-mode I/II V-notched specimens made of Al_2O_3/Cr and Al_2O_3/AlSi12 composites. The Al_2O_3/Cr samples exhibit brittle fracture behavior, while the Al_2O_3/AlSi12 samples show ductile fracture behavior. Detailed studies of the fracture surfaces are conducted to identify fracture micromechanisms in the investigated composites and measure the length of the fracture process zone or the stretching zone ahead of the initial crack tip. The length scale parameter in the phase-field modeling is then set equal to the measured length.

The fracture toughness is determined from the phase-field simulations by fitting the numerical load-displacement curves to the experimental data. The numerically and experimentally determined fracture toughness values are compared to validate the proposed method for the experimental determination of the phase-field length scale parameter.

[1] Darban H., Bochenek K., Węglewski W., Basista M., *Metallurgical And Materials Transactions A*, Vol. 53, p. 2300–2322, 2022.