
Review and perspectives in characterizing anisotropic fracture of nacre-like alumina

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Abstract

In recent decades, researchers have been developing composite materials that mimic the microstructure of natural nacre ("brick-and-mortar" assembly), incorporating components with superior mechanical properties compared to those found in the nature. Among these, Nacre-Like Aluminas (NLA), composed of alumina platelets separated by a glassy phase, have garnered the most attention due to their good tradeoff between strength (470 MPa) and toughness (5.8 MPa.m^{1/2}) achieved within a fully dense ceramic structure **(1)**. The primary reinforcement mechanism that can be found in these composites involves crack deflection at the platelet interfaces, the weakest regions of the material. This deflection increases the surface area over which the crack must propagate, thereby dissipating more energy and significantly enhancing the material toughness. Beyond crack deviation, additional mechanisms, though less dominant, also enhance crack resistance, including platelet interlocking, mineral bridging between platelets, and even crack branching, all of which contribute to the overall improvement in resistance to crack propagation **(2)**.

The unique properties of NLAs are closely tied to their microstructure inducing several reinforcing mechanisms, so they should be associated with their overall anisotropy. This anisotropy is defined by three principal directions of stress application in NLA, referred to as *Across*, *Along*, and *Between* **(3)**, which describe the orientation of crack propagation relative to the microstructure. However, almost all of the studies have been focusing on the "Across notched" configuration because it is the strongest and toughest one when it is just as important or even more so to understand the weakest configuration, the one most likely to be responsible for the fracture of the material under mechanical loading. Nevertheless, only few studies studied NLA anisotropy **(4, 5, 6, 7)**. Therefore, to fully understand NLA anisotropy, detailed characterization of the material properties and interfacial behavior in each of its principal directions under different loading conditions has to be done. This approach is essential for controlling fracture behavior in order to optimizing the material strength and toughness and adapting its performance to specific applications.

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To characterize this anisotropy, bending testing was conducted in each NLA orientation, using both plain and notched samples to evaluate both strength and toughness. A comprehensive characterization was achieved by employing additional techniques to bridge multiple scales—from examining crack characteristics (shape, length, surface, path, and initiation) to performing qualitative and quantitative analyses of microstructural defects (size, type, and location). Further insights were gained through μ -beam flexural tests to estimate interfacial properties and numerical simulations to model and replicate the material's behavior. In summary, this approach offers a more thorough methodology for characterizing the anisotropy of NLAs.

References

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