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ARCHITECTURED CERAMICS WITH IMPROVED TOUGHNESS FOR HIGH TEMPERATURE APPLICATIONS

Abstract

Ceramic materials are excellent candidates for high temperature applications. Conventional ceramics, however, suffer from brittle failure, which limits their applications where mechanical or thermal shocks may exist (e.g., space applications). In this research, a bio-inspired approach is proposed to address the brittleness of conventional ceramics. Many natural materials (e.g., nacre and tooth enamel) demonstrate ductile behavior while mainly composed of brittle mineral building blocks. These brittle building blocks with well-defined architectures offer high stiffness and strength, while a weak polymeric interface between these building blocks often provides the toughness. Inspired by natural materials, a simple, yet scalable procedure, based on cutting and assembly, is employed to fabricate architectured ceramic panels with enhanced toughness behaviour. These panels are examined under out-of-plane quasi-static and impact loading tests while digital image correlation (DIC) is used to study the underlying failure mechanisms. It is found that the architectured ceramic panels demonstrate more energy absorption capability compared to plain ceramic panels by a factor of 5 for quasi-static test and by a factor of 30 for low-velocity impact, depending on the characteristics of architectured ceramics). This improvement comes at an expense of about 50% decrease in stiffness and strength. The DIC results, used for the reconstruction of 3D stresses during the loading stage, reveal that the improved toughness emanates from the relative sliding of neighboring tiles resulting in frictional energy dissipation, a mechanism which is absent in plain ceramics. The finite element analysis method, Workbench LS-DYNA, is used to model quasi static and impact tests and perform a parametric study to investigate effects of different parameters (e.g., dimensions and geometry of each architectured ceramic) on the energy absorption of architectured ceramics. Finally, the experimental results obtained by quasi-static and impact tests are compared with those predicted by the numerical approach to corroborate the numerical predations.