Characterization of the mechanical behavior of fragmented ceramics under impact by using 3D tomographic-based numerical simulation confronted to experimental data

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Abstract

Ceramics are now widely used as front layer of armor configurations against high velocity threats. Indeed, the very high hardness of ceramics such as silicon carbide or boron carbide allows to shatter the projectile and then drastically reduce its perforation potential. A softer backing material (aluminum alloy or composite) is used to absorb the remaining energy through deformation. However, the ceramic under the projectile is a very brittle material that remains intact only during the first microseconds of the impact before fragmenting. Therefore, the mechanical behavior of the fragmented ceramic plays an important role in the performance of the armor.
However, the mechanical behavior of fragmented ceramic is not very well known and especially under impact due to the complexity of the experiments. The so-called tandem impact testing technique (1,2) was considered in the present study. It consists in impacting a ceramic tile two times successively, first, with a flat ended projectile to fragment it and, second, with a conical shaped projectile to perforate the fragmented ceramic tile while measuring the rear side velocity of a backing.

In this study, some SiC Hexoloy® (3,4) tiles were impacted using tandem impacts and some others were scanned using micro-tomography X after the first impact in order to use the obtained fragments distribution for numerical simulation of impact. The mechanical behavior of the fragments has been modeled using the intact behavior of the ceramic based on a JHB (5) constitutive model. The results were compared to data obtained with a homogeneous approach considering the JHB model for the ceramic in its fragmented state. This study should explain the link between the fragments distribution and the mechanical behavior of the ceramic in its fragmented state.

(1) Duplan, Y., & Forquin, P. (2021). Investigation of the multiple-fragmentation process and post-fragmentation behaviour of dense and nacre-like alumina ceramics by means of tandem impact experiments and tomographic analysis. *International Journal of Impact Engineering*, *155*, 103891.

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(2) Zinszner, J. L., Forquin, P., & Rossiquet, G. (2015). Experimental and numerical analysis of the dynamic fragmentation in a SiC ceramic under impact. *International Journal of Impact Engineering*, *76*, 9-19.

(3) Dargaud, M., & Forquin, P. (2022). A shockless plate-impact spalling technique, based on wavy-machined flyer-plates, to evaluate the strain-rate sensitivity of ceramic tensile strength. *Journal of Dynamic Behavior of Materials*, *8*(1), 73-88.

(4) Zinszner, J. L. (2014). Identification des paramètres matériau gouvernant les performances de céramiques à blindage. *These de doctorat, Université de Lorraine.*

(5) Johnson, G. R., Holmquist, T. J., & Beissel, S. R. (2003). Response of aluminum nitride (including a phase change) to large strains, high strain rates, and high pressures. *Journal of Applied Physics*, *94*(3), 1639-1646.