Dynamic radial expansion and fragmentation of porous metal rings

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Abstract

We have conducted dynamic ring expansion tests on 3D-printed AlSi10Mg porous samples utilizing both electromagnetic and mechanical testing techniques. The electromagnetic loading setup developed by Zhang and Ravi-Chandar (2006, 2008) is employed as a benchmark for evaluating and comparing the performance of the experimental configuration recently proposed by Nieto-Fuentes et al. (2023) to investigate the fragmentation of metallic rings using a pneumatic launcher. A total of 69 tests were conducted using expansion rates ranging from 2000 s-1 to 17000 s-1. The tests performed with both experimental techniques were filmed using high-speed cameras to obtain time-resolved information on the mechanics of sample deformation and fragmentation. The recorded data allowed us to determine the number of fragments, the elongation of the specimens at the onset of fracture, and the fragmentation time. Moreover, the fragments ejected from the samples have been soft recovered, measured and weighed. An excellent quantitative agreement has been achieved between the results obtained from electromagnetic and mechanical loading setups regarding the fragments size distribution and the evolution of the number of fragments with the loading rate. This agreement serves as a robust validation for the experimental configuration put forth by Nieto-Fuentes et al. (2023), which allowed reaching higher strain rates than the setup of Zhang and Ravi-Chandar (2006, 2008), and it is notable for its simplicity, fast operation, and quick assembly. The porous microstructure of the rings has been studied before and after testing through X-ray computed tomography unravelling the role of the voids in the dynamic failure of the specimen. Furthermore, the influence of the microstructure on the fragmentation mechanisms has been investigated through finite element simulations that incorporate the initial voids' size distribution of the specimens obtained from X-ray tomography analysis. The numerical calculations results have demonstrated both quantitative and qualitative agreement with the experiments, showing that large pores and clusters favor stress concentration and subsequent fracture initiation. Consistent with the statistical fragmentation theory of Mott (1947) for elastic-plastic materials that break without previous necking, the release waves emanating from the large pore defects and early fractures seem to play a critical role in determining the scale of the fragment size distribution in AlSi10Mg specimens.

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