UNIAXIAL CRUSHING OF SANDWICH PANELS WITH CELLULAR CORES UNDER BLAST LOADING: MODELING AND OPTIMIZATION

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Cellular materials such as metal foams and honeycombs are being considered in a wide variety of structural applications because of their capacity to absorb impact energy. Surprisingly, however, their use under blast loading has often led to enhancement, rather than mitigation, of blast effects. Experiments by Hanssen et al. [1] showed that increased upswing results from the addition of an aluminum foam layer to the face of a massive "pendulum" subjected to blast loading. Nesterenko [2] noted that in these experiments, the blast impulse is imparted primarily to a lightweight plate covering the foam layer, leading to significantly higher kinetic energy than if the same impulse were imparted directly to the more massive pendulum. Xue and Hutchinson [3] noted a similar effect in a computational study of blast loading on sandwich plates, in which the kinetic energy imparted to a sandwich plate was observed to be greater than for a solid plate of the same mass. In spite of this, it was found that deflections of sandwich plates could be significantly less than for the corresponding solid plate. Xue and Hutchinson considered front and back face sheets with equal mass but suggested that further reductions in deflections might be achieved by increasing the mass fraction in the face sheet near the blast.

Motivated by these observations, this paper investigates the influence of mass distribution on the uniaxial crushing of cellular material sandwiched between rigid layers under impulsive pressure loading. A simplified analytical model is developed, and the predictions of this model are compared with explicit finite element computations. In the analytical model, the cellular core material is represented by a rigid, perfectly-plastic, locking model, originally proposed by Reid and Peng [4] for modeling crushing of wood and subsequently applied to cellular metals in a number of studies (e.g., [1,5]). Arbitrary masses of the front and back faces are permitted, and a pressure pulse is applied to the front face with the back face unrestrained. This sandwich model is a generalization of that in [1], which considered a fixed back face, and of that in [5], which considered front and back faces of equal mass with blast loading represented by an initial velocity imparted to the front face. Predictions of this analytical model show excellent agreement with explicit finite element computations, and the model is used to investigate the influence of the mass distribution between the core and the faces. Increasing the mass fraction in the front face is found to increase the impulse required for complete crushing of the cellular core but also to produce undesirable increases in back-face accelerations. Optimal mass distributions are investigated by maximizing the impulse capacity while limiting the back-face accelerations to a specified level.

References

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