Comparative study of the transient behaviour of flat plates composed of various materials under the action of Impulse loading

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1. INTRODUCTION & OBJECTIVE

This work presents a comparative study of the transient behavior of various materials commonly used in the aerospace industry under the influence of impulse loading [1]. Flat plates of identical geometry, boundary condition, and different materials are subjected to impulse loading, and the deflection and stress wave time history is studied. Additionally, the plates with identical areal densities are compared. The plates are subjected to multiple impulse loading, while the analysis is performed considering two finite element models of transient analysis, namely Direct Transient Response (DTR) and Modal Transient Response (MTR).

The aerospace industry commonly relies on two different material categories for aircraft structures. The first category consists of isotropic metals like steel, aluminum, and titanium that have uniform properties in all directions and are well-suited for various aircraft applications. The second category comprises composites reinforced with fibers such as glass, carbon, and aramid, which offer enhanced strength and durability [2].

In terms of mechanical performance, composite materials offer better strength-to-weight ratios than traditional metallic materials; this is due to their unique composition and structure, which allows for greater efficiency and optimization of material properties [3]. These characteristics make composite materials highly desirable for a wide range of applications, including aerospace, automotive, and construction industries [4]. As a result, they are being increasingly used in a variety of structures, including space and underwater vehicles, automotive parts, electronic and medical devices, and sports equipment [5].

When it comes to aerospace applications, structures are often subject to a variety of forces and loading conditions. Loading conditions may be persistent loading conditions that don't change with time. However, loading conditions such as blast shock waves [6], collision impacts [7], harmonic vibrations from aerodynamics, and unbalanced engine forces are time-varying. Hence, it is imperative to conduct an analysis of the transient dynamic behavior of materials, and such an evaluation is essential to ensure the optimal performance of materials [8]. Many previous computational models were developed and validated with experimental setups for this purpose in the ref. [9] [10] [11] [12].

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2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

The present investigation utilized MSC.PATRAN to model the composite laminates and MSC.NASTRAN to serve as a FE solver. The analysis of isotopic and composite plates is done by restricting the plate edges with three sets of boundary conditions (SSSS, CSCS, CCCC). A time history plot of out-of-plane center deflection of the same geometry of flat plate concluded that the isotropic metals performed better than the composites, while composites are lightweight. However, referring to identical areal density, the composites performed better than the isotropic metals. Further, the transient response with different impulses and peak forces is compared considering both the formulations, the DTR and MTR; the accuracy of the same is compared subsequently.

3. REFERENCES

[1] A. Gargano and A. P. Mouritz, "Comparative study of the explosive blast resistance of metal and composite materials used in defence platforms," *Composites Part C: Open Access,* vol. 10, p. 100345, 2023.

[2] M. Mrazova, "Advanced composite materials of the future in aerospace industry," *Incas bulletin,* vol. 5, p. 139, 2013.

[3] Y. M. Tarnopol'skii, "Modern trends in the development of fibrous composites," *Polymer Mechanics,* vol. 8, p. 473–481, 1972.

[4] L. I. N. D. A. Werfelman, "The composite evolution," *AeroSafety World,* vol. 2, p. 17–21, 2007.

[5] J. Reddy, "On refined computational models of composite laminates," *International Journal for numerical methods in engineering,* vol. 27, p. 361–382, 1989.

[6] A. Gargano, R. Das and A. P. Mouritz, "Finite element modelling of the explosive blast response of carbon fibre-polymer laminates," *Composites Part B: Engineering,* vol. 177, p. 107412, 2019.

[7] S. Abrate, "Impact on laminated composite materials," 1991.

[8] A. Bhimaraddi, "Static and transient response of rectangular plates," *Thin-walled structures,* vol. 5, p. 125–143, 1987.

[9] D. Balkan, Ö. Demir and A. Arıkoğlu, "Dynamic analysis of a stiffened composite plate under blast load: a new model and experimental validation," *International Journal of Impact Engineering,* vol. 143, p. 103591, 2020.

[10] R. Houlston, "Finite strip analysis of plates and stiffened panels subjected to air-blast loads," *Computers & Structures,* vol. 32, p. 647–659, 1989.

[11] A. Pagani, M. Petrolo, G. Colonna and E. Carrera, "Dynamic response of aerospace structures by means of refined beam theories," *Aerospace Science and Technology,* vol. 46, p. 360–373, 2015.

[12] J. Chen and D. J. Dawe, "Linear transient analysis of rectangular laminated plates by a finite strip-mode superposition method," *Composite structures,* vol. 35, p. 213–228, 1996.