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Non-Linear Damping Analysis of Sandwich Composite Structures

A. Fereidoon[1], A. Ghoddosian[1] and A. Hazrati Niyari*[2]

[1]Faculty of Mechanical Engineering, Semnan University, Iran

[2]Department of Mechanical Engineering, Islamic Azad University-
Semnan Branch-Iran
*e-mail: a.hazratii@yahoo.com

Abstract

The purpose of this paper is comparsion between damping behavior of PMI and aluminum foam core of sandwich composite panels. In this study A numerical modeling of the nonlinear damping behavior in axisymmetrical conditions was performed using the ABAQUS commercial software. Damping is a useful parameter for controlling the vibration in moving structures. Due to their high stiffness and strength to weight ratios, composite sandwich structures have proven their usefulness in a large number of applications in various technical fields, especially in aeronautics, automotive and civil engineering. The plastic response of the PMI foam core is modeled by the software. The present work should be considered as a step towards developing a more sophisticated numerical model capable of describing nonlinear damping as well as indentation mechanical behavior of sandwich structures.
Keywords:Abaqus software; Damping behavior; Composite panel; Indentation; Plastic response.

1. Introduction

Composites offer smarter structural design than conventional materials because of their superior properties such as light weight, high specific strength and stiffness. Therefore, it is necessary to develop damping prediction methods and determine the most efficient method for predicting the damping of various kinds of composites. In order to identify the PMI foam behavior and numerical simulation review papers [2]. The initial works on the damping analysis and finite element were reviewed extensively in review papers [1,3,4].

when the foams undergo large deformations, the core behavior is non-linear (it crushes) and this leads to formation of a residual dent after unloading. Thus, it is necessary to introduce this non-linearity in the analysis of the damping response of sandwich composite structures. The purpose of this paper is to show how the transverse shear effects combined with a finite element analysis allows us to describe the damping characteristics and the dynamic response of structures constituted of laminates, laminates with sandwich materials.

2. Materials

The present study concerns sandwich composite beams fabricated with Rohacell WF51 Foam and aluminum foams core with a thickness of 40 mm and 1.5 mm thick laminated face sheets. The laminate materials are constituted of E-glass fibres in an epoxy matrix. The nominal density of the Rohacell WF51 foam was 51 kg/m^3. Table.1 shows mechanical properties of sandwich constituents as used in the finite element modeling.

Table 1. Mechanical properties of sandwich constituents as used in the finite element modeling.

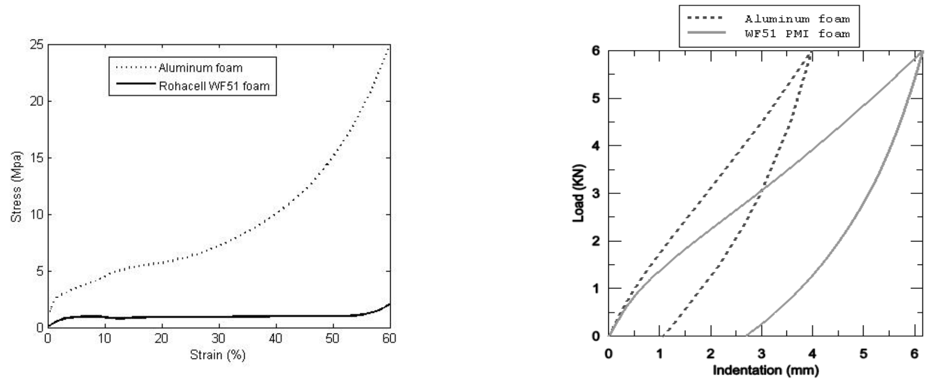
		E_{xx} (Gpa)	E_{yy} (Gpa)	E_{zz} (Gpa)	G_{xy} (Gpa)	G_{yz} (Gpa)	G_{zx} (Gpa)	υ_{xy}	υ_{yz}	υ_{xz}
Core	Rohacell WF51 Foam	0.085	0.085	0.085	0.03	0.03	0.03	0.42	0.42	0.42
	Aluminium Foam	0.06	0.06	0.06	0.15	0.15	0.15	0.32	0.32	0.32
Face	Composite	20.3	4.48	20.3	2.5	2.5	8.5	0.05	0.15	0.15

2. Modelling of sandwich composite panel

The purpose of the finite element analysis was to predict the damping behavior of foam core sandwich composite beams by taking into account both material and geometrical non-linearity. An axisymmetrical idealization was applied for the core, the face sheets and the indentor Four-nodded axisymmetric (CAX4) finite elements were used to discrete the sandwich core and the composite face sheets. For impact analysis the speed at the indentor is 4 mm/mint. All degrees of freedom of the indentor were constrained, except the vertical translation. In order to impose the load, the prescribed vertical displacement conditions were applied to the indentor. The contact interaction between the upper face sheet of the panel and the indentor was modeled by the contact surfaces provided by the ABAQUS package.

The software displays the adopted finite element model (mesh and boundary conditions) of the system ‘‘indentor sandwich panel’’.The load applied to indentor is 6 KN. The plastic part of the response of the PMI foam core material was modeled using the CRUSHABLE FOAM and the CRUSHABLE

FOAM HARDENING options in the ABAQUS software. The hardening behavior was defined in terms of uniaxial compression yield stress versus corresponding logarithmic plastic strain. Fig.1(a) shows the stress–strain curve obtained from the test and Fig.1(b) Comparison of the Load-indentation curves between Aluminum foam and PMI foam deduced from the finite element modeling. Along the curve, characteristic points were selected (in terms of nominal stresses and strains) and transformed into true (Cauchy) stresses and logarithmic plastic strains which were used as input data in the card CRUSHABLE FOAM HARDENING. Due to the elastic-plastic behavior of the foam core the load–indentation curves have a generally non-linear shape that was obtained from the ABAQUS modeling.



(a) (b)

Fig. 1 (a) stress–strain curves under uniaxial compression, (b) Comparison of the Load-indentation curves between Aluminum foam and PMI foam deduced from the finite element modeling**.**

3. Damping analysis of foam core sandwich panels

In order to calculate the dissipation energy in composites, it is essential to accurately evaluate the basic damping loss factors. The literature contains many damping studies pertaining to full coverage of beams and plates with a uniformly distributed constrained layer. However, a much smaller number of studies look into partial coverage, in which the spatial distribution of the damping patches is as important as the thicknesses and material properties of the layers. In the case of studies on shells completely covered with the treatment, many researchers have investigated the variation of natural frequencies and modal loss factors and damping for different geometric and material properties, and for various boundary conditions, e.g, A.Fereidoon, I.W. Jones [5] , Markuš [6]. Modelling can be applied to evaluate the damping properties of structures constituted of laminates. Fig.2 shows the evolution of the plastic zone in the foam core deduced from the modeling procedure. At small deflections of the face sheet, the plastic zone is first developed in radial direction.When the ability of the face sheet to distribute the load in radial direction is exceeded, the plastic zone begins to grow down in the core. Fig.3 shows the evolution of the displacement field deduced from the computer simulations. Fig.4 (a) shows the maximum damping obtained for composite sandwich panel with WF51 PMI and aluminum foam cores and Fig.4 (b) shows strain energy-time obtained from the finite element modeling.

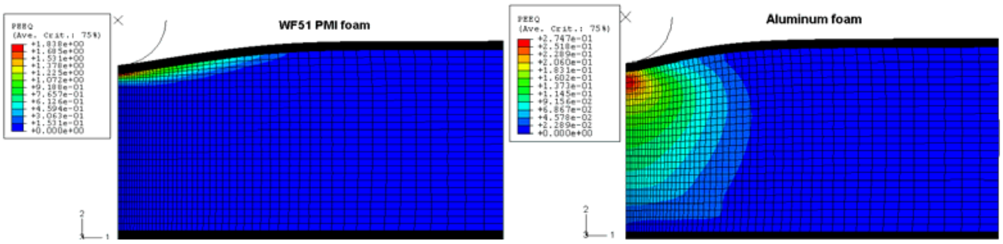


Fig. 2. Predicted contours of the volumetric compacting plastic strain for WF51 PMI and aluminum foams of the composite sandwich panel.

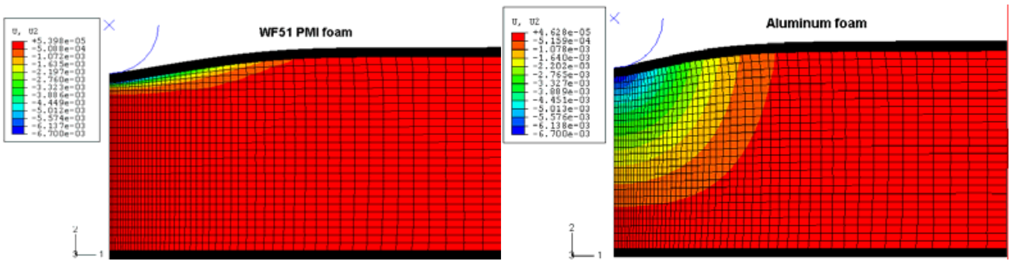
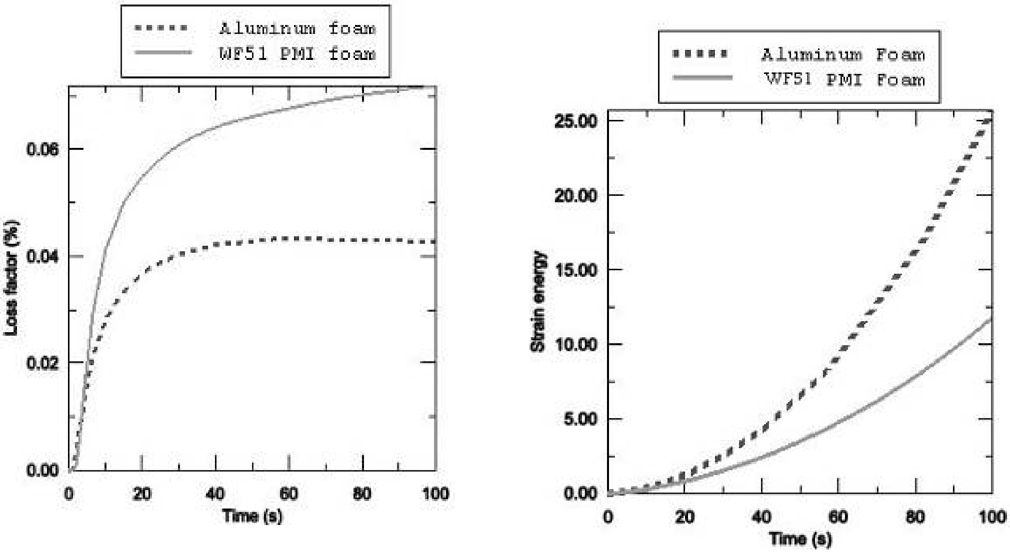


Fig. 3. Evolution of the displacement field for WF51 PMI and aluminum foams of the composite sandwich panel.



(a) (b)

Fig. 4. (a) Comparison of damping loss factor (η) for WF51 PMI and aluminum foams of the composite sandwich panel obtained in the finite element analysis, (b) Comparison of strain energy-time for WF51 PMI and aluminum foams of the composite sandwich panel obtained in the finite element analysis.

4. Conclusion

The purpose of this paper is comparsion between damping behavior of PMI and aluminum foam core of sandwich composite panels. 2D finite element modeling procedure are used for analyzing the non-linear damping behavior of foam and aluminum cores sandwich composite beams. The core was modeled as an elastic–plastic material with hardening. The large deformations induced in the case of localized loading also were taken into account in the modeling. The face sheets were assumed linear-elastic and quasi-isotropic. The indentor was modeled as a rigid cylinder. All degrees of freedom of the indentor were constrained, except translation in vertical direction (normal to the upper face sheet plane). A finite element model was developed capable of describing both loading and frequency steps. The strategy, outlined in the present article, can also be used for analysis of damping mechanical behavior of sandwich panels.

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