Buckling Analysis of Hybrid Bio-composite Plates based on Finite Element Method

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1. INTRODUCTION & OBJECTIVE

In recent days, there has been a rapid growth of bio-composites in industrial applications, research and innovation due to various advantages of these materials compared to synthetic fibre composites. Natural bio-fibres especially plant fibres such as sisal, kenaf, pineapple, ramie, flax, cotton, hemp, jute, bamboo, banana, etc. are generally used as a source of lignocellulosic fibres, which are widely used to reinforce composite materials. Natural fibres are renewable, biodegradable, low-density, low-cost materials with satisfactory mechanical properties, but it cannot replace synthetic fibres in terms of strength. The mechanical strength of natural fibres can be increased by combining them with synthetic fibres using the technique of hybridization, which is used to form hybrid composites. Bio-composite structures are laminated structures, whether they are single fibre or hybrid fibre systems, that are susceptible to delamination caused by manufacturing defects, object impacts, or high stress concentrations due to geometric discontinuities. When a delaminated composite plate is compressed in-plane, local buckling of the delaminated area may occur before global buckling. Therefore, the composite plate has a lower ability to resist compressive loads. The reduction in load carrying capacity due to buckling depends on the material, shape and position of the ply orientation. Therefore, understanding the effects of buckling is necessary to properly design and safe use of hybrid bio-composite plates [1].

In this study, hybrid bio-composite plates have been considered with three different fibres (carbon, flax and aramid) in unidirectional fabric form with epoxy resin and the effects of hybridization on buckling were investigated. The hybrid plates were modelled and analysed in the finite element software ANSYS 16.0, and the numerical results were validated with the experimental results available in the literature [2]. Various parametric studies are performed to determine the critical buckling loads considering different ply orientation and ply sequence.

1.1 Material and Specimen preparation

The materials used for analysis are unidirectional fibre-reinforced epoxy-carbon, epoxy-aramid and epoxy-flax composites. The first two are synthetic fibre composites and the third is natural fibre composites. All of these composites are made with 12 no. of symmetrical layer, and cross-ply laminated layers. The orthotropic elasticity properties of carbon epoxy, aramid epoxy and flax epoxy are listed in Table 1.

Table 1: Material properties

Type of Composite	$E_1 = E_2$ (MPa)	$E_3 = 0.6E_1$ (MPa)	$G_{12} = G_{23} = G_{13}$ (MPa)	μ_{12}	$\mu_{13} = \mu_{23} = 0.6\,\mu_{12}$
Carbon/epoxy (C)	49650	29790	5 000	0.1	0.06
Aramid/epoxy (A)	26780	16068	2560	0.095	0.057
Flax/epoxy (F)	14500	8700	1960	0.153	0.0918

1.2 Modelling of hybrid bio-composites plates

The buckling analysis of hybrid bio-composite plate has been carried out on finite element software ANSYS. The finite element formulation of the composite plate has been accomplished using an 8-noded iso-parametric plate bending element SHELL 281 having six degrees of freedom per node. The first order shear deformation theory has been deployed for the element. The buckling loads of the composite plates with ply sequences (ACF, CAF, CFA) obtained from the present study is validated by comparing with the published experimental result and followed by the parametric studies.

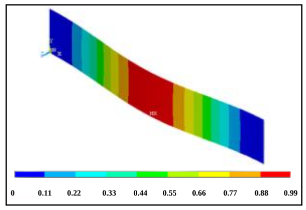

Fig 1. Hybrid bio-composite: 1st mode of buckling

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The buckling loads for the three different ply sequences (ACF, CAF, CFA) corresponding to the cross-ply orientation $[(0/90/0)4]_S$ have been obtained and the results are shown in Table 3. The obtained results are compared with the experimental results available in Ahmed and Rajput [2]. Both the results are found to be in very good agreement. After the validation, parametric study has been carried out to analyse the effect of various boundary conditions viz. SSSS, CCCC, SSCC & SCSC on the buckling behaviour of the hybrid bio-composite plate subjected to the uniaxial compressive loading. The buckling loads for the different boundary conditions are given in Table 4. It may be concluded that the results obtained in the present study may be considered as benchmark problem. Hence more study on Hybrid bio-composite plates are required to enhance the knowledge for future research.

Table 3: Buckling Load for the symmetric Hybrid Composite Plate

Orientation	Ply Sequence	Buckling Load (N)		
		Present Study	Ahmad and Rajput [2]	Deviation (%)
$[(0/90/0)_4]s$	ACF	87.154	85.633	1.77
	CAF	115.484	113.23	1.99
	CFA	109.26	107.44	1.69

Table 4: Buckling Load for the Carbon, Aramid & Flax Composite Plate

Ply Orientation	Ply Sequence	Buckling Load (N)			
		SSSS	CCCC	SSCC	SCSC
$[(0/90/0)_4]s$	CAF	507.45	1120.8	732.56	915.64
	CFA	515.40	1139.8	744.47	930.82
	ACF	501.87	1108.9	724.63	905.80

*S=Simply supported, #C=Clamped

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2. Sameer Ahmad, Leela Dhar Rajput, "Buckling Analysis of Inter-ply Hybrid Composite Plate", ScienceDirect, Materials Today: Proceedings 21 (2020) 1313–1319, 2214-7853 © 2019 Elsevier Ltd.