Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(Special Issue 4) (2021) 613-616
DOI: 10.22060/mej.2020.18025.6716

Effect of adding carbon nanotubes into the matrix material on the buckling behavior of glass/epoxy composite plates: An experimental study

H.R. Sabermanesh, M. Ghannad* , S.M. Hosseini Farrash

Faculty of Mechanical Engineering, Shahrood University of Technology, Shahrood, Iran.

ABSTRACT: In this research, buckling of polymer matrix composite plates containing unidirectional glass fibers under in-plane pressure load is investigated. Moreover, the effect of adding carbon nanotubes as reinforcement into the matrix material on the critical buckling load of composite plates is studied. Using hand lay-up method, rectangular glass/epoxy composite plates with and without carbon nanotubes were fabricated. 0.25, 0.5 and 1.0 weight percent of carbon nanotubes were added to the epoxy resin and composite plates were subjected to the longitudinal in-plane pressure load. The plates were tested under fix ended boundary conditions utilizing Instron hydraulic universal testing machine. Based on the results, adding 0.5 weight percent of carbon nanotubes has the most influence on the critical buckling load of the plates. Results show that adding 0.5 weight percent of carbon nanotubes into the matrix material increases the critical buckling load of the carbon nanotubes /glass/epoxy plate more than two times with respect to that of glass/epoxy composite plate. Furthermore, when the carbon nanotubes weight percent reaches 1 %, because of carbon nanotubes agglomeration, carbon nanotubes are not dispersed well into the epoxy resin and the critical buckling load of the composite plate decreases. To validate the results, buckling analysis of glass/epoxy composite plate was done in Abaqus finite element software. Finite element models confirm the experimental results obtained.

Review History:

Received: Mar. 02, 2020
Revised: May. 08, 2020
Accepted: Aug. 31, 2020
Available Online: Sep. 03, 2020

Keywords:

Composite plate
Carbon nanotube
Glass/epoxy fibers
Buckling analysis
Experimental study

1- Introduction

Sheets are one of the most important and widely used structures in various industries. These structures are utilized in industries such as aerospace, automotive, military and marine. One of the most important issues regarding sheets is the weight of these structures, which should be reduced as much as possible. To this end, the use of composites to replace metals is rapidly expanding. Polymer-based composites, including glass or carbon fibers, are extensively used in industry. These composites are employed in the construction of various types of flying robots, naval vessels, electric vehicles, oil and gas transmission pipes, wind turbine blades, artificial members and other similar applications. Another important issue in the design of composite structures is the stability of these structures against the loads. The buckling phenomenon causes instability of composites and much effort has been made to increase the critical buckling load of these light structures.

Since the discovery of Carbon Nanotubes (CNTs) by Iijima [1], mechanical, electrical and thermal properties of CNT reinforced composites have been investigated in several research studies. In hybrid or multi-scale composites, the matrix material is reinforced with both nano-fillers and micro fibers [2]. Medhoe and Subbarao [3] investigated the reinforcing effect of carbon nanotubes on polymer composite sheets under static loading. Azadi and Rostamiyan [4] employed the Taguchi method and studied the influence of three independent variables (carbon fiber orientation, nano clay and CNT weight percent) on the buckling force of hybrid laminated nanocomposites. Zamani et al. [5] demonstrated the influence of nano-clay on buckling behavior of glass fiber reinforced polymer grid-stiffened nanocomposite shells. Eslami-Farsani et al. [6] utilized an experimental method and investigated the effect of the Multi-Walled CNTs (MWCNTs) addition at various weight percentages with respect to the matrix on the flexural behavior of grid composite structures. Bozkurt et al. [7] produced S-glass fiber-reinforced composite laminates with epoxy resin and different weight contents of nano-clay particles. They analyzed critical buckling loads characteristics along with axial and lateral direction.

To the best knowledge of the authors, few studies have focused on the buckling behavior of hybrid composites. Moreover, using Scanning Electron Microscopy (SEM) images, the effect of CNT-reinforced matrix on the critical buckling force of hybrid composites is discussed in this work. Glass/epoxy and CNT/glass/epoxy with different weight percentages of CNTs are fabricated. Epoxy resin containing 0.25, 0.5 and 1.0 weight percent (wt. %) of CNTs is used to manufacture CNT included specimens. Employing uniaxial buckling test, the critical buckling load for different types of plates is experimentally obtained.

*Corresponding author's email: mghannadk@shahroodut.ac.ir

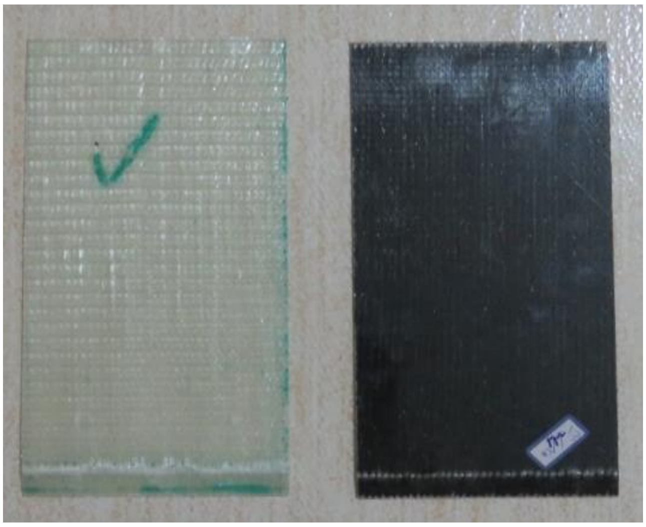

Fig. 1. Glass/epoxy composite plate sample (left) and CNT/glass/epoxy composite plate (right)

Fig. 2. Buckling of composite plate under pressure loading

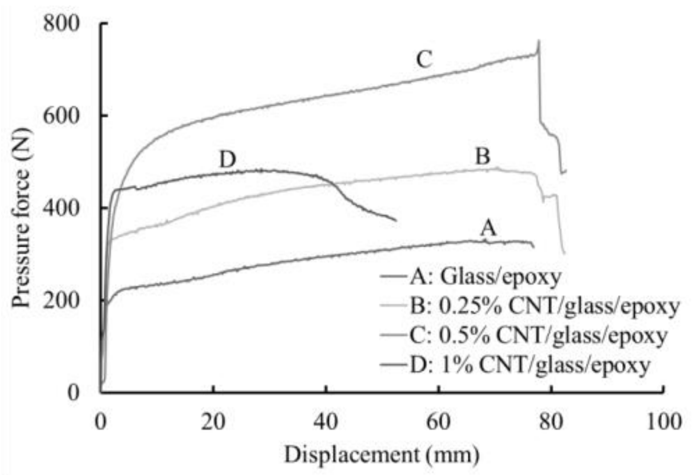

Fig. 3. Effect of adding CNTs with different weight percentages on the force-displacement graph of composite plates

2- Methodology

Unidirectional glass/epoxy and CNT/glass/epoxy hybrid composite plates are manufactured. The combination of mechanical steering and sonication method are used to disperse CNTs into the epoxy resin. The hand layup method is utilized to manufacture three-ply unidirectional composite plates. Plates with different materials are shown in Fig. 1.

A hydraulic universal testing machine (INSTRON STM-150) is used to perform the tensile and buckling tests (Fig. 2).

3- Discussion and Results

To investigate the effect of adding CNTs into the matrix material of glass/epoxy plate, the experimental buckling test was utilized. Three samples of each material were subjected to in-plane unidirectional pressure load. Pressure force-displacement diagrams for glass/epoxy, 0.25%CNT/glass/epoxy, 0.5%CNT/glass/epoxy and 1%CNT/glass/epoxy laminated plates are demonstrated in Fig. 3.

The critical buckling loads (P_{cr}) are extracted from these graphs and summarized in Table 1.

As Table 1 shows, the average critical buckling load for glass/epoxy plate is 191.14 N. Based on the Table, adding 0.5 wt. % of CNTs into the matrix material results in a noticeable improvement in the amount of critical buckling load. This number is 513.42 N for 0.5%CNT/glass/epoxy specimen which indicates 168% increase with respect to that of glass/epoxy specimen. Moreover, the SEM images are taken from the fracture surface of the specimens. Fig. 4 illustrates the proper dispersion of CNTs into the epoxy resin for 0.5%CNT/glass/epoxy specimen.

Fig. 5 represents that adding 1 wt. % of CNTs into the epoxy resin cause the agglomeration of CNTs in some regions of the matrix.

Table 1. Critical buckling loads for composite plates

Plate material	P_{cr} (N)	Improvement (%)
Glass/epoxy	191.14	0.00
0.25%CNT/glass/epoxy	321.16	68.02
0.5%CNT/glass/epoxy	513.42	168.61
1%CNT/glass/epoxy	424.87	122.28

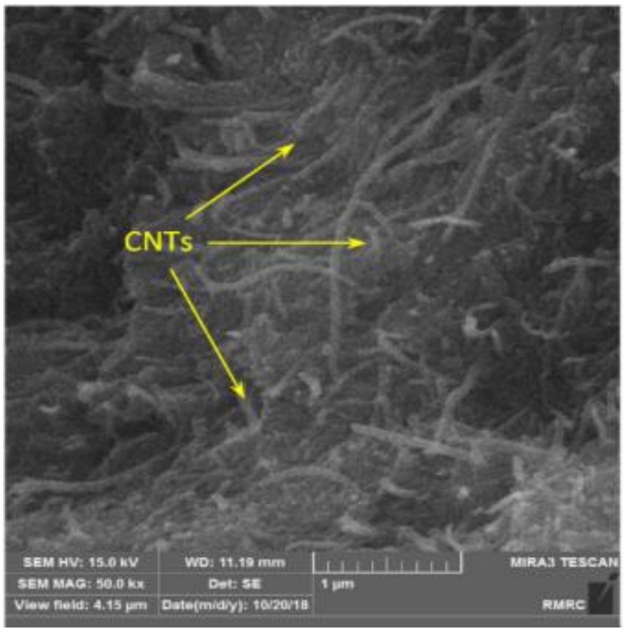

Fig. 4. Homogeneous dispersion of CNTs into the matrix material for 0.5%CNT/glass/epoxy composite plate

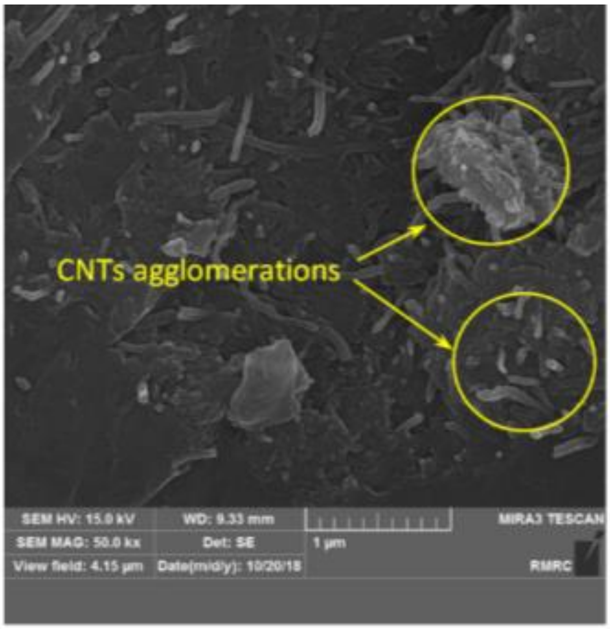

Fig. 5. Nonhomogeneous Dispersion of CNTs into the matrix material for 1%CNT/glass/epoxy composite plate and existence of CNTs agglomerations

4- Conclusions

In this study, the critical buckling load of glass/epoxy and CNT/glass/epoxy plate-shaped specimens are obtained experimentally. Based on the results, a remarkable increase in the amount of critical buckling load is observed when 0.5 wt. % of CNTs is added to the epoxy resin.

References

[1] S. Iijima, Helical microtubules of graphitic carbon, Nature, 354(6348) (1991) 56-58.

[2] M. H. Farrash, M. Shariati, J. Rezaeepazhand, The effect of carbon nanotube dispersion on the dynamic characteristics of unidirectional hybrid composites: An experimental approach, Composites Part B: Engineering, 122 (2017) 1-8.

[3] S. Madhu, V.V. Subbarao, Effect of carbon nanotube reinforcement in polymer composite plates under static loading, International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering, 8(3) (2014) 200- 205.

[4] R. Azadi, Y. Rostamiyan, Experimental and analytical study of buckling strength of new quaternary hybrid nanocomposite using taguchi method for optimization, Construction and Building Materials, 88 (2015) 212-224.

[5] R. Zamani, G.H. Rahimi, M.H. Pol, M. Hedayatian, Reinforcing effect of nanoclay on buckling behavior of nanocomposite grid shells: Experimental investigation, Modares Mechanical Engineering, 15(3) (2015) 411-418, (in Persian).

[6] R. Eslami-Farsani, A. Shahrabi-Farahani, H. Khosravi, M.R. Zamani, A study on the flexural response of grid composites containing multi-walled carbon nanotubes, Journal of Science and Technology of Composites, 4(1) (2017) 101-108, (in Persian).

[7] Ö.Y. Bozkurt, M. Bulut, A. Erkliğ, W.A. Faydh, Axial and lateral buckling analysis of fiber reinforced S-glass/epoxy composites containing nanoclay particles, Composites Part B: Engineering, 158 (2018) 82-91.

HOW TO CITE THIS ARTICLE

H.R. Sabermanesh, M. Ghannad , S.M. Hosseini Farrash, Effect of adding carbon nanotubes into the matrix material on the buckling behavior of glass/epoxy composite plates: An experimental study, Amirkabir J. Mech. Eng., 53(Special Issue 4) (2021) 613-616.

DOI: 10.22060/mej.2020.18025.6716