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Thermal buckling for Nano-composite plate

[1]Ahmed AL-Rajhiy, [2]EmadQasim, [3]HassaneinTahssein

[1]*Babylon University, College of Engineering/ Musayyib,AutomobileEngineering, Iraq.*
[2]*Karbala University, College of Engineering, Oil Engineering, Iraq.*
[3]*Karbala University, College of Engineering, Mechanical Engineering, Iraq.*

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Address For Correspondence:
HassaneinTahssein, Karbala University, College of Engineering, Mechanical Engineering, Iraq.
E-mail : hassanien.tn.89@gmail.com

ABSTRACT

This paper presents a theoretical and experimental analysis of thermal buckling behavior of polymer/MCNTS composite plate. Governing equation and the formula which describe the critical buckling. $T_{cr.}$ Is derivative for thin plate under the effect of thermal oading. A set of sampes which are specially manufactured for this work are tested. The specimen contains different weight fractions of the MCNTS which are 0.5 and 1%. The other composition was PMMA. The experimental results show that the optimum weight fraction of the MCNTS should be within 0.5%. the study shows that the discrepancy between the theoretical and experimental results does not exceed 6%

KEYWORDS:polymer, MCNTS, Nano composite, thermal bucking.

INTRODUCTION

Since the documented discovery of carbon nanotubes (CNTs) in 1991 and the realization of their unique physical properties, including mechanical, thermal, and electrical. Many investigators have endeavored to fabricate advanced CNTs composite materials that exhibit one or more of these properties. Thermal buckling of thin elastic plates is very important in modern engineering[1]. These problems in thermal loads summoned scientists to conduct research and studies for the purpose of improving the plates resistance of heat buckling, they found that for control of this problem depends on several factors, including the dimensions of the plate, boundary condition, the surrounding circumstances and the properties of the constituents of the plate. Dimensions, boundary condition and have varying effects depending on Install case and fit-dimensional[2,3]. The use of composite materials can improve the thermal and mechanical properties of the plate and resists thermal buckling[4,5]. This work deals with the effect of adding the MCNTs to the PMMA plates on critical thermal buckling load. The optimum weight fraction of this addition will be studied.

Theatrical Analysis:

The theoretical analysis of composite plate as in Fig. (1) under the effect of thermal buckling load is based on the classical plate theory. To analysis the problem, Love-Kirchhoff assumptions are used [6]: (1) The straight lines do not undergo axial deformation. (2) Straight lines perpendicular to the mid-surface before deformation remain straight after deformation. (3) The straight liner rotates such that they remain perpendicular to the min-surface after deformation.

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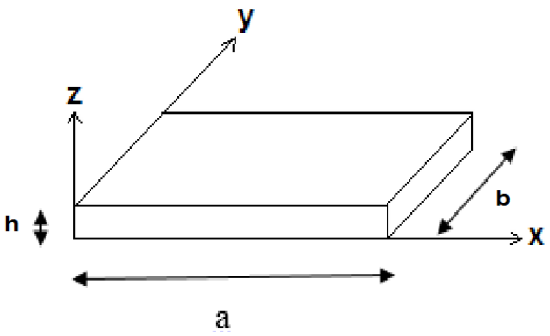


Fig.1: The analysis of plate

For a uniformly heated plate clamped from two opposite edges and free from others, the membrane force can be evaluated directly using the following equation[7]:

$$\left.\begin{aligned} N_x &= \frac{Eh}{1-\upsilon^2}\left(\frac{\partial u}{\partial x}+\upsilon\frac{\partial v}{\partial y}\right)-N_T \\ N_y &= \frac{Eh}{1-\upsilon^2}\left(\frac{\partial v}{\partial y}+\upsilon\frac{\partial u}{\partial x}\right)-N_T \\ N_{xy} &= \frac{E}{2(1+\upsilon)}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right) \end{aligned}\right\} \tag{1}$$

Using the method developed by Meyers and Hyer in conjunction with Galerkins formulation give the buckling force resultants:

$$N_x = \frac{\emptyset_M}{1-\upsilon};\ N_y = \frac{\emptyset_M}{1-\upsilon};\ N_x\,y = \frac{\emptyset_M}{1-\upsilon} \tag{2}$$

Where,

$$\emptyset_M = \alpha E\int_{h/2}^{h/2}\Delta T dt \tag{3}$$

The governing equation of a rectangular plate is:

$$\frac{Eh^3}{(1-\upsilon^2)}\left(\frac{\partial^4 w}{\partial x^4}+2\frac{\partial^4 w}{\partial x^2\partial y^2}+\frac{\partial^4 w}{\partial y^4}\right) = N_x\frac{\partial^2 w}{\partial x^2}+ +2N_{yx}\frac{\partial^2 w}{\partial x\partial y}N_y\frac{\partial^2 w}{\partial y^2} \tag{4}$$

Where N_x, N_y and N_{xy} are the internal forces acting in the middle surface of the plate. The plate is assumed to be a perfectly flat, rectangular plate that is fixed from two edges and free from others, subjected to a uniaxial thermal compressive force N_x in the x-direction [9]. At the fixed-fixed boundary conditions of the plate, both the deflection and slope must vanish along the edge $x=0$, a, as defined:

$$w = 0\,, \qquad \frac{\partial w}{\partial x} = 0$$

Where $W(x)$ is the out-of-plane deflection can be described by [10]:

$$w(x) = \sum\nolimits_{m=1,2,3} A_m\left[cos2\frac{m\pi x}{a}-1\right] \tag{5}$$

where, m indicate the number of half cosine waves in x-direction over the plate. A_m is a constant coefficient. The cosine function describing the out-of-plane deflection automatically satisfies the boundary conditions for plate, at $x = 0$, $x = a$ and $y = 0$, $y = b$ respectively. Substitute Eqn. (5), in to Eqn. (4) gives:

$$\Delta T_{cr} = \frac{\pi^2 h^2}{3(1+\upsilon)a^2\alpha} \tag{6}$$

1. Experimental Work:

3.1 Samples manufacturing:

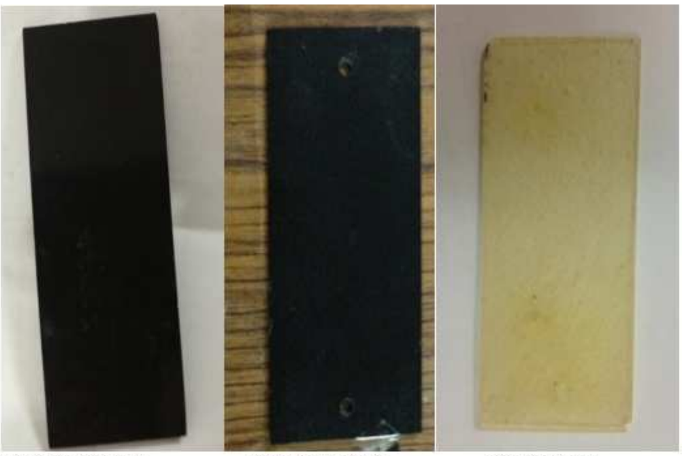
The basic material for samples are Poly-methyl methacrylate (PMMA), liquid and powder, and particles multi carbon nanotube (MCNTs) the dimensions of thermal buckling test specimens (11cm, 5 cm, 0.3 cm), The weight fraction of samples that use at test shown as tables (1)

Table 1: Values of weight of CNTs, matrix and density composite for (16.5 cm^3) for samples thermal buckling test

weight fraction of MCNTs	W_{CNT} (g)	W_{MATRIX} (g)	Density composite (g/cm^3) for (16.5 cm^3)
Neat	0.0	19.47	1.18
0.005	0.097482	19.4964	1.1816
0.01	0.195228	19.5228	1.1832

3.2 Nano composite Preparation:

The specimens test is prepared by dispersing carbon tubes kinetically by using the ultra-sonication device, to achieve better state of dispersion after the nanotubes are treated with liquid and leaves two hours until MCNTs distributed. The treated MCNTs are then added to the unsaturated powder resin and Pour the mixture into the mold and leaves 24 hours and then the mold is placed inside the convection oven at a temperature of 70 for 3 hours, then extracted the mold and sample is grab from it. The surfaces of the samples are mechanically polished to lower the influence of surface flaws. See Fig (2, 3)



0.005 Vf MCNTs 0.01 Vf MCNTs PMMA Neat

Fig. 2: sample after Manufacturing

Fig. 3: the sample after thermal buckling

3.3. Scanning Electron Micrograph (SEM):

This test is done to show the structure of the specimens using scanning electron microscopy technique (SEM). Photos are picked up from the microscope for the tested specimens, as shown in Figs (4, 5). The dark region corresponds to the carbon nanotubes while the brighter correspond to the PMMA.

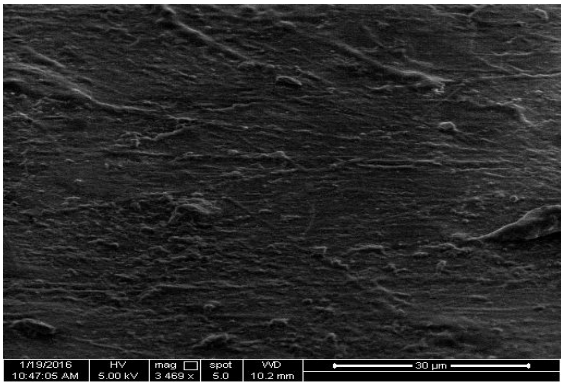


Fig. 4: SEM for the specimen (0.01 V_f CNTs + 0.99 V_pPMMA) nanocomposites

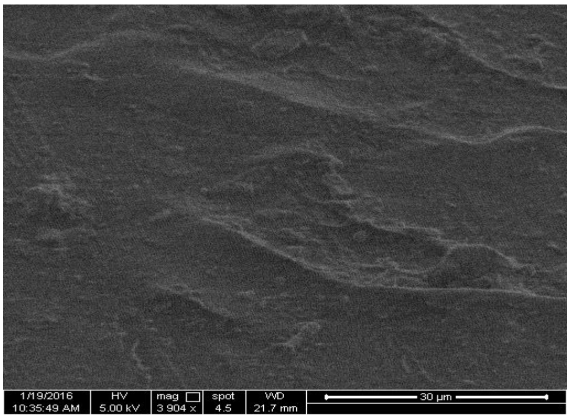


Fig. 5: SEM for the specimen (0.005 Vf CNTs + 0.995 Vp PMMA) nanocomposites

RESULTS AND DISCUSSION

Some theoretical and experimental results will be presented to show the effect of temperature variation on plate buckling. the experimental test of 30 °C. The measured transvers deflection due to thermal loading is recorded in intervals is of 10 °C degrees. The coefficient of thermal expansion (α) and Poisson's ratio (υ) for nanocomposite are find by relying tests as shown in Table. (2) and it's are Compensate in Eqn. (6) to calculate cuticle buckling temperature theoretical.

Table 2: the values thermal expansion coefficient and Poisson's ratio

Weight fraction of MCNTs	thermal expansion coefficient 1/c	Poisson's ratio
0	69.3E-6	0.36
0.005	40E-6	0.337
0.01	58E-6	0.335

The arrangement and operation of the heat source, subjected to a quasistatically increasing uniform temperature field within the region of elastic and the deflection of the plate were measured by dial gauge. The dial gauge device is attached at the center of the plate face, to measure the local in-plane response. For draw the results, chart which represents the x-axis bending values and the y-axis temperature values. The critical buckling temperature of deformed in symmetric mode is determined by the intersection of tangent line from scratch, as described in[11]. And this observed in practice during the sample preparation process, which reduced adhesion force between superficial matrix and MCNTs, which leads to weakening of the interrelationship between matrix and MCNTs, its affects the thermal characteristics. Finally, the critical buckling temperature was comparing with that predicted by nanocomposite plate Eqn. (6). The result is shown in Table. (3), good agreement exists between theory and experiment for the range of temperature and deflection considered in the test. The experimental results are shown in Figs. (6, 7, 8) for different percentage weight fraction of MCNTs. The addition of MCNTs improves the critical temperature value, so that carbon is working on the composition of a series of strong bonds within the polymer, and that is resistant to undergo temperature. There conglomerate MCNTs problem always occur when added to increase rates, so the researchers make improvements

(Functionalization) [12]. in order words, the increase in the weigh fraction of MCNTs higher than 0.5 % MCNTs led to difficulty of penetration between MCNTs and matrix.

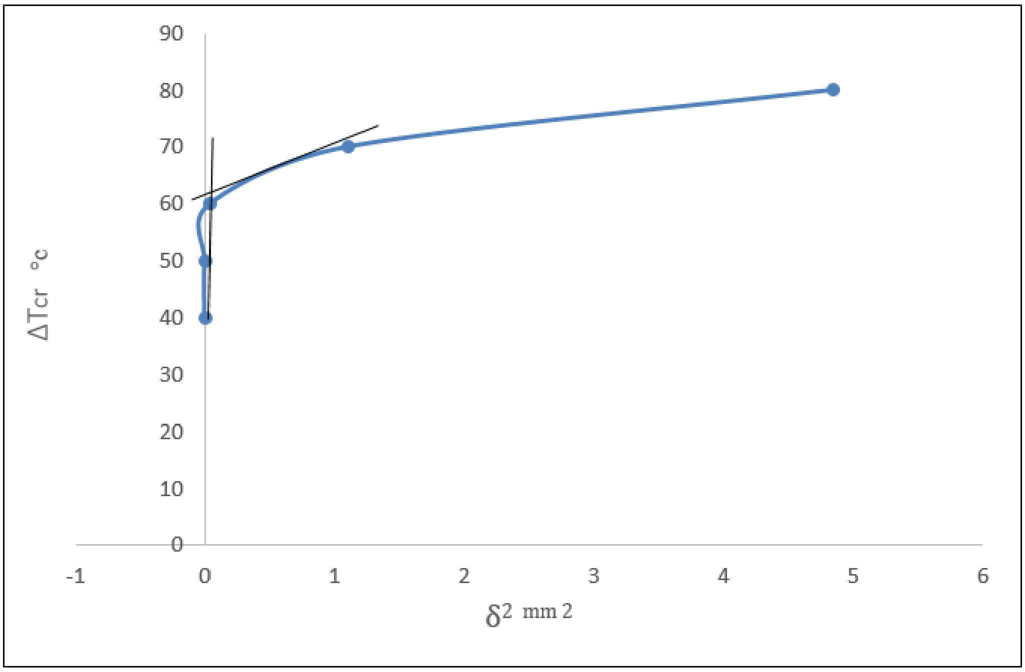


Fig. 6: thermal buckling experiment (□T_{cr}) for sample neat PMMA

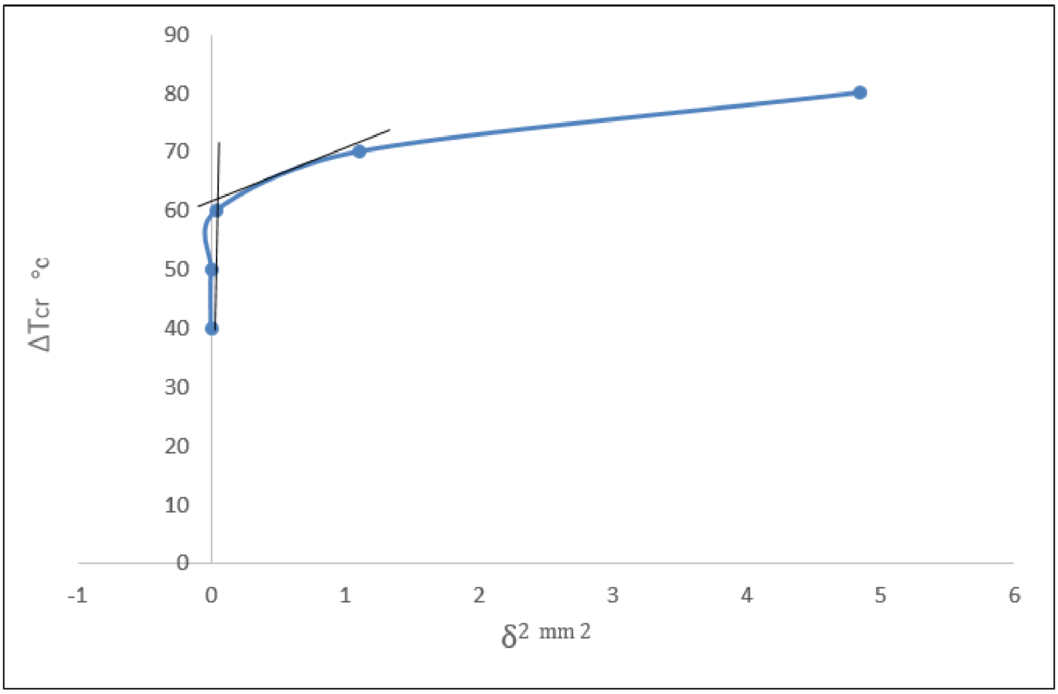


Fig. 7: thermal buckling experiment (□T_{cr}) for Second sample (0.005 V_f CNTs + 0.995 V_pPMMA) Nano composites

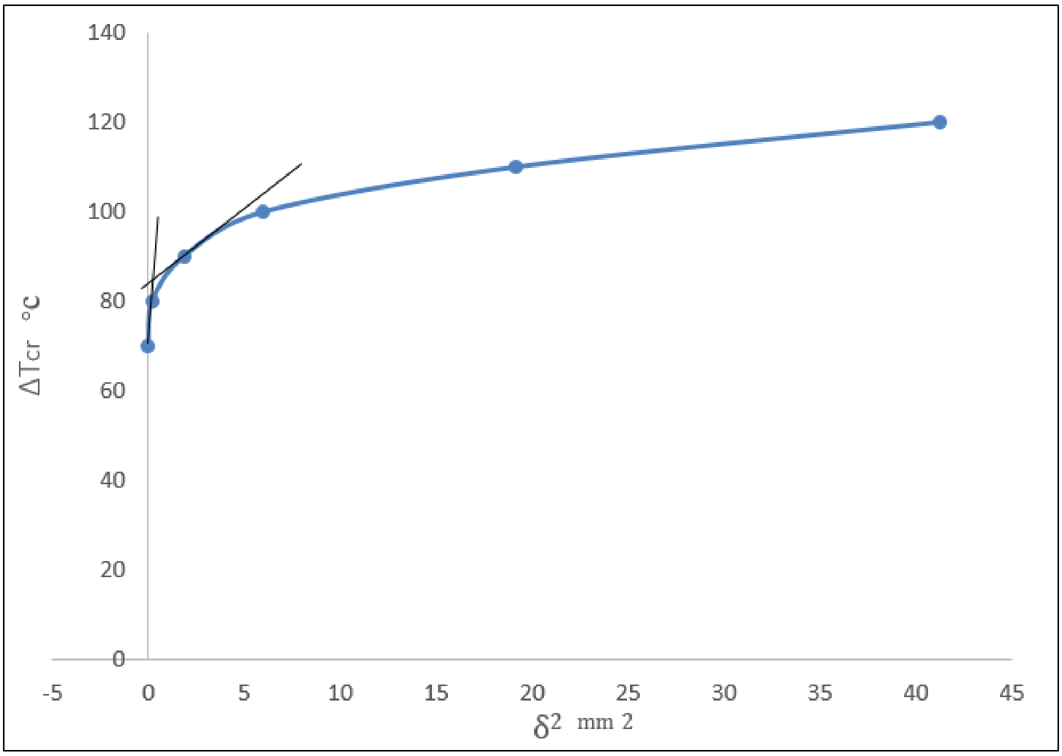


Fig. 8: thermal buckling experiment (□T_{cr}) for sample (0.01 V_f CNTs + 0.99 V_pPMMA) Nano composites

Table 4: Experimental value of the critical buckling temperature

Weight fraction of MCNTs	the critical buckling temperature °C (Experimental)	the critical buckling temperature °C (Theoretical)
0	62	64.1
0.005	117	112.9
0.01	83.3	78

Conclusions:

In this paper, nanocomposite with fixed boundary conditions model is developed to investigate the thermal buckling phenomenon. At different percentage weight fraction of MCNTs. The effective material properties of nanocomposite are evaluated by usin rule of mixture. A general solution has been derived for thin plate subjected to a uniform temperature rise. the first critical buckling temperature has been measured and compared favorably to existing theory. The result is reasonable agreement. Based on the parametric study on the buckling behavior of MCNTs composite plate, some points are concluded.

1- The critical buckling temperature improve with increase the value of MCNTs weight fractions until to reach 1%

2- Increase the proportion of carbon nanotube lead to a conglomerate MCNTs, giving varying properties in general.

3- There different between Experimental and theoretical because:

- Because of the way the sample is installed.
- Weather conditions surrounding.
- Disparity in the distribution of carbon nano composite sample.
- The multiplicity of variables in theoretical calculation equation that rely. on independent tests

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