AIP Conference Proceedings

A study on normal stress in an infinite elastic body with a locally curved carbon nanotube

Cite as: AIP Conference Proceedings **2086**, 030005 (2019); https://doi.org/10.1063/1.5095090
Published Online: 02 April 2019

Kadriye Simsek Alan


View Online


Export Citation

ARTICLES YOU MAY BE INTERESTED IN

Internal groupoid actions and liftings of crossed modules within groups with operations
AIP Conference Proceedings **2086**, 030004 (2019); https://doi.org/10.1063/1.5095089

Multiple-point variogram features for evolving of fractal image compression technique
AIP Conference Proceedings **2086**, 030001 (2019); https://doi.org/10.1063/1.5095086

On the generalized inverse Weibull distribution
AIP Conference Proceedings **2086**, 030002 (2019); https://doi.org/10.1063/1.5095087



AIP Publishing

© 2019 Author(s).

A Study On Normal Stress In an Infinite Elastic Body With A Locally Curved Carbon Nanotube

Kadriye Simsek Alan

Yildiz Technical University
Faculty of Chemistry and Metalurgy, Department of Mathematical Engineering
Davutpasa Campus, 34210, Esenler, Istanbul, Turkey.

ksimsek@yildiz.edu.tr

Abstract. In this study, the results of normal stress values in unidirectional fibrous composite with locally curved carbon nanotube (CNT) were obtained as much as the second approximation and the obtained results were analyzed. For these investigations, were used in the frame of the piecewise homogeneous body model the three-dimensional geometrically nonlinear exact equations of elasticity theory. The boundary value problem is solved by using boundary form perturbation method. For simplicity, a small carbon nanotube is considered and interaction between the carbon nanotubes is not into account. Numerous results are obtained for the normal stress distribution and the effect of the problem parameters on this stress distribution is analyzed.

Key Words: Carbon Nanotube, stress distribution, geometric nonlinearity, locally curved,
PACS: 02.30.Jr, 02.30.Lt, 02.30.Nw, 02.60.Jh, 02.60.Lj, 02.60.Nm

INTRODUCTION

One of the most important factors determining the stress state in fiber composite materials is the curvature of the fibers , [1,5,6,9,10]. For this reason, Akbarov and Guz [2] focused on the stress state in unidirectional composite. The investigation in [2] is made within the framework of a piecewise homogeneous body model, by using the exact three-dimensional equations of elasticity theory. But the unidirectional fibrous composites are traditional materials. Nowadays, nanotechnology is used in the world and the importance of nano materials is increasing day by day. For this reason researchers have concentrated their work on this field. One of these studies Alan and Akbarov [3] studied the normal stresses state in the nanocomposite with a locally curved covered nanofibers. In [4], a method was given for the investigation of the stress distribution in the nanocomposites with unidirectional locally curved and hollow nanofiber. Coban and Kosker [8] was considered the stress distribution in the infinite elastic body containing a single locally curved carbon nanotube (CNT). However, results for the first approximation were obtained only. Increasing the number of approaches is crucial in order to increase the sensitivity of the results

In this study, a mathematical formulation was developed to determine the normal stress distribution of the infinite elastic body containing a single local curved carbon nanotube (CNT) as much as up to the second approximation on the Carbon nanotube and matrix interface . The problem is solved using the boundary form perturbation method. In addition, an Algorithm is designed to solve the related problem. We obtained the numerous numerical results on the normal stress distribution on the surface between the CNT and matrix . The influence of the problem parameters on this distribution were analyzed. The investigation is made in the framework of the three-dimensional geometrically nonlinear exact equations of elasticity theory. The model an infinite body containing a single CNT regards the case where the concentration of carbon nanotubes in the composite is assumed to be low, and the interaction between the carbon nanotubes is neglected.

International Conference of Mathematical Sciences (ICMS 2018)
AIP Conf. Proc. 2086, 030005-1–030005-4; https://doi.org/10.1063/1.5095090
Published by AIP Publishing. 978-0-7354-1816-5/$30.00

FORMULATION OF THE PROBLEM

Infinite elastic body with local curved carbon nanotube is given as in figure 1 . In this work, the cross section of the carbon nanotube normal to its axial line is described two circles of constant radius R_1 and R_2 along the entire length and the body is compressed or stretched of the uniformly distributed normal forces with intensity p acting along axis direction. With the middle line of the carbon nanotube , we associate Lagrangian rectilinear and cylindrical system of coordinates (Figure 1). The carbon nanotube and matrix materials are homogeneous, isotropic and linear elastic. The equation of the carbon nanotube middle line is given as follows:

$$x_1 = F(x_3) = \varepsilon\delta(x_3); x_2 = 0;$$

$$x_1 = A\exp\left(-\left(\frac{x_3}{L}\right)^2\right)\cos\left(m\frac{x_3}{L}\right) = \varepsilon L\exp\left(-\left(\frac{x_3}{L}\right)^2\right)\cos\left(m\frac{x_3}{L}\right) = \varepsilon\delta(x_3). \tag{1}$$

Where A and L geometrical parameter were shown in Figure 1. We assume that A is smaller than L, we describe a small parameter $\varepsilon = \frac{A}{L}, (0 \le \varepsilon < 1)$. The function δ_n^j is the local curving form of the carbon nanotube. For the field equation we refer to Akbarov and Guz [1]. Also, perfect contact conditions are defined at the interfaces S:

$$\sigma^{(1)in}(g_n^j + \nabla_n u^{(1)j})|_{S_1} n_j = 0$$

$$\sigma^{(1)in}(g_n^j + \nabla_n u^{(1)j})|_{S_2} n_j = \sigma^{(2)in}(g_n^j + \nabla_n u^{(2)j})|_{S_2} n_j \tag{2}$$

$$u^{(1)j}|_{S_1} = u^{(2)j}|_{S_2}$$

The conditions are given in Eq. (3)

$$\lim_{r\to\infty} \sigma_{zz}^{(1)} = p$$

$$\lim_{r\to\infty} \sigma_{ij}^{(1)} = 0 \tag{3}$$
$$(ij) \ne zz$$

where n_j are the covariant components of the unit normal vector to the surfaces S. In this way, the mathematical formulation of the problem is completed .The problem was solved by using the boundary form perturbation method given in Akbarov and Guz [1].

NUMERICAL RESULT AND DISCUSSION

The numerical results related to the normal stress are analyzed on the intersection surfaces between the CNT and matrix . We assume that α used in table is smaller than its critical values corresponding to microbukling of the fiber in the matrix in [5]. It is assumed that $\nu^{(1)} = \nu^{(2)} = 0.3$, $\varepsilon = 0.07$, $\theta = 0$ and $\kappa = \frac{R_2}{L}, bk = \frac{h}{R}$ and $\alpha = \frac{p}{E^2}$.

Table 1 shows the effect of various values of $\frac{E^{(2)}}{E^{(1)}}$, m and α on $\frac{\sigma_{\tau\tau}}{|p|}$ normal stress values. In this table, the values of $\frac{\sigma_{\tau\tau}}{|p|}$ are calculated under $\kappa = 0.3, x_3/L = 1.0$, for $m = 0, 1$ and 3 respectively and α is 0.0005 for tension and -0.0005 for compression. From this table it is seen that the absolute maximal values of $\frac{\sigma_{\tau\tau}}{|p|}$ normal stresses increase monotonically with m .

In this work, a method was developed to study the normal stress distribution in an infinite elastic body with a locally curved carbon nanotube. In order to examine the normal stress distribution, the mathematical formulation of the relevant boundary value problem is given. In this case, we assume that the concentration of an infinite elastic body containing a single locally curved carbon nanotube is low. We neglect the interaction between the carbon nanotubes For the investigation, we used the three-dimensional geometrically nonlinear exact equations of the theory of elasticity in the piecewise homogeneous model. We have developed a method that obtains normal stress values as much as up to the second approximation on the interface the carbon nanotube and matrix material. The numerical results were presented for a single locally curved and carbon nanotube. As a result of this research, the following were obtained :

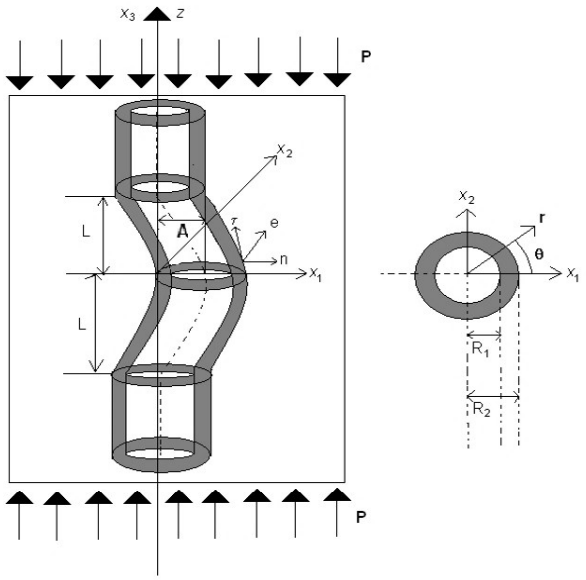


FIGURE 1. The geometry of a Locally Curved Carbon Nanotube and its cross section

TABLE 1. The values $\frac{\sigma_{\tau\tau}}{|p|}$ obtained for various $\frac{E^{(2)}}{E^{(1)}}$

m		0			1			3		
$\frac{E^{(2)}}{E^{(1)}}$		300	500	1000	300	500	1000	300	500	300
Tension	1	1.0551	1.0312	0.9897	1.1593	1.1419	1.1093	1.4986	1.5052	1.5064
	2	1.2328	1.2309	1.2198	1.2996	1.3017	1.2955	1.4940	1.5042	1.5104
Compression	1	-1.0550	-1.0311	-0.9894	-1.1593	-1.1419	-1.1091	-1.4989	-1.5055	-1.5066
	2	-1.2328	-1.2308	-1.2195	-1.2997	-1.3016	-1.2953	-1.4942	-1.5044	-1.5106

(i) When the radius of hollow approach to 0 as a limit , The normal stresses values in the carbon nanotube are the same as to the locally curved nanofiber in an nanocomposite material in same parameter values.

(ii) The absolute maximal values of the normal stresses increase monotonically with m. The numerical results obtained agree with well-known mechanical consideration and, in some particular cases, coincide with known results.

REFERENCES

[1] S.D. Akbarov and A.N. Guz, *Mechanics of Curved Composites*, (Kluwer Academic Publishers, Netherlands, 2000).

[2] S.D. Akbarov and A.N. Guz, Method of Solving Problems in the Mechanics of Fiber Composites With Curved Structures, Soviet Applied Mechanics, 1985, pp. 777-785.

[3] K.S. Alan and S.D. Akbarov, Stress Analyses in an Infnte Elastic Body with a Locally Curved Covered Nanofiber, Mechanics of Composite Materials, 2011, pp.343-358.

[4] K.S. Alan, Normal Stresses in an Infinite Elastic Body with a Locally Curved and Hollow Nanofiber, CMC-Computers Materials & Continua, 2014, pp.1-21.

[5] A.N. Guz, *Failure mechanics of composite materials in compression*, (Naukova Dumka, Russia, 1990).

[6] A.N. Guz, On one two-level model in the mesomechanics of compression fracture of Cracked Composites, Int. Appl. Mech., 2003, pp.274-285.

[7] A.N. Guz, *Fundamentals of the Three-Dimensional Theory of Stability of Deformable Bodies*, (Springer, Newyork, 1999).
[8] F. Coban and R. Kosker, *On The Stress Distribution In An Elastic Body With A Locally Curved Carbon Nanotube*, 3rd Internatonal Symposum On Innovative Technologies In Engineering And Science, Valencia-Spain, 2015, pp.2299-2307.
[9] A. Kelly, Composite Materials: impediments do wider use and some suggestions to overcome these, In Proceeding Book (ECCM-8), Napoles-Italy, 1998, pp. 15-18.
[10] Yu.M. Tarnopolsky, I.G. Jigun and V.A. Polyakov, *Spatially-reinforced composite materials*, (Mashinostroyenia, Moscow-Russia, 1987).