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Research Subjects:
Nanomechanics, Nanomaterials and Biomechanics

Selected Publications:

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Wang, C.Y., Zhang, Y.Y., Wang, C.M. and Tan, V.B.C., **"Buckling of Carbon Nanotubes: A Literature Survey"**, Journal of Nanoscience and Nanotechnology, Vol. 7, No. 12, December 2007 , pp. 4221-4247, doi: 10.1166/jnn.2007.924

ABSTRACT: This survey paper comprises 5 sections. In Section 1, the reader is introduced to the world of carbon nanotubes where their structural form and properties are highlighted. Section 2 presents the various buckling behaviors exhibited by carbon nanotubes that are discovered by carbon nanotube researchers. The main factors, such as dimensions, boundary conditions, temperature, strain rate and chirality, influencing the buckling behaviors are discussed in Section 3. Section 4 presents the continuum models, atomistic simulations and experimental techniques in studying the buckling phenomena of carbon nanotubes. A summary as well as recommendations for future research are given in Section 5. Finally a large body of papers, over 200, is given in the reference section. It is hoped that this survey paper will provide the foundation knowledge on carbon nanotube buckling and inspire researchers to advance the modeling, simulation and design of carbon nanotubes for practical applications.

C. Y. Wang, C. Q. Ru and A. Mioduchowski (Department of Mechanical Engineering, 4-9 Mechanical Engineering Bldg., University of Alberta, Edmonton, Alberta., Canada T6G 2G8), “Axially compressed buckling of pressured multiwall carbon nanotubes”, International Journal of Solids and Structures, Vol. 40, No.15, July 2003, pp. 3893-3911, doi:10.1016/S0020-7683(03)00213-0
ABSTRACT: This paper studies axially compressed buckling of an individual multiwall carbon nanotube subjected to an internal or external radial pressure. The emphasis is placed on new physical phenomena due to combined axial stress and radial pressure. According to the radius-to-thickness ratio, multiwall carbon nanotubes discussed here are classified into three types: thin, thick, and (almost) solid. The critical axial stress and the buckling mode are calculated for various radial pressures, with detailed comparison to the classic results of singlelayer elastic shells under combined loadings. It is shown that the buckling mode associated with the minimum axial stress is determined uniquely for multiwall carbon nanotubes under combined axial stress and radial pressure, while it is not unique under pure axial stress. In particular, a thin N-wall nanotube (defined by the radius-to-thickness ratio larger than 5) is shown to be approximately equivalent to a single layer elastic shell whose effective bending stiffness and thickness are N times the effective bending stiffness and thickness of singlewall carbon nanotubes. Based on this result, an approximate method is suggested to substitute a multiwall nanotube of many layers by a multilayer elastic shell of fewer layers with acceptable relative errors. Especially, the present results show that the predicted increase of the critical axial stress due to an internal radial pressure appears to be in qualitative agreement with some known results for filled singlewall carbon nanotubes obtained by molecular dynamics simulations.

C. Y. Wang, C. Q. Ru, and A. Mioduchowski (Department of Mechanical Engineering, University of Alberta, Edmonton T6G 2G8, Canada), “Applicability and Limitations of Simplified Elastic Shell Equations for Carbon Nanotubes”, J. Appl. Mech., Vol. 71, No. 5, September 2004, pp. 622 – 631, doi:10.1115/1.1778415
ABSTRACT: This paper examines applicability and limitations of simplified models of elastic cylindrical shells for carbon nanotubes. The simplified models examined here include Donnell equations and simplified Flugge equations characterized by an uncoupled single equation for radial deflection. These simplified elastic shell equations are used to study static buckling and free vibration of carbon nanotubes, with detailed comparison to exact Flugge equations of cylindrical shells. It is shown that all three elastic shell models are in excellent agreement (with relative errors less than 5%) with recent molecular dynamics simulations for radial breathing vibration modes of carbon nanotubes, while reasonable agreements for various buckling problems have been reported previously for Donnell equations. For general cases of buckling and vibration, the results show that the simplified Flugge model, which retains mathematical simplicity of Donnell model, is consistently in better agreement with exact Flugge equations than Donnell model, and has a significantly enlarged range of applicability for carbon nanotubes. In particular, the simplified Flugge model is applicable for carbon nanotubes (with relative errors around 10% or less) in almost all cases of physical interest, including some important cases in which Donnell model results in much larger errors. These results are significant for further application of elastic shell models to carbon nanotubes because simplified shell models, characterized by a single uncoupled equation for radial deflection, are particularly useful for multiwall carbon nanotubes of large number of layers.

C.Y. Wang and A. Mioduchowski (Department of Mechanical Engineering, University of Alberta, Edmonton T6G 2G8, Canada), “The effect of dimensional factors on buckling of multiwall carbon nanotubes”, Journal of Applied Physics, Vol. 101, No. 1, June 2009, pp. 014306 – 014306-12, doi: 10.1063/1.2403865
ABSTRACT: Based on a multiple-shell model, a comprehensive investigation has been performed on the effect of three dimensional factors, i.e., aspect ratio, the innermost radius, and the number of layers, on buckling behavior of multiwall carbon nanotubes (MWCNTs) under axial compression or radial pressure. In contrast to previous shell models, which use the single Donnell equation [Wang etal, ASME J. Appl. Mech. 71, 622

(2004)] and thus are only adequate for buckling of MWCNTs of relatively small aspect ratio (e.g., not larger than 10), the present shell model based on the simplified Flugge equation [Wang etal, ASME J. Appl. Mech. 71, 622 (2004)] allows for the study of buckling behavior of MWCNTs without any limitation on their aspect ratios. In addition, the pressure dependence of the interlayer van der Waals interaction coefficient (defined as the second derivative of the interlayer potential energy-interlayer spacing relation) has been considered for pressure-induced buckling of MWCNTs. The relevance of the present shell model for buckling of MWCNTs has been confirmed by the good agreement between the present shell model and available discrete models or experiments. Here, distinct buckling behaviors under axial compression or radial pressure are identified for long and short MWCNTs, separated by a certain critical value of aspect ratio. On the other hand, while the critical buckling load usually changes monotonically with the innermost radius an optimum value of the number of layers associated with the maximum critical buckling pressure is obtained for MWCNTs under radial pressure. In particular, the present shell model shows that the three dimensional factors effecting buckling of MWCNTs are generally interacting with, rather than being independent of, one another.

Tong, F. M., Wang, C. Y. and Adhikari, S. (School of Engineering, Swansea University, Singleton Park, Swansea, Wales SA2 8PP, United Kingdom), "Axial buckling of multiwall carbon nanotubes with heterogeneous boundaries", Journal of Applied Physics, Vol. 105, No. 9, June 2009, pp. 094325-094325-7, doi: 10.1063/1.3125312
ABSTRACT: The finite element method has been employed to study the effects of different boundary conditions on the axial buckling of multiwall carbon nanotubes (MWCNTs). Unlike previous works, both homogeneous and heterogeneous end constraints are considered for the constituent tubes of various MWCNTs comprising shell-type (i.e., the length-to-diameter ratio L/D"j10), beam-type (i.e., L/D"k10), and the two different types of constituent tubes. The results show that clamping the individual tubes of simply supported or free MWCNTs exerts a variety of influences on their buckling behaviors depending on the type of the MWCNTs, the position, and the number of the clamped tubes. Clamping the outermost tube can enhance the critical buckling strain up to four times of its original value and can shift the buckling modes of those MWCNTs consisting both shell- and beam-type tubes. In contrast, little difference can be observed when simply supported ends of MWCNTs are replaced by free ends or vice versa. Explicit buckling mode shapes obtained using the finite element method for various physically realistic cases have been shown in the paper.