Professor Mary C. Boyce

See:
http://meche.mit.edu/people/faculty/index.html?id=11
http://en.wikipedia.org/wiki/Arruda%E2%80%93Boyce_model

Ford Professor of Engineering, Head of Mechanical Engineering Department
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Biographical Sketch:
Professor Mary C. Boyce is the Ford Professor of Engineering and Department Head of Mechanical Engineering at the Massachusetts Institute of Technology. Professor Boyce earned her B.S. degree in Engineering Science and Mechanics from Virginia Tech; and her S.M. and Ph.D. degrees in Mechanical Engineering from the Massachusetts Institute of Technology. She joined the M.I.T. faculty in 1987. Professor Boyce teaches in the areas of mechanics and materials. Her research areas focus primarily on the mechanics of elastomers, polymers, polymeric-based micro- and nano-composite materials, lattice- structured materials, natural materials, and biological macromolecular networks, with emphasis on identifying connections among microstructure, deformation mechanisms, and mechanical properties. She has published over 100 journal papers in the field of mechanics and materials; and has mentored 36 SM Thesis students and 20 PhD students. Professor Boyce has been the recipient of several awards and honors recognizing her research and teaching efforts, including the MIT MacVicar Faculty Fellow, the Department of Mechanical Engineering Keenan Award for Teaching, the Spira Award for Teaching, the NSF Presidential Young Investigator Award, the

ASME Applied Mechanics Young Investigator Award, Member-at-Large of the USNCTAM, Chair of the ASME Applied Mechanics Division, Fellow of the American Academy of Mechanics, Fellow of the ASME, Fellow of the American Academy of Arts and Sciences, and Member of the National Academy of Engineering.

Publications:
Professor Boyce, together with her research group and collaborators, has published over 150 peer-reviewed archival journal publications; over 60 conference proceedings papers, and is a co- inventor on four issued and several pending U.S. Patents.

Selected Publications:

Antonio Pantano, Mary C. Boyce, and David M. Parks (Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139-4307, USA), "Nonlinear Structural Mechanics Based Modeling of Carbon Nanotube Deformation", Phys. Rev. Lett. Vol. 91, 145504 (2003) [4 pages], doi: 10.1103/PhysRevLett.91.145504
ABSTRACT: A nonlinear structural mechanics based approach for modeling the structure and the deformation of single-wall and multiwall carbon nanotubes (CNTs) is presented. Individual tubes are modeled using shell finite elements, where a specific pairing of elastic properties and mechanical thickness of the tube wall is identified to enable successful modeling with shell theory. The effects of van der Waals forces are simulated with special interaction elements. This new CNT modeling approach is verified by comparison with molecular dynamics simulations and high-resolution micrographs available in the literature. The mechanics of wrinkling of multiwall CNTs are studied, demonstrating the role of the multiwalled shell structure and interwall van der Waals interactions in governing buckling and postbuckling behavior.

A. Pantano, M. C. Boyce, and D. M. Parks (Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA), "Mechanics of Axial Compression of Single and Multi-Wall Carbon Nanotubes", ASME J. Eng. Mater. Technol., Vol. 126, No. 3, July 2004, pp. 279 – 284, doi:10.1115/1.1752926
ABSTRACT: A recently developed procedure for modeling the deformation of single and multi-wall carbon nanotubes [13,14] is applied to nanotube buckling and post-buckling under axial compression. Critical features of the model, which is grounded in elastic shell theory, include identification of (a) an appropriate elastic modulus and thickness pair matching both the wall stretching and bending resistances of the single atomic layer nanotube walls, and (b) a sufficiently stiff interwall van der Waals potential to preserve interwall spacing in locally buckled MWNTs, as is experimentally observed. The first issue is illustrated by parametric buckling studies on a SWNT and comparisons to a corresponding MD simulation from the literature; results clearly indicating the inadequacy of arbitrarily assigning the shell thickness to be the equilibrium spacing of graphite planes. Details of the evolution of local buckling patterns in a nine-walled CNT are interpreted based on a complex interplay of local shell buckling and evolving interwall pressure distributions. The transition in local buckling wavelengths observed with increasing post-buckling deformation is driven by the lower energy of a longer-wavelength, multiwall deformation pattern, compared to the shorter initial wavelength set by local buckling in the outermost shell. This transition, however, is contingent on adopting a van der Waals interaction sufficiently stiff to preserve interlayer spacing in the post-buckled configuration.

J. Cao and M. C. Boyce (Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, U.S.A.), “Wrinkling behavior of rectangular plates under lateral constraint”, International Journal of Solids and Structures, Vol. 34, No. 2, January 1997, pp. 153-176, doi:10.1016/S0020-7683(96)00008-X

ABSTRACT: Wrinkling (buckling) during a sheet forming process is a major consideration when designing part shape, die geometry and processing parameters. In most instances, the sheet metal is constrained to some extent between binders and/or matching dies at some stage during processing. In this paper, we will examine the wrinkling behavior of both elastic and elastic-plastic sheet subjected to edge compression and lateral constraint. A criterion for wrinkling under such constraint is established using a combination of finite element analysis and energy conservation. Various methods of incorporating imperfections into a finite element model in order to capture buckling and post-buckling behavior are discussed. A simple and practical form of imperfection for predictive modeling of buckling is given along with a discussion of the sensitivity of the solution to the magnitude and distribution of imperfections. Using the proposed form of imperfection, we are able to accurately simulate the wrinkling behavior under complicated boundary conditions in a predictive manner.

J. Cao and M.C. Boyce (Department of Mechanical Engineering, MIT, Cambridge MA 02139), “A predictive tool for delaying wrinkling and tearing failures in sheet metal forming”, ASME Journal of Engineering Materials and Technology, Vol. 119, October 1997, pp. 354-365

ABSTRACT: In the sheet metal forming industry, there is increasing demand to lower manufacturing costs wile also providing a decrease in product development turnaround period as well as lighter weight products. These demands have put increasing pressure on the development and use of predictive numerical simulations and in the design and optimization of new forming technologies. In this paper, two of the primary in-process failure modes of sheet metal, wrinkling and tearing, are examined followed by construction of an advanced forming technology – Variable Binder Force – using numerical tools. Specifically, a methodology of capturing the onset of wrinkling and postbuckling behavior proposed in Cao and Boyce (1997) is used to predict wrinkling failure in conical and square cup forming. The results obtained from simulations and experiments demonstrate that the proposed method is not only accurate, but also robust. A tearing criterion based on Forming Limit Diagrams of non-proportional loading paths is then developed and again shows excellent predictability. Finally, a Variable Binder Force (VBF) trajectory for conical cup forming is designed using simulations which incorporate feedback control to the binder based on the predictions of wrinkling and tearing of the sheet. Experiments using this predefined VBF trajectory show a 16 percent increase in forming height over the best conventional forming method, that is, constant binder force. The uniqueness of this paper is that numerical simulation is no longer utilized only as a verification tool, but as a design tooll for advanced manufacturing process with the help of the predictive tools incorporated directly into the numerical model.

Singamaneni, S., Bertoldi, K., Chang, S., Jang, J.-H., Young, S.L., Thomas, E.L., Boyce, M.C., Tsukruk, V.V., “Bifurcated Mechanical Behavior of Deformed Periodic Porous Structures”, Advanced Functional Materials, 19, 1426-1436, 2009.

Singamaneni, S., Bertoldi, K., Chang, S., Jang, J.-H., Thomas, E.L., Boyce M.C., Tsukruk, V.V., “Instabilities and Pattern Transformation in Periodic, Porous Elastoplastic Solid Coatings”, ACS Applied Materials and Interfaces, 1, 42-47, 2009.