Dr. Mark W. Hilburger
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Bio
Dr. Mark W. Hilburger is a Senior Research Engineer in the Structural Mechanics and Concepts Branch at NASA Langley Research Center in Hampton VA. He is currently the Principle Investigator and Manager of NASA's Shell Buckling Knockdown Factor Project with the goal to develop and implement new shell buckling design, analysis and testing methods for buckling-critical launch vehicle structures. His responsibilities include defining and managing activities in six technical work areas and the integration of analysis, design, manufacturing and test teams to develop an efficient, multi-disciplinary approach to optimal structural design, verification, validation, and implementation. These technical work areas are performed by a 24-person team across three NASA centers, industry, and academia. He also defines and coordinates Space Act Agreements (SAAs) with Boeing, Northrop-Grumman, and the German Research Laboratory (DLR) and activities under the Space Transportation MOU between NASA and the European Space Agency (ESA).

Dr. Hilburger specializes in the development of high-fidelity structural analysis and design technology and experimental methods for buckling-critical structures. He has 10 national and international invited talks including 3 international keynote lectures, 6 conference special sessions, and a presentation to the NATO Research and Technology Organization. He has also contributed chapters to 3 textbooks, 18 formal publications, 34 conference papers, and 20 NASA publications. He has been presented with numerous awards and including the NASA Exceptional Engineering Achievement Medal, May 11, 2010; the NASA Engineering and Safety Center Engineering Excellence Award, Oct. 2009; selected as of the nations top 100 young engineers and scientist by the National Academy of Engineering, Sept. 2009; and the NASA Silver Snoopy Award, (Astronauts' Personal Achievement Award), November 2006.

He received his M.S.E. and Ph.D. in Aerospace Engineering from the University of Michigan in Ann Arbor, MI in 1995 and 1998, respectively, and his B.S. in Mechanical Engineering from Rutgers University in New Brunswick, NJ in 1993. Mark is a Senior Member of AIAA, and serves on the NESC Structures Technical Discipline Team.

Selected Publications:

Hilburger, M. W., 'Numerical and Experimental Study of the Compression Response of Composite Cylindrical Shells with Cutouts," Ph.D. Dissertation, Aerospace Engineering Dept., Univ. of Michigan, 1998.

Mark W. Hilburger, James H. Starnes, Jr. and Anthony M. Waas, "The response of composite cylindrical shells with cutouts and subjected to internal pressure and axial compression loads", AIAA 39th Structures, Structural Dynamics and Materials Conference, AIAA-1998-1768, 1998, http://hdl.handle.net/2027.42/76299

Mark W. Hilburger, James H. Starnes, Jr. and Anthony M. Waas (1998). "A numerical and experimental study of the response of selected compression-loaded composite shells with cutouts" AIAA-1998-1988, AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference and Exhibit, 39th, and AIAA/ASME/AHS Adaptive Structures Forum, Long Beach, CA, Apr. 20-23, 1998, Collection of Technical Papers. Pt. 3 (A98-25238 06-39). http://hdl.handle.net/2027.42/76998

Hilburger, M. W., Waas, A. M., and Starnes, J. H., Jr., "Response of Composite Shells with Cutouts Subjected to Internal Pressure and Compression Loads," AIAA Journal, Vol. 32, No. 2, 1999, pp. 232-237.

Mark W. Hilburger, Michael P. Nemeth and James H. Starnes, Jr. (NASA Langley Research Center, Hampton, Virginia), "Effective Widths of Compression-Loaded Plates with a Cutout", NASA/TP-2000-210538, October

2000

ABSTRACT: Results from a study of the effects of cutouts and laminate construction on the prebuckling and initial postbuckling stiffnesses, and the effective widths of compression-loaded laminated-composite and aluminum square plates are presented. An effective-width concept is derived for plates with and without cutouts, and experimental and nonlinear finite-element analysis results are presented. Behavioral trends are compared for seven plate families and for cutout-diameter-to-plate-width ratios up to 0.66. A general compact design curve that can be used to present and compare the effective widths for a wide range of laminate constructions is also presented. A discussion of how the results can be used and extended to include certain types of damage, cracks, and other structural discontinuities or details is given. Several behavioral trends are described that initially appear to be nonintuitive. The results demonstrate a complex interaction between cutout size and plate orthotropy that affects the axial stiffness and effective width of a plate subjected to compression loads.

Starnes, J. H., Jr., Hilburger, M. W., and Nemeth, M. P., The Effect of Initial Imperfections on the Buckling of Composite Cylindrical Shells, in Composite Structures: Theory and Practice, ASTM STP 1383, P. Grant and C. Q. Rousseau (editors), American Society for Testing Materials, West Conshohocken, PA, 2000, pp. 529-550.

Hilburger, M. W. and Starnes, J. H., Jr., Effects of imperfections on the buckling response of compression-loaded composite shells, International J. of Non-linear Mechanics, Vol. 37 pp. 623-643 (2002), Special Issue: Stability and Vibration in Thin-Walled Structures, doi:10.1016/S0020-7462(01)00088-9

ABSTRACT: The results of an experimental and analytical study of the effects of initial imperfections on the buckling and postbuckling response of three unstiffened thin-walled compression-loaded graphite-epoxy cylindrical shells with different orthotropic and quasi-isotropic shell-wall laminates are presented. The results identify the effects of traditional and non-traditional initial imperfections on the non-linear response and buckling loads of the shells. The traditional imperfections include the geometric shell-wall mid-surface imperfections that are commonly discussed in the literature on thin shell buckling. The non-traditional imperfections include shell-wall thickness variations, local shell-wall ply-gaps associated with the fabrication process, shell-end geometric imperfections, non-uniform applied end loads, and variations in the boundary conditions including the effects of elastic boundary conditions. A high-fidelity non-linear shell analysis procedure that accurately accounts for the effects of these traditional and non-traditional imperfections on the non-linear responses and buckling loads of the shells is described. The analysis procedure includes a non-linear static analysis that predicts stable response characteristics of the shells and a non-linear transient analysis that predicts unstable response characteristics.

Hilburger M.W., "Nonlinear and Buckling Behavior of Compression-loaded Composite Shells," Proceedings of the 6th Annual Technical Conference of the American Society for Composites, Virginia 2001.

Hilburger, M. W. (1 and 3), Britt, V. O. (2), and Nemeth, M. P. (3)
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"Buckling Behavior of Compression-Loaded Quasi-Isotropic Curved Panels With a Circular Cutout," International Journal of Solids and Structures, Vol. 38, 2001, pp. 1495-1522, doi:10.1016/S0020-7683(00)00114-1

ABSTRACT: Results from a numerical and experimental study of the response of compression-loaded quasi-isotropic curved panels with a centrally located circular cutout are presented. The numerical results were obtained by using a geometrically nonlinear finite element analysis code. The effects of cutout size, panel

curvature and initial geometric imperfections on the overall response of compression-loaded panels are described. In addition, results are presented from a numerical parametric study that indicate the effects of elastic circumferential edge restraints on the prebuckling and buckling response of a selected panel and these numerical results are compared to experimentally measured results. These restraints are used to identify the effects of circumferential edge restraints that are introduced by the test fixture that was used in the present study. It is shown that circumferential edge restraints can introduce substantial nonlinear prebuckling deformations into shallow compression-loaded curved panels that can result in a significant increase in buckling load.

Jaunky, N., Ambur, D. R., Davila, C. G., and Hilburger, M. W., “Progressive Failure Studies of Composite Panels with and without Cutouts,” NASA/CR-2001-211223, September 2001.

Hilburger, M. H., and Starnes, J. H., Jr., "Effects of Imperfections on the Buckling Response of Compression-loaded Composite Shells," International Journal of Non-linear Mechanics, Vol. 37, 2002, pp. 623-643.

Hilburger, M. W., and Starnes, J. H., Jr., "Bucking of Compression-loaded Composite Cylindrical Shells with Reinforced Cutouts," Proceedings of the AIAA/ASME/ASCE/AHS/ASC 43rd Structures, Structural Dynamics, and Materials Conference, Denver, CO. AIAA Paper No. 2002-1516, 2002.

Starnes, James H., Jr. ; Hillburger, Mark W., “Using High-Fidelity Analysis Methods and Experimental Results to Account for the Effects of Imperfections on the Buckling Response of Composite Shell Structures”, March 2003, http://handle.dtic.mil/100.2/ADP014170
ABSTRACT: The results of an experimental and analytical study of the effects of initial imperfections on the buckling response of unstiffened thin-walled compression-loaded graphite-epoxy cylindrical shells are presented. The analytical results include the effects of traditional and nontraditional initial imperfections and uncertainties in the values of selected shell parameters on the buckling loads of the shells. The nonlinear structural analysis results correlate very well with the experimental results. The high-fidelity nonlinear analysis procedure used to generate the analytical results can also be used to form the basis of a new shell design procedure that could reduce the traditional dependence on empirical results in the shell design process.

Hilburger, M. W., and Starnes, J. H., Jr., "Bucking of Compression-loaded Composite Cylindrical Shells with Reinforced Cutouts," NASA/TM-2004-212656, September 2004.

Hilburger, M. W., Nemeth, M. P., and Starnes, J. H., Jr., Shell buckling design criteria based on manufacturing imperfection signatures, NASA/TM-2004-212659, May 2004
ABSTRACT: An analysis-based approach for developing shell buckling design criteria for laminated-composite cylindrical shells that accurately account for the effects of initial geometric imperfections is presented. With this approach, measured initial geometric imperfection data from six graphite-epoxy shells are used to determine a manufacturing-process-specific imperfection signature for these shells. This imperfection signature is then used as input into nonlinear finite-element analyses. The imperfection signature represents a "first-approximation" mean imperfection shape that is suitable for developing preliminary-design data. Comparisons of test data and analytical results obtained by using several different imperfection shapes are presented for selected shells. These shapes include the actual measured imperfection shape of the test specimens, the "first-approximation" mean imperfection shape, with and without plus or minus one standard deviation, and the linear-bifurcation-mode imperfection shape. In addition, buckling interaction curves for composite shells subjected to combined axial compression and torsion loading are presented that were obtained by using the various imperfection shapes in the analyses. A discussion of the nonlinear finite-element analyses is also presented. Overall, the results indicate that the analysis-based approach presented for developing reliable preliminary-design criteria

has the potential to provide improved, less conservative buckling-load estimates, and to reduce the weight and cost of developing buckling-resistant shell structures.

Mark W. Hilburger and James H. Starnes, Jr. (NASA Langley Research Center, MS 190, Hampton, VA 23681-2199, USA), “Effects of imperfections of the buckling response of composite shells”, Thin-Walled Structures Vol. 42, No. 3, March 2004, pp. 369-397, doi:10.1016/j.tws.2003.09.001
ABSTRACT: The results of an experimental and analytical study of the effects of initial imperfections on the buckling response and failure of unstiffened thin-walled compression-loaded graphite-epoxy cylindrical shells are presented. The shells considered in the study have six different shell-wall laminates two different shell-radius-to-thickness ratios. The shell-wall laminates include four different orthotropic laminates and two different quasi-isotropic laminates. The shell-radius-to-thickness ratios include shell-radius-to-thickness ratios equal to 100 and 200. The numerical results include the effects of traditional and nontraditional initial imperfections and selected shell parameter uncertainties. The traditional imperfections include the geometric shell-wall mid-surface imperfections that are commonly discussed in the literature on thin shell buckling. The nontraditional imperfections include shell-wall thickness variations, local shell-wall ply-gaps associated with the fabrication process, shell-end geometric imperfections, nonuniform applied end loads, and variations in the boundary conditions including the effects of elastic boundary conditions. The cylinder parameter uncertainties considered include uncertainties in geometric imperfection measurements, lamina fiber volume fraction, fiber and matrix properties, boundary conditions, and applied end load distribution. Results that include the effects of these traditional and nontraditional imperfections and uncertainties on the nonlinear response characteristics, buckling loads and failure of the shells are presented. The analysis procedure includes a nonlinear static analysis that predicts the stable response characteristics of the shells, and a nonlinear transient analysis that predicts the unstable response characteristics. In addition, a common failure analysis is used to predict material failures in the shells.

Hilburger, M. W., Nemeth, M. P., Riddick, J. C., and Thornburgh, R. P. (Mechanics and Durability Branch, NASA Langley Research Center, Hampton, Virginia 23681-0001), “Effects of elastic edge restraints and initial prestress on the buckling response of compression-loaded composite panels, 45th AIAA SDM Conference, April 2004
ABSTRACT: A parametric study of the effects of test-fixture-induced initial prestress and elastic edge restraints on the prebuckling and buckling responses of a compression-loaded, quasi-isotropic curved panel is presented. The numerical results were obtained by using a geometrically nonlinear finite element analysis code with high-fidelity models. The results presented show that a wide range of prebuckling and buckling behavior can be obtained by varying parameters that represent circumferential loaded-edge restraint and rotational unloaded-edge restraint provided by a test fixture and that represent the mismatch in specimen and test-fixture radii of curvature. For a certain range of parameters, the panels exhibit substantial nonlinear prebuckling deformations that yield buckling loads nearly twice the corresponding buckling load predicted by a traditional linear bifurcation buckling analysis for shallow curved panels. In contrast, the results show another range of parameters exist for which the nonlinear prebuckling deformations either do not exist or are relatively benign, and the panels exhibit buckling loads that are nearly equal to the corresponding linear bifurcation buckling load. Overall, the results should also be of particular interest to scientists, engineers, and designers involved in simulating flight-hardware boundary conditions in structural verification and certification tests, involved in validating structural analysis tools, and interested in tailoring buckling performance.

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“Progressive failure studies of stiffened panels subjected to shear loading”, Composite Structures, Vol. 65, No.2, August 2004, pp. 129-142, doi:10.1016/S0263-8223(03)00153-3
ABSTRACT: Experimental and analytical results are presented for progressive failure of stiffened composite panels with and without a notch and subjected to in-plane shear loading well into the postbuckling regime. Initial geometric imperfections are included in the finite element models. Ply damage modes such as matrix cracking, fiber-matrix shear, and fiber failure are modeled by degrading the material properties. Experimental results from the test include strain full-field data from a video image correlation system in addition to other strain and displacement measurements. Results from nonlinear finite element analyses are compared with experimental data. Good agreement between experimental data and numerical results is observed for the stitched stiffened composite panels studied.

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(3) Analytical and Computational Methods Branch, NASA Langley Research Center, Hampton, VA 23681-2199, USA
“Progressive failure analyses of compression-loaded composite curved panels with and without cutouts”, Composite Structures, Vol. 65, No. 2, August 2004, pp. 143-155, doi:10.1016/S0263-8223(03)00184-3
ABSTRACT: Progressive failure analyses results are presented for composite curved panels with and without a circular cutout and subjected to axial compression loading well into their postbuckling regime. Ply damage modes such as matrix cracking, fiber-matrix shear, and fiber failure are modeled by degrading the material properties. Results from finite element analyses are compared with experimental data. Good agreement between experimental data and numerical results are observed for most part of the loading range for the structural configurations considered. Modeling of initial geometric imperfections may be required to obtain accurate analysis results depending on the ratio of the cutout width to panel width.

Mark W. Hilburger and James H. Starnes Jr. (NASA Langley Research Center, Mechanics and Durability Branch, MS 190, Hampton, Virginia 23681-001, USA), “Buckling behavior of compression-loaded composite cylindrical shells with reinforced cutouts”, International Journal of Non-Linear Mechanics, Vol. 40, No. 7, September 2005, pp. 1005-1021, doi:10.1016/j.ijnonlinmec.2005.02.001
ABSTRACT: Results from a numerical study of the response of thin-walled compression-loaded quasi-isotropic laminated composite cylindrical shells with unreinforced and reinforced square cutouts are presented. The effects of cutout reinforcement orthotropy, size, and thickness on the non-linear response of the shells are described. A high-fidelity non-linear analysis procedure has been used to predict the non-linear response of the shells. The analysis procedure includes a non-linear static analysis that predicts stable response characteristics of the shells and a non-linear transient analysis that predicts unstable dynamic buckling response characteristics. The results illustrate the complex non-linear response of a compression-loaded shell with an unreinforced cutout. In particular, a local buckling response occurs in the shell near the cutout and is caused by a complex non-linear coupling between local shell-wall deformations and in-plane destabilizing compression stresses near the cutout. In general, reinforcement around a cutout in a compression-loaded shell can retard or eliminate the local buckling response near the cutout and increase the buckling load of the shell. However, results are presented that show how certain reinforcement configurations can cause an unexpected increase in the magnitude of local deformations and stresses in the shell and cause a reduction in the buckling load. Specific cases are presented that suggest that the orthotropy, thickness, and size of a cutout reinforcement in a shell can be tailored to achieve improved buckling response characteristics.

Mark W. Hilburger (NASA Langley Research Center, Hampton, Virginia 23681-2199, USA), “Buckling and failure of compression-loaded composite laminated shells with cutouts”, One of the AIAA Structures Meetings after 2005 (date not given in the pdf file; latest reference is dated 2005)
ABSTRACT: Results from a numerical and experimental study that illustrate the effects of laminate orthotropy on the buckling and failure response of compression-loaded composite cylindrical shells with a cutout are presented. The effects of orthotropy on the overall response of compression-loaded shells is described. In general, preliminary numerical results appear to accurately predict the buckling and failure characteristics of the shell considered herein. In particular, some of the shells exhibit stable post-local-buckling behavior accompanied by interlaminar material failures near the free edges of the cutout. In contrast another shell with a different laminate stacking sequence appears to exhibit catastrophic interlaminar material failure at the onset of local buckling near the cutout and this behavior correlates well with corresponding experimental results.

Arbocz, J. and Hilburger, M.W., "Toward a Probabilistic Preliminary Design Criterion for Buckling Critical Composite Shells", AIAA Journal, Volume 43, No. 8, 2005, pp. 1823-1827.

Hilburger, M. W. and Nemeth, M. P., Buckling and failure of compression-loaded composite cylindrical shells with reinforced cutouts, ***Collected Papers in Structural Mechanics Honoring Dr. James H. Starnes, Jr***., NASA/TM-2006-214276, compiled by Norman F. Knight, Jr., Michael P. Nemeth, and John B. Malone, pp. 363-386, February 2006

Mark W. Hilburger, “Chapter 4: The development of shell buckling design criteria based on initial imperfection signatures”, in Buckling and Postbuckling Structures: Experimental, Analytical and Numerical Studies (Computational and Experimental Methods in Structures): Edited by B. G. Falzon and M. H. Aliabadi, Imperial College Press, ISBN: 1860947948 | 2008-05-23, 2008
ABSTRACT: An analysis-based approach for developing shell buckling design factors for cylindrical shells that accurately accounts for the effects of initial geometric imperfections is presented. To develop this approach, measured initial geometric imperfection data from six laboratory-scale graphite-epoxy shells are used to determine a manufacturing-process-specific imperfection signature for these shells. This imperfection signature is then used as input into nonlinear finite element analyses. The imperfection signature represents a “first approximation” mean imperfection shape that is suitable for developing preliminary design data. Comparisons of test data and analytical results obtained by using several different imperfection shapes are presented for selected shells. These imperfection shapes include the actual measured imperfection shape of the test specimens, a “first approximation” mean imperfection shape with plus or minus one standard deviation in the shape, and a linear-bifurcation-mode imperfection shape. In addition, buckling interaction curves for composite shells subjected to combined axial compression and torsion loading are presented that were obtained by using the various imperfection shapes in the analyses. A discussion on the development of experimentally validated nonlinear finite element analyses is also presented. Overall, the results indicate that the proposed analysis-based approach presented herein, for developing reliable preliminary design criteria, has the potential to provide improved, less conservative buckling load estimates, and to reduce the weight and cost of developing buckling-resistant shell structures.

Hilburger, M. W. (NASA - Langley Research Center, Hampton, VA, USA). “Static Buckling Tests of Aerospace Vehicle Structures”. Encyclopedia of Aerospace Engineering, 2010,
doi: 10.1002/9780470686652.eae178

ABSTRACT: Guidelines on the development of a successful test plan for large-scale, aerospace vehicle shell buckling tests with particular attention given to defining test objectives and requirements are presented. In addition, some of the more challenging aspects of test planning, test operations, test article, and test apparatus design are discussed, and recommendations on instrumentation and control system setup for buckling tests and including state-of-the-art measurement approaches and technologies are provided. In many cases, actual examples are given. This chapter is intended to provide the first time as well as the experienced test engineer or project manager with experiences and lessons learned from recent large-scale aerospace vehicle development test activities at NASA.

M. Hilburger (NASA Langley Research Center, Hampton, Virginia, USA, email: mark.w.hilburger@nasa.gov),
"Developments in Shell Buckling Analysis, Design and Testing"
ABSTRACT: High-performance aerospace shell structures are inherently thin-walled because of weight and performance considerations and are often subjected to destabilizing loads. Thus, buckling is an important and often critical consideration in the design of these structures and reliable, validated design criteria for thin-walled shells are needed, especially for shells made of advanced composite materials. Shell-buckling design criteria have a history steeped in empiricism. From approximately 1930 to 1967, many shell-buckling experiments were conducted on metallic shells. Typically, the experiments yielded buckling loads that were substantially lower than the corresponding analytical predictions, which were based on simplified linear bifurcation analyses of geometrically perfect shells with nominal dimensions and idealized support conditions. The primary source of discrepancy between corresponding analytical predictions and experimental results is attributed to small deviations from the idealized geometry of a shell, known as initial geometric imperfections. Empirical design factors, known as "knockdown" factors, were determined from these test data and were to be used in conjunction with linear bifurcation analyses for simply supported shells to adjust or "knockdown" the unconservative analytical prediction. This approach to shell design remains prominent in industry practice, as evidenced by the extensive use of the NASA space vehicle design recommendations. Recent advancements in digital computers, high-fidelity structural analysis tools and testing technologies are enabling the development of a new shell buckling design philosophy, namely, analysis-based knockdown factors. Key enabling technology developments and their implementation in ongoing NASA Shell Buckling Knockdown Factor development activities are presented in this lecture. In addition, the development of a refined shell-buckling preliminary-design criteria that is based on high-fidelity nonlinear finite- element analyses that include the effects of a manufacturing-process-specific geometric imperfection signature is presented.
(No references given. This is not a paper, just an abstract.)