

Curriculum vitae of Olivier A. BAUCHAU

Igor Sikorsky Professor of Rotorcraft,
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1 Interests

Teaching and conducting research in the fields of multibody dynamics, rotorcraft aero-mechanical comprehensive modeling, structural dynamics, and composites materials and structures.

2 Education

Université de l'État à Liège (Belgium): Ingénieur Civil Physicien degree awarded in Jul. 1977. Thesis under Prof. B. Fraeijs de Veubeke entitled: *"Influence of Warping on the Natural Frequencies of Vibration of Box-Beams."*

Massachusetts Institute of Technology (Cambridge, MA.): Master of Science in Aeronautics and Astronautics degree awarded in Jun. 1978. Thesis under Prof. T.H.H. Pian entitled: *"Elastic-Plastic Analysis of Structures Using the Equilibrium Finite Element Method."* Awardee of the Rotary Foundation of the ROTARY INTERNATIONAL 1977–78.

Massachusetts Institute of Technology (Cambridge, MA.): Doctor of Philosophy degree in the field of Structural Dynamics awarded in Jul. 1981. Thesis under Prof. J.W. Mar entitled: *"Design, Manufacturing, and Testing of High-Speed Rotating Graphite/Epoxy Shafts."*



3 Experience

3.1 Position chronology

- Jul. 1982–Aug. 1983: Research Engineer at St. Gobain Recherches in Paris, France. Assignments included modeling of industrial processes in the glass industry.
- Sep. 1983–1995: Assistant Professor, then Associate Professor, Department of Mechanical Engineering, Aeronautical Engineering, and Mechanics at the Rensselaer Polytechnic Institute in Troy, NY.
- Sep. 1995–Aug. 2010: Professor, Daniel Guggenheim School of Aerospace Engineering at the Georgia Institute of Technology in Atlanta, Georgia.
- Aug. 2010–Aug 2014: Professor, University of Michigan-Shanghai Jiao Tong University Joint Institute in Shanghai, China.
- Aug. 2014–Aug 2015: Professor, Department of Mechanical and Aerospace Engineering at The Hong Kong University of Science and Technology in Hong Kong.
- Aug. 2015–present: Igor Sikorsky Distinguished Professor in Rotorcraft, Department of Aerospace Engineering at the University of Maryland, College Park, Maryland. Faculty responsibilities including teaching of graduate and undergraduate courses, and conducting research in the fields of comprehensive rotorcraft analysis, structural and multibody dynamics, and composites materials and structures.

3.2 Consulting experience

Engineering Consultant with: United Technologies Research Center in Hartford, CT.; Sikorsky Aircraft in Stratford, CT.; Bell Helicopter in Fort Worth, TX.; NASA Ames Research Center in Moffet Field, CA; NASA Langley Research Center in Hampton, VA; Advanced Rotorcraft Technology Inc., in Mountain View, CA.; Materials Technologies Corporation in Monroe, CT; Continuum Dynamics, Inc., in Ewing, NJ; Technical Data Analysis, Inc., in Falls Church, VA; Vestas Technology R & D Americas, Inc., in Houston TX. Turkish Aerospace Industries, Inc., Ankara, Turkey. China Engine International Ltd., Beijing, China.

3.3 Fields of expertise

- Teaching undergraduate and graduate courses in the areas of Theory of Structures, Strength of Materials, Advanced Structural Analysis, Design with Composite Materials, Aeroelasticity, Finite Element Method, Engineering Mechanics, Structural Dynamics, Machine Dynamics, Energy Methods in Structural Analysis, Advanced Dynamics, Flexible Multibody Dynamics, and Engineering Laboratories.
- Conducting research in the areas of Finite Element Methods for Structural and Multibody Dynamics, Rotorcraft Aero-Mechanical Analysis and Comprehensive Simulation, Experimental Mechanics and Dynamics, and Composite Materials and Structures.

4 Publications in refereed journals

1. Bauchau, O.A.: “Experimental Measurements of Elastic Shear Modulus of Graphite/Epoxy tubes.” *Journal of Composite Materials*, **15**, 1981, pp 151–156.
2. Bauchau, O.A.: “Optimal Design of High Speed Rotating Graphite/Epoxy Shafts.” *Journal of Composite Materials*, **17**, 1983, pp 170–181.
3. Bauchau, O.A.: “A Beam Theory for Anisotropic Materials.” *Journal of Applied Mechanics*, **52**, 1985, pp 416–422.
4. Bauchau, O.A., Coffenberry, B.S. and Rehfield, L.W.: “Composite Box Beam Analysis: Theory and Experiments.” *Journal of reinforced Plastics and Composites*, **6**(1), 1987, pp 25–35.
5. Bauchau, O.A.: “A Solution of the Eigenproblem for Undamped Gyroscopic Systems with the Lanczos Algorithm.” *International Journal of Numerical Methods in Engineering*, **23**(9), 1986, pp 1705–1713.
6. Bauchau, O.A. and Hong, C.H.: “Finite Element Approach to Rotor Blade Modeling.” *Journal of the American Helicopter Society*, **32**(1), 1987, pp 60–67.
7. Bauchau, O.A. and Hong, C.H.: “Large Displacement Analysis of Naturally Curved and Twisted Beams.” *AIAA Journal*, **25**(11), 1987, pp 1469–1475.
8. Bauchau, O.A. and Hong, C.H.: “Nonlinear Composite Beam Theory.” *Journal of Applied Mechanics*, **55**(1), 1988, pp 156–163.
9. Bauchau, O.A., Krafchak, T.R. and Hayes, J.F.: “Torsional Buckling Analysis and Damage Tolerance of Graphite-Epoxy Shafts.” *Journal of Composite Materials*, **22**, 1988, pp 142–158.
10. Bauchau, O.A. and Hong, C.H.: “Nonlinear Response and Stability Analysis of Beams Using Finite Elements in Time.” *AIAA Journal*, **26**(9), 1988, pp 1135–1142.
11. Bauchau, O.A. and Liu, S.P.: “Finite Element Based Modal Analysis of Helicopter Rotor blade.” *Vertica*, **13**(2), 1989, pp 197–206.
12. Srinivasan, A.V., Cutts, D.G., Shu, H.T., Sharpe, D.L. and Bauchau, O.A.: “Structural Dynamics of a Helicopter Rotor Blade System.” *Journal of The American Helicopter Society*, **35**(1), Jan. 1990, pp 75–85.
13. Bauchau, O.A. and Chiang, W.Y.: “Dynamic Analysis of Rotor Flex-beams Based on Nonlinear Anisotropic Shell Models.” *Journal of The American Helicopter Society*, **38**(1), Jan. 1993, pp 55–61.
14. Bauchau, O.A. and Kang, N.K.: “A Multibody Formulation for Helicopter Structural Dynamic Analysis.” *Journal of The American Helicopter Society*, **38**(2), Apr. 1993, pp 3–14.
15. Bauchau, O.A. and Guernsey, D.: “On The Choice of Appropriate Bases for Nonlinear Dynamic Modal Analysis.” *Journal of the American Helicopter Society*, **38**(4), 1993, pp 28–36.
16. Bauchau, O.A. and Bottasso, C.: “Space-Time Perturbation Modes for Nonlinear Dynamic Analysis.” *Nonlinear Dynamics*, **6**, Jun. 1994, pp 21–35.
17. Bauchau, O.A. and Chiang, W.Y.: “Dynamic Analysis of Bearingless Tail-rotor Blades Based on Nonlinear Shell Models.” *Journal of Aircraft*, **31**(6), 1994, pp 1402–1410.

18. Laulusa, A., Bauchau, O.A. and Theron, N.J.: "Theoretical and Experimental Investigation of the Nonlinear Behavior of Composite Beams." *La Recherche Aéronautique*, **4**, 1995, pp 223–240.
19. Bauchau, O.A., Damilano, G. and Theron, N.J.: "Numerical Integration of Nonlinear Elastic Multibody Systems." *International Journal of Numerical Methods in Engineering*, **38**(16), 1995, pp 2727–2751.
20. Bauchau, O.A. and Theron, N.J.: "Energy Decaying Schemes for Nonlinear Beam Models." *Computer Methods in Applied Mechanics and Engineering*, **134**, pp 37–56, 1996.
21. Bauchau, O.A. and Theron, N.J.: "Energy Decaying Schemes for Nonlinear Elastic Multibody Systems." *Computers and Structures*, **59**(2), pp 317–331, 1996.
22. Yun, S.H. and Bauchau, O.A.: "Improving Modal Parameter Predictions for Jointed Airframe Panels. Part I: Experiments." *Journal of the American Helicopter Society*, **43**(2), pp 156–163, 1998.
23. Yun, S.H. and Bauchau, O.A.: "Improving Modal Parameter Predictions for Jointed Airframe Panels. Part II: Improved Numerical Model." *Journal of the American Helicopter Society*, **43**(2), pp 164–171, 1998.
24. Bauchau, O.A.: "Computational Schemes for Flexible, Nonlinear Multibody Systems." *Multibody System Dynamics*, **2**, pp 169–225, 1998.
25. Bauchau, O.A. and Hodges, D.H.: "Analysis of Nonlinear Multibody Systems with Elastic Couplings." *Multibody System Dynamics*, **3**, pp 163–188, 1999.
26. Bauchau, O.A. and Joo, T.: "Computational Schemes for Nonlinear Elasto-Dynamics." *International Journal for Numerical Methods in Engineering*, **45**, pp 693–719, 1999.
27. Bauchau, O.A. and Bottasso, C.L.: "On the Design of Energy Preserving Schemes for Flexible, Nonlinear Multibody Systems." *Computer Methods in Applied Mechanics and Engineering*, **169**, pp 61–79, 1999.
28. Bauchau, O.A.: "On the Modeling of Friction and Rolling in Flexible Multibody Systems." *Multibody System Dynamics*, **3**, pp 209–239, 1999.
29. Bauchau, O.A.: "On the Modeling of Prismatic Joints in Flexible Multibody Systems." *Computer Methods in Applied Mechanics and Engineering*, **181**, pp 87–105, 2000.
30. Bauchau, O.A.: "Analysis of Flexible Multibody Systems with Intermittent Contacts." *Multibody System Dynamics*, **4**, pp 23–54, 2000.
31. Bauchau, O.A. and Bottasso, C.L.: "Contact Conditions for Cylindrical, Prismatic, and Screw Joints in Flexible Multibody Systems." *Multibody System Dynamics*, **5**, pp 251–278, 2001.
32. Bauchau, O.A. and Nikishkov, Y.G.: "An Implicit Transition Matrix Approach to Stability Analysis of Flexible Multibody Systems." *Multibody System Dynamics*, **5**, pp 279–301, 2001.
33. Bauchau, O.A., Bottasso, C.L. and Nikishkov, Y.G.: "Modeling Rotorcraft Dynamics with Finite Element Multibody Procedures." *Mathematical and Computer Modeling*, **33**, pp 1113–1137, 2001.
34. Bauchau, O.A. and Nikishkov, Y.G.: "An Implicit Floquet Analysis for Rotorcraft Stability Evaluation." *Journal of the American Helicopter Society*, **46**(3), pp 200–209, 2001.
35. Bauchau, O.A., Rodriguez, J. and Bottasso, C.L.: "Modeling of Unilateral Contact Conditions with Application to Aerospace Systems Involving Backlash, Freeplay and Friction." *Mechanics Research Communications*, **28**, pp 571–599, 2001.
36. Bottasso, C.L. and Bauchau, O.A.: "Multibody Modeling of Engage and Disengage Operations of Helicopter Rotors." *Journal of the American Helicopter Society*, **46**(4), pp 290–300, 2001.
37. Bauchau, O.A. and Rodriguez, J.: "Modeling of Joints with Clearance in Flexible Multibody Systems." *International Journal of Solids and Structures*, **39**, pp 41–63, 2002.
38. Bauchau, O.A., Choi, J.Y. and Bottasso, C.L.: "Time Integrators for Shells in Multibody Dynamics." *Computers and Structures*, **80**, pp 871–889, 2002.
39. Bauchau, O.A. and Rodriguez, J.: "Simulation of Wheels in Nonlinear, Flexible Multibody Systems." *Multibody System Dynamics*, **7**, pp 407–438, 2002.
40. Bottasso, C.L., Bauchau, O.A. and Choi, J.Y.: "An Energy Decaying Scheme for Nonlinear Dynamics of Shells." *Computer Methods in Applied Mechanics and Engineering*, **191**, pp 3099–3121, 2002.
41. Yang, Z., Sankar, L.N., Smith, M.J., and Bauchau, O.A.: "Recent Improvements to a Hybrid Method for Rotors in Forward Flight." *Journal of Aircraft*, **39**(2), pp 804–812, 2002.
42. Bauchau, O.A., Choi, J.Y. and Bottasso, C.L.: "On the Modeling of Shells in Multibody Dynamics." *Multibody Dynamics Systems*, **8**, pp 459–489, 2002.

43. Bauchau, O.A., Bottasso, C.L. and Trainelli, L.: “Robust Integration Schemes for Flexible Multibody Systems.” *Computer Methods in Applied Mechanics and Engineering*, **192**, pp 395–420, 2003.
44. Bauchau, O.A.: “A Self-Stabilized Algorithm for Enforcing Constraints in Multibody Systems.” *International Journal of Solids and Structures*, **40**(12–13), pp 3253–3271, 2003.
45. Bauchau, O.A. and Trainelli, L.: “The Vectorial Parameterization of Rotation.” *Nonlinear Dynamics*, **32**(1), pp 71–92, 2003.
46. Bauchau, O.A. and Rodriguez, J.: “Formulation of Modal Based Elements in Nonlinear, Flexible Multibody Dynamics.” *Journal of Multiscale Computational Engineering*, **1**(2 & 3) pp 161–180, 2003.
47. Bauchau, O.A. and Choi, J.Y.: “The Vectorial Parameterization of Motion.” *Nonlinear Dynamics*, **33**(1), pp 165–188, 2003.
48. Bauchau, O.A., Rodriguez, J., and Chen, S.Y.: “Modeling the Bifilar Pendulum Using Nonlinear, Flexible Multibody Dynamics.” *Journal of the American Helicopter Society*, **47**(1), pp 53–62, 2003.
49. Bauchau, O.A. and Rodriguez, J., and Chen, S.Y.: “Coupled Rotor-Fuselage Analysis with Finite Motions Using Component Mode Synthesis.” *Journal of the American Helicopter Society*, **49**(2), pp 201–211, 2004.
50. Choi, J.Y., Ruzzene, M. and Bauchau, O.A.: “Dynamic Analysis of Flexible Supercavitating Vehicles Using Modal-Based Elements.” *SIMULATION*, **80**(11), pp 619–633, 2004.
51. Bauchau, O.A. and Wang, Jielong: “Stability Analysis of Complex Multibody Systems.” *Journal of Computational and Nonlinear Dynamics*, **1**(1), pp 71–80, 2006.
52. Bauchau, O.A. and Liu, H.Y.: “On the Modeling of Hydraulic Components in Rotorcraft Systems.” *Journal of the American Helicopter Society*, **51**(2), pp 175–184, 2006.
53. Bauchau, O.A. and Ju, C.K.: “Modeling Friction Phenomena in Flexible Multibody Dynamics.” *Computer Methods in Applied Mechanics and Engineering*, **195**(50–51), pp 6909–6924, 2006.
54. Laulusa, A., Bauchau, O.A., Choi, J.Y., Tan, V. and Li, L.: “Evaluation of some Shear Deformable Shell Elements.” *International Journal of Solids and Structures*, **43**, pp 5033–5054, 2006.
55. Bauchau, O.A. and Wang, J.L.: “Stability Evaluation and System Identification of Flexible Multi-Body Systems.” *Multibody System Dynamics*, **18**(1), pp 95–106, 2007.
56. Bottasso, L., Bauchau, O.A. and Cardona, A.: “Time-Step-Size Independent Conditioning and Sensitivity to Perturbations in the Numerical Solution of Index-3 Differential Algebraic Equations.” *SIAM Journal on Scientific Computing*, **29**(1), pp 397–414, 2007.
57. Do, N.B., Ferri, A.A., and Bauchau, O.A.: “Efficient Simulation of a Dynamic System with LuGre Friction.” *Journal of Computational and Nonlinear Dynamics*, **2**(4), pp 281–289, Oct. 2007.
58. Shabana, A.A., Bauchau, O.A., and Hulbert, G.M.: “Integration of Large Deformation Finite Element and Multibody System Algorithms.” *Journal of Computational and Nonlinear Dynamics*, **2**(4), pp 351–359, Oct. 2007.
59. Bauchau, O.A. and Wang, J.L.: “Efficient and Robust Approaches to the Stability Analysis of Large Multibody Systems.” *Journal of Computational and Nonlinear Dynamics*, **3**(1), pp 011001-1–12, Jan. 2008.
60. Laulusa, A. and Bauchau, O.A.: “Review of Classical Approaches for Constraint Enforcement in Multibody Systems.” *Journal of Computational and Nonlinear Dynamics*, **3**(1), pp 011004-1– 8, Jan. 2008.
61. Bauchau, O.A. and Laulusa, A.: “Review of Contemporary Approaches for Constraint Enforcement in Multibody Systems.” *Journal of Computational and Nonlinear Dynamics*, **3**(1), pp 011005 1–8, Jan. 2008.
62. Maqueda, L.G., Bauchau, O.A. and Shabana, A.A.: “Effect of the Centrifugal Forces on the Finite Element Eigenvalue Solution of a Rotating Blade: a Comparative Study.” *Multibody System Dynamics*, **19**, pp 281–302, 2008.
63. Bauchau, O.A., Epple, A. and Heo, S.D.: “Interpolation of Finite Rotations in Flexible Multibody Dynamics Simulations.” *Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics*, **222**(K4), pp 353–366, 2008.
64. Bauchau, O.A., Epple, A., and Bottasso, L.: “Scaling of Constraints and Augmented Lagrangian Formulations in Multibody Dynamics Simulations.” *Journal of Computational and Nonlinear Dynamics*, **4**(4), pp 021007-1–9, 2009.
65. Bain, J.J., Sankar, L.N., Prasad, J.V.R., Bauchau, O.A., Peters, D.A., and He, C.: “Computational Modeling of Variable-Droop Leading Edge in Forward Flight.” *Journal of Aircraft*, **46**(2), pp 617–626, 2009.
66. Bauchau, O.A. and Epple, A.: “Improved Computational Strategies for Rotor Blades Presenting High Gradients in Sectional Properties.” *Journal of the American Helicopter Society*, **54**(2), pp 025001 1–7, 2009.

67. Bauchau, O.A.: "Parallel Computation Approaches for Flexible Multibody Dynamics Simulations." *Journal of the Franklin Institute*, **347**(1), pp 53–68, 2010.
68. Bauchau, O.A., van Weddingen, Y. and Agarwal, S.: "Semi-Active Coulomb Friction Lead-Lag Dampers." *Journal of the American Helicopter Society*, **55**(1), 012005, pp 1–12, 2010.
69. Bauchau, O.A. and Wang, J.L.: "Efficient and Robust Approaches for Rotorcraft Stability Analysis." *Journal of the American Helicopter Society*, **55**(3), 032006, pp 1–12, 2010.
70. Bauchau, O.A. and Li, L.H.: "Tensorial Parameterization of Rotation and Motion." *Journal of Computational and Nonlinear Dynamics*, **6**(3), 031007 (8 pages), 2011.
71. Bauchau, O.A., Li, L.H., Masarati, P. and Morandini, M.: "Tensorial Deformation Measures for Flexible Joints." *Journal of Computational and Nonlinear Dynamics*, **6**(3), 031002 (8 pages), 2011.
72. Skjoldan, P.F. and Bauchau, O.A.: "Determination of Modal Parameters in Complex Nonlinear Systems." *Journal of Computational and Nonlinear Dynamics*, **6**(3), 031017 (10 pages), 2011.
73. Chierichetti, M., McColl, C., Palmer, D., Ruzzene, M., and Bauchau, O.A.: "Combined Analytical and Experimental Approaches to Rotor Components Stress Predictions." *Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics*, **225**: pp 322–330, Dec. 2011.
74. Kwak, J.Y., Cho, H.S., Shin, S.J., and Bauchau, O.A.: "Development of Finite Element Domain Decomposition Method Using Local and Mixed Lagrange Multipliers." *Journal of the Computational Structural Engineering Institute of Korea*, **25**(6): pp 469–476, 2012.
75. Bauchau, O.A., Xin, H., Dong, S.Y., Li, Z.H., and Han, S.L.: "Intrinsic Time Integration Procedures for Rigid Body Dynamics." *Journal of Computational and Nonlinear Dynamics*, **8**(1), 011006 (9 pages), 2013.
76. Bauchau, O.A. and Han, S.L.: "Flexible Joints in Structural and Multibody Dynamics." *Mechanical Sciences*, **4**(1): pp 65–77, 2013.
77. Bauchau, O.A. and Han, S.L.: "Interpolation of Rotation and Motion." *Multibody System Dynamics*, **31**(3): pp 339–370, 2014.
78. Bauchau, O.A., Han, S.L., Mikkola, A., and Matikainen, M.K.: "Comparison of the Absolute Nodal Coordinate and Geometrically Exact Formulations for Beams." *Multibody System Dynamics*, **32**(1): pp 67–85, 2014.
79. Kwak, J.Y., Chun T.Y., Cho, H.S., Shin, S.J., and Bauchau, O.A.: "Advanced Domain Decomposition Method by Local and Mixed Lagrange Multipliers." *Journal of the Korean Society for Industrial and Applied Mathematics*, **18**(1): pp 17–26, 2014.
80. Kwak, J.Y., Chun T.Y., Shin, S.J., Bauchau, O.A.: "Domain decomposition approach to flexible multibody dynamics simulation." *Computational Mechanics*, **53**(1): pp 147–158, 2014.
81. Bauchau, O.A. and Han, S.L.: "Three-Dimensional Beam Theory for Flexible Multibody Dynamics." *Journal of Computational and Nonlinear Dynamics*, **9**(4), 041011 (12 pages), 2014.
82. Han, S.L. and Bauchau, O.A.: "Nonlinear Three-Dimensional Beam Theory for Flexible Multibody Dynamics." *Multibody System Dynamics*, **34**(3): pp 211–242, 2015.
83. Bauchau, O.A., Han, S.L., Mikkola, A., Matikainen, M.K. and Gruber, P.: "Experimental Validation of Flexible Multibody Dynamics Beam Formulations." *Multibody System Dynamics*, **34**(4): pp 373–389, 2015.
84. Kwak, J.Y., Cho, H.S., Chun T.Y., Shin, S.J., Bauchau, O.A.: "Domain Decomposition Approach Applied for Two- and Three-dimensional Problems via Direct Solution Methodology." *International Journal of Aeronautical and Space Sciences*, **16**(2): pp 177–189, 2015.
85. Han, S.L. and Bauchau, O.A.: "On the Solution of Almansi-Michell's Problem." *International Journal of Solids and Structures*, **75-76**(1): 156–171, 2015.
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87. Min, B.Y., Sankar, L., and Bauchau, O.A.: "A CFD-CSD Coupled-Analysis of HART-II Rotor Vibration Reduction using Gurney Flaps." *Aerospace Science and Technology* **48**(1): pp 308–321, 2016.
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89. Shen, J., Singleton, J.D., Piatak, D.J., Bauchau, O.A., and Masarati, P.: "Multibody Dynamics Simulation and Experimental Investigation of a Model-Scale Tiltrotor." *Journal of the American Helicopter Society*, **61**(2): 022000 (11 pages), 2016.

90. Bauchau, O.A., Betsch, P., Cardona, A., Gerstmayr, J., Jonker, B., Masarati, P., and Sonnevile, V.: “Validation of Flexible Multibody Dynamics Beam Formulations using Benchmark Problems.” *Multibody System Dynamics*, **37**(1): pp 29–48, 2016.
91. Han, S.L. and Bauchau, O.A.: “A Novel, Single-Layer Model for Composite Plates Using Local-Global Approach.” *European Journal of Mechanics - A/Solids*, **60**: pp 1–16, 2016.
92. Han, S.L. and Bauchau, O.A.: “On the Analysis of Thin-Walled Beams Based on Hamiltonian Formalism.” *Computers and Structures*, **170**(1): pp 37–48, 2016.
93. Han, S.L. and Bauchau, O.A.: “Manipulation of Motion via Dual Entities.” *Nonlinear Dynamics*, **85**(1), pp 509–524, 2016.
94. Han, S.L. and Bauchau, O.A.: “On the Analysis of Periodically Heterogenous Beams.” *Journal of Applied Mechanics*, **83**(9): 091001 (13 pages), 2016.
95. Han, S.L. and Bauchau, O.A.: “Nonlinear, Three-dimensional Beam Theory for Dynamic Analysis.” *Multibody System Dynamics*, **41**(2): pp 173–200, 2017.
96. Eun, W.J., Kim, J.W., Kwon, O.J., Chung, C.H., Shin, S.J., and Bauchau, O.A.: “Coupled Analysis of Thermo-Fluid-Flexible Multi-body Dynamics of a Two-Dimensional Engine Nozzle.” *International Journal of Aeronautical and Space Sciences*, **18**(1): pp 70–81, 2017.
97. Sonnevile, V., Brüls, O. and Bauchau, O.A.: “Interpolation Schemes for Geometrically Exact Beams: a Motion Approach.” *International Journal of Numerical Methods in Engineering*, **112**(9): pp 1129–1153, 2017.
98. Han, S.L. and Bauchau, O.A.: “On the Nonlinear Extension-Twist Coupling of Beams.” *European Journal of Mechanics / A Solids*, **72**: pp 111–119, 2018.
99. Han, S.L. and Bauchau, O.A.: “Spectral Collocation Methods for the Periodic Solution of Flexible Multibody Dynamics.” *Nonlinear Dynamics*, **92**(4), pp 1599–1618, 2018.
100. Han, S.L. and Bauchau, O.A.: “On the Global Interpolation of Motion.” *Computer Methods in Applied Mechanics and Engineering*, **337**(10), pp 352–386, 2018.
101. Wang, L., Diskin, B., Biedron, R.T., Nielsen, E.J., Sonnevile, V., and Bauchau, O.A.: “High-Fidelity Multidisciplinary Design Optimization Methodology with Application to Rotor Blades.” *Journal of the American Helicopter Society*, **64**(3), July 2019, pp. 1-11(11).
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104. Callejo, A., Sonnevile, V. and Bauchau, O. A.: “Discrete Adjoint Method for the Sensitivity Analysis of Flexible Multibody Systems.” *ASME Journal of Computational and Nonlinear Dynamics*, **14**(2), pp 021001 (11 pages), February 2019.
105. Callejo, A., Bauchau, O.A., and Diskin, B.: “Adjoint Method for the Sensitivity Analysis of Composite Beam Cross-Sections.” *Computers and Structures*, **213**, pp 100–111, 2019.
106. Han, S.L. and Bauchau, O.A.: “Discontinuous Galerkin Method and Dual-SLERP for Time Integration of Flexible Multibody Dynamics.” *ASME Journal of Computational and Nonlinear Dynamics*, **15**(9), pp 091003 (9 pages), September 2020.
107. Wang, L., Diskin, B., Biedron, R., Nielsen, E., Sonnevile, V., and Bauchau, O.A.: “Evaluation of High-Fidelity Multidisciplinary Sensitivity Analysis Framework for Multipoint Rotorcraft Optimization.” *Journal of Aircraft*, **57**(5), pp. 830–842, 2020.
108. Han, S.L. and Bauchau, O.A.: “Simulation and Stability Analysis of Periodic Flexible Multibody Systems.” *Multibody System Dynamics*, **50**(4), pp 381–413, 2020.
109. Bauchau, O.A. and Nemani, N.: “Modeling Viscoelastic Behavior in Flexible Multibody Systems.” *Multibody System Dynamics*, to appear, 2020.
110. Sonnevile, V., Scapolan M., Shan, M.H., and Bauchau, O.A.: “Modal Reduction Procedures for Flexible Multibody Dynamics.” *Multibody System Dynamics*, to appear, 2020.

5 Books

1. Bauchau, O.A. and Craig, J.I.: *Structural Analysis with Application to Aerospace Structures*. Springer, Dordrecht, Heidelberg, London, New-York, 2009. ISBN 978-90-481-2515-9.

2. Bauchau O.A.: *Flexible Multibody Dynamics*. Springer, Dordrecht, Heidelberg, London, New-York, 2011. ISBN 978-94-007-0334-6. This book has won a *2012 Textbook Excellence Award* (Texty Award) from the *Text and Academic Authors Association*.

6 Publications in non-refereed journals

1. Bauchau, O.A.: “Finite Element Approach to Rotor Blade Modeling,” and
2. Bauchau, O.A.: “A Comparison of Composite Rotor Blade Models.” Proceedings of the Technical Workshop on Dynamics and Aeroelastic Stability Modeling of Rotor Systems held at the Georgia Institute of Technology, Atlanta GA, Dec. 4–5 1985.
3. Bauchau, O.A.: “Torsional Buckling and Damage Tolerance of Graphite/Epoxy Shafts.” Proceedings of the Workshop on Composite Material and Structures held at the Rensselaer Polytechnic Institute, Troy NY, Sep. 10–11, 1986.
4. Bauchau, O.A.: “Nonlinear Composite Beam Theory,” and
5. Bauchau, O.A.: “An Approach to Ideal Twist Distribution in Tilt Rotor VTOL Blade Design.”
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135. Eun, W.J., Kim, J.W., Jung, C.H., Shin, S.J., Kwon, O.J., Bauchau, O.A.: “Coupled Analysis of Thermo-Fluid-Flexible Multibody Dynamics For a Two-Dimensional Engine Nozzle,” and
136. Bauchau, O.A. and Müller, A.: “The Motion Formalism in Multibody Dynamics.” Proceedings of MULTIBODY DYNAMICS 2015, ECCOMAS Thematic Conference, J. M. Font-Llagunes (ed.), Barcelona, Spain, Jun. 29–Jul. 2, 2015.
137. Han, S.L. and Bauchau, O.A.: “On the Almansi-Michell Problem for Flexible Multibody Dynamics,” (paper DETC2015-47154) and
138. Han, S.L. and Bauchau, O.A.: “Three-Dimensional Non-Linear Shell Theory for Flexible Multibody Dynamics,” (paper DETC2015-47163) and
139. Bauchau, O.A., Lao, Z.J. and Linn, J.: “Formulations of Viscoelastic Constitutive Laws for Beams in Flexible Multibody Dynamics,” (paper DETC2015-47233) and
140. Bauchau, O.A. and Han, S.L.: “Three-Dimensional Plate Theory for Flexible Multibody Dynamics.” Proceedings of the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Boston, MA, Aug. 2–5, 2015, (paper DETC2015-47249).
141. Bauchau, O.A.: “The Motion Formalism for Flexible Multibody Systems,” and
142. Sonneville, V., Brüls, O., and Bauchau, O.A.: “A Lie Group Approach for the Formulation of Beam and Shell Refined Theories used in Flexible Multibody Systems.” Proceedings of the Fourth Joint International Conference on Multibody System Dynamics, Montréal, Canada, May 29–Jun. 2, 2016.
143. Sonneville, V., Brüls, O., and Bauchau, O.A.: “On the Compatibility Equations in Geometrically Exact Beam Finite Element.” Proceedings of the ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Charlotte, NC, Aug. 21–24, 2016, (paper DETC2016-59954).
144. Wang, L., Diskin, B., Biedron, R.T., Nielsen, E.J., Bauchau, O.A.: “Sensitivity Analysis of Multidisciplinary Rotorcraft Simulations.” AIAA Paper 2017-1670 (Jan 2017).
145. Han, S.L. and Bauchau, O.A.: “High-fidelity, 3D Stress Prediction for Composite Rotor Blades,” and
146. Sonneville, V. and Bauchau, O.A.: “Parallel implementation of Comprehensive Rotor Dynamics Simulation Based on the Motion Formalism.” Proceedings of the American Helicopter Society 73rd Annual Forum and Technology Display, Fort Worth, Texas, May 9–11, 2017.
147. Sonneville, V. and Bauchau, O.A.: “Parallel implementation of flexible multibody dynamics simulation based on the motion formalism,” and
148. Sonneville, V., Brüls, O., and Bauchau, O.A.: “Interpolation schemes for geometrically exact beams: a motion approach,” and
149. Callejo, A., and Bauchau, O.A.: “Adjoint sensitivity analysis of three-dimensional beam formulation .” Proceedings of the ECCOMAS Thematic Conference on Multibody Dynamics, Prague, Czech Republic, Jun. 19–22, 2017.

150. Callejo, A., Bauchau, O.A., Diskin, B. and Wang, L.: “Sensitivity Analysis of Beam Cross-Section Stiffness Using Adjoint Method,” (paper DETC2017-67846) and
151. Han, S.L. and Bauchau, O.A.: “Parallel Time-Integration of Flexible Multibody Dynamics based on Newton-waveform method,” (paper DETC2017-68232) and
152. Bauchau, O.A. and Han, S.L.: “Integrating 3D Stress Analysis with flexible Multibody Dynamics Simulation.” Proceedings of the ASME 2017 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Cleveland, Ohio, Aug. 6–9, 2017, (paper DETC2017-67537). Best Paper Award for the 13th International Conference on Multibody Systems, Nonlinear Dynamics, and Control.
153. Bauchau, O.A. and Han, S.L.: “Integration of 3D Stress Analysis with Flexible Multibody Dynamics Simulation.” and
154. Bauchau, O.A. and Sonneville, V.: “Parallel implementation of flexible multibody dynamics simulation based on the motion formalism.” Proceedings of the IUTAM Symposium on Intelligent Multibody Systems–Dynamics, Control, Simulation, Sozopol, Bulgaria, Sep. 11–15, 2017.
155. Sonneville, V. and Bauchau, O.A.: “The Motion Formalism for Flexible Multibody Systems” and
156. Han, S.L. and Bauchau, O.A.: “Spectral Elements Formulation for Geometrically Exact Beam.” Proceedings of the AIAA SciTech, Gaylord Palms, Kissimmee, Florida, Jan. 8–12 2018.
157. Wang, L., Diskin, B., Biedron, R.T., Nielsen, E.J., Sonneville, V., and Bauchau, O.A.: “High-Fidelity Multidisciplinary Design Optimization Methodology with Application to Rotor Blades” and
158. Sonneville, V. and Bauchau, O.A.: “Parallel Implementation of Comprehensive Rotor Dynamics Simulation Based on the Motion Formalism,”
159. Wang, L., Diskin, B., Biedron, R., Nielsen, R., Sonneville, V., and Bauchau, O.A.: “Multidisciplinary Design Optimization Methodology with Application to Rotor Blades,” and
160. Sinotte, T. and Bauchau, O.A.: “Effect of Curvature on the Structural Dynamics of Composite Rotor Blades.” Proceedings of the 2018 American Helicopter Society Technical Meeting on Aeromechanics Design for Transformative Vertical Flight, San Francisco, CA, Jan. 16–18, 2018.
161. Sonneville, V., Bauchau, O.A., and Sinotte, T.: “Modal reduction of Fatigue Sensitive Components for Comprehensive Rotorcraft Dynamics Simulation.” Proceedings of the American Helicopter Society 74th Annual Forum and Technology Display, Phoenix, Arizona, May 15–17, 2018.
162. Bauchau, O.A. and Nemani, N.: “Formulation of Viscoelastic Constitutive Laws for Beams in Flexible Multibody Dynamics” and
163. Callejo, A. and Bauchau, O.A.: “Efficient Design Optimization of Beam Cross-sections for Multibody Dynamics” and
164. Sonneville, V. and Bauchau, O.A.: “Comparison of Motion Representations for Efficient Numerical Simulation of Flexible Multibody Systems.” Proceedings of the Fifth Joint International Conference on Multibody System Dynamics, Lisbon, Portugal, Jun. 24–28, 2018.
165. Callejo, A., Sonneville, V., and Bauchau, O.A.: “Sensitivity Analysis of Flexible Multibody Systems Based on the Motion Formalism and the Discrete Adjoint Method,” (paper DETC2018-86211) and
166. Sonneville, V. and Bauchau, O.A.: “A Motion Formalism Approach to Modal Reduction for Flexible Multibody System Applications.” Proceedings of the ASME 2018 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Québec, Canada, Aug. 26–29, 2018, (paper DETC2018-86143).
167. Wang, L., Diskin, B., Biedron, R., Nielsen, E., Sonneville, V. and Bauchau, O.A.: “High-Fidelity Multidisciplinary Sensitivity Analysis Framework for Multipoint Rotorcraft Optimization.” Proceedings of the AIAA Scitech 2019 Forum, San Diego, California, Jan. 7–11, 2019, (AIAA 2019-1699). 2019 AIAA Multidisciplinary Design Optimization Best Paper Award.
168. McColl, C., Bauchau, O.A., Sonneville, V., deMontfort, C., Harper, B., McGinty, R., Bazilevs, Y.: “Load Confluence Algorithm Applied to a Combined Rotor/Fuselage Loads Model w/ Extended Application to Structural Fatigue Life Tracking,” and
169. Callejo, A., Bauchau, O.A., Diskin, B.: “Parallel Sensitivity Analysis of Rotor Blade Cross-Sections,” and
170. Sinotte, T., Bauchau, O.A.: “Experimental Strain Measurements of Highly Curved Blades.” Proceedings of the American Helicopter Society 75th Annual Forum and Technology Display, Philadelphia, Pennsylvania, May 13–16, 2019.

171. Bauchau, O.A. and Han, S.L.: “Continuous and Discontinuous Galerkin Formulation for Periodic Problems and Stability Analysis of Flexible Multibody Dynamics.” Proceedings of the ECCOMAS Thematic Conference on Multibody Dynamics, Duisburg, Germany, July 15–18, 2019.
172. Scapolan, M., Sonnevile, V., Callejo, A., and Bauchau, O.A.: “Component-Based Modeling and Sensitivity Analysis of Composite Beam Cross-Sections,” (paper IDETC2019-98065),
173. Bauchau, O.A. and Han, S.L.: “Efficient Finite Element Formulation for Geometrically Exact Beams.” (paper IDETC2019-97639), Best Paper Award for the 15th International Conference on Multibody Systems, Nonlinear Dynamics, and Control, and
174. Han, S.L. and Bauchau, O.A.: “Stability Analysis of Periodic Solutions for Flexible Multibody Dynamics.” Proceedings of the ASME 2019 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Anaheim, CA, Aug. 18–21, 2019 (paper IDETC2019-97651). Best Paper Award for the 15th International Conference on Multibody Systems, Nonlinear Dynamics, and Control.
175. Sinotte, T. and Bauchau, O.A.: “Novel Approach for Experimental Measurement of Sectional Stiffness Properties of Composite Rotor Blades.” Proceedings of the 45th European Rotorcraft Forum, Warsaw, Poland, Sep. 17–20, 2019.
176. Bauchau, O.A. and Shan, M.H.: “Finite Element Models for Flexible Cosserat Solids,” (paper IDETC2020-22134), 2020 Best Paper Honorable Mention Award at the 16th International Conference on Multibody Systems, Nonlinear Dynamics, and Control that you received from the ASME Design Engineering Division and MSNDC Committee.
177. Bauchau, O.A. and Pennisi, G.: “Variational Principles for Non-Material Systems Within an Arbitrary Lagrangian Eulerian Description of Motion.” (paper IDETC2019-22494), and
178. Scapolan, M., Shan, M.H., and Bauchau, O.A.: “Modal Reduction Procedures for Flexible Multibody System Applications.” Proceedings of the ASME 2020 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Virtual Conference, Aug. 17–19, 2020 (paper IDETC2020-22149).
179. Sinotte, T. and Bauchau, O.A.: “Experimental Measurement of Sectional Stiffness Properties of Composite Rotor Blades.” Proceedings of the American Helicopter Society 76th Annual Forum and Technology Display, Virtual Conference, October 5–8, 2020.

7 Reports

1. Bauchau O.A. and Hong C.H.: “Large Displacement Analysis of Naturally Curved and Twisted Beams.” Rensselaer Polytechnic Institute Rotorcraft Technology Center Report No D-86-1, Jul. 1986.
2. Bauchau O.A., Loewy R.G. and Bryan P.S.: “An Approach to Ideal Twist Distribution in Tilt Rotor VTOL Blade Designs.” Rensselaer Polytechnic Institute Rotorcraft Technology Center Report No D-86-2, Jul. 1986.
3. Bauchau O.A. and Liu S.P.: “DYMORE: A Finite Element Based Modal Analysis of Helicopter Rotors.” Contract Report to Sikorsky Aircraft, Mar. 1989.
4. Bauchau O.A. and Kang N.K.: “Nonlinear Dynamic Analysis of Flexible Multibody Systems.” NASA Contractor Report 187597, Jul. 1991.
5. Bauchau O.A., Choi J.Y. and Bottasso C.L.: “On the modeling of shells in multibody dynamics.” NASA/CR-2000-210556, ICASE Report No. 2000-42, Nov. 2000.
6. Bottasso C.L., Bauchau O.A. and Choi J.Y.: “An energy decaying scheme for nonlinear dynamics of shells.” NASA/CR-2000-210557, ICASE Report No. 2000-43, Nov. 2000.

8 Grants and Contracts

8.1 As Principal and Co-Principal Investigator

1. “Anisotropic Beam Theory.” Composite Materials and Structures Program; NASA/AFOSR. Leading investigator, 1983–1986, (Share: USD210k).
2. “Finite Element Analysis of Helicopter Rotor Blades.” Center of Excellence in Rotorcraft Technology; ARO. Leading investigator, 1984–1987, (Share: USD129k).
3. “Ballistic Damage Tolerance of Helicopter Drive Shafts.” Center of Excellence in Rotorcraft Technology; ARO. Leading investigator, 1984–1987, (Share: USD92k).

4. "An Approach to Ideal Twist Distribution in Tilt Rotor VTOL Blade Design." Boeing Helicopter Company. Co-principal investigator (with Dr. R.G. Loewy, 1985–1986, (Share: USD20k).
5. "Rotorcraft Maneuver Loads." Center of Excellence in Rotorcraft Technology; ARO. Leading investigator, 1987–1992, (Share: USD180k).
6. "Rotorcraft Composite Fuselage Frames." Center of Excellence in Rotorcraft Technology; ARO. Leading investigator, 1987–1992, (Share: USD195k).
7. "Helicopter Composite Blade Dynamics." United Technologies, Sikorsky Aircraft. Principal investigator, 1988–1990, (USD25k).
8. "Design of Automotive Braided Drive Shafts." Nippon Steel. Principal investigator, 1988–1990, (USD20k).
9. "Nonlinear Dynamic Analysis of Flexible Multibody Systems." NASA. Principal investigator, 1989–1991, (USD60k).
10. "Rotorcraft Technology Center." ARO and Rotorcraft industry consortium. Co-principal investigator (with Dr. R.G. Loewy), 1992–1995, (USD450k, Share: USD100k).
11. "Establishing a Rensselaer Rotorcraft Technology Center Automated Data Processing Facility." ARO. Co-principal investigator (with Dr. R.G. Loewy), 1993, (USD427k, Share: USD150k).
12. "Augmentation of Rotorcraft Technology Center." ARO and Rotorcraft Industry Consortium. Co-principal investigator (with Dr. A.Z. Lemnios), 1993–1994, (USD529k, Share: USD200k).
13. "Multibody Dynamic Analysis of Rotorcraft Systems." United Technologies Sikorsky Aircraft. Principal investigator, 1992–1994, (USD30k).
14. "Efficient Solution Procedures for Rotorcraft Aeroelastic Analysis." National Rotorcraft Technology Center. Principal Investigator (with Drs. L.N. Sankar and M.J. Smith), 1996–2001, (USD500k, Share: USD150k).
15. "Novel Approaches to the Stability Analysis of Complex Rotorcraft Systems." National Rotorcraft Technology Center. Principal Investigator (with Dr. D.A. Peters), 1996–2001, (Share: USD375k).
16. "Acoustic Emission Bearing Fault Diagnostics System." AI Signal Research, Huntsville AL. Principal investigator, 1998–1999, (USD75k).
17. "Comprehensive Aeromechanical Analysis Using Integrated Analysis Tools." Rotorcraft Industry Technology Association (with Drs. Hodges and Craig), 2000–2003, (USD300k, Share: USD120k).
18. "Multibody Approach to the Dynamic Analysis of Space Structures with Actuated Components." AFOSR. Co-Principal Investigator (with Dr. D.H. Hodges), 2001–2004, (USD308k, Share: USD150k).
19. "Elastically Tailored Smart Composite Rotor Blades." National Rotorcraft Technology Center. Co-Principal Investigator (with Drs. E.A. Armanios and D.S. Dancila), 2001–2005, (USD500k, Share: USD150k).
20. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Principal Investigator, Rotorcraft Industry Technology Association, 2001–2003, (USD300k).
21. "Analysis of Rotor Systems with Inter-Blade Dampers." Bell Helicopter. Principal Investigator, 2003, (USD44k).
22. "Hosting the Tenth International Workshop on Dynamics and Aeroelastic Stability Modeling of Rotorcraft Systems." Army Research Office. Principal Investigator, 2003, (USD8k).
23. "Modeling of Unilateral Contact Conditions in Aerospace Systems." AFOSR. Co-Principal Investigator (with Dr. A.A. Ferri), 2003–2006, (USD339k, Share: USD180k).
24. "Multibody Dynamic Analysis Approach to Comprehensive Rotorcraft Modeling." Rotorcraft Industry Technology Association. Principal Investigator, 2004–2007, (USD300k).
25. "Comprehensive Aeromechanical Analysis Using Integrated Analysis Tools." Rotorcraft Industry Technology Association (with Drs. Hodges and Craig), 2004–2006, (USD200k, Share: USD90k).
26. "Multibody Dynamics Approach to the Comprehensive Modeling of Rotorcraft Systems." Army Research Office. Principal Investigator, 2005, (USD30k).
27. "Unsteady Trim Procedures for the Simulation of Maneuvering Rotorcraft with Comprehensive Models." Army Research Office. Principal Investigator, (with Dr. Carlo L. Bottasso), 2005–2008, (USD227k, Share: USD120k).
28. "Validation of Comprehensive Multibody Code for the UH-60 Aircraft." Sikorsky Aircraft. Principal Investigator, 2005–2006, (USD96k).
29. "Multibody Dynamic Analysis Approach to Comprehensive Rotorcraft Modeling." Center for Rotorcraft Innovation. Principal Investigator, 2007–2010, (USD300k).

30. "Semi-active damper concepts for rotorcraft." Materials Technology Corporation. Principal Investigator, 2005–2006, (USD85k).
31. "Innovative Strategies for Rotary-Wing Coupled Aeroelastic Simulations." NASA. Co-Principal Investigator, (with Dr. Marilyn Smith), 2007–2010, (USD453k, Share: USD210k).
32. "First principles based modeling of elastomeric dampers." SBIR program; Materials Technologies, Inc. Principal Investigator, 2009–2011, (USD98k).
33. "Combined Analytical and Experimental Approaches to Rotor and Dynamic Component Stress Predictions." SBIR program; Technical Data Analysis, Inc. Co-Principal Investigator, (with Dr. Massimo Ruzzene), 2009–2011, (USD211k, Share: USD110k).
34. "High Performance Computing For Rotorcraft Structural Analysis." SBIR program; Advanced Rotorcraft Technology, Inc. Principal Investigator, 2009–2011, (USD200k).
35. "A Confluence Technique for Dynamic Loads Evaluation and Structural Identification of Wind Turbines." State Key Laboratory for Noise and Vibration. Principal Investigator, 2011–2012, (USD16k).
36. "An Analytical-Experimental Technique for Dynamic Loads Evaluation and Structural Identification (Digital Twins) of Wind Turbines." University of Michigan, Shanghai Jiao Tong University joint research initiative. Co-Principal Investigator, (with Dr. Carlos Cesnik), 2011–2012, (USD150k, Share: USD75k).
37. "Dymore Development Project." Bell Helicopter, Textron, Inc. Principal Investigator, 2011–2012, (USD23k).
38. "A Study of Flexible Multi-Body Systems for Mechanisms under Thermo-Fluid Environment." Korean Agency for Defense Development. Co-Principal Investigator with Prof. Shin, Seoul National University and Prof. Kwon, Korean Advanced Institute for Science and Technology, 2012–2015, (Share: USD78k).
39. "Analytical and Experimental Investigation of Laminated Composite Shells for Multibody Dynamics Applications." National Science Foundation of China. Co-Principal Investigator with Prof Liu, Jinyang, 2012–2016, (USD130k, Share: USD65k).
40. "Dymore Development Project." Bell Helicopter, Textron, Inc. Principal Investigator, 2012–2013 (USD32k).
41. "Development of Discrete Adjoint Capability for Rotorcraft Comprehensive Code." NASA-National Institute of Aerospace. Principal Investigator, 2016–2018 (USD354k).
42. "High-Fidelity Structural Design Environment for Rotor Blades." Vertical Lift Research Center of Excellence; ARO-NAVY-NASA. Leading investigator, 2016–2021 (Share: USD500k).
43. "Structural Dynamics Investigation of Highly Curved Rotor Blades." University of Maryland-Army Research Laboratory APG-CRA. Leading investigator, 2016–2018, (Share: USD200k).
44. "Prediction of Rotor Loads from Fuselage Sensors for Improved Structural Modeling and Fatigue Life Calculation." STTR program phase 1; Technical Data Analysis, Inc. Leading Investigator, 2017–2018, (USD46k).
45. "Development of Discrete Adjoint Capability for Rotorcraft Comprehensive Code." NASA-National Institute of Aerospace. Principal Investigator, 2016–2017(USD170k).
46. "Structural Dynamics Investigation of Highly Curved Rotor Blades" University of Maryland-Army Research Laboratory Aberdeen Proving Grounds-Cooperative Research Agreement. Leading investigator, 2016–2018, (Share: 300k)
47. "Enhanced Aeromechanical Loads and Stress Assessment." Broad Agency Announcement For Applied Aviation Technologies; Advanced Rotorcraft Technology, Inc. Leading Investigator, 2017–2020, (USD816k).
48. "Development of Parallel Algorithms for Rotorcraft Comprehensive Analysis." NASA-National Institute of Aerospace. Principal Investigator, 2017–2018(USD80k).

8.2 As Investigator

1. "Micro-cracking of Ceramic Matrix composites." High Temperature Structural Composites Program; DARPA/ONR. Leading investigator, 1986–1987, (Share: USD35k).
2. "Revolutionary Physics-Based Design Tools for Quiet Helicopters." Defense Advanced Research Project Agency (with Drs. Sankar, Brentner, Long, Menon, Morris, Ruffin, Smith, Gandhi), 2005–2006, (USD2,400k, Share: USD240k).
3. "Combat Search and Rescue (CSAR) Vertical Takeoff and Landing Gyrodyne Demonstrator Aircraft "HELIPLANE" Phase 1." Defense Advanced Research Project Agency (with Drs. Schrage, Ahuja, Hodges, Komerath, Sankar), 2005– 2006, (USD1,200k, Share: USD200k).

9 Presentations

1. "Finite Element Approach to Rotor Blade Modeling," and
2. "A Comparison of composite Rotor Blade Models." Presented at the Technical Workshop on Dynamics and Aeroelastic Stability Modeling of Rotor Systems held at the Georgia Institute of Technology, Atlanta GA, Dec. 4–5 1985.
3. "Box Beam Analysis: Theory and Experiments." Invited Seminar at the Virginia Polytechnic Institute, Blacksburg VA, May 7, 1986.
4. "Warping Deformations in Composite Helicopter Rotor Blades." Invited Seminar at the Chung Shan Institute, Long Tang, Taiwan, Jun. 12, 1986.
5. "Torsional Buckling and Damage Tolerance of Graphite/Epoxy Shafts." Presented at the Workshop on Composite Material and Structures held at the Rensselaer Polytechnic Institute, Troy NY, Sep. 10–11, 1986.
6. "Innovative Design with Composite Materials." Invited Presentation at the Winter Gordon Research Conference on Composites, Santa Barbara CA, Jan. 12–16 1987.
7. "Finite Elements Approach to Helicopter Blade Aeroelasticity." Invited Seminar at United Technologies Research Center, Hartford CT, May 19, 1987.
8. "Nonlinear Composite Beam Theory," and
9. "An Approach to Ideal Twist Distribution in Tilt Rotor VTOL Blade Design." Presented at the Workshop on Dynamics and Aeroelastic Stability Modeling of Rotor Systems held at the Florida Atlantic University, Boca Raton FL, Nov. 18–20 1987.
10. "Applications of Composite Materials to Helicopter Structures." Presented at the Center for Composite Materials and Structures Overview, held at the Rensselaer Polytechnic Institute, Troy NY, Mar. 2–3, 1988.
11. "Nonlinear Dynamic Analysis of Composite Helicopter Rotor Blade." Invited Seminar at Syracuse University, Syracuse NY, Mar. 4, 1988.
12. "Dynamic Analysis of a Model Rotor in a Vacuum." Presented at the Second Workshop on the Integrated Technology Rotor, NASA Ames Research Center, Moffet Field CA, Aug. 2–3, 1988.
13. "A Finite Element Based Modal Approach to Multibody Dynamics." Presented at the ARO Workshop on Multibody Dynamics, Research Triangle Park NC, Dec. 12, 1988.
14. "Nonlinear Dynamic Analysis of Composite Helicopter Rotor Blade." Invited Seminar at National Taiwan University, Taipei, Taiwan, Republic of China, Dec. 27, 1988.
15. "DYMORE: A Finite Element Based Modal Analysis for Rotorcraft Modeling." Presented at Sikorsky Aircraft, Stratford CT, May 10, 1989.
16. "Torsional Buckling Analysis and Damage Tolerance of Graphite/Epoxy Helicopter Drive Shafts." Presented at the 45th Annual Forum of the American Helicopter Society, Boston MA, May 22–24, 1989.
17. "Analysis and Design of Curved Composite Beams." Presented at the 2nd International Workshop on Composite Materials and Structures for Rotorcraft, Rensselaer Polytechnic Institute, Troy NY, Sep. 14–15, 1989.
18. "Nonlinear Dynamics of Flexible Multibody Systems with Rotating Components." Presented at the 5th DAMVIBS meeting, NASA Langley Research Center, Hampton VA, Sep. 10–11, 1990.
19. "Dynamic Analysis of Rotor Flex-Structures Based on Nonlinear Anisotropic Shell Models," and
20. "On The Choice of Appropriate Bases for Nonlinear Dynamic Modal Analysis." Presented at the International Technical Specialists' Meeting on Rotorcraft Basic Research, Georgia Institute of Technology, Atlanta GA, Mar. 25– 27, 1991.
21. "Direct Integration of Helicopter Rotor Nonlinear Finite Element Dynamic Equations," and
22. "Multibody Formulation for Helicopter Nonlinear Dynamic Analysis." Presented at the Fourth Workshop on Dynamics and Aeroelastic Stability Modeling of Rotorcraft Systems. University of Maryland, College Park MD, Nov. 19–21, 1991.
23. "On Design and Optimization of Curved Composite Beams." Presented at the 48th Annual Forum of the American Helicopter Society, Washington DC, Jun. 3–5, 1992.
24. "Multibody Formulation for Helicopter Nonlinear Dynamic Analysis." Presented at Bell Helicopter Textron, Inc. Fort Worth TX, Aug. 27, 1992.
25. "Energy Balance Methodologies for Helicopter Stability Analysis." Presented at Boeing Helicopter Corporation, Philadelphia PA, Jul. 8, 1992.

26. "Comprehensive Structural Dynamic Analysis Methodologies for Rotorcraft." Presented at United Technologies Sikorsky Aircraft, Stratford CT, Jul. 13, 1992.
27. "Structural Models for Comprehensive Rotorcraft Analysis." Presented at the Beamology Workshop, NASA Ames Research Center, Moffet Field CA, Oct. 13, 1992.
28. "Dynamic Analysis of a Helicopter Tail-rotor Based on Nonlinear Shell Models." Presented at the ASME Winter annual Meeting, Anaheim CA, Nov. 9–13, 1992.
29. "Multibody Formulation for Nonlinear Dynamic Analysis." Presented at the Rensselaer Polytechnic Institute Civil Engineering Department Seminar Series, Troy NY, Nov. 24, 1992.
30. "Secondary Stresses in Composite Sandwich Structures and Curved Frame Members." Presented at the Gordon Research Conference on Composites, Ventura CA, Jan. 11–15, 1993.
31. "Helicopter Blade Design for Vibration Minimization by Optimal Placement of Moving Masses." Presented at the AHS International Technical Specialists' Meeting on Multidisciplinary Design Optimization, Atlanta GA, Apr. 27– 28, 1993.
32. "Eigendeformation Modes in Beams and Plates." Presented at the Second U.S. National Congress on Computational Mechanics, Washington DC, Aug. 16–18, 1993.
33. "Nonlinear Dynamic Analysis of Multibody Systems." Presented at Rensselaer Polytechnic Institute, Troy NY, Oct. 6, 1993.
34. "Nonlinear Damper Effect on Ground Resonance." Presented at the Fifth International Workshop on Dynamics and Aeroelastic Stability Modeling of Rotorcraft Systems, Rensselaer Polytechnic Institute, Troy NY, Oct. 18–20, 1993.
35. "Multibody Formulation for Tandem Rotor Helicopters." Presented at Boeing Helicopter Company, Philadelphia PA, Feb. 22, 1994.
36. "Multibody Formulations for Rotorcraft Aeroelasticity." Presented at United Technologies Sikorsky Aircraft Division, Stratford CT, May 5, 1994.
37. "A Multibody Formulation for Helicopter Structural Analysis." Presented at the Army Applied Aviation Technology Directorate, NASA Langley Research Center, Hampton VA, Nov. 18, 1993.
38. "Dynamics of Helicopter Rotors with Movable Masses." Presented at the Vehicle Structures Directorate, NASA Langley Research Center, Hampton VA, Jun. 14, 1994.
39. "Multibody Formulations for Rotorcraft Aeroelasticity," and
40. "Computation of the Sectional Properties of Beams." Presented at NASA Ames Research Center, Moffet Field CA, Jul. 20, 1994.
41. "Multibody Formulation for Rotorcraft Dynamic Analysis." Presented at School of Aerospace Engineering, Georgia Institute of Technology, Atlanta GA, Oct. 4, 1994.
42. "Multibody Formulation for Power Transmission Drive Systems." Presented at the KAMATICS Corporation, Bloomfield CT, Oct. 1, 1994.
43. "Energy Decaying Scheme with Adaptive Time Step Methodology for Nonlinear Beam Models," and
44. "Dynamic Analysis of Nonlinear Elastic Multibody Systems Using Energy Decaying Schemes." Presented at the 36th Structures, Structural Dynamics, and Materials Conference, New Orleans LA, Apr. 10–13, 1995.
45. "Multibody Formulation for Rotorcraft Dynamic Analysis." Presented at the American Helicopter Society 51st Annual Forum and Technology Display, Fort-Worth TX, May 9–11, 1995.
46. "Dynamic Analysis of Helicopter Airframe Components." Presented at the 6th International Workshop on Dynamics and Aeroelastic Stability Modeling of Rotorcraft Systems, University of California in Los-Angeles, Los-Angeles CA, Nov. 22–24, 1995.
47. "Nonlinear Aeroelastic Effects in Damage Composite Aerospace Structures." Presented at the AFOSR Structural Mechanics Workshop, Virginia Beach VA , Jun. 24–27, 1996.
48. "Energy Decaying Schemes for Nonlinear Elastic Multibody Systems." Presented at the pre-nominated session on multibody dynamics at the 19th International Congress of Theoretical and Applied Mechanics, Kyoto Japan, Aug. 24–30, 1996.
49. "Advanced CFD and CSD Methods for Multi-Disciplinary Applications in Rotorcraft Problems." Presented at the 6th AIAA/NASA/USAF Multi-Disciplinary Analysis and Optimization Symposium, Bellevue WA., Sep. 4–6, 1996.
50. "Computational Schemes for the Analysis of Nonlinear Elastic Multibody Systems." Presented at the Georgia Institute of Technology Mechanics Seminar Series, Atlanta GA, Dec. 5, 1996.

51. "Nonlinear Aeroelastic Effects in Damaged Composite Aerospace Structures." Presented at the 35th Aerospace Sciences Meeting and Exhibit, Reno NV, Jan. 6–9, 1997.
52. "Improved Finite Element Modeling of Helicopter Airframe Connections." Presented at the American Helicopter Society 53rd Annual Forum and Technology Display, Virginia Beach VA, Apr. 29–May 1, 1997.
53. "Computational Schemes for Nonlinear Elastodynamics and Multibody Dynamics." Presented at the 4th National Congress on Theoretical and Applied Mechanics, Brussels, May 22–23, 1997. (Keynote lecture)
54. "Computational Schemes for Nonlinear Elastic Multibody Systems." Presented at the 16th Biennial Conference on Mechanical Vibration and Noise, Sacramento CA, Sep. 14–17, 1997.
55. "A Comparison of Various Methods for Stability Analysis." Presented at the Seventh International Workshop on Dynamics and Aeroelasticity Stability Modeling, St. Louis MO, Oct. 14–16, 1997.
56. "An Implicit Floquet Theory for Rotorcraft Stability Analysis." Presented at the American Helicopter Society 54th Annual Forum and Technology Display, Washington DC, May 20–22, 1998.
57. "Analysis of Flexible Multibody Systems with Intermittent Contacts." Presented at the Seventh Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures, Blacksburg VA, Jul. 26–30, 1998.
58. "On the Modeling of Prismatic Joints in Flexible Multibody Systems," and
59. "On the Modeling of Friction and Rolling in Flexible Multibody Systems." Presented at the Sixth Pan-American Congress on Applied Mechanics, Rio de Janeiro, Brazil, Jan. 4–8, 1999.
60. "Reduced Order Models for Aeroelastic Stability Analysis." Presented at the 40th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, St Louis MO, Apr. 12–15, 1999.
61. "On the Modeling of Cylindrical and Prismatic Joints in Flexible Multibody Systems." Presented at EUROMECH Colloquium 404 of Advances in Computational Multibody Dynamics, Lisbon, Portugal, Sep. 20–23, 1999.
62. "On the Modeling of Variable Diameter Tilt Rotor." Presented at the Eighth Army Research Office Workshop on Aeroelasticity of Rotorcraft Systems, Penn State University, State College PA, Oct 18–20, 1999.
63. "Contact Conditions for Cylindrical, Prismatic, and Screw Joints in Flexible Multibody Systems." Invited Seminar, ETH seminar series in Applied Mechanics, ETH Zürich, Jan. 13, 2000.
64. "Finite Element Based Multibody Dynamics Approach to Rotorcraft Modeling." Presented at United Technologies, Sikorsky Aircraft, Stratford CT, Mar. 16, 2000.
65. "Computational Schemes for Nonlinear Elasto-Dynamics," and
66. "Contact Conditions for Cylindrical, Prismatic, and Screw Joints in Flexible Multibody Systems," and
67. "On the Modeling of Friction and Rolling in Flexible Multibody Systems." Presented at the 41th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Atlanta GA, Apr. 3–6, 2000.
68. "Stability Analysis of Comprehensive Rotorcraft Models." Presented at the American Helicopter Society 56th Annual Forum and Technology Display, Virginia Beach VA, May 2–4, 2000.
69. "Numerical and Physical Stability Analysis of Flexible Multibody Systems." Invited presentation at the NATO Advanced Research Workshop on Computational Aspects of Nonlinear Structural Systems with Large Rigid Body Motions. Pultusk, Poland, Jul. 2–7, 2000.
70. "An Implicit Transition Matrix Approach to Stability Analysis of Flexible Multibody Systems." Presented at the 20th International Congress of Theoretical and Applied Mechanics, Chicago IL, Aug. 27th–Sep. 2nd, 2000.
71. "A Multibody Dynamics Approach to the Modeling of Wind Turbines." Presented at the General Purpose Aeroelastic Code Evaluation Workshop, National Renewable Energy Laboratory, National Wind Turbine Center, Boulder CO, Oct. 23–24, 2000.
72. "Multibody Modeling of Engage and Disengage Operations of Helicopter Rotors." Presented at the AHS Rotorcraft Dynamics and Aeromechanics Specialists' Meeting, Atlanta GA, Nov. 13–14, 2000.
73. "A Finite Element Based Tool for the Comprehensive Analysis of Rotorcraft Systems." Presented at the Review of Integrated Helicopter Design Tools: Technology for Rotorcraft Integrated Analysis and Design, West Palm Beach FL, Nov. 29–30, 2000.
74. "A Finite Element Based Tool for the Analysis of Nonlinear Flexible Multibody Systems." Presented at the Air Force Research Laboratory, Space Vehicle Directorate, Kirtland AFB, NM, Mar. 5th, 2001.
75. "On the Modeling of Shells in Multibody Dynamics." Presented at the First MIT Conference on Computational Fluid and Solid Mechanics, Cambridge, MA, Jun. 12–15, 2001.

76. "An Energy Decaying Scheme for Nonlinear Dynamics of Shells." Keynote Lecture presented at the Second European Conference on Computational Mechanics, Cracow, Poland, Jun. 26–9, 2001.
77. "A General Purpose Multibody Code Based on Conserving/Dissipative Algorithms." Presented at the Sixth U.S. National Congress on Computational Mechanics, Dearborn, MI, Aug. 1–3, 2001.
78. "Modeling of Joints with Clearance In Flexible Multibody Systems." Presented at the 18th Biennial Conference on Mechanical Vibration and Noise, Pittsburgh PA, Sep. 9–12, 2001.
79. "On the Modeling of Shells in Multibody Dynamic." Presented at the 18th Biennial Conference on Mechanical Vibration and Noise, Pittsburgh PA, Sep. 9–12, 2001.
80. "Comprehensive Aeromechanical Analysis Using Integrated Analysis Tools," and
81. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Rotorcraft Industry Technology Association Year End Review in Arlington TX, Feb. 26–28, 2002.
82. "Multibody Approach to the Dynamic Analysis of Space Structures with Actuated Components." Presented at the AFOSR Computational Mathematics and Applied Mathematics Program Review, Shalimar FL, May 29–31, 2002.
83. "Modeling the Bifilar Pendulum Using Nonlinear, Flexible Multibody Dynamics." Presented at the American Helicopter Society 58th Forum and Technology Display, Montréal, Québec, Canada, Jun. 11–13, 2002.
84. "Modeling of a Vibration Absorber Using Nonlinear, Flexible Multibody Dynamics: The Bifilar Pendulum." Presented at the Fifth World Congress on Computational Mechanics. Vienna, Austria, Jul. 7–12, 2002.
85. "Dynamic Simulation of Cables and Membranes." Invited presentation at the Fifth World Congress on Computational Mechanics. Vienna, Austria, Jul. 7–12, 2002.
86. "Comprehensive Aeromechanical Analysis Using Integrated Analysis Tools," and
87. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Rotorcraft Industry Technology Association Year End Review in Phoenix AZ, Feb. 25–28, 2003.
88. "Coupled Rotor-Fuselage Analysis with Finite Motions Using Component Mode Synthesis." Presented at the American Helicopter Society 59th Forum and Technology Display, Phoenix AZ, May 6–8, 2003.
89. "Modeling of Contact Conditions with Application to Aerospace Systems Involving Backlash, Free-play and Friction." Presented at the 7th US National Congress on Computational Mechanics, Albuquerque NM, Jul. 28–30, 2003.
90. "A Self-Stabilized Algorithm for Enforcing Constraints in Multibody Systems." Presented at the 19th Biennial Conference on Mechanical Vibration and Noise, Chicago IL, Sep. 2–6, 2003. Paper DECT 2003 VIB-48332.
91. "Validation of Sectional Analysis Tools for Blade Design Process," and
92. "Extension-Twist Coupling Optimization in Composite Rotor Blades." Presented at the Tenth International Workshop on Aeroelasticity of Rotorcraft Systems, Atlanta, Georgia, Nov. 3 - 4, 2003.
93. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Rotorcraft Industry Technology Association Year End Review in Atlanta GA, Feb. 18–20, 2004.
94. "Modeling of Unilateral Contact in Multibody Systems." Presented at the XXII Southeastern Conference on Theoretical and Applied Mechanics, Tuskegee AL, Aug. 15-17, 2004.
95. "Modeling of Unilateral Contact Conditions in Aerospace Systems." Presented at the Contractor's Meeting in Mechanics of Materials and Devices & Structural Mechanics Wintergreen Resort, Wintergreen, VA, Aug. 18-21, 2004.
96. "Development and Validation of Accurate and Efficient Cross-sectional Analysis Tools," and
97. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Rotorcraft Industry Technology Association Year End Review in Philadelphia PA, Feb. 15–17, 2005.
98. "DYMORE A Finite Element Based Tool for the Analysis of Nonlinear Flexible Multibody Systems." Invited seminar in the Morphing Lecture Series presented at the National Institute of Aerospace in Hampton VA, Jul. 26, 2005.
99. "Modeling of Unilateral Contact Conditions in Aerospace Systems." Presented at the Contractor's Meeting in Mechanics of Materials and Devices & Structural Mechanics, Eldorado Hotel, Santa Fe, NM, Aug. 29–Sep. 1, 2005.
100. "Modeling Friction Phenomena in Flexible Multibody Dynamics." Presented at the Sixth European Conference on Structural Dynamics, Paris, France, Sep. 4–7, 2005.
101. "Stability Analysis of Complex Multibody Systems," and

102. "Reduced Stability to Perturbations in the Numerical Solution of Multibody DAE's." Presented at the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Long Beach, CA, Sep. 24–28, 2005.
103. "Aeromechanical Stability Augmentation Using Semi-active Friction Modulation of Lag Dampers," and
104. "On the Modeling of Hydraulic Components in Rotorcraft Systems," and
105. "Stability Analysis of Complex Rotorcraft Systems." Presented at the Eleventh International Workshop on Rotorcraft Dynamics and Aeroelasticity, Boca Raton, Florida, Oct. 12-14, 2005.
106. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Center for Rotorcraft Innovation Year End Review in Dallas TX, Feb. 21–23, 2006.
107. "Efficient and Robust Approaches to the Stability Analysis of Large Multibody Systems." Invited Seminar presented at the University of Illinois at Chicago, Mar. 28, 2006.
108. "On the Modeling of Hydraulic Components in Rotorcraft Systems," Best paper in the session award, and
109. "The Semi-Active Coulomb Friction Damper Concept." Presented at the American Helicopter Society 62nd Forum and Technology Display, Phoenix AZ, May 9–11, 2006. Best paper in the session award.
110. "DYMORE: A Finite Element Based Tool for Coupled CSD/CFD Aeroelastic Simulation of Rotorcraft." Invited seminar presented at the NASA Langley Research Center, Hampton VA, Jul. 13, 2006.
111. "Stability Analysis of Complex Multibody Systems." Presented at the 7th World congress on Computational Mechanics, Los Angeles CA, Jul. 16-22, 2006.
112. "Development and Validation of Accurate and Efficient Cross-sectional Analysis Tools," and
113. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Center For Rotorcraft Innovation Year End Review in Philadelphia PA, Feb. 14–15, 2007.
114. "Improved Computational Strategies for Rotor Blades Presenting High Gradients in Sectional Properties," and
115. "Efficient and Robust Approaches for Rotorcraft Stability Analysis." Presented at the American Helicopter Society 63rd Forum and Technology Display, Virginia Beach VA, May 1–3, 2007.
116. "Stability Evaluation and System Identification for Rotorcraft Systems." Invited seminar presented at Konkuk University, Seoul, South Korea, Jun. 15, 2007.
117. "Performance Evaluation of Numerical Integration Schemes for Flexible Multibody Systems," and
118. "Optimal Control Based on Subspace Identification Algorithms for Multibody Systems." Presented at the MULTIBODY DYNAMICS 2007, ECCOMAS Thematic Conference, Milano, Italy, 25–28 Jun. 2007.
119. "DYMORE: A Finite Element Based Tool for coupled CSD/CFD Aeroelastic Simulations." Invited seminar presented at Bell Helicopter, Dallas, Texas, Jul. 19, 2007.
120. "Enforcing Constraints in Multibody Systems: A Review" Presented at the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Las Vegas, NV, Sep. 4–7, 2007. Keynote Lecture.
121. "Stability Evaluation and System Identification of Flexible Multibody Systems" Presented at the International Forum on Rotorcraft Multidisciplinary Technology for Dual Applications, Seoul, South-Korea, Oct 15–17, 2007.
122. "Enforcing Constraints in Multibody Systems: A Review" Invited seminar presented at Seoul National University, South-Korea, Oct. 17, 2007.
123. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Center for Rotorcraft Innovation Year End Review in Phoenix AZ, Feb. 19–20, 2008.
124. "Effect of Modeling Approximations on the Stability of Autopilot Controllers." Presented at the American Helicopter Society 64th Forum and Technology Display, Montréal, Québec, Canada, Apr. 29–May 1, 2008.
125. "Flexible Multibody Dynamic Simulations." Invited Seminar presented at the Charles Stark Draper Laboratory, Cambridge, Massachusetts, Jul. 31st, 2008.
126. "Rotorcraft Comprehensive Simulation using Finite Element Based Multibody Formulations." Invited Seminar presented at the Technische Universität München, München, Germany, Dec. 5, 2008.
127. "Finite Element Based Formulations for Flexible Multibody Dynamics." Invited Seminar presented at the Pennsylvania State University, University Park, PA, Feb. 2, 2009.
128. "Finite Element Based Formulations for Flexible Multibody Dynamics." Invited Seminar presented at University of California, Berkeley, Berkeley, CA, Feb. 17, 2009.
129. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Center for Rotorcraft Innovation Year End Review in Mountain View CA, Feb. 24–26, 2009.

130. "Development of Parallel Computation Tools for Flexible Multibody Systems." Invited Seminar presented at University of Texas, Arlington, TX, Oct. 2, 2009.
131. "Interpolation of Finite Rotations in Flexible Multibody Dynamics Simulations," and
132. "Scaling of Constraints and Augmented Lagrangian Formulations in Multibody Dynamics Simulations." Presented at the MULTIBODY DYNAMICS 2009, ECCOMAS Thematic Conference, Warsaw, Poland, 29 Jun.–2 Jul. 2009.
133. "Development of Parallel Computation Tools for Flexible Multibody Systems." Invited Seminar presented at the Nanyang Technological University, Singapore, Nov. 23, 2009.
134. "Finite Element Based Multibody Dynamic Analysis Approach to Rotorcraft Modeling." Presented at the Center for Rotorcraft Innovation Year End Review in Atlanta GA, Feb. 23–25, 2010.
135. "Combined Analytical and Experimental Approaches to Rotor and Dynamic Component Stress Predictions." Presented at the Airloads Workshop, Atlanta GA, Feb. 25–26, 2010.
136. "Nonlinear Stability Analysis of Wind Turbines." Presented at the National Renewable Energy Laboratory, Golden CO, Mar. 5, 2010.
137. "Tensorial Deformation Measures for Flexible Joints." Invited Seminar presented at the University of Maryland Baltimore Campus, Baltimore, Mar. 12, 2010.
138. "Scaling of Constraints and Augmented Lagrangian Formulations in Multibody Dynamics Simulations." Invited Seminar presented at the University of Maryland Baltimore Campus, Baltimore, Mar. 12, 2010.
139. "Tensorial Deformation Measures for Flexible Joints." Invited Seminar presented at the University of Michigan - Shanghai Jiao Tong University Joint Institute, Shanghai, China, May 18, 2010.
140. "Intrinsic Flexible Joints," and
141. "Parallel Computation Approaches for Flexible Multibody Dynamics Simulations." Presented at the First Joint International Conference on Multibody System Dynamics, Lappeenranta, Finland, 25–27 May 2010.
142. "Tensorial Deformation Measures for Flexible Joints." Invited Keynote lecture Presented at the Symposium on the Mechanics of Slender Structures, Donostia - San Sebastián, Euskadi, Spain 21–23 Jul. 2010.
143. "Tensorial Deformation Measures for Flexible Joints." Presented at the Department of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, China, Sep. 26, 2010.
144. "Scaling of Constraints and Augmented Lagrangian Formulations in Multibody Dynamics Simulations." Presented at the School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China, Oct. 8, 2010.
145. "Scaling of Constraints and Augmented Lagrangian Formulations in Multibody Dynamics Simulations." Invited seminar presented at the Middle East Technical University, Department of Aerospace Engineering, Ankara, Turkey, Dec. 3, 2010.
146. "Scaling of Constraints and Augmented Lagrangian Formulations in Multibody Dynamics Simulations." Invited seminar presented at Tsinghua University, Department of Engineering Mechanics, Beijing, China, Dec. 9, 2010
147. "Beam Theories of Multibody Dynamics Applications," and
148. "Selection of Rotation Variables for Multibody Dynamics Formulations." Presented at the MULTIBODY DYNAMICS 2011, ECCOMAS Thematic Conference, Brussels, Belgium, 4–7 Jul. 2011.
149. "Stability Analysis for Complex Wind Turbine Models." Presented at Vestas Technology R & D Americas, Inc, in Houston TX, Sep. 1, 2011.
150. "Finite Element Based Multibody Formulations for Flexible Multibody Systems." Invited seminar presented at the Huazhong University of Science and Technology, Aerospace Research Center, Wuhan, China, Dec. 20, 2011.
151. "Intrinsic Formulations for Flexible Multibody Dynamics." Keynote Lecture presented at the Second Joint International Conference on Multibody System Dynamics, Stuttgart, Germany, May 29 - Jun. 1, 2012.
152. "Finite Element Based Multibody Formulations for Wind Turbines." Invited seminar presented at the Pusan National University, Busan, South Korea, Jul. 25, 2012.
153. "Localized Lagrange Multipliers in Flexible Multibody Dynamics." Keynote Lecture presented at the Sixth Asian Conference on Multibody Dynamics, Shanghai, China, Aug. 26 - 30, 2012.
154. "Modeling Flexibility in Multibody Systems." Keynote Lecture presented at the Fifth Recurdyne User's conference, Seoul, South Korea, Oct. 25-26, 2012.

155. “Three-Dimensional Beam Theory for Flexible Multibody Dynamics.” Invited seminar presented at the Fraunhofer Institute, ITWM, Kaiserslautern, Germany, Apr. 12, 2013.
156. “Three-Dimensional Beam Theory for Flexible Multibody Dynamics.” Invited seminar presented at the University of Erlangen-Nuremberg, Germany, Apr. 26, 2013.
157. “Experimental Validation of Flexible Multibody Dynamics Beam Formulations,” and
158. “Benchmark Problems for Beam Models in Flexible Multibody Dynamics,” and
159. “Three-Dimensional Beam Theory for Flexible Multibody Dynamics.” Presented at the MULTIBODY DYNAMICS 2013, ECCOMAS Thematic Conference, Zagreb, Croatia, 1–4 Jul. 2013.
160. “Advanced Plate Theory for Multibody Dynamics,” and
161. “Advanced Beam Theory for Multibody Dynamics,” and
162. “Comparison of the Absolute Nodal Coordinate and Geometrically Exact Formulations for Beams.” Presented at the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Portland, OR, Aug. 4–7, 2013.
163. “Comprehensive Modeling of Rotorcraft Using Finite Element Multibody Dynamics Procedures.” Invited seminar presented at the Hong Kong University of Science and Technology, Hong Kong, Nov. 25, 2013.
164. “Dimensional Reduction Procedures for Comprehensive Modeling of Rotorcraft.” Invited seminar presented at the Hong Kong University of Science and Technology, Hong Kong, Jan. 22, 2014.
165. “Comprehensive Modeling of Rotorcraft Using Finite Element Multibody Dynamics Procedures.” Invited seminar presented at the Université de Liège, Liège, Belgium, Feb. 10, 2014.
166. “An Approach to Three-Dimensional Beam Theory: SectionBuilder.” Invited seminar presented at LMS Samtech, a Siemens Business, Angleur, Belgium, Feb. 18, 2014.
167. “Dimensional Reduction Procedures for Flexible Multibody Systems.” Invited seminar presented at the University of Stuttgart, Stuttgart, Germany, Mar. 17, 2014.
168. “Dimensional Reduction Procedures for Flexible Multibody Systems.” Invited seminar presented at the Karlsruhe Institute of Technology, Karlsruhe, Germany, Mar. 20, 2014.
169. “An Approach to Three-Dimensional Beam Theory: SectionBuilder.” Invited seminar presented at SIMPACK AG, Gilching, Germany, Mar. 25, 2014.
170. “A Novel Parallel Algorithm for Rotor Dynamics Simulation.” Presented at the American Helicopter Society 70th Annual Forum and Technology Display, Montréal, Québec, Canada, May 20–22, 2014.
171. “Validation of Flexible Multibody Dynamics Beam Formulations using Benchmark Problems,” and
172. “A Novel Parallel Algorithm for Flexible Multibody Dynamics Simulation,” and
173. “Nonlinear Three-Dimensional Beam Theory for Flexible Multibody Dynamics.” Presented at the Third Joint International Conference on Multibody System Dynamics, The Seventh Asian Conference on Multibody Dynamics, BEXCO, Busan, Korea, Jun. 30–Jul. 3, 2014.
174. “Simulation Tools for Aerospace Flexible Multibody Systems Dynamics.” Invited seminar presented at the Hong Kong Society of Theoretical and Applied Mechanics, Hong Kong, Oct. 18, 2014.
175. “Dimensional Reduction Procedures for Flexible Aerospace Systems.” Invited seminar presented at the Seoul National University, Seoul, South Korea, Dec. 23, 2014.
176. “Integrating Three-Dimensional Stress Evaluation with Rotorcraft Comprehensive Analysis.” Invited seminar presented at the University of Maryland, College Park, MD, Apr. 6, 2015.
177. “Validation of Flexible Multibody Dynamics Beam Formulations using Benchmark Problems,” and
178. “Three-Dimensional Nonlinear Shell Theory for Flexible Multibody Dynamics,” and
179. “The Motion Formalism in Multibody Dynamics.” Presented at the MULTIBODY DYNAMICS 2015, ECCOMAS Thematic Conference, Barcelona, Spain, Jun. 29–Jul. 2, 2015.
180. “On the Almansi-Michell Problem for Flexible Multibody Dynamics,” and
181. “Three-Dimensional Non-Linear Shell Theory for Flexible Multibody Dynamics,” and
182. “Formulations of Viscoelastic Constitutive Laws for Beams in Flexible Multibody Dynamics,” and
183. “Three-Dimensional Plate Theory for Flexible Multibody Dynamics.” Presented at the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Boston, MA, Aug. 2–5, 2015.

184. “Integrating Three-Dimensional Stress Evaluation with Rotorcraft Comprehensive Analysis.” Invited seminar presented at the National Institute of Aerospace, Hampton, VA, Nov. 19, 2015.
185. “The Motion Formalism for Flexible Multibody Systems,” and
186. “A Lie Group Approach for the Formulation of Beam and Shell Refined Theories used in Flexible Multibody Systems.” Presented at the Fourth Joint International Conference on Multibody System Dynamics, Montréal, Canada, May 29–Jun. 2, 2016.
187. “*SectionBuilder*: Refined Beam Theory for Comprehensive Rotorcraft Analysis.” Invited seminar presented at Advanced Rotorcraft Technology, Sunnyvale, California, Jul. 7, 2016.
188. “The Motion Formalism for Flexible Multibody Systems.” Invited seminar presented at NASA Ames Research Center, Moffet Field, California, Jul. 7, 2016.
189. “Kinematic Compatibility Equations for Geometrically Exact Beam Elements.” Presented at the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Charlotte, NC, Aug. 21–24, 2016.
190. “Integrated, Efficient Analysis of Flexible Multibody Systems.” Keynote lecture presented at the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Charlotte, NC, Aug. 21–24, 2016.
191. “Refined Beam Theory for Flexible Multibody Dynamics Systems.” Presented at the Society of Engineering Science 53rd Annual Technical Meeting, College Park, MD, Oct. 2–5, 2016.
192. “Integrating 3D Stress Evaluation With Rotorcraft Comprehensive Analysis.” Invited seminar presented at Brunel University London, Uxbridge, UK, Nov. 24, 2016.
193. “Interpolation Schemes for Geometrically Exact Beams: A Motion Approach,” Presented at the ECCOMAS Thematic Conference on Multibody Dynamics, Prague, Czech Republic, Jun. 19–22, 2017.
194. “Integrating 3D Stress Analysis with flexible Multibody Dynamics Simulation.” Presented at the ASME 2017 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Cleveland, Ohio, Aug. 6–9, 2017. (Best Paper Award for the 13th International Conference on Multibody Systems, Nonlinear Dynamics, and Control).
195. “Integration of 3D Stress Analysis with Flexible Multibody Dynamics Simulation,” and
196. “Parallel Implementation of Flexible Multibody Dynamics Simulation Based on the Motion Formalism.” Presented at the IUTAM Symposium on Intelligent Multibody Systems–Dynamics, Control, Simulation, Sozopol, Bulgaria, Sep. 11–15, 2017.
197. “Flexible Multibody Dynamics Tools For Rotorcraft Comprehensive Analysis.” Invited seminar presented at the National Institute of Aerospace, Hampton, VA, Sep. 28, 2017.
198. “The Motion Formalism for Flexible Multibody Systems.” Presented at the AIAA SciTech, Gaylord Palms, Kissimmee, Florida, 8–12 Jan. 2018.
199. “Formulation of Viscoelastic Constitutive Laws for Beams in Flexible Multibody Dynamics” Presented at the Fifth Joint International Conference on Multibody System Dynamics, Lisbon, Portugal, Jun. 24–28, 2018.
200. “A Motion Formalism Approach to Modal Reduction for Flexible Multibody System Applications.” Presented at the ASME 2018 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Québec, Canada, Aug. 26–29, 2018.
201. “Solutions of Boundary Value and Periodic Problems for Flexible Multibody Dynamics Systems.” Invited seminar presented at the National Institute of Aerospace, Hampton, VA, Sep. 28, 2018.
202. “Continuous and Discontinuous Galerkin Formulation for Periodic Problems and Stability Analysis of Flexible Multibody Dynamics.” Presented at the ECCOMAS Thematic Conference on Multibody Dynamics, Duisburg, Germany, July 15–18, 2019.
203. “Finite Elements Based Techniques for Flexible Multibody Dynamics.” Invited seminar presented at the NASA Langley Research Center, Hampton, VA, Aug. 12, 2019.
204. “Efficient Finite Element Formulation for Geometrically Exact Beams.” Presented at the ASME 2019 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Anaheim, CA, Aug. 18–21, 2019.

10 Graduate students

10.1 Doctoral students at the Rensselaer Polytechnic Institute

1. Hong, C.H.: “Finite Element Approach to the Dynamic Analysis of Composite Helicopter Blades.” Oct. 1987.
2. Chiang, W.Y.: “Structural Dynamic Analysis of Bearingless Rotor Blades.” May 1992.
3. Peck, A.W.: “Design and Analysis of Curved Composite Components for Rotorcraft Fuselage Frames.” Aug. 1992.
4. Kang, N.K.: “Nonlinear Multibody Formulation for Rotorcraft Analysis.” May 1993.
5. Damilano, G.J.: “Finite Element Methods for Nonlinear Elastic Constrained Multibody Systems.” Aug. 1993.
6. Lee, M.R.: “Minimization of Helicopter Rotor Blade Loads Using Formal Optimization and Adjustable Masses.” Aug. 1993.
7. Theron, N.J.: “Multibody Dynamic Analysis of Helicopter Rotors.” Dec. 1994.
8. Lee, M.S.: “Nonlinear Finite Element Based Multibody Analysis for Rotor Dynamics.” Sep. 1995.
9. Yun, S.H.: “Vibration Prediction Capabilities of Helicopter Airframe Connections.” Jun. 1996.

10.2 Doctoral students at the Georgia Institute of Technology

1. Nikishkov, Y.G.: “Computational Stability Analysis of Dynamical Systems.” Aug. 2000.
2. Rodriguez, J.: “Modeling of Complex Systems using Nonlinear, Flexible Multibody Dynamics.” Aug. 2002.
3. Choi, J.Y.: “Flexible Multibody Analysis of Thin Structures with Actuated Components.” Dec. 2002.
4. Agarwal, S.: “Aeromechanical Stability Augmentation Using Semi-Active Friction Based Lead Lag Damper.” Dec. 2005.
5. Wang, J.L.: “Efficient and Robust Approaches to the Stability Analysis and Optimal Control of Large-Scale Multibody Systems.” Aug. 2007.
6. Liu, H.Y.: “Interfacing Comprehensive Rotorcraft Analysis with Advanced Aeromechanics and Vortex Wake Models.” May 2008.
7. Chakravarty, U.: “SectionBuilder: An Innovative Finite Element Based Tool for Analysis and Design of Composite Beam Cross-Sections.” May 2008.
8. Epple, A.: “Methods for Increased Computational Efficiency of Multibody Simulations.” Aug. 2008.
9. Ju, C.K.: “Modeling Friction Phenomena and Elastomeric Dampers in Multibody Dynamics Analysis.” Aug. 2009.
10. Van Weddingen, Y.: “Friction Based Lead-Lag Dampers for Rotorcraft.” May 2010.
11. Zaki, A.: “Unsteady Aerodynamic models for Rotorcraft Applications.” May 2011.
12. Heo, Seundo: “Parallel computation Algorithms for Multibody Dynamics Simulations.” Aug. 2017.

10.3 Doctoral students at the University of Maryland

1. Han, Shilei: “Integration of Flexible Multibody Dynamic Analysis with Dimensional Reduction Techniques”. May 2019.
2. Sinotte, Tyler: “Experimental Measurement of Sectional Stiffness Properties of Composite Rotor Blades”. May 2020.

11 Short courses

Involved in teaching the following short courses:

1. “Composite Materials and Structures,” short course held at Sikorsky Aircraft in Stratford CT, Oct. 1985, Dec. 1985, and Feb. 1986.
2. “Rotorcraft Structural Dynamic, Vibrations, and Aeroelasticity,” short course held at the Naval Postgraduate School in Monterey CA, Jul. 1986, and 87; and at the Rensselaer Polytechnic Institute Jun. 1987, 88, 89, and 90.
3. “Advanced Composite Materials and Structures,” short course held at the Rensselaer Polytechnic Institute in Jul. 1986, 87, 88, 89, and 90.

4. “Composite Materials and Structures,” short course held at Eastman Kodak Company, Rochester NY, Feb. 1987.
5. “Finite Element Methodologies in Rotorcraft Dynamics,” short course held at Agusta, S.p.a., Gallarate, Italy, May 21–23, 1990.
6. “Contemporary Rotorcraft Structural Dynamics and Aeroelasticity,” short course held at Patuxent River Naval Air Station, Lexington Park MD, Aug. 23–27, 1993.
7. “Modeling Rotorcraft Systems Using Multibody Formulations,” short course held at The National Institute of Aerospace, Jun. 14–18, 2004.
8. “Multibody Dynamics for Rotorcraft: Formulation and Numerical Applications,” short course held at Konkuk University, Seoul, South Korea, Jul. 7–11, 2008 and at Seoul National University, Seoul, South Korea, Jul. 14–18, 2008.
9. “Comprehensive Modeling of Wind Turbines using Multibody Dynamics Formulations,” short course held at Vestas Technology R & D Americas, Inc, in Houston TX, Jul. 8–11, 2009.
10. “Multibody Dynamics for Rotorcraft: Formulation and Numerical Applications,” short course held at TAI - Turkish Aerospace Industries, Helicopter Flight Sciences, Ankara, Turkey, Nov. 29–Dec. 3, 2010.
11. “Multibody Dynamics for Wind Turbines: Formulation and Numerical Applications,” short course held at China Engine International Ltd., Beijing, China, Jun. 13–17, 2011.
12. “Implementation of Dymore for Rotorcraft Dynamics,” short course held at TAI - Turkish Aerospace Industries, Helicopter Flight Sciences, Ankara, Turkey, Dec. 15–17, 2014.
13. “Flexible Multibody Dynamics,” short course held at the Technische Universität München, Lehrstuhl für Windenergie, Munich, Germany, Jun. 2–25, 2015.
14. “Motion formalism for flexible multibody dynamics,” short course held at the Fifth Joint International Conference on Multibody System Dynamics – IMSD 2018 in Lisbon, Portugal, June 23–24, 2018.
15. “The motion formalism for flexible multibody systems: A practical introduction,” short course held at the ASME 2019 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Anaheim, CA, Aug. 18–21, 2019.

12 Service

12.1 Professional Contributions

1. American Institute of Aeronautics and Astronautics, Senior Member 1985–2017, Fellow, 2018.
2. American Society of Mechanical Engineers, Associate Member 1984–2008, Fellow, 2009. Member: *ASME Technical Committee on Multibody Systems and Nonlinear Dynamics* (2005–2011)
3. American Helicopter Society, Member 1985–2015, Technical Fellow, 2016. Member: *Dynamics Committee*. (1996–1998, 2000–2002, 2007–2009)
4. Associate Editor: *Journal of the American Helicopter Society*. (1993–2010)
5. Advisory Board: *Multibody System Dynamics*. Member 2002–present.
6. Associate Editor: *Journal of Computational and Nonlinear Dynamics*. (2005–2011)
7. Guest Editor: *Computer Methods in Applied Mechanics and Engineering*, special issue on “Computational Multibody Dynamics,” Jan. 2006; *ASME Journal of Computational and Nonlinear Dynamics*, special issue on “Computational Multibody Dynamics,” Jul. 2010.
8. Associate Editor: *Journal of Multi-body Dynamics (Part K of the Proceeding of the Institution of Mechanical Engineers)* (2009–present)
9. *International Federation for the Promotion of Mechanism and Machine Science*. Committee on Multibody dynamics, 2012–present.
10. Associate Editor: *Journal of Vibration and Acoustics*. (2012–2013)

12.2 Department and University Committees

1. AE Committee on Post Tenure Review, 2002, Chair.
2. AE Committee on Aeroelasticity and Dynamics, 1995–present; 2001–present, Chair.
3. AE Faculty Honors Committee, 2000–present.
4. AE Committee on Structural Mechanics & Material Behavior, 1995–present.

13 Honors and Awards

1. *Prix Auguste Sacré* awarded by the *Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique* for the period 1994–2000. In recognition of his work in Structural Dynamics, and Rotors and Rotor Blade Dynamics.
2. The *National Aeronautics and Space Administration* Group Achievement Award awarded to the NASA/Army UH-60A Airloads Program Team for “enabling, for the first time, the characterization and understanding of a helicopter’s complex, unsteady, aerodynamic operating environment.” May 2007.
3. Fellow of the *American Society of Mechanical Engineers*, 2009.
4. “Thanks for being a great teacher!” award. *In appreciation of your teaching style and dedication to helping student learn in Advanced Dynamics*, Georgia Institute of Technology Center for the Enhancement of Teaching and Learning, May 3, 2007.
5. “Thanks for being a great teacher!” award. *In appreciation of your teaching style and dedication to helping student learn in Advanced Dynamics*, Georgia Institute of Technology Center for the Enhancement of Teaching and Learning, Mar. 30, 2010.
6. Appointed “*Zhiyuan Chair Professor of Mechanical Engineering*” at Shanghai Jiao Tong University in 2011.
7. Awarded the “*1000 People Plan*” of the Chinese Government in 2011.
8. The book entitled “Flexible Multibody Dynamics” has won the *2012 Textbook Excellence Awards* (Texty Award) from the *Text and Academic Authors Association*.
9. Aug.-Wilhelm Scheer Visiting Professor at the Technische Universität München, München, Germany, Jun. 2–25, 2015. Host: Prof. Carlo Bottasso, Lehrstuhl für Windenergie.
10. 2015 *d’Alembert Award* of the *American Society of Mechanical Engineers*. The *d’Alembert Award*, established in 2005, recognizes lifelong contributions to the field of multibody system dynamics. The award is presented by ASME’s Design Engineering Division and awarded at the annual ASME International Conference on Multibody Systems, Nonlinear Dynamics and Control, as part of the ASME International Design Engineering Technical Conferences.
11. Technical Fellow of the *American Helicopter Society*, 2016.
12. Fellow of the *American Institute of Aeronautics and Astronautics*, 2018.
13. National Institute of Aerospace Distinguished Langley Professor, 2019.