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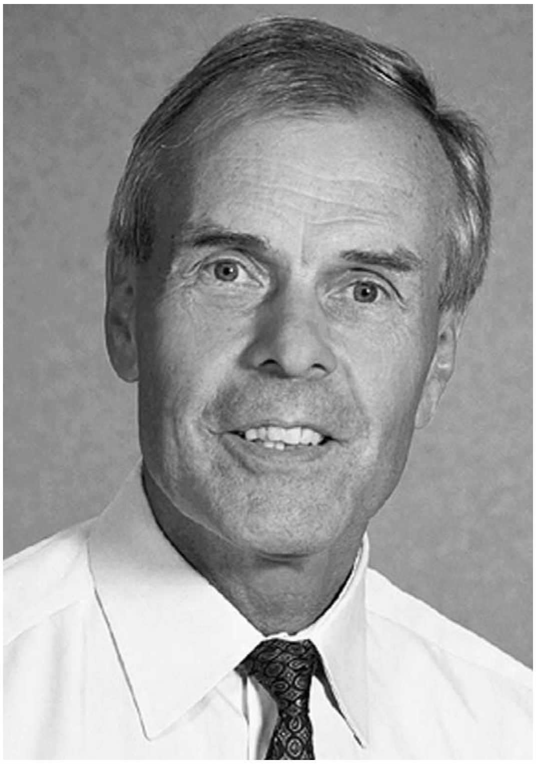
Preface



It is our distinct privilege and pleasure to present this special issue of *Computers and Structures* in celebration of the 60th birthday of Klaus-Jürgen Bathe. Presented in this issue is a compilation of more than 50 papers, authored by more than 100 distinguished researchers from academia, industry and government, addressing a wide breadth of topics in computational fluid and solid mechanics. Each of these exceptional papers share the common attribute of having been significantly influenced by Jürgen's extraordinary contributions to the field of computational mechanics. Indeed, it comes as no surprise that Jürgen is considered by many as the father of modern day computational mechanics, because of his tremendous contributions to the field and because through his work numerous engineers, for the first time, were actually able to use finite element methods (FEMs).

The child prodigy of a proud German heritage, Jürgen was born in Berlin in May 1943. The Bathe family left Berlin prior to the end of World War II and settled finally in the town of Oldenburg located in northern Germany. Shortly after he graduated from high school at the top of his class, Jürgen moved to Namibia where he worked on a farm for three months. He then left for South Africa where he worked at a variety of jobs, including surveyor on two road-construction projects.

Eventually, Jürgen was offered a scholarship to study civil engineering at the University of Cape Town where

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he graduated as a gold medallist in 1967. During his undergraduate studies, Jürgen became fascinated with computer-based analysis of structures and wrote his very first technical article entitled "The Use of the Electronic Computer in Structural Analysis" published in *Impact, Journal of the University of Cape Town Engineering Society*. In this paper Jürgen first reveals himself as a visionary in computational mechanics which is embodied in the statement "... Progress in design of new structures seems to be unlimited." (see front of his 1996 book).

Soon after graduating from the University of Cape Town, Jürgen entered graduate school at the University of Calgary, Canada. There he received the MS Degree in civil engineering in 1969. Immediately upon completion of his graduate studies at Calgary, Jürgen entered the Ph.D. program in civil engineering at the University of California, Berkeley. It was during these Berkeley years that Jürgen developed the foundation for his impressive career. He spent the first year of his graduate studies at Berkeley under the advisement of Alexander Scordelis studying computational methods for bridge analysis. Jürgen was then awarded a University Scholarship to complete his Ph.D. studies. With E.L. Wilson and R.W. Clough as his advisors, Jürgen selected numerical solution techniques for large eigenvalue problems as his Ph.D. dissertation topic. His dissertation is the basis for many numerical eigensolvers still in use today.

After completing his Ph.D. thesis in 1971, Jürgen remained at Berkeley as a post-doctoral fellow and consultant to industry until the end of 1974. During that time he developed the FEM computer programs SAP IV and NONSAP, and also wrote his first textbook *Numerical Methods in Finite Element Analysis*. His pioneering work during the Berkeley years has had a profound impact on the field of computational mechanics. The subspace iteration method, a numerical eigensolver and a product of his Ph.D. work, is still used extensively in almost all FEM computer programs. The FEM computer programs SAP IV and NONSAP have been used by thousands of individuals and organizations to learn about and, for the first time, to actually apply the FEM in research and practice. The designs of numerous structures have been based on analyses conducted using these computer programs. Countless graduate students worldwide have founded their graduate studies on SAP IV and NONSAP analyses. The impact of Jürgen's work on the evolvement of computational mechanics during his Berkeley years alone is unrivaled by the entire career achievements of many famous researchers and practitioners in the field.

In 1975, Jürgen joined the Department of Mechanical Engineering at the Massachusetts Institute of Technology. During his career at MIT he has taught courses in the areas of applied mechanics, FEMs for structures and fluids, dynamics, and continuum mechanics. His research has focused primarily on the nonlinear analysis of structures, heat transfer, field problems and fluid–structure interactions using modern computational techniques. Jürgen has authored three textbooks on FEM analysis and has edited a number of proceedings books on the subject. He is the author of more than 200 technical papers and resides on the editorial boards of many international journals. Jürgen is also the author of 34 MIT produced video-lectures on linear and nonlinear FEM analysis. These tapes have been used by individuals and organizations around the world to study the FEM and its applications.

While Jürgen has made numerous fundamental and far-reaching contributions to the field of computational mechanics, see our summary below, a crown jewel of Jürgen's illustrious career is the highly renowned ADINA finite element computer program suite. As Director of ADINA R&D, he has carefully guided the development of the ADINA System from its infancy. ADINA is used worldwide in engineering practice, research, and education in applications involving the static and dynamic nonlinear analysis of solids and structures, and the analysis of heat transfer and field problems, Navier–Stokes fluid flows, and fluid–structure interactions. Many of the solution techniques developed for ADINA have subsequently been implemented in other commercially available FEM computer programs. The ADINA program has frequently been selected, both by individuals and organizations, as the analysis tool of choice because the prescribed solution methods are known to be reliable and effective. For example, after the 1989 Loma Prieta and 1994 Northridge earthquakes, the ADINA program was chosen by the California Department of Transportation for the re-analysis of seven existing highway bridges, including the San Francisco Bay Bridge, and ADINA is currently being used in the design of the new Bay Bridge.

The papers presented in this special issue, written by Jürgen's former students, his colleagues, and users of ADINA, serve as a testimony to the tremendous impact his contributions have had on FEM analysis and the field of computational mechanics in general. The papers in this volume not only address topics in the traditional areas of civil and mechanical engineering, but transcend also into new areas such as the rapidly emerging disciplines of biomechanical and biomedical engineering. We extend our deepest appreciation to the contributing authors for sharing in this honor to Jürgen. We also would like to apologize to all those who would have liked to contribute to this volume but who we missed to contact.

In closing, we would like to express our heartfelt appreciation to Jürgen, not only for his outstanding contributions to the profession, but more importantly for his friendship and collegiality. We wish him continued health, happiness and prosperity on this momentous occasion in his life.

Contributions by Klaus-Jürgen Bathe

The achievements of Jürgen are clearly unique as a researcher in the field of computational mechanics. He has made outstanding contributions through four specific venues:

(i) He has pioneered new FEMs now widely used in engineering analysis.
(ii) He has contributed to the advancement of the fundamental theory of FEMs.
(iii) He has developed finite element software that is employed routinely worldwide by thousands of organizations.
(iv) He has been actively engaged in transferring university research results to Industry through his publications, computer program developments, and the organization of fourteen international bi-annual held conferences for Industry and Academia at MIT.

Although more than 10 years younger than the others, Jürgen has been recognized as one of the five early pioneers of the FEM in a survey article by J. Mackerle, Computers and Structures, Vol. 80, page 1596, 2002.

In the following, we briefly summarize Jürgen's contributions in several specific areas of computational mechanics and list some of his relevant publications.

Linear dynamic analysis

The topic of his doctoral work was the solution of large eigenvalue problems arising in frequency and mode shape calculations or linearized buckling analysis. As part of that research, Jürgen developed the basic subspace iteration method. The subspace iteration method is today employed in practically all major structural analysis programs for the solution of frequencies and mode shapes in dynamic, vibration and earthquake analysis of structures.

KJ Bathe, Solution Methods for Large Generalized Eigenvalue Problems in Structural Engineering, Report UCSESM 71-20, Department of Civil Engineering, University of California, Berkeley, November 1971 (Ph.D. thesis).

KJ Bathe and EL Wilson, Large Eigenvalue Problems in Dynamic Analysis, ASCE, Eng. Mech. Div., Vol. 98, 1471–1485, December 1972.

KJ Bathe and EL Wilson, Solution Methods for Eigenvalue Problems in Structural Mechanics, Int. J. for Numerical Methods in Engineering, Vol. 6, 213–266, 1973.

KJ Bathe, Convergence of Subspace Iteration, in Formulations and Computational Algorithms in Finite Element Analysis (KJ Bathe, JT Oden and W Wunderlich, eds.), M.I.T. Press, 1977.

KJ Bathe and S Ramaswamy, An Accelerated Subspace Iteration Method, J. Comp. Meth. in Appl. Mech. and Eng., Vol. 23, 313–331, 1980.

Nonlinear dynamic analysis

For the step-by-step solution of nonlinear dynamic response, effective time integration schemes must be employed and, as probably first shown by Jürgen, using implicit methods, iterations to satisfy the governing dynamic equilibrium equations are required. Jürgen analyzed time integration schemes and made their use for stable nonlinear dynamic analyses widely available in the programs NONSAP and ADINA.

EL Wilson, I Farhoomand and KJ Bathe, Nonlinear Dynamic Analysis of Complex Structures, International Journal of Earthquake Engineering and Structural Dynamics, Vol. 1, 241–252, 1973.

KJ Bathe and EL Wilson, Stability and Accuracy Analysis of Direct Integration Methods, International Journal of Earthquake Engineering and Structural Dynamics, Vol. 1, 283–291, 1973.

KJ Bathe, H Ozdemir and EL Wilson, Static and Dynamic Geometric and Material Nonlinear Analysis, Report UCSESM 74-4, Department of Civil Engineering, University of California, Berkeley, February 1974.

KJ Bathe, Static and Dynamic Geometric and Material Nonlinear Analysis Using ADINA, Report 82448-2, Acoustics and Vibration Laboratory, M.I.T., May 1976, revised May 1977.

SM Ma and KJ Bathe, On Finite Element Analysis of Pipe Whip Problems, J. Nuclear Engineering and Design, Vol. 37, 413–430, 1976.

KJ Bathe and H Ozdemir, Elastic–Plastic Large Deformation Static and Dynamic Analysis, Computers & Structures, Vol. 6, No. 2, 81–92, 1976.

KJ Bathe, Finite Element Formulation, Modeling, and Solution of Nonlinear Dynamic Problems, in Numerical Methods for Partial Differential Equations (SW Parter, ed.), Academic Press, 1979.

KJ Bathe and V Sonnad, On Effective Implicit Time Integration in Analysis of Fluid-Structure Problems, Int. J. Numerical Methods in Eng., Vol. 15, 943–948, 1980.

KJ Bathe and AP Cimento, Some Practical Procedures for the Solution of Nonlinear Finite Element Equations, J. Computer Meth. in Applied Mech. and Eng., Vol. 22, 59–85, 1980.

KJ Bathe and S Gracewski, On Nonlinear Dynamic Analysis using Substructuring and Mode Superposition, Computers & Structures, Vol. 13, 699–707, 1981.

Shell elements

The MITC shell elements that Jürgen developed with his students are widely recognized as the best shell elements available. The MITC basic four-node element is offered in modern finite element programs as the major element to use.

EN Dvorkin and KJ Bathe, A Continuum Mechanics Based Four-Node Shell Element for General Nonlinear Analysis, Engineering Computations, Vol. 1, 77–88, 1984.

KJ Bathe and EN Dvorkin, A Formulation of General Shell Elements—The Use of Mixed Interpolation of Tensorial Components, Int. J. for Numerical Methods in Engineering, Vol. 22, 697–722, 1986.

M Bucalem and KJ Bathe, Higher-Order MITC General Shell Elements, Int. J. for Numerical Methods in Engineering, Vol. 36, 3729–3754, 1993.

KJ Bathe, A Iosilevich and D Chapelle, An Evaluation of the MITC Shell Elements, Computers & Structures, Vol. 75, 1–30, 2000.

KJ Bathe, A Iosilevich and D Chapelle, An Inf-Sup Test for Shell Finite Elements, Computers & Structures, Vol. 75, 439–456, 2000.

KJ Bathe, PS Lee and JF Hiller, Towards Improving the MITC9 Shell Element, Computers & Structures, Vol. 81, 477–489, 2003.

Plate bending analysis

The plate bending elements developed with students and colleagues are unique in that they have a strong mathematical basis and are optimal elements.

KJ Bathe and EN Dvorkin, A Four-Node Plate Bending Element Based on Mindlin/Reissner Plate Theory and a Mixed Interpolation, Int. J. for Numerical Methods in Engineering, Vol. 21, 367–383, 1985.

KJ Bathe, F Brezzi and SW Cho, The MITC7 and MITC9 Plate Bending Elements, Computers & Structures, Vol. 32, No. 3/4, 797–814, 1989.

KJ Bathe, M Bucalem and F Brezzi, Displacement and Stress Convergence of the MITC Plate Bending Elements, J. Eng. Computations, Vol. 7, No. 4, 291–302, 1990.

F Brezzi, KJ Bathe and M Fortin, Mixed-Interpolated Elements for Reissner / Mindlin Plates, Int. J. for Numerical Methods in Engineering, Vol. 28, 1787–1801, 1989.

Nonlinear analysis of solids and structures

The finite element methods for nonlinear analysis developed by Jürgen with students and colleagues have been seminal contributions and are recognized to be most effective. They have been widely adopted in computer programs. These procedures include the updated and total Lagrangian formulations, the mixed displacement–pressure formulation, the contact algorithms, and the algorithms for inelastic analysis.

KJ Bathe, E Ramm and EL Wilson, Finite Element Formulations for Large Deformation Dynamic Analysis, Int. J. for Numerical Methods in Engineering, Vol. 9, 353–386, 1975.

KJ Bathe, S Bolourchi, S Ramaswamy and MD Snyder, Some Computational Capabilities for Nonlinear Finite Element Analysis, J. Nuclear Engineering and Design, Vol. 46, 429–455, 1978.

KJ Bathe and S Bolourchi, Large Displacement Analysis of Three-Dimensional Beam Structures, Int. J. for Numerical Methods in Engineering, Vol. 14, 961–986, 1979.

KJ Bathe and S Ramaswamy, On Three-dimensional Nonlinear Analysis of Concrete Structures, J. Nuclear Engineering and Design, Vol. 52, 385–409, 1979.

MD Snyder and KJ Bathe, A Solution Procedure for Thermo-Elastic-Plastic and Creep Problems, J. Nuclear Engineering and Design, Vol. 64, 49–80, 1981.

KJ Bathe and C Almeida, A Simple and Effective Pipe Elbow Element—Interaction Effects, J. Appl. Mech., Vol. 49, 165–171, 1982.

KJ Bathe, C Almeida and LW Ho, A Simple and Effective Pipe Elbow Element—Some Nonlinear Capabilities, Computers & Structures, Vol. 17, 659–667, 1983.

KJ Bathe and EN Dvorkin, On the Automatic Solution of Nonlinear Finite Element Equations, Computers & Structures, Vol. 17, 871–879, 1983.

KJ Bathe, AB Chaudhary, EN Dvorkin and M Kojic, On the Solution of Nonlinear Finite Element Equations, Proceedings of the Int. Conference on Computer-Aided Analysis and Design of Concrete Structures, Split, Yugoslavia, September 1984.

KJ Bathe and AB Chaudhary, A Solution Method for Planar and Axisymmetric Contact Problems, Int. J. for Numerical Methods in Engineering, Vol. 21, 65–88, 1985.

AB Chaudhary and KJ Bathe, A Solution Method for Static and Dynamic Analysis of Three-Dimensional Contact Problems with Friction, Computers & Structures, Vol. 24, No. 6, 855–873, 1986.

T Sussman and KJ Bathe, Studies of Finite Element Procedures—Stress Band Plots and the Evaluation of Finite Element Meshes, Engineering Computations, Vol. 3, 178–191, 1986.

T Sussman and KJ Bathe, A Finite Element Formulation for Nonlinear Incompressible Elastic and Inelastic Analysis, Computers & Structures, Vol. 26, 357–409, 1987.

M Kojic and KJ Bathe, The Effective-Stress-Function Algorithm for Thermo-Elasto-Plasticity and Creep, Int. J. for Numerical Methods in Engineering, Vol. 24, 1509–1532, 1987.

KJ Bathe, J Walczak, A Welch and N Mistry, Nonlinear Analysis of Concrete Structures, Computers & Structures, Vol. 32, No. 3/4, 563–590, 1989.

SW Chae and KJ Bathe, On Automatic Mesh Construction and Mesh Refinement in Finite Element Analysis, Computers & Structures, Vol. 32, 911–936, 1989.

AL Eterovic and KJ Bathe, A Hyperelastic-Based Large Strain Elasto-Plastic Constitutive Formulation with Combined Isotropic-Kinematic Hardening using the Logarithmic Stress and Strain Measures, Int. J. Numerical Methods in Engineering, Vol. 30, 1099–1114, 1990.

AL Eterovic and KJ Bathe, On the Treatment of Inequality Constraints Arising from Contact Conditions in Finite Element Analysis, Computers & Structures, Vol. 40, 203–209, 1991.

K Kato, NS Lee and KJ Bathe, Adaptive Finite Element Analysis of Large Strain Elastic Response, Computers & Structures, Vol. 42, 829–855, 1993.

NS Lee and KJ Bathe, Error Indicators and Adaptive Remeshing in Large Deformation Finite Element Analysis, Finite Elements in Analysis and Design, Vol. 16, 99–139, 1994.

G Gabriel and KJ Bathe, Some Computational Issues in Large Strain Elasto-Plastic Analysis, Computers & Structures, Vol. 56, No. 2/3, pp. 249–267, 1995.

P Gaudenzi and KJ Bathe, An Iterative Finite Element Procedure for the Analysis of Piezoelectric Continua, J. of Intelligent Material Systems and Structures, Vol. 6, No. 2, 266–273, 1995.

KJ Bathe and PA Bouzinov, On the Constraint Function Method for Contact Problems, Computers & Structures, Vol. 64, No. 5/6, 1069–1085, 1997.

KJ Bathe, J Walczak, O Guillermin, PA Bouzinov and H Chen, Advances in Crush Analysis, Computers & Structures, Vol. 72, 31–47, 1999.

D Pantuso, KJ Bathe and PA Bouzinov, A Finite Element Procedure for the Analysis of Thermo-Mechanical Solids in Contact, Computers & Structures, Vol. 75, 551–573, 2000.

M Kawka and KJ Bathe, Implicit Integration for the Solution of Metal Forming Processes, in Computational Fluid and Solid Mechanics, (KJ Bathe, ed.), Elsevier Science, 283–286, 2001.

N El-Abbasi and KJ Bathe, Stability and Patch Test Performance of Contact Discretizations and a New Solution Algorithm, Computers & Structures, Vol. 79, 1473–1486, 2001.

S Rugonyi and KJ Bathe, Lyapunov Characteristic Exponent Calculation for Finite Element Discretized Models, in Computational Fluid and Solid Mechanics (KJ Bathe, ed.), Elsevier Science, 1640–1643, 2001.

S Rugonyi and KJ Bathe, An Evaluation of the Lyapunov Characteristic Exponent of Chaotic Continuous Systems, Int. J. Numerical Methods in Engineering, Vol. 56, 145–163, 2003.

Analysis of heat transfer and field problems

For the finite element analysis of field problems with free surfaces and phase changes, Jürgen and his students formulated some very efficient algorithms. These techniques are now widely used in research and industry.

KJ Bathe, ADINA-T—A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis of Temperatures, Acoustics and Vibration Laboratory, Report 82448-5, Department of Mechanical Engineering, M.I.T., May 1977, revised December 1978.

KJ Bathe and M Khoshgoftaar, Finite Element Free Surface Seepage Analysis Without Mesh Iteration, J. of Num. and Anal. Methods in Geomechanics, Vol. 3, 13–22, 1979.

KJ Bathe and M Khoshgoftaar, Finite Element Formulation and Solution of Nonlinear Heat Transfer, J. Nuclear Engineering and Design, Vol. 51, 389–401, 1979.

RO Ritchie and KJ Bathe, On the Calibration of the Electrical Potential Technique for Monitoring Crack Growth Using Finite Element Methods, J. of Fracture, Vol. 15, 47–55, 1979.

WD Rolph III and KJ Bathe, An Efficient Algorithm for Nonlinear Heat Transfer with Phase Changes, Int. J. for Numerical Methods in Engineering, Vol. 18, 119–134, 1982.

Inviscid fluids with structural interactions

Very efficient finite element formulations were developed by Jürgen and his students for the analysis of inviscid fluids, whose response is described by a velocity potential, interacting with structures. These formulations are now widely used in industry. In addition, important insight was revealed regarding mixed displacement/pressure based formulations.

LG Olson and KJ Bathe, Analysis of Fluid-Structure Interactions—A Direct Symmetric Coupled Formulation Based on a Fluid Velocity Potential, Computers & Structures, Vol. 21, 21–32, 1985.

LG Olson and KJ Bathe, An Infinite Element for Analysis of Transient Fluid-Structure Interactions, J. Engineering Computations Vol. 2, 319–329, 1985.

C Nitikitpaiboon and KJ Bathe, An Arbitrary Lagrangian–Eulerian Velocity Potential Formulation for Fluid–Structure Interaction, Computers & Structures, Vol. 47, 871–891, 1993.

KJ Bathe, C Nitikitpaiboon and X Wang, A Mixed Displacement-Based Finite Element Formulation for Acoustic Fluid–Structure Interaction, Computers & Structures, Vol. 56, 225–237, 1995.

X Wang and KJ Bathe, Displacement/Pressure Based Mixed Finite Element Formulations for Acoustic

Fluid–Structure Interaction Problems, Int. J. for Numerical Methods in Engineering, Vol. 40, 2001–2017, 1997.

X Wang and KJ Bathe, On Mixed Elements for Acoustic Fluid–Structure Interactions, Mathematical Models & Methods in Applied Sciences, Vol. 7, No. 3, 329–343, 1997.

Navier–Stokes fluid flows with structural interactions

Jürgen has greatly advanced with his students and colleagues the solution of Navier–Stokes fluid flows fully coupled with structural deformations. For such analyses, the new flow-condition-based-interpolation (FCBI) scheme to solve the incompressible Navier–Stokes equations has been developed. The structures can undergo large deformations, inelastic material response and contact, and the fluid can be incompressible or fully compressible, and the combined fluid structure system can be subjected to complex multi-physics effects. The techniques developed have made it possible to analyze many problems that could not be solved before.

KJ Bathe, H Zhang and MH Wang, Finite Element Analysis of Incompressible and Compressible Fluid Flows with Free Surfaces and Structural Interactions, Computers & Structures, Vol. 56, No. 2/3, 193–213, 1995.

KJ Bathe, Simulation of Structural and Fluid Flow Response in Engineering Practice, Computer Modeling and Simulation in Engineering, Vol. 1, 47–77, 1996.

KJ Bathe, S Rugonyi and S De, On the Current State of Finite Element Methods—Solids and Structures with Full Coupling to Fluid Flows, Proceedings of Plenary Lectures of the Fourth International Congress on Industrial and Applied Mathematics (JM Ball and JCR Hunt, eds.), Oxford University Press, 2000.

KJ Bathe, H Zhang and S Ji, Finite Element Analysis of Fluid Flows Fully Coupled with Structural Interactions, Computers & Structures, Vol. 72, 1–16, 1999.

D Hendriana and KJ Bathe, On Upwind Methods for Parabolic Finite Elements in Incompressible Flows, Int. J. Num. Methods in Eng., Vol. 47, 317–340, 2000.

S Rugonyi and KJ Bathe, On the Finite Element Analysis of Fluid Flows Fully Coupled with Structural Interactions, Computer Modeling in Engineering & Sciences, Vol. 2, 195–212, 2001.

H Zhang and KJ Bathe, Direct and Iterative Computing of Fluid Flows Fully Coupled with Structures, Computational Fluid and Solid Mechanics (KJ Bathe, ed.), Elsevier Science, 1440–1443, 2001.

KJ Bathe and H Zhang, A Flow-Condition-Based Interpolation Finite Element Procedure for Incompressible Fluid Flows, Computers & Structures, Vol. 80, 1267–1277, 2002.

KJ Bathe, JF Hiller and H Zhang, On the Finite Element Analysis of Shells and their Full Interaction with Navier–Stokes Fuid Flows, in Computational Structures Technology (BHV Topping and Z Bittnar, eds.), Civil-Comp Press, 2002.

Meshless method—the method of finite spheres

At present, Jürgen continues his research with students to develop a general and effective meshfree method—the ''Method of Finite Spheres''. This technique represents a generalization of the FEM and uses no mesh. The availability of a meshless method could significantly advance the field; however, the method should be truly meshless and be computationally effective, including accuracy considerations, when measured against the traditional FEM.

S De and KJ Bathe, The Method of Finite Spheres, Computational Mechanics, Vol. 25, 329–345, 2000.

S De and KJ Bathe, Displacement/Pressure Mixed Interpolation in the Method of Finite Spheres, Int. J. for Numerical Methods in Engineering, Vol. 51, 275–292, 2001.

S De and KJ Bathe, The Method of Finite Spheres with Improved Numerical Integration, Computers & Structures, Vol. 79, 2183–2196, 2001.

Fundamental theoretical contributions

Throughout the development of new computational techniques, Jürgen has emphasized the need for reliable and effective methods that are mathematically well founded. Such methods make lasting contributions to the field. His fundamental contributions with students and colleagues in techniques for rigorous testing of finite element discretizations are well recognized.

KJ Bathe and F Brezzi, On the Convergence of a Four-Node Plate Bending Element Based on Mindlin/Reissner Plate Theory and a Mixed Interpolation, in Mathematics of Finite Elements and Applications V (R Whiteman, ed.), Academic Press, 1985.

KJ Bathe and F Brezzi, A Simplified Analysis of Two Plate Bending Elements—the MITC4 and MITC9 Elements, Proceedings, Numerical Methods in Engineering: Theory and Applications, Univ. College Swansea, Wales, July 1987.

F Brezzi and KJ Bathe, A Discourse on the Stability Conditions for Mixed Finite Element Formulations, J. Computer Methods in Applied Mechanics and Engineering, Vol. 82, 27–57, 1990.

NS Lee and KJ Bathe, Effects of Element Distortions on the Performance of Isoparametric Elements, Int. J. for Numerical Methods in Engineering, Vol. 36, 3553–3576, 1993.

D Chapelle and KJ Bathe, The Inf-Sup Test, Computers & Structures, Vol. 47, No. 4/5, 537–545, 1993.

D Pantuso and KJ Bathe, A Four-Node Quadrilateral Mixed-Interpolated Element for Solids and Fluids, Mathematical Models & Methods in Applied Sciences, Vol. 5, No. 8, 1113–1128, 1995.

A Iosilevich, KJ Bathe and F Brezzi, On Evaluating the Inf-Sup Condition for Plate Bending Elements, Int. J. for Numerical Methods in Engineering, Vol. 40, 3639–3663, 1997.

D Pantuso and KJ Bathe, On the Stability of Mixed Finite Elements in Large Strain Analysis of Incompressible Solids, Finite Elements in Analysis and Design, Vol. 28, 83–104, 1997.

D Chapelle and KJ Bathe, Fundamental Considerations for the Finite Element Analysis of Shell Structures, Computers & Structures, Vol. 66, 19–36, 711–712, 1998.

D Chapelle and KJ Bathe, The Mathematical Shell Model Underlying General Shell Elements, Int. J. for Numerical Methods in Engineering, Vol. 48, 289–313, 2000.

KJ Bathe, The Inf-Sup Condition and its Evaluation for Mixed Finite Element Methods, Computers & Structures, Vol. 79, 243–252, 971, 2001.

PS Lee and KJ Bathe, On the Asymptotic Behavior of Shell Structures and the Evaluation in Finite Element Solutions, Computers & Structures, Vol. 80, 235–255, 2002.

JF Hiller and KJ Bathe, Measuring Convergence of Mixed Finite Element Discretizations: An Application to Shell Structures, Computers & Structures, Vol. 81, 639–654, 2003.

Solution of algebraic finite element equations

The Gauss-elimination based solvers for finite element equations developed by Jürgen and colleagues have continuously represented the state of the art. Still today, the computer program ADINA developed under his leadership, probably contains the fastest direct solver for general large-size finite element systems. The solver is now used to analyze finite element models in engineering practice requiring the solution of a million equations on a standard PC.

KJ Bathe and EL Wilson, NONSAP—A Nonlinear Structural Analysis Program, J. Nuclear Engineering and Design, Vol. 29, 266–293, 1974.

KJ Bathe, Finite Elements in CAD and ADINA, Nuclear Engineering and Design, Vol. 98, 57–67, 1986.

KJ Bathe, O Guillermin, J Walczak and H Chen, Advances in Nonlinear Finite Element Analysis of Automobiles, Computers & Structures, Vol. 64, 881–891, 1997.

Textbooks

The three textbooks Jürgen has authored had a significant impact on the use, research and development of FEMs. There are two distinguishing features to these books. Firstly, the books explain in detail, with many examples, how FEMs are formulated, function, and can be implemented for the analysis of solids, structures, and fluids. And, secondly, the books bring together the physical and mathematical aspects of finite element formulations with emphasis on the reliability of the techniques. Jürgen has continuously emphasized that only reliable FEMs should be used in practice.

The books have been widely adopted as standard reference texts.

KJ Bathe and EL Wilson, Numerical Methods in Finite Element Analysis, Prentice-Hall, 1976.

KJ Bathe, Finite Element Procedures in Engineering Analysis, Prentice-Hall, 1982.

KJ Bathe, Finite Element Procedures, Prentice Hall, 1996.

Also, a new book is in press:

D Chapelle and KJ Bathe, The Finite Element Analysis of Shells—Fundamentals, Springer-Verlag.

Computer program developments

We have previously mentioned that a key contribution has been his pioneering developments of state-of-the-art computer programs. As principal author, Jürgen developed in 1972–1974, the SAP IV and NONSAP finite element programs. He began the development of the ADINA program in 1974 and since 1986, as a Director of the company ADINA R&D, he has directed the development of the ADINA System.

KJ Bathe, EL Wilson and FE Peterson, SAP IV—A Structural Analysis Program for Static and Dynamic Response of Linear Systems, Earthquake Engineering Research Center Report no. 73-11, College of Engineering, University of California, Berkeley, June 1973, revised April 1974.

KJ Bathe, EL Wilson and R Iding, NONSAP—A Structural Analysis Program for Static and Dynamic Response of Nonlinear Systems, Report UCSESM 74-3, Department of Civil Engineering, University of California, Berkeley, February 1974.

KJ Bathe, ADINA—A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis, Report 82448-1, Acoustics and Vibration Laboratory, M.I.T., September 1975, revised May 1977, revised December 1978.

KJ Bathe, Remarks on the Development of Finite Element Methods and Software, Int. J. of Computer Applications in Technology, Vol. 7, Nos. 3–6, 101–107, 1994.

KJ Bathe, ADINA System, Encyclopaedia of Mathematics, Vol. 11, 33–35, 1997.

ADINA Theory & Modeling Guide, ARD 02-7, ARD 02-8 and ARD 02-9, ADINA R&D, Inc., September 2002.

Organization of conferences

Jürgen organized the 12 international conferences entitled Nonlinear Finite Element Analysis and ADINA, held until 1999 for Industry and Academia bi-annually at MIT. The Proceedings of the last ten conferences were published by Elsevier Science. The objective of these conferences was to present, assess, and publish techniques for state-of-the-art computational modeling of complex problems in engineering.

Proceedings of the twelfth conference Nonlinear Finite Element Analysis and ADINA, KJ Bathe, ed., Special issue of Journal Computers & Structures, Vol. 72, 1–456, 1999 (a reference to the earlier Conference Proceedings is given therein).

At present, Jürgen is organizing the Series of MIT Conferences on Computational Fluid and Solid Mechanics, with the First Conference having been held at MIT in June 2001, and the Second Conference to be held at MIT on June 17–20, 2003. The objectives and mission are to bring together Industry and Academia in research and developments, and to foster the next generation in computational mechanics.

KJ Bathe, ed., Computational Fluid and Solid Mechanics, Proceedings of the First M.I.T. Conference on Computational Fluid and Solid Mechanics, Elsevier Science, 2001.

KJ Bathe, ed., Computational Fluid and Solid Mechanics, Proceedings of the Second M.I.T. Conference on Computational Fluid and Solid Mechanics, Elsevier Science, to appear in 2003.
http://www.secondmitconference.org/

The foregoing short summary of Jürgen's contributions, of course, cannot begin to describe the extent to which many of his students and colleagues have benefited from working with him over the years. He has been a guiding light to his students and an inspirational collaborator for many colleagues.

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