

JAN DREWES ACHENBACH

Walter P. Murphy Professor

Distinguished McCormick School Professor

Departments of Civil and Environmental Engineering, Mechanical Engineering,
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Northwestern University

PERSONAL DATA

Birth date: August 20, 1935, Leeuwarden, Netherlands

Nationality: USA (naturalized, 1978)

EDUCATION

1953-1959 Technische Hogeschool, Delft, aeronautical engineering

1959-1962 Stanford University Major: aeronautics and astronautics

Minor: mathematics

DEGREES

PH.D. 1962 Stanford University

ACADEMIC CAREER

1962-1963 Preceptor, Columbia University

1963-1966 Assistant Professor of Civil Engineering
Northwestern University

1966-1969 Associate Professor of Civil Engineering
Northwestern University

April 1969 - Visiting Associate Professor

June 1969 University of California, La Jolla

September 1969- Professor of Civil Engineering
March 1981 Northwestern University

September 1970- Visiting Professor,
April 1971 Technische Hogeschool, Delft

March 1981 - Walter P. Murphy Professor, Departments of Civil and
Environmental Engineering, Mechanical Engineering, and
Engineering Science and Applied Mathematics

September 1985 - Director, Center for Quality Engineering
2006 and Failure Prevention, Northwestern University

September 1992 - Distinguished McCormick School Professor, Northwestern
University

OTHER ACADEMIC APPOINTMENTS

September 1981 - Consulting Professor, Huazhong Institute of Science
and Technology

Wuhan, Hubei, Peoples Republic of China

MAJOR AWARDS

2005 U.S. National Medal of Science

2003 U.S. National Medal of Technology

Member National Academy of Sciences, 1992

Member National Academy of Engineering, 1982

Fellow American Academy of Arts and Sciences, 1994

Corresponding Member Royal Dutch Academy of Arts and Sciences, 1999

Honorary Member, American Society of Mechanical Engineers, 2002
Timoshenko Medal, American Society of Mechanical Engineers, 1992
William Prager Medal, Society of Engineering Science, 2001
McDonnell-Douglas Model of Excellence Award, 1996
American Academy of Mechanics Distinguished Service Award, 1997
ASEE Curtis W. McGraw Research Award, ASEE, 1975
Fellow Society of Engineering Science, 2002
Fellow American Association for the Advancement of Science, 1998
Fellow Acoustical Society of America, 1998
Fellow American Society of Mechanical Engineers, 1979
Fellow American Academy of Mechanics, 1973
Fellow Japan Society for the Promotion of Science, 1988
Outstanding Paper Award, Materials Evaluation (American Society for Nondestructive Testing), 2002
ICCES Medal, International Conference on Computational & Experimental Engineering and Sciences, 2003
Tutorial Citation Award, American Society for Nondestructive Testing, 2004
SPIE-NDE Lifetime Achievement Award, 2005
Best Paper Award, SPIE's International Symposium on NDE, 2006

EDITORSHIPS

Member Editorial Board, Proceedings National Academy of Sciences, 2003-2005
Contributing Editor: Mechanics of Composite Materials and Structures, 1994-1998
Editorial Board: Research in Nondestructive Evaluation, 1989-present
Editorial Board: Journal of Nondestructive Evaluation, 1989-present
Member International Advisory Editorial Board: Acta Mechanica Sinica, 1988-1998
Member Board of Editors: North Holland Series in Applied Mathematics and Mechanics, 1982 – 2007.
Associate Editor, Journal of Applied Mechanics, 1982-1983
Chairman Editorial Committee: 50th Anniversary Issue, Journal of Applied Mechanics, 1982-1983
General Editor: Mechanics and Mathematical Methods-Series of Handbooks, North-Holland Publishing Co., 1980-2006.
Editor-in-Chief, WAVE MOTION, an International Journal Reporting Research on Wave Phenomena, 1979-present
Member Editorial Board, Journal of Thermal Stresses, 1978-2003
Member Board of Editors, International Journal of Solids and Structures, 1971-1996
Associate Editor, Journal of Applied Mechanics, 1971-1976
Member Editorial Advisory Board of ELASTICITY, 1970-2007.
Acting Editor, International Journal of Solids and Structures, 1969-1970

MAJOR COMMITTEES

Chairman Symposium Selection Committee, International Union of Theoretical and Applied Mechanics, 2000-present
Committee on Membership, National Academy of Engineering, 1997-2000
International Advisory Committee of the 14th World Conference on Nondestructive Testing, 1996

Peer Committee for Mechanical Engineering, National Academy of Engineering, 1995-1997

Class III Membership Committee, National Academy of Sciences, 1994

National Materials Advisory Board, 1994-1998

Member-at-Large, American Association for the Advancement of Science, 1994-1998

NIST Review Panel for Manufacturing Engineering, 1992-1998

Review Committee for Nominations for Fellow of the ASME, 1988-1994

Chairman ASME Thurston Lecture Committee, 1987-1989

U.S. National Committee on Theoretical and Applied Mechanics, 1972-1978, 1986-present

Congress Committee, International Union of Theoretical and Applied Mechanics, 1986-1994

Executive Committee Applied Mechanics Division ASME, 1979-1985

President, American Academy of Mechanics, 1978-1979

President, Association of Chairmen of Departments of Mechanics, 1971-1973

RESEARCH ACCOMPLISHMENTS

Over a period of some thirty-five years, I have made contributions to the general area of ultrasonics, particularly for applications to quantitative non-destructive evaluation.

This narrative describes my principal achievements on seven topics:

1. Acoustic Microscopy
2. Practical Applications of Quantitative Ultrasonics
3. Laser-Based Ultrasonics
4. Diffraction Coefficients
5. Dynamic Behavior of Composites
6. Dynamic Fracture
7. Elastodynamics

1. *Acoustic Microscopy*. The uniqueness of my work rests on the combination of measurements by line-focus acoustic microscopy with a novel theoretical measurement model for very accurate determination of thin-film elastic constants.

An acoustic microscope has four main components. The most important one is the acoustic probe, a sapphire rod with a transducer at the top end and a spherical or cylindrical lens at the bottom, where the probe is coupled to the specimen by a drop of distilled water. The other components are the pulse-mode measurement system for transmitting and receiving signals, the mechanical system for alignment and movement of the specimen, and a computer for controlling the system and processing the recorded wave forms. Two modalities of acoustic microscopy exist: imaging with a spherical lens, and quantitative microscopy, primarily with a cylindrical (line-focus) lens. Quantitative line-focus acoustic microscopy is a suitable technique to determine the local elastic constants of thin films. The technique is based on the measurement of the so-called $V(z)$ curve, which is a recording of the voltage output of the transducer when the distance between the lens and the specimen is changed. Oscillations appear in the $V(z)$ curves due to interference between the rays of ultrasound specularly reflected by the specimen and the rays associated with propagation over a very short distance of a leaky surface acoustic wave on the specimen. The phase velocity of a leaky surface wave can

be determined from the period, Δz , of the periodic oscillations, using a relationship based on ray considerations.

Around 1985, I started a laboratory in quantitative ultrasonics. Among the instrumentation that was used and further developed in the laboratory was a line-focus acoustic microscope, at that time a new instrument. The experimental work on measurement of the $V(z)$ curve was supplemented by theoretical work on measurement models. Joint theoretical/experimental work, particularly on the very accurate determination of the elastic constants of anisotropic thin films, via the measurement of wave speeds, which was possible by virtue of the line-focus feature of the lens in conjunction with software developed in the laboratory, was reported in a number of papers written jointly with graduate students. A novel feature was the use of an accurate measurement model with all the systemic features of the actual measurement process, but based on rigorous analysis. The use of this model made it possible to obtain the material parameters with great accuracy by systematically minimizing the difference between measured and calculated $V(z)$ curves. A number of papers were published, and eventually an invited review paper was written (with J. Kim and Y. C. Lee), "Measuring Thin-Film Elastic Constants by Line-Focus Acoustic Microscopy," (in *Advances in Acoustic Microscopy*, Vol. 1, ed. by Andrew Briggs, Plenum Press, pp. 153-208, 1995).

The principal applications of this work were for the characterization of the thin film coatings that are widely used in surface engineering to extend the life or enhance the performance of components. For example, transition metal carbides and nitrides have extremely high melting points and extreme hardness, excellent high-temperature strength, and good corrosion resistance. They are used for thin film coatings to produce wear-resistant surfaces, for thermal barriers, to provide corrosion protection against harsh environments, and for other applications.

Film/substrate systems are prepared by deposition techniques, such as physical vapor deposition and chemical vapor deposition. The mechanical properties of the thin film, and the adhesion between coating layers and between the coating and the substrate, determine its functional characteristics. These properties are very sensitive to a number of factors, which are determined by the deposition technique and by processing parameters. The thin-film properties may be quite different from bulk properties.

The original work in my laboratory was done for protective films, but the technique can equally well be used, as it has been, for the much thinner films that are used in electronic and optical devices.

2. *Practical Applications of Quantitative Ultrasonics.* My co-workers and I have come up with new techniques for practical applications of ultrasonics to detection and sizing of cracks and corrosion in metal structures.

An example is the detection of corrosion and stress-corrosion cracks in the wing box of the DC-9. In the mid-nineties, Northwest Airlines had more than 160 DC-9 aircraft, older than 20 years, in operation. These aircraft needed periodic check-ups for corrosion in the inner layers of the wing box, which is a fuel compartment. The old way was to enter the wing box for visual inspections or to disassemble the wing from the fuselage. This procedure took 800 hours. My team developed an ultrasonic technique for non-destructive testing of the wing, by penetration of ultrasound from the outside of the wing, without wing box entry or disassembly. This reduced the inspection time to 50 hours and

saved Northwest Airlines millions of dollars. The technique is now also being used by other airlines and by the U.S. Air Force. Some details were published in “An Ultrasonic Technique to Detect Corrosion in DC-9 Wing Box: From Concept to Field Application,” *Materials Evaluation*, Vol. 52, No.7, pp. 848-852, 1995 (with I. Komsky, G. Andrew, B. Grills, J. Register, G. Linkert, G. Huerto, A. Steinberg, M. Asbaugh, D. Moore, and H. Weber). The team was awarded the 1997 Model of Excellence Award by the McDonnell-Douglas Co., now part of the Boeing Co.

A second example is a successful project carried out for the U.S. Air Force with Warren Robins Air Logistics Center, in which an ultrasonic technique was developed to detect fatigue cracks in weep holes in the internal wing structure of C141 aircraft. Weep holes are placed in the risers of inner wing panels of C-141 aircraft in order to allow fuel to be properly distributed during flight. Each C-141 inner wing contains over 700 weep holes located either separately or in groups of two or three. These holes give rise to stress concentrations that can lead to fatigue cracks. The work, which was reported in “Case Study for the Implementation of an Automated Ultrasonic Technique to Detect Fatigue Cracks in Aircraft Weep Holes,” (with J. Aldrin, G. Andrew, C. Pan, B. Grills, R. T. Mullis, F. W. Spencer, and M. Golis), *Materials Evaluation*, Vol.59, No.11, pp.1313-1319, 2001, received the 2002 Best Paper Award from the American Society for Nondestructive Testing. The technique is now being further developed for detection of cracks in other parts of the wing structures of Air Force planes.

3. *Laser-Based Ultrasonics*. This technique involves both ultrasound generation and detection. The irradiation of the surface of a solid by a high-rate pulse of laser light provides an effective way of generating ultrasound, particularly in the form of ultrasonic surface waves. For detection, a laser interferometer can be used. The irradiation of the surface of a solid by pulsed laser light generates wave motion in the solid material. Since the dominant frequencies of the generated wave motion are generally above 20,000Hz, the waves are not audible to the human ear, and they are therefore termed ultrasonic waves. There are generally two mechanisms for such wave generation, depending on the energy density deposited by the laser pulse. At high energy density, a thin surface layer of the solid material melts, followed by an ablation process whereby particles fly off the surface, thus giving rise to forces which generate the ultrasonic waves. At lower energy density the surface material does not melt, but it expands at a high rate and wave motion is generated due to thermoelastic processes. As opposed to generation in the ablation range, laser generation of ultrasound in the thermoelastic range does not damage the surface of the material.

Ultrasound generation by laser irradiation in the thermoelastic regime is of great interest for applications in quantitative non-destructive evaluation, since it provides a number of advantages over conventional generation by piezoelectric transducers. These are: higher spatial resolution, non-contact generation and detection of ultrasonic waves, use of fiber optics, narrow-band and broad-band generation, absolute measurements, and ability to operate on curved and rough surfaces and at hard-to-access locations. On the receiving side, surface ultrasonic waves can be detected using piezoelectric (PZT) or EMAT transducers, or, alternatively, optical interferometers in a completely laser-based system. Ultrasound generated by laser irradiation contains a large component of surface wave motion, and is therefore particularly useful for the detection of surface-breaking

cracks. A Scanning Laser Source technique (SLS), which greatly improved detectability of surface-breaking cracks, was developed with my co-workers for this purpose, and reported in a paper with A. K. Kromine, P.A. Fomitchov and S. Krishnaswamy entitled “Laser Ultrasonic Detection of Surface Breaking Discontinuities: Scanning Laser Source Technique,” *Materials Evaluation*, Vol.58, pp.173-177, 2000. Other contributions of note in this area are the development of a dual-probe laser interferometer, reported in a paper with Jin Huang, a Graduate Student at the time, in the *Journal of the Acoustical Society of America*, Vol.90, pp.1269-1274, 1991. To make a quantitative approach feasible, in recent years, I have done work on measurement models for laser-based ultrasonics, reported in a paper entitled “Simplifications for the Calculation of Surface Wave Pulses Generated by Laser Irradiation,” *Journal of the Acoustical Society of America*, Vol.116, pp.1481-1487, 2004.

4. *Diffraction Coefficients*. In 1896, Arnold Sommerfeld published a seminal paper that solved the problem of edge diffraction of electromagnetic and acoustic waves by a semi-infinite flat screen. The result proved to be extremely important in radar technology, optics, and acoustics. In 1958, J. B. Keller pointed out that an asymptotic form of Sommerfeld’s result, termed the diffraction coefficient, provides a canonical solution and thereby an important building block for his geometrical theory of diffraction.

The corresponding three-dimensional problem of diffraction by a crack in an isotropic elastic solid is much more complicated than the Sommerfeld problem, because there are two fundamental waves in a solid: longitudinal and transverse waves, and an additional appearance of surface waves on the faces of the crack. In 1976, together with a Post Doc (A. K. Gautesen) and a graduate student (H. McMacken), we solved the canonical problem of diffraction of a plane wave incident under an arbitrary angle with the edge of a semi-infinite crack in an elastic solid. Two papers were initially published: “Geometrical Theory of Diffraction for 3-D Elastodynamics,” *Journal of the Acoustical Society of America*, Vol.61, pp.413-421, 1977; and “Surface Wave Rays in Elastodynamic Diffraction of Cracks,” *Journal of the Acoustical Society of America*, Vol. 63, pp.1824-1831, 1978. The 1977 paper was included in the list of major contributions to physical acoustics compiled by the Acoustical Society of America.

The solutions for the diffraction coefficients allowed the same authors to generalize the geometrical theory of diffraction to scattering by cracks of arbitrary shape. Other workers in the USA and the UK subsequently used the results in computer programs for the detection of cracks in nuclear reactors, engine components, and other safety-critical structures.

The work on diffraction coefficients and applications to scattering by cracks of finite dimensions was consolidated in a book by Achenbach, Gautesen and McMacken: *Ray Methods for Waves in Elastic Solids – With Applications to Scattering by Cracks*, Pitman Advanced Publishing Program, Boston/London/Melbourne, 1982.

5. *Dynamic Behavior of Composite Materials (1964-1975)*. In the mid-sixties these inhomogeneous materials were represented by a homogeneous but anisotropic material, via the “effective modulus” theory. This was often not acceptable at higher frequencies. In the period 1964-1966, my co-workers and I developed a more general model based on a generalized continuum theory. A method was given to calculate the material constants

for the generalized continuum model from the elastic constants of the constituents of the composite material and from geometrical parameters. This was done for laminated media and fiber-reinforced composites. The new theory properly represented such dynamic effects as dispersion at high frequencies. Numerous papers were published and eventually the theory was summarized in a monograph entitled *A Theory of Elasticity with Microstructure for Directionally Reinforced Composites*, CISM Monograph 167, Springer-Verlag, Vienna/New York, 1975.

6. *Dynamic Effects on Fracture (1968-1980)*. With Eshelby (UK) and Broberg (Sweden), I was one of the first to study dynamic effects on fracture, both due to high crack propagation speeds or due to dynamic external excitation. Expressions were derived for elastodynamic stress intensity factors, and these were combined with energy conditions for the propagation of a crack. A first publication in this area was "Extension of a Crack by a Shear Wave," *Zeitschrift fur angewandte Mathematik und Physik*, Vol. 21, pp. 887-900, 1970. In 1974, I published a review paper, entitled "Dynamic Effects in Brittle Fracture," in *Mechanics Today*, Vol.7, ed. by S. Nemat Nasser, Pergamon Press, pp. 1-57, which spurred interest in this area. Many investigators have further developed this topic.

Work in the field eventually expanded to include shear rupture on fault planes for earthquake mechanisms, non-linear and plasticity effects, dynamic branching and fragmentations and large-scale numerical simulations.

7. *Elastodynamics*. In recent work I have returned to the classical theory of waves in elastic solids. A new formulation was derived to express guided waves in terms of a carrier wave propagating along the waveguide. The carrier wave, which is the solution of a simple reduced wave equation, carries the thickness motion. Examples of applications are Lamb waves in a layer and Rayleigh surface waves. This work was carried out parallel to a novel application of elastodynamic reciprocity whereby a problem is solved by combining its solution with a virtual wave solution in the reciprocity theorem. The combination of the two new formulations was extremely useful in deriving expressions for wave motion generated by internal and surface excitation of a solid body. The results have appeared in a new book entitled *Reciprocity in Elastodynamics*, Cambridge University Press, 2004.

EDUCATIONAL LEADERSHIP

I have supervised over 35 Ph.D. students, several of whom occupy important positions in academia and in industry, here and abroad. In 1993, I was elected to the Chicago Tribune Tempo All-Professor Team in the sciences. My principal book, *Wave Propagation in Elastic Solids*, was published in 1973 (Elsevier Science, Ltd., Amsterdam). It was the first book on elastic waves to be published since the much earlier work by Kolsky. It covered the then state of the art. The book was extremely well received. It is still in print, in paperback form. Since 1973, numerous other books on elastic waves have been published, but my book is probably still the most frequently referenced book in the general area of waves in elastic solids.

SELECTED PUBLICATIONS:

BOOKS

Wave Propagation in Elastic Solids, North-Holland Publishing Company/American Elsevier, Amsterdam/New York, 1973.

A Theory of Elasticity with Microstructure for Directionally Reinforced Composites, CISM Monograph 167, Springer Verlag, Vienna/New York, 1975.

Ray Methods for Waves in Elastic Solids – with Applications to Scattering by Cracks, (with A. K. Gautesen and H. McMaken), Pitman Advanced Publishing Program, Boston/London/Melbourne, 1982.

Reciprocity in Elastodynamics, Cambridge University Press, Cambridge, UK, 2003.

SELECTED PAPERS

(with H. I. Epstein), “Dynamic Interaction of a Layer and a Half-Space,” *J. of the Engr. Mechs. Div. ASCE*, **93**, pp. 27-42, 1967.

(with C. T. Sun and G. Herrmann), “Continuum Theory for a Laminated Medium,” *J. of Applied Mech.*, **35**, pp. 467-475, 1968.

“Dynamic Effects in Brittle Fracture,” in *Mechanics Today*, **1**, ed. by S. Nemat-Nasser, Pergamon Press, Oxford, UK, pp. 1-57, 1974.

(with A. K. Gautesen), “Geometrical Theory of Diffraction for Three-D Elastodynamics,” *J. Acoust. Soc. Am.*, **61**, pp. 413-421, 1977.

(with L. Adler, D. Kent Lewis and H. McMaken), “Diffraction of Ultrasonic Waves by Penny-Shaped Cracks in Metals: Theory and Experiment,” *J. Acoust. Soc. Am.*, **66**, pp. 1848-1856, 1979.

(with Ch. Zhang), “A New Boundary Integral Equation Formulation for Elastodynamic and Elastostatic Crack Analysis,” *J. of Appl. Mech.*, **111**, pp. 284-290, 1989.

(with H. Zhu), “Effect of Interfacial Zone on Mechanical Behavior and Failure of Fiber-Reinforced Composites,” *J. Mech. Phys. Solids*, **37**, pp. 381-393, 1989.

(with J. Huang), “Dual-Probe Laser Interferometer,” *J. Acoust. Soc. Am.*, **90**, pp. 1269-1274, 1991.

(with J. O. Kim) “Line-Focus Acoustic Microscopy to Measure Anisotropic Acoustic Properties of Thin Films,” *Thin Films*, **214**, pp. 25-34, 1992.

(with J. Huang and S. Krishnaswamy), “Laser-Generation of Narrow-Band Surface Waves,” *J. Acoust. Soc. Am.*, **92**, pp. 2527-2531, 1992.

(with I. N. Komsky, Y. C. Lee and Y. C. Angel), “Self-Calibrating Ultrasonic Technique for Crack Depth Measurement,” *J. of Nondestr. Eval.*, **11**, pp. 103-108, 1992.

“Measurement Models for Quantitative Ultrasonics,” *J. Sound and Vibration*, **159**, pp. 385-401, 1992.

(with C. Y. Wang), “Elastodynamic Fundamental Solutions for Anisotropic Solids,” *Geophys. J. Int.*, **118**, pp. 384-392, 1994.

(with J. Kim and Y.-C. Lee), “Measuring Thin-Film Elastic Constants by Line-Focus Acoustic Microscopy,” *Advances in Acoustic Microscopy*, ed. by Andrew Briggs, **1**, pp. 153-208, 1995.

(with I. N. Komsky, G. Andrew, B. Grills, J. Register, G. Linkert, G. Huerto, A. Steinberg, M. Asbaugh, D. Moore, and H. Weber), “An Ultrasonic Technique to Detect

Corrosion in DC-9 Wing Box: From Concept to Field Application,” *Materials Evaluation*, **52**, pp. 848-852, 1995.

(with Z. M. Connor, W. Li, and M. E. Fine), “Fatigue Crack Initiation and Growth in Riveted Specimens: An Optical and Acoustic Microscopic Study,” *Int. J. Fatigue*, **19**, Supplement **1**, pp. S331-S338, 1997.

(with P. A. Fomitchov and S. Krishnaswamy), “Compact Phase-Shifted Sagnac Interferometer for Ultrasound Detection,” *Optics & Laser Technology*, **29**, pp. 333-338, 1997.

(with A. K. Kromine, P. A. Fomitchov, and S. Krishnaswamy), “Laser Ultrasonic Detection of Surface-Breaking Discontinuities: Scanning Laser Source Technique,” *Materials Evaluation*, **58**, pp. 173-177, 2000.

“Calculation of Surface Wave Motions Due to a Subsurface Point Force: An Application of Elastodynamic Reciprocity,” *J. Acoust. Soc. Am.*, **107**, pp. 1892-1897, 2000.

(with J. Aldrin, G. Andrew, C. Pan, B. Grills, R. T. Mullis, F. W. Spencer and M. Golis), “Case Study for the Implementation of an Automated Ultrasonic Technique to Detect Fatigue Cracks in Aircraft Weep Holes,” *Materials Evaluation*, **59**, pp. 1313-1319, 2001.

“Laser Excitation of Surface Wave Motion,” *J. Mech. Phys. Solids*, **51**, pp. 1885-1902, 2003.

“Simplifications for the calculation of surface wave pulses generated by laser irradiation,” *J. Acoust. Soc. Am.*, **116**, pp.1481-1487, 2004.

“The Thermoelasticity of Laser-Based Ultrasonics,” *J. of Thermal Stresses*, **28**, pp. 713-728, 2005.

“Combination of a Virtual Wave and the Reciprocity Theorem to Analyze Surface Wave Generation on a Transversely Isotropic Solid,” *Philosophical Magazine*, **85**, pp. 4143-4157, 2005.

“Reciprocity and Related Topics in Elastodynamics,” *Applied Mechanics Reviews*, **59**, pp. 13-32, 2006.

(with S.S. Kulkarni, L. Sun, B. Moran and S. Krishnaswamy) “A Probabilistic Method to Predict Fatigue Crack Initiation,” *Int. J. of Fracture*, **137**, pp. 9-17, 2006.

(with L. Sun, S. Kulkarni and S. Krishnaswamy), “Technique to Minimize Couplant-Effect in Acoustic Nonlinearity Measurements,” *The Journal of the Acoustical Society of America*, **120**, pp. 2500-2505, 2006.

“Application of the Reciprocity Theorem to Analyze Ultrasound Generated by High-Intensity Surface Heating of Elastic Bodies,” *Journal of Thermal Stresses*, **30**, pp. 841-853, 2007.

(with G. Petculescu), “Schedule Based NDT and Structural Health Monitoring of Safety Critical Composite Structures,” *Materials Evaluation*, **65**, pp. 731-739, 2007.

(with S.S. Kulkarni), “Optimization of inspection schedule for a surface-breaking crack subject to fatigue loading,” *Probabilistic Engineering Mechanics*, **22**, pp. 301-312, 2007.

(with S.S. Kulkarni), “Structural Health Monitoring and Damage Prognosis in Fatigue,” *Structural Health Monitoring*, **7**, pp. 37-49, 2008.