

Curriculum Vitae

Bhagwan D. Agarwal, Ph. D.
Engineering and Materials Consultant

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SUMMARY OF EXPERTISE AND EXPERIENCE

Thirty five years of experience in engineering and materials consulting, research, development, and management. Areas of expertise include composite materials, plastics, mechanical engineering, mechanics, automotive, aerospace, failure analysis, forensic investigations, stress analysis (FEA), design analysis and evaluation, experimental testing and research. Extensive experience and diversified expertise enable competent and efficient handling of complex and multidisciplinary projects.

Co-authored three books on composite materials and over 70 technical papers. Hold two US Patents on automotive gaskets. Teach SPE co-sponsored courses on Failure Analysis of Plastic Products through Stress Analysis Methods. Widely consulted by government, industry, and attorneys.

EDUCATION

Ph. D.	Mechanics, Illinois Institute of Technology, Chicago, 1972
MS	Mechanics, Illinois Institute of Technology, Chicago, 1970
BS	Mech. Engg. Birla Institute of Technology, Ranchi, India, 1965

EXPERIENCE AND ACCOMPLISHMENTS

Adjunct Consultant, Packer Engineering, Naperville, IL, June 2001--Present

Adjunct Consultant, Bodycote Broutman Polymer Laboratory, Melrose Park, IL, 2001 -- Present

Vice President, Engineering Services, L. J. Broutman & Associates/Bodycote Polymer Broutman Laboratory, Melrose Park, IL, 1996--2001

Senior Research Associate (on Leave of Absence from IIT Kanpur) Fel-Pro, Inc., Skokie, IL 1991--1993

Dean of Research and Development (Concurrent with Professor) Indian Institute of Technology, Kanpur, 1988—1990

Professor/Assistant Professor, Indian Institute of Technology, Kanpur, 1972—1996

Research/Teaching Assistant, Illinois Institute of Technology, Chicago, 1968—1972

Lecturer, Birla Institute of Technology, Ranchi, India, 1965—1968

HONORS AND AWARDS

- 1996 Gold Medal for Best Paper Aerospace Engineering Division Institution of Engineers (India)
- 1988 Karunesh Memorial Lecturer Indian Society for Theoretical and Applied Mechanics
- 1986 Gold Medal for Best Paper Aerospace Engineering Division Institution of Engineers (India)
- 1985 Member, Government of India Delegation to USSR
- 1968-1972 Research Fellowship, IIT Chicago

CONSULTING EXPERT IN LITIGATION CASES

Provided technical consulting in litigation cases including testimony at trials and in depositions in patent infringement and product liability cases. Conducted testing, calculations including FEA analysis, and literature search and review for expert reports and other purposes. Following is a list of products involved in the cases:

- Long fiber reinforced plastics
- Underground gasoline storage tanks
- Fiberglass pipes in water treatment plant
- Fiberglass pipeline for sewage and agriculture
- FRP ladders
- FRP boats
- Plastic pipe liners for sewage pipeline rehabilitation
- Polybutylene pipe and plumbing fittings
- Wheel chair
- Wood saw
- Mechanical lift
- Metal braided pipe
- High pressure hose
- Propane tank
- PVC sprinkler system
- Household water softener
- Instant water heater
- Adhesive system for labels
- Aircraft windows
- Helicopter gear
- Toilet flush tank

- Glass windows

- Asbestos reinforced plastic products
- Automobile tyres
- Reinforced polymer tanks for chemical treatment plant

UNIVERSITY CONSULTING

I. Industrial

Borg-Warner Chemicals, Parkersburg, West Virginia
 Fel-Pro, Inc., Skokie, IL
 L. J. Broutman & Associates, Chicago
 Indian Explosives, Ltd., Kanpur, India

II. Government

Aeronautics Research and Development Board, New Delhi
 Indian Airforce, Agra

GRANTS AND CONTRACTS

Sponsors

National Science Foundations, Washington, D.C.
 Aeronautics Research and Development Board, New Delhi

PROFESSIONAL SOCIETY MEMEBERSHIPS

- American Society for Testing and Materials - Member
- Institution of Engineers (India) - Fellow
- Society for Experimental Mechanics (formerly SESA) – Former Member
- American Water Works Association – Former Member
- Indian Society for Technical Education – Former Member
- British Society for Strain Measurement – Former Member

JOURNAL EDITING POSITIONS

- Mechanics of Composite Materials and Structures-Editorial Board
- Advanced Composite Materials-Editorial Board
- Plastics Engineering and Technology-Editorial Board
- The Institution of Engineers (India)- Former chairman, Solid Mechanics and Stress Analysis Group

COURSES FOR INDUSTRY

Teach courses for industry on Failure Analysis of Plastic Products. These one day continuing education courses are co-sponsored by SPE or American Plastics Council, and are offered every year. The courses have been found very useful by the attendees over the years.

PATENTS

1. "Molded Plastic Gasket Having A Combination Sealing Bead" US Patent Number 5,228,702, July 20, 1993 (with Vance D. Browne).
2. "Molded Plastic Gasket Having An Improved Sealing Bead" US Patent Number 5,295,698, March 22, 1994 (with Colin Chen).

PUBLICATIONS

A. BOOKS

1. ANALYSIS AND PERFORMANCE OF FIBER COMPOSITES, Third Edition
B.D. Agarwal, L.J. Broutman and K. Chandrashekhara
John Wiley & sons, New York, (SPE Monograph), In Press, 2005
2. ANALYSIS AND PERFORMANCE OF FIBER COMPOSITES, Second Edition
B.D. Agarwal and L.J. Broutman
John Wiley & sons, New York, (SPE Monograph), 1990; 449 pages
3. ANALYSIS AND PERFORMANCE OF FIBER COMPOSITES
B.D. Agarwal and L.J. Broutman
John Wiley & Sons, New York, (SPE Monograph), 1980; 355 pages
4. ANALYSIS AND PERFORMANCE OF FIBER COMPOSITES, Czech Translation
(Translators: Lubonir Sodomka, Richard Bares, Jan Javornicky, and Jaroslava Zemankeva) B.D. Agarwal and L.J. Broutman, SNTL-Praha 1987

B. BOOK CHAPTERS

1. "Fracture Toughness of Fiber Reinforced Composites", in Encyclopedia of Engineering Materials, Edited by N.P. Cheremisinoff, Marcel Dekker, New Jersey, 1990
2. "Fracture Toughness of Glass/Epoxy Composites through J-integral Approach", in Advances in Aerospace Structures and Allied Fields, Edited by T.K. Vardan, 1988

C. RESEARCH PAPERS PUBLISHED IN REFEREED JOURNALS

(Grouped according to research areas)

I. Fracture of Composite Materials

1. "Crack Induced Dynamic Damage Growth in Fibre Composites", Mechanics of Composite Materials and Structures, Vol. 2, 1995, p. 295-308, (with K.K. Bajpai and Rajesh Sharma).
2. "Influence of Moisture Absorption on Fracture Toughness of Kevlar Fabric/Epoxy Composite", Journal of The Institution of Engineers (India), Vol. 76, September 1995, p. 23-28, (with S.Ravi and NGR Iyengar).
3. "Determination of Stress Intensity Factor in Orthotropic Composite Materials Using Strain Gages", Engineering Fracture Mechanics, Vol. 32, No. 3, 1989, p. 469-477, (with A. Shukla and Bharat Bhushan).
4. "Fracture Toughness of Glass/Epoxy Laminates Through J-Integral Approach", Composite Structures, Vol. 9, 1988, p. 37-51, (with K.K. Bajpai).
5. "Influence of Specimen Width, Thickness and Fibre Concentration on Fracture Toughness (J_c) of Short Fibre Composite", Journal of Aerospace Engineering, Division of the Institution of Engineers (India), Vol. 66, Part AE2, March 1986, p. 47-51, (with B.S. Patro and P. Kumar).
6. "Determination of the Fracture Toughness of Fabric Reinforced Composites by the J-Integral Approach", Composites Science and Technology Vol. 25, No. 4, 1986, p. 311-323, (with S.K. Khanna and P. Kumar).
7. "Crack Length Estimation Procedure for Short Fiber Composites: An Experimental Evaluation", Polymer Composites, Vol. 6, No.3, July 1985, p. 185-190, (with B.S. Patro and P. Kumar).
8. "Prediction of Instability Point During Fracture of Composite Materials", Composites Technology Review, Spring 1985, p. 173-176, (with B.S. Patro and P. Kumar).
9. "Fracture Behavior of Glass-Cloth Reinforced Composites", Polymer Composites, Vol. 6, No. 1, Jan. 1985, p. 29-33, (with D.C. Agarwal and K. Banerjee).
10. "J-Integral as Fracture Criterion for Short Fiber Composites: An Experimental Approach", Engineering Fracture Mechanics, Vol. 19, No. 4, 1984, p. 675-684, (with B.S. Patro and P. Kumar).

11. "Influence of Matrix Properties on Fracture Toughness of Short Fiber Composites", Materials Science and Engineering, Vol. 52, No. 2, 1982, p. 139-145, (with G.S. Giare).
12. "Crack Growth Resistance of Short Fiber Composites: I - Influence of Fiber Concentration, Specimen Thickness, and Width", Fibre Science and Technology, Vol. 15, No.4, 1981, p. 283-298, (with G.S. Giare).
13. "Crack Growth Resistance of Short Fiber Composites: II - Influence of Test Temperature", Fibre Science and Technology, Vol. 16, No. 1, 1982, p. 19-28. (with G.S. Giare).
14. "Fracture Toughness of Short Fiber Composites in Mode II and III", Engineering Fracture Mechanics, Vol. 15, No. 1-2, 1981, p. 219-230, (with G.S. Giare).

II. Non-Destructive Evaluation

15. "Acoustic Emission Studies of Fatigue Damage Growth in Carbon Fabric Reinforced Epoxy Composite", Advanced Composite Materials, Vol. 2, No. 2, p. 117-134, 1992 (with N.K. Arya and N.G.R. Iyengar).
16. "Development of an Automated Ultrasonic C-Scan System for Composite Materials", Journal of Pure and Applied Ultrasonics, Vol. 12, No. 4, 1990 (with S.Y. Mahajan and N.N. Kishore).
17. "Damage Characterization in Kevlar/epoxy Composites Using Acoustic Emission Technique", Journal of Pure and Applied Ultrasonics, Vol. 11, 1989, p. 54-61, (with D.S. Rajan and N.N. Kishore).

III. Fatigue of Composite Materials

18. "Damage Initiation and Growth in Kevlar/Epoxy Composite Subjected to Axial Fatigue Loading", The Journal of The Aeronautical Society of India, Vol. 41, No. 4, Nov. 1989, p. 357-365, (with S.K. Majumdar).
19. "Strain Controlled Flexural Fatigue of Unidirectional Composite", Composites Technology Review, Vol. 4, No. 1, Spring 1982, p. 6-13, (with S.K. Joneja).
20. "Strain Controlled Off-axis (10°) Flexural Fatigue of Unidirectional Composite", Fibre Science and Technology, Vol. 14, 1981, p. 69-80, (with S.K. Joneja).
21. "Flexural Fatigue of a Unidirectional Composite in Longitudinal Direction", Materials Science and Engineering , Vol. 46, 1980, p. 63-68, (with S.K. Joneja).

22. "Progresive Damage in GFRP Under Constant Deflection Flexural Fatigue", Fibre Science and Technology, Vol. 12, No. 5, September 1979, p. 341-352, (with S.K. Joneja).
23. "Flexural Fatigue Properties of Unidirectional Composites in Transverse Direction", Composites Vol. 10, No. 1, January 1979, p. 28-30, (with S.K. Joneja).
24. "Predictions of Low Cycle Fatigue Behavior of GFRP: An Experimental Approach", Journal of Materials Science, Vol. 10, No.1, January 1975, p. 193-199, (with J.W. Dally).
25. "Low Cycle Fatigue Behavior of Glass Fiber Reinforced Plastics", Proceedings of the Army Symposium on Solid Mechanics, 1970 - Lightweight Structures, Watertown, Massachusetts, AMMRC MS 70-5, December 1970, (with J.W. Dally).

IV. Photo-Orthotropic-Elasticity

26. "A Stress Separation Technique for Photo-Orthotropic Elasticity", Composites Technology Review, Vol. 5, No. 3, Fall 1983, (with P.K. Jha).
27. "An Approximate Method of Orthotropic Photoelastic Analysis", Experimental Mechanics, Vol. 23, No. 1, March 1983, p. 55-58.
28. "Exact and Approximate Strain Optic Laws for Photoelastic Composites", Polymer Composites, Vol. 3, No. 3, July 1982, p. 146-151, (with S.K. Chaturvedi).
29. "Improved Bifringent Composites and Assessment of Photoelastic Theories", Fibre Science and Technology, Vol. 11, No. 6, November 1978, p. 399-422, (with S.K. Chaturvedi).
30. "Development and Characterization of Optically Superior Photoelastic Composite Materials", International Journal of Mechanical Sciences, Vol. 20, No. 7, 1978, (with S.K. Chaturvedi).

V. Finite Element Analysis

31. "Effect of an Interfacial Layer on the Properties of Fibrous Composites: A Theoretical Analysis", Fibre Science and Technology, Vol. 12, No. 2, March 1979, p. 149-158, (with R.K. Bansal).
32. "Plastic Analysis of Fibre Interactions in Discontinuous Fibre Composites", Fibre Science and Technology, Vol. 10, No. 4, October 1977, p. 281-297, (with R.K. Bansal).
33. "A Theoretical Study of the Effect of an Interfacial on the Properties of Composites", Polymer Engineering and Science, Vol. 14, No. 8, August 1974, p. 581-588, (with L.J. Broutman).

34. "Effect of the Interface on the Mechanical Properties of Composite Materials", Rheologica Acta, Vol. 13, No. 8, June 1974, p. 1128-1134, (with L.J. Broutman).
35. "Three-Dimensional Finite Element Analysis of Spherical Particle Composites", Fibre Science and Technology, Vol. 7, No. 1, January 1974, p. 63-68, (with L.J. Broutman).
36. "Elastic Plastic Finite Element Analysis of Short Fibre Composites", Fibre Science and Technology, Vol. 7, No. 1, January 1974, p. 45-62, (with J.M. Lifshitz and L.J. Broutman).
37. "A Theoretical Analysis of the Effect of the Interface on Composite Toughness", SPI, 28th Annual Technical Conference, Section IV-B, February 1973, p. 1-8, (with L.J. Broutman).
38. "Micromechanics Analysis of Porus and Filled Ceramic Composites", Journal of American Ceramic Society, Vol. 54, No. 12, Dec. 1971, p. 620-624, (with G.A. Panizza and L.J. Broutman).

VI. Others

39. "The Role of Numerical Stress Analysis in Failure Analysis of a Medical Device", Plastics Engineering, Vol. LV, No. 5, May 1999, p. 45-47, (with Y. Chen and Paul K. So).
40. "Semianalytical Solution for Epoxy-amine Curing in the Presence of Nonisothermal Effects", Polymer Engineering and Science, Vol.34, No.5, March 1994, p. 405-413, (with S. Gupta and A. Kumar)
41. "Dynamic Compressive Behaviour of Unidirectional GFRP for Various Fibre Orientations", Materials Letters, Vol. 4, No. 2, February 1986, p. 111-116, (with P. Kumar and Anita Garg).
42. "High Strain Rate Behaviour of Unidirectional GFRP", Journal of Aeronautical Society of India, Vol. 38, No. 1, February 1986, p. 11-16, (with P. Kumar and Anita Garg).
43. "Damping Characteristics of Fibre Composites with Imperfect Bonding Part I-Low Volume Fraction Composites", Journal of Reinforced Plastics and Composites, Vol. 1, 1982, p. 40-63, (with N.N. Kishore and A. Ghosh).
44. "Damping Characteristics of Fibre Composites with Imperfect Bonding Part II-Low Volume Fraction Composites", Journal of Reinforced Plastics and Composites, Vol. 1, 1982, p. 64-81, (with N.N. Kishore and A. Ghosh).
45. "Damping Characteristics of Particulate Composites with Imperfect Bonding",

Journal of Reinforced Plastics and Composites, Vol. 1, 1982, p. 353-369, (with N.N. Kishore and A. Ghosh).

46. "Brittle Coating Analysis of Orthotropic Materials", International Journal of Engineering Science, Vol. 17, No. 2, 1979, p. 169-172, (with S.K. Chaturvedi).
47. "Brittle Coating Studies of Fibrous Composites", STRAIN, Vol. 14, 1978, p. 131-136, (with S.K. Chaturvedi).
48. "Strength and Failure Mechanisms of Anisotropic Composites", Fibre Science and Technology, Vol. 10, No. 1, January 1977, p. 37-51, (with J.N. Narang).

D. PAPERS PUBLISHED IN SEMINARS, SYMPOSIA, CONFERENCE VOLUMES

1. "Steel Wire Reinforced Plastic Composite Pipe" Proceedings of the SPE's 62nd Annual Technical Conference, Chicago, IL, May 16-20, 2004, (with L.J. Broutman and D.B. Edwards).
2. "Finite Element Analysis of Plastic Plumbing Assemblies" Proceedings of the SPE's 57th Annual Technical Conference, New York, NY, May 2-6, 1999, (with Y. Chen and L.J. Broutman).
3. "Dynamic Damage Growth Studies in Fiber Composites", Proc. International Conference on Fibre Reinforced Structural Plastics in Civil Engineering, IIT Madras, p. 334-338, December 18-20, 1995, (with K.K. Bajpai, S. Ravi, and R. Sharma).
4. "Studies on Moisture Absorption in Composites through Accelerated Testing", Proc. National Symposium on Development in Advanced Composites and Structures (NSDACS'94) DRDL, Hyderabad, p. 238-243, September 17, 1994, (with S. Ravi and NGR Iyengar).
5. "Study of Crack Induced Damage Growth in Dynamically Loaded Fibre Composites", Proc. National Seminar on Aero Structures (NASAS' 93) IIT Kanpur, p. 59-60, December 29-30, 1993, (with Rajesh Sharma).
6. "High Speed Photographic Facility at IIT Kanpur", Proceedings of the International Conference on Plasticity and Mechanics (IMPLAST'93), IIT Delhi, December 1993, p. 507-518, (with K.Ramesh, Arun Shukla, K.K. Bajpai and J. Yadav).
7. "Damage Proagation during Flexural and Axial Fatigue of unidirectional Kevlar Fabric Reinforced Epoxy Composite", VII International Conference on Composite Materials, China, August 1-4, 1989, (with S.K. Majumdar and Bharat Bhusan).
8. "Software to Characterize Damage in Kevlar/Epoxy Composites using Acoustic Emission Technique", ISNDT Seminar on Non-Destructive Testing (SNDT-88),

Delhi, (with D.S. Rajan and N.N. Kishore).

9. "Some New Results in the Damage Identification in Kevlar/Epoxy Composites", World Meeting on Acoustic Emission, Charlotte, North Carolina, USA, March 20-23, 1989, (with D.S. Rajan and N.N. Kishore).
10. "Fracture Toughness of Quasi-isotropic and Crossplied Laminates: J-Integral Approach", 1987 Spring Conference on Experimental Mechanics and Manufacturer's Exhibit, June 1987, Houston, (with K.K. Bajpai).
11. "Finite Element Prediction of Fracture Toughness of Composite Laminates Through J-Integral Approach", Nineteenth National Symposium on Fracture Mechanics, June 30 - July 2, 1986, San Antonio, Texas, (with B.P. Singh and B.K. Mishra).
12. "Fracture Toughness of Composite Laminates Through J-Integral Approach", 1986 Spring Conference on Experimental Mechanics and Manufacturer's Exhibit, June 1986, New Orleans, Louisiana, (with K.K. Bajpai).
13. "J-Integral as a Fracture Criterion for Fabric Reinforced Composites", 1985 Spring Conference on Experimental Mechanics and Manufacturer's Exhibit, June 1985, Las Vegas, (with S.K. Khanna and P. Kumar).
14. "High Velocity Impact Behaviour of Unidirectional GFRP", National Symposium on Recent Trends in the Development of the Composite Materials, December 1983, Pune, (with R.K. Nakrani and P. Kumar).
15. "Dynamic Compression Behaviour of GFRP", Seminar on Design and Development in Aeronautics, October 1983, Bangalore, (with L.J. Rao and P. Kumar).
16. "The J-Integral as a Fracture Criterion for Composite Materials", Second International Conference on Composite Structures, September 1983, Paisley, Scotland, (with P. Kumar and B.S. Patro).
17. "Strain Controlled Flexural Fatigue of Unidirectional Composites", SESA's Fourth International Congress on Experimental Mechanics", May 1980, Boston, MA, (with S.K. Joneja).
18. "An Approximate Method of Orthotropic Photoelastic Analysis", SESA's Fourth International Congress on Experimental Mechanics, May 1980, Boston, MA.
19. "Crack Propagation in Off-axis (10°) Unidirectional Glass- Epoxy Composites During Flexural Fatigue", International Conference on Fracture Mechanics in Engineering Applications, March 1979, Bangalore, (with S.K. Joneja).

20. "On the Use of Brittle Coating for Stress Analysis of Fibrous Composites", International Symposium on Newer Fibres and Composites, February 1978, Bombay, (with S.K. Chaturvedi).
21. "Off-Axis Fatigue Properties of Unidirectional Composites", International Symposium on Newer Fibres and Composites, February 1978, Bombay, (with S.K. Chaturvedi).
22. "Experimental Investigation of the Properties of Anisotropic Composites", The Second International Conference on Mechanical Behavior of Materials, August 1976, Boston, MA, (with S. Singh and J.N. Narang).
23. "On the Anisotropic Mechanical Properties of Fibrous Composites", The International Symposium on Composites and Fibres, January 1976, New Delhi.
24. "Effect of the Interface on Mechanical Properties of Composites for Structural Applications", National Symposium on Composites for Structural Applications, 1975, Madras, (with L.J. Broutman).