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Dr. Prabhat Krishnaswamy
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Education

Ph.D., Mechanical Engineering, University of Washington, 1990
M.S, Mechanical Engineering, University of Massachusetts, 1981
B.S, Mechanical Engineering, Indian Institute of Technology, 1979

Qualifications

Prior to joining Emc² in 1998 Dr. Krishnaswamy worked as a Senior Research Scientist at Battelle Memorial Institute, the world's largest contract research organization that is based in Columbus, Ohio. He was the Principal Investigator and Program Manager for many research programs within the Engineering Mechanics Department and the Advanced Materials Group

Dr. Krishnaswamy has conducted extensive research in both analytical and experimental areas of engineering mechanics and is a renowned expert in the mechanical behavior of plastics and polymeric composites for structural load-bearing applications.

Over the last ten years Dr. Krishnaswamy has led the technology development and worldwide standards activities in the area of thermoplastic composite lumber. He was the principal investigator and program manager for a multi-client effort to develop performance requirements and standards for thermoplastic composite lumber in structures. These activities involved coordination with state governments, federal agencies, research organizations, and private sector firms working towards the development of markets and applications for this new class of materials. This new industry is now estimated to be ~\$1BN and growing at more than 20 percent annually.

Dr. Krishnaswamy serves on Governor Bob Taft's Advisory Council within the Ohio Department of Natural Resources.

Relevant Experience

Product and Process Development for Thermoplastic Composites: Dr. Krishnaswamy has developed unique technologies for advanced thermoplastic composites in structural applications. Three of these technologies developed in the last two years have led to products and processing methods that have been patented and are now being commercialized.

Polyethylene Gas Distribution Pipelines. Developed design basis for 50-year service life of medium and high-density polyethylene gas piping systems including slow crack growth, rapid crack propagation, in-service load determination, joining, and failure analysis. Task leader in conducting

Prabhat Krishnaswamy (continued)

research on dynamic brittle fracture of polyethylene gas distribution piping at cold temperatures. Experimental results from the basis for designing large-diameter plastic piping systems.

Natural Fiber Reinforcements for Thermoplastics. There is growing interest in using wood, hemp, flax, jute, kenaf and other lingo-cellulosic fibers to reinforce thermoplastics due to their performance, properties and price advantages coupled with their biodegradability. Dr. Krishnaswamy has developed breakthrough technologies for processing of these natural fiber composites for a variety of extrusion, compression and injection molded applications where these fibers can successfully replace glass-fiber in numerous products in building, construction, automotive and other transportation sectors in the market.

He has led several research programs in natural fiber composites and composite lumber development for commercial and the federal government clients including the United States Department of Agriculture, the Department of Defense, the Environmental Protection Agency and some of the largest paper mills in the country.

Thermoplastic Lumber and Standards Activities: Dr. Krishnaswamy has significant experience in managing large, collaborative, international technology development programs involving interdisciplinary fields. He is the Technical Director on the board of the Plastic Lumber Trade Association. Being an active member of the Society of Plastics Engineers he has chaired numerous sessions at Annual and Regional Technical Conferences.

He currently chairs the Section at the American Society of Testing and Materials (ASTM) responsible for developing all standards for plastic lumber materials. He has authored all test methods and specifications for the use of these materials in structures and is currently authoring the “Design Guide for Structural Thermoplastic Lumber” for use of these materials in commercial and waterfront applications.

ASTM has recognized his contributions with a ‘Distinguished Service Award.’ He was also awarded First Place in the World Standards Day Paper Competition on Standards and the Environment for his work in recycled plastic lumber standards. Dr. Krishnaswamy received the first place award at the World Standards Day Paper Competition in 2001.

Finite Element Modeling of Plastics and Composites. Dr. Krishnaswamy has worked extensively in developing and implementing finite element algorithms for nonlinear, viscoelastics (time-dependent), orthotropic, and time-independent material behavior. These models are widely applicable in describing the inelastic behavior of polymer, polymeric composites, and metals under monotonic, sustained (creep) as well as cyclic loads. Such models are needed to conduct detailed analysis of plastic components in order to accurately determine the stress concentration and possible failure locations in plastics and composites components. The use of simulation of such design results in significant cost savings compared to trial-and-error approaches.

Plastics and Composite Products Design. By integrating injection molding simulation, material property information, and performance evaluation methods, Dr. Krishnaswamy has developed a methodology to cut the cost and reduce the cycle time in designing polymeric products. This design procedure known as the P³ approach – Processing, Properties and Performance, is especially useful for products made of polymeric composites and other advanced materials. He is extending this

Prabhat Krishnaswamy (continued)

work in re-designing plastic lumber materials with laminate reinforcement to meet structural requirements in marine and boardwalk applications.

NASA Composites Consortium. Dr. Krishnaswamy was the principal collaborator in technology transfer of composites modeling capabilities from NASA-Lewis to commercial and non-aerospace applications. He has conducted critical evaluation of PC-based programs for design and structural analysis of composites developed at NASA. These codes can be used for developing new composites as well as for successfully predicting the mechanical behavior of fiber and particulate reinforced for polymer, ceramic and metal matrix composites.

Rapid Crack Propagation in Plastic Pipelines. Task leader in conducting research on dynamic brittle fracture of polyethylene gas distribution piping at cold temperatures. Results from this work are used as a basis for designing large-diameter plastic piping systems.

Ductile Fracture of Plastics. Experimentally evaluated the ductile fracture of tough plastics using elastic plastic fracture mechanics and demonstrated for the first time that tough polymers exhibit tearing instability. Characterized fracture surface morphology using scanning electron microscopy.

Computational Fracture Mechanics. Dr. Krishnaswamy has conducted finite element analyses study the influence of various linear and nonlinear constitutive models on the parameters that govern creep crack growth in viscoelastic materials such as polymers and polymeric composites. As part of his dissertation, he has demonstrated for the first time that the choice of a given constitutive model leads to stress-redistribution during creep in complex geometries.

Full-Scale Fracture Testing of Structures. Task leader in correlating various small-scale impact tests with more fundamental fracture mechanics tests and accurately predicting full-scale fracture behavior of heavy-wall steel components used in gas transmission piping. Also conducted several failure investigations on pipeline components. Have recently been involved in extensive due-diligence for plastics and thermoset composite products used in natural gas pipeline components, including high energy full-scale tests.

Elastic-Plastic Fracture Mechanics Analysis of Nuclear Piping Components. Extended the state-of-the-art in elastic-plastic fracture mechanics methodology to the application and validation of the leak-before-break approach used in analyzing nuclear piping components with flaws.

Program Management. As deputy program manager for the Short Cracks in Piping and Piping Welds Program for the US Nuclear Regulatory Commission Dr. Krishnaswamy coordinated all the activities of the \$1M/year effort. He also was the leader for all the analysis work. This research involved evaluating the structural integrity of nuclear piping with short cracks in both the base and weld metals. Currently, he is the program manager for a four-year, international, multi-client, collaborative research program to develop acceptance criteria for blunt, erosion-corrosion type of flaws in power plant piping components.

Dr. Krishnaswamy has over 50 publications in refereed technical journals, conference proceedings and has been invited to give numerous seminars in academic and commercial institutions in the area of structural applications of plastics and composites. A complete list of his publications is provided below. Dr. Krishnaswamy also holds four U. S. Patents with additional applications that are currently under review at the USPTO.

Prabhat Krishnaswamy (continued)

List of Publications:

1. "Ductile Fracture of Polypropylene," *Proceedings of the Second International Symposium on Environmental Degradation of Materials*, Virginia, pp. 493-504, 1981 (P. Krishnaswamy and J. A. Donovan).
2. "Fracture of Polypropylene," *Proceedings of the Fifth Churchill Conference on Deformation Yield and Fracture of Polymers*, Cambridge, England, March 1983 (J. A. Donovan and P. Krishnaswamy).
3. "Simplified Model for Predicting Elastic to Plastic Instability Loads for Circumferential Cracked Pipes in Bending," *Circumferential Cracks in Pressure Vessels and Piping - II, ASME PVP Vol. 95*, pp. 79-99, 1983 (G. M. Wilkowski and P. Krishnaswamy).
4. "Rapid Crack Propagation in Polyethylene Pipes," *Proceedings of the 1983 International Gas Research Conference*, pp. 235-243, 1983 (P. Krishnaswamy, W. A. Maxey, Dr. L. E. Hulbert, and M.M. Mamoun).
5. "Studies on Heavy-Wall Pipeline Component Toughness Requirements Versus Full-Scale Burst Test Behavior", *Proceedings of the NG-18/EPRG Fifth Biennial Joint Technical Meeting on Line Pipe Research*, pp. 4-1 to 4-25, September 1983 (P. Krishnaswamy and G. M. Wilkowski).
6. "The Use of Charpy and Robertson Tests in Predicting Rapid Crack Propagation in Polyethylene Pipes," *Proceedings of the Eighth Plastic Fuel Gas Pipe Symposium*, New Orleans, Louisiana, pp. 128-132, December 1983 (P. Krishnaswamy, W. A. Maxey, L. E. Hulbert, and M. M. Mamoun).
7. "Single Specimen J-Resistance Curve Evaluation Using the D.C. Electric Potential Method and a Computerized Data Acquisition System," *Fracture Mechanics: Fifteenth Symposium ASTM STP 833*, pp. 553-576, 1984 (G. M. Wilkowski, J. O. Wambaugh, and P. Krishnaswamy).
8. "Tearing Instability in Polypropylene," *Polymer*, Vol. 26, pp. 1963-1970, 1985 (P. Krishnaswamy and J. A. Donovan).
9. "A Design Procedure And Test Method to Prevent Rapid Crack Propagation (RCP) in PE Gas Pipe," *Proceedings of the GRI Fifth Plastic Piping Workshop*, pp. 144-153, June 1985 (P. Krishnaswamy and L. E. Hulbert).
10. "Flaw Tolerance of Heavy-Section Valves and," *Proceedings of the AGA/PRC's 7th Symposium on Line Pipe Research*, pp. 13-1 to 13-36, October 1986 (G. M. Wilkowski, P. Krishnaswamy and J. O. Wambaugh).
11. "Finite Element Modeling of Crack Tip Behavior in Viscoelastic Materials - Part I: Linear Behavior," *International Journal For Numerical Methods in Engineering*, Vol. 30, pp. 371-387, 1990 (P. Krishnaswamy, M. E. Tuttle, A. F. Emery, and J. Ahmad).
12. "Finite Element Modeling of the Time-Dependent Behavior of Nonlinear Ductile Polymers," *Proceedings of the ASME Winter Annual Meeting - Plastics and Plastic Composites*, Vol. 29, pp. 77-99, 1991. Also appeared in *Polymer Engineering & Science*, Vol. 32, pp.1086-1096, 1992 (P. Krishnaswamy, M. E. Tuttle, A. F. Emery and J. Ahmad).
13. "Effect of Finite Radius on Time-Dependent Crack-Tip Stress Fields in Ductile Polymers," *Time Dependent Failure of Polymers: Experimental Studies*, ASME AMD-Vol. 155, pp. 29-37, 1992 (B. N. Leis, P. Krishnaswamy, and S. K. Naboulsi).
14. "Finite Element Modeling of Crack-Tip Behavior in Ductile Polymers - Stationary and Growing Cracks," *Time Dependent Failure of Polymers: Experimental Studies*, ASME AMD-Vol. 155, pp. 39-49, 1992 (P. Krishnaswamy, M. E. Tuttle, A. F. Emery, and J. Ahmad).
15. "Effect of Aging on the Predicted Maximum Moment-Carrying Capacity of Circumferentially Cracked Cast Stainless Steel Pipe," *Proceedings of the USNRC Aging Research Information*

Prabhat Krishnaswamy (continued)

- Conference, pp. 341-368, NUREG /CP-0122, Vol. 2, March, 1992 (P. Krishnaswamy, P. M. Scott and G. M. Wilkowski).
16. "Short Cracks in Piping and Piping Welds", *Proceedings of the USNRC Nineteenth Water Reactor Safety Meeting*, pp. 73-96, NUREG /CP-0119, Vol. 1, April 1992 (G. M. Wilkowski, P. Krishnaswamy, F. Brust and others).
 17. "A Computational Study of Time Dependent Crack Growth Process," *Fracture and Damage*, ASME, AD-Vol. 27, pp. 23-30, 1992 (P. Krishnaswamy and F. W. Brust).
 18. "Consideration of History Dependent Damage in Creep Crack Growth," *Proceedings of the U.S. Department of Energy Basic Sciences Conference*, July 1992 (F. W. Brust, P. Krishnaswamy and B. Majumdar).
 19. "Finite Element Analysis of History Dependent Damage in Time Dependent Fracture Mechanics," *Proceedings of the ASME PVP Conference, Fatigue, Fracture and Risk*, PVP - Vol. 241, pp. 69-76, 1992; also appeared in *Journal of Pressure Vessel Technology*, Vol. 115, pp. 339-347, November 1993 (P. Krishnaswamy, F. W. Brust and N. D. Ghadiali).
 20. "Further Studies of History-Dependent Loading in the Creep-Crack Growth Regime," *Fracture Mechanics: Application of New Materials*, ASME PVP-Vol. 260, pp. 49-58, 1993 (F. W. Brust, P. Krishnaswamy and B. Majumdar).
 21. "Finite Element Modeling of Creep Crack Growth in 316 Stainless and 9Cr-1Mo Steels," *Proceedings of the Eleventh International Invitational UACEM Symposium*, pp. 371-386, August 1993 (P. Krishnaswamy and F. W. Brust).
 22. "Further Results in the Short Cracks in Piping and Piping Welds Program," *Transactions of the Twentieth Water Reactor Safety Information Meeting*, October, 1993 (G. Wilkowski, P. Krishnaswamy, F. W. Brust and others).
 23. "Current Results from the NRC's Short Cracks in Piping and Piping Welds Research Program," *Proceedings of the Structural Mechanics in Reactor Technology (SMIRT) Conference, Stuttgart, Germany*, 1993 (G. Wilkowski, P. Krishnaswamy, F. W. Brust and others).
 24. "Key Results from the NRC's Short Cracks in Piping and Piping Welds Research Program," *Transactions of the Twenty-Second Water Reactor Safety Information Meeting*, October, 1994 (G. Wilkowski, P. Krishnaswamy, F. W. Brust and others).
 25. "Investigation of Fracture Parameters for History Dependent Creep Crack Growth," presented at the *12th US National Congress of Applied Mechanics, Seattle, Washington*, June 26-July 1, 1994 (P. Krishnaswamy and F. W. Brust).
 26. "An Assessment of Proposed Changes in ASME Section III Allowable Stresses on the Critical Flaw Sizes of Piping," presented at the *Structural Mechanics in Reactor Technology (SMIRT) Conference, Porto Alegre, Brazil*, 1995 (P. Krishnaswamy, N. Ghadiali and G. Wilkowski).
 27. "A Finite Element Algorithm To Study Creep Crack Growth Based on the Creep Hardening Surface," *International Journal For Numerical Methods In Engineering*, Vol. 38, pp. 969-987, 1995 (P. Krishnaswamy, F. W. Brust and N. D. Ghadiali).
 28. "Reducing Cycle Time in Designing Polymeric Products Using Computer Simulation," *Proceedings of the Society of Plastics Engineers ANTEC '95*, pp. 2958-2963, May 1995 (P. Krishnaswamy, N.D. Ghadiali, and C.R. Miele).
 29. "Developing Standards for Recycled Plastics Products: A Case Study - Recycled Plastics Lumber Pallet," presented at the *National Recycling Coalition 14th Annual Congress and Exposition*, Kansas City, Missouri, September 1995 (P. Krishnaswamy).
 30. "Establishing Design Guidelines for the Use of Manufactured Recycled Plastic Lumber in Structural Applications," *Proceedings of the Society of Plastics Engineers, Regional Technical Conference ARC '95*, pp. 183-197, 1995 (P. Krishnaswamy, R. Francini and J Zhang).
 31. "Improvements to Surface-Cracked Pipe J-estimation Schemes, Validation by Experiments and

Prabhat Krishnaswamy (continued)

- Proposed Modification of the ASME Section XI Pipe Flaw Evaluation Criteria," *21st MPA Seminar – Approaches to Lifetime Extension of Nuclear Power Plants*, Vol.2, pp. 38.1-38.21, Stuttgart, Germany, October 1995 (P. Krishnaswamy, G. M. Wilkowski, and others).
32. "Advanced LBB Methodology And Considerations," *Proceedings of the Seminar on Leak Before Break in Reactor Piping and Vessels*, NUREG-CP-015, pp. 601-613, Lyons, France, October, 1995 (R. Olson, S. Rahman, P. Scott, R. Mohan, T. Kilinski, D. Rudland, P. Krishnaswamy and G. Wilkowski).
 33. "Evaluation of Manufactured Recycled Plastic Lumber (MRPL) for Pallet Applications," presented at the *American Chemical Society, Midwest Regional Meeting on Polymer Life Cycles*, Akron, Ohio, May 31-June 2, 1995 (P. Krishnaswamy, R. Wesson, R. Francini, and A Krishna).
 34. "Proposed Procedure for Modification of the ASME Section XI Pipe Flaw Evaluation Criteria Based on a New Surface-Cracked Pipe J-Estimation Scheme," 1996 (G. Wilkowski, P. Scott, P. Krishnaswamy and Y. H. Choi).
 35. "Developing Performance Based Standards For Recycled Plastic Lumber and Its Products," *Proceedings of the DOE Pollution Prevention Conference XII – 21st Century, Session 19*, 1996 (P. Krishnaswamy and C. Miele).
 36. "Virtual Design Methodologies to Accelerate and Optimize New Product Development" Invited Lecture at the *North American Advanced Materials Center Conference of Emerson Electric Company*, November, 1996 (P. Krishnaswamy).
 37. "History Dependent Load Effects in Composites," *Proceedings of the American Composites Society*, 1997 (F. W. Brust, R. Mohan and P. Krishnaswamy).
 38. "Comparison of Flaw Acceptance Criteria for Blunt Erosion-Corrosion Type of Defects in Piping," *Proceedings of the SMIRT 14 Conference*, Lyon, France, 1997 (P. Krishnaswamy, G. Wilkowski, T. Griesbach and S. Gosselin).
 39. "Progress in Development of Acceptance Criteria for Local Thinned Areas in Pipe and Piping Components," *Proceedings of the SMIRT Post-Conference Seminar 2*, 1997 (G. Wilkowski, D. Stephens, P. Krishnaswamy and others).
 40. "A Review of the Analysis Methods and Acceptance Criteria for Local Thinned Areas in Piping and Piping Components," *Proceedings of the 1997 Pressure Vessels and Piping Conference*, July 1997 (D. Stephens, P. Krishnaswamy, R. Mohan, D. Osage and G. M. Wilkowski).
 41. "Applying Life Cycle Decision Methodology to Pollution Prevention Decision-making," *Proceedings of the DOE Pollution Prevention Conference XIII - Spotighting Success, Session 12*, 1997 (K. Yuracko, M. Gresalfi, P. Krishnaswamy, P. Yerace, and B. Lehrter).
 42. "Establishing Design Guidelines for Using Recycled Plastic Lumber," *Invited Talk at the Fourth International Conference on Woodfiber-Plastic Composites*, pp. 124-129, 1997 (P. Krishnaswamy).
 43. "An ABAQUS-Compatible User Subroutine UMAT Based on Two-Surface Constitutive Model for Cyclic Plasticity of Nonlinear Hardening Stainless Steels," presented at the *ASME Pressure Vessel and Piping Conference*, July 1998 (Y. Zhao, P. Krishnaswamy, and D. Rudland).
 44. "Design Guidelines and Life-Cycle-Cost Analysis for the Use of Recycled Plastic Lumber (RPL) in Structures," *Materials and Technologies for Sustainable Construction Symposium A - CIB World Building Congress Proceedings, Volume 1*, pp. 275-283, Gavle, Sweden, June 1998 (P. Krishnaswamy).
 45. "Prediction of Time-Dependent Failure Behavior of Plastics and Composites," Invited lecture at the *Elastomer - Service Life Prediction Symposium '98*, Akron, Ohio, September 9-10, 1998 (P. Krishnaswamy).
 46. "RPLDB 1.0 - Development of an Interactive Recycled Plastic Lumber Database for the Design Engineer," *International Composites Expo '99*, Technical Paper, Session 12-A, May 1999 (P. Krishnaswamy and N. D. Ghadiali).

Prabhat Krishnaswamy (continued)

47. "Demonstration Projects Using Recycled Plastic Lumber: Pedestrian Bridge at Ft. Leonard Wood, MO and Waterfront Boardwalk at Kelley's Island, OH," *International Composites Expo '99*, Technical Paper, Session 12-B, May 1999 (R. G. Lampo and P. Krishnaswamy).
48. P. Deardorff, A., Krishnaswamy, P., and others, "ASME SECTION XI Evaluation Methods and Acceptance Criteria for Analytical Evaluation of Wall Thinning due to Flow Accelerated Corrosion," ASME PVP Conference, July 1999.
49. "Long-Term Durability of RPL in Structures," to be presented at *R-2000 5th World Congress and Envirotech Trade Show*, Toronto, June 2000. (P. Krishnaswamy and R. B. Francini)
50. "Progress in Development of Acceptance Criteria for Local Thinned Areas in Pipe and Piping Components," *Nuclear Engineering and Design* 195 pp 149-169, 2000. (G. Wilkowski, D. Stephens, P. Krishnaswamy, B. Leis, and D. Rudland).
51. "Acceptance Criteria for Blunt Erosion-Corrosion Type of Flaws in Piping - Comparison of Analyses and Full-Scale Experiments," to be presented at the *ASME PVP Conference*, Seattle, July, 2000. (P. Krishnaswamy, G. M. Wilkowski, D. Rudland, and P. Scott).
52. "Demonstration of the Performance of Recycled Plastic Lumber in Structures," presented at *R-2000 5th World Congress and Envirotech Trade Show*, June 2000 (D. Stusek and P. Krishnaswamy).
53. Development of Industry Consensus Standards for Recycled Plastic Lumber," presented at the *R-2000 5th World Congress and Envirotech Trade Show*, Toronto, June 2000 (R. Lampo. P. Krishnaswamy, and A. Robbins).
54. "Weathering Effects on Mechanical Properties of Recycled HDPE Based Plastic Lumber," presented at *SPE ANTEC-2001*, May, 2001 (J. Lynch, T. Nosker and others).
55. "Introducing the First Recycled Plastic Bridge in the World," presented at the *International Bridge Conference*, June 2001, (with M. G. McLaren and others).
56. "Recycled Plastic Lumber Standards – from waste plastics to plastic lumber bridges," *The Journal of the Standards Engineering Society*, Vol. 53, No. 5, September/October 2001. Also re-printed in *ASTM Standardization News*, December 2001; *The Construction Specifier*, January, 2002; *The ANSI Reporter*, Autumn/Winter 2001; and *Defense Standardization Journal Magazine*, 2002 (with Richard G. Lampo).
57. "Considerations for Probabilistic Analysis to Assess Potential Changes to Large-Break LOCA Definition for ECCS Requirement," presented at the *ICONE-10*, 2002 (with Gery Wilkowski and others).
58. "Structural Grade Recycled Plastic Lumber Products," Invited Lecture, Northeast Recycling Council's (NERC), Fall Meeting, Northampton, MA, October, 2003.
59. "Welding of Recycled Thermoplastic Lumber for Structural Components," to be presented at the Society of Plastics Engineers, Annual Technical Conference, 2004. (with Dave Grewell and Avi Benatar).
60. P. Krishnaswamy, E. Focht, D.J. Shim, T. Zhang, "Use of Polyethylene (PE) Pipe in Safety-Related, Class 3, Service-Water Piping," 16th International Conference on Nuclear Engineering, ICONE16-48830, Orlando, Florida, 2008.
61. P. Krishnaswamy, E. Focht, D.J. Shim, " Use of Polyethylene (PE) Pipe in Safety-Related Nuclear Power Plant Piping," *Plastics Pipes XIV*, Session 6A, Budapest, Hungary, 2008
62. D.J. Shim, P. Krishnaswamy, E. Focht, " Comparison of Parent and Butt Fusion Material Properties of High Density Polyethylene," ASME Pressure Vessels and Piping Conference, PVP2009-78066, Prague, Czech Republic, 2009.
63. D.J. Shim, P. Krishnaswamy, S Kalyanam, Y. Hioe, "Viscoelastic Finite Element Modeling of Bimodal High Density Polyethylene (HDPE) Piping Materials for Nuclear Safety-Related Applications," ASME Pressure Vessels and Piping Conference, PVP2010-25715, Seattle, WA,

Prabhat Krishnaswamy (continued)

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64. P. Krishnaswamy, D.J. Shim, "A Review of Service Life Prediction Models for Polyethylene Piping for Nuclear Safety-Related Applications," *Plastics Pipes XV*, Vancouver, Canada, 2010.
 65. S. Kalyanam, D.J. Shim, Y. Hioe, P. Krishnaswamy, "Slow Crack Growth Resistance of Parent and Joint Materials from PE4710 Piping for Safety-Related Nuclear Power Plant Piping," *ASME Pressure Vessels and Piping Conference*, PVP2011-57874, Baltimore, MD, 2011.
 66. S. Kalyanam, P. Krishnaswamy, M. Uddin, D.J. Shim, "A Simplified Stress Intensity Factor Relation for Assessment of External Axial Flawed Safety-Related Nuclear Power Plant HDPE Piping," *ASME Pressure Vessels and Piping Conference*, PVP2011-57904, Baltimore, MD, 2011.
 67. S. Kalyanam, P. Krishnaswamy, D.J. Shim, Y. Hioe, E. Focht, "Structural Integrity of HDPE Piping and Joints in Nuclear Safety-Related Applications," *20th International Conference on Nuclear Engineering*, ICONE20-54192, Los Angeles, CA, 2012.
 68. P. Krishnaswamy, S. Kalyanam, Y. Hioe, D.J. Shim, "A Methodology to Predict Critical Flaw Size in HDPE Piping and Joints in Nuclear Safety-Related Applications," *Plastics Pipes XVI*, Session 2B, Barcelona, Spain, 2012.
 69. P. Krishnaswamy, S. Kalyanam, D.J. Shim, S. Kawaguchi, T. Shimura, "Assessment of Slow Crack Growth Test Methodologies Used to Predict Service Life of High Density Polyethylene Piping for Gas Transport," to be published at the *ASME Pressure Vessels and Piping Conference*, PVP2013-97416, Paris, France, 2013.

Prabhat Krishnaswamy (continued)

List of Patents:

1. "Thermoplastic Composite Lumber Having Reinforcing Laminate of Unidirectional Fibers," United States Patent 6,391,456, May 21, 2002.
2. "Structural Recycled Plastic Lumber," United States Patent 6,497,956, December 24, 2002.
3. "Thermoplastic Composite Lumber Having Reinforcing Laminate of Unidirectional Fibers," United States Patent 6,749,709, June 15, 2004.
4. "Fibrillated Bast Fibers as Reinforcement for Polymeric Composites," United States Patent 6,767,634, July 27, 2004.
5. "Soft Crack Arrestors for Pipeline," United States Patent, 8,353,317, January 15, 2013.