**ANDREJ V. CHERKAEV**
Professor of Mathematics
**Curriculum Vitae**

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**Education**
Leningrad Polytechnic Institute, 1967-1973. Areas: Applied Mathematics, Continuum Mechanics and Control Theory. Physical-Technical Institute, Academy of Sciences of USSR, 1975-1979. Areas: Applied Mathematics and Mathematical Physics.

**Degrees**
Doctor of Sciences (Habilitation) - 1988. Leningrad State University.
Ph.D. (Candidate of Sciences) - 1979. Leningrad Polytechnic Institute.
MS (Engineer diploma) - 1973. Leningrad Polytechnic Institute.

**Appointments**
1992-present: Professor, University of Utah.
2002: Senior visitor. Math department, Danish Technical University.
1991: Senior Visiting Fellow, CIMS, New York University.
1989-1990: Professor, Saint-Petersburg Marine Technical University.
1975–1989: Research Fellow, Ioffe Institute of Tech. Physics, Acad. Sc. USSR.

**Research Fields**
Optimal design. Nonquasiconvex multivariable variational problems. Homogenization. Composites. Bounds for effective properties. Physics and mechanics of non-homogeneous bodies. Lattice models.

**Major research directions and accomplishments**

• Together with Konstantin Lurie, we first showed that solution of a generic problem of optimal design does not exist in a class of "conventional" layouts, but only in a set of composites with infinitesimal microstructure. We demonstrated the first examples of this kind: an elastic bar with maximal and minimal torsion stiffness, an *optimal thermolense*, a structured material which best redirects and concentrates thermal flux. Together with Leonid Gibiansky, we discovered optimal microstructures of bending plates and 3d elastic bodies.

• Over two decades, I worked on "solutions" of non-convex variational problems that actually do not have solutions. Namely, the minimizing sequences oscillate in infinitely small scales and converge to measure-valued functions. These limits are described by *relaxed solutions* that lead to description of effective properties. The first version of the method for optimal bounds for effective properties the so-called *translation method* – was suggested by Lurie and me in 1982 to find exact bounds for anisotropic effective conductivity. Then, the method was applied to find optimal structures for two- and three-dimensional elastic composites with extremal stiffness, optimal structures for a polycrystal, etc. Together with Leonid Gibiansky, we improved 2d Hashin-Shtrickman bounds, replacing them with a coupled effective bulk-shear moduli bound. The early papers on the subject were collected in the book [1] that I edited, the finding were summarized in my book [2].

• Recently, I generalized the translation method and found exact bounds for multicomponent isotropic composites and optimal structures for the three-material G-closure. In collaboration with my then PhD student Yuan Zhang we found optimal bounds and structures for anisotropic composites. Currently, I am working with Grzegorz Dzierzanowski to extend the method to multicomponent elastic composites in order to apply them to structural optimization.

• I worked out several new types of microstructures, starting with particular multiscale repeated laminates, where I proved optimality of such structures in problems for elastic and conducting composites. In 1995, in collaboration with Graeme Milton, we suggested a new class of metamaterials. One structure of this class, the pentamode material, was produced this year by Martin Wegener and his group at the Karlsruhe Institute of Technology (KIT), this work attracted the attention of the media. I recently also suggested structures of "wheel assemblage" and "hairy spheres" that generalize Hashin-Shtrikman coated circles and spheres. Together with my student Alex Pruss, we calculated effective properties of "spiral assemblages", and similar exotic structures which are candidates for metamaterials.

• Together with Leonid Gibiansky, we suggested a new minimal variational principle for real and imaginary parts of the potential in complex-valued conductivity and viscoelasticity; the method is based on duality and Legendre transform. This principle was generalized and applied to viscoelastic problems by Berryman, Gibiansky and Milton, and later generalized to dynamic problems (MIlton).

• I worked on discrete lattice models of composites and phase transition. Together with Alex Panchenko and Andrey Kouznetzov (WSU), we described unstressed "still states" in a lattice that is undergoing a phase transition and suggested a model of dynamics of an irreversible transition. Together with Seubpong Leelavanichkul, we studied breakable lattices, introduced lattice damage tensor and used it for a suggested mesoscale model of damageable lattice dynamics.

• I am currently working on a large project on protective structures, waves of damage in structured materials, and waves of phase transitions. In collaboration with Elena Cherkaev and Leonid Slepyan, we have described a new type of nonlinear waves of phase transition that correspond to a self-repeated process fueled by instantly applied self-induced excitation; the simplest example of such waves is a falling domino train. Based on our analysis, we suggested structural design (bistable links) with superior resistance against an impact (waiting link structures). A part of the project was conducted in collaboration with our postdocs Liya Zhornitskaya, Vladimir Vinogradov, Seubpong Leelavanichkul. The concept of a bistable-link structure was experimentally verified by the colleagues from Mechanical Engineering Department. This project was funded by ARO and resulted in two SBIR competitions for industrial production of the suggested protective structures.

• Together with Seubpong Leelavanichkul, we investigated an *inverse optimization problem*: determination of a goal functional from the observed optimal solution. We looked at a morphology of a biostructure, perfected by evolution. Namely, we studied possible reasons for wood fibers spiraling around trunks of Ponderosa pine. We developed a theory for elastic cylinders with helicoidal symmetry that describes elastic response of trees' trunks, as well as cables and similar structures. Based on the analysis, we suggested and verified several hypotheses for the spiraling phenomenon and the angle of the helices. The results attracted an attention of several engineers and biologists.

• In collaboration with Elena Cherkaev, we suggested a novel approach to robust optimal design in the case when the external forces are not completely known. The proposed minimax design principle selects the worse case loading and optimizes the design against it. Typically, we have to deal with multiple equally unfavorable loadings, and the optimal design distributes the resources to equally resist any of them. The problem is reduced to a bifurcation problem, and in a special case to a Steklov eigenvalue problem with multiple principal eigenvalue. We also proved that an invariance

of the admissible loading to reflection or rotation leads to corresponding symmetry of the optimal design which is analogous to the celebrated Noether theorem.

**Educational activity**

• Recently, four PhD dissertations were defended under my supervision.
Ismail Kucuk (2004). Optimal and suboptimal elastic design methods.
Nathan Albin (2006). Optimality of the translation bounds for linear conducting composites
Seubpong Leelavanichkul (2007). Helicoidal Morphology in Engineering Structures
Yuan Zhang (2010). G-closure of three-material composite properties.

• I served in a number of PhD and Master students advisory committees in math, physics, mechanical and chemical engineering, supported and collaborated with several postdoctoral fellows.

• Together with Robert Palais and Elena Cherkaev, we worked on an NSF-sponsored project for Internet math teaching tools and developed a number of websites.

• Elena Cherkaev and my website on math jokes and folklore has been visited by more than a *million* people from more than 130 countries. It is used in several math departments as a tool for attracting prospective students.

**Synergistic activity**

Current: In July 2012, I organized the White Nights Workshop "Exotic Structures and Homogenization" in Saint Petersburg, Russia, see $http://apm-conf.spb.ru/esh_2012.php$.
Together with Graeme Milton, we are organizing the international conference: Continuous Models and Discrete Systems (CMDS-13) in June 2014.

I serve as a member of the

• International Advisory Board for "Archive of Mechanics".

• Editorial Board of "Interdisciplinary and Structural Optimization".

I was the co-organizer/member of scientific committee of a number of conferences, such as:

• NIST International Workshop on Optimal Design of Materials and Structures. Salt Lake City, Utah, 1995.

• The World Congress of Structural Optimization, Goslar, Germany, 1995.

• ETOPIM. Snowbird, Utah, 2002.

• New trends in Material Design of Complex Systems in Space and Time November 2005, WPI.

• The World Congress of Structural and Multidisciplinary Optimization, Rio de Janeiro, 2005.

• AMS Special Session on Nonconvex Variational Problems: Recent Advances and Applications, Worcester, 2006.

• Fall Western Section Meeting, Salt Lake City, 2006

• The World Congress of Structural and Multidisciplinary Optimization, Lisbon, 2009

**Results dissemination** I have given courses on "New Math for New Materials" at the Institute of Applied Mechanics, Russian Academy of Sciences (October-November 2007, St.Peterburg, Russia) and on Optimal Structures in St Petersburg Marine University in December 2011.

I participate in 4-6 conferences annually and regularly give colloquium and seminar talks. This year, I gave invited talks at

– ICIAM. Vancouver August 2011,

– University of Houston - colloquium lecture, November 2012

– Joint AMS, MAA, SIAM meeting, Boston, January 2012,

– Workshop on Hyperbolic Conservation Laws and Infinite-Dimensional Dynamical Systems. University of Pittsburgh - March 2012,

– PDEs and Dynamical Systems Conference - Suzdal, June 2012 - plenary address.

**Publications**

Books:

[1] Topics in the mathematical modeling of composite materials, A.Cherkaev and R. Kohn editors, Birkhausen, NY, 1997.

[2] A. Cherkaev. Variational methods for structural optimization. Springer Verlag, NY, 2000.

I published more than 100 research papers, see http://www.math.utah.edu/ cherk/listpubl.html below are 12 selected papers:

[3] K. A. Lurie and A. V. Cherkaev. Exact estimates of conductivity of composites formed by two isotropically conducting media taken in prescribed proportion. Proceedings of the Royal Society of Edinburgh: Section A, 99, 1984, 71-87

[4] A.V. Cherkaev, L.V. Gibiansky. Coupled estimates for the bulk and shear moduli of a two-dimensional isotropic elastic composite. JMPS, 41 (5), 1993, 937-980

[5] A. V. Cherkaev and L. V. Gibiansky, Variational principles for complex conductivity, viscoelasticity, and similar problems in media with complex moduli, Journal of Mathematical Physics, 35, 1994, 127-145.

[6] G.W. Milton, A.V. Cherkaev Which elasticity tensors are realizable? J. Eng. Mater. Technol., 117, 4, 1995, 483-494.

[7] A. Balk, A. Cherkaev, L. Slepyan Dynamics of chains with non-monotone stressstrain relations. JMPS, 49, 2001, 131-171.

[8] S. Leelavanichkul and A. Cherkaev. Why grains in the tree's trunk spiral: mechanical perspective. Structural and Multidisciplinary Optimization, 28, 2-3, 2004, 127 - 135.

[9] E. Cherkaev, A. Cherkaev. Principal compliance and robust optimal design. Journal of Elasticity, 2003, 72, 71-98.

[10] A. Cherkaev, E. Cherkaev, and L. Slepyan, Transition waves in bistable structures. J. Mech. Phys. Solids, 53/2, , 2005, 383-436.

[11] A.Cherkaev. Bounds for effective properties of multimaterial conducting composites. Int. J. Mech. Mater. 41(4), 2009, 411-433.

[12] A. Cherkaev, A. Kouznetzov, A. Panchenko. Still states of bistable lattices, compatibility, and phase transition. Cont. Mech Thermodynamics, 22, 2010, 421-444.

[13] A. Cherkaev, Y. Zhang, Optimal anisotropic three-phase conducting composites: Plane problem. Int. J. Solids and Structures, 48 (20), 2011, 2800-2813.

[14] A. Cherkaev, Optimal three-material wheel assemblage of conducting and elastic composites. Int. J. Eng. Sc. 59, 2012, 2739.