

# Vitae supplement, 2019-24

## Report on relevant activities and accomplishments

Andrej Cherkaev

### 1 Research

In these five years, I worked in several research areas:

#### **Discrete structures**

- Theory of compatibility conditions in planar trusses (a collaborative project with Andrejs Treibergs and Predrag Krtolica).

We formulated a comprehensive theory of compatibility of planar trusses, investigated their continuum limits, and described the application to characterization of damaged trusses, see [8].

- Theory of damage spread in lattices and design of impact-resistant structures (a collaborative project with Michael Ryvkin, Tel Aviv University).

Dealing with the volatile process of micro-cracks growths, we suggested several criteria for the damage spread, criteria (norms) of damage level in a beam lattice [2]. We proposed a design of fault-tolerant structured materials [3]. In collaboration with an experimental lab in Technion that 3D-printed and tested our designs, we validated the theory [7]. We also analyzed [10] elastic fields and effective properties of randomly damaged triangular beam lattice:

- Dynamic homogenization of a chain of masses and bistable springs (in collaboration with our undergraduate student Charlotte Blake), see [6].

The minimal homogenized energy of the chain of equal masses and non-monotonic springs corresponds to the convex envelope of the springs' energy or the Maxwell rule for the force-vs-elongation dependence. We investigated the effect of the dynamics of inertial masses on the minimal energy. Using the Central Limit Theorem, we found that the Maxwell law is replaced by a one-parameter family of homogenized dependencies; the parameter is the initial kinetic energy of the spring system.

### Variational problems: Optimal structures

- The current paper [15] summarized and generalizes the approach to structures of optimal multimaterial composites that store minimal energy. Because all structures are compared, the fields in an optimal structure or a fractal limit of structural sequences are either constant or belong to the null space of the *translated* energy. This feature allows for reducing the problem to nonlinear programming. I argue about the constraints on the optimal fields that follow compatibility requirements. I plan to apply the approach to find optimal structures of multiphase composites in 3D.

- In collaboration with Elena Cherkaev and Konstantin Lurie, we described [13] the principles of optimal structures and space-time composites for focusing and energy accumulation.

- Clusters of bubbles were analyzed in a collaborative project with Dong Wang and Braxton Osting; see [5]. Utilizing novel computational methods, we investigated classical two- and three-dimensional problems of a cluster of bubbles with fixed areas (volumes) that minimize the boundaries' total perimeter (area). In particular, we found sudden configuration transformations when the size of one of the bubbles decreases.

- In collaboration with Vladimir Mityushev [11], we found effective properties of an assemblage of inhomogeneous spheres, and in collaboration with Vladimir Mityushev, Natalia Rylko, and Pieter Kurtyka [12], we applied the analysis for description of Al/nano-TiC composites.

### Miscellaneous

- The article [1] in SIAM News describes various applications of Pentamode materials that Graeme Milton and I suggested years earlier and that were constructed by Martin Wegener and Muamer Kadic.

- A paper [4] is a biography assay of Konstantin Lurie.

- I participated in organizing the CMDS conference in Paris (summer of 2023) and in editing the follow-up Springer volume [14]

**NSF Support** I worked on the NSF DMS grant Award No1515125 "Optimal Multimaterial Composites and Exotic Structures"

### References

- [1] A.Cherkaev, M.Kadic, G.W.Milton, M.Wegener. 2019. Pentamode materials: From underwater cloaking to cushioned sneakers News. Soc. Ind. Appl. Math 52 (4).

- [2] A.Cherkaev, M.Ryvkin. 2019. Damage propagation in 2d beam lattices: 1. Uncertainty and assumptions *Archive of Applied Mechanics* 89 (3), 485-501.
- [3] A.Cherkaev, M.Ryvkin. 2019. Damage propagation in 2d beam lattices: 2. Design of an isotropic fault-tolerant lattice *Archive of Applied Mechanics* 89 (3), 503-519.
- [4] A.Cherkaev, K.C.Le. 2019. Introduction to the Special Issue in honor of Konstantin Lurie. *Archive of Applied Mechanics* 89 (3), 403-407.
- [5] D.Wang, A.Cherkaev, B.Osting. 2019. Dynamics and stationary configurations of heterogeneous foams. *Plos one* 14(4), e0215836.
- [6] C.Blake, A.Cherkaev. 2020. Dynamic Homogenization of a Chain with Bistable Springs. *Statistical Approach. Nonlinear Wave Dynamics of Materials and Structures*, 77-96.
- [7] M.Ryvkin, V.Slesarenko, A.Cherkaev, S.Rudykh. 2020. Fault-tolerant elastic-plastic lattice material *Philosophical Transactions of the Royal Society A*, 378 (2162), 20190107.
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- [9] A.B.Freidin, L.L.Sharipova, A.Cherkaev. 2021. On equilibrium two-phase microstructures at plane strain *Acta Mechanica* 232 (5), 2005-2021.
- [10] M.Ryvkin, A.Cherkaev. 2021. Analysis of randomly damaged triangular beam lattice: elastic field and effective properties. *Mathematics and Mechanics of Solids* 26 (8), 1219-1237.
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- [13] A.Cherkaev, E.Cherkaev, K.Lurie. 2023. Optimal structures for focusing and energy accumulation: mathematical models and intuition. Proceedings of the Royal Society A, Volume 479, Issue 2277, article id.20220342
- [14] Continuum Models and Discrete Systems. 2024. F. Willot, J.Dirrenberger, S.Forest, D.Jeulin, A.Cherkaev eds, Springer. (in press)
- [15] A.Cherkaev. 2024. Structure of fields in extremal 2D conducting multimaterial composites. In Continuum Models and Discrete Systems. F. Willot, J.Dirrenberger, S.Forest, D.Jeulin, A.Cherkaev eds, Springer (in press)
- In preparation**
- [16] Andrej Cherkaev, Elena Cherkaev. Calculus of Variations and Applications (Textbook).
- [17] Andrej Cherkaev. Optimal structures for three-material 3D composites.

## 2 Impact and dissemination

### Google scholar stats

	Total	Since 2019
Citations	5021	1022
h-index	33	16
i10-index	73	27

see <https://scholar.google.com/citations?user=snCtzBIAAAAJ>

### ResearchGate stats

- Reads of the research items: 20,360 (+51 last week)
- Research Interest Score: 2,077 (+6.60 last week)
- The Research Interest Score is higher than 97% of researchers with work related to: Applied Mathematics

see <https://www.researchgate.net/profile/Andrej-Cherkaev/stats/reads>

## Conferences

- Invited Speaker at the ICoNSoM 2024 International Conference on Nonlinear Solid Mechanics, Sardinia, Italy, June 11-14, 2024, Cagliari, Sardinia, Italy
- Invited Speaker, SIAM Conference on Mathematical Aspects of Materials Science, Pittsburgh, PA, May 19-23, 2024
- Invited Speaker at the minisymposium, International Congress for Industrial and Applied Mathematics, Tokyo, Japan. Aug. 2023
- Invited Speaker, The Fourteenth International Symposium on Continuum Models and Discrete Systems, CMDS14, Paris, France, June 25-30, 2023
- Invited Speaker at the conference "Quasiperiodic Structures and Composites - Arctic Quasiperiodic Workshop", Lulea, Sweden, June 3-8, 2023
- Invited Speaker at the Electrical, Transport, and Optical Properties of Inhomogeneous Media (ETOPIM 12) conference, Besançon, France, July 4-8, 2022.
- Invited Speaker at the International Workshop on Applications of Geometric Methods of Functional Analysis. *Celebrating the 100th anniversary of Mark A Krasnoselski*, Dallas, Texas, May 2022
- Invited Speaker at the conference "Quasiperiodic Structures and Composites - Arctic Quasiperiodic Workshop", Sweden, June 20-23, 2022.
- Invited Speaker at the International Conference on Nonlinear Solid Mechanics (ICoNSoM 2022), Alghero, Sardinia, Italy, June 13-16, 2022.
- Invited Speaker at the 4th Annual Meeting of the SIAM Texas-Louisiana Section, South Padre Island, Texas, Nov. 5-7, 2021.
- Invited Speaker at the minisymposium "Mathematical modeling and analysis of problems in materials science and fluid dynamics", SIAM Conference on Mathematical Aspects of Materials Science (MS21), May 17-28, 2021.
- Invited Speaker at the minisymposium "Multiscale and Asymptotic Analysis, Modeling, and Simulation for Applications in Materials Science and Fluid Dynamics" at the International Congress on Industrial and Applied Mathematics (ICIAM), July 15-19, 2019, Valencia, Spain.
- Invited Speaker at the minisymposium "Periodicity Effects in Vibro-Acoustics," COMPDYN 2019, 24-26 June, 2019, Crete, Greece.

### 3 Future professional plans

- I am working with our postdoctoral fellows Debdeep Bhattacharya and Tyler Evans on several aspects of dynamic homogenization of vibrating lattices after study in [6]. Numerical simulations revealed several interesting phenomena. I expect that we submit several papers shortly.

- I want to further develop and utilize the developed in [15] principles to find optimal structures of 3D multimaterial composites [17].

- I want to submit the "Calculus of Variations" book [16] to a publisher.

### 4 Teaching and advising

With Elena Cherkaev, we are finishing the "Calculus of Variations and Applications" [16]. The chapters are already online as the lecture notes for my class m-5500.

**Teaching** I taught the following classes:

- MATH 3010 - 001 History Of Math

I prepared online presentations of all lectures. I am still weighing whether or not they should be published.

- MATH 5500 - 001 Calculus of Variations

For this course, I developed a syllabus and prepared lecture notes that are now transforming into a textbook.

- MATH 5710 - 001 Intro Appl Math

- MATH 5770 - 001 Intro to Optimization

*I was on Sabbatical leave in 2022-2023.*

### 5 Service

I served

- on the committees in the Department as assigned by the chair.

- on the editorial boards in Archive of Mechanics and Journal of Structural and Multidisciplinary Optimization.

- on the NSF panels.

- as a co-organizer of the SMDS-14 (Discrete Models and Continuous Systems) conference in Paris in June 2023.

- as the guest editor for the special issue of "Archive of Applied Mechanics," and I coauthor the Introduction to it, see [4].

- as a reviewer for several journals in Mechanics and Optimal Design.