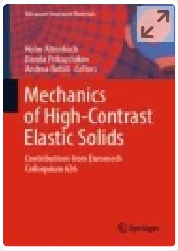

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Blur Effect in a Multiple Particle Inverse Problem for Fiber-Reinforced Composites

V. Mityushev, Zh. Zhunussova, K. Dosmagulova & H. Akca

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Abstract

The Prony method of scattering data analysis is extended to an inverse problem for a fiber-reinforced composite. Unidirectional fibers of shear moduli μ_k $(k = 1, 2, \ldots, n)$ are embedded in the host of shear modulus μ. We consider antiplane strain of the fibrous composite when a section perpendicular to the axis of fibers is the unit disk which contains n non-overlapping inclusions. The contact between the components is supposed to be perfect. The main attention is paid to rigid

inclusions when $\mu_k \gg \mu$. Let the longitudinal displacement *u* be given on the unit circle. Other components of displacement vanish in the unit disk in the antiplane statement. The considered problem is written in terms of complex potentials and solved by a method of functional equations. In particular, the out-of-plane traction proportional to the normal derivative $\frac{\partial u}{\partial \mathbf{n}}$ is found on the unit circle. This yields a constructive method to the symbolic approximation of the Dirichlet-to-Neumann operator for an arbitrary multiply connected circular domain. The method is applied to the inverse problem for non-overlapping equal disks whose centers a_k $(k = 1, 2, \ldots, n)$ have to be determined. Let the displacement *u* and the traction $\mu \frac{\partial u}{\partial \mathbf{n}}$ be given on the outer unit circle. We construct explicitly a polynomial $P_n(z)$ whose complex roots coincide with the centers of inclusions a_k. This result can be considered as a solution to the special Prony problem. The considered examples demonstrate the effect of blurring for large *n* when disks in the near-boundary vicinity are properly determined. The location of the deeper disks is blurry and can be determined by the same equation $P_n(z) = 0$ but solved with higher accuracy.

References

1. Beck JV, Blackwell B, Charles JR (1985) Inverse heat conduction, 1st edn. Wiley Inc, New York

2. Alifanov OM, Artyukhin EA, Rumyantsev SV (1995) Extreme methods for solving ill-posed problems with applications to inverse heat transfer problems. Begell House Inc., New York

3. Cherkaeva E, Tripp AC (1996) Inverse conductivity problem for inaccurate measurements. Inverse Probl 12:869–883

4. Kuchment P (2013) The radon transform and medical imaging, CBMS-NSF regional conference series in applied mathematics

5. Necat Ozisik M (2000) Inverse heat transfer: fundamentals and applications. CRC Press, Boca Raton

6. Hetmaniok E, Slota D, Witula R, Zielonka A (2015) An analytical method for solving the two-phase inverse Stefan problem. Bull Polish Acad Sci Tech Sci 63:583–590

7. Hetmaniok E, Slota D, Zielonka A (2015) Using the swarm intelligence algorithms in solution of the two-dimensional inverse Stefan problem. Comput Math Appl 69(4):347–361

8. Colton D, Kress R (2013) Inverse acoustic and electromagnetic scattering theory. Springer, Berlin

9. Isakov V (2017) Inverse problems for partial differential equations. Springer, Berlin

10. Kress R (2012) Inverse problems and conformal mapping. Complex Var Elliptic Equ 57:301–316

11. Ammari H, Garnier J, Kang H, Lim M, Yu S (2014) Generalized polarization tensors for shape description. Numer Math 126:199–224

12. Munnier A, Ramdani K (2018) Calderón cavities inverse problem as a shape-from-moments

problem. Quart Appl Math 76:407–435

13. Czapla R (2016) Basic sums as parameters characterizing, Silesian. J Pure Appl Math 6:85–96

14. Mityushev VV, Rogosin SV (2000) Constructive methods for linear and nonlinear boundary value problems for analytic functions. Chapman & Hall/CRC, Boca Raton

15. Gluzman S, Mityushev V, Nawalaniec W (2018) Computational analysis of structured media. Elsevier, Amsterdam

16. Carriere R, Moses RL (1992) High resolution radar target modeling using a modified Prony estimator. IEEE Trans Antennas Propag 40:13–18

17. Ebenfelt P, Gustafsson B, Khavinson D, Putinar M (eds) (2005) Quadrature domains and their applications. Advances and applications, operator theory. Birkhäuser Verlag, Basel

18. Muskhelishvili NI (1966) Some basic problems of the mathematical theory of elasticity, 5th edn. (Russian) Nauka, Moscow

19. Bergman DJ (1976) Calculation of bounds for some average bulk properties of composite materials. Phys Rev B 14:4304

20. Drygaś P, Gluzman S, Mityushev V, Nawalaniec W (2020) Applied analysis of composite media. Analytical and computational results for materials scientists and engineers. Elsevier, Amsterdam

21. Rylko N (2015) Edge effects for heat flux in fibrous composites. Comput Math Appl 70:2283–2291

22. Rylko N (2015) Fractal local fields in random composites. Comput Math Appl 69:247–254

23. Rylko N, Wojnar R (2015) Resurgence edge effects in composites: fortuity and geometry. In: Mladenov IM, Hadzhilazova M, Kovalchuk V (eds) Geometry, integrability, mechanics and quantization. Avangard Prima, Sofia, pp 342–349

24. Drygaś P, Mityushev V (2009) Effective conductivity of arrays of unidirectional cylinders with interfacial resistance, Q. J Mech Appl Math 62:235–262

25. McPhedran R, Shadrivov I, Kuhlmey B et al (2011) Metamaterials and metaoptics. NPG Asia Mater 3:100–108

26. Craster RV, Kaplunov J (2013) Dynamic localization phenomena in elasticity. Acoustics and electromagnetism. Springer, Vienna

27. Palmer SJ, Xiao X, Pazos-Perez N et al (2019) Extraordinarily transparent compact metallic metamaterials. Nat Commun 10:2118

28. Cadogan CC (1971) The Möbius function and connected graphs. J Combin Th B 11:193–200

29. Kaplunov J, Prikazchikov DA, Sergushova O (2016) Multi-parametric analysis of the lowest natural frequencies of strongly inhomogeneous elastic rods. J Sound Vib 366:264–276

30. Kaplunov J, Prikazchikov DA, Prikazchikova LA, Sergushova O (2019) The lowest vibration spectra of multi-component structures with contrast material properties. J Sound Vib 445:132–147

31. Kaplunov J, Prikazchikov DA, Sergushova O (2017) Lowest vibration modes of strongly inhomogeneous elastic structures. In:

Altenbach H, Goldstein R, Murashkin E (eds) Mechanics for materials and technologies. Advanced structured materials. Springer, Cham, pp 265–277

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