

Colloquium Final Report

N. 626 – Mechanics of high-contrast elastic composites

Dates and location: **06/09/2021 - 08/09/2021, Keele, UK**

Chairperson **Dr Danila Prikazchikov**

Co-Chairperson **Prof Andrea Nobili**

Conference fees

- regular registration **0.0 €**

What other funding was obtained? **N/a**

What were the participants offered? **The conference run in online mode on the platform provided, due to Covid-19 restrictions. There were 42 talks presented, each of 20 min length, over the three days.**

Number of members of Euromech (reduced registration fee) **31**

Number of non-members of Euromech (full registration fee) **23**

Applicants (members)

- I David Abrahams
- Holm Altenbach
- Igor Andrianov
- Atul Bhaskar
- Davide Bigoni
- Claude Boutin
- Vladimir Bratov
- Weiqiu Chen
- Francesco Dal Corso
- Michel Destrade
- Yibin Fu
- Yuxin Fu
- Lusine Ghulghazaryan
- Julius Kaplunov
- Luca Lanzoni
- Gennady Mishuris
- Alexander Movchan
- Michael Nieves
- Grigor Nika
- Andrea Nobili
- Anna Pandolfi

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- Danila Prikazchikov
- ENRICO RADI
- Stephan Rudykh
- Michael Smith
- Valery Smyshlyaev
- Sergey Sorokin
- Ruxandra Stavre
- David Steigmann
- Konstantin Volokh
- Richard Wiltshaw

Applicants (non members)

- Mohammed Alkinidri
- Marco Amato
- Noël Challamel
- John Chapman
- Mikhail Cherdantsev
- Kirill Cherednichenko
- Teng Fang
- Massimiliano Gei
- Muhammad Hawwa
- Kevin Jose
- Ilia Kamotski
- Alexander Kiselev
- Sergey Kuznetsov
- Katie Madine
- Vladimir Mityushev
- Anatolij Nikonov
- Grigory Panasenko
- Aaron Pim
- Ludmila Prikazchikova
- Kumbakonam Rajagopal
- Giuseppe Saccomandi
- Onur Şahin
- Cesare Signorini

Scientific Report

Analysis of strongly inhomogeneous elastic structures, including multi-component elements, composites, as well as periodic media, is an important area of modern interdisciplinary research, having numerous engineering applications, including but not limited to bio-inspired composites, soft robotics, modelling of photovoltaic panels and laminated glass, insulation panels, etc. The significance of accounting for the presence of high contrast in physical and geometrical properties leading to drastic change in mechanical behaviour compared to homogeneous materials or those with moderate or mild contrast, motivates theoretical and experimental analysis of the related problems. Recent advances in this area allow a more accurate modelling of high-contrast composite solids and structures.

The main focus of the Colloquium “Mechanics of High-Contrast Elastic Composites” was on bringing together researchers from diverse multi-disciplinary areas to exchange and share the latest achievements over the fields of their expertise. The main topics of the Colloquium included:

- Thin laminates:

High-contrast thin laminates have a number of important engineering applications,

e.g. laminated glass. The related problems have been addressed in a number of talks, in particular developing engineering and asymptotic theories for high-contrast layered structures, studying the effect of strong inhomogeneity on the dynamic behaviour, a delicate issue of formulating boundary conditions, etc. [Altenbach, Askari, Boutin, Fu, Ghulghazaryan, Kaplunov]. Extra low-frequency spectra, occurring when the hard components perform almost rigid body motion, was noted as an important feature associated with dynamics of strongly inhomogeneous structures.

- Multispan waveguides:

The problems for layered structures are closely related to those for multi-component waveguides. The results of exact and asymptotic treatment of some of these problems were presented at the Colloquium, including in particular, considerations of strongly inhomogeneous bars, as well as the problem of flutter of a multispan structure in a supersonic flow [Amato, Kuznetsov, ?ahin].

- Engineered micro-structured materials:

Another important focus of the colloquium was on the mechanical behaviour of engineered materials with micro-structure, including fibre-reinforced composites. The presented results include in particular problems for structures with inclusions [Chen, Dal Corso, Mityushev, Nieves], as well as asymptotic formulations for the micro-structured plates [Nobili], and also studies of meta-concrete [Pandolfi] and meta-materials designed for applications at extreme deformations [Bigoni]. Inspiring talks by Steigmann and Rajagopal studied cutting edge problems of stress concentrations near a hole in a fibre-reinforced elastic solid, and development of the Cosserat model in a solid containing curved and twisted fibres.

- Periodic structures:

High contrast also plays an important role in analysis of periodic media. A number of rigorous mathematical treatments were presented, including sharp operator-norm asymptotics for thin elastic plates with rapidly oscillating periodic properties [Cherednichenko], stochastic homogenisation of high-contrast media [Cherdantsev], uniform asymptotics for a family of degenerating variational problems with applications to error estimates in high-contrast homogenisation problems [Kamotski], as well as analysis of norm-resolvent convergence to zero-range models with internal structure in models with strong inhomogeneities [Kiselev], and a technique of high-contrast dynamic homogenisation of periodic micro-resonances with random properties [Smyshlyaev]. In addition, the analytical solution for a cell problem in case of homogenization of transport properties of densely packed, high-contrast fibre composites was presented [Andrianov].

- Industrial applications:

A healthy number of modern engineering applications of high-contrast media were discussed, including laminated glass [Boutin], lightweight structures [Altenbach], biomechanical applications, nonlinear bio-composites and soft materials [Destrade, Rudykh, Saccomandi, Volokh], understanding the role of inhomogeneities during hydraulic fracture [Mishuris], investigations of engineered materials with enhanced dynamic performance [Pandolfi]. An interesting idea of employing strongly inhomogeneous seismic barriers was also proposed [Bratov]. In addition, several talks were dealing with analysis of strong inhomogeneous problems of fluid-solid interaction, including development of high-contrast asymptotic techniques [Panasencko] and a study of wave propagation in fluid-filled periodic shells composed of high-contrast cells [Sorokin].

The Colloquium highlighted a number of important effects of strong inhomogeneity in various fields of mechanics. The subject is clearly of interdisciplinary nature, and it was an excellent opportunity to bring together (though in online format) experts from various branches of modern engineering, including mechanical, civil, material engineering along with applied mathematicians to discuss the theoretical and experimental challenges related to the effect high contrast in a number of technical

problems. Recent advanced methodologies were discussed, including rigorous and formal asymptotic techniques, robust computational schemes and fresh experimental results.

The colloquium has gathered 56 participants from 19 countries, including valuable contributions from the well-known international centres of excellence, such as Aalborg University (Denmark), University of California Berkeley, Texas A&M (USA), Rheinisch-Westfälische Technische Hochschule Aachen, Weierstraß-Institut für Angewandte Analysis und Stochastik (Germany), NUI Galway (Ireland), École nationale des travaux publics de l'État (ENTPE), University Jean Monnet (France), Zhejiang University, Tianjin University (China), Technion – Israel Institute of Technology (Israel), Politecnico di Milano, University of Perugia, University of Trento (Italy), Krakow Technical University (Poland), Saint-Petersburg State University (Russia), University of Bath, University of Cambridge, Imperial College London, University of Liverpool, University of Southampton and University College London (UK). The organisers are very pleased with their contributions.

Both during and after the colloquium we had very positive feedback both for the scientific content. We would like to thank European Mechanical Society for its support in organization of the Colloquium.

Appendix:

Participants of EUROMECH Colloquium ?626

Euromech Members:

1. I David Abrahams
2. Holm Altenbach
3. Igor Andrianov
4. Atul Bhaskar
5. Davide Bigoni
6. Claude Boutin
7. Vladimir Bratov
8. No?l Challamel
9. Kirill Cherednichenko
10. Weiqiu Chen
11. Francesco Dal Corso
12. Michel Destrade
13. Yibin Fu
14. Yuxin Fu
15. Lusine Ghulghazaryan
16. Julius Kaplunov
17. Luca Lanzoni
18. Gennady Mishuris
19. Vladimir Mityushev
20. Alexander Movchan
21. Michael Nieves
22. Grigor Nika
23. Andrea Nobili
24. Anna Pandolfi
25. Danila Prikazchikov
26. Ludmila Prikazchikova
27. Enrico Radi
28. Stephan Rudykh
29. Michael Smith

30. Valery Smyshlyaev
31. Sergey Sorokin
32. Ruxandra Stavre
33. David Steigmann
34. Konstantin Volokh

Non-Members:

1. Muhammad Hawwa
2. Ilia Kamotski
3. Cesare Signorini
4. Kumbakonam Rajagopal
5. Teng Fang
6. Kevin Jose
7. Massimiliano Gei
8. Alexander Kiselev
9. Grigory Panasenko
10. Aaron Pim
11. Mikhail Cherdantsev
12. Katie Madine
13. Mohammed Alkinidri
14. Anatolij Nikonov
15. Onur ?ahin
16. Richard Wiltshaw
17. Marco Amato
18. Sergey Kuznetsov
19. Giuseppe Saccomandi
20. John Chapman

It was also agreed to waive the fees for two more participants, Prof Reinaldo Rodríguez-Ramos (Cuba) and Dr Amir Askari (Iran).

Number of participants from each country

COUNTRY	PARTICIPANTS
United Kingdom	18
Italy	10
Russia	3
Turkey	1
Slovenia	1
Saudi Arabia	2
Armenia	1
France	3
Germany	3
United States	3
China	3
Israel	1
Anguilla	1
Ireland	1
Denmark	1
Romania	1
Poland	1
TOTAL	54

Please send this report in electronic form to the Secretary General of EUROMECH, within one month after your Colloquium.