



11th European Solid Mechanics Conference

4 - 8 July 2022, Galway, Ireland


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11th European Solid Mechanics Conference

4 - 8 July 2022, Galway, Ireland

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Welcome

Dear Colleagues,

It gives me great pleasure to announce the 11th European Solid Mechanics Conference to be held in Galway, Ireland, 4th – 8th July, 2022 (ESMC 2022). The conference is being held under the auspices of the European Mechanics Society (EUROMECH <https://euromech.org/>).

The European Solid Mechanics Conference is the major event for the solid mechanics community in Europe, and provides a unique forum for scientists and engineers from Europe and across the world to exchange ideas on the current state-of-the-art in the mechanics of solids, on new concepts and ideas and to identify new research directions.

Solid mechanics is the bedrock of engineering design in areas such as mechanical engineering, civil and structural engineering, and biomedical engineering. It is a critically important element in the design and development of almost all technologies and products in these areas, such as aircraft, automobiles, buildings, bridges, and medical implants and devices. Further, solid mechanics is a key enabler in the development of new technologies that address the major global challenges of our time in sustainability, renewable energy and health.

The first European Solid Mechanics Conference was held in Munich in 1991. This very successful conference initiated a tri-annual series with subsequent conferences held in Genova, Stockholm, Metz, Thessaloniki, Budapest, Lisbon, Graz, Madrid and Bologna. The 11th European Solid Mechanics Conference will take place at the National University of Ireland Galway, in the city of Galway, Ireland.

We have assembled an outstanding group of invited lecturers for the conference, covering the General Lecture and five Plenary Lectures.

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The conference is organised in terms of the following eight themes:

- Mechanics of Materials
- Biomechanics and Medical Implants
- Continuum Mechanics
- Experimental Mechanics
- Computational Mechanics
- Dynamics, Waves and Metamaterials
- Structural Mechanics
- Multiphysics and Multiscale Problems

There is a General Session for each theme and over fifty Mini-Symposia that cover a range of specialised topics, grouped under each theme.

We warmly welcome you to the wonderful city of Galway for what promises to be a very exciting and stimulating event.

Yours sincerely,

Peter E. McHugh
Chair of ESMC 2022



Peter E. McHugh, PhD, DSc, MRIA, FIEI, FIAE, CEng
Professor of Biomedical Engineering | Ollamh le hInnealtóireacht Bhithleigheis
School of Engineering | Scoil na hInnealtóireachta **#ESMC2022**
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Excellent work Vikram and colleagues

@dsrl_ucdmech and great to have you with us

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MS- 6-4

Mini-symposium title

6-4 – Nonlinear Waves in Solids

Organisers

Aleksei Porubov (St. Petersburg State University), Giuseppe Saccomandi (University of Perugia), Harold Benjamin (NUI Galway)

Mini-symposium description

The propagation of finite amplitude waves has fascinated scientists for long time. The subject of non-linear waves is better established and has been studied in greater depth in fluids than in solids, probably because they are much more difficult to observe in the latter than in the former. John Scott Russell was able to observe the solitary water wave traveling on the Union Canal in Edinburgh, just by jumping on his horse but, for example, seismic waves travel typically at several kilometers per second! Moreover, the amplitude of a motion in a solid is bounded by the elastic limit of the solid itself and for this reason the vast majority of scientific and technological applications in solid acoustics takes place in the context of linear wave propagation. Despite this situation nonlinear wave theories in elastic solids are beginning to attract more and more interest this is due because they score important successes in many fields of science and engineering. For example, ultrafast scanners provide a powerful tool for detecting shear wave propagation in biological soft tissues, the so called “dynamic non-linear elastic behavior” in earth materials has been observed in Geophysics investigation and many time dependent properties of meta-materials may be understood only in a nonlinear context.

The aim of the present mini symposia is to attract leading experts in nonlinear wave propagation in solids to list the theoretical advances in the field that are accompanying the development of new applications and technologies. We consider non-linear effects from different points of view. First of all we consider the possibility to approach the fully non-linear equations of motions, but we consider of interest the strong and fruitful approximation of small-amplitude motions superimposed on large strains or the approaches connected with the weakly non-linear theory of elasticity. In such a way we hope to attract a wide range of mathematical methods and modeling approaches, giving a broad overview of the topic of waves in nonlinear solids.

[Back to Mini-Symposia](#)

Home	Venue/Accommodation
Programme	Sponsors & Exhibitors
Abstract	Travel to Ireland
Registration	



Mini-Symposia 6-4 - Nonlinear Waves in Solids (Session 1)

📅 Thursday, July 7, 2022

🕒 4:15 PM - 6:15 PM

📍 Room 16

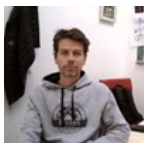
Speaker



Prof. Andrus Salupere
Professor
Tallinn University Of
Technology

- KEYNOTE - On the application of Haar wavelet based numerical methods for solving nonlinear wave equations

Abstract PDF 



Prof. Stefan Catheline
Professor
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Membrane waves, topological ray deviation and experimental model of gravitational lens effect

Abstract PDF 

Dr. Tanel Peets
Research Scientist
Tallinn University of
Technology

Mechanical waves in myelinated biomembrane

Abstract PDF 

Chair



Harold Benjamin
MSCA Postdoctoral
Fellow
NUI Galway

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Mini-Symposia 6-4 - Nonlinear Waves in Solids (Session 2)

📅 viernes, julio 8, 2022

🕒 10:15 - 12:15

📍 Room 16

Speaker

Mr Gianmarco Pinton

Associate Professor

Select Title

Shear shock wave injury in vivo: ultrasound imaging of local high rate biomechanics and neurofunctional response

Abstract PDF 



Prof. Juan Archilla

Professor

Universidad de Sevilla

Two dimensional breathers in the frequency-momenta representation

Abstract PDF 

Chair



Harold Benjamin

MSCA Postdoctoral Fellow

NUI Galway

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On the application of Haar wavelet based numerical methods for solving nonlinear wave equations

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Keywords: Haar wavelets, nonlinear wave equations, numerical methods

For the numerical solution of nonlinear wave equations, one has to approximate the partial derivatives with respect to time as well as space coordinates. Local or global methods can be used for this reason. The most typical example of local methods is the finite difference method. The discrete Fourier transform related pseudospectral method is a popular example of global methods. In the present paper application of another global method, the Haar wavelet method (HWM) [1], is discussed. According to the HWM, the highest order derivative included in the differential equations is expanded into the Haar series and the lower order derivatives are approximated making use of integration. Lepik developed the integration techniques for the HWM (see [1] and references therein)

We used the Korteweg–de Vries, the modified Korteweg–de Vries, the sine–Gordon, and the Burgers’ equations as model equations. In the classical case, application of the HWM means, that both, the spatial and the temporal partial derivatives are approximated making use of Haar wavelets. However, an approach where Haar wavelets are used only for approximation of spatial derivatives is used in the present contribution. For integration with respect of time variable, standard ODE solvers are used here. In order to improve the efficiency of the method the higher order HWM (HOHWM) is worked out in [2]. For further improvement of the efficiency of the method, the HOHWM should be used on static nonuniform as well as on adaptive grids [3]. Specific examples will be given during the presentation.

In conclusion. It appeared, that the adaptive HOHWM is a good tool for solving nonlinear PDEs having abrupt changes in the solution. The method allowed obtaining results of higher accuracy than the uniform or static nonuniform grid HOHWM. This significantly decreases the computational complexity needed to obtain results of a certain accuracy.

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Membrane waves, topological ray deviation and experimental model of gravitational lens effect

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Elastic membranes are often used as didactic demonstration of gravitation from the general relativity perspective. Indeed, trajectories of rolling spheres such as billiard balls influence each other through the deformation their mass print within the membrane tissue as would the space-time curvature of gravity. The analogy is pushed here using membrane waves. Indeed, rules of topology apply to masses and waves. We show through experiments and curved manifold simulations that wave propagation due to topological deviation of a two-dimensional flat fabric membrane, justifies classical analogy with gravitational lenses. This allows revisiting through membrane waves, the famous 1919 Eddington experiment that demonstrated light deviations of stars in the vicinity of the sun. It is our hope that the experiment described here will provide new insight for the testing of geometry effects on wave propagation. Also, inspired by acoustic metamaterials, it is our hope to use a more correctly constructed membrane to observe quantified exchanges of geometric waves with their elementary mesh.

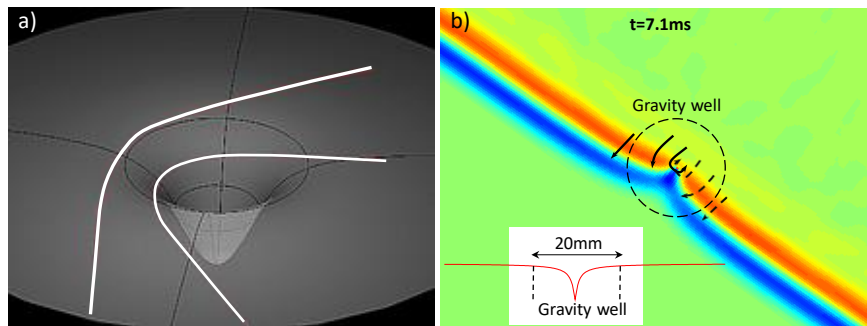


Figure : Near a massive object, deviation of light rays (left) and plane wave aberration (right).

Mechanical waves in myelinated biomembrane

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Keywords: nerve axon, dispersion, microstructured material

In cell biophysics, much attention is recently paid to the analysis of mechanical deformation of biomembranes. It has been shown by many experiments that an electrical nerve signal is accompanied by a mechanical wave. The exact role of the mechanical processes in nerve signalling is still an open question.

From the structural viewpoint, the biomembranes are built up by bilayers of phospholipids, which can be viewed as microstructured solid. In terms of continuum mechanics, such biomembranes could be compared with microstructured materials [1]. In unmyelinated biomembranes, the longitudinal mechanical waves are described by the improved Heimburg-Jackson (iHJ) equation [2, 3] involving amplitude-dependent nonlinearities and dispersive terms due to elasticity and inertia of the lipid structure (microstructure).

Most nerve axons in mammals are myelinated and in recent decade it has become clear that a myelin sheath plays a far greater role in nervous function than that of an insulation [4]. The structure of the myeline in simplified terms is composed of several bilayers glued together with proteins. For describing the longitudinal waves in the myelinated biomembrane, a novel mathematical model is proposed based on physical considerations and experience from continuum mechanics of microstructured materials with several scales [1]:

$$\begin{aligned} U_{TT} &= c_3^2 U_{XX} + NUU_{XX} + MU^2 U_{XX} + NU_X^2 + 2MUU_X^2 - \\ &\quad H_1 U_{XXX} + H_2 U_{XTT} - \mu_3 U_T + F_3(Z, J, P) + A_4 \Phi_X, \\ \Phi_{TT} &= A_1 \Phi_{XX} - A_2 \Phi - A_3 U_X. \end{aligned} \quad (1)$$

Here $U = \Delta\rho$ is the longitudinal density change, c_3 is the sound velocity in the unperturbed state, N, M are nonlinear coefficients, H_i are dispersion coefficients and μ_3 is the dissipation coefficient. The influence of the myeline sheath is modelled by field Φ and A_i are dimensionless parameters.

This model involves two wave operators: one describing the process in a single bilayer and another – the process in a structure with multiple layers. The dispersion analysis of this model demonstrates the role of higher-order dispersive terms that influence the phase and group velocities. The numerical analysis is carried out by using the pseudospectral method [5]. The physical effects involve the narrowing of a pulse and the possibility of emerging an oscillatory package of waves.

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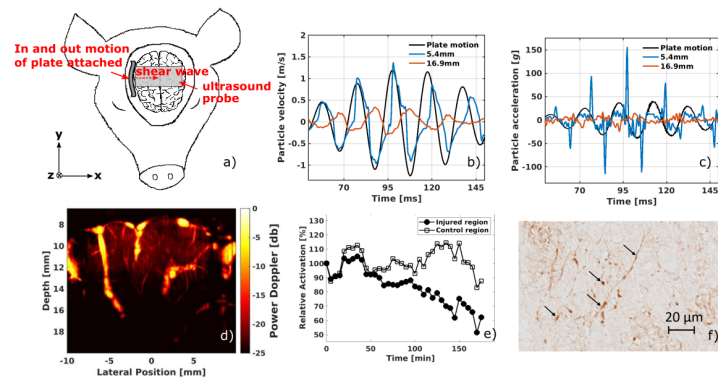
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Shear shock wave injury in vivo: ultrasound imaging of local high rate biomechanics and neurofunctional response

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Keywords: Shear shock waves, traumatic brain injury, ultrasound imaging

Using high frame-rate ultrasound and $< 1\mu\text{m}$ sensitive motion tracking we showed shear waves sent to the *ex vivo* brain developing into shear shock waves, with destructive local accelerations [1]. Here shear shock waves are propagated in the *in vivo* brain and the local biomechanics are imaged. Post injury, functional ultrasound imaging sequence were used to image the neurovascular response and functional connectivity matrix in the brain for four hours. This combined imaging approach provides a direct link between the local high-rate biomechanics and injury progression. Evidence is presented supporting the hypothesis that shear shock waves are responsible for deep traumatic brain injuries. A craniectomy was performed in the porcine head. A plate source was attached to the brain and vibrated using a 50Hz pulse at 39g by coupling to an electromechanical shaker. The moving brain was at 2900 images/s, using a custom imaging sequence with 8 interleaved wide beam emissions. Beamformed images were tracked for shear shock wave motion. Post impact, the brain was imaged using high frame-rate Doppler sequences (MS-250 probe, plane-wave compounding at 2000 images/s during 10 sec bursts every 1 min, for 180 mins). The Doppler spectrum was calculated from the beamformed RF data and power Doppler images were obtained at 7.5 images/s. Activation maps were calculated between the resting power Doppler and each power Doppler image as a function of time. Post euthansia, the brain was removed, fixed (10% formalin) and sectioned. Amyloid-beta precursor protein (bAPP) was used to stain the axonal pathology.



a) In vivo porcine brain set-up b-c) shear shock waves observed 5.4mm deep inside brain using a 39g excitation at 50Hz (blue plot). d) Power Doppler image post injury e) Increased activation in injured side of the brain f) Axonal injury detected on the injured side using histological analysis post-injury.

figuration. The average activation from the functional imaging showed a progressive 41% decrease in the injured side of the brain with respect to the control side, which remained stable. The bAPP staining showed axonal damage between 6 - 11 mm from the brain surface, consistent with the location of ultrasonic imaging of shear shock waves.

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[2] Tripathi et al., *J. Comput. Phys.* (2019)

Shear shock waves were observed in the porcine brain 5.4mm from the plate with a peak acceleration of 155g from a 39g impact. Computer simulations of this nonlinear wave propagation were performed using our custom solver [2] and a convincing match between the two was observed for this *in situ* con-

Two dimensional breathers in the frequency-momenta representation

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Keywords: moving breathers, hexagonal lattices, silicates

Discrete breathers are localized vibrations in nonlinear lattices that can be mobile. The observation of breathers in ω - q representation, especially in the moving frame, has revealed to be very useful [1]. It was refined considering the frequencies in the moving frame [2]. In systems with a substrate potential, the generic solution is a breather joined to a wing, that is, an extended wave that travels with the breather [2].

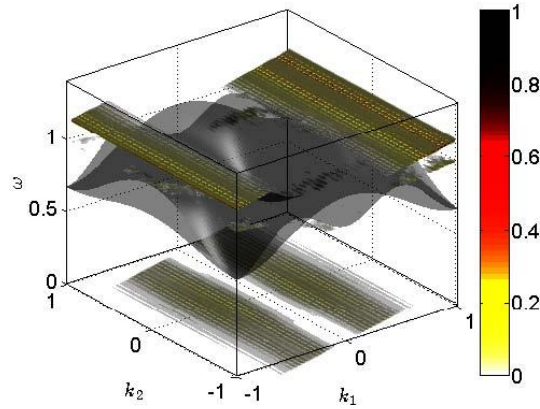


Fig. 1: The ω - q representation of a 2D breather coupled to a soliton travelling parallel to the k_1 -axis. It consists of two planes parallel to the k_2 -axis, that is, with $\partial\omega/\partial k_2=0$. Both planes cut the ω -axis at their frequency in the moving frame, equal to zero for the soliton and different from zero for the breather.

However, the theory had only been developed in one dimension. In this paper we extend it to two dimensions and apply it to a system that models the cation layer of silicates [3]. Breather lines transform in breather planes and it is revealed that breathers may have attached a soliton, depending on the initial conditions. References from the reference list must be cited in the text in square brackets, e.g. [1] for a single citation or [1, 3] for multiple citations. In the reference list, the font should be 10 point Times italic or Times New Roman italic.

Acknowledgments:

J.F.R. Archilla thanks Archilla thanks a travel grant from VIPPITUS-2020 and project MICINN PID2019-109175GB-C22. J. Bajars acknowledges support from PostDoc Latvia grant No.1.1.1.2/VIAA/4/20/617.

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