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ECCOMAS NEWSLETTER — APRIL 2019

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The European Community on Computational Methods in Applied Sciences entered the year of 2019 with a strong commitment to continue its wide-ranging activities of the past years. We shall further and by all available means engage in supporting the European computational science & engineering community by creating opportunities for exchanging novel ideas and promoting collaboration. Our mission is to support joint efforts in research and innovative industrial applications of European universities, research institutes and industry active in the broadly understood field of numerical methods and computer simulations in engineering and applied sciences. We shall continue to assist researchers and institutions to effectively address critical technological and social problems in the above broad field of science and modern technology with particular emphasis on multidisciplinary applications. To this aim we shall continue to organize large-scale congresses, actively support regional and thematic conferences, endorse smaller workshops, promote young investigator meetings and courses as well as encourage organization of open industrial days in different areas of our common interest.

The key main events of the current year are:

- **34 Thematic Conferences on a great variety of topics organized in many countries across the whole of Europe,**
- **the fifth ECCOMAS Young Investigators Conference (YIC 2019) in Krakow, Poland with the 9th PhD ECCOMAS Olympiad, followed at the same location by an ECCOMAS Special Interest Conference in the form of the joint Polish Congress of Mechanics/Computational Mechanics Conference,**
- **two ECCOMAS Advanced Courses:**
  - CISM-ECCOMAS International Summer School on "Coherent Structures in Unsteady Flows: Mathematical and Computational Methods", at the International Centre for Mechanical Sciences, Udine, Italy,
  - ECCOMAS Advanced Course on “Mathematical Theory of Finite Elements” at the Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland,
- **ECCOMAS PhD AWARDS 2018 to be selected at the end of April by the ECCOMAS PhD Award Committee in the form of the best two theses on computational methods in applied sciences and engineering.**

We should also remember that the main event organized by ECCOMAS has been the large European Congress on Computational Methods in Applied Sciences and Engineering taking place every four years. The previous most successful Congresses were held in Brussels, Belgium (1992), Paris, France (1996), Barcelona, Spain (2000), Jyvaskyla, Finland (2004), Venice, Italy (2008) in conjunction with the World Congress on Computational Mechanics of IACM, Vienna, Austria (2012) and Crete, Greece (2016). The next, VIII European Congress will be organized jointly with the 14th WCCM and it will be held in Paris, France on July 19-24, 2020.

As every organization aspiring to play an important role in an active and diversified community we face a number of challenges. As the most important among them I would consider establishing a stronger connection with the individual researchers in the ECCOMAS community. ECCOMAS is at present an “organization of organizations”. This setup makes perfect sense from a historical perspective, but it requires reconsideration in the context of present developments. Therefore, there is an on-going work on modifying the constitution underlying the ECCOMAS activities.

As always, we are looking forward to the exchange of ideas as to the ways we can best serve the European community of researchers and engineers in the key area of modern science and technology in which we all are professionally engaged. The needs of industry in this respect are enormous. I know it from hands-on experience in the area of science of materials in which I have long been active myself and which is one of the most promising and fast developing areas of modern technology. I have over years convincingly learned that the techniques of computer simulations are a key factor determining the pace of progress in this area. And we know that in other areas the situation is similar.

In the end I take the opportunity to wish all our member organizations and all the colleagues participating in the ECCOMAS activities every professional success in the current year of 2019!

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As the most reflective earth surface, the ice- and snow-covered areas play an important role in climate models. In particular, sea ice is the second largest boundary between the Earth’s surface and atmosphere and a key player in the global climate system. The accuracy of its predictive calculation is therefore of major interest. The seasonal cycle of sea ice is one of the most dynamic components, influenced by the action of winds, currents and temperature fluctuations. During their respective winter seasons, sea ice typically covers up to 15 million square kilometers of the Arctic Ocean, and up to 19 million square kilometers of the Southern Ocean. In contrast, the Greenland ice sheets and the Antarctic ice sheets respectively cover 1,7 and 14 million square kilometers only.

Unlike ice sheets, sea ice is formed from salty ocean water, with frazil crystals floating to the surface. This process is relatively slow compared to freezing processes in freshwater ice, because salt water sinks away from the cold surface before it is cold enough to freeze. However, with time and the roughness of the ocean, the frazil crystals accumulate and bond together into round pieces, called pancakes (see figure 1). The diameter of those circular disks varies from 30 centimetres to 3 meters. Due to the ocean waves, the pancakes bump into each other and form raised edges on their perimeter.

Collecting pancake ice samples was one of the primary objectives of the winter 2017 cruise of the S.A. Agulhas II, funded by DST/NRF that took place from 28 June to 13 July 2017. Together with Prof. Tim Ricken (Universität Stuttgart), we proposed to join the team on board to develop computational sea ice models. Among the other scientific teams on board, we supported to obtain ice cores from consolidated ice and large ice floes (see figure 4) to develop computational models based on observed and measured data to study and predict the break-up and fracture evolution of sea ice. The mechanical properties of the stored ice samples were analysed at UCT laboratories improving the understanding of the complex material behaviour of sea ice.

In the large-scale physical sea ice models, the sea ice concentration and the sea ice thickness are the main parameters describing the sea ice cover. Together with the velocity, since sea ice is almost continuously in motion, these are the usual unknowns of the numerical model, where the motion of sea ice results from the momentum balance with four external forces $f$ and the internal stresses $\sigma$. The primary force responsible for ice motion is the wind that blows on the top surface. Typically in the opposite direction, the ocean current force acts as a drag. Since ocean currents and winds occur at a global scale, neither the Coriolis force nor the so-called sea surface tilt, the force resulting from differences in surface level, can be neglected.

The fifth force affecting the ice motion is the one resulting from the internal stresses. Observing sea ice when it is pushed together by converging winds or currents, for instance against a coast, one notes that sea will be staked and

Figure 1. Pancake ice
therefore is modelled as a compressible fluid. However, this holds only up to a certain limit after which sea ice will deform and then eventually break apart. Therefore, sea ice is following a nonlinear viscous-plastic constitutive law.

This constitutive law, together with the momentum balance, can be considered in the context of the finite element method. This, however, leads to a strong nonlinear system of equations, and modern finite element techniques including modified Newton solver and multiscale methods are required. Despite the success of those techniques in other fields, their use in current sea ice models is very limited. Only recently, the analytical Jacobian matrix corresponding to a standard finite element formulation was presented in [1]. It is proven to be positive definite in such way that the global convergence of a damped Newton iteration is guaranteed. This finite-element formulation seeks the velocity, ice strength and ice thickness in the standard conforming finite element spaces.

The crucial internal stresses can be computed in a post-processing. They are contained in the Hilbert-Space of square-integrable functions \( L^2 \). This means that their normal component, and thus the surface traction forces, cannot be evaluated. Since the force resulting from the internal stresses is the most variable force affecting the ice motion, this leads to an unfortunate lack of accuracy, see [2]. The appropriate space for the evaluation of normal components is the Hilbert space \( H(\text{div}) \), the space of vector-valued functions whose divergence is a square-integrable function. A finite-dimensional conforming space for this Hilbert-Space is the Raviart-Thomas finite element space, see [3]. In the lowest-order case, the Raviart-Thomas functions consist of vector-valued piecewise linear functions, with constant and continuous normal components on the facets of the elements. In this lowest-order case, there is therefore one degree of freedom on each facet. The next to lowest-order case considers piecewise linear normal components on each facet. Then, one additional degree of freedom for each component has to lie in the interior of the element in order to retain an optimal convergence order. In general, the normal components of the Raviart-Thomas functions of order \( k \) are piecewise polynomials of degree \( k \), giving \( k+1 \) degrees of freedom for each facet as illustrated in figure 2.

Fortunately, from a sufficiently accurate \( L^2 \) approximation of the internal stresses, it is possible to reconstruct internal stresses in \( H(\text{div}) \), in such a way on each element that the momentum balance is conserved. Besides the fact of improving the accuracy, the reconstruction is also useful for a posteriori error estimation. In fact the hypercircle theorem of Prager and Synge states that the difference between the stresses associated to the variational formulation and the reconstructed stresses leads to an upper bound for the error. Since this quantity is based on the information about the computational solution, it is called a posteriori error estimator. The upper bound is concerned with the efficiency of the estimator, and

\[ k + 1 \text{ degrees of freedom for } v_h \cdot n \text{ on each edge} \]

*Figure 2. Raviart-Thomas element*
it can be shown that this estimator is also reliable and that it can be computed locally. This means that the local contributions can be computed on each finite element and used as a refinement-indicator in the adaptive refinement strategy.

The modification of the hypercircle theorem from Prager and Synge for challenging problems including the sea ice dynamics to design an a posteriori error estimator is a topic of active research. The reconstruction of stress tensors in the Raviart-Thomas space conserving the angular momentum in a weakly way was discovered only recently (see [4,5]), and the extension to non-linear problems is still in its infancy (see [6]). Although the convergence of such a reconstruction-based adaptive finite element method is usually empirically observed to perform very well, the mathematical justification for the optimal convergence of the adaptive meshes generated by the algorithm is also challenging and not yet established for many problems.

An alternative approach to the stress-reconstruction consists in using variational principles involving a direct approximation of the internal stresses. Least-squares finite element methods are therefore an attractive class of methods therefore, due to their inherent a posteriori error indicator. The basic idea consists in minimizing the $L^2$ residuals in the first-order system of partial differential equations. In the case of sea ice dynamics, the internal stresses appear as a variable in the momentum balance, and their definition is kept as a second equation. This method combines the advantages of the mixed finite element methods with the production of a symmetric and positive definite discrete system.

Moreover, there is no compatibility condition between the finite element spaces needed, in such way that the conforming spaces for the displacements and the internal stresses of the sea ice can be chosen considering the best approximation properties only.

Moreover, once coercivity of the formulation is established the least-squares method allows for an immediate a posteriori error control by the computable residual of the least squares functional. Using a separate marking (see [7]) seems to be a promising approach for the optimal convergence of the least-squares functional associated to the sea ice dynamics. Moreover, in the least-squares methods, the error estimator is not restricted to the solution of the variational formulation, but can be used for any conforming approximation. In particular, it gives an additional indication about the difference between the reconstructed internal stresses mentioned previously and the true error.

Exploiting these strong connections between the different numerical stress approximations leads to encouraging results as shown in figure 3. Still, the current state of our research leaves many open questions that have to be answered by future work.

The collaboration between mathematicians and engineers as...
started aboard the SA Agulhas facing the difficult weather conditions (see figure 4) is thereby crucial and suggests that the accurate discretisation of the internal stresses of sea ice will reduce the discrepancy between the sea ice simulations and the satellite observations and improve the numerical simulation of climate models.

REFERENCES


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DESIGN CHALLENGES AND OPPORTUNITIES OF 3D PRINTING

ABSTRACT

In the future, the number and complexity of products made using additive manufacturing (AM) techniques will increase rapidly. The development of softwares and algorithms related to processes will eliminate extra intermediate steps between the product design and the end product, and will finally give us more intelligent way to manufacture these new products. More efficient 3D printing processes will enable the production of cheaper individual items and, furthermore, they will increase the demand for these high-quality tailored unrivalled solutions. The market potential is huge. However, at present the fundamentals of the area are only lightly studied and several key challenges concerning structural behavior and performance have to be solved before these techniques can be used in a widespread, cost-effective manner. Success in this task creates a basis for mathematical modeling and design, which will considerably accelerate the development time cycle of consumer products. With new computational methods becoming even more sophisticated and faster, the repeatability and reliability of the product design process will improve, enabling further production quality advances in the manufacturing industry. 3D printing assisted by Artificial Intelligence (AI) will become one of the major components of concept of ‘Industry 4.0’ approaching independently operating and even self-contained systems.

1 ADDITIVE MANUFACTURING CHANGE THE WORLD

Additive manufacturing also known as rapid prototyping or 3D printing is a rapidly evolving and expanding product manufacturing discipline, which will drastically change our understanding and thinking of industrial production in the future. 3D printing process can be applied for several materials, for example, plastics, metals, ceramics, graphite, graphene and concrete. The benefits of additive manufacturing are numerous: 3D printed objects can be easily produced wherever and whenever needed, and it is possible to make significant changes with respect to original blueprints during the process. Moreover, different materials will be more efficiently used and, for example, some of the traditional metal processing methods will be partly or wholly replaced by alternative additive manufacturing solutions. As methods and techniques evolve the production of tailored multi-material 3D printed objects will increase and new innovative structures will emerge. Additive manufacturing can also decrease the complexity of engineering solutions in final products because some of the traditionally required assembly constraints can be loosened, and optimally, the printed products are ready-to-use when the printing process is completed. One major game change when using 3D printing techniques is its possibility to tailor solutions uniquely and still produce products efficiently, a number of items in one run. One of the most significant challenges is the part quality. Available material combinations, inadequate dimensional tolerances, surface roughness, and other volumetric defects constrain the quality and eventually define the mechanical properties of the part, which are crucial for product functionality. The defects may be related to several stages at workflow: wrong product design, problems with deposition system, uneven cooling, poor parameter selection or scanning strategy etc. For example, the properties of parts produced by fused deposition modeling (FDM) method are often related to the
orientation of the printing trajectories (routes, see Fig. 1) defined in the slicing operation and the patterns chosen to infill objects.

The 3D technology itself is not new, but since the expiration of the key patents, low cost 3D printers have emerged in the daily use of small companies and individual hobbyists. Material extrusion based techniques are most commonly available and has become the most popular rapid prototyping techniques for plastic materials in the last decade. All 3D printing processes follow generally similar steps. Commonly, the object is designed with CAD (Computer Aided Design) software and imported to the slicer program in a stereo lithography (STL) format. The program cross-sections the model into individual thin layers of defined heights and converts all necessary information into the g-code that can be directly read by the 3D printer. Based on this control information the required tasks tailored to a specific 3D printing technique, machine and used material(s) are executed. As an example, in FDM process, the printer heats up a liquefier to the right temperature to melt the polymer filament, and begins extruding the material. Filaments are fed through the heated liquefier by two drive wheels and extruded through a nozzle onto the platform. After each layer is finished the build platform moves down (or nozzle moves up) by a specified layer height, and the process repeats for the next cross-sectioned layer until the object is completed, see Fig. 2. This article is a result of an ongoing cooperation between technology enterprises and Faculty of Information Technology, University of Jyväskylä. The projects ‘Opti3D’ and ‘Industry 4.0 - Additive Manufacturing Technologies’ are funded by Regional Council of Central Finland.

Figure 1: Trajectories of the bottom layer (top-left) and the top layer (top-right) of the two layer sample. Both layers were printed with 0.06 mm thickness. Magnification including both layers (bottom-left). The histogram of the total trajectory length printed in specific orientation (bottom-right). The sample was originally designed for the accuracy testing of the printer.

Figure 2: Ultimaker 3 Extended 3D printer producing statue (left). The statue is printed with black ABS (acrylonitrile butadiene styrene) and white water-soluble PVA (polyvinyl alcohol) is used as support material. Statue (original design grabcad.com/library/wolf-ring-1) after the support material has been dissolved (right).
2 STRUCTURAL PROPERTIES OF 3D PRINTED OBJECTS

The number of studies being conducted on additive manufacturing has increased progressively during last years. From reference [1], reader will find an excellent review of various themes related to these technologies. One major perspective has been the physical testing of tensile strength, fatigue and other characteristics of the final products. The effect of design of FDM build parameters on the properties of ABS filament parts was studied in [2] and [3]. The layer orientation was found to have significant effects on the tensile strength, modulus of rupture, and impact resistance in [2]. Congruent results were also achieved in [3] of the trajectory orientation effects on tensile and compressive strengths. The overlap of trajectories had also clear effect on tensile strength while bead width, model temperature, and color were insignificant factors. Anisotropic characteristics were observed and assumed to be caused by air gaps between trajectories and weak interlayer bonding and porosity in [2] and [3].

In [4], the tests and results along with statistical analyzes of the data clearly suggest that specimens with 0.2 mm layer thickness are stronger than specimens with 0.4 mm layer thickness, and that layer thickness and trajectory orientation both have a significant effect on the mechanical properties of material. In [5], FDM was used to produce PLA (polylactic acid) filament specimens for mechanical properties testing. Trajectory orientation had only small effect on tensile strength and bending stress, while in fatigue testing, the 90 degrees specimens were clearly the least resistant to fatigue loadings. The study was continued using ABS filament in [6] with a conclusion that 0 degree orientation yield the highest mechanical properties and that the mechanical properties improves when number of layers increase. However, after 12 layers the effect of increasing more layers on the increase of the elastic modulus and maximum stress is only minor. In the article [7], Wendt et al. proposed that, in order to establish AM as a group of controlled and competitive processes for the production of loaded parts, it is the necessity to establish a complete methodology for the extraction of relevant mechanical properties from simple mechanical tests like the tensile test. In reference [8], the authors have also taken into account the flexural creep modulus of three AM polymeric materials made by SLS (selective laser sintering) and FDM. From the experimental results they concluded that the mechanical properties decrease with increasing temperature. More tensile test are reported e.g. in [9] and [10].

Compression has been considered
for example by Guessasma et al. in the study [11], where they considered that the nature of the arrangement of porosity and its orientation play a central role in either enforcing rapid damage growth or slowing down its extension. In the article [12] the compression test data indicates that the 45 degrees trajectory specimens are significantly weaker in compression than other trajectory orientations, and they distort prior to failure as a result of shearing along the trajectory axes. Moreover, tension tests indicate that the ultimate and yield strengths are the largest for the 0 degrees trajectory orientation, followed by the +45/-45, 45, and 90 orientations in descending order. The Taguchi method was used in the case of experimental catapult design in order to achieve optimum elastic performance of a compliant ABS prototype in the article [13]. The measurements of compressive strength in [14] showed that parts created by three different techniques, FDM, 3D printer and NCDS (nano composite deposition system), have anisotropic characteristics. From the compression test, it was confirmed that the "build" direction was an important process parameter that affects the mechanical properties. In addition, it was found that parts created with a 3D printer had low compressive strength compared to other processes, and that FDM parts had high compressive strength.

In the study [15], a functional relationship between the process parameters and strength (tensile, flexural and impact) were determined using response surface methodology. As a result authors found that if the number of layers is larger, it will result high temperature gradient towards the bottom of the part. Moreover, an increase in the number of layers also rises the number of heating and cooling cycles and thus residual stress accumulation increases. The authors continued their studies in the article [16] where they concluded that the reason for low strength is also due to anisotropy, caused by the polymer molecules aligning themselves with the direction of flow when they are extruded through the head nozzle. They used artificial neural networks (ANN) in this case and finally found the optimal parameter setting through Quantum-behaved Particle Swarm Optimization (QPSO).

In the study [17], the production cost was analyzed, and it was concluded that the cost depends on the production time and support material (see Fig. 2). The authors noticed that by selecting an optimal part orientation in FDM process, it is possible to shorten the production time and reduce material consumption. If strength is of primary concern and the demand is to manufacture stronger parts, then the position of the parts must be designed to carry tensile loads along trajectories.

Internal stresses arising during 3D printing process are closely related to the previously mentioned parameters and strength properties. During the last decade studies related to the internal stresses in 3D printed objects have been performed; see for example [18] and [19].

3 Full Potential Of 3D Printing Available By Computational Methods

Recently more attention has been drawn to the mathematical modeling and computing of properties related to final products. In the study [20], a mathematical model for predicting the tensile elastic properties of fiber reinforced 3D printed components is presented. The procedure is straightforward. At first,

Figure 4: Magnifications (x1000) of the 3D print in Fig. 3: a single hole (left) and the oriented pattern (right) from the test plate. The black paper is used as background.
micromechanical models are used to determine the effective properties of the FDM printed components. Second, a coordinate system transformation is applied to the solid and infill layers. Finally, volume averaging of the stiffness matrices of each of the crosssectional regions is performed. In [21] a finite element analysis related to the part distortions was performed. It was concluded that the printing speed and the layer thickness are the most important factors affecting the part distortion. Modeling of residual stresses in the case of laser assisted additive manufacturing was considered in [22]. It was shown that the residual stresses can be decreased by reducing the layer thickness. Residual stress build-up in metal based additive manufacturing was also considered in [23] via finite element modeling. It was concluded that the bed pre-heating temperature has the largest quantitative impact on the residual stress. Temperature gradients during selective laser melting (SLM) were simulated in [24]. It was found that the highest temperature gradients exist at the start of the first track scan. Simulations related to the residual stress in SLM was also performed in [25]. The effect of process parameters such as laser power, scan speed and scan strategy were investigated. The results suggested that the stress gradually increases during the SLM process due the heat accumulation effect.

Only few examples about modeling and simulation related to the additive manufacturing are given above; more information can be found, for example, from the reference [26]. During the last years the publication rate of these studies have increased enormously. Challenges are related, for example, to phase-changing and different scales and knowledge of material behaviour due to melting. The enlargement of the additive manufacturing and increased computing power will inevitably lead to expand the ‘traditional’ modeling and simulation approaches to more sophisticated method including online measurements and optimization assisted by Artificial Intelligence. With these computational tools the real power of additive manufacturing can be obtained.

4 Demonstration of Few Advanced Methods In The Context Of Design Science

The additive manufacturing technology is at the intersection of mechanics, materials and computational science. A close interaction between different approaches is needed to produce high precision and performance products as well as intelligent systems without need of human intervention.

The imperfections arising during AM process can be studied by transmitting light when object is printed using material behaving as dielectric in the visible region. Fig. 3 presents the transmittance of printed samples produced using layout of Fig. 1 and co-polyester and polycarbonate as filament materials. Lowered transmission in some parts of the trajectory interfaces makes them visible. This is caused by light scattering at irregularities, such as air gaps between adjacent trajectories (see Fig. 4). By introducing polarizing elements on transmission measurement, the internal stress state is revealed based on photoelastic phenomenon.
Many transparent noncrystalline materials become optically anisotropic when internal stresses exist. The components of the light wave that are parallel and perpendicular to the direction of the stress propagate through the plastic at different speeds inducing retardation between the two components. This retardation is proportional to internal principal stresses according to the stress-optic law

\[ \Delta \sigma = t \Delta \sigma \]

(1)

where \( \Delta \sigma \) is the retardation, \( t \) is the thickness, \( C_B \) is the stress-optical constant of material in Brewsters and \( \sigma_1 \) and \( \sigma_2 \) are the stresses in the principal directions. When monochromatic light is used, the dark and light fringes appears, whereas with white light illumination colored fringes are observed. The qualitative analysis of white light experiment can be done using The Michel-Levy chart. The Stokes or Jones calculus are used for quantitative modeling. The spectral imaging improves the possibilities to extent the photoelastic techniques to stress analysis of 3D printed objects. A schematically simulated stress field with layer-wise optimized trajectories with in-plane topology of sample (Fig. 3) is presented in Fig. 5. Localized stress concentrations caused e.g. by mechanical loading, non-uniform temperature, inadequate or non-uniform annealing and sharp corners or protrusions can be analyzed by simulations and measurements and they can be used also for quality control during production.

5 Conclusion

Despite the fact that additive manufacturing is a recent production method, a great amount of experimental and modeling work has been already performed. However, as an immature technology there are substantial challenges to be overcome; only few important questions are studied more closely. A more extensive view is required to optimize both the printing process and properties of the printed object. Moreover, as a component of 'Industry 4.0' the 3D printing should be able to operate as a solid part with cyber-physical systems, internet of things, smart factory and internet of services. It is clear that many advances can be achieved in a near future with Artificial Intelligence. Nevertheless, the development of 3D printing requires a great amount of computational tools before changing the world once and for all.

References


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ELASTIC METAMATERIALS FOR VIBRATION CONTROL

INTRODUCTION

Metamaterials are artificial materials which show peculiar properties, barely found in natural material. The quest for exceptional performances is a longstanding task in the field of electromagnetism, with focus on negative refraction index, electromagnetic bandgap, tunability. A special case of electromagnetic metamaterial is represented by photonic crystals [1]: they are artificial periodic structure, possibly composed of different materials, whose peculiar bandgap features depend on the unit cell geometry more than the specific features of the constituents. More recently, the class of metamaterials has been extended to the field of mechanics, with the introduction of phononic crystals [2]. The earlier research activities were focused on the achievement of special features in elastic wave propagation through the mismatch between impedance of different materials [3] or the presence of locally resonant mechanisms [4]. In most cases, elastic metamaterials are represented by periodic media whose elastic dispersion plot exhibits bandgaps, i.e. bounded frequency regions in which the propagation of elastic waves is inhibited. In fact, in those regions the solution of the dispersion equations yields wave vectors with an imaginary part, that means that only evanescent waves are admitted. The central frequency and the size of the bandgap basically depend on the employed materials and on the shape of the unit cell.

The field of elastic metamaterials is steadily increasing, in view of possible applications in different ambiats, at different scales. At the microscale, the control of elastic waves can be used for the realization of elastic mirrors, in order to create resonant cavities or to minimize the energy loss due to the radiation of elastic waves in the support. Moreover, it is possible to create elastic waveguides, acoustic superlenses and wave concentrators for the purpose of energy harvesting. Obviously, in spite of the subwavelength properties of metamaterials, the central frequency of the bandgap is strictly connected to the size of the unit cell. As a consequence, the application at the microscale is typically referred to the MHz range; on the contrary, if the unit cell size is in the order of centimeters, the frequency range is shifted towards hundreds of hertz. Several applications can be envisaged in that case, too: attenuation of machine vibrations, noise suppression, acoustic cloaking. Finally, elastic metamaterials are currently proposed for shielding against seismic waves: in view of the extremely low frequency of seismic waves (a few hertz, typically), seismic metamaterials should be represented by large scale periodic structures, for example a periodic arrangement of drilled piers in the ground which surrounds the structure to be protected. A review of the above mentioned applications can be found in [5].

The present paper deals with elastic metamaterials composed of a single material (i.e. solid-void metamaterials). Consequently, the suitable design of the unit cell plays a paramount role in the definition of the dispersion properties. For any application, it is highly desirable to optimize the shape of the hole in the PnC unit cell in order to obtain the largest full 3D bandgap, with ultra-subwavelength property. In the next sections, some research results are described with reference to that scientific target. More precisely, the description starts from the application of shape optimization procedures to the case of slab-like metamaterials. Subsequently, the extension to 3D structure is introduced, with reference to experimental evidences explained by means of a simple mechanical model. Finally, the possible achievement of tunable bandgap via the coupling with auxetic behavior is described.

SHAPE OPTIMIZATION OF SLAB-LIKE METAMATERIALS

The dispersion plot of a periodic media is obtained by considering the wave vectors in the first zone of the reciprocal lattice: in the case of
in-plane propagation for a slab-like metamaterial, such a zone is represented in Figure 1 with reference to a square-symmetric unit cell. The so-called Irreducible Brillouin Zone (IBZ) is the green triangle: the wave vectors contained in the IBZ are representative of all the possible vectors in the reciprocal space. The dispersion plot is referred to the wave vectors on the perimeter of the IBZ: it is common practice to assume that such a subset of wave vectors could provide all the relevant information for bandgaps, even though there is no formal proof. The dispersion plot can be computed by means of several techniques, among which the most versatile is the Finite Element Method: a set of eigenvalue problems is solved for the discretized unit cell, provided that the suitable Bloch-Floquet periodicity conditions are implemented. Figure 1 shows the dispersion plot for the simplest case of solid-void metamaterial, namely a slab, whose thickness is \( t = 0.5 \alpha \), with a periodic array of circular holes, radius \( R = 0.4 \alpha \). The blue lines are referred to 2D waves, which involve the in-plane displacements only. It is worth noting the presence of a bandgap, identified by the red dotted lines. When 3D waves are considered, i.e. in-plane propagation of waves which involve the out-of-plane displacement as well, the yellow lines are introduced and no bandgap is obtained. In other words, membrane waves are stopped in a certain frequency region, whereas bending waves of any frequency are transmitted through the periodic media.

In order to improve the performances of slab-like metamaterials, a shape optimization technique is applied: the optimal geometry of the unit cell is sought in order to maximize the width of the 3D bandgap, in the presence of a stiffness constraint. The objective function is given by the relative bandgap width, i.e. the ratio of the frequency range and the central frequency of the bandgap. A simple optimization procedure, based on the Bidirectional Evolutionary Structural Optimization (BESO), is proposed in [6] and [7]. The optimal shape is obtained at the end of an iterative process, adding or removing solid elements on the basis of the sensitivity of the objective function. The procedure is simple yet effective: it produces an optimal shape in a few iterations, with excellent performances with respect to other optimization strategies. As an example, Figure 2 shows the optimal shape that is achieved if the bandgap between eigenvalues number 12 and 13 is considered. The final shape is
basically represented by quasi-circular discs connected by thin ligaments. The relative bandgap width is 60%, which is very large if compared to other slab-like metamaterials proposed in the literature (a thorough comparison is reported in [7]). Moreover, the bandgap width can be increased to more than 70% by slightly changing the out-of-plane thickness of the slab. Indeed, if one considers different values of the ratio between the thickness and the size of the unit cell, a non-monotonic trend of the bandgap is observed, with a maximum around $t/a = 0.583$.

**3D Elastic Metamaterials: Design and Experiments**

The encouraging results obtained for slab-like metamaterials represent the spur to make something similar for three-dimensional structures. To that purpose, a 3D unit cell is designed according to the optimal shape described in Figure 2: instead of discs connected by ligaments in two directions, the unit cell is composed of spheres connected by three orthogonal ligaments [8], as shown in Figure 3 (the figure contains also the IBZ for such a 3D artificial crystal with cubic symmetry). If the unit cell side length is $a$, the radius of the spheres is $R = 0.33 \ a$ and the width of the ligaments (square cross-section) is $w = 0.1 \ a$. The dispersion diagram, see Figure 4, shows the bandgap relative width equal to 132.2%: the good performances of the slab-like metamaterials are thus amplified for the three-dimensional counterpart. With the purpose of achieving a final confirmation of the wave filtering behavior, a set of experimental tests is carried out on a prototype composed of 3x4x4 cells, with unit size equal to 5 cm. The geometric complexity of the metamaterial is not a problem for modern additive manufacturing techniques. As shown in [8], a very accurate prototype is obtained via selective laser sintering of nylon material. The experiments are carried out with the prototype based on a bubble wrap layer, in order to provide a suitable decoupling with respect to the substrate. Then, a harmonic elastic wave is introduced on one face of the prototype by means of an inertial actuator, in the range 0.5-20 kHz; the output is measured on the opposite face by means of a piezoelectric accelerometer. A transmission diagram is obtained, in terms of the ratio between the output and the input accelerations. The experiments confirm a sudden drop of the transmission around 3.9 kHz and a significant attenuation (-80 dB) until the end of the investigated frequency range. The presence of an ultrawide bandgap is confirmed, with nice agreement with the numerical predictions. It is worth noting that the accurate modelling of the experiments should take into account the viscoelastic behavior of nylon: the Standard Linear Solid model is sufficient to obtain a satisfactory description of the frequency-dependent response of the nylon prototype.

**3D Elastic Metamaterials: Interpretative Model**

The investigation of the outstanding performances of the proposed metamaterial starts from the study of the wave transmission modes which correspond to the opening and the closing of the bandgap. The opening happens in the symmetry point R, which means that the wave vector has three equal components and that the motion is characterized by a phase change equal to $\pm \pi$.
between one cell and the contiguous ones. The mode shape, shown in Figure 4, is characterized by the quasi-rigid translation of the spheres, with axial deformation of the ligaments. Such a mode is a “global” one, in the sense that it involves a huge portion of the mass. As a consequence, the frequency is low and the bandgap opens subwavelength. On the other hand, in the closing mode (which corresponds to the X symmetry point) the spheres are almost motionless and the displacement is localized in the ligaments, that present axial deformation, in one direction, and bending deformation, in the other two directions. Such a “local” mode is connected to a very small excited mass: as a matter of fact, the mass of the ligaments is less than 2% of the mass of the spheres. In view of the comparable stiffness, the local closing modes is endowed with a considerably larger frequency therefore the ultrawide bandgap is obtained. It is possible to say that the wave transmission is dominated by the mode separation between global and local modes.

The global mode can be easily interpreted by using a monoatomic spring-mass chain. The mass $M$ is equal to the mass of one sphere. Account taken of the size of the unit cell $a = 5$ cm and of the properties of nylon around the opening frequency (density $\rho = 930$ kg/m$^3$, Young’s modulus $E = 1750$ MPa), one finds:

$$M = \rho \left(\frac{4}{3}\pi R^3\right) = 17.5e-3 \text{ kg}$$

The stiffness is simply connected to the axial deformation of the ligaments, with cross-section $A = w^2$ and length $l = a - 2R$:

$$K = \frac{EA}{l} = 2573 \text{ N/mm}.$$ 

For a monoatomic spring-mass chain, the bandgap opens at the frequency:

$$f = \frac{(1/2\pi)^2}{(K/M)^{1/2}} = 3.862 \text{ kHz}.$$ 

Such a result is in excellent agreement with the experimental outcomes and with the numerical predictions.

The interpretative model, based on mode separation and mass-spring behavior for the opening mode, paves the way to the development of other elastic metamaterials, whose properties can be suitably established by defining the equivalent stiffness and the equivalent mass. As an example, it is possible to enhance the subwavelength properties by reducing the opening frequency, that can be obtained through the increase of the mass or the reduction of the stiffness. The latter option is considered in [9], where a new metamaterial is proposed, with ligaments that behave like a frame instead of an axial connection (see Figure 5). The bending stiffness of the frame is by far smaller than the axial stiffness of the metamaterial in Figure 3, so that a significant reduction of the opening frequency
is expected. Indeed, as shown also experimentally, the opening frequency for a unit cell of 5 cm is more or less one half with respect to the previous case. Moreover, the new metamaterial shows two additional features, strictly connected to the mode separation. First, the attenuation in the bandgap region attains a theoretical value of -250 dB: the experiments cannot reproduce such a behavior in view of the instrumental resolution, that leads to a lower bound of appreciable attenuation at -80 dB. Second, the closing mode of the bandgap, that should be located in the brown frame, is so much localized that cannot be excited by the actuator: the two subsequent bandgaps are “fused” together and a flat response is obtained in the laboratory. The behavior of a low-pass mechanical filter is approached.

The investigation of elastic metamaterial is leveraged for implementing a mechanically tunable filter for elastic waves. The idea is to replace the elastic ligaments by means of suitably designed springs, in order to realize an auxetic mechanism (see Figure 6 [10]). Two typical features of metamaterials, i.e. bandgap and auxetic behavior, are joined. As shown in Figure 6, the masses are now represented by ellipsoidal shapes and a set of folded springs is introduced as elastic ligaments. The static analyses of the unit cells confirm a negative apparent Poisson’s ratio almost equal to -0.6. The bandgap features are investigated for increasing values of applied displacement, using both the analytical tool described in the previous section and the Finite Element Method. The analyses indicate that the bandgap width is steadily increased as the applied displacement increase: a mechanical tuning of the wave filter is achieved. Such a peculiar behavior has been proven experimentally, as shown in Figure 7. The prototype is again realized via selective laser sintering and the unit cell size is 5 cm. The experimental setup is similar to the previously described cases, with the addition of a transverse static load, that introduces the auxetic deformation as shown in Figure 6. The transmission diagram is measured for the undeformed state and for two deformed configurations, with unit elongation equal to 0.47% and 0.93%, for conf. 1 and conf. 2, respectively. By considering, conventionally, that bandgap opens and closes when the attenuation is -40dB (red dashed line in Figure 7), one finds that the bandgap is enlarged of 3.1% and 6.2% for the two deformed configurations. The bandgap tuning is confirmed numerically, via the application of a visco-elastic model for nylon.

**CONCLUSIONS**

The paper deals with the mechanical features of periodic elastic structures, that are applied in the field of elastic wave filtering and guiding. A strategy is presented with the purpose of enhancing the performances in terms of bandgap width, position in the frequency spectrum and tunability, finally achieving full control of three-dimensional elastic wave propagation through the periodic media. The strategy builds on specific insights about the wave propagation in elastic metamaterials. It relies on analytical and numerical predictions and its effectiveness is experimentally confirmed. This paves the way for the development of a new class of periodic structures, endowed with robust and reliable wave attenuation over a wide frequency band.
BIBLIOGRAPHY


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The *Sociedad Española de Matemática Aplicada*, SeMA, was created in 1991, following the success and continuity of the Spanish Congresses of Differential Equations and their Applications (CEDYA) that began in 1978. It was legally founded on February 25th, 1993, but there are documents reporting a meeting in 1988 of a set of about twenty mathematicians, representing most of the Spanish research groups in Applied Mathematics that, led by Prof. Antonio Valle, decided that the XI edition of CEDYA, to be held in Málaga in 1989, would also be entitled “First Congress of Applied Mathematics” (I CMA). It was later, during the celebration of the XII CEDYA–II CMA at the Universidad de Oviedo in 1991, when more than a hundred mathematicians supported, by registering as members, the creation of SeMA as a society aiming to integrate researchers interested in Applied Mathematics living or working in Spain.

The mission envisioned for SeMA in its early years was to contribute in a coordinated manner to the development of mathematics in connection with its applications and the need to solve real world problems in science and industry. The underlying motivation was the quantitative deep change occurred in the preceding decade in the application of the mathematical techniques and methodologies, due to the rapid development of scientific computing as a new emerging field. Today the activity of SEMA is based upon the consideration that mathematical modeling, analysis, numerical simulation and control techniques are essential tools to understand and solve many challenging problems appearing in physics, chemistry, engineering, biomedical sciences, geosciences, economy or finance, among others.

Nowadays the society has 494 individual members, some of them living or working across the Spanish borders, and 47 Institutional ones. Its Executive Council is composed by eleven members: the President, a Vice-President, the Secretary General, the Treasurer and 7 members elected for a period of 3 years and renewable for a second term. The President is elected for a period of two years, renewable for a second term. The Executive Council decides on all important matters concerning the society and meets at least once a year. The General Assembly of the society is open to all members of SeMA and meets once every year to approve the budget and discuss other matters.

SeMA holds cooperation agreements and reciprocity membership with many mathematical societies. In Spain, RSME - *Royal Spanish Society of Mathematics*, SCM - *Catalan Society of Mathematics*, SEIO - *Spanish Society of Statistics and Operational Research*, AMS and SIAM in the USA, SIMAI in Italy, SMAI in France and GAMM in Germany. In addition, SeMA is a corporate member of several international mathematical organizations, such as the European Mathematical Society (EMS), the *International Mathematical Union* (IMU, through the Spanish CEMAT, that is, the *Comité Español de Matemáticas*) and the *Centre International de Mathématiques Pures et Appliquées* (CIMPA).

We highlight the long standing relation of SeMA with the European Community on Computational Methods in Applied Sciences (ECCOMAS), and the active participation of SeMA members in its Technical Committees and activities. SeMA selects every year a candidate for the ECCOMAS Best Thesis Award in what has become a high-level, hard competition. The merits of the selected candidate are recognized in a special conference in one of the special meetings of the society.

SeMA is also a full member of the *International Council for Industrial and Applied Mathematics* (ICIAM), a worldwide organization for professional applied mathematics societies, and for other societies with a significant interest in industrial or applied mathematics.
The ICIAM Council sponsors the International Congresses on Industrial and Applied Mathematics, held every four years, which have become reference international congresses in the field of applied mathematics. At the 2013 meeting of the Board of ICIAM, SEMA won the bid to organize the ICIAM 2019 congress, setting a milestone in the history of our relatively young society. The organization of ICIAM 2019, which will be held on July 15–19, 2019 in Valencia (Spain) https://iciam2019.org, represents a true challenge for SeMA, as well as a recognition of the strength of the applied mathematics community in Spain. A special mention also goes to the collaboration between SEMA, SIMAI, SMAI and SBMAC, who presently fund the Lagrange Prize, created on the initiative of the first three societies and first awarded in the ICIAM 1999 congress. The prize, which is awarded at the opening ceremony of the ICIAM congresses, was established to provide international recognition to individual mathematicians who have made an exceptional contribution to applied mathematics throughout their careers. The recipient of the 2019 Lagrange prize is G. Papanicolaou ‘for his brilliant use of mathematics to solve important problems in science and engineering; in particular, problems involving inhomogeneity, wave propagation, random media, diffusion, scattering, focusing, imaging, and finance’.

There are two special scientific events in our society. The CEDYA/CMA congresses, held every two years, have consolidated themselves as a focal meeting point for applied mathematicians in Spain. The week-long meetings include plenary talks by international experts, special minisymposia, contributed lectures and poster sessions. The latest edition, http://www.cedya2017.org, was held in Cartagena in 2017. On alternate years, and in collaboration with the French SMAI, the society sponsors the Spanish-French Jacques Louis Lions schools for graduate students. These schools are addressed to young researchers, specially pre and post-doctoral applied mathematicians and engineers, as well as to industrial technicians interested in learning state of the art numerical simulation techniques that may be useful in their field. The latest school was held in Las Palmas de Gran Canaria.

In addition, the society has strived to consolidate its scientific publications. The scientific part of the Boletín de la Sociedad Española de Matemática Aplicada, has become a peer-reviewed international scientific journal: the SeMA Journal, published by Springer since 2010. It contains articles and review papers written in English on high-level achievements in applied mathematics, covering theoretical as well as numerical results and also their practical applications. In order to promote the publication of high-quality scientific papers and reviews in Applied Mathematics, SeMA sponsors yearly the SeMA Journal Best Paper Award.

The cooperation SEMA-SIMAI Springer Series of advanced textbooks and research monographs deserves special mention. Launched in 2013, the series enjoys a very successful acceptance in the international Applied Mathematics community, and its impact is well above average. There are 18 volumes already published, and a few more are in production or waiting for final approval. Modeling and simulation are very much appreciated in our series, as we understand that they must be at the core of the mission of Mathematics reaching out to society.

Our society also seeks to recognize the scientific contributions of young researchers by sponsoring the SeMA Prize to Young Researchers, established in 1998 and awarded annually to a young researcher under 34. This award was renamed the SeMA–Antonio Valle Prize to Young Researchers in 2013, in recognition of the efforts dedicated by Prof. Antonio Valle, first president of SeMA, to the promotion of young researchers in the field of Applied Mathematics.

SeMA has also a genuine concern for increasing outreach activities that show the impact that applied mathematics has nowadays in the development of modern societies. In recent times, and motivated by the need to bring ICIAM 2019 closer to the general public, SeMA has promoted a program of conferences designed for pre-university students, where state of the art achievements carried out by some of our members are described in an informal manner to a non-specialized public. These conferences have shown a great potential in terms of motivating STEM careers among young people that tend to see mathematics as an abstract subject which is far away from the real and complex problems of everyday life.

ROSA DONAT, PRESIDENT OF SEMA,
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The Greek Association of Computational Mechanics (GR.A.C.M.), an affiliated member organization of ECCOMAS, hosted its 9th International Congress on Computational Mechanics from the 4th to the 6th of June 2018. The Conference took place at the Cultural Center of Chania which is located at the center of the city of Chania of Crete, Greece. Chairman of the Conference was George Stavroulakis, former president of GR.A.C.M.

More than 150 researchers participated in the Conference specializing in a wide range of topics related to computational solid and fluid mechanics. 3 plenary talks were given by distinguished researchers in the fields of Structures (Torgeir Moan, of the Norwegian University of Science and Technology), Computational Structural Mechanics (Alessandro Reali, of the University of Pavia, and Biomechanics (Triantafyllos Stylianopoulos, of the University of Cyprus).

48 full papers were compiled in an electronic book published by the Technical University of Crete (TUC). The book of abstracts and the book of full-length papers are available at the repository of the University Library:


Large emphasis was given by the Association to attract young researchers in the field of Computational Mechanics which resulted in an increased percentage of participants under the age of 35. In the opening ceremony, the Young Investigator’s award, for the best Ph.D thesis of the year 2015, was conferred upon Dr. Georgios Vogiatzis for his research work on multiscale simulations of polymer-matrix nanocomposites.

The city of Chania, host city of the Conference, is one of the more picturesque places in Crete. It combines hospitality, unique culture and history, delicious cuisine, fresh products with the beautiful natural environment, which is an amazing puzzle of seaside, mountains and lakes. Thus, it provided a very friendly and comfortable place for the participants. The Congress Dinner was held beside the seaside of Koum-Kapi, where the participants tasted fine Cretan «mezedes» and plates.

For those interested in the activities of 9GRACM further information is available on the conference site http://9gracm.tuc.gr/.

On the 28th of February 2019 elections took place for the executive board of GR.A.C.M. for the period 2019-2021. Professor Konstantinos Spiliopoulos was elected as the new president of GR.A.C.M.

KONSTANTINOS V. SPILIOPoulos, NATIONAL TECHNICAL UNIVERSITY OF ATHENS

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In 2003, ECCOMAS initiated the successful experience of creating a series of Thematic Conferences (TC), to be held in the odd years. Among the first cohort of thematic conferences, some were already well-established events, adopting after 2003 the ECCOMAS TC label. Some others were created precisely in 2003 and therefore have the ECCOMAS TC label as birthmark. This is the case of the international conference in ADaptive MOdeling and Simulation. The ADMOS acronym was created by Prof. Nils-Erik Wiberg, from Chalmers University of Technology, at the origin of the idea and chairman of the two first editions (2003 and 2005).


The traditional topics of the conference pertain to the Verification and Validation paradigm. Thus, under the Verification label, we find techniques for discretization error assessment and adaptivity (Verification consists in answering the question “are we solving the equation right?” and, if the answer is no, put a remedy). On the other hand, the Validation part of the conference discusses the methodologies for assessing the modeling error, and hence calibrating and adaptively enriching the model (similarly, Validation consists in answering the question “are we solving the right equation?” and, if the answer is no, use a more sophisticated model).

The evolution of computational sciences led to extend the scope and explore the interactions of the original topics with some emerging disciplines. This is the case of high performance computing, reduced order models, data assimilation, advanced material modeling and machine learning. In order to include these techniques in the ADMOS
agenda, we invited renowned experts in these fields to deliver plenary talks and illustrate the feedback they expect from the ADMOS community. For example, with the plenary talks of Prof. Anthony Patera in Paris 2011 and Prof. Francisco Chinesta in Lisbon 2013 the reduced order model community found his place at ADMOS events. Later, the ETN AdMoRe organized a thematic session and a poster competition (see figure 1) in that field in Verbania 2017 and will repeat in ADMOS 2019. The ADMOS community enjoyed interesting discussions in a pleasant atmosphere, see figure 2.

The 2019 edition of ADMOS is going to be held in El Campello (Alicante, Spain), hosted by Prof. Juan José Ródenas and Prof. Enrique Nadal from Universitat Politècnica de València. The web site is already available at https://congress.cimne.com/admos2019, see figure 4.

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The International Congress for Industrial and Applied Mathematics (ICIAM) is a carefully prepared, worldwide event held every four years. The last ICIAM events have taken place in Vancouver (2011) and Beijing (2015). The number of attendees to these conferences has steadily increased, reaching 3500 registrations in the Beijing edition.

The Spanish Society of Applied Mathematics (SEMA) will organize the next ICIAM Congress, that will take place in Valencia from July 15th to 19th, 2019.

ICIAM is an international organization that brings together societies of applied and industrial mathematics worldwide, with the goal of working in a coordinated way for the advancement of Industrial and Applied Mathematics. Currently, the number of full members is 22, from all over the world, with 16 associated members. SEMA is a full member of ICIAM.

The SEMA candidacy to organize ICIAM-2019 had the support of many Applied Mathematics societies. In particular, it included all the applied mathematics societies in the Mediterranean area which are ICIAM members, and many societies in Latin America and northern and equatorial Africa. We were also fortunate to have the support of Dr. Alfio Quarteroni, who agreed to be the Chairman of the SPC (Scientific Committee Pannel). Last, but not least, His Majesty the King Felipe VI of Spain agreed to chair the Honour Committee of the conference, a fact of enormous importance for the social relevance of the event in the media.

The SPC appointed 27 plenary speakers, researchers of global excellence with a variety of gender, thematic and geographical origin. ICIAM2019-Valencia Congress will also host talks of the five ICIAM awards, so as the Olga Taussky-Todd and the Outreach Public lecturers. Further it will host SIAM and SEMA national congresses as embedded meetings (https://iciam2019.org). There is moreover a sub-venues program, in which the Spanish cities of Bilbao, Coruña, Málaga, Santiago de Compostela, Sevilla and Zaragoza will organize a program of satellite events. These events are a part of a global Satellite Events Programme, that includes more than 30 events.

ICIAM2019-Valencia Congress has developed a financial aid program for developing countries and young researchers, that will fund over 250 scholarships. Our main sponsor is Banco Santander. We have also implemented a crowd-funding programme (P2B) across Spanish organisms. In addition ICIAM society funds 20 scholarships for developing countries. In total 326 thematic minisymposia (including 2896 talks), 22 industrial minisymposia (including 152 talks), 981 contributed talks and 380 posters have been submitted.

Organizing ICIAM 2019 will certainly play an extremely dynamic role in the development of applied and industrial mathematics in Spain, generating a qualitative, and hopefully also quantitative, leap in its relations with industry, but also in the national assessment of Applied Mathematics, and the international liaison role of Spain between Europe, Latin America and Africa.

We have the unique opportunity to make ICIAM-2019-Valencia a great event of exceptional scientific quality. We invite all ECCOMAS members to join this thrilling journey across industrial and applied mathematics.

ICIAM2019-Valencia Chairman:
Tomás Chacón
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The International Association for Computational Mechanics (IACM) and the European Community on Computational Methods in Applied Sciences (ECCOMAS) are pleased to announce the joint organization of the 14th World Congress in Computational Mechanics (WCCM XIV) and 8th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2020).

This joint event is expected to be one of the largest computational mechanics and applied mathematics events ever organized with an expected participation from all parts of the globe, representing multiple sectors, academia, industry and government institutions.

Through the organization of minisymposia, it will both cover the latest developments in all aspects of computational mechanics, computational fluid dynamics and applied mathematics in conjunction with industrial needs as well as emerging ones. This congress shall fully engage computational mechanics in the XXI century.

The congress will take place at the “Palais des Congrès”, situated in Paris 17th district, Porte Maillot, a stone’s throw from the Champs-Elysées. The Palais des Congrès is a leading venue for conferences, trade shows, corporate events and shows.

The Palais des Congrès de Paris is one of the reasons why the capital is a world leader in hosting congresses. It is also a favourite place for lovers of the performing arts – musicals, symphony orchestras, international ballets and exceptional concerts take place within its walls. Issy-Les-Moulineaux and Versailles, our two other Palais des Congrès sites, offer rich and varied artistic programmes.

**Important Dates**

- Call for Minisymposia proposals: From December 14, 2018
- Deadline for Minisymposia proposals: May 15, 2019
- Notification of Minisymposia acceptance: June 2019

**Conference Chairman:**
Francisco Chinesta

**Conference Co-Chairmen:**
Rémi Abgrall, Olivier Allix, Michael Kaliske

website: www.wccm-eccomas2020.org
ECCOMAS 5th Young Investigators Conference 2019

ECCOMAS PhD Olympiad 2019

The 5th ECCOMAS Young Investigators Conference (YIC2019) will take place from September 1st through 6th, 2019 at AGH University of Science and Technology, Krakow, Poland. It aims to bring together young researchers working in the field of computational science and engineering. As in the previous conferences organized under the auspices of the European Community on Computational Methods in Applied Sciences (ECCOMAS), the focus is on the application of computational methods and modeling to different areas. The target group of the YIC2019 are young researchers, however senior scientists are welcome. ECCOMAS PhD Olympiad will take place during the Conference.

website: www.yic2019.agh.edu.pl
contact: yic2019@agh.edu.pl

ECCOMAS Young Investigators Conference

Open Call for 2021

The European Community on Computational Method in Applied Sciences (ECCOMAS) invites institutions from all over Europe to present proposals for the organization of the 6th Young Investigators Conference (YIC), to be held between April and September, 2021.

Previous Young Investigators Conferences took place at the University of Aveiro, Portugal, (2012), Bordeaux, France (2013), in Aachen, Germany (2015) and Milan, Italy (2017). In September 2019 the YIC takes place at the AGH University of Science and Technology, of Krakow, Poland. Since 2013 the Young Investigators Conferences are offered on a two-year interval in odd years in geographically varying areas. The conferences are organized and run by young investigators and supported by senior scientists. The target groups are PhD students in all stages of their PhD programs, postdocs and young researchers, under the age of 35.

In conjunction with the 6th Young Investigators Conference in 2021 the ECCOMAS PhD Olympiad 2021 has to be organized.

Institutions interested in organizing YIC 2021 are kindly requested to submit a proposal to the ECCOMAS Secretariat (eccomas@cimne.upc.edu) before MAY 15, 2019.
OBITUARY ERWIN STEIN (1931-2018)

With great sadness we have to announce that our highly esteemed colleague Erwin Stein, Professor emeritus of Structural Mechanics and Computational Mechanics at the Leibniz University in Hannover (Germany), passed away on December 19, 2018. Erwin has been one of the founding fathers of computational mechanics in Europe and he was a leader in our field. Among the many awards and distinctions that he received, is the Ritz-Galerkin Medal (2012), the highest distinction awarded by ECCOMAS. Erwin held great respect in the field of computational mechanics and he was a mentor and a dear friend to many in the ECCOMAS community.

Erwin Stein made profound contributions to the development of computational mechanics, notably to the theory of finite-element methods and their application in solid mechanics. His work has been characterized by a thorough and rigorous approach. From the earliest stages of his career Erwin actively pursued interactions with the applied mathematics community, which resulted in many fundamental contributions. Particularly notable in this respect are his seminal contributions to error estimation and adaptivity. His contributions to computational mechanics span more than half a century, and during this entire period Erwin acted in the vanguard of our field. His scientific legacy comprises more than three hundred scientific works and includes the Encyclopedia of Computational Mechanics, for which he served as one of the editors. Erwin Stein has also made a lasting impact in the field of computational mechanics as an advisor to several generations of doctoral students, many of whom have become full professors later in their careers.

Our community has lost an eminent colleague and many of us have lost a dear friend. Our thoughts are with Erwin’s family and loved ones. His scientific legacy will be remembered by generations to come.

OBITUARY JASON REESE (1967-2019)

It is with deep regret that we have to announce that our esteemed colleague Jason Reese, Regius Professor of Engineering and Royal-Academy-of-Engineering Chair in Emerging Technologies in the University of Edinburgh (UK), passed away on March 8, 2019. Prof. Reese was an authority in modeling, analysis and simulation of multiscale fluid systems. He received a great number of awards and distinctions, including fellowships of the Royal Society of Edinburgh and of the Royal Academy of Engineering. Jason was an active member of the ECCOMAS community, and as co-chair of last year’s ECCM-ECFD conference in Glasgow he was a driving thrust behind the conference’s success.

Jason Reese was a good friend to many in our community and he will be dearly missed. Our heartfelt sympathies go out to Jason’s family and loved ones.
# ECCOMAS Thematic Conferences 2019

<table>
<thead>
<tr>
<th>Acronym</th>
<th>ECCOMAS Thematic Conference</th>
<th>Location</th>
<th>Date</th>
</tr>
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<tbody>
<tr>
<td>KomPlas Tech</td>
<td>Conference on Computer Methods in Materials Technology</td>
<td>Zakopane, Poland</td>
<td>Jan 13 - 16</td>
</tr>
<tr>
<td>HONOM</td>
<td>European Workshop on High Order Nonlinear Numerical Methods for Evolutionnary PDEs: Theory and Applications</td>
<td>Madrid, Spain</td>
<td>Apr 1 - 5</td>
</tr>
<tr>
<td>SYMCOMP</td>
<td>International Conference on Numerical and Symbolic Computation: Developments and Applications</td>
<td>Porto, Portugal</td>
<td>Apr 11 - 12</td>
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<tr>
<td>MultiBioMe</td>
<td>Multiscale Problems in Biomechanics and Mechanobiology</td>
<td>Cargese, Corsica (France)</td>
<td>Apr 22 - 25</td>
</tr>
<tr>
<td>MARINE</td>
<td>VIII International Conference on Computational Methods in Marine Engineering</td>
<td>Gothenburg, Sweden</td>
<td>May 13 - 15</td>
</tr>
<tr>
<td>ADMOS</td>
<td>IX International Conference on Adaptive Modeling and Simulation</td>
<td>Campello (Alicante), Spain</td>
<td>May 27 - 29</td>
</tr>
<tr>
<td>IPM</td>
<td>5th International Conference on Inverse Problems in Mechanics of Structures and Materials</td>
<td>Rzeszow, Poland</td>
<td>May 22-24</td>
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<tr>
<td>COUPLED PROBLEMS</td>
<td>VIII International Conference on Coupled Problems in Science and Engineering</td>
<td>Barcelona, Spain</td>
<td>Jun 3 - 5</td>
</tr>
<tr>
<td>CFRAC</td>
<td>Sixth International Conference on Computational Modeling of Fracture and Failure of Materials and Structures</td>
<td>Brauschwei, Germany</td>
<td>Jun 12 - 14</td>
</tr>
<tr>
<td>CSAI</td>
<td>Computational Sciences and AI in Industry: the new digital technologies for solving future societal and economical challenges</td>
<td>Jyväskylä, Finland</td>
<td>Jun 12-14</td>
</tr>
<tr>
<td>COMPDYN</td>
<td>7th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering</td>
<td>Creta, Greece</td>
<td>June 24 - 26</td>
</tr>
<tr>
<td>UNCECOMP</td>
<td>International Conference on Uncertainty Quantification in Computational Sciences and Engineering</td>
<td>Creta, Greece</td>
<td>June 24 - 26</td>
</tr>
<tr>
<td>M-FET</td>
<td>2nd Modern Finite Element Technologies - Mathematical and Mechanical Aspects</td>
<td>Bad Honnef, Germany</td>
<td>Jul 1 - 3</td>
</tr>
<tr>
<td>ICCCM</td>
<td>International Conference on Computational Contact Mechanics</td>
<td>Hannover, Germany</td>
<td>Jul 3 - 5</td>
</tr>
<tr>
<td>X-DMS</td>
<td>eXtended Discretization MethodS</td>
<td>Lugano, Switzerland</td>
<td>Jul 3 - 5</td>
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<tr>
<td>SMART</td>
<td>8th Conference on Smart Structures and Materials</td>
<td>Paris, France</td>
<td>Jul 8 - 12</td>
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<tr>
<td>Acronym</td>
<td>ECCOMAS Thematic Conference</td>
<td>Location</td>
<td>Date</td>
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<tr>
<td>CMP4</td>
<td>Computational Modelling of Multi-Uncertainty and Multi-Scale Problems</td>
<td>Porto, Portugal</td>
<td>Jul 15-17</td>
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<tr>
<td>MULTIBODY</td>
<td>Multibody Dynamics</td>
<td>Duisburg, Germany</td>
<td>Jul 15-18</td>
</tr>
<tr>
<td>COMPLAS</td>
<td>XIV International Conference on Computational Plasticity</td>
<td>Barcelona, Spain</td>
<td>Sept 5-7</td>
</tr>
<tr>
<td>Sim-AM</td>
<td>II International Conference on Simulation for Additive Manufacturing</td>
<td>Pavia, Italy</td>
<td>Sept 11-13</td>
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<tr>
<td>EUROGEN</td>
<td>International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control with Applications to Industrial and Societal Problems</td>
<td>Guimarães, Portugal</td>
<td>Sept 12-14</td>
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<tr>
<td>MSF</td>
<td>4th International Conference on Computational Methods for Solids and Fluids</td>
<td>Sarajevo, Bosnia and Herzegovina</td>
<td>Sept 18-20</td>
</tr>
<tr>
<td>IGA</td>
<td>VII International Conference on Isogeometric Analysis</td>
<td>Munich, Germany</td>
<td>Sept 18-20</td>
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<tr>
<td>COMPOSITES</td>
<td>VII Conference on Mechanical Response of Composites</td>
<td>Girona, Spain</td>
<td>Sept 18-20</td>
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<tr>
<td>CMCS</td>
<td>Computational Modeling of Complex Materials Across the Scales</td>
<td>Glasgow, UK</td>
<td>Oct 1-4</td>
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<tr>
<td>CompCancer</td>
<td>Computational Simulation of Cancer: Molecular and Cellular Dynamics</td>
<td>Porto, Portugal</td>
<td>Oct 7-10</td>
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<tr>
<td>FORM &amp; FORCE</td>
<td>XI Internacional Conference on Textile Composites and Inflatable Structures and IASS SYMPOSIUM 2019</td>
<td>Barcelona, Spain</td>
<td>Oct 7-10</td>
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<tr>
<td>VipIMAGE</td>
<td>VII Conference on Computational Vision and Medical Image Processing</td>
<td>Porto, Portugal</td>
<td>Oct 16-18</td>
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<tr>
<td>CORASS</td>
<td>3th International Conference on Rehabilitation and Sustainability of Structures – Advanced structural models, materials and applications</td>
<td>Coimbra, Portugal</td>
<td>Oct 16-18</td>
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<tr>
<td>PARTICLES</td>
<td>VI International Conference on Particle-based Methods</td>
<td>Barcelona, Spain</td>
<td>Oct 28-30</td>
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<tr>
<td>ICBT</td>
<td>III International Conference on Biomedical Technology</td>
<td>Hannover, Germany</td>
<td>Nov 18-20</td>
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<tr>
<td>MORTech</td>
<td>5th International Workshop on Reduced Basis, POD and PGD Model Reduction Techniques</td>
<td>Paris, France</td>
<td>Nov 20-22</td>
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<tr>
<td>CM3</td>
<td>Digital Technologies in Transport</td>
<td>Barcelona, Spain</td>
<td>Nov 25-27</td>
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**Other ECCOMAS Conferences 2019**

| YIC | ECCOMAS Young Investigators Conference 2019 | Krakow, Poland | Sept 1-6 |