9th GRACM

International Congress on Computational Mechanics

4-6 June 2018, Chania

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Editors: Manolis Papadrakakis, National Technical University of Athens
Georgios E. Stavroulakis, Technical University of Crete

Book of Abstracts

ΕΚΔΟΣΕΙΣ ΠΟΛΥΤΕΧΝΕΙΟΥ ΚΡΗΤΗΣ

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Chania, Greece 2018

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PREFACE

The present electronic book is the book of abstracts submitted and presented at the 9th GRACM International Congress on Computational Mechanics, which was held at the Technical University of Crete, Chania, June 4-6, 2018. The congress was organized by the **Greek Association of Computational Mechanics** (GRACM) with the support of the **Institute of Computational Mechanics & Optimization** (CoMecO) of School of Production Engineering & Management of Technical University of Crete.

Three invited papers and 86 contributed papers have been presented at the conference and in the four minisymposia organized within it.

The Editors would like to thank all the authors of the papers for their active participation in the conference, the reviewers of the papers, the members of the Executive Council of GRACM who served as members of the Scientific Committee of the conference and the distinguished invited lecturers, who kindly accepted the invitation.

Thanks are also due to all the people who provided technical and secretarial support to the Congress, especially to Mrs. Maria Bakatsaki from the Technical University of Crete, as well as to the Technical University of Crete Press, which published the present book.

Chania, June 2018

The 9th GRACM Congress co-chairmen

- Manolis Papadrakakis, National Technical University of Athens, GRACM Chairman
- Georgios E. Stavroulakis, Technical University of Crete, GRACM Vice-Chairman

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MS1-Computational Analysis of Advanced Materials

Invited Speakers

DYNAMIC ACTION EFFECT ANALYSIS FOR STRUCTURAL INTEGRITY MANAGEMENT OF VERY LARGE FLOATING BRIDGES

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ABSTRACT

To improve the efficiency of transport systems across straits, bridges, submerged tunnels and subsea tunnels are introduced to replace ferries. For wide and especially deep straits, bridges are attractive. When in addition the strait is deep water, floating bridges or submerged tunnels are economical option. Designing a reliable and cost-effective floating bridge for a wide and deep fjord is very challenging. The floating bridge is subjected to permanent, traffic and environmental loads. The latter include wind, wave and current loads as well as possibly seismic loads. All these loads and load effects should be properly evaluated for ultimate limit state design check. In this paper a brief overview of relevant concepts are given, with a focus on floating bridges. In particular, the methods for modelling wind-, wave-, and current-induced load effect are described for an end-anchored curved floating bridge and briefly for a floating suspension bridge, which were early concepts for crossing the Bjørnafjord. The considered floating bridges are about 4600 m long. One concept consists of a cable-stayed high bridge part and a pontoon-supported low bridge part. The suspension bridge is supported by two pylons resting on floating bodies. They both have a number of eigen-modes, which might be excited by the environmental loads. Results are presented especially for the low bridge. The sway motion, axial force and strong axis bending moment of its bridge girder are mainly induced by lift, drag and moment wind loads, while the heave motion, weak axis bending moment and torsional moment are mainly induced by wave loads. Turbulent wind on the low bridge can cause significantly larger low-frequency eigen-mode resonant responses than the second-order difference frequency wave loads. Current loads mainly reduce the sway motion, axial force and strong axis bending moment.

PREDICTIVE MODELING TOWARDS PRECISION MEDICINE IN CANCER THERAPY: CHALLENGES AND PROMISE

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Keywords: tumor growth, cancer therapy, mathematical models, biomechanics, tumor biology.

ABSTRACT

A solid tumor is an aberrant tissue made of cancer cells and a variety of host cells, including cells of the immune system—all embedded in an extracellular matrix—nourished by blood vessels and drained by lymphatic vessels. Tumor progression and response to treatment is a complicated biological procedure involving many inter-related processes that occur at multiple spatio-temporal scales. In addition, tumor growth at the confined space of the surrounding host tissue, involves the generation of mechanical forces both within the tumor and between the tumor and the host tissue. These mechanical forces, coupled with aberrant tumor blood vessels, induce abnormal solid and fluid stresses that facilitate tumor progression and hinder response to various treatments. As a result, tumor progression cannot always be investigated by using only biological experiments and mathematical models can complement experimental/clinical data to improve cancer prognosis and treatment. Furthermore, tumor growth might differ significantly between different tumor types, among tumors of the same type, in the same tumor at different stages of growth and between the primary tumor and its metastases. Therefore, the use of precision medicine for patient specific therapy becomes imperative in many cases.

In my talk, I will present a finite elements-based computational framework for tumor growth and response to treatment taking into account components of the biological and biomechanical micro-environment of tumors. The model accounts for macroscopic tumor growth employing principles from continuum mechanics, which are coupled with a methodology to account for both tissue-level and cellular level events. Specifically, the model accounts for three different phenotypes of cancer cells—nonstem cancer cells (CCs), stem-cell like cancer cells (CSCs) (which are more resistant to drugs, hypoxia, and the immune system), and CCs that are induced by chemotherapy to acquire a more stem-like phenotype, which we refer to as treatment-induced cancer cells (ICCs), as well as immune cells [natural killer (NK) cells, CD8+ Tcells, and Tregs], the tumor vasculature, and their interactions (Fig. 1). The model also accounts for the delivery and cell killing potential of chemotherapy based on the dose and schedule, and for transformations among CCs, CSCs, and ICCs. Magnetic Resonance Imaging (MRI) can be also used along with 3D reconstruction software to derive patient specific geometries and thus, define the computational domain for the simulations. Results will be presented for the validation and the predictive capabilities of this modelling framework and limitations will be discussed.

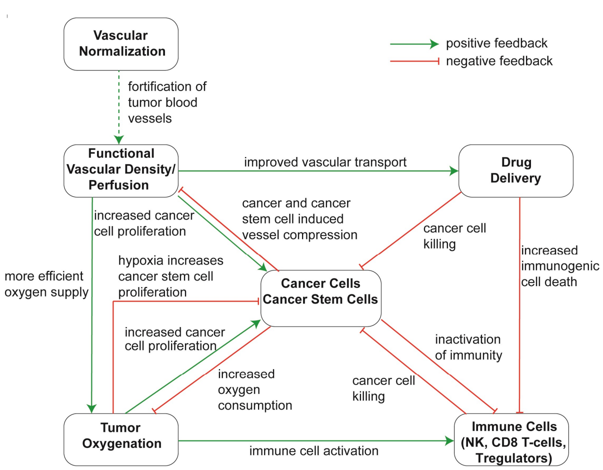

Figure 1. Schematic of interactions among model components. An increase in vascular density improves drug and oxygen delivery. Increases in drug levels result in more efficient killing of CCs, CSCs, and ICCs. Higher oxygen concentrations accelerate the proliferation rates of CCs and the activity of immune cells, whereas hypoxia favors CSC and ICC proliferation. An increase in immune response results in more efficient killing of all cancer cells. Increased proliferation of all cancer cell types leads to increased oxygen consumption, inactivation of immune cells, and decrease vessel diameters due to compression. Vascular normalization improves functionality of the vascular network, which enhances cancer cell proliferation, but increased drug delivery kills proliferating cancer and immune cells. (Mpekris F. et al., PNAS, 114(8):1994-1999, 2017).

ADVANCED MODELING AND APPLICATIONS OF ISOGEOMETRIC SHELLS

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Keywords: Isogeometric Analysis, Kirchhoff-Love shells, Composites, Fluid-Structure Interaction.

ABSTRACT

Isogeometric Analysis (IGA) is a recent simulation framework, originally proposed by Hughes et al. in 2005[1], to bridge the gap between Computational Mechanics and Computer Aided Design (CAD). The basic IGA paradigm consists of adopting the same basis functions used for geometry representations in CAD systems - such as, e.g., Non-Uniform Rational B-Splines (NURBS) - for the approximation of field variables, in an isoparametric fashion. This leads to a cost-saving simplification of the typically expensive mesh generation and refinement processes required by standard finite element analysis. In addition, thanks to the high-regularity properties of its basis functions, IGA has shown a better accuracy per-degree-of-freedom and an enhanced robustness with respect to standard finite elements in a number of applications ranging from solids and structures to fluids and fluid-structure interaction (FSI), opening also the door to geometrically flexible discretizations of higher-order partial differential equations in primal form, as well as to highly efficient (strong-form) collocation methods. In particular, this higher regularity gave "new life" to shell modeling and applications, making it possible to easily and efficiently implement (rotation-free) Kirchhoff-Love shells[2].

Within this context, this lecture focuses on some recent advances on modeling and applications of shell structures allowed by the unique IGA features. In particular, we herein focus on three interesting problems. The first one is related to an inexpensive modeling strategy for composites[3]. The proposed approach consists of an isogeometric discretization comprising a single element through the thickness and a post-processing technique able to recover an accurate out-of-plane stress state by direct integration of the equilibrium equations in strong form. We then present two novel isogeometric approaches for specific FSI problems. The first one exploits a boundary integral formulation of Stokes equations to model the surrounding flow and a nonlinear Kirchhoff-Love shell theory to model the elastic behavior of the structure[4]. The proposed method seems to be particularly attractive for the simulation of falling objects, since only the boundary representation (B-Rep) of the thin structure middle surface is needed to describe the entire studied problem. Finally, the goal of the last considered application is to show the high flexibility and potential of so-called "immersogeometric" methods to study complex problems as those typically found in Biomechanics[5]. Within this framework, FSI simulations of patient-specific aortic valve designs are successfully carried out and also compared with medical images.

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Parallel Sessions

Session A1-1

A PERFORMANCE-BASED SEISMIC DESIGN METHOD FOR RC/MRFS USING MODAL STRENGTH REDUCTION FACTORS

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Keywords: Seismic Design, Reinforced Concrete Structures, Force Based Design, Performance Based Design, Modal Strength Reduction Factors, Equivalent Modal Damping Ratios.

Abstract *A performance-based seismic design method for plane reinforced concrete (R/C) moment-resisting frames (MRF) is proposed. The method is a force-based seismic design one, utilizing not a single strength reduction factor as all modern codes do, but different such factors for each of the first significant modes of the frame. These modal strength reduction factors incorporate dynamic characteristics of the structure, different performance targets and different soil types. Thus, the proposed method can automatically satisfy deformation demands at all performance levels without requiring deformation checks at the end of the design process, as it is the case with code-based design methods. Empirical expressions for those modal strength reduction factors as functions of period, deformation/damage and soil types, which can be used directly in conjunction with the conventional elastic pseudo-acceleration design spectra with 5% damping for seismic design of R/C MRFs, are provided. These expressions have been obtained through extensive parametric studies involving nonlinear dynamic analyses of 38 frames under 100 seismic motions. The method is illustrated by numerical examples which demonstrate its advantages over code-based seismic design methods.*

DYNAMIC RESPONSE OF AN INFINITE BEAM RESTING ON A WINKLER FOUNDATION TO A LOAD MOVING ON ITS SURFACE WITH VARIABLE SPEED

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Keywords: Infinite beam, Winkler foundation, Moving load, Variable speed, Fourier transform, Laplace transform

ABSTRACT

The problem of the dynamic response of an infinite beam resting on a Winkler foundation to a load moving on its surface with variable speed is solved here analytically/numerically under conditions of plane strain. The beam is linearly elastic with viscous damping and obeys the theory of Bernoulli-Euler. The elastic foundation is characterized by its spring constant and hysteretic damping coefficient. The moving point load has an amplitude harmonically varying with time and moves with constant acceleration or deceleration along the top beam surface. The problem is solved by first applying the Fourier transform with respect to the horizontal coordinate x and the Laplace transform with respect to time t to reduce the governing equation of motion of the beam to an algebraic one, which is solved analytically. The transformed beam deflection solution is inverted numerically after some simplifying analytical manipulations to produce the time domain beam response. Parametric studies are conducted in order to assess the effects of the various parameters on the response of the beam, especially those of acceleration and deceleration. Comparisons with the case of a finite beam are also done in order to assess the effect of the beam length.

NUMERICAL INVESTIGATION OF A HIGHLY EFFECTIVE HYSTERETIC NONLINEAR ENERGY SINK IN SHOCK MITIGATION

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Keywords: Nonlinear energy sink, Nonlinear oscillations, Targeted energy transfer, Bouc-Wen model, Negative stiffness, Passive energy transfer.

ABSTRACT

Passive vibration suppression is an open research field which finds application to numerous scientific areas including acoustics, aeroelasticity, earthquake, mechanical and aerospace engineering. One of the oldest passive vibration control devices is the Tuned Mass Damper (TMD) consisting of a mass, a spring and a viscous damper which is attached to a primary vibrating system in order to suppress undesirable vibrations. The natural frequency of the TMD is usually tuned in resonance with the fundamental mode of the primary structure. Thus, a large amount of the structural vibrating energy is transferred to the TMD and then dissipated by damping. Even though TMDs are known for their effectiveness, they possess certain drawbacks. First, environmental influences and other external parameters may alter the TMD properties, disturbing its tuning. Consequently, its performance can be significantly reduced. Second, a large oscillating mass is generally required in order to achieve significant vibration reduction, rendering its construction and placement rather difficult.

In light of the above, new nonlinear strategies in vibration absorption have been introduced which overcome the disadvantages of linear TMDs. Among them, Nonlinear Energy Sink (NES) has gained tremendous attention by researchers who investigated the Targeted Energy Transfer (TET) through different designs of NESs. In principle, the NES is a nonlinear attachment coupled to a linear system which irreversibly dissipates energy through nonlinear stiffness elements. NESs, unlike TMDs, do not need to be tuned to a particular frequency in order to dissipate energy effectively. Instead, they absorb energy at a wider range of frequencies and, therefore, are more robust than TMDs. In the literature, seven types of NESs have been recorded so far. In Type I, II and III NES designs, an essential nonlinear cubic spring has been employed with linear (Type I and III) or nonlinear (Type II) damping. In Type IV NES design, a rotating NES has been introduced coupled to a primary linear oscillator through an essentially nonlinear inertial nonlinearity, whereas Type V and VI designs are devoted to strongly nonlinear vibro-impact coupling.

In this work, the behavior of a new highly effective Hysteretic Nonlinear Energy Sink (HNES) coupled to a linear primary oscillator is investigated in shock mitigation. Apart from a small mass and a nonlinear elastic spring of the Duffing oscillator, the HNES is also comprised of a purely hysteretic and a linear elastic spring of potentially negative stiffness, connected in parallel. The Bouc-Wen model is used to describe the force produced by the purely hysteretic and linear elastic springs. Coupling the primary oscillator with the HNES, two nonlinear equations of motion are derived, as well as one evolution equation for the hysteretic parameter, which are integrated numerically using the analog equation method. The performance of the HNES is examined by quantifying the percentage of the initially induced energy in the primary system that is passively transferred and dissipated. Remarkable results are achieved for a wide range of initial input energies. The great performance of the HNES is mostly evidenced when the linear spring constant takes on negative values.

ACCUMULATED DAMAGE IN NONLINEAR CYCLIC STATIC AND DYNAMIC ANALYSIS OF REINFORCED CONCRETE STRUCTURES THROUGH 3D DETAILED MODELING.

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Keywords: Damage factor, nonlinear dynamic analysis, reinforced concrete, finite element method, 3D detailed modeling

ABSTRACT

Accurate nonlinear cyclic static and dynamic analysis of reinforced concrete structures is necessary when trying to capture the behavior of concrete structures during earthquake excitations. The development of an objective and robust 3D constitutive modeling approach that will be able to account for the accumulated material damage during the cyclic loading of concrete structures is of great importance in order to realistically describe the physical failure mechanisms[1] . The proposed method is based on the experimental results and the concrete modelling of Kotsovos and Pavlovic[2] as modified by Markou and Papadrakakis[3]. The objective of this research work is to propose a computationally efficient modeling method that accounts for the accumulated damage developed in both concrete and steel materials during cyclic static and dynamic excitations.

Two new damage factors are proposed herein that take into account the number of openings and closures of cracks during the nonlinear cyclic analysis, thus provide with the ability to account for the accumulated damage in both steel and concrete materials. Furthermore, a solution strategy that describes the behavior of concrete during the cyclic static and dynamic analysis is also presented.

The proposed numerical method is validated by comparing its numerical response with the corresponding experimental data of a beam-column frame joint and a two-storey reinforced concrete frame (Figure 1), which were tested under cyclic static and dynamic loading conditions, respectively. Based on the numerical findings, the proposed algorithm manages to accurately capture the experimental results, while the simulation of the understudy models was performed with computational robustness and efficiency. This numerical outcome demonstrates the potential of the proposed 3D detailed modeling approach to be implemented for the seismic assessment of full-scale reinforced concrete structures through nonlinear cyclic static and dynamic analysis.

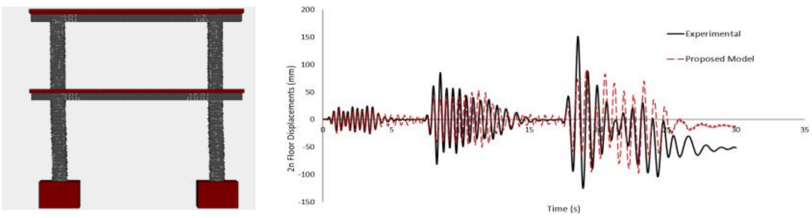

Figure 1: RC frame. Comparison between the numerical and experimental results of the 2nd level displacement response.

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NONLINEAR LOCAL BUCKLING ANALYSIS OF BEAMS EMPLOYING A HIGHER ORDER BEAM THEORY

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Keywords: Distortion, Warping, In-plane deformation, Out-of-plane deformation, Beam, Postbuckling analysis, Non-linear analysis

ABSTRACT

In most cases in the analysis of beam-like structures, Euler – Bernoulli beam theory assumptions are adopted, while in the case of non-negligible shear deformation effect, these assumptions are relaxed by using Timoshenko beam theory. However, both theories maintain the assumptions that plane cross-sections remain plane (no out-of-plane deformation) and that their shape does not change after deformation (no in-plane deformation). In order to take into account warping effects in the context of a beam theory, the inclusion of non-uniform warping is necessary, relaxing the assumption of plane cross-section. The shear flow associated with non-uniform warping leads also to in plane deformation of the cross-section, relaxing the assumption that the cross-section shape does not change after deformation. For this purpose the so-called higher order beam theories have been developed taking into account warping[1] (out-of-plane deformation) and distortional (in-plane deformation) effects[2]. In order to avoid the usage of 2d or 3d theory of elasticity models, in this paper, a beam finite element is employed for the postbuckling analysis[3] of arbitrarily shaped homogeneous beams, taking into account warping and distortional phenomena due to axial loading, shear, flexure and torsion. The beam is subjected to arbitrary axial, transverse and/or torsional concentrated or distributed load, while its edges are restrained by the most general linear boundary conditions. The analysis consists of two stages. In the first stage, where the Boundary Element Method is employed, a cross-sectional analysis is performed based on the so-called sequential equilibrium scheme establishing the possible in-plane (distortion) and out-of-plane (warping) deformation patterns (axial, flexural and torsional modes) of the cross-section[4]. In the second stage, where the Finite Element Method is employed, the extracted deformation patterns are included in the buckling analysis multiplied by respective independent parameters expressing their contribution to the beam deformation. The four rigid body displacements of the cross-section together with the aforementioned independent parameters consist the degrees of freedom of the beam. The non-linear finite element equations are formulated with respect to the aforementioned degrees of freedom. The influence of warping and distortional phenomena in postbuckling analysis is investigated through numerical examples with practical interest.

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KDAMPER CONCEPT IN SEISMIC ISOLATION OF MULTI STOREY BUILDING STRUCTURES

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Keywords: Seismic Isolation, Negative Stiffness, Building Structures, Transfer Functions, Optimization

ABSTRACT

The KDamper is a novel passive vibration isolation and damping concept, based essentially on the optimal combination of appropriate stiffness elements, which include a negative stiffness element. The KDamper concept ensures the static stability of the structure, does not require heavy masses and can achieve better dynamic characteristics, compared to the "Quazi Zero Stiffness" (QZS) isolators and the traditional Tuned Mass Damper (TMD). Contrary to the TMD and its variants, the KDamper substitutes the necessary high inertial forces of the added mass by the stiffness force of the negative stiffness element. Among others, this can provide comparative advantages in the very low frequency range. The paper proceeds to a systematic approach for the optimal design and selection of the KDamper parameters, for a multi storey building structure. A dynamic system consisting from a simplified flexible structure model and KDamper devises is considered and its transfer functions are derived. These transfer function are formed for various implementations of the KDamper devises, and are transformed in a parametric form, and an optimization procedure is used to minimize them for appropriate excitation and response points. Finally, an application case of a 3-storey concrete building structure is presented under seismic excitations of broad frequency range.

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Session B1-1

NUMERICAL AND ASYMPTOTIC SOLUTIONS OF AXISYMMETRIC POISEUILLE FLOWS OF YIELD STRESS FLUIDS WITH PRESSURE-DEPENDENT RHEOLOGICAL PARAMETERS

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Keywords: Bingham Plastic, Poiseuille Flow, Lubrication Approximation, Pressure-Dependent Yield Stress, Pseudospectral Method.

ABSTRACT

The lubrication flow of a Bingham plastic in long tubes of varying radius is modeled extending the approach proposed by Fusi et al.[1,2]. The advantage of that method is that the yield surface separating the region where the material is deformed (yielded region) from the region where it moves as a solid (unyielded region) is determined explicitly. In the present work, both the plastic viscosity and the yield stress are assumed to vary linearly with the total pressure. Under the lubrication approximation, the flow problem is reduced to a system consisting of a non-linear first-order differential equation and an algebraic one, in which the unknowns are the total pressure $p(z)$ and the radius of the yield surface $\sigma(z)$. Once $p(z)$ and $\sigma(z)$ are calculated the velocity of the unyielded core and the two-dimensional velocity components in the yielded region are calculated by means of explicit formulas.

The resulting system of equations is solved by using a pseudospectral numerical method utilizing Chebyshev orthogonal polynomials and an analytical perturbation method with the small parameter being the difference β-α, where α and β are the dimensionless growth parameters of the plastic viscosity and the yield stress, respectively. In the former method, ten spectral coefficients are adequate to fully resolve the pressure and yield-surface profiles down to machine accuracy. In the latter one, three terms in the perturbation expansions are found analytically, and then are suitably processed using series-convergence-acceleration techniques. The agreement between the two techniques is excellent.

The implications of the pressure-dependence of the material parameters and the applicability windows of the method in terms of the applied pressure difference are discussed. In particular, the numerical results show that the shape of the yield surface depends on the relative values of the growth parameters α and β. When α=β the radius $\sigma(z)$ of the unyielded core is constant, in agreement with the analytical solution.[3] If $\alpha>\beta$, then $\sigma(z)$ is decreasing and if $\alpha<\beta$, $\sigma(z)$ is increasing downstream.

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RAREFIED PULSATILE PRESSURE-DRIVEN FULLY-DEVELOPED GAS FLOW IN LONG CIRCULAR TUBES

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Keywords: Pulsatile flows, Oscillatory flows, Knudsen number, BGK, Richardson effect.

ABSTRACT

Pulsatile rarefied flows are of main interest in pressure sensors and in boundary layer flow controllers as well as in heat transfer enhancement applications. Pulsatile flows in the hydrodynamic limit haven been extensively investigated. However, the corresponding work in rarefied gases is very limited.

Here, the pulsatile pressure-driven fully-developed rarefied gas flow through a long circular tube driven is investigated. The pulsatile motion is the sum of a steady-state flow plus an oscillatory one[1]. In dimensionless form, the problem is characterized by the gas rarefaction parameter, which is proportional to the inverse Knudsen number and the oscillation parameter, defined as the ratio of the collision frequency over the pressure gradient oscillation frequency. The flow is simulated based on the time-dependent linearized BGK kinetic model equation subject to Maxwell diffuse-specular reflection.

Computational results of the amplitude and the phase angle of the flow rate, mean wall shear stress, pumping power and time-average pumping power, as well as of the periodic time evolution of these macroscopic quantities, are provided, in a wide range of the involved parameters. The results are successfully validated with corresponding analytical results in the slip and free molecular regimes and numerical results in steady fully-developed flow. In general, as the oscillation frequency is increased the amplitude of the macroscopic quantities is decreased and their phase angle lag with respect to the pressure gradient is increased. Actually, at very high frequencies the amplitude tends to diminish, while the phase lag reaches the maximum value of 90^{o}. At low frequencies, the time-dependent flow becomes quasi-steady and gradually tends to the corresponding steady-steady one, which is reached faster as the flow becomes more rarefied. In terms of the gas rarefaction, there is a non-monotonic behavior and the maximum flow rate amplitude may be observed at some intermediate value of the gas rarefaction parameter depending upon the oscillation parameter. The time-average pumping power is increased as the oscillation frequency is reduced and its maximum value is one half of the corresponding steady one. The summation of the two pumping powers yields the total average pulsatile pumping power.

Furthermore, the pressure, viscous and inertia forces acting on the rarefied flow are computed in terms of the gas rarefaction and oscillation parameters. When the flow is dominated by viscous forces it consists of one oscillating viscous region, while when it is dominated by inertia forces, it consists of two regions, namely the core region oscillating in a plug mode plus the oscillating thin viscous or Stokes layer with the velocity overshooting (Richardson effect) adjacent to the wall. These effects, well-known in the viscous regime, are also present here in the transition (rarefied) regime and depend both on the gas rarefaction and oscillation parameters.

It is hoped that the present work may be useful in experimental work related to pulsatile gas microflows as well in the design of microfluidic devices (sensors, controllers, resonators).

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HYDRODYNAMIC EFFECTS ON PHASE SEPARATION MORPHOLOGIES IN EVAPORATING THIN FILMS OF POLYMER SOLUTIONS

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Keywords: Thin films, phase separation, hydrodynamic stability, direct numerical simulations

ABSTRACT

We examine effects of hydrodynamics on phase separation morphologies developed during drying of thin films containing a volatile solvent and two dissolved polymers. Cahn-Hilliard and Flory-Huggins theories are used to describe the free energy of the phase separating systems. The thin films, considered as Newtonian fluids, flow in response to Korteweg stresses arising due to concentration nonuniformities that develop during solvent evaporation. Hydrodynamic stability and direct numerical simulations are employed to investigate the effects of a Peclet number, defined in terms of system physical properties, as well as the effects of parameters characterizing the speed of evaporation and preferential wetting of the solutes at the gas interface. For systems exhibiting preferential wetting, diffusion alone is known to favor lamellar configurations for the separated phases in the dried film. However, a mechanism of hydrodynamic instability of a short length scale is revealed, which beyond a threshold Peclet number may deform and break the lamellae. The critical Peclet number tends to decrease as the evaporation rate increases and to increase with the tendency of the polymers to selectively wet the gas interface. As the Peclet number increases, the instability moves closer to the gas interface and induces the formation of a lateral segregation template that guides the subsequent evolution of the phase separation process. On the other hand, for systems with no preferential wetting or any other property asymmetries between the two polymers, diffusion alone favors the formation of laterally separated configurations. In this case, concentration perturbation modes that lead to enhanced Korteweg stresses may be favored for sufficiently large Peclet numbers. For such modes a second mechanism is revealed, which is similar to the solutocapillary Marangoni instability observed in evaporating solutions when interfacial tension increases with the concentration of the non-volatile component. This mechanism may lead to multiple length scales in the laterally phase separated configurations.

HOW TO MAKE A SPLASH: HIGH SPEED DROP IMPACT AT ARBITRARY ANGLES OF INCIDENCE

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Keywords: drop impact, splashing, asymptotic analysis, volume-of-fluid method, direct numerical simulations.

ABSTRACT

High speed drop impact is of great relevance in a number of prominent industrial contexts, ranging from icing prevention in aeronautics to combustion applications, inkjet printing and agricultural sprays. A new model for oblique drop impingement onto aircraft surfaces and associated analytical and numerical advances are proposed in this body of work[1].The approach incorporates the detailed fluid dynamical processes often ignored in this setting, such as the drop interaction with the surrounding air flow, drop deformation, rupture and coalescence, as well as the motion of the ejected microdrops in the computational domain (see Figure 1 for example scenarios). Direct numerical simulations based on the volume-of-fluid technique[2] are performed using modelling assumptions which enable us to take advantage of the disparity of lengthscales in the system. Comparisons are performed in the pre-impact regime with available experimental data[3], while the early stages of the impact are validated using the analytical framework provided by Wagner theory, context in which recent developments are also presented[4]. We then concentrate on quantifying useful information on the liquid movement over longer timescales.

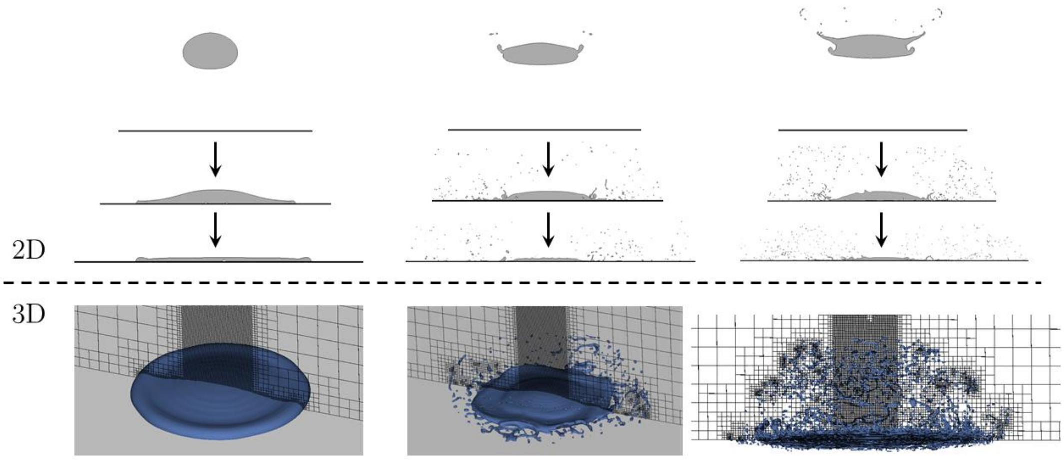

Figure 1: Snapshots of impact dynamics in both two (above) and three (below) dimensions for small, moderate and large drops (from left to right), outlining the change in behaviour from spreading to violent splashing.

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STATIC ARRANGEMENT AND DYNAMIC RESPONSE OF A CAPILLARY POROUS SYSTEM IN THE PRESENCE OF ADHESIVE AND LORENTZ FORCES

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Keywords: Capillary Pore System, Adhesion, Lorentz force, Drop ejection

ABSTRACT

One of the most promising methods to circumvent problems concerning the plasma-wall interaction is the Capillary Porous System (C.P.S.) [1]. In this arrangement, a porous mesh acts as a capillary pump that replenishes the liquid metal protecting the divertor region from extreme plasma activity. In order to assess the stability threshold of the porous structure and predict the onset of break-up and drop ejection [2], there is need to investigate the static arrangement of the liquid metal that coats the porous matrix as a function of the liquid metal physical properties, operating conditions and the topography of the porous mesh, Fig. 1a.

To this end, our previous parametric study [3] was extended to cover a wide range of overpressures between the liquid metal reservoir and the surrounding plasma. A numerical solution was obtained via the finite element methodology that solves the Young-Laplace equation, which incorporates the interfacial tension between liquid metal and surrounding medium, gravitational and pressure forces, and adhesive forces between the liquid metal and porous substrate. The latter arise as a result of intermolecular interactions and are assembled in a disjoining pressure term. Two different kinds of intermolecular potential were investigated, namely, a long range attractive short range repulsive potential and a purely repulsive potential.

It was thus seen for realistic reservoir overpressures, i.e. approaching vacuum conditions, that micron or even submicron coatings are established as a result of the balance between pressure and intermolecular forces. In this regime the pore size and mesh topography start playing an important role in the static arrangement, Fig. 1b. Furthermore, a threshold reservoir over-pressure exists beyond which a static arrangement with the liquid metal coating the CPS, is not possible. In the presence of a magnetic field and an incoming electric current, a steady state circulatory motion is established within each pore due to the Maxwell stresses that develop, while the interface with plasma is pushed out of the pore as the magnetic pressure increases. For fixed interaction potential a critical angle exists at the pore "mouth" beyond which a balance between magnetic pressure and adhesion is not possible and a steady state arrangement cannot be found. It is conjectured that this threshold is associated with loss of stability of the liquid metal coating and the onset of drop ejection.

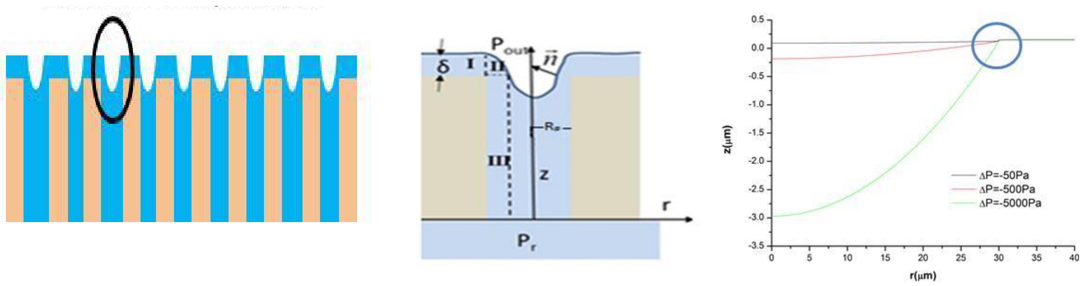

Figure 1: (a) Schematic of the static arrangement of the liquid metal coating in the pore level. (b) Static arrangement at the pore mouth varying the reservoir overpressure, $\Delta P = P_r - P_{out}$.

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GENERATING LIFT BY BLOWING ON A BLADE AIRFOIL

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Keywords: Airfoil, Lift coefficient, Air jet.

ABSTRACT

In nearly all modern applications, lift is generated on airfoils by moving the blade into a (usually) quiescent air. In aircraft wings it is the entire aircraft that is being pushed by the corresponding propulsion unit, while in helicopters the wing rotates under the action of a heat engine. In the present study it is proposed to investigate a new approach, the ability of a linear air jet to generate a lifting force on an airfoil by blowing against the blade leading edge.

The study is based on the results of a numerical simulation provided by the ANSYS-FLUENT commercial suite of the flow interaction between a linear jet and a NACA geometry airfoil.

The blowing process was not focused on the suction or the pressure sides of the airfoil as done in previous studies (where the jet acted as a lift coefficient enhancement mechanism), but it was divided equally to both surfaces. The different nature of the two surface curvatures, provided a corresponding static pressure non-uniformity that lead to the generation of a lift force.

These data provided a positive answer to the above fundamental question and established the basis for analyzing the interaction between the jet flow and the corresponding airfoil. The simulations showed that lifting coefficients of the order of C_L=1 may be realized, something that could may make economically viable the proposed lift generation mechanism for vertical take off and landing vehicles driven by a reduced power level engine.

In addition, the analysis of the data indicated that the lift generated by the flow of the jet on the two exposed surfaces of the airfoil is regulated by the rate at which the two corresponding wall jets dissipate.

Session A1-2

AERODYNAMIC SHAPE OPTIMIZATION OF DIFFUSER AUGMENTED WIND TURBINE BLADES USING ASYNCHRONOUS PARALLEL DIFFERENTIAL EVOLUTION

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Keywords: aerodynamic shape optimization, diffuser augmented wind turbines, rotor blades, asynchronous differential evolution algorithm, parallelization, meta-models

ABSTRACT

In recent years, the ever increasing world energy consumption, as well as the global awareness about the adverse environmental impact of the intense fossil fuels exploitation, have pushed towards the reconsideration of traditional energy practices and the systematic investigation, development and application of alternative energy production technologies. As a result, the wind power sector is nowadays one of the fastest growing industries and the most substantial provider of renewable and sustainable energy. However, the unpredictable nature of the wind and its relatively dilute energy content are significant barriers to the even broader adoption of wind turbines technology, since these factors tend to upsurge the cost of the derived energy.

To this end, the development of efficient wind concentrators that substantially increase the energy density of wind and enhance the power output of wind turbines, has long been pursued. The Diffuser Augmented Wind Turbine (DAWT) can be viewed as such an innovative wind energy conversion system for energy production in site-specific cases, which involves the attachment of a static diffuser around the turbine, in order to control the expansion of the airstream and create a region of high subatmospheric pressure at the diffuser exit; a phenomenon that eventually results in the augmentation of the mass flow rate passing through the turbine. Hence, such a configuration has the potential to yield power performance coefficients well in excess of the Betz limit and thus, to extract additional power from the wind, compared with a conventional bare wind turbine with the same rotor diameter.

In this study, a methodology for the twist and chord optimization of DAWT blades is demonstrated, by using a parallel asynchronous and meta-model assisted Differential Evolution algorithm (DE). The concept underlying the followed parallelization strategy is to enable the cooperation of the algorithm with different simulation software in the form of executables. The required data transfer between the DE and the simulation software is succeeded with appropriate text files, while the communication among the processors and the parallel implementation is achieved using MPI (Message Passing Interface) library functions. Additionally, further acceleration of the optimization process is achieved through the combination of the DE with a Multilayer Perceptron (MLP) and a Radial-Basis Function (RBF) Artificial Neural Networks (ANNs), which serve as surrogate models and work as an ensemble. The number of hidden units in each one of the two hidden layers of the MLP network is twice the number of the design variables, while for the RBF networks the number of centers is set equal to 2/3 of the number of training data. Direct learning is used for the training of each RBF network, based on a matrix formulation of its governing equations and the back-propagation algorithm is applied to determine the synaptic weights of the MLP network, through an iterative supervised training procedure. Finally, as long as the evaluation of each candidate design is concerned, an in-house computational Blade Element Momentum (BEM) code is used, which is based on the modification of the momentum part of the classical BEM theory; thus, it is capable to account for the diffuser's effect on the calculation of the axial and tangential induction factors, through the utilization of the velocity speed-up distribution over the rotor plane of the unloaded diffuser. Furthermore, a detailed Glauert's correction model, which employs Buhl's modification, specially tailored for the DAWT case is included, to deal with the high values of the axial induction factor.

RAREFIED GAS FLOW ANALYSIS OVER A RE-ENTRY SPACE CAPSULE GEOMETRY

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ABSTRACT

During the past decades, significant efforts have been exerted for the prediction of rarefied gas flows, especially in aerospace applications. Such flows appear to be considerably different from those at the continuum regime, making Navier-Stokes equations to fail against such phenomena without further modification.

To this end, a modified in-house academic CFD solver is presented and assessed in this study [1]. Navier-Stokes equations are discretized with a node-centered finite-volume method and hybrid unstructured grids. For fluids in slip flow regime, i.e., with Knudsen number greater than 0.01, the no-slip condition is no longer valid on solid wall surfaces, hence, velocity slip and temperature jump boundary conditions are applied on solid walls instead. Due to spurious oscillations that might appear, especially during the initial steps of the iterative solution, a normalization scheme is used to allow for the gradual approximation of the corresponding slip and jump values. Additionally, the second-order accurate slip model of Beskok and Karniadakis [2] is implemented to increase the accuracy in the same area, avoiding the numerical difficulties entailed by the calculation of the second derivative of slip velocity when complex geometries and unstructured hybrid grids are coupled.

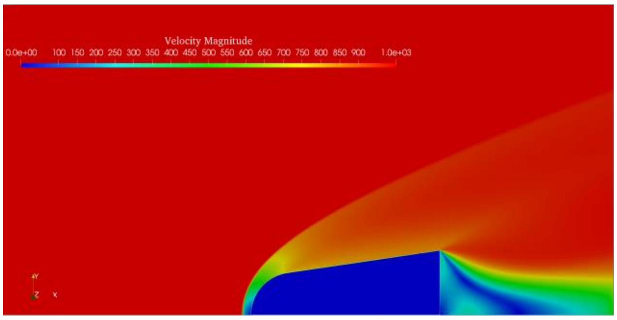

Figure 1. Velocity contours over the re-entry space capsule, extracted with the SPARTA solver

The proposed solver is validated against rarefied laminar gas flow (inside the slip flow regime) over a re-entry space capsule geometry, i.e., the blunt portion of a spaceship returning to Earth after a spaceflight. The extracted results are compared with those derived by the parallel open-source kernel SPARTA [3]. The latter is based on the DSMC method, a widely applied methodology for rarefied gas flow problems, which regards the division of the flow domain into computational cells where the macroscopic flow properties are retrieved, depending on the intermolecular collisions of simulated particles. A satisfactory agreement is succeeded, demonstrating the modified proposed solver's potential to predict accurately such complex flows.

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NUMERICAL FLOW SIMULATION OVER THE M151 COMBAT AIRCRAFT MODEL USING GALATEA SOLVER

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ABSTRACT

During the past decades, CFD has become an indispensable tool of the aerospace manufacturing process and product design as it allows for the prediction of aerodynamic behavior of an aircraft in a relatively short period of time. Nevertheless, many issues remain still incomplete in the CFD field, necessitating for further research and consequently validation and verification of corresponding solvers.

An academic CFD code, named *Galatea* [1], is presented and assessed in this paper, which is based on the RANS equations along with appropriate turbulence models (k-ε, k-ω and SST) to simulate inviscid and viscous laminar or turbulent compressible fluid flows. Spatial discretization is succeeded with a node-centered finite-volume scheme on 3D hybrid unstructured grids, composed of tetrahedra, prisms and pyramids. For the calculation of the convective fluxes the Roe's approximate Riemann solver is applied, along with a second-order spatial accurate scheme, based on the MUSCL approach and appropriate slope limiting functions. Time integration is succeeded with an explicit scheme, employing a four-stage Runge–Kutta method. In order to alleviate the common shortcoming of increased computational time of such unstructured solvers, a directional full-coarsening agglomeration multigrid scheme is adopted, coupled with the local time-stepping technique and a parallelization strategy, based on the domain decomposition approach and the MPI library functions.

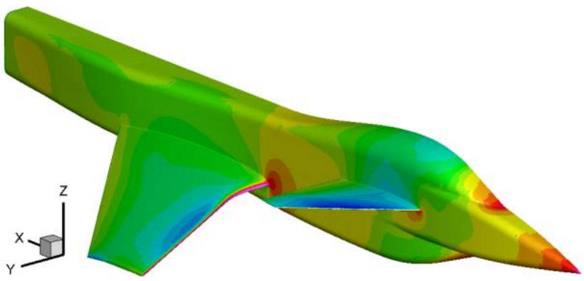

Figure 1. Dimensionless pressure contours on the M151 aircraft surface, produced by the *Galatea* solver

Galatea is used against the ARA (Aircraft Research Association) M151/1 test case, concerning an uncommon combat aircraft research model with forward swept wings (FSWs) and canards [2]. FSW is a state-of-the-art configuration regarding the aerodynamic design of fighter aircrafts. It entails significant performance advantages, comparing to the Back Swept Wing (BSW), especially when it is coupled with supercritical airfoils, canards, fly-by-wire system and advanced composite materials, i.e., it results in improvement of aerodynamic efficiency, low-speed handling, maneuverability at high angles of attack, etc. In this study, a configuration of M151/1 with expanding fuselage is examined, while the produced results, are compared with those, extracted with the commercial CFD software ANSYS CFX. A satisfactory agreement is obtained, demonstrating the proposed solver's potential to predict accurately such complex flows.

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A COMPUTATIONAL STUDY OF THE FLOWFIELD INSIDE A REDUCED AIRFOILS CASCADE

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Keywords: Airfoils cascade, Aerodynamic losses.

ABSTRACT

The simplest experimental facility that has proven to be able to provide reliable experimental simulation data for the blade channels in axial compressors and turbine cascades has been the "Cascade Wind Tunnel" (CWT). These facilities employ usually 7 to 11 airfoils in series in order to achieve the necessary periodicity in flow conditions that characterizes the flow fields in actual turbomachinery. The relevant facilities provide data for the velocity and the pressure field around the airfoils (which allows the measurement of the cascade aerodynamic losses) as well as the heat flux field on the exposed surfaces of the cascade (which leads to correct estimates for the heat loading of the turbine blades in actual Gas Turbine applications).

In order to increase the size of the blade channels (i.e. improve the spatial discretization of the measured parameter distributions) it is proposed to reduce the number of the airfoils involve in any given facility. The question that arises concerns the minimum number of airfoils that guarantee periodicity of the flow fields inside the blade channels and the degree of deviation between an infinite (i.e. large number of airfoils) and a corresponding cascade with a reduced number of airfoils.

These flow fields were evaluated by employing the ANSYS-FLUENT commercial suite for a cascade employing different numbers of airfoils that were employed in earlier NACA experiments.

The results of the computational simulation were analyzed so as to provide a design guide for the following aspects of the relevant flow fields

1. The distribution of the static pressure along the exposed surface of the blade centerline.
2. The nature of the secondary flow field inside two consecutive blade channels
3. The corresponding distribution of the heat fluxes (Stanton numbers) on the end-walls of the same channels.

The results indicated that a four airfoil cascade is probably the simplex geometry that may provide reasonably reliable results.

MULTI-OBJECTIVE OPTIMIZATION OF A FLAPPING FOIL SYSTEM FOR THRUST AUGMENTATION IN SHIP PROPULSION

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Keywords: Flapping foil, thrust augmentation, multi-objective, boundary element method.

ABSTRACT

A state-of-the-art application of biomimetics, i.e. the artificial imitation of natural models in order to design efficient technological systems, concerns the design of devices for propulsion augmentation. Such devices, inspired by the thunniform swimming mode, have been proposed for ship thrusters[1]. The performance of a flapping foil system that performs a combination of two periodic (sinusoidal) motions, namely a heaving motion and a pitching one with a phase lag between them, has been experimentally studied[2] and numerically simulated by means of a panel method[3] as well as by an unsteady Navier-Stokes solver[4].

The authors , aiming to develop in the long-term, a control method for dynamically modifying the motion of the flapping foil for maximum thrust gain in an efficient way, numerically investigated the effect of basic motion parameters on thrust augmentation and propulsion efficiency[5]. Parametric studies were performed for these parameters, namely amplitude and frequency of the heaving and pitching motions and phase lag between the two motions by means of a lower fidelity (compared to Navier-Stokes) but very fast Boundary Element solver. These studies showed the trends of the flapping foil performance in terms of appropriate performance indices and revealed that the corresponding objectives seem to be contradicting. Furthermore, a static single-objective optimization problem to seek the values of the motion parameters that maximize the efficiency of the flapping foil system was stated and solved. However, the optimal solution in terms of efficiency yielded very low thrust, dictating that multi-objective problems have to be solved in order to obtain practical and profitable solutions.

In the present paper, the previous work[5] is extended to the study of a multi-objective optimization problem for the same flapping foil system that take into account combination of objectives like maximization of thrust coefficient (C_T), maximization of efficiency (η) and minimization of the power required for the foil motion in terms of power coefficient (C_P). In particular, optimal solutions in the sense of Pareto are sought for the simultaneous maximization of thrust and efficiency and the results are physically interpreted.

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OPTIMAL DESIGN OF LARGE SPAN STRUCTURES USING THE MBN DISPLACEMENT CONTROL SYSTEM

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Keywords: Optimal prestressing, Displacement minimization problem, Passive control, Large span structures

ABSTRACT

The structural performance of large span structures with the prestressed control system MBN (type MBN after Michalopoulos, Baniotopoulos, Nikolaidis) corresponding to lines of curved cable nets is herein investigated. This prestressing control system is based on the cable supported beam concept with prestressing control so that the structural behavior of the system is optimized. The novel optimal control system is a prestressing cables mechanism, where permanent loads are relieved by two lines of external curved cables (α) and the moving loads relieved by a passive control system of internal to the deck curved cables (β) that consists of a sequence of highly prestressed segments with significant length, being interconnected by non prestressed segments of small length. The structural system under consideration seems to be appropriate for the design of large span bridges. The passive control design of the system leads to an optimal control problem for structures governed by variational inequalities. The accurate simulation of the complex action of the cables on the structure has been performed by means of the Finite Element Method within an Optimal Prestressing theoretical framework. In this paper a bridge model of span length L=200,0m is proposed and studied as a numerical application of the method.

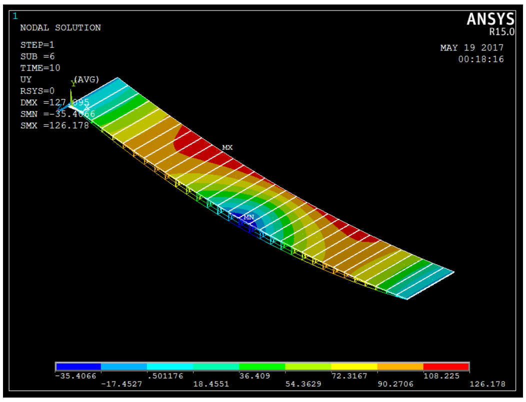

Figure 1. Nodal displacements of a large span bridge model formed by the MBN displacement control system

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MS1-Computational Analysis of Advanced Materials

Organizer: E. E. Theotokoglou

PRELIMINARY ANALYSIS METHOD FOR CFRP LAMINATE CAI STRENGTH DEGRADATION EVALUATION

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Keywords: Explicit Finite Element Method, Composite Materials, Low Velocity Impact, BVID

ABSTRACT

Low velocity impact damage on carbon reinforced polymer laminate composites has been identified as a key threat to airframe structural integrity since it reduces the strength under compressive loading[1, 2]. Airworthiness certification specifications dictate that the airframe structural components up to the full scale subassemblies have to adhere to the strength and fatigue airworthiness requirements imposed whilst being damaged. Expensive testing surveys can be reduced in cost and scope if properly and partially substituted by numerical evaluation of structural strength. The study presented herein combines a set of numerical tools for generating an approach to numerically quantify the compression after impact strength of CFRP laminates and assess the impact damage implications at the preliminary design stage.

A validated, simplified method of delamination modeling has been implemented in the explicit finite element method analysis of low –velocity impact on multiple laminate configurations as well as in the CAI test simulation (Figure 1). The developed procedure gives satisfactory results for the analysis configuration[3]. Moreover, there is a high potential for the method to be applicable to a general case with the minimal use of experimental testing and accessible material data. Further investigation is also needed to check its validity in a larger variety of cases and dependent[1].

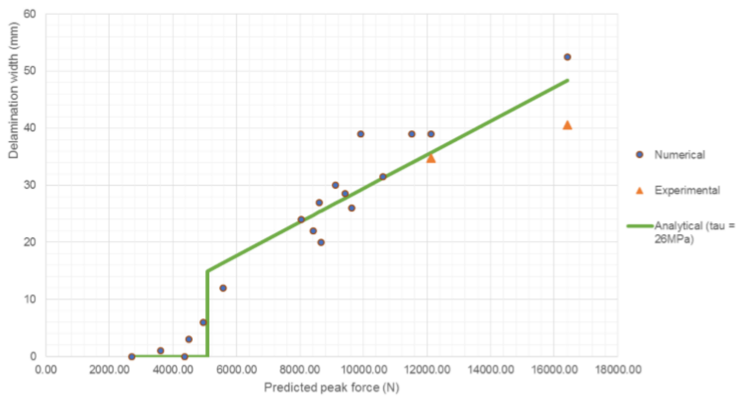

Figure 1: Delamination size prediction model compared with available experimental and obtained numerical data

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COMPUTATIONAL MODELING FOR THE STOCHASTIC YARN VARIABILITY OF BRAIDED COMPOSITES DUE TO MANUFACTURING PROCESSES

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Keywords: Braided textiles, uncertainties, random fields, multiscale modeling, Kriging

ABSTRACT

The several manufacturing stages a braided textile must go through until its completion, append random material defects in terms of geometry. These uncertainties are not only difficult to predict, but also hard to be minimized, and since they mostly occur in lower scales, they significantly affect the response of materials with such a heterogeneous nature. Realistic numerical, multiscale models should account for the variability of their representative volume elements, thus have the ability to include spatial randomness.

In this work, novel modeling strategies are proposed for the consideration of geometrical uncertainties of 3D braided composites. The problem of distorted yarns due to high levels of compaction is simulated with a technique inspired from random inclusion studies, able to describe the yarn section of the mesoscale with a 1D random field. This approach can randomize sections of any shape. The problem of yarn waviness (stochastic deviations from the hypothetical perfect yarn trajectory) is dealt with a formulation based on Gaussian process modeling (a.k.a. Kriging), where 1D Gaussian random fields are appropriately tailored to match the systematic yarn path (trend). Statistical characteristics (e.g. correlation, variance etc.) gathered from physical samples can be included in the proposed approach in a straightforward manner, while several other advantages over older techniques are discussed.

All modeling techniques discussed herein, are suitable for finite element simulations. Applications for a 3D braided multiscale model (based on previous work[1] by the authors) are presented, emphasizing on the variability of the elastic tensor of the macroscale due to each type of uncertainty. The voxel method is used for the discretization of the imperfect volume element. The need for realistic uncertainty quantification is highlighted, while the coupling of manufacturing processes and structural mechanics is more crucial than ever.

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COMPUTATIONAL FRAMEWORK FOR MODELING AND FATIGUE DAMAGE IDENTIFICATION OF COMPOSITE CARBON FIBER STRUCTURAL SYSTEMS

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Keywords: Modal identification, Model updating, Large scale structures, Structural Dynamics.

ABSTRACT

A computational framework for dynamic analysis and fatigue damage identification of linear and nonlinear structural systems, applying a fatigue damage accumulation methodology is proposed in this work. The methodology is applied on composite cylindrical parts, produced on a spinning axis by winded carbon fibers, cascaded on specified number of plies, in various angles and directions. First, a discrete FE model of the examined structure is developed, by consecutive shell and solid elements, simulating each carbon fiber ply and rasin matrix. Focusing on the updating methodology, coupled with robust, accurate and efficient finite element analysis software, the linear and non-linear behavior of the composite parts was examined under various load conditions followed by equivalent experimental trials, in order to classify the material properties (isotropic, orthotropic, anisotropic) and develop a high-fidelity FE model. This is achieved through combining modal residuals, that include the lowest identified modal frequencies and mode shapes, with response residuals, that include shape and amplitude correlation coefficients considering measured and analytical frequency response functions and time-histories of strains and accelerations. Single objective structural identification strategies without the need of sub-structuring methods, are used for estimating the parameters (material properties in each deformation plane) of the finite element model, based on minimizing the deviations between the experimental and analytical dynamic characteristics[1]. A stochastic optimization evolution strategy is applied in parallel computing, to solve the single-objective optimization problem, arising from combining the above residuals. The effect of model error, finite element model parameterization, number of measured modes and number of mode shape components on the optimal models along with and their variability, are examined. In order to assess the fatigue damage and remaining lifetime, the full stress time histories of the composite parts were estimated, at critical locations, by imposing simulated ISO road profiles in the FE model of a small vehicle made of cylindrical carbon fiber parts, using the updated parameters. Fatigue is subsequently estimated using the Palmgren-Miner damage rule, S-N curves, and rainflow cycle counting.

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DYNAMIC ANALYSIS OF A CERAMIC/METAL FUNCTIONALLY GRADED THERMOELASTIC LAYER UNDER RAMP-TYPE THERMAL LOADING

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Keywords: Functionally Graded Material, Temperature-Dependency, Coupled Thermoelasticity, Transient Analysis.

ABSTRACT

In the case of large temperature variations, the thermomechanical properties of a material should be considered as temperature-dependent rather than constants. In the present article the effect of the temperature-dependency of the properties on the thermoelastic response of a ceramic/metal functionally graded layer of finite thickness L (Figure 1) is investigated. The functionally graded layer is subjected to uniform ramp-type thermal loading at its upper surface, i.e. the temperature of the upper surface gradually rises from reference temperature T_0 to temperature T. The resulting transient fields of stress and temperature inside the layer are presented, within the theory of linear coupled thermoelasticity[1].

In the above analysis, zirconia is used as the ceramic material and a titanium alloy is used as the metal material. The properties of these materials are assumed to be a cubic function of the temperature[2]. Moreover, the variation of the properties inside the functionally graded layer is considered to be linear. For the numerical analysis the Galerkin finite element method is used, whereas the Newmark method is employed for the time integration of the problem. The effect of the temperature-dependency of the properties in the case of a functionally graded thermoelastic half-space has already been discussed by the authors[3].

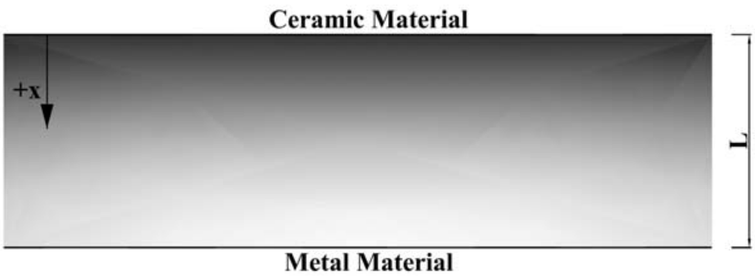

Figure 1: A ceramic/metal functionally graded layer.

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MULTISCALE MATERIAL AND TOPOLOGY OPTIMIZATION OF A CARBON-NANOTUBE REINFORCED COMPOSITE STRUCTURE

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Keywords: Multiscale optimization, Topology Optimization, Multiscale analysis, Homogenization, Solid isotropic material with penalization (SIMP), Carbon-nanotube reinforced composites (CNT-RCs).

ABSTRACT

Owing to the growing industry of manufacturing microscopically heterogeneous materials at an ever-smaller scale**,** multiscale optimization has gained significant traction over the last decade, since it makes possible the otherwise computationally infeasible task of optimizing large-scale structures made from such materials. The current work proposes a novel multiscale optimization technique, applied on a carbon-nanotube reinforced polymer structure, which allows optimizing concurrently the topology of the macroscopic structure and the parameters describing the microscopic structure. The structure was analyzed using a three-level multiscale technique, and the optimization was performed at the top two levels: 1. At the lowest, atomic level, a short carbon nanotube represented as a space frame was analyzed. 2. At the microscopic level, a small specimen consisting of a polymer matrix containing a nanotube, represented as a truss rod was analyzed. 3. At the macroscopic level, a small cantilever beam was analyzed. The analysis at the microscopic and macroscopic levels were performed simultaneously, using a nested solution scheme[1] combined with a homogenization technique[2]. The structure was optimized with regard to the topology of the macroscopic structure and the angles of the nanotubes at the microscopic level, so that the potential energy of the macroscopic structure was minimized. To this end, the topology of the structure at the macroscopic level was described using the Solid isotropic material with penalization (SIMP)[3] technique. This formulation of the topology optimization problem allowed it to be combined with the optimization of the nanotube angles at the lower level.

Acknowledgements: This work has been supported by the European Research Council Advanced Grant "MASTER – Mastering the computational challenges in numerical modeling and optimum design of CNT reinforced composites" (ERC-2011-ADG_20110209).

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DESIGN AND STRUCTURAL ANALYSIS OF WIND TURBINE BLADES FOR STRUCTURAL HEALTH MONITORING CONSIDERATION

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Keywords: Wind Turbine Blade, Structural Health Monitoring, Composite Materials, Structural Analysis, CAD.

ABSTRACT

In the present investigation, a large-scale composite wind turbine blade model is first designed and then analyzed under different loading and damage scenarios in order to assess the integrity of the structure. The main focus of the paper is the study of the influence of several damage patterns while the blade is in operation, in conjunction with structural failures identification by using dynamic measurements from the structure.

In the baseline scenario, a large-scale wind turbine with blade span of approximately 20 meters is considered. In terms of design approach, the Blade Element Momentum (BEM) theory will be promoted. The whole idea behind BEM assumes that the forces acting on the operating wind turbine blades are responsible for the change in axial momentum of the air passing through the swept area of the rotating wind turbine blades.

As for the materials that are used, it is worth mentioning that there is a wide range of options in terms of materials and manufacturing techniques utilized in the wind turbine industry. The most common material combinations used are composite laminates with embedded threaded steel rods in the root section, connecting the blade to the hub through a bolted connection. Polyester, vinyl ester and epoxy resins are common, matched with reinforcing wood, glass, and carbon fibers. In the present investigation a composite epoxy glass, a carbon fiber and a memory foam material are used.

A preliminary analysis for the structural health monitoring is done in the present study. Namely, several investigations are carried out in order to calculate the mechanical response behavior of the structure under different failure scenarios.

Acknowledgments

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Session A1-3

A STUDY ON SOLUTION ALGORITHMS FOR CRACK GROWTH PROBLEMS USING XFEM

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Keywords: Crack Propagation, Iterative Solvers, Preconditioner, Reanalysis, XFEM.

ABSTRACT

The extended finite element method (XFEM) enriches the polynomial basis functions of standard finite elements with specialized non-smooth functions. The resulting approximation space can be used to solve problems with moving discontinuities, such as cracks, while avoiding the computational cost of remeshing. Although the local enrichment strategy of XFEM is computationally efficient, it can rapidly increase the size of the resulting linear system in large scale problems. In addition, the stiffness matrix may become ill-conditioned, causing slow convergence of iterative solvers. In this paper, a comparative study of well-known direct and iterative solution algorithms for solving the resulting linear system is presented, in terms of their efficiency and robustness. Various techniques such as reanalysis, renumbering and preconditioning are considered to take advantage of the stiffness matrix form in an effort to reduce the overall computational cost. The performance of compared algorithms is determined by means of different metrics in computationally intensive benchmarks problems of fracture mechanics.

THE INFLUENCE OF FRACTURE-SURFACE NORMAL AND SHEAR STRESS LOADING ON CRACK-TIP SINGULAR PLASTIC FIELDS

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Keywords: Crack-tip, singular plastic fields, loaded cracks, shear tractions, Drucker-Prager.

ABSTRACT

We investigated the singular plastic fields at the crack tip that is loaded with normal and shear loads due to a viscous flow in a hydraulic fracture. The level of the expected shear load in comparison with the normal load is first examined. The lubrication flow and plastic deformation are decoupled assuming that the relation between applied shear load and normal load follows a linear Coulomb friction-type relation. This decoupling allows the investigation of the two bounds of the solution. Both the applied normal and shear loads at the fracture surfaces are assumed to exhibit singular behavior near the tip which is compatible with the plastic singular stress fields that are investigated. The fractured material is assumed to obey a non-associative Drucker-Prager solid with power law hardening response[1,2,3].

The singular values and the corresponding fields were determined over a range of material parameters related to hardening, pressure sensitivity, non-associativity and surface friction. For both von-Mises material and associative Drucker-Prager material we found that the level of singularity is given by 1/n where n is the power coefficient of the hardening relation. Deviation from material associativity produces consistent small increases of the level of singularity (Fig.1a). This level of singularity is stronger than the HRR value, 1/ (n+1), which has been originally determined for traction free crack surfaces. We found that shear loading does not influence the level of singularity but it changes the shape of the developed plastic zones with the emergence of a boundary layer near the fracture surface[4] (Fig1b).The near-tip stress, strain and displacement profiles will be illustrated for a few representative cases.

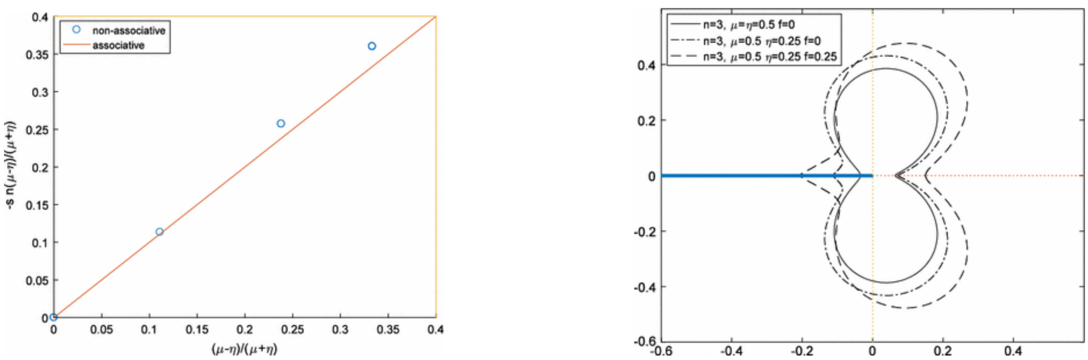

Figure 1: a) Level of singularity versus deviation from non-associativity b) Contours of effective stress for Drucker-Prager hardening (n=3) associative (solid line, μ=0.5 η=0.5) and non-associative material with smooth crack surfaces (dashed-dotted lines, μ=0.5 η=0.25, f=0) and frictional surfaces (dashed, μ=0.5 η=0.25, f=0.15).

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CAMBER CONTROL OF STRUCTURES USING SHAPE MEMORY ALLOYS

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Keywords: shape memory alloy, shape control, finite element modeling, optimization, smart materials

ABSTRACT

Shape memory alloys (SMAs) are materials with unique properties that today find application in many engineering fields and systems including the shape control of airfoils. Upon cooling or under the application of stress (or both), SMAs undergo a change in their crystal structure from a cubic austenitic phase to a number of martensitic variants. Subsequently, when these alloys are heated, or when the applied stress is removed, the SMA's are able to recover their original shape. These unique properties allow to use SMA tendons as actuators if they are appropriately constrained. SMAs are very efficient since they are able to produce large forces thanks to their large maximum stress capacity which is of the order of 350MPa. Furthermore, they can fully recover their shape from large strains of the order of 8%.

The paper discusses the use of SMAs for the shape control of a deformable structure, such as a truss. More specifically, we use SMA tendons in order to apply forces produced by the heating, or the cooling, of SMA tendons. Smartly positioning pairs of tendons within the structure, we are able to apply large forces by adjusting the temperature of every SMA tendon. Such a system allows to camber the structure to a target shape; a function that has applications in many engineering fields. The proposed methodology is nested in an iterative optimization algorithm that determines the temperature increment of every tendon in order to set the shape of the airfoil as closely as possible to the desired cambered configuration. The structure is modelled with the aid of the finite element (FE) method which allows to integrate the various components of the structure to a model that is material nonlinear due to the presence of the SMA tendons. The solution of the optimization problem determines for every time step the desired temperature increment of every tendon. The objective function of the optimization problem is the norm of the difference of the obtained displacements and the target shape, while the optimization algorithm is solved at every time increment with the aid of a Genetic Algorithm. The proposed algorithm is demonstrated on a simple truss structure.

INVESTIGATION OF THE POSITION OF THE PIEZOELECTRIC PATCHES ON A SHUNTED PIEZOELECTRIC BEAM

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Keywords: Smart Structures, Piezocomposites, Shunt Circuits

ABSTRACT

Smart structures with embedded sensors, actuators, or even control systems have the ability to respond and/or suppress excitations which, in turn, are caused by external and/or unknown reasons. Various smart materials such as piezoelectrics, piezoceramics, electrostrictive materials, magnetostrictive materials, etc. can be used to provide flexible structures with smart characteristics. It is noteworthy that the combination of both functions, i.e. sensing and actuation, is possible, due to the nature of the piezoelectric effect. Thus, an increasing interest in passive control of vibrations by shunted piezoelectric transducers with electrical impedances is observed during the last years. Shunt piezoelectric systems are very popular in structural damping applications [1], [2]. The main characteristic of such systems is that they can absorb vibrations and destroy the kinetic energy, by consuming it in an electric circuit which consists of resistors, inductors and capacitors. The aim of the present paper is to investigate the optimal placement of the piezoelectric patches on a shunted piezoelectric beam which consists of an elastic part and a pair of piezoelectric elements which are connected to the shunt circuits. The investigation is carried out using the tools of modal analysis for the evaluation of the different positions of the patches.

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EARLY WARNING AND HAZARD ANALYSIS SYSTEM IN REPUBLIC OF SERBIA

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Keywords: Landslide, Hazard, Report, Early-warning system.

ABSTRACT

Landslides are among the most dangerous natural threats to human lives and property, especially in times of dramatic climate change effects on one hand, and urban sprawl and land consumption on the other. Usual landslide triggers are floods and high-yield rainfall, which was the case in the catastrophic cyclone Tamara episode that stroke Serbia and surrounding countries in May 2014.

Landslide reports (in analogue form) greatly underestimated the realistic number of landslides (concentrating more on urgent/acute cases), and was uneven because they were collected by different institutions, depending on the acute needs.

In this respect, it is essential to produce unified large-scale reports of such events and use them for the state-of-the-art hazard analysis and to develop early-warning system. The actual state of affairs in this field in Serbia is presented in this paper.

MS2-Computational Techniques and Tools in Natural Disaster Risk Management

Organizers: Milan Gocić, NatRisk Erasmus+ project

EARLY WARNING AND HAZARD ANALYSIS SYSTEM IN REPUBLIC OF SERBIA

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Keywords: Landslide, Hazard, Report, Early-warning system.

ABSTRACT

Landslides are among the most dangerous natural threats to human lives and property, especially in times of dramatic climate change effects on one hand, and urban sprawl and land consumption on the other. Usual landslide triggers are floods and high-yield rainfall, which was the case in the catastrophic cyclone Tamara episode that stroke Serbia and surrounding countries in May 2014.

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In this respect, it is essential to produce unified large-scale reports of such events and use them for the state-of-the-art hazard analysis and to develop early-warning system. The actual state of affairs in this field in Serbia is presented in this paper.

SMOOTHING TECHNIQUES ON PRECIPITATION TIME SERIES

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Keywords: Forecast, smoothing, precipitation, Serbia.

ABSTRACT

One of important elements in natural hazards analysis is forecast of time series. It is necessary to prepare data before forecasting i.e. to spot and to separate the periodic component of the time series, because periodicity usually has large periods of oscillation, which can bring significant problems in interpreting obtained results. Smoothing technique which is based on removing a random component and uncovering a long-term macro-periodicity can be used for solving this problem.

This paper analyzes different smoothing techniques for precipitation time series in Serbia for the period 1946–2015. Three smoothing methods were analyzed (moving average method, exponential smoothing and Holt-Winters forecasting model) in order to investigate their applicability in analyzing of precipitation series.

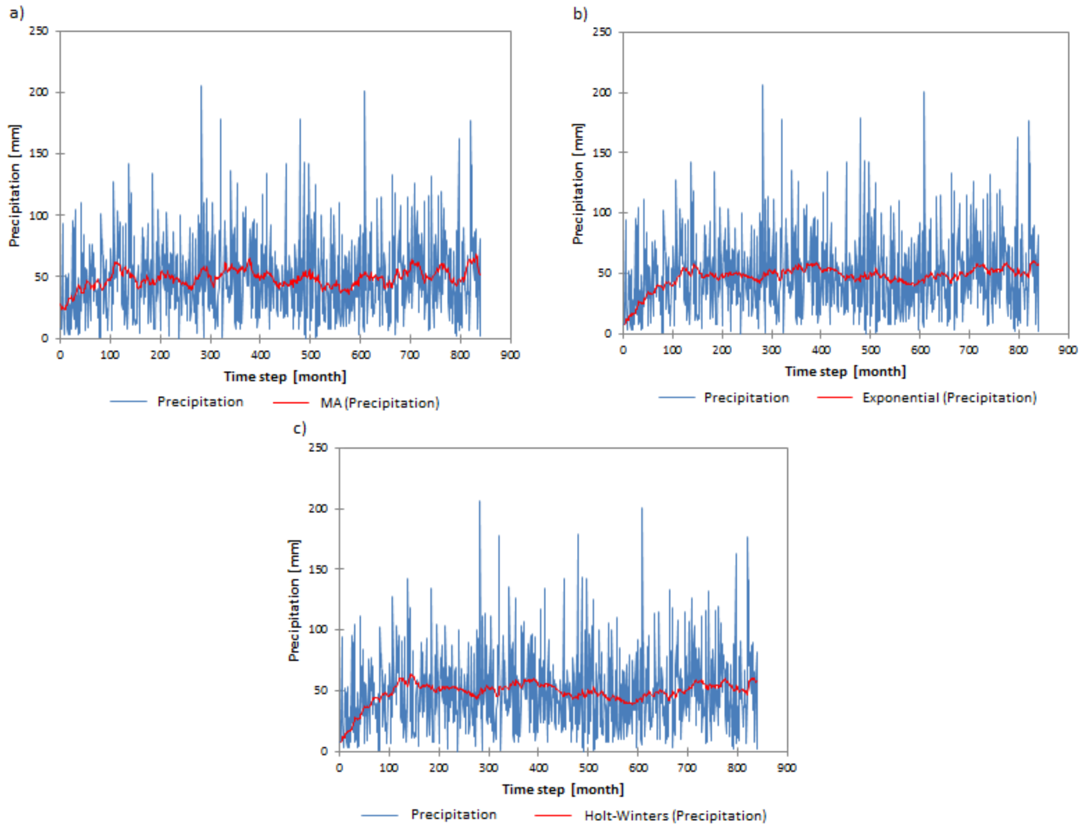

Figure 1: Results of smoothing techniques for the precipitation in Nis
a) Moving average method, b) Simple exponential method and c) Holt-Winters method.

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GIS APPLICATION IN FLOODS RISK ASSESSMENT IN LEPOSAVIC

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Keywords: flood, risk, assessment, GIS.

ABSTRACT

The paper represents the risk assessment and mapping of all rivers in Leposavic Municipality that have been flooding or have a potential for flooding of agriculture land, houses, roads, bridges and other objects. For each river, those flooded or potentially flooded surfaces are presented by category of risk (high risk, medium risk and low risk) as well as the causes of the flooding and recommendations for short term and long-term activity protection against floods. The risk assessment and mapping shows exact places where they are causing damage and also proposes activities that need to be taken to eliminate these damages. By analyzing the locations and vicinity of the human activities, it sets the river priority for intervention. This is enabled by information presented through the Geographical Information System Elements (GIS)[1] of the Water Framework Directive. Although the information presented by GIS depends on the availability of the spatial and field data, it is valuable tool in risk assessment in determining the cumulative sensitivity of the certain region to the floods[2].

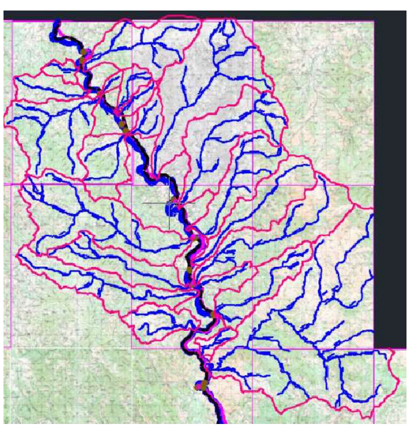

Fig.: River network of Leposavic Municipality

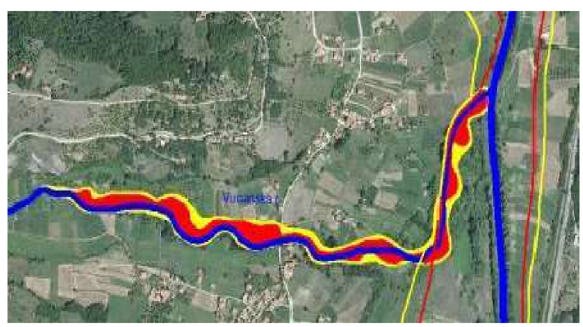

Fig.2: Vulnerable area of river Vucanska reka

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LEAD PARTICLES DISPERSION MODELING IN EXTREME WEATHER CONDITIONS FROM TAILING WASTE IN ZVEČAN

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Keywords: Wind rose, lead particles, air pollution simulation.

ABSTRACT

"Gornje polje"tailing waste deposit is situated close to the river Ibar, between Kosovska Mitrovica and Zvecan municipalities. The tailing waste was deposited from the beginning (1930) since 1983. It occupies the surface of 50 ha with 12,000,000 m^3 of waste.. The tailing waste is dry, oxidized and mostly solid. In order to estimate environmental risk, several studies were done. Based on the chemical composition it was concluded that the main risk originates from lead based particles. In the climatic conditions on site during summer and winter periods (wind rate 3.3) lead particles concentrations in the air were measured[1], and compared with the concentration range calculated by using SCREENview, Screening Air Dispersion Model. Contamination with lead bearing particles exceeding maximum limits was 2 km. Lead containing material was initially investigated by using multiple instrumental techniques, Scanning Electron Microscopy, X-Ray Diffreation and Granulometric testing[2], in order to determine diameter, shape and mineralogy of particles being dispersed by the wind. Emission rate of the particles was measured in the laboratory, where the initial values for modelling were tested. In the situation of extreme weather, the reports have recorded the maximum wind velocity of 12m/s, for three days in a roll, so that value for the wind speed was inserted into calculation. Air Dispersion model has shown that in that case, the range of pollution exceeding maximum limits will cover the area of 11 km in diameter, and it will be directed to the south, endangering large populated area.

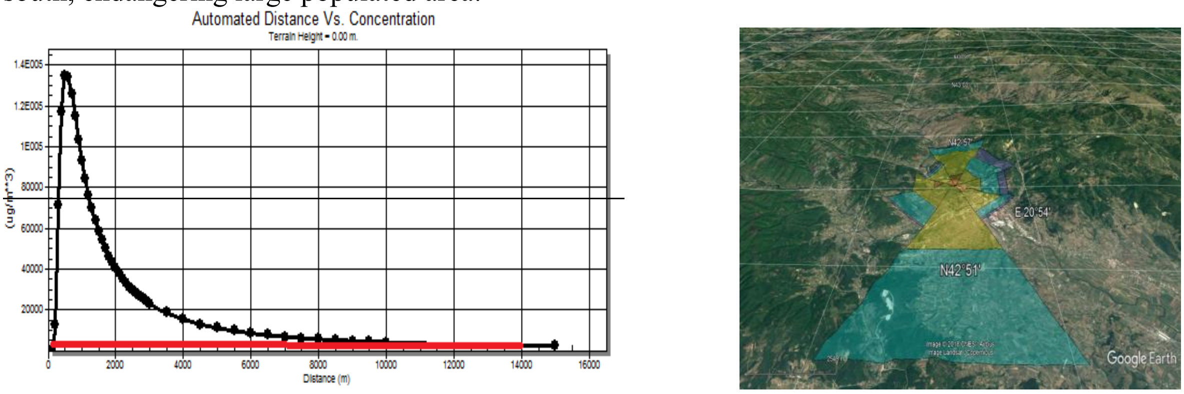

Figure 1: (a) Calculated particles dispersion. (b) Pollution coverage of the area.

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GIS EXTENSION TOOL FOR VISUALIZATION OF FLOOD RISK EVALUATIONS

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Keywords: visualization, GIS, spatial interpolation, flood, prediction

ABSTRACT

Due to unpredictable climate change, flood risk is likely to increase, so floods gain possibility of affecting large regions. This led to the development of many flood estimation systems. Previous research has proven accurate detection of rainfall is of great importance for the warning of possible flooding. In previous decades, different numerical methods for detection of precipitation using information about the received signal level of commercial microwave links are developed. Thus, it becomes possible to acquire precipitation data estimation and combine it with digital elevation models (DEM) to perform food risk evaluation for a particular area of interest. Having DEM and raster images both combined within Geo-Information Systems (GIS), it is our opinion that appropriate GIS extension tool can be developed for performing and visualizing flood risk evaluations.

In this paper, we will present experimental usage of estimated spatial distributions of ground-level precipitation within GIS-based technical platform for flood analysis and risk management. Technical platform is based on a custom developed GIS extension tool capable of providing support for diverse data types, data conversion, visualization and analysis. The GIS tool is enhanced with a data acquisition module capable of importing ground-level precipitation data generated by analyzing the attenuation of microwave signals of cellular networks. Microwave links can be observed as a type of sensor that can be used for the areas not covered by other types of meteorological sensors. The signal attenuation analysis along the lines of these links generates a good estimation of ground precipitation and this data is transformed into a set of georeferenced points associated with expected rainfall amount. GIS tool imports this data into a kriging module that implements an advanced geostatistical procedure whose purpose is to generate a spatial interpolation of given rainfall data and generate estimated precipitation surface which covers the whole space under analysis. Once the surface is generated, GIS tool calculates the overall amount of rainfall for the area covered with microwave links. The overall rainfall amount is the input needed for flood analysis to be possible. GIS tool integrates DEM model of the observed area and uses it to determine the point with lowest elevation in observed area that is used as a starting point for flood fill algorithm implemented within GIS tool. GIS tool simulates flooding in iterations by increasing the reached water level at the point with lowest elevation while population the rest of the area according to flood fill algorithm. After each iteration, the amount of water used for filling the area is checked against the total amount of rainfall estimated by kriging algorithm. Once the total amount of rainfall is reached, the simulation ends and GIS tool visualizes the area expected to be flooded.

Session A2-1

NUMERICAL SOLUTION OF VARIABLE ORDER FRACTIONAL DIFFERENTIAL EQUATIONS. APPLICATIONS TO MECHANICS

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Keywords: Variable Order Fractional Derivative; Numerical Solution; Variable Order Fractional Oscillator.

ABSTRACT

A method for the numerical solution of variable order (VO) fractional differential equations (FDE) is presented. It applies to explicit and implicit linear as well as to nonlinear VO FDEs. Although the extension from constant-order FD to VO FD may seem somewhat natural and several systems have been modeled with VO FDs due to its advantages [1], this idea has been advanced only very slowly. Apparently, this extension may be have been prevented by the difficulty to obtain solutions to VO FDEs.

The Caputo type FD is employed for its advantages over other types of FDs

$$D^{\alpha(t)}u(t) = \frac{1}{\Gamma[1-\alpha(t)]}\int_0^t (t-x)^{-\alpha(t)}\dot{u}dx\,, \qquad 0 < \alpha(t) \le 1,\;\; t > 0 \tag{1}$$

where $a(t)$ is the variable order of the FD, which may depend on time t (explicit VO FD) or also on the field function or its derivatives (implicit VO FD).

The integral in Eq. (1) is approximated using the AEM as in [2]. This yields the following expression to approximate the VO FD

$$(D^{\alpha(t)}u)_n = c_1^n\dot{u}_1^m + c_2^n\dot{u}_2^m \ldots + c_n^n\dot{u}_n^m\,, \qquad \dot{u}_r^m = (\dot{u}_{r-1} + \dot{u}_r)\,/\,2\,, \qquad r = 1,2,\ldots,n \tag{2}$$

where

$$c_r^n = \frac{1}{\Gamma[1-\alpha(nh)]}\int_{(r-1)h}^{rh}(nh-x)^{-\alpha(nh)}dx, \qquad r = 1,2,\ldots,n \quad n = 1,2,\ldots,N \tag{3}$$

Eq. (2) provides the key for the solution of VO FDEs. The method is stable and simple to implement numerically. It is illustrated with the solution of VO FDE describing the response of the VO fractional oscillator

$$a_1\ddot{u} + a_2 D^{a(t)}u + a_3 u = p(t), \qquad u(0) = u_0,\; \dot{u}(0) = \dot{u}_0 \tag{4}$$

for $a(t) = d - k(1-\exp(-t)$ (explicit VO FDE) and $a(t) = d - k\tanh(|\,\dot{u}\,|)$ (implicit VO FDE); d, k constants.

Application of the developed numerical scheme yields the system of the nonlinear algebraic equations

$$a_1 q_n + a_2(c_1^n\dot{u}_1^m + c_2^n\dot{u}_2^m \ldots + c_n^n\dot{u}_n^m) + a_3 u_n = p_n \tag{5a}$$

$$\begin{bmatrix} -h & 1 \\ 1 & 0 \end{bmatrix}\begin{Bmatrix} \dot{u}_n \\ u_n \end{Bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}\begin{Bmatrix} \dot{u}_{n-1} \\ u_{n-1} \end{Bmatrix} + \begin{bmatrix} -\dfrac{c_1}{2} \\ \dfrac{c_2}{2} \end{bmatrix} q_n + \begin{bmatrix} -\dfrac{c_1}{2} \\ \dfrac{c_2}{2} \end{bmatrix} q_{n-1} \tag{5b}$$

which is solved recursively for $n = 1,2,\ldots,N$. The obtained results validate the efficiency and accuracy of the developed method.

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A NEW BOUNDARY ELEMENT SOLUTION TO PLATES ON ELASTIC FOUNDATION VIA HELMHOLTZ'S POTENTIALS

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Keywords: Boundary Element Method; Plate on elastic foundation; Helmholtz' potentials representation.

ABSTRACT

A new BEM is presented for the analysis of plates on elastic foundation. Their response is governed by the equation [1-3]

$$D\nabla^4 w - G\nabla^2 w + kw = f(x,y)\,, \qquad x,y \in \Omega \tag{1}$$

$w(x,y)$ is the deflection surface, $f(x,y)$ the transverse load, and G,k the subgrade parameters ($G \neq 0, k \neq 0$ Pasternak, $G=0, k\neq 0$ Winkler elastic foundation).

The solution is sought as the sum of the homogeneous solution w_0 and a particular solution w_p

$$w = w_0 + w_p\,, \qquad D\nabla^4 w_0 - G\nabla^2 w_0 + kw_0 = 0\,, \qquad D\nabla^4 w_p - G\nabla^2 w_p + kw_p = f(x,y) \tag{2a,b,c}$$

The homogeneous solution is obtained as a sum of two Helmholtz potentials $\phi(x,y), \psi(x,y)$

$$w_0(x,y) = \phi(x,y) + \psi(x,y) \tag{3}$$

which are expressed by their integral representation in terms of the boundary values and the normal derivatives [4]

$$\varepsilon_1\phi = \int_\Gamma (v_1\phi_{,n} - \phi v_{1,n})ds\,, \qquad \varepsilon_2\psi = \int_\Gamma (v_2\psi_{,n} - \psi v_{2,n})ds \tag{4a,b}$$

where v_1 and v_2 are the fundamental solutions of the Helmholtz and modified Helmholtz equation, Eqs. (4a,b), and $\varepsilon_1, \varepsilon_2$ the free term coefficients. The particular solution $w_p(x,y)$ is evaluated analytically using a simple method developed by Katsikadelis [5].

The two boundary conditions for the plate problem together with the boundary integral equations (4a,b) provide a set of four boundary equations, which are solved numerically to give the Helmholtz potentials, hence the solution of the plate problem.

The search for the solution via Helmholtz's potentials, motivated from the Almansi representation of the biharmonic equation [6], paves the path for the development of a pure BEM for any order the poly-harmonic equation

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A PARALLEL ALGORITHM FOR THE EMBEDDED REINFORCEMENT MESH GENERATION OF LARGE-SCALE REINFORCED CONCRETE MODELS

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Keywords: Parallel Algorithms, Embedded Reinforcement, Mesh Generation, Large-Scale Models.

ABSTRACT

Modeling of large-scale reinforced concrete structures[1] under monotonic and cyclic[2] analysis requires significant computational demand given that models can incorporate hundreds of thousands of embedded rebars. In order to discretize and simulate any reinforced concrete structure by the 3D detailed modeling approach[3], the embedded mesh has to be generated prior to the analysis, a procedure that is controlled by the hexahedral mesh that is used to discretize the concrete domain.

Numerically managing the computational demands that rise from the embedded mesh generation procedure can be challenging and time-consuming, especially in the case where the numerical models foresee the use of more than half a million of embedded rebars[1]. Parallel processing and the use of a simple but efficient algorithmic implementation are presented in this research work. The use of OpenMP API for Shared Memory Parallelization specifications is adopted herein so as to integrate the proposed embedded mesh generation algorithm[1] with the ability to use multiple cores during the search and creation of embedded rebars within large-scale hexahedral meshes. In order to investigate the performance of the proposed algorithm, a reinforced concrete model of a Reactor Building was constructed that foresees the use of 181,076 concrete hexahedrons and 2,703,400 embedded rebar elements.

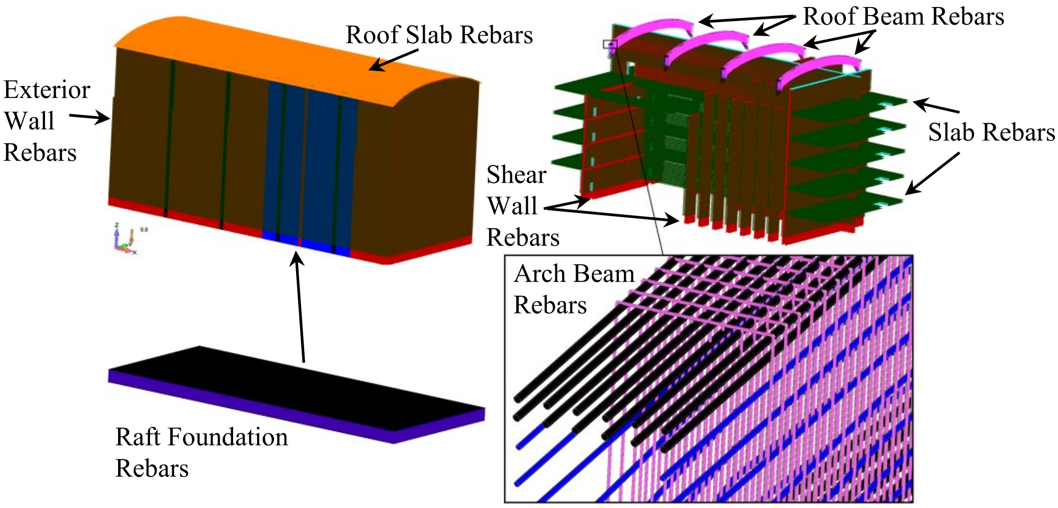

Figure 1 Reactor Building. Embedded rod element finite element mesh.

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REVISION OF BEAM MODELING WITH LARGE ROTATIONS

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Keywords: manifold SO(3), invariant formulation, non-linear finite elements.

ABSTRACT

Beam modeling is used in the deformation and motion analysis of slender structural members. In this work, the state of the art concerning the essential rod theory in non-linear regime is summed up. The basic assumption is that the plane of the cross-section remains planar and rigid, and the material is homogeneous, isotropic and linear elastic.

A geometric illustration on the rotation manifold SO(3) is given, through the comparison of two formulations describing the orientation change of the cross-section, the first that uses additive rotation increments[1] and the second that uses spin increments[2]. The invariance properties, i.e. the objectivity and path-independence, are satisfied in the latter case, where the whole rotation is shown on the manifold as it is split into an elemental and a local cross-sectional spin relatively to the element.

Two finite element formulations are derived as well, and used in benchmark examples. In the second one, the interpolation is performed for the local spins of the nodes, which refer to the same tangent space; this idea leads to the invariance of the formulation. The test cases show clearly that the strain energy is not distorted, neither due to the rigid motion (objectivity), nor due to the path that has been followed (path-independence).

Thus, the comparison between the two formulations will help a researcher, who is ensuing research in this area, to realize the numerical procedures that have to be followed in the construction of any invariant model with large rotations.

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ADOMIAN DECOMPOSITION METHOD FOR FIRST ORDER PARTIAL DIFFERENTIAL EQUATIONS WITH PIECEWISE DATA

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Keywords: Adomian decomposition, semi-analytic method, meshfree, exact solution, first order partial differential equation, Riemann problem, piecewise data, method of characteristics.

ABSTRACT

The Adomian decomposition method (ADM) is a very powerful technique to solve nonlinear problems, including ordinary differential equations, partial differential equations (PDEs), differential-algebraic equations, differential-difference equations, integro-differential equations, stochastic systems and eigenvalue problems, etc. It is well known in literature that this method gets the rapidly convergent series solution and is a typical semi-analytic method with meshfree. For certain problems it even becomes an analytic method that captures the exact solution.

But ADM is not perfect. It is purely algebraic manipulation to compute solution without knowing geometry and physical meaning. We will show ADM has trouble to solve Riemann problems alone. Therefore the method of characteristics is chosen to assist ADM and overcome ADM's weakness. This combination is capable to deal with first order PDEs, linear and quasi-linear, with nonsmooth variables or piecewise initial/boundary conditions. Our numerical experiments show the proposed combined method for Riemann problems is far more accurate, reliable and efficient than existing traditional methods.

MS3-Optimization in Structural Mechanics via Metaheuristic Algorithms

Organizers: Gebrail Bekdaş, Aylin Ece Kayabekir

THE ANALYSES OF SPATIAL CABLE STRUCTURES EMPLOYING NEW GENERATION METAHEURISTIC METHODS

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Keywords: Cable structures, TPO/MA, Metaheuristic methods, Structural analyses.

ABSTRACT

By using minimization of the total potential energy theory and metaheuristic methods (TPO/MA)[1], the solution of degrees of freedom of cable structures can be found for the solution with minimum energy. In this study, new generation metaheuristic methods (Flower Pollination Algorithm: FPA and Teaching Learning Based Optimization: TLBO) were used in finding the solution of cable structures. The results were compared with the Harmony Search (HS) algorithm.

The model of the numerical example is shown in Fig. 1. The structural system consists of 38 cable elements with 160 kN/m^2 elasticity modulus. Concentrated loads with 6.8 kN intensity are applied to all inner nodes in z direction. The cross sectional areas of elements are 350 mm^2 and 120 mm^2 in x and y directions, respectively. The pre-stress loads are 90 kN and 30 kN for the elements in x and y direction, respectively. Since the system is symmetric, quarter model is investigated for the solution.

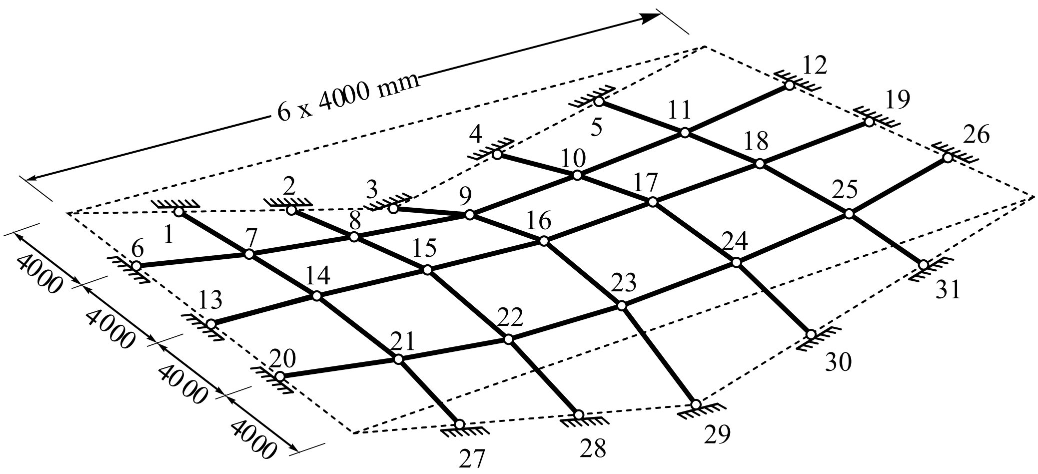

Figure 1: The cable structure.

The minimum total potential energy was found as 6.515x10^6 Nmm for FPA and TLBO while the minimum energy is 6.517x10^6 for the HS based methodology. The iteration of generation of solution was done for 430000 times. The best results are obtained at 10240th and 9330th iterations for FPA and TLBO, respectively. HS is not effective to find the same best solution with FPA and TLBO in 430000 iterations.

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METAHEURISTIC METHODS IN STRUCTURAL ENGINEERING BENCHMARK PROBLEMS: THE WEIGHT OPTIMIZATION OF CANTILEVER BEAMS

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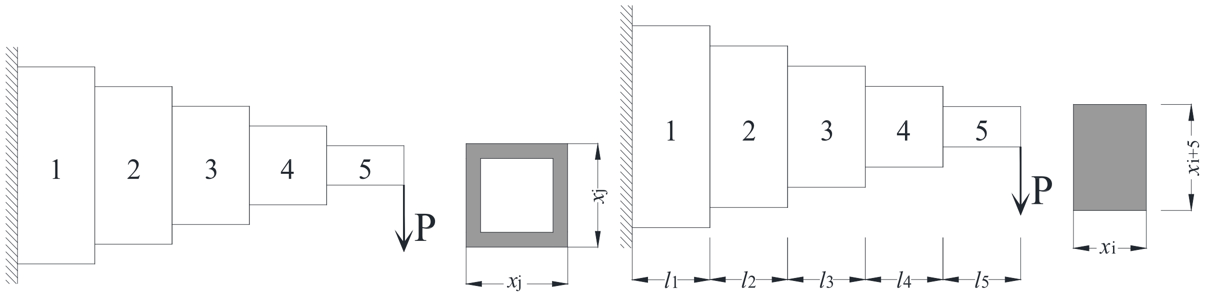
Keywords: Metahuristic methods, Optimization, Cantilever beams.

ABSTRACT

In structural engineering, the optimum design problems are nonlinear because of the design constraints which are highly depended to the design variables. For that reason, deriving optimum design formulations may be hard or impossible. In this study, two weight optimization of cantilever beams examples which are benchmark problems, are presented.

The first example developed Fleury and Braibant[1] is shown in Fig. 1a and the optimization problem has five design variables (x_j for j=1 to 5 for different cross sections). The problem is optimized for an objective function, which is the minimization of the weight of the beam. The optimization is subjected to a deflection constraint at the end point. By using Flower Pollination Algorithm (FPA)[2], the minimum objective function value is found as 1.33997, which is the best value in the previously considered methods. The second cantilever beam optimization problem (Fig. 1b) was originally given by Thanedar and Vanderplaats[3] has 10 design variables such as the widths (x_i for i=1-5) and the heights (x_{i+5} for i=1-5) of the cantilever beam. The objective of the optimization problem is to minimize the volume of the beam subjected to 5 stress constraint, a deflection constraint and 5 constraint considering the ratio of width and height of the cross sections.

In the final study, the numerical examples will be optimized by using several metaheuristic algorithms (for example; Particle Swarm Optimization, Harmony Search, Jaya Algorithm, Teaching Learning Based Optimization, Grey Wolf Algorithm) and the robustness of these algorithms will be evaluated by running the optimization process for 30 times.



(a) (b)

Figure. 1: The cantilever beam (a) Example 1 (b) Example 2

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THE PERFORMANCE OF METAHEURISTIC ALGORITHMS ON WEIGHT OPTIMIZATION OF TRUSS STRUCTURES BY USING DIFFERENT GROUPING OPTIONS

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Keywords: Truss structures, Optimization, Metaheuristic methods.

ABSTRACT

The weight optimization of truss structures is the most popular application area of metaheuristic methods in structural mechanics. Generally, all newly developed algorithms are proposed for the problem and these algorithms are tested on benchmark problems. An algorithm may be more effective in finding a better solution than the others, while another one may outperform the others in another structural model. In the optimum design, the members of truss structures are grouped and the number of design variables is reduced. In that case, the metaheuristic algorithm can easily find the best solution. In the benchmark problems, the improvement of the minimum cost is generally very small. For example, the improvement may be only in decimal values while the weight of a 200 bar truss structure is nearly 25000 lb. Also, the optimum design variables are found as very sensitive values (too many decimal places) in computational optimization. Whereas, the optimum values are also presented in studies in less decimal places and the design constraints may be violated.

In this study, metaheuristic methods such as Jaya algorithm (JA)[1] and Flower Pollination Algorithm (FPA)[2] are employed for the weight optimization of trusses by using different grouping options for the members. Thus, really improved minimum weights of the truss structures are found. The weight optimization is done for two space structures (25 bars and 72 bars as seen in Fig. 1) and a plane structure (200 bar). The performances of the algorithms are tested on the different numbers of member grouping.

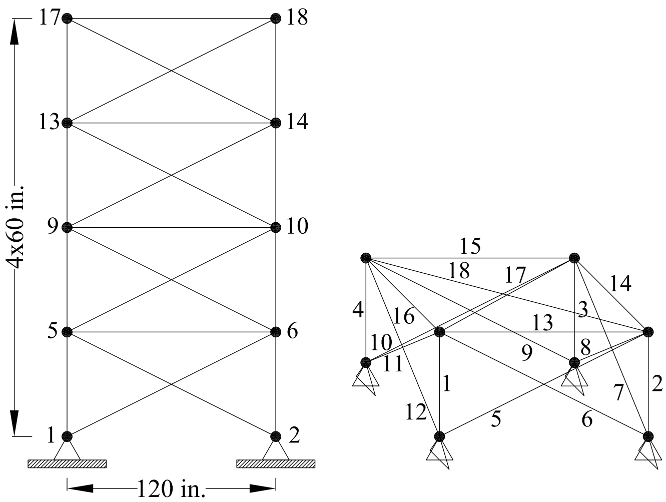

Figure 1: 72-bar truss structure[3]

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OPTIMUM COST DESIGN OF WELDED BEAMS BY JAYA ALGORITHM AND FLOWER POLLINATION ALGORITHM

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Keywords: Welded beam, Optimization, Jaya Algorithm, Flower pollination algorithm.

ABSTRACT

Optimization is needed for all mechanical and structural engineering designs. For structural members, the optimization is a non-linear problem because of the existing design constraints needed for the safety. The non-linear design optimization problems have been solved by using metaheuristic methods. In this study, a welded beam design problem which is given by Rao[1], is optimized by using two different metaheuristic methods such as Flower Pollination Algorithm (FPA)[2] and Jaya Algorithm (JA)[3] and the results are compared with the other methods. These two algorithms have been excellently applied to several engineering optimization problems. FPA inspired from the pollen transfer process of flowering plants and uses two types of pollinations (global and local) according a switch probability. JA uses only a single phase considering the best and worst existing solutions.

In the problem, the beam is welded to a member with an applied force (P) at the end. The four design variables of the problem are x_1, x_2, x_3 and x_4, which are height of weld (h), length of weld (l), breadth of member (b) and thickness of the member (t), respectively. The objective function (f(x)) is the minimization of the cost of the welding as seen in Eq. (1).

$$\text{Minimize} \quad f(x) = 1.10471\, x_1^2 x_2 + 0.04811\, x_3 x_4 (14.0 + x_2) \tag{1}$$

The problem is subjected to seven design constraints which are related to the shear stress (τ(x)), bending stress (σ(x)), buckling load on the bar ($P_c(x)$), end deflection of the beam (δ(x)) and side constraints. These constraints are as follows:

$$g_1(x) = \tau(x) - 13000 \le 0 \tag{2}$$
$$g_2(x) = \sigma(x) - 30000 \le 0 \tag{3}$$
$$g_3(x) = x_3 - x_4 \le 0 \tag{4}$$
$$g_4(x) = 1.10471\, x_1^2 + 0.04811\, x_3 x_4 (14.0 + x_2) - 5.0 \le 0 \tag{5}$$
$$g_5(x) = 0.125 - x_1 \le 0 \tag{6}$$
$$g_6(x) = \delta(x) - 0.25 \le 0 \tag{7}$$
$$g_7(x) = 6000 - P_c(x) \le 0 \tag{8}$$

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SYMBIOTIC ORGANISMS SEARCH BASED OPTIMAL DESIGN OF STEEL RIGID FRAMES

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Keywords: Steel Rigid Frames, Structural Optimization, Metaheuristics, Symbiotic Organisms Search.

ABSTRACT

Optimal design of steel rigid frames has always been the indispensable desire of structural engineers. On the other hand, this demand was remained unsatiated until the intense utilization of computers and stochastic search techniques come in to the view in structural design. This was by virtue of the fact that conventional methods were not capable of coping with having the satisfying solutions for optimum design of real-sized structures like steel rigid frames. Afterwards, for last three decades, various numbers of novel nature inspired metaheuristics have been improved on structural optimization field in an unpredictable manner. This enhancement bring out rapid development of so many novel structural optimization techniques which has given sufficient confidence to structural engineers to consider more practical designs. The main gist lies behind those techniques is that those methods borrow their essential ideas from natural phenomena such as process of annealing, natural evolutionary processes, foraging of animals, human memory and brainstorming, performance of a musician, and so forth. The stochastic search based optimization algorithms effectively explore the search space to determine an optimal solution without needing any gradient information. Unlike gradient-based methods, metaheuristics make use of the probabilistic transition rules, which leads to very powerful and robust search mechanisms because the randomness of these methods makes the algorithm converge a different final solution in each case.

Generally, the principle objective of the structural design problems is to find the minimum weight in an economical way. So, those kind of minimum weight design problem turns out to be a nonlinear programming problem which is very hard to solve by using classical methods that are time consuming, as well. The most practical and economical way for obtaining such kind of complex programming problems is utilizing one of the recent metaheuristic algorithms. The novel addition to metaheuristic algorithms is so-called Symbiotic Organisms Search (SOS) proposed by Cheng and Prayogo[1]. This technique is based on the interactions relationship between two organisms in ecosystems. The mostly common symbiotic relations between the organisms in ecosystem are mutualism, commensalism, and parasitism. Mutualism is a symbiosis relationship in which both organisms benefits. Commensalism is symbiosis in which one organism benefits and the other is not harmed or helped. If in an interaction one organism benefits and other organism harmed, the relation is called Parasitism. Based on the principles of biological interaction in ecosystem mutualism phase, commensalism phase, and parasitism phase are developed[2]. In this paper, the SOS algorithm has been examined for real-sized steel rigid frames whose economical solutions are the most challenging and has proved to be a superior performer with other old-fashion metaheuristics.

OPTIMAL DISCRETE DESIGN OF STEEL TRUSS SYSTEMS USING SYMBIOTIC ORGANISMS SEARCH

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Keywords: Steel Rigid Frames, Structural Optimization, Metaheuristics, Symbiotic Organisms Search.

ABSTRACT

Nowadays, structural designers are very comfortable by using optimization algorithms which are powerful tools for obtaining the optimal structure under certain design limitations. From past to present, design of steel truss systems is the one of the most attractive constructional subject in which challenging mathematical programming methods are utilized to extract the formulations and to yield the optimum design. Metaheuristic algorithms have appealed great interest since they have excellent talent to procure a solution for discrete optimum design problems; e.g. steel truss systems. In this study, a Symbiotic Search Organisms (SOS) algorithm is represented to reach the optimum steel truss design by minimizing the structural weight via selecting the cross-sectional properties of truss members from a standard set of available profile lists. Symbiotic Organism Search (SOS) has been recently enhanced among metaheuristic optimization techniques and also, it has very increasing popularity in order to have ability of solving complex numerical optimization problems as steel truss systems. SOS algorithm simulates the one of the famous natural phenomena which is the symbiotic relationships (mutualism, commensalism, and parasitism) between organisms in an ecosystem. SOS algorithm includes five main steps; at the first step, an ecosystem should be conceived. This is called a population of organisms. By detecting the best organism, the fitness value for each organism is calculated. In the second step, the stages of biological interaction between the best organism and an organism are carrying out so as to execute random selection of the ecosystem. At last step, the next generation is created and the ecosystem is updated. Both termination criteria and the size of the ecosystem are checked whether give an end to optimization process or not. If one of the termination criteria is met then the best organism is kept as optimum solution. Otherwise, SOS returns to second step and iterates the process until termination criteria is met[1]. In this study, to find the optimal discrete design of steel truss systems, one of the most recent and innovative metaheuristic search techniques, so-called SOS algorithm, is presented which is not suffering the discrepancies of mathematical and gradient-based optimum design methods.

OPTIMUM DESIGN OF REINFORCED CONCRETE FOOTINGS UNDER AXIAL LOADING USING DISCRETE AND CONTINUOUS DESIGN VARIABLES

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Keywords: RC footing, Optimization, Metaheuristic Algorithms.

ABSTRACT

In this study, the optimum design of reinforced concrete (RC) footings is investigated by using discrete and continuous variables. The optimization methodology employs metaheuristic algorithms in development of candidate solutions.

The optimum sizing and reinforcement design of reinforced concrete (RC) footings is investigated by using several metaheuristic algorithms. The design methodology contains two state limits such as geotechnical and structural ones as design constraints and the codes of American Concrete Institute[1] (ACI318) are considered. The metaheuristic algorithms such as Flower Pollination Algorithm (FPA)[2], Teaching Learning Based Optimization (TLBO)[3] , Jaya Algorithm (JA)[4] and a hybrid algorithm (JA1SP) are employed. JA1SP use the single phase of JA and student phase of TLBO by considering a probability to choose a phase. The total material cost of RC footing is the design objective and it is penalized with a big value (10^6 \$) if the constraints are violated. In Fig. 1, the optimized RC footing is shown with the design variables. X_1-X_3 are dimensional design variables while X_4 and X_5 are the sizes of reinforcement bars and X_6 and X_7 are the distances between bars.

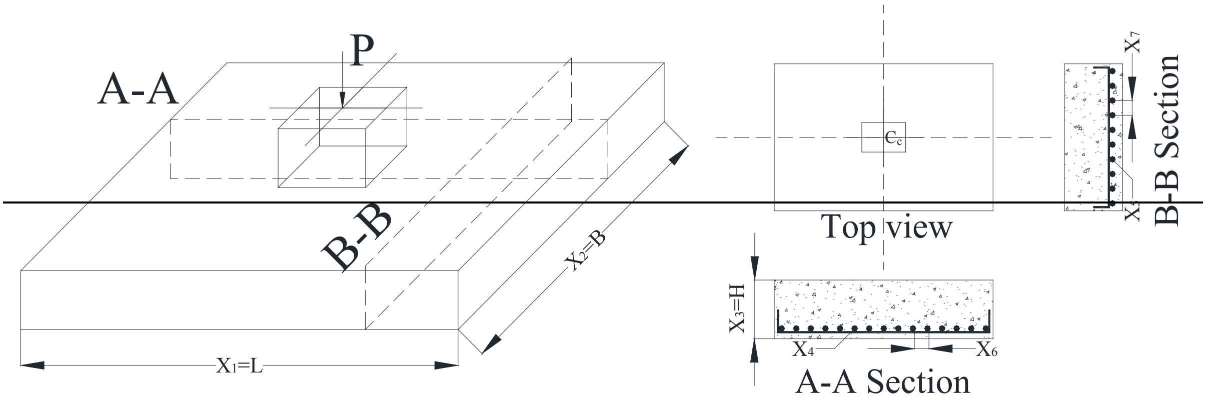

Figure. 1. The optimization problem with design variables

Since the possible results of design variables are less in discrete optimization, all algorithms are effective on finding the same results with a little computational effort and robustness (except FPA). In continuous optimization, the developed hybrid algorithm (JA1SP) has significant contribution in finding the best result immediately and robustly.

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Session A2-2

APPLICATION OF THE FINITE SUPERELEMENT METHOD FOR THE DOUBLY PERIODIC FUNCTIONALLY GRADED SOLID CALCULATION

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Keywords: finite superelement, Bernstein polynomials, elasticity, functionally graded material, doubly periodic medium.

ABSTRACT

The well-known finite element method is not effective in case of continuously heterogeneous media, such as functionally graded solids. But single finite superelement [1] can represent an inhomogeneous region, dependently of superelement's basis power.

In the paper, a numerical model of a functionally graded elastic medium by the finite superelement method is constructed. The superelement is developed by meshless method [2] and based on Bernstein polynomials [3]. A number of problems of the theory of elasticity are considered: doubly periodic media are constructed from one or two types of characteristic regions under external loadings.

The first heterogeneous region is a central damaged area; the second one is a central distributed inclusion. Several doubly periodic combinations of these regions were considered. Stress-strain states are obtained (an example of stress states are shown in fig. 1, 2).

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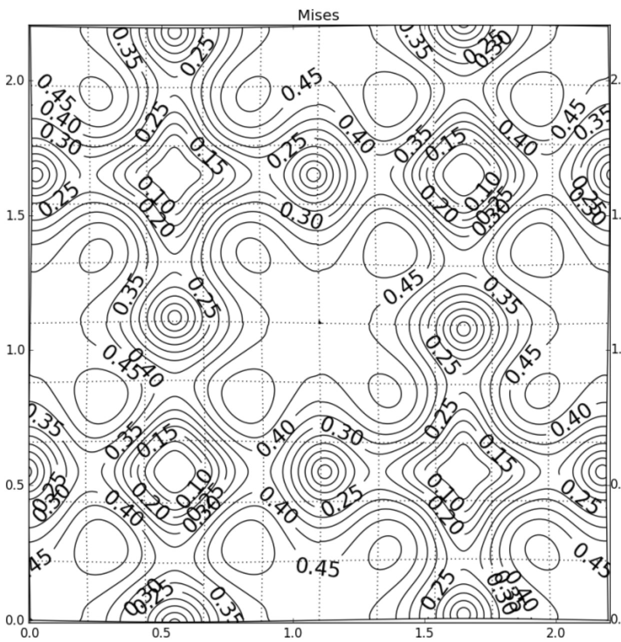

Fig. 1. Von Mises' stress [MPa]

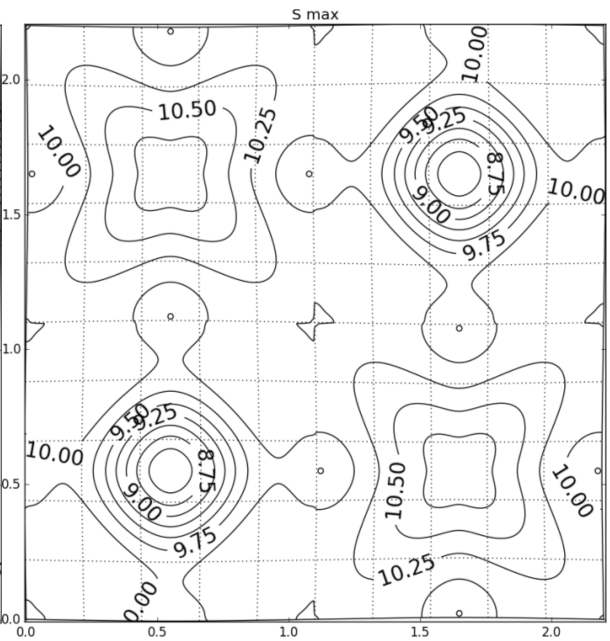

Fig. 2. Maximal tensile stress [MPa]

INVESTIGATION OF SUPPORT CONDITIONS BETWEEN STACKED REINFORCED CONCRETE BEAMS USING EXPERIMENTAL MODAL ANALYSIS AND FINITE ELEMENT METHODS

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Keywords: Beam junctions, finite element method, Experimental modal analysis, Modal assurance criterion, Contact stiffness.

ABSTRACT

The prediction of vibration transmission in collapsed and fragmented reinforced concrete buildings has the potential to inform decisions about the possibility to detect human survivors trapped in buildings after earthquakes by using structure-borne sound propagation. This paper focuses on the investigation of the support conditions between two stacked reinforced concrete beams using experimental modal analysis and finite element methods. Finite element models of five different junctions of two beams with surface-to-surface and edge-to-surface support conditions between the beams, were developed in Abaqus and validated against the results of experimental modal analysis, in terms of eigenfrequencies and mode shapes. It is shown that the contact between the two beams in each junction is elastic and that the value of the contact stiffness is independent of the shape of the junction.

EFFECTS OF THERMAL DEFORMATION ON THE BUCKLING RESISTANCE OF STEEL FRAMED MEMBERS EXPOSED TO FIRE

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Keywords: Fire design, Transient analysis, Coupled-field analysis, Thermal deviation, Load bearing capacity

ABSTRACT

The accidental situation of fire in steel members lead to changes their physical and mechanical properties when temperature is significantly increasing during time. According to Eurocode 3, the critical load of a steel member at uniform temperature increase is defined by using a reduction factor to the load bearing capacity properties. The effect of the thermal deformation resulting from thermal gradients across the cross-section due to different insulating condition at each side could change the bearing capacity of the steel member. In order to determine the influence of this thermal deviation to the critical design load of a steel member an advanced calculation scheme is herein proposed. This scheme combines a transient thermal analysis of the steel section exposed to fire with a coupled field structural analysis of the respective critical steel member including different thermal load action across the cross-section. In the present paper a steel column in a certain fire compartment of a building is studied. The overall analysis of both models has been made by the ANSYS computer software.

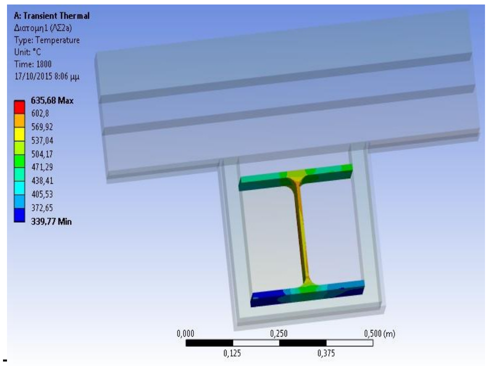

Figure 1. Temperature distribution on the cross section of a steel column in the thermal analysis model.

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A FIBER APPROACH TO THE LARGE DEFLECTION ANALYSIS OF BEAMS BY BEM

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Keywords: Nonlinear analysis, Boundary Elements, Beam.

ABSTRACT

The objective of this paper is to present a new fiber approach to the large deflection analysis of initially straight Euler-Bernoulli beams by the Boundary Element Method (BEM). The large deflection theory result from the nonlinear kinematic relation, which retains the square of the slope of the deflection, while the strain component remains still small compared with the unity. Thus, the beam undergoes large displacements with small strain and moderate rotations (intermediate nonlinear theory) under general boundary conditions which may be nonlinear. The formulation of the problem is in terms of the axial and transverse displacements while the two governing equations are coupled and nonlinear. The obtained coupled system of nonlinear differential equations is solved using the Analog Equation Method (AEM), a BEM-based method[1]. According to the AEM, the two coupled nonlinear differential equations are replaced by two equivalent uncoupled linear ones pertaining to the axial and transverse deformation of a substitute beam with unit axial and bending stiffness subjected to fictitious load distributions under the same boundary conditions.

Although a direct solution to this problem has already been presented[2], in this work an alternative fiber approach is proposed. In this approach, a discretization is being applied in both the longitudinal diection and the cross-sectional plane and an iterative numerical process is commenced. First, initial fictitious load distributions are assumed at beam's each cross-section and the displacements and their derivatives are computed using the AEM. Consequently, the two stress resultants - i.e. the axial force and bending moment - are evaluated by appropriate integration over the cross-section. In the end, the derivatives of the stress resultants are evaluated and the equilibrium of the governing equations is checked. If the equilibrium is satisfied, the process is terminated. Otherwise, the fictitious load distributions are updated and the procedure starts over again. Several representative examples are studied and the results are compared to those taken from the literature validating the reliability and effectiveness of the proposed method.

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FINITE ELEMENT ANALYSIS OF AGGREGATED ELONGATED VAULTED STRUCTURES

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Keywords: finite elements, masonry, structural dynamics, vaulted structures

ABSTRACT

Aggregated buildings represent an important and typical peculiarity in many old town centers. They consist of buildings in continuity with common walls in between them, which lead to a structural dynamic behaviour as a group. The same structural system appears in old monastic and agricultural or arsenal complexes.

The experience of earthquakes which affected old town centers with masonry aggregated buildings creates the need to analyze the behavior of these systems, taking into account the specific geometric characteristic, structural materials and boundary conditions. Their dynamic response relates with the stiffness of each building separately as well as the stiffness of the overall complex.

Analysis of historical aggregated buildings is important to understand the way the structure behaves and to understand the origin and significance of the cracks, if they are visible. Only with a good comprehension of both aspects can the engineer or architect take decisions about the techniques of conservation which could be used. In parallel, in study of one building of aggregated buildings with absence of data about the adjacent buildings, a lot of many queries appear on the simulation. The increasing interest in historic architectural heritage and the need for conservation of historical structures has led to the continuous development of many methods for the analysis of masonry structures and especially the vaults.

The aim of this research is the static and dynamic analysis of the existing state (taking into account the structural pathology) of part of a monastic share studied by the finite element method in order to document the causes of its deterioration. There are two elongated vaulted spaces where the transverse wall has collapsed and there is a visible crack in the one vault. With respect to the longitudinal walls, one is compact with only a small door opening, the other consisting of a system of arched structures that are supported by large pillars. In our study different finite element models are analyzed in order to simulate each vaulted structure separate or connected, in order to study the dynamic behaviour of these buildings in continuity.

The absence of symmetry to the construction, due to differences of the transverse walls, the differences to stiffness of the longitudinal walls and the different boundary conditions, led to necessity of three dimensional modeling of the structure. Because the study takes place at the macro level, it was assumed that the masonry walls are composed of homogeneous and isotropic continuum low tension material with elastic-plastic behaviour in compression. A parametric investigation was done on the influence of modelling various parameters like weak material areas, crack and boundary conditions to the dynamic behaviour.

MS4-Passive, Active and Semi-Active Control of Seismic Structures

Organizers: Sinan Melih Nigdeli, Seda Öncü Davas

THE ROBUSTNESS OF OPTIMUM TUNED MASS DAMPERS DESIGN USING TRANSFER FUNCTION AMPLITUDE AND JAYA ALGORITHM

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Keywords: Tuned mass damper, Jaya algorithm, Transfer function.

ABSTRACT

The optimization of tuned mass dampers for structures is a s tochastic problem because of existing of damping. In that case, heuristic algorithms are useful tools in that field for an objective function in frequency or time domain. In the present study, the transfer function response of structures are minimized by using TMDs optimized by the developed methodology employing the newly developed Jaya algorithm (JA) which is a recently proposed simple but powerful algorithm. The numerical experiments on methodology are presented by using 10 story and 40 story structures with comparison of other algorithms such as harmony search (HS), flower pollination algorithm (FPA), teaching learning based optimization (TLBO) and two new versions of Jaya algorithm with Lévy flights. The first hybrid algorithm (JALF) uses Lévy distribution (LD) instead of linear distribution. The other one (2PJA) uses two phases with LD and linear distribution.

The numerical examples involve two shear buildings which are 10-story and 40-story structural models. The mass of the TMD is limited in order to prevent the extreme increase of the axial loads of the structure. Also, the other design variables are searched in a solution range in order to find optimum results easily. The mass of the TMD (m_d) must be less than 10% of the total mass of the structures. The lower bound for m_d is 1%. The period of the TMD (T_d) is between 0.8 and 1.2 times of the critical period of the structure. The damping ratio (ξ_d) is between 1% and 30%. The total mass of the 40-story structure may be too much, for that reason, the maximum mass ratio is taken as 2% for a second case.

All algorithms are effective in finding the optimum TMD parameters minimizing the maximum amplitude of the top story acceleration transfer function (TF_N). The main factor of the comparison of the algorithms are the required computational effort which is the best for FPA and the classical JA. On the contrary, the variants such as JALF and JA2P are worse than the classical JA. For the 40- story structure, JA is better than FPA in computational effort.

The optimum TMD is both effective in the reduction of maximum top story displacements and total accelerations for both structures with 10 and 40 stories. Also, detuning of mass damper is an important problem because of the uncertainty of the main-structure properties. The optimum TMD is robust against the change of the mass or stiffness of the structure by ±50% difference. As an example, the top story acceleration transfer function plot for different masses are shown in Figure 1. Only, the second case of 40-story structure is not robust when the 50% uncertainty is possible. This situation is resulted from small mass of TMD comparing to the total mass of 40-story structure. Whereas, Case 2 may be more practical TMD comparing to Case 1.

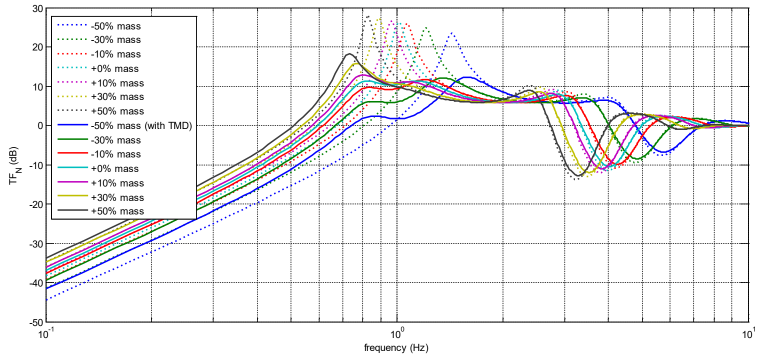

Figure 1: TFN plot of 10-story structure for mass uncertainty

THE MASS RATIO FACTOR ON OPTIMUM DESIGN OF STROKE LIMITED TUNED MASS DAMPERS

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Keywords: Stoke capacity, Tuned mass damper, Optimization, Metaheuristic methods.

ABSTRACT

Tuned mass dampers (TMDs) are vibration absorber devices used in mechanical systems. The efficiency of TMDs depend on an excellent tuning of parameters. For that reason, metaheuristic methods are effective on the optimization problem. TMDs are also used on civil structures to reduce structural vibration resulting from wind, earthquake and traffic excitations.

In the present study, the mass factor for stroke limited TMDs is investigated by optimizing the stiffness and damping properties of TMDs. In the optimization methodology, a method based on Jaya Algorithm (JA) and time-history analyses is proposed. JA[1] is a metaheuristic algorithm using the best and worst existing solutions of the candidate solutions in modification of the randomly assigned design variables.

The design variables of the optimization process are the period (T_d), and the damping ratio (ξ_d) of TMD. The objective of the optimization is to minimize the structural displacement without exceeding stroke capacity (stmax) which is normalized with the response of the structure without TMD. In the optimization process, the response under 6 excitations is considered. These excitations are impulsive motions such as directivity pulses and flint step. These two type pulses are considered for 3 different pulse period (T_p) and these pulses are generated by the equations of Makris[2].

As the numerical example, five different mass ratios (μ) which is the ratio of mass of TMD and structure, is investigated. The period and damping ratio of single degree of freedom (SDOF) superstructure is 2s and 5%, respectively. The range of T_d is between 0.5 and 1.5 times of the superstructure period. The range of ξ_d is between 0.01 and 0.4. The stmax is taken as 2. The optimization process is done for 200 iterations by taking the population value as 10. The optimum results for different mass ratio values are presented in Table 1.

Table 1: The optimum result for different mass raitos

μ	0.050	0.100	0.150	0.200	0.250
T_d	2.172	2.107	2.079	1.929	2.034
ξ_d	0.238	0.185	0.140	0.047	0.047
OF	1.491	1.376	1.260	1.209	1.172
Stroke	2.000	2.000	2.000	2.000	2.000

As seen from the results, the stroke of the optimum TMD is always at the maximum limit. By the increase of the mass ratio, the optimum damping ratio of TMD is getting lower. As expected, the performance of the TMD is positively affected by the increase of the mass ratio, but the increase of the mass may be harmfully effective on the vertical load bearing elements of the structure.

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OPTIMIZATION OF PROPORTIONAL-INTEGRAL-DERIVATIVE TYPE CONTROLLERS FOR ACTIVE SEISMIC CONTROL OF SINGLE DEGREE OF FREEDOM STRUCTURES

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Keywords: Optimization, Structural control, Metaheuristic methods.

ABSTRACT

Under seismic effects like earthquakes, undesired vibrations occur in structures. In order to reduce the maximum amplitude of vibrations and to obtain a rapid steady-state response, active structural control systems have been used. In these system, the parameters of the controllers must be perfectly tuned in order to obtain effective and robust control without stability problems. In this study, metaheuristic methods are used in the methodology to obtain optimum parameters of Proportional Integral Derivative (PID) type controller used in active tendon control of structures. Currently, the method involves single degree of freedom (SDOF) structures. The model of the system is shown as Fig. 1.

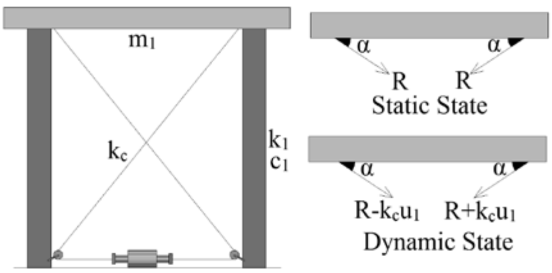

Figure. 1: SDOF model with active tendons and control forces

In Fig. 1, R is the pre-stress force on cables. The control signal is u_1 and it is obtained with PID control. K_p, T_i and T_d are the PID controller parameters which are namely; proportional gain, the integral response and the derivative response, respectively. The mass (m_1), the stiffness (k_1), the damping coefficient (c_1), the angle of tendons respect to ground (α) and the stiffness of tendons (k_c) are 2924 kg, 1390000 N/m, 1581 Ns/m, 36º and 372100N/m, respectively.

The optimization process was done for pulses with 1.5s period (T_p) and 230 cm/s peak ground velocity. New generation metaheuristic algorithm such as Flower Pollination Algorithm (FPA), Teaching Learning based Optimization (TLBO) and Jaya Algorithm (JA) were used and the optimum results were compared with a previously developed numerical algorithm. All metaheuristic algorithms are effective to find the best optimum result (K_p=-0.5, T_i= 0.005s and T_d=0.3634s). The metaheuristic approach is better than the numerical algorithm under different excitations with additional impulsive motions[1] for the reduction of the displacement (x_1) of the SDOF structure. For example, the maximum displacement is 0.8 cm for a directivity pulse with 1.5s and 200 cm/s peak ground velocity by using an active tendon system optimized with metaheuristic methods. This value is 2.77 cm for numerical algorithm and 3.77 cm for the uncontrolled structure.

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SENSITIVITY OF THE PROBABILISTIC RESPONSE OF SEMI-ACTIVE ISOLATED BUILDINGS TO THE PROBABILITY DISTRIBUTION TYPES OF RANDOM SYNTHETIC EARTHQUAKE PARAMETERS

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Keywords: Probability distribution types, near-fault earthquakes, cumulative distribution functions, Monte-Carlo simulation

ABSTRACT

Since the number of historical near-fault earthquake records is inadequate, artificially developed ones (a.k.a. pulse models) can be used alternatively in systematic evaluation (via parametric or Monte Carlo analysis) of semi-active isolated buildings. In case of a probabilistic investigation that makes use of Monte Carlo Simulation technique, which is more realistic, the uncertainties in the parameters of the pulse models should be considered by modelling them as random variables. The pulse velocity, the pulse period, and the pulse damping parameters of the Agrawal and He [1] pulse model used in this study are modeled as random variables. Since there is not enough statistical information about these parameters, different types of probability distributions that best fit to their nature can be assumed. In this study, the aforementioned random parameters are modeled with both normal and weibull distributions, which are among the commonly used ones in engineering [2], and the sensitivity of the probabilistic seismic response of a generic low-rise semi-active isolated building [3] to the aforesaid probability distribution types is determined by employing Monte-Carlo Simulation method. In order to exhibit the extent of this sensitivity, the results are presented in the form of cumulative distribution function plots of peak base displacements and peak top floor accelerations in a comparative fashion.

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INFLUENCE OF SHAPE PARAMETER/COEFFICIENT OF VARIATION OF RANDOM SYNTHETIC EARTHQUAKE PARAMETERS ON THE PROBABILISTIC RESPONSE OF SEMI-ACTIVE ISOLATED BUILDINGS

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Keywords: Coefficient of variation, shape parameter, normal distribution, weibull distribution, Monte-Carlo simulation technique.

ABSTRACT

Synthetic pulse models that represent near-fault earthquakes may be used to determine the seismic performance of buildings employing semi-active seismic isolation systems. For a realistic evaluation, it is necessary to consider the uncertainties in these pulse models besides the uncertainties in the isolation systems. A parameter with an uncertainty is defined as a random variable that follow a certain probability distribution which is consistent with its nature such as normal, lognormal, uniform, or weibull. Being the main parameters characterizing Agrawal and He [1] synthetic pulse model used in this study, the pulse period and the pulse velocity are modeled as random variables following weibull distribution while the pulse damping follows normal distribution. The shapes of probability distributions play important role in describing the level of uncertainty. The shape of normal distribution is controlled by coefficient of variation whereas that of weibull distribution depends on so-called shape parameter [2]. Here, the influence of the shape parameter and the coefficient of variation on the probabilistic seismic response of a generic low-rise semi-active isolated building [3] is investigated using Monte-Carlo simulation technique. Comparison of the cumulative distribution function plots of peak base displacements and peak top floor accelerations portray the extent of this influence.

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[2] Haldar, A., Mahadevan, S. (2000), *Probability, Reliability and Statistical Methods in Engineering Design*, John Willey & Sons.
[3] S. Öncü-Davas, Probabilistic Behavior of Buildings with Semi-active Seismic Isolation Systems under Earthquake Loads, Istanbul University, PhD Dissertation (unpublished).

METAHEURISTIC AND FREQUENCY DOMAIN BASED OPTIMIZATION OF TUNED MASS DAMPERS AND VERIFICATION OF THE RESULTS ON TIME HISTORY ANALYSES

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Keywords: Tuned mass damper, Jaya algorithm, Transfer function.

ABSTRACT

The optimization of tuned mass dampers for structures is a stochastic problem because of existing of damping. In that case, heuristic algorithms are useful tools in that field for an objective function in frequency or time domain. In the present study, the transfer function response of structures are minimized by using TMDs optimized by the developed methodology employing the newly developed Jaya algorithm which is a recently proposed simple but powerful algorithm. The numerical experiments on methodology are presented by using a 10 story structure and a 40 story structure with comparison of other algorithms such as harmony search, flower pollination algorithm, teaching learning based optimization and a new version of Jaya algorithm combined with Lévy flights.

The main purpose of TMD is to damp vibrations by reducing the maximum displacement and providing a rapid steady-state response. For that reason, the optimum results were tested by using several groups of earthquake data. These data are found in FEMA P-695: Quantification of Building Seismic Performance Factors (FEMA, 2009) [1]. The optimum TMD parameters were tested under the far-field ground motions, near-field ground motions including or not including significant impulsive pulses.

The fault parallel (FP) component (DUZCE/BOL090) of Bolu record of the 1999 Düzce earthquake is the most critical excitation for the 10-story structure in far-fault results. The maximum displacement for the 10th story is 0.4101m and the optimum TMD is effective to reduce it to 0.2622 with 36.06% performance. Also, the maximum top story acceleration is reduced to 12.0121m/s^2 from 19.2864m/s^2 for the same excitation.

The maximum top story displacement under near-field records with pulses is 0.6457m and it is reduced to 0.5052m by using the optimum TMD (21.76% reduction). The critical excitation is the fault normal (FN) component (Northhr/Rrs-032) of 01 Rinaldi Receiving Sta. station of the 1994 Northridge earthquake.

The critical excitation of near-field records without pulses is FN component of Tcu084 record of 1999 Chi-Chi earthquake for the 10-story structure. The optimum TMD is effective in reducing of the peak value by 20.07% (from 0.9920m to 0.5311m).

In the 40 story example, the optimum TMD parameters were found for two cases of maximum mass ratio. In Case 1 and 2, the maximum allowable mass ratio of the TMD is 10% and 2%, respectively. The reduction of maximum top story displacements of 40-story structure with TMD optimized with Case 1 are 12.38% and 35.82 for far-field and near field records, respectively. These percentages are respectively reduced to 7.53% and 20.79 in Case 2 for far-field and near field critical excitations.

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Session A2-3

NON LINEAR HOMOGENIZATION THEORIES WITH APPLICATIONS TO TRIP STEELS

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Keywords: Homogenization; Elasto-plasticity; Composite materials; Finite strains; TRIP steels

ABSTRACT

A general model for N−phase isotropic, incompressible, rate-independent elasto-plastic materials at finite strains is developed. Special attention is given to particulate microstructures, i.e., composite materials with a distinct matrix phase and an isotropic distribution of spherical particles. The particles are stiffer than the matrix phase, which is the case in most metallic materials of interest, such as TRIP steels, dual phase steels, aluminum alloys, and others. The formulation is based on the non-linear variational homogenization method of Ponte Castañeda [1]. The homogenization approach leads to an algebraic optimization problem, which for a two-phase material $(N=2)$ is solved analytically [2], whereas for $N \geq 3$ the solution is obtained numerically by using the methodology of Kaufman *et al*. [3] and the CONMAX software.

The model is validated by periodic three-dimensional unit cell calculations comprising a large number of spherical inclusions distributed randomly in a matrix phase. The homogenization technique provides accurate estimates not only for the effective flow stress but also for the average strains in the constituent phases. These estimates form the basis for the development of an approximate analytical model for the elastoplastic behavior of a composite with hardening phases. The predictions of the model are in excellent agreement with the results of detailed unit cell finite element calculations of a composite with hardening phases for different types of loadings, including uniaxial tension and finite shear [1].

The homogenization theory is also used to develop a constitutive model for the mechanical behavior of **TRIP** (**TR**ansformation **I**nduced **P**lasticity) steels. TRIP steels are basically composite materials with evolving volume fractions of the constituent phases. Specifically, we consider multiphase TRIP steels that consist of a ferritic matrix with dispersed bainite and retained austenite, which transforms gradually into martensite as the material deforms plastically. The calibration of the model is based on uniaxial tension tests on TRIP steels. The constitutive model is used also for the calculation of "**F**orming **L**imit **D**iagrams" (FLDs) for sheets made of TRIP steels; it is found that the TRIP phenomenon increases the strain at which local necking results from a gradual localization of the strains at an initial thickness imperfection in the sheet.

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PRELIMINARY COMPUTATIONAL APROACH OF PLASMA DYNAMIC EVOLUTION PRODUCED BY LOW CURRENT TABLE-TOP PINCH PLASMA DEVICES

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Keywords: Magneto Hydro Dynamics - MHD, Plasma physics, Plasma pinch devices, Radiation transport.

ABSTRACT

Pulsed power generators like Z- and X- Pinch devices are able to produce hot and dense plasma. This type of plasma attracts the research interest due to the important emerging applications which cover a wide range of disciplines[1] like high energy density physics – HEDP, inertial confinement fusion, laboratory astrophysics and in point projection radiography. In order to study such a multiphysics problem, the development of advanced computational models and simulation schemes is required, in order to give insights to experimental results.

It has been proven that transient and rapidly evolving electromagnetic - EM, electrothermomechanical - ETM and magnetohydrodynamics - MHD effects, simultaneously affect the formation of plasma and therefore the onset of the plasma instabilities[2,3]. In our preliminary computational study, the astrophysical MHD code PLUTO is partially modified to simulate the dynamics of plasma evolution. New algorithms for the PLUTO modules that extend the field of the applicability of the code to the laboratory plasmas are developed and preliminary tested, summarized so far to the: i. modified PVTE equations of state - EOS using tabulated data[4] by SESAME Database ii. electric resistivity according to the formulation of Spitzer (1962) iii. radiative losses from an optically thin plasma using tabulated data[5] by FLYCYK code iv. modified radiation transfer model updated to include metal materials v. determination of plasma temperature, for which the effective ionization charge state, tabulated values[5] by the FLYCYK code are used.

The development and assembling of these five algorithms including these novel modifications of PLUTO will make us able to study the formation of minidiodes and constrictions and also micro explosions of the hot points, on Z- and X- Pinch type loads using various radiation transfer MHD models.

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SIMULATIONS OF LASER ASSISTED MACHINING AND CONVENTIONAL CUTTING OF AISI H-13 STEEL

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Keywords: Laser assisted machining - LAM, Laser preheating, Finite Element Method, Metal Cutting.

ABSTRACT

Laser-assisted machining - LAM[1] is an advanced promising method capable of increasing the machinability of hard-to-cut materials, by decreasing the values of the cutting forces, extending the tool life and therefore the increase of productivity. During LAM, the workpiece is heated directly by a laser beam ahead of the cutting tool. The laser heating results to the yield strength and hardness reduction of the workpiece material. LAM is a complex manufacturing method, combining all the classic cut parameters, such as cutting speed, feed rate, depth of cut with the laser parameters, like the laser power, the spot radius and the beam profile. Thus, computer simulations of the LAM cutting processes are essential for the optimization of the cutting conditions and the machinability of high strength material parts.

The current research focuses on the finite element simulation of the machinability of AISI H-13 steel parts, with conventional[2,3] and laser-assisted machining. Thermal-structural numerical modeling and simulations of the conventional orthogonal cutting of AISI H-13 steel and laser-assisted orthogonal cutting, are performed and validated with literature results[2]. The cutting tool is modeled as a rigid FEM body that incrementally penetrates the flexible deformable workpiece. The laser beam is modeled as a Gaussian moving heat source. The dynamic elastoplastic behavior of the workpiece material is investigated by taking into account the Johnson-Cook constitutive strength material model[4]. Parametric simulations are carried out for cutting speed, feed rate, Johnson-Cook material properties at different laser powers and for a constant spot radius.

These two machining methods are compared according to the obtained numerical results for the cutting forces, temperature distributions, plastic strains and residual stresses. The influence of the laser assistance is discussed, and valuable conclusions are drawn for the contribution and effectiveness of the aforementioned parameters to the models' dynamic behavior.

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MESOSCALE RANDOM FIELDS FOR THE APPARENT MATERIAL PROPERTIES OF RANDOM MICROSTRUCTURES

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Keywords: Random microstructures, Apparent properties, Mesoscale random fields, Stochastic finite elements.

ABSTRACT

In this paper, an efficient computational procedure is presented for the determination of mesoscale random fields describing the spatial variation of the apparent material properties of various types of random microstructures (particle-, CNT-reinforced composites and defective graphene lattices). The proposed approach is based on computer-simulated images of the microstructures and combines the extended finite element method (XFEM) with Monte Carlo simulation in order to analyze the microstructure models and obtain statistical information for the apparent properties in each mesoscale size[1]. Useful conclusions are derived regarding the effect of basic microstructural features, such as particle/matrix stiffness ratio and defect type, on the probability distribution and correlation structure of the random fields. Moreover, sample functions of the mesoscale random fields are generated using the spectral representation method in conjunction with translation field theory. The generated sample functions can be used as input in the stochastic finite element analysis of composite structures to investigate the effect of the probabilistic characteristics of the underlying microstructure on the response variability[2].

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MULTISCALE MODELING OF THE MECHANICAL BEHAVIOR OF GRAPHENE AT FINITE STRAINS

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Keywords: Multiscale Modeling, Graphene, non-linear mechanical behavior

ABSTRACT

The use of graphene and carbon nanotubes, as a filler for the creation of ultra-strong nanocomposites is on the increase, due to their extraordinary mechanical properties. Reliable computational models for the mechanical behavior of this outstanding material that will allow for the full exploitation of its properties and the optimal design of its applications, are therefore necessary. In our previous work, we developed a methodology for the modeling of graphene with equivalent shell elements, an accurate and computationally efficient model, surrogate for the widely used atomistic simulations. In our present work, we developed a more advanced model that can be used in geometrically nonlinear problems that involve finite straining of graphene. The hyperelastic strain energy potential used in the equivalent finite element model of graphene is derived from molecular structural mechanics simulations, based on homogenization principles. The proposed formulation is given in detail and numerical examples that demonstrate its accuracy and its efficiency, in comparison with the full scale MSM model, are also presented.

ESTIMATION OF INSERTION LOSS OF SOUND BARRIERS VIA FINITE ELEMENT METHOD

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Keywords: Sound barriers, insertion loss, finite element method.

ABSTRACT

Sound barriers are an important aspect of fighting noise pollution caused by major infrastructure projects such as roads and railways. Accurate modeling of the acoustic behavior of barriers can lead to effective designs which in turn can improve the living conditions of populations in areas with excessive sound levels. The main phenomenon characterizing the acoustic performance of a sound barrier is diffraction, while absorption and transmission are also important. The performance of a sound barrier is measured by insertion loss which is defined as the difference in sound level at a receiver location with and without the presence of a noise barrier, assuming no change in the sound level of the source. Ray tracing techniques have been used to establish the acoustic performance of a barrier and still remain the basis of most of the practical methods for calculating barrier performance. Finite element method (FEM) is a powerful numerical technique that can be utilized for the modeling of wave phenomena and can simultaneously incorporate effects of diffraction, absorption and transmission both in frequency and time domain. Scope of this study is the calculation of insertion loss of sound barriers via FEM and comparison of the results with ray tracing techniques.

In this study the FEM was used to model the Helmholtz equation with a sound source and the effects of diffraction of a sound barrier in the frequency domain. For mesh creation the rule of thumb $\lambda/h=5$ was applied where λ and h respectively denote wavelength of upper limit frequency and the maximum nodal distance. The open pressure acoustic domain was modeled with the use of a perfectly matched layer. Two models were created: for the first one the sound pressure at the receiver point was calculated with the presence of a sound barrier and for the second one without a sound barrier for the same source position. Insertion loss was calculated as the difference in sound level at receiver location with and without the presence of a noise barrier. For the same source and receiver positions insertion loss was calculated also with ray tracing techniques.

The insertion loss between the results obtained with the FEM and ray tracing techniques was assessed in order to quantify the results. Results compared with Kurze-Anderson and Tatge equations (Li and Wong 2005) indicate that there is a difference less than 1 dB and less than 0.3 dB respectively for all frequencies calculated.

Implications of the findings suggest that FEM can be used effectively for the modeling of insertion loss of sound barriers. Application of the method can be extended in 3d space to predict the behavior of sound barriers with various shapes, in a tilt angle, with a profile which absorbs or disperses sound, galleried and cantilevered barriers. Also diffracting-edge barriers such (T-shaped, Y-shaped), multiple-edge and Tubular cappings barriers along with optimization and active noise control can be utilized and modeled with the use of FEM.

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Session A3-1

THE STRUCTURAL INTEGRITY OF UNBURIED OFFSHORE PIPELINES ACROSS ACTIVE TECTONIC FAULTS

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Keywords: Subsea pipelines, Structural integrity, Fault crossing, Finite-element modelling

ABSTRACT

Due to the need to transport hydrocarbons from offshore oil & gas fields to onshore treating and export facilities and country markets, offshore pipelines are crossing wide areas with geomorphological and geological conditions that may present a variety of geohazards such as active seismic faults, earthquake-induced liquefaction or slope instability regions. Geohazards impose substantial ground deformations to the pipelines and potentially threaten their integrity. Permanent ground-induced actions due to earthquakes are applied on the pipeline in a quasi-static manner, and are not necessarily associated with severe seismic shaking, but may cause serious plastic deformation to the pipeline, leading to pipe wall fracture and loss of containment[1]. Potential damages and disruptions of a subsea pipeline caused by geohazards may affect the service life and lead to significant financial losses due to service interruptions, explosions and environmental contamination.

Fault crossing is one of the major hazards to offshore pipelines, whether buried or unburied. Numerous investigations have been carried out for different types of ground movements. The pipeline's ability to deform in the plastic range under tension helps prevent rupture at fault crossings. If compression of the pipeline in a fault crossing is unavoidable, the compressive strain should be limited to within the local buckling criteria[2]. The type of faulting and the estimate of soil displacements are the main factors for designing pipelines to resist permanent ground deformation at fault crossings.

This preliminary study addresses the mechanical behavior of unburied steel pipelines crossing active tectonic normal-slip faults. The investigation aims to determine the stresses developed on the steel pipes at fault crossings based on parametric numerical simulation of the nonlinear response of a 3D simplified model. The study is based on finite element analysis that takes into account large strains and displacements and inelastic material behavior. Steel pipes with diameter to thickness ratio and material grade typical for oil and gas pipelines are considered. The analysis is conducted through an incremental application of fault displacement and determines strains developed on the tension and compression sides in the pipe. Appropriate performance criteria of the steel pipeline are defined and monitored throughout the analysis. The results from the present study can be used for the development of performance-based design methodologies for unburied steel pipelines.

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NUMERICAL STUDY OF OFFSHORE NATURAL GAS PIPELINES SUBJECTED TO SUBMARINE LANDSLIDES

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Keywords: Numerical Simulations, Offshore Pipelines, Natural Gas, Geohazards, Submarine Landslides, Kinematic Distress, Mitigation Measures.

ABSTRACT

Natural gas is undoubtedly one of the main energy sources of our era with increasing demand and continuous exploitation of new onshore and offshore deposits. The transportation of natural gas to the urban and industrial centres is accomplished either in liquefied form via LNG ships, or in gaseous form via large-scale pipeline networks. These networks consist of offshore and onshore parts, extending for hundreds of kilometres, while very frequently are placed on the seabed in big depths. For instance, Trans Adriatic Pipeline (TAP) is a 878 km long pipe with an offshore part of 105 km, which connects Albania and Italy, reaching the depth of 820 m in the Adriatic Sea. Certainly, such pipelines are very important infrastructures, since any possible damage may cause serious problems and devastating consequences on the environment and the economy. Geohazards, such as strong ground motion, active faults, offshore landslides and debris flows, tsunamis, etc, consist, among others, the most crucial threats that an offshore pipeline has to overcome during its installation and functioning.

The fact that onshore pipelines have been constructed for several decades, are easily accessible and placed on known soil conditions has led to national/international standards and guidelines for their efficient design against geohazards. On the other hand, offshore pipelines are far from that level, since there is no similar experience yet and deep water soil conditions are highly adverse and difficult to determine. The current Norwegian DNV (Det Norske Veritas) standard consist a first attempt to propose an efficient design methodology for offshore pipelines. The investigation of kinematic distress due to geohazards, such as landslides, necessitates the accurate response assessment of pipelines through experimental, analytical and numerical models. Nonetheless, only a limited number of numerical and analytical approaches can be found in the recent literature.

The purpose of this work is to study numerically, utilizing the finite element method and realistic data from the offshore part of the Trans Adriatic Pipeline, the kinematic distress of offshore natural gas pipelines due to several loading conditions resulting from submarine landslides. Firstly, numerical models are developed and compared with available analytical and numerical solutions. Various parameters, such as the finite element type and mesh discretization, the pipe-soil interaction simulation, the boundary conditions, the expansion length, etc, are investigated in order to propose the most accurate and effective approaches. Subsequently, the use of efficient mitigation measures in different positions along the pipeline route is examined in order to reduce its vulnerability in an optimal techno-economical manner. These mitigation measures can be, among others, the use of anchor points, elastic joints, different material properties and/or cross section dimensions, prefabricated curvatures. The findings of the aforementioned parametric study are summarized into a preliminary proposal for guidelines for the efficient design of offshore natural gas pipelines subjected to submarine landslides.

EFFECTS OF THE SOIL-STRUCTURE-INTERACTION PHENOMENON ON RC STRUCTURES WITH PILE FOUNDATIONS

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Keywords: Soil-Structure-Interaction, FEA, Reinforced Concrete, Pile Foundation, Cyclic Loading.

ABSTRACT

The Soil-Structure Interaction (SSI) has a significant effect on the overall structural behavior of reinforced concrete buildings, especially under cyclic loading conditions. Considering the SSI effects within experimental setups comprise cumbersome procedures that are usually very difficult to control and monitor. Furthermore, when the foundation type of the structure foresees the use of pilecaps connected to piles, accounting for the SSI effect becomes further complicated to investigate. Consequently, most SSI experiments involve very simple geometry configurations for specimens under monotonic loading conditions. The need for developing new numerical methods that will enable realistic capturing of this phenomenon[1], is deemed to be of great importance[2].

This research work aims to study the SSI effect for the case of a 6-storey building with a pile foundation undergoing cyclic loads. The numerical model foresees the study of the main shear wall of the structure that is connected to six reinforced concrete slabs and is resting on a pilecap that is connected to three piles found within a soil class E, according to ASCE7-10. By using the hexahedral isoparametric finite element, the structure is discretized in 3D, where the adopted concrete material model is integrated with the smeared crack approach and the steel bars are modelled by using embedded rebar elements. Both soil and concrete foundation are discretized with hexahedral elements, while monotonic and cyclic analyses are performed in order to study the mechanical behavior of the fixed-base structure and the corresponding SSI counterpart structure that is founded on the flexible soil.

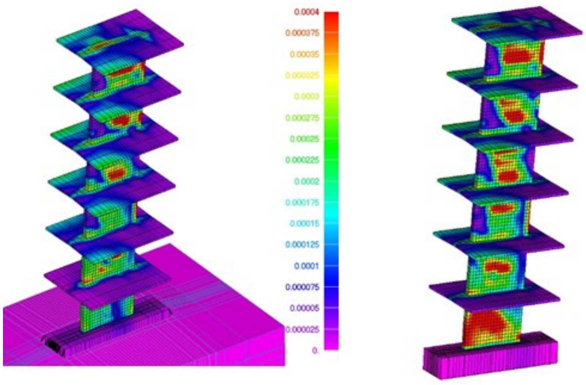

Figure 1 von Mises Strain contour of the (Left) SSI model and (Right) Fixed-base model.

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NUMERICAL SIMULATION OF ATHEROSCLEROTIC PLAQUE GROWTH IN RIGHT CORONARY ARTERIES

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Keywords: Computational Fluid Dynamics, Coronary Artery, Plaque Concentration, Wall Shear Stress.

ABSTRACT

Atherosclerosis is a leading cause of mortality in the all developed countries. This disease begins with endothelial dysfunction, which favors lipid and cell elements crossing inside blood vessel wall. Interaction between the blood and the plaque can lead to plaque rupture. An important hemodynamic parameter in interaction between fluid and vessel wall is the wall shear stress (WSS), which is the mechanical force imposed on the endothelium by the flowing blood. The objective of this study is to examine influence of wall shear stress on the atherosclerosis development. Using computational fluid dynamics (CFD) in right coronary arteries, previously obtained using DICOM images, numerical simulation was performed. Also, plaque concentration in the arterial wall was calculated. The three-dimensional blood flow was described using Navier–Stokes equation and the continuity equation. Mass transfer within the blood lumen and through the arterial wall is coupled with the blood flow and is modeled by a convection–diffusion equation. Kedem–Katchalsky equations were used for transports the low-density lipoproteins (LDL) in the lumen and throw the vessel tissue. The inflammatory process is modeled using three additional reaction–diffusion partial differential equations. The results for plaque concentration for the right coronary arteries are presented (Figure 1).

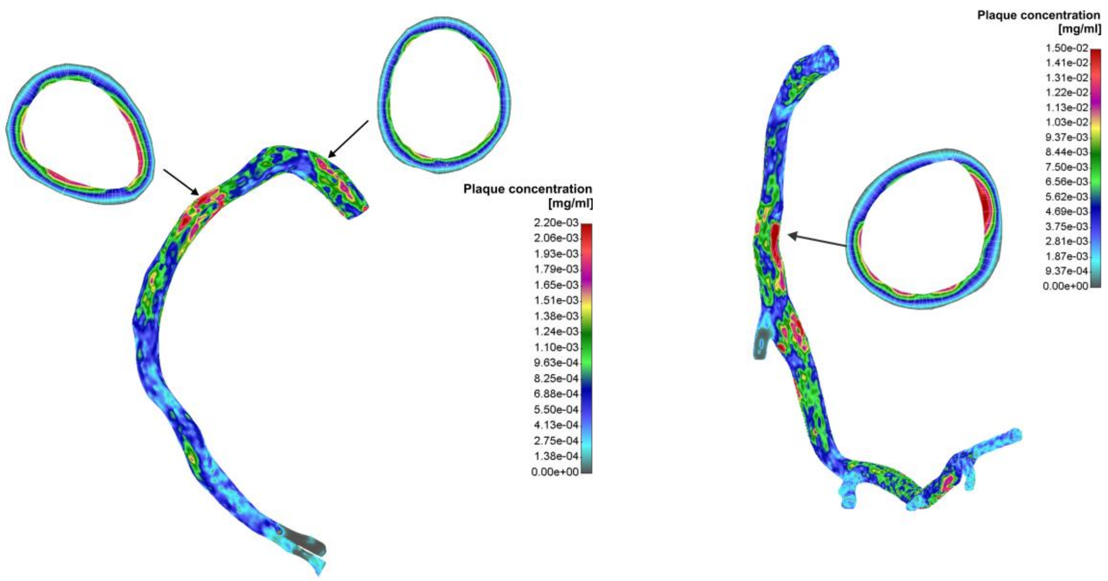

Figure 1: (a) Plaque concentration patient #1. (b) Plaque concentration patient #2.

EFFECT OF ELECTRICAL CONDUCTIVITY AND MAGNETIZATION ON THE BIOMAGNETIC FLUID FLOW OVER A STRETCHING SHEET

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Keywords: Stretching sheet, Biomagnetic fluid, Ferrohydrodynamics, Magnetohydrodynamics, ferrofluid, magnetic fluid, magnetization.

ABSTRACT

The Biomagnetic Fluid Flow (BFD) (blood) over a stretching sheet in the presence of magnetic field is studied. For the mathematical formulation of the problem both magnetization and electrical conductivity of blood are taken into account. The BFD model used is consistent with both principles of Magnetohydrodynamics (MHD) and FerroHydroDynamics (FHD). The physical problem is described by a coupled, nonlinear system of ordinary differential equations subject to appropriate boundary conditions. The solution is obtained numerically by applying an efficient numerical technique based on finite differences method. The obtained results are presented graphically for different values of the parameters entering into the problem under consideration. Emphasis is given to the study of the effect of the MHD and FHD interaction parameters on the flow field. It is apparent that both parameters effect significantly on various characteristics of the flow and consequently neither electrical conductivity nor magnetization of blood could be neglected.

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Session B3-1

THE MAEM FOR THE VISCOELASTIC ANALYSIS OF CYLINDRICAL SHELL PANELS

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Keywords: Viscoelastic Analysis, Meshless Analog Equation Method (MAEM), Radial Basis Functions (RBFs), Fractional Differential Equations, Cylindrical Shells.

ABSTRACT

A purely meshless method is presented for the viscoelastic analysis of cylindrical shell panels, based on the Analog Equation Method (AEM) [1]. The constitutive equations of the viscoelastic material are expressed in differential form using fractional derivatives. The proposed analysis is illustrated with the fractional Kelvin-Voigt model. The three linear fractional differential equations describing the response of the shell are converted into three quasi-static linear problems subjected to three fictitious time dependent loads under the same boundary and initial conditions. The solution is approximated by new RBFs, which result from the integration of the analog equations. The studied examples demonstrate the efficiency and the accuracy of the developed method.

The starting point of the investigation is the Flügge type differential equations, which together with the boundary and initial conditions and the stress resultants in terms of the displacements for thin-walled cylindrical shells of uniform thickness, made of an isotropic, linearly elastic material can be found in [2-3]. We obtain the viscoelastic equations described with the multi-term differential model of fractional-order by applying the operators **P, Q** to the stress resultants and displacements, respectively, in the stress resultants-displacements equations and then using the equilibrium equations. The operators **P**, **Q** are given as

$$\mathbf{P}=\sum_{k=0}^{l} p_k D_c^{a_k} \quad , \mathbf{Q}=\sum_{k=0}^{m} q_k D_c^{a_k}$$

in which $D_c^{a_k}$ is the Caputo fractional derivative [4] of order a_k, with $a_0=0$ and p_k, q_k are the viscoelastic parameters , which satisfy certain conditions resulting from the second law of thermodynamics [4]. Note that for $l=m=0$ it is $\mathbf{P}=\mathbf{Q}=1$ and in this case, we obtain the constitutive equations of the elastic material. Using the procedure described in detail in [3-4] a system of linear Fractional Differential Equations (FDEs) with respect to time results, the solution of which gives the unknown coefficients and then the displacements. For the fractional Kelvin-Voigt model which has been used in this investigation, it is $l=0$, $m=1$ and $p_0=1$, $q_0=1$ with $q_1=\eta$ being the viscous parameter. The resulting linear Fractional Differential Equations with respect to time are of order $0<a\leq 1$, so one initial condition is needed, namely the initial displacements. The equations are solved using the procedure described in detail in [4-5]. In this investigation, the time dependent terms in the boundary conditions are neglected.

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A SPECTRAL COLLOCATION METHOD FOR VIBRATION SUPPRESSION OF SMART ELASTIC PLATES

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Keywords: Smart Plate Model, Fourier Expansions, Collocation Method, Fuzzy Control, Computational Algorithm.

ABSTRACT

A dynamic control model for vibration suppression of a smart elastic plate is considered. A behavior of the plate is described by a nonlinear dynamic model, which presents an extension of the nonlinear von Kármán plate system for large deflections (Ciarlet-Rabier [1], etc.) on a control problem. The plate is subjected to external transversal disturbances and generalized control forces, produced by the electromechanical coupling effects. Various boundary conditions are considered. In order to suppress vibrations, control forces are located at the discrete points on the plate domain.

A solution of the dynamic mechanical problem, namely, a displacement $w(t,x,y)$ and the Airy stress potential $\psi(t,x,y)$ and also the velocity $w_t(t,x,y)$ are expanded into double Fourier's series. The Fourier expansions for the linear Kirchhoff-Love plate equation for small deflections (Reddy [2], etc.) have been proposed in [3], and later for the nonlinear case in [4], [5]. In these works Galerkin's method for the discretization has been applied. Here we develop a collocation method for the spatial discretization of the initial boundary value problem, which allows us easily to manipulate with loading and control forces by locating them at the collocation points. The main idea of the collocation approach is in considering collocation points $\{(x_m,y_n), 0<x_m<l_1, 0<y_n<l_2, m,n=1,2,\dots,N\}$ on the spatial domain $G=(0,l_1)\times(0,l_2)$. The nonlinear mechanical model after applying this method in the operator form is written as follows

$$L(w,\psi)|_{(x=x_m,y=y_n)} = [Q]|_{(x=x_m,y=y_n)} + [Z]|_{(x=x_m,y=y_n)},\ m,n=1,2,\dots N,$$

where the differential operator L is defined in [4], $w=w(t,x,y)$ is the displacement, $\psi=\psi(t,x,y)$ is the Airy stress function, $[Q]$ are the external loading forces and $[Z]$ are the control forces.

Our purpose is to suppress vibrations of the plate by controlling the time-dependent coefficients in the partial sums of the double Fourier series for the solution. The system of ordinary differential equations, obtained after the spatial discretization of the initial mechanical model by the collocation method, is solved by means of the Newmark method.

The nonlinear controller is designed, based on an application of a fuzzy inference system of Mamdani type. The proposed here technique has first been implemented in [6] for the linear model with the simply supported boundary conditions using state space representation in SIMULINK environment.

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FREE AND FORCED VIBRATION ANALYSIS OF GRADIENT ELASTIC BEAM STRUCTURES BY MEANS OF FINITE ELEMENT METHOD

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Keywords: Free and Forced Vibration Analysis, Beam Structures, Gradient Elasticity, Finite Element Method.

ABSTRACT

This paper investigates the free and forced vibration response of gradient elastic beam structures by means of finite element method. More specifically, the dynamic stiffness matrix of a gradient elastic flexural Bernoulli-Euler beam finite element is analytically constructed in the frequency domain. The simple gradient theory of elasticity with just one material constant (internal length) in addition to the classical moduli is applied. Use of this dynamic stiffness matrix for a plane system of beams enables one through a finite element analysis to determine its dynamic response to harmonically varying with time external load or the natural frequencies and modal shapes of that system. The response to transient loading is obtained with the aid of Laplace transform. Examples are presented to illustrate the method and demonstrate its advantages.

SOLVING ENGINEERING OPTIMIZATION PROBLEMS WITH AN EFFICIENT HYBRID NATURE-INSPIRED ALGORITHM

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Keywords: Engineering Optimization, Swarm Intelligence, Metaheuristic Algorithms, Random Search, Hybrid Schemes.

ABSTRACT

Engineering optimization is the process of finding the minimum or maximum of one or more objectives related to a particular application. The main aim of engineering optimization is to achieve the best possible result for a product or a process utilizing the available resources and conforming to the imposed constraints. For this purpose, efficient computational tools are used to analyze and compare rapidly and accurately a huge number of alternatively designs. Engineering optimization problems are often characterized by high complexity as they include many design variables and constraints. These equality and/or inequality constraints can have the form of nonlinear expressions or simple bounds.

Initially, mathematical programming based optimizers were applied, while nature-inspired optimization methods have received great attention in recent years. Their main advantage is that they can obtain the best possible solution (i.e., global optimum) utilizing schemes that imitate nature and are based on Darwinian theory of evolution (e.g., mutation, survival of the fittest, etc). Metaheuristic optimizers belong to the category of nature-inspired algorithms and represent stochastic formulations with local search and randomization. Diversification and intensification consist two of the major components of these algorithms. Swarm-intelligence (SI) methodologies are constantly gaining popularity among nature-inspired metaheuristic techniques since they can provide optimum solutions for challenging problems. Cuckoo Search (CS) and Bird Swarm Algorithm (BSA) are representative SI-based optimization methods. CS is an evolutionary algorithm based on the obligate brood parasitism of a certain species of cuckoos that lay their eggs in the nests of other host birds (of other species). To analyze the search space in a successful manner, CS algorithm is usually enhanced by Lévy flights, which is a typical flight behavior presented by many birds and fruit flies. On the other hand, BSA is a bio-inspired algorithm that simulates the social behavior and interactions in bird swarms. Typically, three kinds of such activities are included in BSA, such as foraging, vigilance and flight behavior.

In many cases, hybrid optimization schemes have been used by combining two or more algorithms. The aim of hybrid optimizers is to alleviate their drawbacks and maximize their advantages. In this manner, the improvement of original algorithms' performance, i.e., the achievement of the global optimal solution and a faster convergence rate is accomplished. Hence, to enhance the computational efficiency of basic CS and BSA algorithms, a hybrid approach, namely CS-BSA is formulated in the present study. More specifically, critical parameters of BSA are introduced into the CS algorithm to improve the convergence towards optimum solution. A number of engineering benchmark problems, as well as real life engineering applications such as seismically isolated liquid storage tanks, are used to prove the efficiency of the proposed hybrid CS-BSA approach. The results are compared with the original CS algorithm and other popular nature-inspired metaheuristic optimizers, namely, Particle Swarm Optimization (PSO) and Differential Evolution (DE).

INFLUENCE OF TIME DERIVATIVES IN THE BOUNDARY CONDITIONS OF VISCOELASTICITY PROBLEMS

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Keywords: Viscoelasticity, fractional differential constitutive models, boundary conditions, analog equation method.

ABSTRACT

The viscoelastic behavior of materials is usually modeled with differential constitutive equations with integer or fractional order time derivatives. Using such models, we obtain the governing equations in terms of the displacements of the structure with the associated boundary and initial conditions. The natural boundary conditions include time derivatives of the displacements of the structure at the boundary. Thus, the boundary conditions in viscoelasticity problems are differential equations, contrary to elasticity problems, where they are algebraic equations. In all papers, to our knowledge, researchers neglect the time derivatives in the boundary conditions of viscoelastic problems. Though this assumption is arbitrary, it is adopted to make possible the solution.

In this paper the problem is solved including the time derivatives in the natural boundary conditions. It is illustrated by investigating the response of a viscoelastic beam. The fractional Kelvin-Voigt model is adopted. The governing equations result by taking the dynamic equilibrium of a beam element. Thus, we have

$$EIw_{,xxxx} + \eta EID_c^a w_{,xxxx} + \rho A w_{,tt} = f \tag{1}$$

where $w(x,t)$ is the transverse deflection of the beam; E, ρ and η are the Young modulus, the mass density and the viscous parameter of the material, respectively; A and I are the area and the moment of inertia of the cross section of the beam; D_c^a is the Caputo fractional derivative of order $0 < a \leq 1$. The pertinent boundary and initial conditions are given as

$$a_1 w(0,t) + a_2\left[EIw_{,xxx}(0,t) + \eta EID_c^a w_{,xxx}(0,t)\right] = a_3(t) \tag{2a}$$

$$\overline{a}_1 w(l,t) + \overline{a}_2\left[EIw_{,xxx}(l,t) + \eta EID_c^a w_{,xxx}(l,t)\right] = \overline{a}_3(t) \tag{2b}$$

$$b_1 w_{,x}(0,t) + b_2\left[EIw_{,xx}(0,t) + \eta EID_c^a w_{,xx}(0,t)\right] = b_3(t) \tag{2c}$$

$$\overline{b}_1 w_{,x}(l,t) + \overline{b}_2\left[EIw_{,xx}(l,t) + \eta EID_c^a w_{,xx}(l,t)\right] = \overline{b}_3(t) \tag{2d}$$

$$w(x,0) = \overline{w}(x)\,,\ \dot{w}(x,0) = \dot{\overline{w}}(x) \tag{3a,b}$$

where $a_k, \overline{a}_k, b_k, \overline{b}_k$ $(k = 1,2)$ are given constants and $a_3(t), \overline{a}_3(t), b_3(t), \overline{b}_3(t), \overline{w}(x)$ and $\dot{\overline{w}}(x)$ are known functions.

Eq. (1)-(3) represent an initial boundary value problem with second order time derivatives in the equation of motion and fractional time derivatives of order $0 < a \leq 1$ in the natural boundary conditions. Using the Analog Equation Method, the equation of motion and the boundary conditions are transformed to an initial value problem, which is solved numerically. Various types of boundary conditions are studied and the results are compared with those obtained by neglecting the time derivatives in the natural boundary conditions.

SOLVING THE NONLINEAR BOUNDARY LAYER FLOW EQUATIONS WITH PRESSURE GRADIENT AND RADIATION

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Keywords: Boundary layer problem, pressure gradient, thermal radiation, homotopy analysis method.

ABSTRACT

The boundary layer problem of the incompressible, laminar flow past a flat plate with pressure gradient and radiation is studied. The partial differential equations (PDEs) describing this problem are the continuity, the energy and the momentum equation with the boundary layer simplifications. Using the dimensionless Falkner-Skan transformation, a nonlinear coupled system of PDEs is obtained. This system is solved via the homotopy analysis method (HAM) in order to obtain an analytical solution that describes radiation and pressure gradient effects on the boundary layer flow. The analytical results are in very good agreement with the corresponding numerical.

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Session A3-2

A BOUNDARY LAYER APPROACH FOR THE SOLUTION OF THE GENERAL SINGLE CONTACT FRICTIONAL PROBLEM IN MULTIBODY DYNAMICS

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Keywords: Analytical dynamics, Unilateral constraint, Manifold with boundary, Frictional contact.

ABSTRACT

This study presents a new formulation of the dynamics of systems involving a single frictional contact. An analytical dynamics framework is employed, together with some fundamental tools of differential geometry. This provides a foundation for applying Newton's law of motion to systems possessing configuration manifolds with boundary. It is shown that the contact phase takes place inside a thin boundary layer, where the dominant dynamics is described by a set of three ordinary differential equations. The study includes a selected se t of examples, with emphasis put in investigating phenomena arising during central or eccentric collision of bodies.

Dynamics of systems having components that come in contact during their motion is a classical subject of Mechanics due to its large practical significance and theoretical beauty (e.g., [1,2]). Based on the type of approach adopted, the previous studies can be divided in two categories. In the first one, the contact is assumed to be instantaneous. This causes a discontinuity in the velocities, accompanied by unbounded contact forces, leading to the necessity of employing techniques of Non-smooth Mechanics [2]. These approaches predict the post-impact velocities through an algebraic process, using the pre-impact velocities and appropriate restitution coefficients. On the other hand, the second category of previous studies is based on the Darboux-Keller approach [1]. They all consider the normal impulse as an independent time-like variable and lead to an approximate set of equations of motion during the contact phase in the form of ordinary differential equations (ODEs).

In the present study, an analysis was developed on the dynamic problem of the single point frictional collision between two bodies. This analysis was performed within the framework of analytical dynamics, by employing some key concepts of differential geometry [3]. First, a boundary was constructed for the original configuration manifold by using the condition of no impenetrability. Then, the essential geometric properties of the constrained manifold were determined and found to change significantly near the boundary of the configuration manifold [4]. This provided the foundation for applying Newton's law of motion and led to an elegant geometric picture. Specifically, the motion during the contact phase was found to be governed by a set of three ODEs, when expressed in a special coordinate system. The inertia of the figurative particle representing the motion of the system was found to increase rapidly as it approaches the boundary along an axis normal to it. At the same time, a strong repulsive force arises, pushing this particle away from the boundary. In addition, friction was found to activate action along two special tangential directions only, determined by the mapping with the physical space. Finally, the equations of motion in the original coordinate system were simply obtained by a proper projection of these three ODEs. After completing the analysis, the study was focused on investigating several phenomena arising during frictional contact, by using selected mechanical examples.

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APPLICATION OF AN AUGMENTED LAGRANGIAN METHODOLOGY TO DYNAMICS OF MULTIBODY SYSTEMS WITH EQUALITY CONSTRAINTS

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Keywords: Multibody systems, Equality motion constraints, Three field weak form, Augmented Lagrangian.

ABSTRACT

Some new theoretical and numerical results are presented for a class of multibody systems subjected to equality motion constraints. The formulation is based on a new set of equations of motion, represented by a system of second order ordinary differential equations (ODEs). First, these equations are put in a weak form. Also, the position, velocity and momentum type quantities are assumed to be independent, leading to a three field set of equations. This set is put in an augmented Lagrangian form and is used for producing a new time integration scheme. The validity and efficiency of this scheme is verified by applying it to example systems.

Improving the understanding on the dynamics of constrained mechanical systems leads to useful design gains in many engineering areas. Typically, the equations of motion for this class of systems are derived and cast in the form of a set of differential-algebraic equations (DAEs) of high index. However, both the theoretical and the numerical treatment of DAEs is a delicate and difficult task [1]. The present formulation is based on a new set of equations of motion, represented by a coupled system of second order ODEs [2]. The original configuration manifold possesses general geometric properties. Moreover, there exists a set of holonomic and/or nonholonomic equality motion constraints. For computational purposes, it is convenient to put the equations of motion in a weak form. Moreover, it is advantageous to consider the position, velocity and momentum variables as independent quantities [3]. Finally, all these lead to an augmented Lagrangian formulation [4,5], in a natural way, by just adding suitable penalty terms.

The weak form developed provides a firm basis for constructing appropriate numerical discretization schemes, leading to improvements over existing schemes. The validity and efficiency of such a scheme was tested and illustrated by applying it to a large number of examples. First, it was verified that it passes successfully all the tests related to a special set of benchmark problems, chosen by the multibody dynamics community [6]. The new scheme was also applied to large scale industrial problems. For instance, results were obtained for a complex ground vehicle model, executing a typical double lane change maneuver. These results were compared with results obtained by applying two state of the art codes (i.e., ADAMS and MotionSolve). Both of these codes set up the equations of motion and solve them numerically as a system of DAEs. The results illustrate the advantages of the new numerical scheme.

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SEISMIC RESPONSE ESTIMATION OF RIGID AND FLEXIBLE ROCKING FRAMES USING SIMPLE FINITE ELEMENT MODELS

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Keywords: rocking frame, rocking bridge, Finite Element modeling, non-linear response history analysis, earthquake engineering.

ABSTRACT

The paper examines the seismic response of rocking frames with both rigid and flexible columns using simplified Finite Element modeling. Rocking frames are found in ancient structures where free-standing pillars are capped with a freely supported rigid beam (architrave). Today rocking frames are becoming popular in various systems, especially bridges, due to their remarkable resistance to earthquakes despite the apparent lack of a lateral load carrying mechanism. Makris and his coworkers have shown that the seismic behavior of rocking frames can be modelled as an equivalent rocking block assuming that the deformation of the structural members is negligible. In this work, initially we solve the rocking frame as an equivalent block with the aid of a simple single-degree-of-freedom rocking oscillator neglecting the influence of sliding or uplift. Using the FEM method, we show that rocking frame can be modelled using beam elements connected to rotational springs in the base and the deck/epistyle level which have a negative stiffness moment-rotation relationship. The later approach allows to solve rocking frames which are either rigid or flexible, have more than two columns (i.e. an array of free-standing columns), or have columns of different height and width (asymmetric rocking frame). FEM modeling also offers stable solutions for rocking frames with vertically restrained columns with an elastic tendon that passes through its centerline. More importantly, this solution scheme can be implemented in Finite Element codes which are widely available and engineers are comfortable with. Energy dissipation is modelled with an "event-based" damping scheme considering an equivalent restitution factor obtained from Housner's coefficient of restitution. The proposed modeling was used for assessing the dynamic response and the stability of different types of rocking frames under simple wavelets and real ground motion records demonstrating that accurate results using this method can be obtained, avoiding complicated and specifically-tailored analytical solutions.

A SPECTRAL STOCHASTIC FINITE ELEMENT FORMULATION FOR NONLINEAR ANALYSIS OF STOCHASTIC STRUCTURES

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Keywords: Spectral Stochastic Finite Element method, stochastic structural analysis, geometrical nonlinearity, stochastic load control, stochastic displacement control

ABSTRACT

Despite the significant work that has been made over the last decades in the field of stochastic analysis of structures, in cases where the structures exhibit strongly nonlinear behavior due to material and/or geometric nonlinearities, the knowledge we have about their behavior remains quite narrow, posing, a challenging task for the researchers nowadays. In this work, a novel methodology is presented in order to address the issue of geometric non-linearity in the context of the stochastic finite element method. More specifically, a reformulation of the Spectral Stochastic Finite Element Method (SSFEM) is proposed, in which the stochastic part of the incremental displacements, formulated in the frame of a Newton-Raphson solution scheme, is projected onto a Polynomial Chaos Expansion (PCE) basis. The unknown expansion coefficients form an augmented system of nonlinear equations, which can be solved with the use of standard iterative solvers such as the load control and displacement control method, appropriately extended to their stochastic counterparts. This work focuses mainly on stochastic structural elements with random material properties and the numerical examples presented include truss and frame structures with strong geometrically nonlinear behavior. In all test cases the proposed method achieves high accuracy with low computational cost.

NUMERICAL INVESTIGATION OF THE PROGRESSIVE COLLAPSE OF STEEL STRUCTURES DUE TO PLAN IRREGULARITIES

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Keywords: progressive collapse, irregularity in plans, steel structures, non-linear dynamic analysis, non-linear static analysis.

ABSTRACT

Three buildings of different height, regular and irregular as per their plan layout, are designed according to AISC (2010) and ASCE7 (2010). These structures were considered to be located in regions with different seismic activity with the purpose of observing their dynamic response under seven load-column-removal scenarios by using non-linear static and dynamic analyses. Non-linear dynamic analyses examine the effect of columns removal on adjacent columns, including node-displacement configurations whilst non-linear static analyses focus on the push-over curve and yield load factor. The results indicate that irregular structures designed in site class C seismic zone do collapse in most of the column removal scenarios. It is also demonstrated that higher level of redundancy showed by the 5-storey with respect to the 2-storey building plays an important role in the prediction of progressive collapse. The collected data lead to various reflections related to regular and irregular building performance under seismic load and the importance of prioritising redundancy and robustness in the context of ultimate limit strength design approaches.

DYNAMIC RESPONSE OF MASONRY BUILDINGS CONSIDERING THE TIME-DEPENDENT SOIL SATURATION CONDITIONS

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Keywords: Masonry Buildings, Seismic Hazard, Soil-Structure Interaction, Soil Saturation, Incremental Dynamic Analysis, Limit States, Rehabilitation Measures.

ABSTRACT

The main aim of this work is to investigate the seismic vulnerability of traditional masonry buildings, taking into account the impact of dynamic soil-structure interaction (SSI). More specifically, this paper examines the dynamic response of a typical unreinforced masonry (URM) building constructed over a silty sand layer. The main novelty of the present study is that it considers time-varying soil mechanical properties, since they are taken as dependant on the soil saturation level[1], which changes annually (in a cyclic manner during the four seasons).

For this purpose, the dynamic response of the URM building and its foundation is numerically examined via repeated incremental dynamic analyses, considering the impact of SSI along with the nonlinear behavior of the soil and the structure. A suite of twenty input motions -recorded in similar soil conditions- was selected to obtain a reliable assessment of the dispersion of engineering demand parameters (EDPs) of the examined masonry building. In addition, the repeated analyses of the soil-structure coupled finite element model were performed for eight different saturation levels, covering a wide range of soil conditions to elaborately investigate the problem at hand.

In addition, a new structural assessment approach, which aims to identify the performance levels (i.e., Limit States) of historic buildings after performing certain seismic rehabilitation measures[2], was applied. This methodology attempts to provide a framework that quantifies the "safe" duration (i.e., nominal life) of an intervention that upgrades structural integrity in a specified manner. The nominal life of an intervention is defined as the period for which this action ensures that the structure fulfills selected performance level(s) for a certain probability of exceedance (e.g., probability of exceedance 10% and 20% in 50 years, respectively for Significant Damage and Damage Limitation Levels).

Under this perspective, simple and efficient -in terms of time, cost and effectiveness- interventions were applied in the original UMR building in order to improve its dynamic response and reduce its vulnerability under the examined circumstances. Firstly, the nominal life of each coupled structural model (initial and retrofitted) with constant soil saturation conditions is calculated. Subsequently, the calculation of nominal life is performed in a more realistic manner, by taking into account the annual changes in the soil saturation level.

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Session B3-2

VIBRATIONAL FEATURES OF THE TRADITIONAL PERCUSSION INSTRUMENT BENDIR USING LASER HOLOGRAPHIC INTERFEROMETRY AND FINITE ELEMENT ANALYSIS METHODS

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Keywords: Electronic Speckle Pattern Interferometry – ESPI, Modal analysis, Applied acoustics, Finite Element Method - FEM, Thermomechanical simulations

ABSTRACT

The vibrational characteristics of the traditional percussion music instrument Bendir are studied in this paper. A structural finite element - FE model is developed and validated by experiments[1]. Time-averaged laser Electronic Speckle Pattern Interferometry – ESPI is experimentally performed on the Bendir for the determination of its eigenmodes and respective eigenfrequencies[2]. The eigenmodes of the FE model and the respective eigenfrequencies are also numerically identified by the modal finite element analysis performed. The comparison of the experimental results against the computational results leads to the validation of the computational approximation and confirms the geometrical details and the material properties, assigned to the CAD/FEM developed model.

Furthermore, the initial physical and mechanical parameters of this percussion instrument are modified. The membrane of Bendir is being pre-stressed and its temperature is controllable increased. The effects of these changes to the eigenmodes and eigenfrequencies of the instruments are again experimentally measured. The FE model is appropriately modified in order to include the thermomechanical characteristics of the real physical problem.

The new multiphysics eigenmode simulation results are compared to the experimental results and are found to be in a very good agreement. This combination of FEM with the ESPI is providing a new methodology able to certify and clarify the manufacturing and performance of percussion instruments.

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A NOVEL MODEL FOR THE STATIC RESPONSE OF COATED MICROBUBBLES: ESTIMATION OF ELASTIC PROPERTIES & SIMULATIONS

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Keywords: Coated Microbubble, Elastic properties, Disjoining Pressure, FEM.

ABSTRACT

Coated microbubbles (MBs), also known as contrast agents, are powerful contrast enhancers in medicine. Two major families are normally employed, namely those coated by polymeric and lipid shells. The former type of MBs is characterized by a lager Young modulus, while the latter are softer. Accurate estimation of their elastic properties, namely area dilatation (χ) and bending modulus (k_b), is a key to design and optimize their response in the vascular bed. Atomic force microscopy experiments (afm) have been proven a reliable tool for the characterization of the elastic properties for both types of coatings in the form of force-deformation (F-d) curves[1-5]. In this context, a novel theoretical/numerical model has been developed[6] in order to describe the static response of coated MB under the cantilever of an afm. Due to the hydrophilic nature of these coatings an ultrathin liquid film occupies the space between the shell and the cantilever. As the relative position of the cantilever and the MB is reduced the film is thinning and the local pressure due to the disjoining pressure increases, thus gradually the shell is compressed. The disjoining pressure is a manifestation of short range intermolecular forces and can be expressed via an interaction potential. MBs covered with polymers exhibit an initial linear response in f-d curve (F~d), known also as Reissner regime, while as the force increases, buckling takes place resulting a non-linear response ($F \sim d^{0.5}$), known as Pogorelov regime. MBs covered with lipid initially follow the Reissner regime, but due to the compressibility of the encapsulated gas buckling is bypassed to a curved upwards regime ($F \sim d^3$). Employing analytical models for both types of response, the area dilatation and bending moduli can be estimated for the characterization of their elastic coating. In addition, simulations are performed in order to compare against afm measurements available from the literature, where the effect of elastic properties, surface tension, cantilever geometry and non-symmetry conditions are studied.

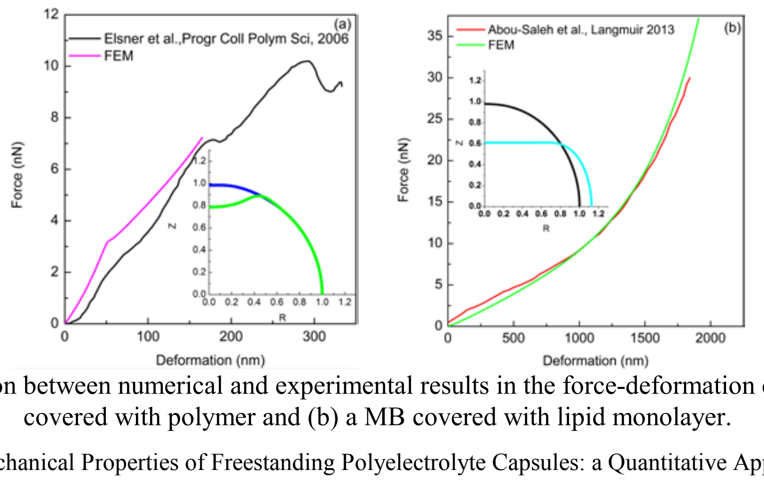

Figure 1: Comparison between numerical and experimental results in the force-deformation curves for (a) a MB covered with polymer and (b) a MB covered with lipid monolayer.

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A REDUCED-ORDER MODEL FOR EFFICIENT CFD ANALYSIS OF CHEMICAL VAPOR DEPOSITION PROCESSES

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Keywords: Chemical Vapor Deposition, Reduced Order Model, Principal Component Analysis, Artificial Neural Networks.

ABSTRACT

A reduced order model (ROM)[1] is developed and an associated computational framework is introduced for coping with a large-scale detailed CFD model of a Chemical Vapor Deposition (CVD) process[2]. The CVD process produces specialized coatings (thin films) which are used in a wide range of products and further processes. These thin films are produced from gaseous precursor compounds that enter the specially designed reactors along with carrier gases and participate in a network of homogeneous and heterogeneous chemical reactions.

The CFD model of the process includes the transient nonlinear momentum, heat, mass and species transport equations in three dimensions along with the multiple chemical reactions that describe the thin film deposition on the reactor's substrate. The equations are discretized and solved with the commercial CFD code ANSYS/Fluent, which implements the finite volume method. The proposed reduced-order model is based on the so-called method of Snapshots[3] in conjunction with the Proper Orthogonal Decomposition (POD)[4]. Here the snapshots are instances along the trajectory of the time-dependent CFD model without chemical reactions and pertinent species transport equations. This offers significant advantages as it greatly reduces the computational cost. The resulting dominant eigendirections span the solution space with adequate accuracy providing thus a solid basis. The time-dependent coefficients of the basis' components are derived by means of Artificial Neural Networks (ANN)[5]. Also, the training of the latter requires only snapshots of the process model without the chemical reactions which renders the proposed methodology applicable in conjunction with any CFD code. The resulting ROM computes approximations of the temperature and velocity field distributions which are subsequently fed into the high-fidelity model that yields the corresponding deposition rate cost-effectively in only a few iterations.

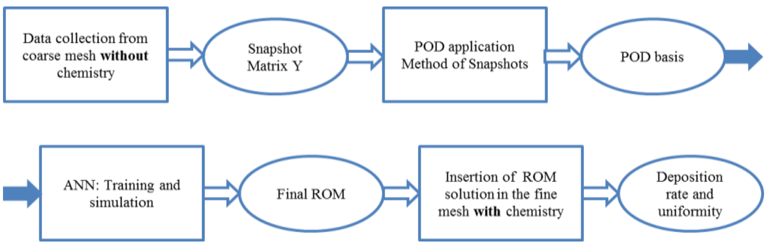

Figure 1: Schematic illustration of the computational framework.

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EFFECT OF SURFACTANTS ON INTERFACIAL STABILITY OF MULTILAYER SHEAR FLOWS

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Keywords: multilayer flow, interfacial instability, surfactants.

ABSTRACT

The flow of multiple superposed layers of viscous liquids, known as multilayer flow, is of central importance in the rapidly burgeoning field of microfluidics. The ability to manipulate flows of this type is fundamental; one possible approach is by using chemical additives known as surfactants, which can greatly influence such flows especially at small scales.

This talk will present a theoretical study that utilises mathematical modelling and numerical computations to scrutinise the effect of (insoluble and soluble) surfactants on the stability of multilayer shear flows in channels. Understanding stability is essential for efficient flow control in applications where (stable) uniform films or (unstable) interfacial waves are desired.

The flow configuration comprises two superposed layers of viscous and immiscible fluids confined in a long horizontal channel. The two fluids can have in general different densities, viscosities and depths, but here the interest lies in the scenario with one of the layers being very thin compared to the other. The surfactant can be insoluble[1], i.e. located at the interface between the two fluids only, or soluble[2] in the thin film. An asymptotic model is therefore derived in the thin-layer approximation, consisting of a set of nonlinear PDEs to describe the evolution of the film, interfacial and bulk surfactant concentration.

Linear stability analysis is also performed to investigate the stability properties of the system and establish regions in the parameter space where instability and non-trivial dynamics are expected. The identified instabilities are followed into the nonlinear regime via extensive numerical computations of the model system, aiming to map and explore the vast solution space. The computations implement highly accurate and stable implicit-explicit BDF schemes in time (with an implicit discretisation of the linear part of the system and an explicit discretisation of the nonlinear part) and spectral methods in space[3].

Interfacial instabilities are induced due to the acting forces of gravity and inertia, as well as the action of Marangoni forces generated as a result of the dependence of surface tension on the interfacial surfactant concentration. The underlying physical mechanism responsible for the formation of interfacial waves will be discussed, together with the complex flow dynamics (typical nonlinear phenomena associated with thin-film flows include travelling waves, solitary pulses, quasi-periodic and chaotic dynamics).

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NUMERICAL EVALUATION OF A TEFLON BASED PIEZOELECTRIC SENSOR EFFECTIVITY FOR THE MONITORING OF EARLY AGE COCRETE STRENGTHING

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Keywords: Piezoelectric Sensors, Concrete Strengthening Monitoring, Finite Element Modeling

ABSTRACT

Piezoelectric materials and especially piezo-ceramic Lead Zirconate Titanate, commonly known as PZT, have been successfully implemented both as sensing and actuating devices in monitoring of concrete dynamic behavior and structural integrity[1]. In most of concrete related monitoring cases PZT elements have the shape of patches or small plates and either attached surficial on structural members or embedded in concrete mass. Present paper investigates the effectivity of an innovative Teflon based PZT Sensor (TPS) which is embedded in mass of a concrete cubic specimens and perform monitoring of early age strengthening procedure[2]. Teflon is used for the fabrication of a durable casing aiming to the protection of PZT ceramic patch both from concrete moisture and loading due to strengthening conditions. The evaluation of mechanical interaction between TPS electrical response and concrete structural conditions is achieved by applying Finite Element Method (FEM) numerical analysis. Concrete strengthening structural influence is introduced to FEM modelling as time-depended changing of Young Modulus, adopting a proposed by Eurocode 2 model that correlates empirically Young modulus with concrete age. Observation of changes that TPS-acquired Electro-Mechanical Impedance (EMI) frequency response signature emerges, due to concrete Young modulus age-related evolution, can establishes a diagnostic methodology for the evaluation of concrete strengthening procedure.

Finite Elements analysis aims to the enhancement of Teflon casing design and properly selection of PZT adhesive materials in order to be achieved the optimum dispersion of PZT generated mechanical energy in concrete mass. A major problem that usually encountered in concrete dynamic response based structural control is the high, comparing to metallic structures, amount of mechanical energy that required for the efficient excitation of a concrete member. High attenuation and local stiffness that concrete exhibits inhibit the mechanical energy to stimulate vibration modes that will give detectable peaks in EMI signatures. So the detection of structural integrity deterioration by observing signature peaks changes becomes seriously restricted.

From the results of FEM modeling derives that the sensors which are embedded in concrete mass acting like concrete's aggregates and has the ability to spread their effectiveness in a greater area of concrete than those sensors which are surficial attached. The changes in EMI signatures can be manipulated for the evaluation of early age concrete Young modulus alteration during strengthening procedure. Finally numerical results give essential information concerning the optimal mechanical properties of adhesive material which are used for the attachment of PZT inside Teflon casing.

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TOPOLOGY OPTIMIZATION OF LATTICE STRUCTURES

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Keywords: Topology optimization, lattice structures, additive manufacturing

ABSTRACT

Topology optimization (TO) methods determine the overall configuration of shape elements in a design problem. As structural optimization methods, finite element analyses are performed typically during each iteration of the optimization method, which means that TO can be computationally demanding. Two main approaches have been developed for TO problems: truss-based and volume-based density methods.

The density-based TO method that is most common, and is used in the commercial software packages, is known as the SIMP (Solid Isotropic Material with Penalization) method. The starting geometry for the problem is a rectilinear block that is composed of a set of voxels. Each voxel has a density value which is used as its design variable. A density value of 1 indicates that the material is fully dense, while a value of 0 indicates that no material is present. At this stage, we can adjust the density of the material in solid and lattice structures. For example, we could specify that elements with material density values between 0.7 and 1.0 are solid, and elements with material density values between 0.4 and 0.7 are lattice structures. Elements with material density values less than 0.4 are removed from the model. Lattices can be applied to all of the elements in our design area or only those elements with material density values within a particular range.

A lattice is a thin truss-like shape that it can be used in additive manufacturing (3D printing) to create a lightweight part that still maintains its structural strength and integrity. The optimal topology optimization solution could be a combination of solid and lattice structures that satisfies all the loading and support conditions of the model. This new model can be produced via additive manufacturing technics, like 3d print.

The topology optimization solution has been applied to a shoe-sole model in order to produce a lightweight, personalized shoe which also will have the maximum shock absorption and resistance.

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