Feedback-based metamaterials for enhanced waveguiding

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ABSTRACT

Metamaterials, composed of architectured and usually periodically arranged unit cells, have significantly expanded our ability to shape wave propagation across physical domains. While passive metamaterials have enabled dispersion engineering, cloaking, and topologically protected transport, their performance is ultimately restricted by the fixed properties of their constitutive elements. Many desirable forms of wave manipulation—such as directional, non-local, or complex-valued couplings—are difficult to realize within purely passive platforms.

Active metamaterials, and especially those operating through real-time feedback, lift these limitations by embedding sensors, actuators, and control algorithms directly into the material architecture. Through closed-loop interactions, they synthesize effective couplings unattainable in passive media: they can break reciprocity, control gain and loss with precision, generate spatially and temporally varying potentials, and continuously reconfigure their response while maintaining global stability. In this sense, feedback becomes not an accessory, but a fundamental design dimension for advanced waveguiding.

In this talk, I will introduce a unified framework in which feedback-based acoustic and mechanical metamaterials are modeled as effective continuous media derived from their discrete controlled architectures. Within this framework, we demonstrate several forms of enhanced wave manipulation. One example is non-Hermitian tunneling, where feedback-induced asymmetric couplings cause waves to extinguish within a region while reconstructing beyond it, thereby creating quiet zones and a selective transmission. Another is the acceleration of wave packets, achieved by tuning parity–time-symmetric interactions to yield group velocities exceeding the intrinsic speed of sound without modifying the physical geometry. We further show how feedback can emulate a funnel-like potential that bends waves analogously to gravitational lensing, enabling smooth steering and focusing. Additionally, dynamically engineered flat-band dispersion allows waves to be trapped or strongly localized in specific regions, offering active control over energy concentration.

Taken together, these results reveal how feedback-based metamaterials can enhance waveguiding capabilities beyond what passive systems can achieve. They point toward a versatile class of architectured materials whose functionality is not built into their geometry alone but programmed and continuously reshaped through active, real-time control.

Soft hyperelastic orthotropic lattice structures: Numerical homogenization and experimental validation

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ABSTRACT

Lattice structures are increasingly used in biomechanical applications such as shoe soles, cushions, prosthetics, and orthotics because their mechanical properties can be locally tailored by adjusting topology. Advancements in additive manufacturing have enabled the fabrication of previously unattainable complex geometries. Finite Element Analysis (FEA) is commonly used to predict their mechanical response and inform inverse design algorithms. Yet, simulating lattice geometries poses significant computational demands owing to the large number of elements required to mesh them. Homogenization, in which the lattice is replaced with an equivalent homogeneous material, overcomes this challenge. However, determining suitable constitutive models and parameters for nonlinear, anisotropic materials remains difficult. This work presents numerical homogenization using a compressible hyperelastic orthotropic constitutive law and experimental validation on soft lattice structures fabricated from thermoplastic polyurethane (TPU) using selective laser sintering (SLS) [1, 2].

We performed experimental and numerical analyses of thick-beam-based lattice structures generated in Creo 9 and manufactured using a Lisa Pro (Sinterit, Poland) SLS 3D printer with Flexa Bright TPU powder. Material parameters were calibrated from tension and compression experiments across three printing orientations [1]. We then conducted FEAs simulating large uniaxial tension, compression, and shear deformations and fitted the homogenized Fung compressible orthotropic hyperelastic model to the results [2]. We investigated lattice cells with various geometrical parameters and fitted model parameters for each case. Numerical results were validated against compression experiments on lattice structures using 3D digital image correlation (DIC) to measure full-field surface deformations in addition to global force-displacement responses.

Replacing the lattice structure with the homogenized material reduced computational time by up to three orders of magnitude while maintaining prediction accuracy, with deviations less than 8.3% in reaction force and 5.6% in deformation compared to exhaustive lattice simulations [1]. This method enables efficient design of biomechanical interfaces with spatially variable properties achieved through local geometric tailoring of lattice cells.

References

1. Raf, D., et al. *Mechanics of Materials* 212:105534, 2026. DOI: 10.1016/j.mechmat.2025.105534
2. Raf, D., et al. *Engineering Archive* Preprint DOI: 10.31224/4689

Soft mechanics of physically cross-linked hydrogels

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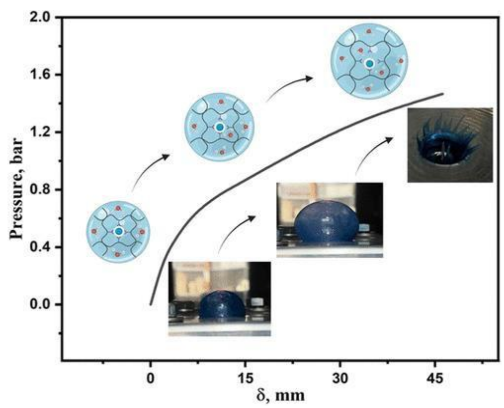
ABSTRACT

Physically cross-linked hydrogels strengthened by dynamic metal-ligand interactions have emerged as promising candidates for critical applications in electronics, soft robotics, energy storage devices and biomedical applications, which require high toughness, recoverability, and multiaxial load-bearing capability. In this work, we investigate poly(methacrylamide-*co*-vinyl imidazole)-Ni (PMV-X-Ni) hydrogels and provide a combined experimental-computational framework to understand their nonlinear mechanical response under large deformation. Hydrogels with varying imidazole content (40-70 mol%) were synthesized in our study. Their rheological and uniaxial behaviors were first characterized to quantify the influence of metal-ligand cross-links on stiffness, relaxation time, and recoverability. An in-house developed bulge test device was then used to study the equi-biaxial response. To this end, we derive a hyperelastic constitutive model with a description of failure and validate it experimentally. This study demonstrates that incorporating imidazole-Ni^{2+} metal-ligand cross-links can significantly enhance several mechanical properties. For instance, increasing the imidazole content from 40 to 70 mol % improves the elastic modulus by 400% and the ultimate equi-biaxial stress by 80%. The detailed analysis further reveals that the inflation of these hydrogels strongly depends on structural evolution.



The proposed experimental-computational methodology provides a robust approach to characterize and model physically cross-linked hydrogels enabling an effective way to develop, improve and model tunable metal ligand-based hydrogels for applications in soft robotics, stretchable electronics, and energy storage devices.

References:

1. M. Goswami, A. Dutta, R. Kulshreshtha, G. Vasilyev, E. Zussman, K. Volokh, Mechanics of physically cross-linked hydrogels: Experiments and theoretical modeling, Macromolecules 58 (9) (2025)
2. K. Balakhovsky and K. Y. Volokh. “Inflation and rupture of rubber membrane”. International Journal of Fracture 177.2 (2012), pp. 179–190.
3. Y. Lev, A. Faye, K. Volokh, Thermoelastic deformation and failure of rubberlike materials, Journal of the Mechanics and Physics of Solids 122 (2019) 538–554.

A phase field model for heterogeneous materials with application to bone fracture

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ABSTRACT

Bone fracture prediction by CT-based finite element analysis based on maximum principal strain criterion can predict fracture initiation load within 80% accuracy (conservative prediction) [1]. It cannot predict the crack path which may also be of interest for clinical application.

Phase Field Models (PFMs) may improve bone fracture predictions [2], however, PFM predictions are highly influenced by the heterogeneous critical Energy Release Rate (ERR) G_{Ic}, critical ultimate stress and Young modulus of the bone. To improve fracture initiation and crack path predictions in human long bones by PFM we apply numerical-experimental methods to determine the material properties of bone tissue so to be used in conjunction with CT-based FEA. We firstly focus on the femoral cortex and failure in transverse direction (perpendicular to osteons).

Human fresh frozen femurs were CT-scanned to obtain bone density along the femur, then sliced to create three point bending specimens in which crack like defects were inserted. These specimens were then micro-CT scanned before loaded to fracture. Using standards designed for metals and concrete, we computed the critical Stress Intensity Factor (K_{Ic}) through a three-point bending test setup combined with Digital Image Correlation (DIC). This allowed us to establish a qCT-based correlation for G_{Ic}, which was validated using PFM and FEA. Additionally, fracture experiments on unnotched bone specimens were conducted to estimate the critical strain ε_c through DIC measurements and the results were compared with data available in the literature. We performed validation with PFM and FEA to determine the appropriate critical strain among the yield and ultimate strain values. FE results will be presented using the newly computed material properties to predict fracture loads of human bones.

References

[1] Z. Yosibash et al, Predicting the stiffness and strength of human femurs with real metastatic tumors. *Bone*, 69:180-190, 2014

[2] L. Hug et al, Predicting Fracture in the Proximal Humerus using Phase Field Models. *J Mech Behavior Biomed Mat*, 134:105415, 2022.

Strut and tie ML AI models for reinforced concrete analysis

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ABSTRACT

Reinforced concrete structures traditionally rely on Bernoulli-Euler beam theory, which assumes linear stress distribution. However, in D-regions areas near support or geometric discontinuities these assumptions break down, and more advanced methods are required, Strut and Tie method (STM) is one of the most popular. STM models rely heavily on mechanical judgment of the engineer, to determine optimal configurations, creating barriers to efficient design. This study examines machine learning algorithms to predict internal forces in deep beams with consider as D-regions. A hybrid ML/AI data bases were evaluated using standard formulation, and validated for three ML/AI approaches, linear regression, with and without polynomial expansion (2nd and 3rd order), and Artificial Neural Networks (ANN). The most advanced linear regression model and the ANN model achieved excellent accuracy, which is appropriate for structural design. The results demonstrate that machine learning can effectively automate STM analysis for deep beams, eliminating expert-dependency and enabling efficient structural design more types of D-regions.

On deep learning calibration for DEM simulation of sedimentary and igneous rocks

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ABSTRACT

We propose a Deep Learning (DL)-based calibration procedure of particle-based material model parameters for rock materials simulated by the Discrete Element Method (DEM). We create Discrete Element models using Bond-Particle Models (BPM) [1] to simulate Uniaxial Compression tests and Brazilian tests commonly used for experimental determination of material parameters. After simulation, the microscopic parameters of the model are fed into a constructed DL system based on the Multi-Layer Perceptron regressor as input data and the functional depending on macroscopic critical stresses and strains as the output. As a result, a set of optimal microscopic parameters has been found and tested in a simulation using the same DEM Model. Then, we compared the resulting stress–strain curve with the experimental data used as a reference for calibration. Additionally, the stability of the obtained model in terms of reproducibility of the stress–strain curve has been tested by simulating Uniaxial Compression for DEM models with different particle packing. The discrete element models obtained with material parameters have showcased excellent stability and consistency with experimental data, especially for hard rocks. For soft rocks, the model showcases nonlinear elastic behavior upon loading due to the inherent features of BPM. We have conducted a correlation analysis, from which we were able to see the dependence of target parameters (critical stresses) on the variation of the calibrated parameters. The analysis shows that bond diameter is the most crucial parameter, whose calibration should be prioritized. In addition, we have computed the statistical indicators that have only reinforced that conclusion. The procedure can be used to simulate rocks in geomechanics and geoengineering problems demanding discontinuous rock description, such as multiple crack formation, drilling, boring, and rock blasts [2].

References:

[1] Potyondy, D.O., Cundall, P.A., 2004. A bonded-particle model for rock. International Journal of Rock Mechanics and Mining Sciences 41, 1329–1364. https://doi.org/10.1016/j.ijrmms.2004.09.011

[2] Kholodniak, M., Panchenko, A., Berinskii, I., 2026. On deep learning calibration for DEM simulation of sedimentary and igneous rocks. Powder Technology 470, 121929. https://doi.org/10.1016/j.powtec.2025.121929

Additive Vanka smoothing improves scalability of shifted Laplacian multigrid preconditioner for the acoustic Helmholtz equation

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ABSTRACT

We present an improved multigrid preconditioner for the acoustic Helmholtz equation with enhanced scalability. Standard multigrid fails to converge for the Helmholtz equation, and the well-known complex shifted Laplacian method overcomes it by adding a complex shift and using the shifted system as a preconditioner. However, the added complex shift grows with the frequency and interferes with the preconditioner's scalability. By carefully designing different ingredients of the multigrid cycle, the presented method enables deep multigrid V-cycles with a small and bounded shift, even when many levels are used. We validate our method theoretically by local Fourier analysis, and hold numerical experiments for homogeneous and heterogeneous media. We show that our method outperforms plain shifted Laplacian in terms of runtimes and performs well on challenging geophysical media in 2D and 3D.

A purely mechanical version of a thermomechanical Eulerian formulation of a size-dependent elastic-inelastic Cosserat continuum

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ABSTRACT

A purely mechanical version of a thermodynamically consistent theory for finite deformation size-dependent elastic-inelastic response of a Cosserat material with a deformable director triad di has been developed by the direct approach. A unique feature of the proposed theory is the Eulerian formulation of constitutive equations, which do not depend on arbitrariness of reference or intermediate configurations or definitions of total and plastic deformation measures. Inelasticity is modeled by an inelastic rate tensor in evolution equations for microstructural vectors. These microstructural vectors model elastic deformations and orientation changes of material anisotropy. General hyperelastic anisotropic constitutive equations are proposed with simple forms in terms of derivatives of the strain free energy, which depends on elastic deformation variables that include elastic deformations of the directors relative to the microstructural vectors. An important feature of the model is that the gradients of the elastic director deformations in the balances of director momentum control size dependence and are active for all loadings. A numerical solution of the small deformation equations for a damaging elastic material is shown which demonstrates that the deformable Cosserat model predicts size-dependent, mesh-independent predictions of the development of localization regions.

Skew-boundary condition incorporating the load-controlled implicit elastoplastic FEM for bearing capacity of jack-up rig

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ABSTRACT

This study proposes a robust computational framework for assessing the bearing capacity of three-dimensional (3D) jack-up platforms resting on Mohr–Coulomb soil. While the backward Euler-based implicit elastoplastic stress integration typically provides higher accuracy and stability than the forward Euler-based explicit scheme—due to the enforcement of the Kuhn–Tucker–Karush (KTK) consistency condition—it often experiences convergence difficulties in complex soil–structure interactions such as jack-up rigs. To address this limitation, a new implicit algorithm is developed by computing the trial stress increment with the consistent tangent stiffness matrix. The framework combines a load-controlled approach, an implicit elastoplastic finite element method based on the consistent tangent stiffness and a skew-boundary condition interface model, implemented in a coupled MATLAB–Python environment. Validation against analytical and numerical benchmarks demonstrates that the computed bearing capacity factor (N_c) for a single spudcan with an open cavity closely agrees with the values predicted by established methods such as the society of naval architects and marine engineers (SNAME) and international organization for standardization (ISO) guidelines. The results confirm that the proposed implicit formulation effectively eliminates artificial rate-dependent effects observed in explicit elasto-viscoplastic analyses [1,2], yielding enhanced numerical stability, accuracy, and physical realism in modeling soil–jack-up interactions.

References:

[1] Phuor T, Harahap ISH, Ganz A, Trapper PA. Bearing capacity of 3D jack-up rig by skew-boundary condition with viscoplasticity element-by-element method. Ocean Eingineering 2025;322:120501.

[2] Phuor T, Chen Y, Yang Z, Zhao C. Load-controlled element-by-element method incorporating skew-boundary condition for soil-structure interactions: application to punch-through analysis of the 3D jack-up rig. Computers and Geotechnics 2025;180:107079.

Layout and shape optimization of thin-walled beams with buckling considerations

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ABSTRACT

This work presents a new approach for the optimization of thin-walled beams. The method relies on the well-known ground-structure method, usually used in truss optimization. The thickness of the segments forming the beam's cross-section and the location of their connections are considered as design variables. This enables sizing, layout, and shape optimization of these elements. The optimization problem is formulated by considering the buckling resistance of the structure, its compliance, and the total volume of the design. The buckling load factors are computed through linearized buckling analysis using the finite strip method. The problem is solved using a gradient-based algorithm, with consistent analytical sensitivities derived via the adjoint variable method. The occurrence of spurious buckling modes, which may appear during optimization due to joints connecting thin segments, is demonstrated. A procedure for automatically filtering these modes is incorporated into the optimization algorithm. In addition to the primary physical objectives, the objective function is augmented with costs accounting for manufacturability by using a smooth approximation of the number of segments in the design. This promotes designs with fewer segments according to a user defined weighting parameter. Several numerical studies are presented, including comparison with topology optimization, investigation of various optimization parameters, and the design of a wing box. The results show that the proposed approach produces designs in close agreement with those obtained from topology optimization, while requiring significantly less computational effort. The optimized designs obtained with buckling considerations highlight the ability of the method to enhance the local buckling resistance of thin-walled beams by increasing the webs' self-moment of inertia about their weak axis.

Efficient reliability-based design optimization of dynamic linear systems subjected to filtered white-noise input

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ABSTRACT

Optimization of structural systems comes as a means to obtain economic and well-functioning structures. In real-scale problems, typically a "cost" function is minimized, and functions expressing structural performance are considered as constraints. A key characteristic of structural systems is that they typically involve many uncertainties. The uncertainties originate from the random nature of the system's inputs, and of its parameters. These uncertainties cause difficulties in predicting the response, which is also random. In some cases, the uncertainties have a huge effect on the performance of the system.

The attempt to account for randomness in optimizations has brought forth the ongoing research on Reliability-Based Design Optimization (RBDO). In this subdiscipline of structural optimization, the formulations comprise one or more functions that express the reliability-level of the structure. These analyses aim at finding the probability of failure of a given realization of the building.

This work presents a structural optimization methodology for linear systems subjected to dynamic loads, under reliability constraints. The reliability analysis is conducted via First-Order-Reliability-Method (FORM), that, by itself, requires the solution of an optimization problem. Thus, the structural optimization problem is solved using a double-loop approach in which the FORM optimization is nested. That is, the FORM optimization is performed at each design iteration. Both inner and outer optimization problems are solved with gradient-based algorithms. The sensitivity of the reliability index is efficiently evaluated using perturbation theory. The evaluation of the limit-state function is efficiently achieved via the solution of the linear algebraic Lyapunov equations. The white-noise input to these equations is filtered to represent realistic dynamic loadings in the frequency domain. These equations result in the steady-state response covariance matrix (mean-square values) of the responses of interest, hence replacing the known integral over the frequency range.

The application of the methodology is demonstrated through two examples: (a) a footbridge subjected to crowd excitation, and (b) a flexural frame subjected to a seismic event. Control devices for both these examples are optimized, considering the reliability level of the design. It is shown that a slight increase in the additional damping can significantly reduce the probability of failure to a predefined value.

First-order equivalent static loads for dynamic response optimization

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ABSTRACT

Optimization of structures subjected to dynamic loading aims to determine an optimal design that maximizes performance while satisfying prescribed constraints. Incorporating the full dynamic response in the optimization loop is computationally demanding, as the transient analysis must be repeated at each design iteration. To alleviate this burden, the Equivalent Static Loads (ESL) approach has been widely adopted. With ESL, the dynamic optimization problem is replaced by a sequence of static subproblems. Each subproblem is associated with a specific time step, and the equivalent static loads produce the same displacements as those generated by the original dynamic loads. In the original ESL approach, the equivalent loads are computed with a zeroth-order formulation, meaning that they do not carry sensitivity information with respect to the design variables. Consequently, ESL cannot, by definition, identify optimal solutions of the original dynamic problem. This limitation is directly addressed in the present work through the introduction of the First-Order Equivalent Static Loads (F-ESL) approach. Unlike ESL, F-ESL incorporates first-order sensitivity information into the equivalent loads, enabling the static subproblems to recover the optimality characteristics of the original dynamic formulation. To further enhance computational efficiency, a Selective F-ESL (SELF-ESL) extension is proposed, in which only the design-driving time steps (and the associated loads) are retained in the static subproblems. This selective procedure considerably reduces the computational cost without compromising the accuracy of the optimal solution obtained. The proposed approaches are implemented and evaluated through a series of numerical examples involving sizing optimization of 2D and 3D truss and frame structures subjected to transient loads. The results demonstrate the accuracy, robustness, and computational advantages of the suggested formulations compared to direct dynamic response optimization.

Modelling fidelity of offshore jacket platforms

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ABSTRACT

This study investigates the numerical fidelity required for reliable nonlinear finite element analysis (NLFEA) of fixed offshore jacket platforms, with emphasis on joint flexibility, soil-structure interaction, and geometrical imperfections. A representative four-legged X-braced North Sea jacket was modelled in Abaqus using combinations of beam and shell elements to capture both global system behaviour and local joint deformation mechanisms. Eight environmental loading directions (end-on and broadside) were examined under incrementally applied operational and extreme storm loads.

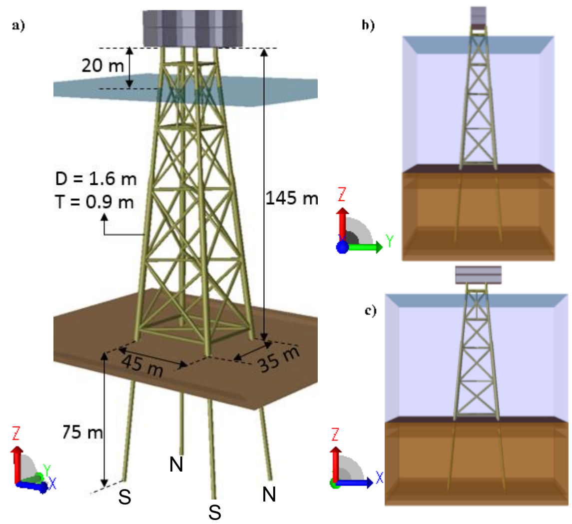

Fig. 1NLFEA model of jacket platform: (a) isometric view; view from (b) X and (c) Y directions.

Joint flexibility was introduced through face-to-face and centre-to-centre joint modelling approaches as well as an advanced hybrid shell-beam representation. Results show that neglecting joint flexibility can overestimate platform strength by up to ~12% and significantly overestimate global deformability and base shear capacity. Soil-structure interaction was incorporated via nonlinear distributed springs along embedded piles. The presence of a piled foundation caused a severe reduction in global stiffness (≈50%), driven by rotational and translational compliance at the seabed. Geometrical imperfections were assigned to compression legs based on industry-standard equivalent imperfection amplitudes. Although imperfections did not significantly influence initial stiffness or ultimate strength, they produced large increases in initial deformation and resulted in substantial reductions in base shear capacity, particularly for end-on loading directions. Across all simulations, failure was governed by brace buckling in bays where leg stiffness transitioned abruptly, while shell-based joint modelling enabled localisation of yielding and earlier softening. The findings confirm that joint flexibility, soil-structure interaction and imperfections must be explicitly represented to avoid non-conservative strength predictions when assessing ageing offshore structures.

Discrete body dynamics method for open- and closed-chain systems with joint compliance

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ABSTRACT

Dynamic simulation of mechanical systems is a central tool for research, development, and design. In complex systems it is essential to use numerical methods that describe the system through physical parameters, initial conditions, and applied forces. Methods of this type allow modeling without deriving the equations of motion analytically. Existing numerical approaches can be grouped into several main families. The first is Multibody Dynamics (MBD), which is based on differential algebraic equations. This formulation requires a Newton-Raphson convergence process and involves high computational complexity with finite numerical accuracy. The second family includes Impulse Based formulations, which are stable and allow relatively large time steps, although the accuracy is reduced. A third family is the Recursive-Newton-Euler formulation (RNE), which has low computational complexity but may propagate errors between bodies, and becomes more complex in closed chain configurations.

This work introduces Discrete Body Dynamics (DBD), a new modeling and numerical method that provides low computational complexity together with high accuracy. The method eliminates explicit constraints. All internal forces in the system, including joint forces, contact and friction forces, and torsional springs, are represented by spring-damper elements. Each body is solved independently in its own coordinate system. The numerical structure is element wise, which enables natural parallelization. The method is inherently suitable for mechanisms that include joint compliance, a property that characterizes most real mechanical systems. Friction modeling fits naturally within the DBD framework. The method can reproduce complex friction phenomena such as pre-sliding, stick-slip, frictional lag, and jamming. Classical MBD methods often struggle to capture these effects in a stable and accurate manner. In terms of performance, the method shows high accuracy and computational efficiency for systems with natural frequencies of up to approximately 250 hertz. This frequency range is common in relatively stiff systems such as suspension bushings. The accuracy achieved by the method is comparable to that of the fully analytical Lagrange formulation.

Accelerating numerical computations using NextSilicon Maverick-II

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ABSTRACT

NextSilicon has been developing unique, groundbreaking hardware and software for an HPC accelerator. Under this concept , hardware threads are configured at runtime to optimize the performance of computational kernels. Promising results of several HPC benchmarks have already been exposed, including HPCG and GUPS.

NextSilicon's software supports conventional parallel programming paradigms such as OpenMP and Kokkos, in addition to its own parallel programming API. This means that programs written for shared memory parallelization over CPU can easily and portably run on this power-efficient platform. Several large open source applications are already being accelerated on NextSilicon's hardware, such as Devito (Fast Stencil Computation from Symbolic Specification), LAMMPS (Large-scale Atomic/Molecular Massively Parallel Simulator) and SPARTA (a Monte Carlo simulator). In this talk we will offer a taste of the paradigm change of running scientific programs over the NextSilicon architecture by presenting examples from NextSilicon's upcoming sparse matrix library.

Prediction of residual stress distribution at GTAW welded thin-walled aluminum pipes utilizing COMSOL Multiphysics, validated by micro-hardness analysis

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ABSTRACT

Residual stress generated during Gas Tungsten Arc Welding (GTAW) of Aluminum alloys play a crucial role in determining mechanical and structural stability. In addition, fatigue resistance of the welded components is affected as well. The governing parameters of the welding window are balance and frequency of the Alternating Current (AC) welding mode. Those values were implemented to the numerical model, to investigate the weld pool geometry, along with metallographic and micro-harness analysis. In this study, a coupled thermo-mechanical finite element model has developed, using COMSOL Multiphysics. This model intends to simulate the transient temperature field, and the subsequent evolution of residual stress in GTAW welded thin-walled Aluminum pipes. The model incorporates temperature dependent thermal and mechanical properties, to visualize the interaction among heat flow, thermal expansion, and stress concentration, during the cooling stage. To achieve an indirect experimental validation, micro-hardness analysis was conducted through the weld cross-section. Still, this analysis does not directly indicate the presence of residual stress. Difference in the micro-hardness profile was correlated with regions of tensile and compressive stress, as predicted by the numerical model. Moreover, a metallographic analysis has been performed to show the different regions at the weld joint, i.e. the Weld Metal (WM), the Heat Affected Zone (HAZ), and the Base Metal (BM), especially the weld pool geometry. Thus, this research might contribute to improving the HAZ mechanical properties by minimized failure of the component. The combined computational and experimental approach offers an effective methodology for evaluating residual stress distribution in thin-walled Aluminum pipes during the welding process and can lead to enhanced performance and reliability of the component.