איגוד ישראלי לשיטות חישוביות במכניקה – אישח"מ
Israel Association for Computational Methods in Mechanics – IACMM

ISCM - 49

יום העיון הארבעים ותשעה במכניקה חישובית

The 49th Israel Symposium on Computational Mechanics (ISCM-49)

בחסות:
המכללה האקדמית להנדסה ע"ש סמי שמעון
המחלקה להנדסת מכונות

מועד: **יום חמישי, 24 במרץ, 2022**

מיקום: **אודיטוריום מינקוף M152, קמפוס באר שבע**

הרשמה

דמי הרשמה ליום העיון:

חברי אישח"מ בשנת 2022-חינם
לא חברים-80 ש"ח

דמי חבר באישח"מ: 150 ש"ח לשנה (דמי חבר כוללים חברות במהלך שנת 2022)
כולל ימי עיון של אישח"מ, חברות באיגוד הבין-לאומי למכניקה חישובית IACM ובאיגוד האירופאי ECCOMAS, מנוי לעלון IACM, והנחות בארועים מיוחדים של אישח"מ וכנסי ECCOMAS

תעריפים מוזלים (לסטודנטים לתואר ראשון ולחיילים בשרות חובה)
דמי חבר לשנה – 80 ש"ח
דמי הרשמה ליום עיון – 40 ש"ח

הודעה

אחד המרצים (לא כולל הרצאות מוזמנות) ביום העיון ה-48 וה-49 יזכה בתמיכת האיגוד לנסיעה לכנס בינלאומי בתחום המכניקה החישובית!!!

מארגנים מקומיים

ד"ר ניר טרבלסי
המחלקה להנדסת מכונות
המכללה האקדמית להנדסה -SCE
טלפון: 08-647-5630
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ד"ר אלעד פריאל
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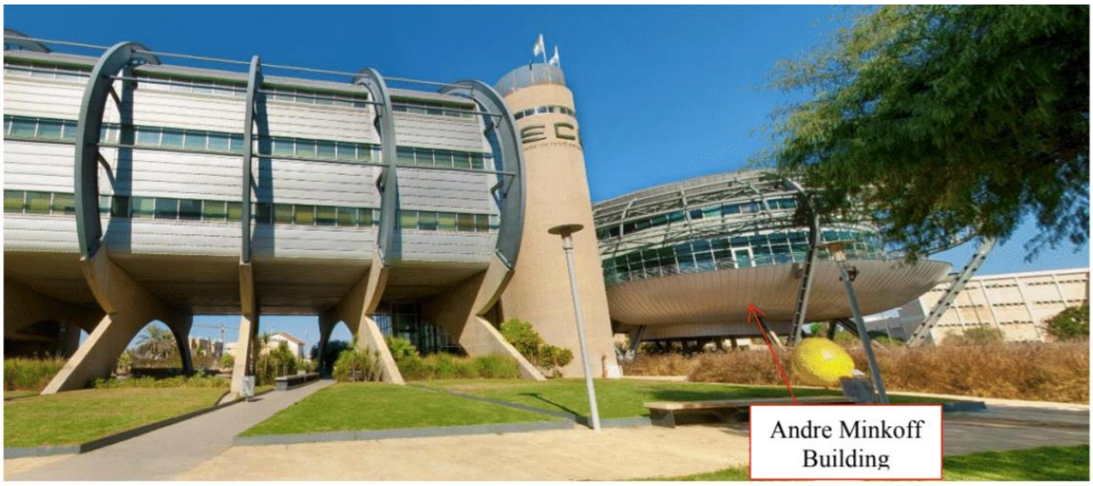
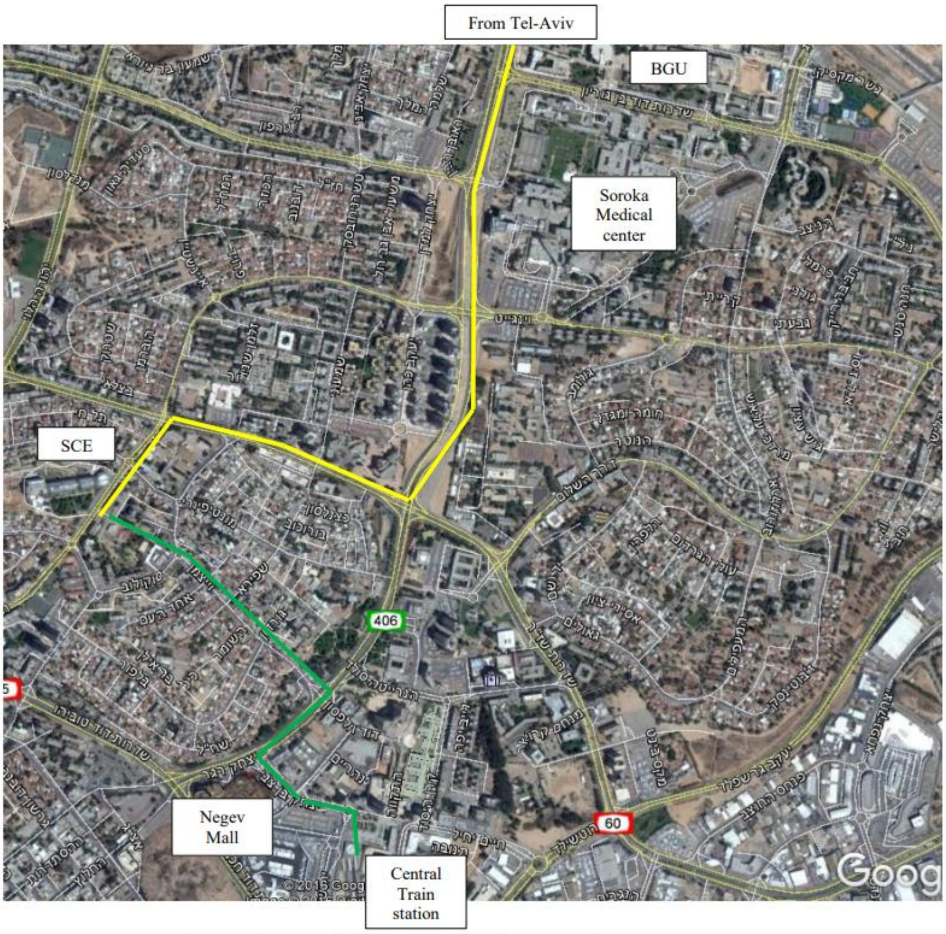
Location

The conference will take place in the **M152 Auditorium located in the Andre Minkoff building** the first building on the right when entering the campus.



Directions



By car: Coming from the north (Tel-Aviv) drive straight from the entrance to Bee-Sheva (Rager St.) right to Derech HaMeshahrerim and turn left on Haim Nachman Bialik St. Parking inside the campus.
By Train: Exit at the central Beer-Sheva train station about 15 min walk to the college or take a taxi (about three-five min drive).

ISCM-49 participants can park inside the college by showing this program at the gate

יום העיון הארבעים ותשעה במכניקה חישובית
The 49th Israel Symposium on Computational Mechanics (ISCM-49)

8:00-9:15 **Registration and Coffee**

9:15-9:30 **Opening**

9:30-11:00 **Session 1**

9:30-10:00 ***Keynote lecture****: Identification of Soft Tissue Material Parameters Using Inverse Finite Element Analysis*
D. Solav, Z. Oddes
Faculty of Mechanical Engineering, Technion-Israel Institute of Technology, Haifa, Israel

10:00-10:20 *Phase Field Modeling of Humeral Neck Fracture*
L. Hug, G. Dahan, S. Kollmannsberger, E. Rank, Z. Yosibash
Chair of Computational Modeling and Simulation, Technical University of Munich, Munich, Germany

10:20-10:40 *Rheological model for tumor cell progression and metastasis*
L. Daraf, Y. Feldman
Department of Mechanical Engineering, Ben Gurion University, Beer Sheva, Israel

10:40-11:00 *Numerical Modelling of Spatial Porosity and Asymmetry Impact on Maternal Blood Flow and Oxygen Transport in the Placenta*
T. Mekler, R. Plitman Mayo, G. Marom
School of Mechanical Engineering, Tel Aviv University, Tel Aviv, Israel

11:00-11:30 **Coffee break**

11:30-13:00 **Session** 2

11:30-12:00 ***Keynote lecture:*** *Development of an Immersed Boundary Method for Interactions between Rigid Bodies and High-Speed Compressible Flows*
Y. Kozak, M. Ezra
School of Mechanical Engineering, Tel Aviv University, Tel Aviv, Israel

12:00-12:20 *A study of pre-heating stages in electron beam melting using numerical simulations*

E. Landau, E. Tiferet, Y. Ganor, D. Braun, G. Ziskind
Department of Mechanical Engineering, Ben Gurion University, Beer Sheva, Israel
Nuclear Research Center Negev, Israel

12:20-12:40 *A physically-informed Deep-Learning approach for locating sources in a waveguide*
Eli Mtanes, Symeon Papadimitropoulos, Dima Batenkov,Adar Kahana, Eli Turkel
School of Mathematical Sciences, Tel Aviv University, Tel Aviv, Israel

12:40-13:00 *Shape Identification of Scatterers Using a Time-Dependent Adjoint Method*
A. Sayag, D. Givoli
Faculty of Aerospace Engineering, Technion-Israel Institute of Technology, Haifa, Israel

13:00-14:20 **Lunch break.** IACMM council meeting.

14:20-14:30 **General Assembly of the association**

14:30-16:20 Session 3

14:30-15:00 ***Keynote lecture:*** *Modeling cracks in soft materials using the material-sink theory*

K.Y, Volokh, S. Abu-Qbeitah, M. Jabareen
Faculty of Civil and Environmental Engineering, Technion - Israel Institute of Technology, Haifa, Israel

15:00-15:20 *Insights from a strain model of faulty bearings validated by FBG measurements*

R. Ohana, R. Klein, J. Bortman
Department of Mechanical Engineering, Ben Gurion University, Beer Sheva, Israel

15:20-15:40 *Modelling ductile failure initiation and damage propagation in metallic materials under general loading conditions*

N. Rom, J. Bortman, E. Priel
Department of Mechanical Engineering, Ben Gurion University, Beer Sheva, Israel
Department of Mechanical Engineering, Shamoon College of Engineering, Beer Sheva, Israel

15:40-16:00 *A Comparative Study of Stochastic Methods for Delamination Analysis*

N. Malkiel, O. Rabinovitch
Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology, Israel

16:00-16:20 *Optimization based seismic retrofitting of frame structures with negative stiffness devices and fluid viscous dampers*

O. Idels, O. Lavan
Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology, Israel

16:20 Closing

Identification of soft tissue material parameters using inverse finite element analysis

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ABSTRACT

Mechanical simulation of soft tissues is required in various applications (e.g., computational mechanical design of medical devices, surgical simulations, haptics, and more). Reliable simulation requires representing the tissues with realistic constitutive laws and material parameters. Soft tissues exhibit nonlinear behavior and are commonly modeled using hyperelastic formulations. The large variability between tissue regions and different people typically necessitates subject-specific *in-vivo* characterization. Standard mechanical tests are typically too invasive to be considered in *in-vivo* settings. Alternatively, non-invasive indentation test is utilized, coupled with inverse finite-element analysis (iFEA), for identifying the material parameters. However, determining which measurements and optimization procedures must be conducted in order to identify a unique parameter set remains unclear. This work discusses some of the theoretical, computational, and experimental challenges involved in identifying material parameters using indentation and iFEA. For example, assigning realistic boundary conditions, accounting for subject movement artifacts, tackling the uniqueness problem, and more.

Specifically, we study the parameters' sensitivity to different measurements, including the indenter's force and displacement (which are often the only measurements taken) and the full-field surface deformations (which can be measured using three-dimensional digital image correlation). Here, we use a simplified axisymmetric FE simulation, where the soft tissue material was modeled as nearly-incompressible hyperelastic (e.g., Neo-Hookean, Mooney-Rivlin, Ogden, and more), and a rigid indenter was prescribed with displacement steps. The simulation was repeated for a wide range of parameter sets. The optimization objective function was defined as $F_{obj} = \eta V + (1-\eta)W,\ \eta \in [0,1]$, where V and W represent the normalized relative errors of the indenter's reaction force and the surface's displacement field, respectively. The parameter space was explored in terms the objective function's value and gradients, which determined the parameters' identifiability. We found that the objective function's sensitivity to each parameter changes significantly for different choices of η. The results indicate that even a set of only two hyperelastic parameters could not be reliably identified using only measurements of the indenter's force-displacement curve. Adding surface deformation measurements improved the identifiability for some material models, but was insufficient for others. Accordingly, we discuss different considerations for formulating an appropriate objective function, and propose a multi-step optimization routine that makes use of this behavior to identify the material parameters more reliably.

Phase Field Modeling of Humeral Neck Fracture

Lisa Hug[1], Gal Dahan[2], Stefan Kollmannsberger[1], Ernst Rank[1], Zohar Yosibash[2]

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ABSTRACT

In this contribution, we present a numerical framework for the simulation of fracture in human bones, which combines a phase-field model for brittle fracture with the Finite Cell Method (FCM). As presented in [4, 3], integration of the FCM [2] as an embedded domain approach enables the efficient simulation of complex geometries without the need to generate boundary conforming meshes. The phase-field model was adapted to reproduce the fracture behavior in human long bones by introducing a spatially varying critical energy release rate following [5]. The validity of the phase-field model is discussed based on experimental data of three humeri that were fractured at the anatomical neck [1]. The qualitative comparison of fracture patterns shows a very good agreement of computed crack paths with experimental results. Digital Image Correlation (DIC) measured strains, and experimental failure loads are compared against the numerical computations. The choice of the phase-field length scale parameter is discussed, and it is shown, that the proposed model can reproduce both fracture loads and the experimentally observed crack patterns if calibrated correctly. The results demonstrate the potential of the proposed framework to simulate fracture in human humeri.

[1] Dahan, Gal, et al. "Finite element analyses for predicting anatomical neck fractures in the proximal humerus." Clinical Biomechanics 68 (2019): 114-121.

[2] Düster, Alexander, et al. "The finite cell method for three-dimensional problems of solid mechanics." Computer methods in applied mechanics and engineering 197.45-48 (2008): 3768-3782.

[3] Hug, Lisa, et al. "A 3D benchmark problem for crack propagation in brittle fracture." Computer Methods in Applied Mechanics and Engineering 364 (2020): 112905.

[4] Nagaraja, Sindhu, et al. "Phase-field modeling of brittle fracture with multi-level hp-FEM and the finite cell method." Computational mechanics 63.6 (2019): 1283-1300.

[5] Shen, Rilin, et al. "A novel phase field method for modeling the fracture of long bones." International journal for numerical methods in biomedical engineering 35.8 (2019): e3211.

Rheological model for tumor cell progression and metastasis

מודל ריאולוגי להתפתחות ושליחת גרורות של תאי גידול

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ABSTRACT

Tumor cell progression and metastasis are complex phenomena, that involve ongoing molecular and cellular changes. Despite significant progress being made in the fundamental understanding of the biological and genetic events driving both phenomena, much remains to be elucidated regarding the influence of the tumor microenvironment on tumor initiation and progression as well as response to treatment. As such, the development of a theory correlating tumor cell progression and metastasis with biomechanical abnormalities in tumors and their microenvironment due to the continuous buildup of mechanical stresses may be viewed as a timely – and indeed urgent – need.

We present ongoing development of the rheological model capable to simulate for tumor cell progression and metastasis. The model treats the carcinoma as visco-elastic fluid and aims to be able: (i) to model the motility of both individual cells and cell colonies, and (ii) to consider realistic variations in the sizes and shapes of cells in different regions of the cell colony.

The digital images of carcinomas obtained by employing of the developed model have been extensively validated by comparison with the data available in the literature in terms of the conservation of area after cell division, the cell area doubling time, the duration of the cytokinesis process, and the temporal evolution of the proliferation and the tumor area. Using the developed numerical methodology, we propose a theory that provides a new insight into the mechanisms of the tumor development and explains complex biological phenomena, such as fingering formation along the periphery of the tumor and the growth priorities given to individual cells during the tumor development in terms of minimizing the mechanical energy stored within the growing tumor.

Numerical Modelling of Spatial Porosity and Asymmetry Impact on Maternal Blood Flow and Oxygen Transport in the Placenta

Tirosh Mekler[1], Romina Plitman Mayo[2], Gil Marom[1]

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ABSTRACT

The human placenta is a complex organ whose function is not fully understood because clinical studies are restricted by ethical constraints, limited imaging resolution, and availability of the organ. A computational fluid dynamics model of maternal hemodynamics and oxygenation patterns is proposed to better understand the complexity of placenta biomechanics. The objectives of this study are to find how morphological variations in the fetal villi density and in the number and locations of the decidual veins (DVs) affect the hemodynamics and oxygenation. A commonly used approach for numerically simulating the maternal blood flow inside the intervillous space is to model the flow that percolates through the villi branches as a porous medium. Unlike previous studies that assumed homogeneous porosity, the main structure of the villous tree was included in the current model, and the porosity was spatially distributed. The oxygen uptake inside the placenta was compared for different porosity values. Additionally, various morphologies with different asymmetries were examined, such as different locations and the number of DVs. The internal structure has a significant impact on the flow field and oxygen uptake, as demonstrated by a comparison of several cases with equal volumetric porosity but different spatial distributions of local porosity. The location of DVs and their asymmetric distribution also have a major effect on the oxygen distribution. Specifically, if there are two DVs close to each other or several DVs that contribute to the "short circuit" effect of the maternal blood. Computational modeling is proving to be a valuable tool for investigating the flow mechanics and mass transport in the human placenta. The oxygenation efficiency of the materno-placental circulation is undoubtedly affected by morphological changes.

Development of an Immersed Boundary Method for Interactions between Rigid Bodies and High-Speed Compressible Flows

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ABSTRACT

Immersed Boundary Methods (IBM) allow modeling fluid-solid interactions via structured grids. Thus, meshing can be avoided and highly efficient structured grid flow solvers can be utilized. In the current study, we utilize a Ghost Cell Method that relies on interpolation for determining approximate boundary conditions in the ghost cells. However, for high-speed compressible flow regimes, discontinuities in the flow can affect the interpolation accuracy and compromise the solution accuracy and stability. This issue is known to affect high-order interpolations, which can provide superior accuracy for continuous flows. Non-linear interpolation techniques can allow high-order interpolation that is oscillation free. This work introduces an implementation, verification, and validation of a standard low-order interpolation IBM technique in our massively parallel compressible flow solver - Athena-RFX++. Then, the effect of high-order non-linear interpolation techniques on the solution accuracy is studied in detail. In the future, the presented IBM implementation in the Athena-RFX++ numerical framework will be further developed to include additional physical effects, such as deformable bodies and chemical reactions.

A study of pre-heating stages in electron beam melting using numerical simulations

Eran Landau[1,3], Eitan Tiferet[2,3], Yaron Ganor[2,3], Dor Braun[2], Gennady Ziskind[1]

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[2] *AM Center, Rotem Industries LTD, Israel*
[3] *Nuclear Research Center Negev (NRCN), Israel*

ABSTRACT

Additive manufacturing by electron beam powder bed fusion (EBM) requires careful process thermal management. Particularly, unlike other powder bed fusion methods, significant pre-heating of the powder prior to melting is essential in order to ensure sufficient adhesion between the powder particles (through partial sintering and thermal expansion). This is required in order to avoid kinetic effects from a concentrated melting electron beam (AKA powder smoking). The pre-heating algorithm used in most EBM machines is material-specific with reliable results only for materials after rigorous testing procedures. Therefore, in order to allow reliable adaptation of new build materials in EBM, the pre-heating thermal management must be adequately studied and characterized. In this work, the thermal history of the pre-heated powder is studied using dedicated transient numerical simulations in finite elements. The first step in developing reliable pre-heating thermal simulations included a dedicated full-3D model of the ARCAM Q20+ machine build chamber, including all participating components (e.g. start-plate, heat shields, build stage, powder hoppers, etc.) in order to model the thermal boundary conditions. This model included a grey-body radiation cavity space, with several modified gap-conductance contact interactions tailored to the given geometry, in addition to 3D conduction. A series of dedicated validation experiments were performed using spatially distributed thermocouple measurements over the start-plate and heat shields over long duration pre-heating, and a good agreement was obtained between the experimental and computed results [1]. In the next step, the boundary conditions were analyzed and implemented onto a unique multi-stage additive pre-heating simulation with time-scale resolution of adaptable size. The additive model uses progressive element volume activation to introduce new powder layers mimicking an actual rake spread as in an EBM machine. The electron beam energy deposition is modelled using adaptive scaling which adjusts to the required time-incrimination resolution. Since this sort of computation may become too expensive depending on the time-scaling level of the moving heat source (the pre-heating beam travels at ~40-46m/s), the algorithm is adapted so the process may be solved in larger time-increments by scaling the energy deposition into several simultaneous line-blast energy sources. It is then possible to dictate in any certain portion of the transient, a reduction of the time-incrimination scale for short durations in order to assess some more local thermal phenomena where it is of interest. This approach enables generating a database of simulation results for different pre-heating cases (e.g. beam current, velocity and scan path) including 1st and 2nd pre-heating and post cooling or heating. These results can then be examined against complying pre-heating (only) experiments to assess the resulting "melt-safe" level of the pre-heated powder per material.

[1] E.Landau, E. Tiferet, Y. Ganor, R. Ganeriwala, M.Matthews, D.Braun, M. Chonin and G. Ziskind."Thermal characterization of the build chamber in electron beam melting", *Additive manufacturing*, vol. 36, no. 101535, 2020.

A physically-informed Deep-Learning approach for locating sources in a waveguide

Symeon Papadimitropoulos[1], Dima Batenkov[1], Adar Kahana[2], Eli Turkel[1]

[1] School of Mathematical Sciences, Tel Aviv University, Tel Aviv, Israel
[2] Division of Applied Mathematics, Brown University, Providence, RI, USA

ABSTRACT

We consider the problem of locating multiple sources in a waveguide environment, using deep learning. Our data consist of the sensor recordings of the acoustic pressure field generated by the sources, along a single vertical array. We assume time-harmonic sources, and working on the frequency domain, where wave propagation in the waveguide is governed by the Helmholtz equation.

Traditional imaging methods, such as Kirchhoff migration, depend on the back-propagation of our data to an imaging window, using appropriate imaging functionals. In our approach, we create different scenarios for the sources location and the number, and each scenario will be a sample in our data that we use as input to the learning model. We want the learning model to infer the correct location of the sources in the domain. For that, we create a label for each sample and, inspired by image segmentation,we assume that each point source is the middle of a segment in the image and our goal is to find all the segments in that image.

Current results show great accuracy in recovering the true locations of the sources. We also develop a physically-informed loss term, which makes the network "aware" of the physical problem and utilizes the knowledge of the wave problem to get better performance.

Shape Identification of Scatterers Using a Time-Dependent Adjoint Method

זיהוי צורה של פגמים בעזרת שיטת צמוד תלוית-זמן

Amit Sayag[1], Dan Givoli[2]
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ABSTRACT

This work deals with the inverse problem of accurately identifying the shape, size and location of structural scatterers by measuring wave signals. The presented method is based on two stages: In the first stage we use the well-known ATI method to get rough details about the scatterer, which enable us to choose a good initial guess for the scatterer’s shape. In the second stage we use a gradient-based algorithm to iterate the initial guess. The main innovation in this work is that the calculation of the gradient, which represents the sensitivity of the cost functional to the scatterer's geometry, is calculated efficiently using the adjoint method. This is a well-known method which is being used in many fields (such as aerodynamics, seismic imaging, geophysics, etc.), but it was never used for a direct defect shape identification using waves measurements.

Modeling cracks in soft materials using the material-sink theory

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ABSTRACT

In the present talk, we report on the development of a finite element formulation for the material-sink approach for modeling quasi-static crack propagation in hyperelastic solids. Rupture of molecular bonds leads to material disintegration and appearance of a crack. Though there are two crack surfaces, the bond breakage is not confined to them – it is diffused, and the loss of local bonds leads to the localized material (molecular) loss. The latter notion triggers consideration of mass density as a variable that numerically declines in the area where damage localizes into a crack. This physical notion requires mathematical consideration of mass balance as an additional and active law, which regularizes the computational model. Numerical examples of the fracture of aneurysm material demonstrate the high robustness of the proposed approach.

תובנות ממודל עיבור למסב עם פגם אשר עבר ולידציה ע"י מדידות FBG
Insights from a strain model of faulty bearings validated by FBG measurements

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Abstract

Condition based maintenance (CBM) is the preferred approach in rotating machinery and aim to replace the commonly used approach of maintenance based on service time. To achieve an effective CBM, different types of sensors should be placed in the system for condition monitoring to detect the location of the fault and its severity. In this research, a Fiber Bragg Grating (FBG) has been used for condition monitoring on spalls in deep grove ball bearings. The usage of FBG sensors is relatively new for health monitoring systems of rotating machinery. Therefore, there is not enough understanding of the strain signature measured by the FBG. To examine the phenomena in the strain signals, a physics-based model of the strain signature has been developed. In this model, two complementary models were integrated, a finite element (FE) model and a dynamic model. The strain model describes the interaction between the rolling elements (REs) and the bearing housing and simulate the strain behavior measured on the bearing housing. The simulation results are validated with strain signals measured by the FBG sensor at different stages of an endurance test. The model allows simulation of a wide range of spall lengths and describes the behavior of the strain signals for different levels of misalignment. The insights from the model enabled the development of an algorithm that assess the severity of the defect during bearing operation.

Modelling ductile failure initiation and damage propagation in metallic materials under general loading conditions

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In order to properly characterize failure limits for metallic materials, the scientific community has developed numerous failure criteria. These criteria can in general be classified into two different categories: criteria that differentiate between damage initiation and damage evolution, and criteria that describe the whole failure process. Currently, there is no agreement in the scientific community regarding the most accurate criterion when it comes to predicting damage initiation and/or evaluation in metallic materials. Many of the ductile failure criteria incorporate some plastic strain measure as a governing parameter for failure initiation. Nevertheless, to the best of the authors' knowledge, a study, dedicated to investigating the accuracy of different criteria on the specific ductility of the material has not been conducted. It could be that a certain criteria are valid only for limited values of ductility.

In this study, experimental and computational analyses were conducted in order to investigate the influence of the materials ductility on the failure prediction capabilities of different failure criteria based on the Continuum Damage Mechanics (CDM) approach. Compression experiments of different specimen geometries were conducted on two different types of metals, with varying ductility levels – Al7075-T651 and Al2024-T351. The displacement and strain fields were measured using Digital Image Correlation (DIC). Each specimen geometry resulted in a unique triaxiality-plastic strain relation up to initial failure. Finite element models of the experiments were developed and validated against the DIC measurements. The computations were used to compute the different parameters required in order to determine failure initiation and evolution for the various criteria examined (stress, strain and energy density based criteria). The computational-experimental methodology reported in [1] and based on [2] was used to determine a damage initiation failure curve for each metal. Furthermore, an energy based damage evolution criterion was implemented in order to capture the propagation of the initial cracks for the compression specimens. Finally, three-point bending experiments on bars with complex geometries were conducted in order to test the different criteria against data which was not used in the parameter identification process.

References

[1] P. Martins and et al, "Characterization of fracture loci in metal forming," *Int. J. Mech. Sci*, no. 83, pp. 112-123, 2014.

[2] C. Silva and et al, "Failure by fracture in bulk metal forming," *J. Mat. Proc. Tech 215*, pp. 287-298, 2015.

A Comparative Study of Stochastic Methods for Delamination Analysis

מחקר השוואתי של שיטות סטוכסטיות לאנליזה של דלמינציה

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ABSTRACT

One of the most critical failure modes in layered structures is delamination between the bonded layers, and the various mechanisms of interfacial failure drew a lot of research attention over the last decades. While the majority of the available research refers to the problem as a deterministic one, i.e., one that is governed by a set of exactly known quantities, in real world problems some measure of uncertainty regarding the physical quantities is always present. This inevitable feature drives the problem into the stochastic world. The brittle, dynamic and potentially catastrophic nature of this mode of failure further highlights the need to consider the inevitable uncertainty and to assess the stochastic nature of the structural response.

Although the impact of parametric uncertainty on the mechanical response of general structural systems may be a major player, the study of this impact in the context of interfacial failure of layered structures is rather limited. A survey of the literature reveals many studies that are dedicated to the development of stochastic analysis methods for uncertain mechanical systems but relatively few implement these methods in real-world problems of layered structures. Even fewer addressed this challenge in the context of the evolution of interfacial failure.

The current study aims to point at, quantify, and examine a range of stochastic analysis methods that can be suitable for this purpose, to demonstrate their use and implementation, and, above all, to compare the different methods in terms of their relative merits, advantages, and disadvantages. This comparison examines the ability of the different methods to assess the stochastic nature of the different response aspects along the structural failure process, and weights the merits and deficiencies of each method. The focus is on such methods that can take advantage of already existing deterministic solvers of the structural problem and broaden the span of the analysis to the probabilistic regime. By that, the current study paves the way to a sound and consistent estimation of the stochastic response of layered structures along the evolution of interfacial failure, when parametric uncertainty of the system is considered.

Optimization based seismic retrofitting of frame structures with negative stiffness devices and fluid viscous dampers

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ABSTRACT

In the past few decades, the performance-based design (PBD) philosophy became more popular. This, among other reasons, motivates the seismic retrofitting of existing structures. When seismic retrofitting is sought, its design is usually done with the goal of obtaining a better performance level and reducing the expected damage and economic losses

This work presents, a gradient-based optimization approach for the seismic retrofitting of inelastic moment resisting frames (MRFs) equipped with nonlinear fluid viscous dampers (FVDs) and negative stiffness devices (NSDs). The goal of the optimization is to minimize a cost-related objective function that accounts for the initial cost of the supplemental FVDs and NSDs. The mechanical properties and the topological layout of both the FVDs and NSDs are considered as design variables and simultaneously optimized during the optimization process. A loss estimation analysis is utilized as a performance constraint, where the PEER framework is adopted. The structural response is evaluated using a nonlinear time history analysis (NTHA), which accounts for the nonlinear behavior of the MRF elements, FVDs, and NSDs. The optimization problem is formulated using differentiable functions only, making it suitable for an efficient gradient-based optimization solution scheme. The gradients are efficiently derived using the adjoint sensitivity analysis approach.