Editorial

Institution of MECHANICAL ENGINEERS
Journal of MECHANICAL ENGINEERING SCIENCE

Proc IMechE Part C:
J Mechanical Engineering Science
2024, Vol. 238(3) 621–623

DOI: 10.1177/09544062231216509
journals.sagepub.com/home/pic
Sage

Special issue: Advanced mathematical modeling in mechanical engineering

Ivana Atanasovska[1], Santosh Patil[2] and Víctor Roda Casanova[3]

With the advances in mathematical modeling, different mathematical methods and approaches are applied to solve a variety of problems in applied mechanics and mechanical engineering. Based on these premises, the '1st International Conference on Mathematical Modeling in Mechanics and Engineering-ICME2022′ was held in Belgrade, Serbia, 8–10 September 2022. It aimed to bring together leading academic scientists, researchers, and research scholars to exchange and share experiences and research results on various aspects of mathematical modeling in mechanics and engineering. The specific topics included the most recent innovations, theories, and algorithms, as well as practical challenges and solutions in the fields of classical and applied mechanics, computational mechanics, applied mathematics and physics, as well as structural mechanics and engineering. The special issue of the Advanced Mathematical Modeling in Mechanical Engineering is the collection of the selected 14 contributions from the Conference. The accepted articles are mainly focused on a few contemporary topics within mathematical modeling applications for engineering problems, such as advanced mathematical modeling of coupled mechanical problems, mathematical optimization algorithms, dynamics of complex mechanical systems, finite element analysis (FEA), new experimental approaches, damage mechanics and failure.

The dynamics, thermodynamics, and fluid mechanics are studied in the articles of this Special issue[1–4] in the framework of classical and applied mechanics coupled with other mechanical phenomena. Dosaev et al. [1] studied the serpentine motion of a trimaran robot simultaneously by numerical and experimental simulations, combining robot dynamics with hydrodynamics. Advanced mathematical numerical simulations are the main framework of the nonlinear research presented by Sidorov et al.,[2] too. This research investigates the frame structure dynamic behavior utilizing the nonlocal in-time damping model, devoted to the numerical analysis of the dynamic response of composite frame structures considering its internal friction properties utilizing the nonlocal in-time model of material damping. Bouna et al. [3] proposed solving transient heat transfer in plates using high-order isogeometric analyses and high-order time integration schemes. A major advantage of the proposed approach comes from the high-order continuity between elements and the high-order time integration schemes so that the numerical solution can be significantly more accurate than the standard approaches. Several test examples for the transient diffusion problem are presented. Compared to standard methods and for a prescribed accuracy, the proposed approach requires significantly fewer degrees of freedom and a corresponding improvement in computational efficiency. Shrivas et al. [4] give mathematical modeling for the applied mechanic's problem of physiological loading-induced streaming potentials in osteogenesis imperfecta bone, presenting coupled mechanics research of fluid flow, physiological loading, poroelastic modeling, and osteogenesis imperfecta.

Advanced mathematical optimization methods are analyzed and researched by solving a series of multiparametric optimization for real engineering problems.[5–7] In Abderazek et al.,[5] a new hybrid optimization algorithm (improved differential evolution and Nelder-Mead - IDE-NM) is introduced for optimizing the multi-objective machining process during the turning operation under three modes of lubrication conditions. Five mixed design variables are considered in the optimization procedure, including the cutting speed, feed rate, depth of cut, mode of lubrication,

[1]Mathematical Institute of the Serbian Academy of Sciences and Arts, Belgrade, Serbia
[2]Department of Mechanical Engineering, Manipal University Jaipur, Jaipur, Rajasthan, India
[3]Department of Mechanical Engineering and Construction, Universitat Jaume I, Castelló de la Plana, Spain

Corresponding author:
Ivana Atanasovska, Mathematical Institute of the Serbian Academy of Sciences and Arts, Kneza Mihaila 36, 11000 Belgrade, Serbia.
Email: iatanasovska@mi.sanu.ac.rs

and the type of cutting material. For verification, the results obtained by IDE-NM are compared with those of four recent metaheuristics, and the results show that the proposed algorithm outperforms other state-of-the-art optimization methods in terms of robustness, high success rate, and can provide effective solutions. The research subject of Bizic et al.[6] is the application of the marine predator algorithm (MPA) to optimize the suspension of rail vehicles with coil springs. The aim is to reduce the mass of a set of coil springs as the main parts of rail vehicle suspension. The optimization problem comprises six optimization parameters, an objective function, and 16 constraints (eight for each coil spring in the set). The acquired results showed that the given optimization approach with MPA provides a significant mass decrease compared to the conventional design method of rail vehicle suspension with coil springs. One more specific engineering problem is presented and solved by mathematical optimization procedure using the Water Evaporation Optimization (WEO) algorithm in Pavlovic et al. [7] The subject of the optimization in this article is the weight optimization of the main girder of the bridge crane with a non-symmetric box-like cross-section. The strength analysis in characteristic points of the critical cross-section and the local stability of plates were conducted using Eurocodes. This study aimed to prove that a proper choice of geometry for the cross-section plates and their additional design elements can have a meaningful impact on the weight. The optimization procedure with 11 variables and more than 20 constraint functions using the WEO algorithm successfully avoided the trap of getting into the local minimum during the search.

Few more articles are dedicated to specific construction engineering problems.[8,9] Zoric and Trajkovic-Milenkovic[8] develop a semi-analytical mathematical model for solving elastoplastic deflection of prismatic fixed-end beams with circular cross-sections loaded by lateral displacement at one end of the beam, suitable for different engineering applications. Homogenous and isotropic beams with bilinear elastoplastic strain hardening behavior are covered in the proposed solution. The elastic deflection of a beam is determined by the Bernoulli–Euler formula, and an incremental procedure for determining the curvature of the plasticized region of the beam is suggested. The proposed semi-analytical solution is validated by the finite element analysis and experimental results available in the literature. The specific problem of the vibration serviceability assessment and numerical modeling of an existing steel truss footbridge is presented in the article by Roda-Casanova et al. [9] The described complex dynamic problem of this engineering construction is researched experimentally and modeled mathematically. By mathematically describing the experiments and developing a detailed 3D numerical model adjusted by means of a genetic algorithm, the vibration serviceability of the structure is assessed based on current codes and regulations.

Gears are still a part of almost all complex mechanical systems and deserve the attention of scientists due to numerous unsolved problems. Accordingly, a series of articles within this Special Issue is dedicated to the mathematical modeling of different state-of-the-art problems in gears.[10–13] One of the subjects in focus in this field is new materials for gear manufacturing with an investigation of their characteristics versus traditional steel gears. In these senses, polymer gears were investigated by Jain and Patil,[10] who presented an investigation on the effect of strain rate on standard involute and asymmetric polymer gears using the newly designed fixture and methodology. On the other side, Vasileiou et al.[11] give a comprehensive investigation of the characteristics of fully ceramic gears, focus the research on the main challenges of using high-end ceramic gears, and attempt to provide insight on defining the design envelope of such gears to counter the main disadvantages. Comparative assessment of the performance of fully ceramic gear designs versus their conventional steel counterparts is performed through quasi-static FEA simulations to set the basic design requirements for such gears and to promote further investigation of the feasibility of their usage in high power density applications. On the other side, a few of the presented research deal with the well-known problems of gears, such as conventional tooth contact analysis[12] and vibration analysis of gearboxes in order to prevent failures.[13] In Temirkhan et al.,[12] the quasi-static model of the three-dimensional geometrical non-conjugate contact problem is studied. The set of contact equations is formulated by using a new parameterization that enables the reduction of the conventional system of five nonlinear equations. It is shown that the novel mathematical model is computationally efficient and demonstrates increased accuracy and stability of the numerical solution. Boudhraa et al. [13] investigate the effect of gearbox faults on the current signal by defining an analytical correlation between the physical presence of the fault and the stator current. The theoretical development is supported by experimental measurements taken on a back-to-back planetary gearbox. The presented comparative investigation gives a comparison of different techniques and highlights the efficiency of each of them.

One more article is dedicated to research on the failure of complex structures made of composite materials.[14] This article covers a few different topics of this SI, such as up-to-date materials, coupled mechanical phenomena, as well as experimental investigation, mathematical modeling, and engineering applications. The presented research is based on the failure analysis of a composite beam of a novel unmanned aerial vehicle (UAV). The study was performed to determine the cause of the failure of certain layers of the composite laminate, as well as complementary numerical and experimental analyses were performed.

It can be concluded that the articles included in this SI cover developments in the subjects of interest within mechanical engineering, even within multiphysics and coupled problems, and give new viewpoints within the analyzed state-of-the-art research topics.

Acknowledgements

We would like to thank the Editor in Chief Prof. Dr. John Chew, Editor Prof. Dr. Aldo Sorniotti, and the Publishing Editor Martin McDonald, for their unlimited support and effort and the editorial managers for their professional support; special thanks to all the authors for their contribution to this special issue.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Funding Part of this work was supported by the Ministry of Sciences Technological Development and Innovation, Republic of Serbia, Grant 451-03-47/2023-01/200029.

References

1. Dosaev M, Golovanov S, Klimina L, et al. Serpentine motion of a trimaran robot. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 737–745.
2. Sidorov VN, Shitikova MV, Badina ES, et al. Numerical simulation of the frame structure dynamic behavior utilizing the nonlocal in time damping model. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 769–774.
3. Bouna R, Izem N, Seaid M, et al. High-order methods for thermal behavior of plate structures with internal heat sources. *Proc IMechE, Part C: J Mechanical Engineering Science* 2022; 238: 624–641.
4. Shrivas NV, Tiwari AK, Patil S, et al. Physiological loading-induced streaming potentials in osteogenesis imperfecta bone. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 693–707.
5. Abderazek H, Laouissi A, Nouioua M, et al. Optimization of turning process parameters using a new hybrid evolutionary algorithm. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 758–768.
6. Bizic M, Bulatovic R and Petrovic D. Optimization of suspension of rail vehicles with coil springs using marine predators algorithm. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 642–653.
7. Pavlović GV, Zdravković NB, Savković MM, et al. Light-weight design of an overhead crane's girder with a non-symmetric box cross-section. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 666–676.
8. Zorić A and Trajković-Milenković M, M Semi-analytical solution for elastoplastic deflection of prismatic fixed-end beams with circular cross-section. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 677–692.
9. Roda-Casanova V, Hernández-Figueirido D, Sancho Bru JL, et al. Numerical modelling and vibration serviceability assessment of a steel footbridge with a significant 3D dynamic behaviour. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 708–723.
10. Jain M and Patil S. Investigation on the effect of strain rate on standard involute and asymmetric polymer gears using the newly design fixture for single tooth testing method. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 746–757.
11. Vasileiou G, Rogkas N, Markopoulos A, et al. Fully ceramic versus steel gears: potential, feasibility and challenges. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 775–784.
12. Temirkhan M, Amrin A, Spitas V, et al. Convergence and accuracy problems of the conventional TCA model – critical analysis and novel solution for crowned spur gears. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 724–736.
13. Boudhraa S, Fernandez del Rincon A, Chaari F, et al. Multiphysics and comparative analysis on failure detection in planetary gears. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 785–798.
14. Milic M, Svorcan J, Zoric N, et al. Mathematical modeling and experimental investigation of a composite beam failure - case study. *Proc IMechE, Part C: J Mechanical Engineering Science* 2023; 238: 654–665.