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HABILITATION THESIS SUMMARY

Title:

Frontier Developments in Continuum Mechanics and Nonlinear Dynamics: Theories, Methods, and Applications

Domain: Mathematics

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The present thesis is a comprehensive exploration of advanced topics in continuum mechanics, numerical analysis, and their applications in material science and chemistry. It is structured into three main chapters, each delving into specific areas of research that build upon the author's previous work and contributions to the field.

The first chapter focuses on the author's research in continuum mechanics, specifically on thermoelastic materials with double porosity structures. This chapter is an extension of the author's PhD thesis in Mathematics, completed in 2019, and presents significant advancements in understanding the complex interactions between thermal and mechanical behaviors in materials with double porosity. The chapter is divided into three sections, each highlighting research published in reputable journals such as Continuum Mechanics and Thermodynamics and Scientific Annals of Ovidius University. The studies presented in this chapter explore various theoretical frameworks, including Betti's reciprocity relation, Moore–Gibson–Thompson (MGT) thermoelasticity theory, and Green-Lindsay thermoelasticity, applied to double porous materials. These frameworks are essential for addressing the stability, uniqueness, and dynamic responses of these materials, with implications for their use in engineering and technology, particularly in environments subjected to extreme thermal and mechanical stresses.

The second chapter shifts focus to the numerical analysis of dynamical systems, employing methods such as numerical fractional calculus. This chapter builds on the author's PhD thesis in Mechanical Engineering, completed in 2010, and demonstrates the application of these numerical methods in solving complex systems that are difficult to address analytically. The chapter is divided into four sections, with research published in journals like Dynamic Systems and Applications and Scientific Annals of Ovidius University. The studies cover a wide range of topics, including the dynamics of a double pendulum system, the motion of a heavy ball on a rotating wire, and the numerical approach to solving the telegrapher equation. The results obtained from these studies underscore the power of numerical methods in capturing the intricate behaviors of dynamical systems, such as chaotic motion and periodic oscillations, which are often challenging to predict using traditional analytical approaches.

The third chapter applies the findings from the study of dynamical systems to the field of chemistry, particularly in the analysis of porous materials and their applications in combustion processes. The first section of this chapter presents research on the chaotic behavior of Barium Titanate nanoparticles, published in Physics Letters A, which extends the Hamiltonian framework to reveal the complex vibrational dynamics of these nanoparticles under certain conditions. This study builds on previous work by Koo and Lee, who explored ferroelectricity and antiferromagnetism in multiferroic materials. The second section investigates the porosity of waste wood briquettes and its impact on combustion, published in Waste and Biomass Valorization. This research introduces novel methods for assessing briquette porosity, offering new insights into heat and mass transfer processes in these materials and extending existing porosity models to a new application.

Each chapter of the thesis not only builds on the author's previous work but also makes significant contributions to their respective fields. The research presented in the first chapter advances the theoretical understanding of thermoelastic materials with double porosity, providing new tools for analyzing and designing materials for high-stress environments. The second chapter demonstrates the effectiveness of numerical methods in exploring complex dynamical systems, offering practical solutions for problems that are otherwise analytically intractable. Finally, the third chapter showcases the application of these advanced mathematical and numerical techniques in real-world problems, such as the chaotic dynamics of nanoparticles and the optimization of combustion processes in porous materials.

Overall, this thesis highlights the importance of combining rigorous theoretical frameworks with powerful numerical methods to tackle complex problems in material science, mechanical engineering, and chemistry. The results obtained from the various studies not only advance the state of knowledge in these fields but also provide practical insights that could inform the development of new technologies and materials. The simulations and analyses conducted using tools like MATLAB and Maple further demonstrate the utility of these methods in both academic research and applied engineering contexts.