

Solvability and optimal controls for semilinear fractional evolution hemivariational inequalities

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This paper is concerned with the control systems of semilinear fractional evolution hemivariational inequalities and their optimal controls in Banach space. Firstly, the existence of mild solutions is obtained and proved mainly by using a well-known fixed point theorem of multivalued maps and the properties of generalized Clarke subdifferential. Then, by applying generally mild conditions of cost functionals, we investigate the existence results of the optimal controls for fractional differential evolution hemivariational inequalities. Finally, an example is given to demonstrate the applicability of the main results. Copyright © 2016 John Wiley & Sons, Ltd.

Keywords: solvability; optimal control; hemivariational inequalities; generalized Clarke subdifferential; fractional evolution equations

1. Introduction

Hemivariational inequality problem is a new type of inequality problem that was introduced by Panagiotopoulos to deal with problems in mechanics and engineering whose variational forms are such inequalities that express the principle of virtual work or power [1, 2]. Recently, many researchers have paid increasing attention to the control problems of hemivariational inequality. More precisely, Migórski and Ochal [3] investigated the optimal control problems for the parabolic hemivariational inequalities. Park and Park [4, 5] obtained the existence of optimal control pairs to the hyperbolic systems. Liu and Li [6] studied the approximate controllability of hemivariational inequalities. For more details, the readers can refer to [7–12] and the references therein, where the treatment relies on monotonicity principles, projection arguments, topological method, and nonsmooth critical point theory.

In addition, fractional differential equations have emerged as an important area of investigation because more and more researchers have found that these have become efficient tools in the modelling of many phenomena and the fact that fractional derivatives provide an excellent instrument for the description of memory and hereditary properties in model [13, 14]. Indeed, there has been a significant development on fractional differential systems in the past decades (see [15–18] and the references therein). It is remarkable that the study of fractional evolution equations and their optimal controls have become an active area of investigation recently. Because the pioneering work of fractional evolution equations associated with some probability densities has been studied by El-Borai [19, 20], the study of the existence, controllability, and optimal controls of the fractional semilinear evolution equations and inclusions have been extensive, we refer the reader to [21–24] and the references therein.

However, to the best of our knowledge, the solvability and optimal controls for fractional evolution hemivariational inequalities are still untreated topics in the literature, and this is one of the motivations of the present work. In this paper, we will be concerned with the solvability and optimal controls of the following evolution control systems described by hemivariational inequalities with fractional derivative:

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Hemivariational Inequalities

**Siegfried Carl, Vy Khoi Le, Dumitru
Motreanu**



Hemivariational Inequalities:

Mathematical Theory of Hemivariational Inequalities and Applications Zdzistaw Naniewicz, P. D.

Panagiotopoulos, 2021-07-28 Gives a complete and rigorous presentation of the mathematical study of the expressions hemivariational inequalities arising in problems that involve nonconvex nonsmooth energy functions A theory of the existence of solutions for inequality problems involving nonconvexity and nonsmoothness is established **Hemivariational**

Inequalities Panagiotis D. Panagiotopoulos, 2012-12-06 The aim of the present book is the formulation mathematical study and numerical treatment of static and dynamic problems in mechanics and engineering sciences involving nonconvex and nonsmooth energy functions or nonmonotone and multivalued stress strain laws Such problems lead to a new type of variational forms the hemivariational inequalities which also lead to multivalued differential or integral equations Innovative numerical methods are presented for the treatment of realistic engineering problems This book is the first to deal with variational theory of engineering problems involving nonmonotone multivalued relations their mechanical foundation their mathematical study existence and certain approximation results and the corresponding eigenvalue and optimal control problems All the numerical applications give innovative answers to as yet unsolved or partially solved engineering problems e g the adhesive contact in cracks the delamination problem the sawtooth stress strain laws in composites the shear connectors in composite beams the semirigid connections in steel structures the adhesive grasping in robotics etc The book closes with the consideration of hemivariational inequalities for fractal type geometries and with the neural network approach to the numerical treatment of hemivariational inequalities Variational and Hemivariational Inequalities - Theory, Methods and Applications

DANIEL Goeleven, Dumitru Motreanu, 2003-08-31 This book includes a self contained theory of inequality problems and their applications to unilateral mechanics Fundamental theoretical results and related methods of analysis are discussed on various examples and applications in mechanics The work can be seen as a book of applied nonlinear analysis entirely devoted to the study of inequality problems i e variational inequalities and hemivariational inequalities in mathematical models and their corresponding applications to unilateral mechanics It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics It is the first textbook including a comprehensive and systematic study of both elliptic parabolic and hyperbolic inequality models dynamical unilateral systems and unilateral eigenvalues problems The book is self contained and it offers for the first time the possibility to learn about inequality models and to acquire the essence of the theory in a relatively short time Audience The book is suitable for researchers and for doctoral and post doctoral courses Variational and Hemivariational Inequalities Theory, Methods and Applications

D. Goeleven, Dumitru Motreanu, Y. Dumont, M. Rochdi, 2013-11-27 This book includes a self contained theory of inequality problems and their applications to unilateral mechanics Fundamental theoretical results and related methods of analysis are discussed on various examples and applications in mechanics The work can be seen as a book

of applied nonlinear analysis entirely devoted to the study of inequality problems i.e. variational inequalities and hemivariational inequalities in mathematical models and their corresponding applications to unilateral mechanics. It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics. It is the first textbook including a comprehensive and systematic study of both elliptic, parabolic and hyperbolic inequality models, dynamical unilateral systems and unilateral eigenvalues problems. The book is self-contained and it offers for the first time the possibility to learn about inequality models and to acquire the essence of the theory in a relatively short time.

Variational-Hemivariational Inequalities with Applications Mircea Sofonea, Stanislaw Migorski, 2024-12-23

Variational Hemivariational Inequalities with Applications Second Edition represents the outcome of the cross fertilization of nonlinear functional analysis and mathematical modelling demonstrating its application to solid and contact mechanics. Based on authors' original results, the book illustrates the use of various functional methods including monotonicity, pseudomonotonicity, compactness, penalty and fixed point methods in the study of various nonlinear problems in analysis and mechanics. The classes of history dependent operators and almost history dependent operators are exposed in a large generality. A systematic and unified presentation contains a carefully selected collection of new results on variational hemivariational inequalities with or without unilateral constraints. A wide spectrum of static, quasistatic, dynamic contact problems for elastic, viscoelastic and viscoplastic materials illustrates the applicability of these theoretical results. Written for mathematicians, applied mathematicians, engineers and scientists, this book is also a valuable tool for graduate students and researchers in nonlinear analysis, mathematical modelling, mechanics of solids and contact mechanics. New to the second edition: Convergence and well posedness results for elliptic and history dependent variational hemivariational inequalities; Existence results on various optimal control problems with applications in solid and contact mechanics; Existence, uniqueness and stability results for evolutionary and differential variational hemivariational inequalities with unilateral constraints; Modelling and analysis of static and quasistatic contact problems for elastic and viscoelastic materials with locking effect; Modelling and analysis of viscoelastic and viscoplastic dynamic contact problems with unilateral constraints.

Advances in Variational and Hemivariational Inequalities Weimin Han, Stanisław Migórski, Mircea Sofonea, 2015-03-02. This volume is comprised of articles providing new results on variational and hemivariational inequalities with applications to Contact Mechanics unavailable from other sources. The book will be of particular interest to graduate students and young researchers in applied and pure mathematics, civil, aeronautical and mechanical engineering and can be used as supplementary reading material for advanced specialized courses in mathematical modeling. New results on well posedness for stationary and evolutionary inequalities and their rigorous proofs are of particular interest to readers. In addition to results on modeling and abstract problems, the book contains new results on the numerical methods for variational and hemivariational inequalities.

Finite Element Method for Hemivariational Inequalities J. Haslinger, M. Miettinen, Panagiotis D.

Panagiotopoulos, 2013-03-09 Hemivariational inequalities represent an important class of problems in nonsmooth and nonconvex mechanics. By means of them problems with nonmonotone possibly multivalued constitutive laws can be formulated, mathematically analyzed and finally numerically solved. The present book gives a rigorous analysis of finite element approximation for a class of hemivariational inequalities of elliptic and parabolic type. Finite element models are described and their convergence properties are established. Discretized models are numerically treated as nonconvex and nonsmooth optimization problems. The book includes a comprehensive description of typical representatives of nonsmooth optimization methods. Basic knowledge of finite element mathematics, functional and nonsmooth analysis is needed. The book is self-contained and all necessary results from these disciplines are summarized in the introductory chapter. Audience: Engineers and applied mathematicians at universities and working in industry. Also graduate level students in advanced nonlinear computational mechanics, mathematics of finite elements and approximation theory. Chapter 1 includes the necessary prerequisite materials. Mathematical Theory of Hemivariational Inequalities and Applications Zdzistaw Naniec, P. D. Panagiotopoulos, 2021-07-29 Gives a complete and rigorous presentation of the mathematical study of the expressions hemivariational inequalities arising in problems that involve nonconvex nonsmooth energy functions. A theory of the existence of solutions for inequality problems involving nonconvexity and nonsmoothness is established. **Variational and Hemivariational Inequalities - Theory, Methods and Applications** D. Goeleven, Dumitru Motreanu, 2013-12-11 This book includes a self-contained theory of inequality problems and their applications to unilateral mechanics. Fundamental theoretical results and related methods of analysis are discussed on various examples and applications in mechanics. The work can be seen as a book of applied nonlinear analysis entirely devoted to the study of inequality problems, i.e. variational inequalities and hemivariational inequalities in mathematical models and their corresponding applications to unilateral mechanics. It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics. It is the first textbook including a comprehensive and systematic study of both elliptic, parabolic and hyperbolic inequality models, dynamical unilateral systems and unilateral eigenvalue problems. The book is self-contained and it offers for the first time the possibility to learn about inequality models and to acquire the essence of the theory in a relatively short time. Audience: The book is suitable for researchers and for doctoral and post doctoral courses. **Minimax Theorems and Qualitative Properties of the Solutions of Hemivariational Inequalities** Dumitru Motreanu, Panagiotis D. Panagiotopoulos, 2013-12-01 Boundary value problems which have variational expressions in form of inequalities can be divided into two main classes. The class of boundary value problems (BVPs) leading to variational inequalities and the class of BVPs leading to hemivariational inequalities. The first class is related to convex energy functions and has been studied over the last forty years and the second class is related to nonconvex energy functions and has a shorter research life beginning with the works of the second author of the present book in the year 1981. Nevertheless a variety of important results have

been produced within the framework of the theory of hemivariational inequalities and their numerical treatment both in Mathematics and in Applied Sciences especially in Engineering It is worth noting that inequality problems i.e. BVPs leading to variational or to hemivariational inequalities have within a very short time had a remarkable and precipitate development in both Pure and Applied Mathematics as well as in Mechanics and the Engineering Sciences largely because of the possibility of applying and further developing new and efficient mathematical methods in this field taken generally from convex and or nonconvex Nonsmooth Analysis The evolution of these areas of Mathematics has facilitated the solution of many open questions in Applied Sciences generally and also allowed the formulation and the definitive mathematical and numerical study of new classes of interesting problems

Nonlinear Inclusions and Hemivariational Inequalities Stanisław Migórski, Anna Ochal, Mircea Sofonea, 2012-09-18 This book introduces the reader the theory of nonlinear inclusions and hemivariational inequalities with emphasis on the study of contact mechanics The work covers both abstract results in the area of nonlinear inclusions hemivariational inequalities as well as the study of specific contact problems including their modelling and their variational analysis Provided results are based on original research on the existence uniqueness regularity and behavior of the solution for various classes of nonlinear stationary and evolutionary inclusions In carrying out the variational analysis of various contact models one systematically uses results of hemivariational inequalities and in this way illustrates the applications of nonlinear analysis in contact mechanics New mathematical methods are introduced and applied in the study of nonlinear problems which describe the contact between a deformable body and a foundation Contact problems arise in industry engineering and geophysics Their variational analysis presented in this book lies the background for their numerical analysis This volume will interest mathematicians applied mathematicians engineers and scientists as well as advanced graduate students

Variational-Hemivariational Inequalities with Applications Mircea Sofonea, Stanisław Migórski, 2017-10-23 This research monograph represents an outcome of the cross fertilization between nonlinear functional analysis and mathematical modelling and demonstrates its application to solid and contact mechanics Based on authors original results it introduces a general fixed point principle and its application to various nonlinear problems in analysis and mechanics The classes of history dependent operators and almost history dependent operators are exposed in a large generality A systematic and unified presentation contains a carefully selected collection of new results on variational hemivariational inequalities with or without unilateral constraints A wide spectrum of static quasistatic dynamic contact problems for elastic viscoelastic and viscoplastic materials illustrates the applicability of these theoretical results Written for mathematicians applied mathematicians engineers and scientists it is also a valuable tool for graduate students and researchers in nonlinear analysis mathematical modelling mechanics of solids and contact mechanics

Encyclopedia of Optimization Christodoulos A. Floudas, Panos M. Pardalos, 2008-09-04 The goal of the Encyclopedia of Optimization is to introduce the reader to a complete set of topics that show the spectrum of research the richness of ideas and the breadth of

applications that has come from this field The second edition builds on the success of the former edition with more than 150 completely new entries designed to ensure that the reference addresses recent areas where optimization theories and techniques have advanced Particularly heavy attention resulted in health science and transportation with entries such as Algorithms for Genomics Optimization and Radiotherapy Treatment Design and Crew Scheduling *Minimax Theorems and Qualitative Properties of the Solutions of Hemivariational Inequalities* Dumitru Motreanu, P. D. Panagiotopoulos, 1999 The present book is the first ever published in which a new type of eigenvalue problem is studied one that is very useful for applications eigenvalue problems related to hemivariational inequalities i e involving nonsmooth nonconvex energy functions New existence multiplicity and perturbation results are proved using three different approaches minimization minimax methods and sub critical point theory Nonresonant and resonant cases are studied both for static and dynamic problems and several new qualitative properties of the hemivariational inequalities are obtained Both simple and double eigenvalue problems are studied as well as those constrained on the sphere and those which are unconstrained The book is self contained is written with the utmost possible clarity and contains highly original results Applications concerning new stability results for beams plates and shells with adhesive supports etc illustrate the theory Audience applied and pure mathematicians civil aeronautical and mechanical engineers *Variational and Hemivariational Inequalities* Daniel Goeleven, D. Motreanu, 2003 This book includes a self contained theory of inequality problems and their applications to unilateral mechanics Fundamental theoretical results and related methods of analysis are discussed on various examples and applications in mechanics The work can be seen as a book of applied nonlinear analysis entirely devoted to the study of inequality problems i e variational inequalities and hemivariational inequalities in mathematical models and their corresponding applications to unilateral mechanics It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics It is the first textbook including a comprehensive and systematic study of both elliptic parabolic and hyperbolic inequality models dynamical unilateral systems and unilateral eigenvalues problems The book is self contained and it offers for the first time the possibility to learn about inequality models and to acquire the essence of the theory in a relatively short time Audience The book is suitable for researchers and for doctoral and post doctoral courses **Industrial Mathematics and Statistics** J. C. Misra, 2003 This comprehensive volume introduces educational units dealing with important topics in Industrial Mathematics and Statistics *Nonsmooth Variational Problems and Their Inequalities* Siegfried Carl, Vy Khoi Le, Dumitru Motreanu, 2007-06-07 This monograph focuses primarily on nonsmooth variational problems that arise from boundary value problems with nonsmooth data and or nonsmooth constraints such as multivalued elliptic problems variational inequalities hemivariational inequalities and their corresponding evolution problems It provides a systematic and unified exposition of comparison principles based on a suitably extended sub supersolution method **Geometry and Non-Convex Optimization** Panos M. Pardalos, Themistocles M.

Rassias,2025-07-24 This book offers a comprehensive exploration of the dynamic intersection between geometry and optimization It delves into the intricate study of Hermite Hadamard inequalities Hilbert type integral inequalities and variational inequalities providing a rich tapestry of theoretical insights and practical applications Readers will encounter a diverse array of topics including the bounds for the unweighted Jensen s gap of absolutely continuous functions and the properties of Barrelled and Bornological locally convex spaces The volume also covers advanced subjects such as multiobjective mixed integer nonlinear optimization and optimum statistical analysis on sphere surfaces Contributions from eminent scholars provide a deep dive into C ternary biderivations Erd s Szekeres products and variational principles making this book a must read for those seeking to expand their understanding of these complex fields Ideal for researchers and scholars in mathematics and optimization this volume is an invaluable resource for anyone interested in the latest developments in geometry and nonconvex optimization Whether you are a seasoned academic or a graduate student this book will enhance your knowledge and inspire further research in these fascinating domains

Variational and Hemivariational Inequalities - Theory, Methods and Applications DANIEL Goeleven,Dumitru Motreanu,2014-01-23 This book includes a self contained theory of inequality problems and their applications to unilateral mechanics Fundamental theoretical results and related methods of analysis are discussed on various examples and applications in mechanics The work can be seen as a book of applied nonlinear analysis entirely devoted to the study of inequality problems i e variational inequalities and hemivariational inequalities in mathematical models and their corresponding applications to unilateral mechanics It contains a systematic investigation of the interplay between theoretical results and concrete problems in mechanics It is the first textbook including a comprehensive and systematic study of both elliptic parabolic and hyperbolic inequality models dynamical unilateral systems and unilateral eigenvalues problems The book is self contained and it offers for the first time the possibility to learn about inequality models and to acquire the essence of the theory in a relatively short time Audience The book is suitable for researchers and for doctoral and post doctoral courses

An Introduction to Theory and Applications of Stationary Variational-Hemivariational Inequalities Weimin Han,2024-11-01 This book offers a comprehensive and accessible introduction to the mathematical theory of stationary Variational Hemivariational Inequalities VHIs a rapidly growing area of research with significant applications in science and engineering Unlike traditional approaches that rely heavily on abstract inclusion results for pseudomonotone operators this work presents a more user friendly method grounded in basic Functional Analysis VHIs include variational inequalities and hemivariational inequalities as special cases The book systematically categorizes and names different VHIs making it easier for readers to understand the specific problems being addressed Designed for graduate students and researchers in mathematics physical sciences and engineering this monograph not only provides a concise review of essential materials in Sobolev spaces convex analysis and nonsmooth analysis but also delves into applications in contact and fluid mechanics Through detailed explanations and

practical examples the book bridges the gap between theory and practice making the complex subject of VHIs more approachable By focusing on the well posedness of various forms of VHIs and extending the analysis to include mixed VHIs for the Stokes and Navier Stokes equations this book serves as an essential resource for anyone interested in the modeling analysis numerical solutions and real world applications of VHIs

Adopting the Track of Term: An Psychological Symphony within **Hemivariational Inequalities**

In a global eaten by monitors and the ceaseless chatter of instant transmission, the melodic beauty and emotional symphony created by the prepared term frequently disappear into the backdrop, eclipsed by the relentless sound and interruptions that permeate our lives. But, nestled within the pages of **Hemivariational Inequalities** a marvelous literary prize filled with fresh thoughts, lies an immersive symphony waiting to be embraced. Constructed by a wonderful composer of language, this fascinating masterpiece conducts readers on a psychological trip, skillfully unraveling the concealed songs and profound impact resonating within each cautiously constructed phrase. Within the depths of this poignant examination, we will examine the book is central harmonies, analyze their enthralling publishing style, and surrender ourselves to the profound resonance that echoes in the depths of readers souls.

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






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