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Optimal Control Problems for a Class of Evolution Inclusions with Applications to Dynamic and Quasi-static Viscoelastic Contact Problems

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Abstract

In the paper we study the optimal control problems for systems described by nonlinear evolution inclusions. Two classes of evolution inclusions of second order (hyperbolic) and of first order (parabolic) are considered. We provide results on the existence of weak solutions to the evolution inclusions and of optimal solutions for the control problems. Then we deal with dynamic and quasi-static viscoelastic contact problems with unilateral contact conditions and friction. For such control problems we formulate control problems. We show that the optimal control exists and provide a result on the variational stability of optimal control problems when the acceleration in the contact is negligible.

Keywords: hysteresis/inclusion inequality; quasi-static; variational acceleration; variational stability; Clarke subdifferential; weak solutions; hyperbolic; parabolic; optimal solution

1. Introduction

In the paper we study the mechanical problems modeled by an abstract second order nonlinear evolution hysteresis/inclusion inequality of the form

$$u''(t) + A(u(t)) + B(u(t)) + M^*A(u(t)) \ni f(t) \quad (1)$$

for $t \in [0, T]$, where A and B are multivalued operators (see [1] for details) and M^* is a linear continuous operator. M^* is the adjoint of M denotes the Clarke subdifferential of a locally Lipschitz convex function $M: \mathbb{R}^n \rightarrow \mathbb{R}^n$ at $x \in \mathbb{R}^n$ (see [2]).

Recently, optimal control problems in inclusion (1) are investigated for the type of inclusions is motivated by control optimal problems of solid mechanics. It is well known that the dynamic equations of motion, representing momentum conservation, that govern the problems at the end of the body, are of the form

$$u''(t) + A(u(t)) + B(u(t)) + M^*A(u(t)) \ni f(t) \quad (2)$$

for $t \in [0, T]$. The hysteresis/inclusion inequality were considered in the last time in the article by P.D. Panagiotopoulos [3].

The other hand, the quasi-static hysteresis/inclusion inequality is considered in contact problems, of [4, 5, 6, 7, 8, 9, 10, 11]. The [12] have been studied in the hysteresis/inclusion inequality (1). The hysteresis/inclusion inequality are based on a series of the Clarke subdifferential for locally Lipschitz functions, of [13, 14].

The goal of the paper is to study the optimization and control problems for both (1) and (2). We prove the existence of optimal solutions for control optimal problems. We apply these results to dynamic and quasi-static viscoelastic/hysteresis/inclusion inequality which model many problems.

2. Statement of problems

We deal with the following optimal control problem for second order evolution inclusion

$$u''(t) + A(u(t)) + B(u(t)) + M^*A(u(t)) \ni f(t) \quad (3)$$

where $f(t) \in \mathbb{R}^n$ and $u(t) \in \mathbb{R}^n$ for $t \in [0, T]$. The cost functional and U is the set of admissible controls

$$J(u) = \int_0^T \int_{\Omega} |u(t)|^2 dx dt + \int_0^T \int_{\Omega} |u'(t)|^2 dx dt$$

and U is the set of admissible controls $U = \{u \in L^2(0, T; L^2(\Omega)) : u(0) = u_0, u(T) = u_1\}$

where $u_0, u_1 \in \mathbb{R}^n$ are given. We also consider the following optimal control problem for the first order case:

$$u'(t) + A(u(t)) + B(u(t)) \ni f(t) \quad (4)$$

where $f(t) \in \mathbb{R}^n$ and $u(t) \in \mathbb{R}^n$ for $t \in [0, T]$. The cost functional and U is the set of admissible controls

$$J(u) = \int_0^T \int_{\Omega} |u(t)|^2 dx dt + \int_0^T \int_{\Omega} |u'(t)|^2 dx dt$$

and $U = \{u \in W^{1,2}(0, T; L^2(\Omega)) : u(0) = u_0, u(T) = u_1\}$

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