



Optimal energy decay for a viscoelastic Kirchhoff equation with distributed delay acting on nonlinear frictional damping

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ABSTRACT

In this paper, we have analysed the influence of viscoelastic and frictional damping on the decay rate of solutions for a Kirchhoff-type viscoelastic wave equation with a distributed delay acting on nonlinear internal damping. Taking the relaxation function of a fairly large class and using the method of energy in which we introduce an adapted Lyapunov functional and by exploiting certain properties of convex functions, under certain assumptions on the constants of system, we obtain the optimal decay rate of energy in the sense that it is compatible with the decay rate of the relaxation function.

ARTICLE HISTORY

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KEYWORDS

viscoelastic Kirchhoff equation; frictional damping; nonlinear distributed delay; optimal decay rate

1. Introduction

The modelling of a natural phenomena is generally written by PDE, taking into account the current state at time t . However, most natural phenomena are often very complicated and depend not only on the present state but also on the history of the system, which is called a time-delay system. Delays appear frequently in engineering, they are a source of instability and degraded performance, and they greatly growing the difficulty of stability analysis and control of dynamical systems.

Consequently, time-delay systems have attracted the attention of many authors and have become an active area of research in recent years. Nicaise and Pignotti (2006) studied a wave equation with linear frictional damping and internal delay of the form

$$u_{tt} - \Delta u + \mu \phi u_t + a(x) [\mu_1 u_t(x, t) + \mu_2 u_t(x, t - \tau)] = 0 \\ \text{in } \Omega \times (0, +\infty),$$

where a is a function acting in part of Ω . Under the assumption $\mu_2 < \mu_1$, he obtained the exponential stability of the problem in a general space dimension by using a suitable observability estimate and by using compactness-uniqueness arguments. Further if $\mu_1 = \mu_2$, he showed that there exists a sequence of arbitrary small (and large) delays such that instabilities occur. In the case $\mu_2 > \mu_1$, he also got delays which destabilise the system. Furthermore, Benaïssa et al. (2014) considered the following equation

$$u_{tt} - \Delta u + \int_0^t h(t-s) \Delta u(s) ds + \mu_1 g_1(u_t(x, t)) \\ + \mu_2 g_2(u_t(x, t - \tau)) = 0 \quad \text{in } \Omega \times (0, +\infty),$$

under certain assumptions on the relaxation function h , the functions g_1 and g_2 , and on the constants μ_1 and μ_2 , they

used the Faedo-Galerkin method for proved the global existence of weak solution and obtained general decay of solution by introducing an appropriate Lyapunov functional. In addition, many authors have studied problems where time delay appears, we refer readers to Alahau-Boussouira et al. (2014), Dai and Yang (2014), Gerbi and Said-Houari (2012), Gherraïbia and Boumaza (2020), Kafini (2021), Lekdim and Khemmoudj (2021), Liu and Zhang (2016), Pignotti (2012), Piskin and Yulsekkaya (2021), Wu (2013) and the references therein.

The above cases are local delays in time τ , on the other hand, the delay term distributed over the interval $[t_1, t_2]$ written in the following form $\int_{t_1}^{t_2} \mu(s) u_t(x, t - s) ds$. Consequently, in case of a delay concentrated at a time τ , the distributed delay term $\int_{t_1}^{t_2} \mu(s) u_t(x, t - s) ds$ becomes simply a delay term $u_t(x, t - \tau)$. Nicaise and Pignotti (2008) studied the following wave equation with linear frictional damping and internal distributed delay

$$u_{tt} - \Delta u + \mu \phi u_t + a(x) \int_{t_1}^{t_2} \mu(s) u_t(x, t - s) ds = 0 \\ \text{in } \Omega \times (0, +\infty),$$

with initial and mixed Dirichlet-Neumann boundary conditions and a is a suitable function defined in Ω . They obtained the exponential decay of the solution under the condition $\|\mu\|_{\infty} \int_{t_1}^{t_2} \mu(s) ds < \mu_0$.

On the other hand, there are materials in nature with natural damping. They are called viscoelastic materials and transforms the energy of the system into heat. This makes the system dissipative which is an advantage for the stability of the dynamic systems, see for example Christensen (1982), Coleman and Noll (1961), Fabrizio and Morro (1992), and Meirovitch (2001). The importance of the viscoelastic properties of materials has been realised because of the rapid developments in rubber and plastic industry. Many advances

Energy Decay And Boundary Control For Distributed Parameter Systems With Viscoelastic Damping

Sabine Zange



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Energy Decay and Boundary Control for Distributed Parameter Systems with Viscoelastic Damping ,1989 This report concerns several aspects of active and passive stabilization of materials and structures together with related dynamic problems with potential applications to stabilization Results are described for determination of the interacting effects of viscoelastic and feedback dissipation in the damping of oscillations in certain rods and beams Loss of stability or of well posedness due to feedback delays is described Additional results concern analysis of energy decay in elastic beams and an investigation of the Signorini problem for motion of an elastic body that abuts a rigid obstacle Numerical and analytic studies are described for Bingham fluids as well as for several problems involving two fluid flows Finally work on control problems for the Navier Stokes equations is summarized **Scientific and Technical Aerospace Reports** ,1991 *The Shock and Vibration Digest* ,1992 *Estimation and Control of Distributed Parameter Systems* Wolfgang Desch,F. Kappel,Karl Kunisch,1991 **Control and Estimation of Distributed Parameter Systems** F. Kappel,Karl Kunisch,Wilhelm Schappacher,1989 **Government Reports Announcements & Index** ,1991 *Energy Decay and Control for Elastic and Viscoelastic Distributed Parameter Systems* ,1994 Research is reported on the dynamic behavior of viscoelastic structures with emphasis on the interaction between passive damping and active feedback control mechanisms A main focus is the approximation of optimal compensators for simple mechanical systems involving viscoelastic elements by realizable compensators In the frequency domain this corresponds to the mathematical problem of approximating a transcendental function by a rational one under suitable stability constraints and performance criteria The work involves the analytic study of partial product approximations to transfer functions for rods and beams as well as a mainly numerical study concerned with replacing the complex modulus for the viscoelastic material by a rational function that reflects the most significant properties of the material A second focus of the research is a new formula that makes clear the relation between initial data and the smoothness and decay rates of solutions of the equations for a viscoelastic system with stabilizing boundary feedback SIAM Journal on Control and Optimization Society for Industrial and Applied Mathematics,2004 *Government Reports Annual Index* ,1991 Mathematical Reviews ,2003 *Applied Mechanics Reviews* ,1989 **Space Station Systems** ,1990 *NASA SP.* ,1991 **Large Space Structures and Systems in the Space Station Era** ,1991 **Space Station Systems: A Bibliography with Indexes (supplement 10)** ,1990 *Technology for Large Space Systems: A Bibliography with Indexes (supplement 22)* ,1990 **Large Space Structures & Systems in the Space Station Era** ,1991 *International Aerospace Abstracts* ,1996 **Modeling, Signal Processing, and Control for Smart Structures 2007** Douglas K. Lindner,2007 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in

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