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Shear deformation damping of a double-beam structure

Tomasz Szmidt *

Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland

A R T I C L E I N F O

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A B S T R A C T

The dynamics of twin cantilever beams connected at their free ends by a viscoelastic member is investigated. A series of experiments with damping members made of various materials was conducted. A dynamic model of the structure is proposed. It fits the experimental data well, and allows estimating the Kirchhoff modulus and shear damping coefficient of the member. The influence of geometry of the damping element on oscillatory characteristics of the system is investigated.

1. Introduction

Double-beam systems, which consist of two elastic and slender parallel solids, are elements of various devices as well as of mechanical, civil, and aircraft structures. Examples include aircraft wing spars, double-beam cranes, railway tracks resting on a foundation, bridge spans, pipelines, and trusses. Twin beams can also be encountered in mechanical systems on a smaller scale, for example linear guideways used in plotters or during such technological processes as cutting. Mechanical vibrations of all these systems increase their wear, cause fatigue, increase the risk of failure, produce excessive noise, and lead to a lack of precision during the technological process. Their reduction is a task of extreme importance, contributing to the improvement of the operating conditions of the machines and their safety.

Therefore double-beam systems have attracted interest over the past decades, and various aspects of their dynamics have been investigated. In such systems, mechanical energy can be dissipated during the relative transverse motion of the beams, which leads to deformations of a viscoelastic damper placed between them, see for example [1] or [2]. However, when the beams synchronize their motion, damping becomes ineffective. The problem is overcome in sandwich beams – structures made of a viscoelastic core placed between two rigid facesheets. Over half a century ago it was theoretically and experimentally confirmed that the shear deformation of the soft middle layer, which occurs during the flexural vibrations of the structure, is the predominate mechanism of energy dissipation in a sandwich beam [3]. Both mechanisms of energy dissipation are employed in [4], where the dynamics of two parallel cantilever beams with a damping element based on dry friction is investigated.

* Tel.: +48 22 826 12 81x267.
E-mail address: tszmidt@ippt.pan.pl

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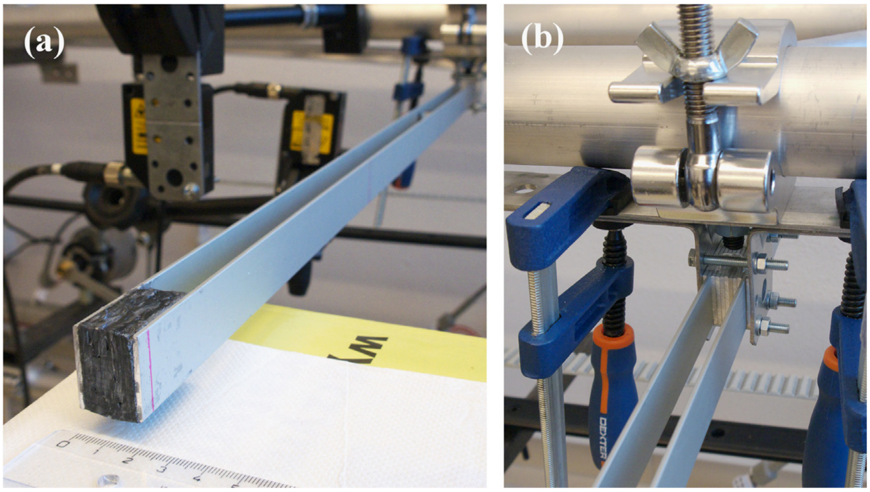

Fig. 1. Double-beam structure, (a) damping member, and (b) support.

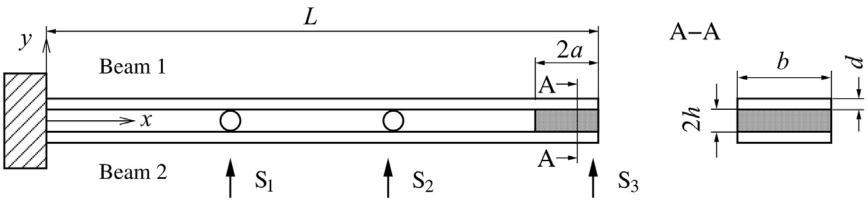

Fig. 2. Scheme of the analyzed structure.

Passive methods of vibration reduction are not always sufficiently effective, especially in systems working under variable loads or environmental conditions. Thus a range of active and semi-active techniques have been proposed. Active control systems are based on force actuators that are attached to a structure and can increase its stability or perform desired trajectories. However, a drawback is their high power consumption. A recent trend has been to develop semi-active methods, which are also safer in the case of a control system failure [5]. In [6], friction damping of a beam system is analyzed. Piezoelectric elements are used to control contact forces in the joints connecting the beams. In [7], the so-called Prestress Accumulation-Release (PAR) strategy is investigated. It is based on releasing the strain energy accumulated in the structure during its deformation process. Numerical studies are presented for a layered beam, where the control is based on disconnecting and connecting the two layers. This can be used for semi-active vibration suppression of pipeline systems or pedestrian walkways. In [8], a method for the semi-active control of a double-beam system subjected to a travelling load was proposed. Two elastic beams are joined by controllable magnetorheological dampers. Due to its simplicity and better efficiency than a passive solution, the method can be applied to bridges or linear guideways. The research [9] deals with the damping of the vibrations of twin cantilever beams connected by an elastomer composite with ferromagnetic particles, whose damping coefficient and shear modulus increase when it is exposed to a magnetic field. A simple heuristic control strategy allows reducing vibrations more effectively than if the elastomer was permanently activated. A very similar system is experimentally investigated in [10], however in that study an elastic hermetic container filled with granules acts as the damping member. Changing the underpressure value inside the container allows changing the stiffness and damping properties. The application of vacuum packed particles for vibration reduction is a new concept proposed in [11].

The main goal of the present paper is to propose and experimentally verify a dynamic model for such systems as those analyzed in [9,10]. The key feature is that the damping member is modelled as a two-link diagonal truss. The model can be the basis for the development of optimal control strategies for such systems. Moreover, it may be helpful for establishing the geometrical and physical parameters which provide possibly the highest efficiency of vibration suppression.

2. Experimental method

A simple laboratory set-up has been built to observe and study the shear deformation damping of a double-beam system. The analyzed structure is presented in Figs. 1 and 2. It consists of two identical beams having length $L = 700$ mm, width $b = 25$ mm, and thickness $d = 2$ mm. The beams are made of an aluminum alloy of mass density $\rho = 2.7$ g cm^{-3}. They are mounted in parallel in a clamped configuration and connected at their free ends by a polymer member. The member