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Nonlinear vibrations of a sandwich piezo-beam system under piezoelectric actuation

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Abstract: In this paper the problem of nonlinear vibrations of an actuated sandwich slender piezo-system is discussed. The considered system is composed of a host beam with piezoelectric patches bonded to its top and bottom surface, respectively. The host beam ends are supported to prevent longitudinal displacements. By introduction a constant and uniform electric field to each piezo element, an axial compressive or tensile piezoelectric force is induced. Once opposing directions of the electric field vector for both piezo patches, one of the piezo element is compressed, whereas the second one is under tension, what results in the system's bending. The main objective of performed studies is to analyse how different ways of piezoelectric actuation affect the system deflection, which, as a result, modifies its natural nonlinear frequency. The priority parameters are the beam and piezo elements thicknesses, the level of piezoelectric forces actuation, the pattern of forces induction. The problem is formulated on the basis of Hamilton's principle and solved with the use of a perturbation method. During the first sequence of performed calculations, the geometry of the system modified by the electric field is considered. After determination of the structure configuration, the dynamic system response is examined to find its characteristic features. It is proved that the system deflection and its nonlinear frequency depends strongly on the way of the piezoelectric forces induction. Moreover, it is shown that both the static and dynamic responses are very sensitive to any changes in physical or geometrical properties of the structure.

Keywords: piezoelectric actuation, piezoelectric bending, sandwich beam, nonlinear vibrations

1. Introduction

In recent years, smart structures solutions are strongly sought and deeply investigated by many researchers due to its properties giving the possibility of actively or passively enhance system performance. Piezoceramic rods, plates, patches, rings etc. are one of these smart elements, where under applied stress one generates voltage on its surface (direct piezoelectric effect) or under applied constant electric field a shape deformation may be observed (reverse piezoelectric effect). In engineering applications, the main goal is to enhance system prebuckling capacity and/or move the natural frequencies of elastic structures far enough from a possible excitation band. Enhancement of buckling capacity via the piezoelectric actuation in a simply supported beam with the possibility of one of the supports to move in the longitudinal direction in comparison to the beam with both ends preventing longitudinal displacements was discussed by de Faria [1]. It is proved that in the beam with both ends preventing longitudinal displacement the stress stiffening effect achieved via piezoelectric actuation allow to counteract the beam instability. Static and dynamic response control in Euler-Bernoulli beam with different end supports and a pair of perfectly bonded piezoelectric patches is discussed in [2]. It is demonstrated that the lower the overall stiffness of the system, the higher the influence of the residual force is observed on both critical load and transversal vibration frequency. Zenz and Hummer [3] investigated critical load, tip displacements and natural vibrations in a cantilever beam subjected to the conservative compressive force, where on top and bottom surface of host beam were attached piezo patches. By introducing into the piezo elements different voltage values, system was forced to bend. It is shown forced bending influence the load-frequency relationship. In this paper the idea of using actuacting bending moment is adopted for the shape and vibrations control of a simply supported beam with both ends preventing longitudinal displacements, shown in Fig. 1.

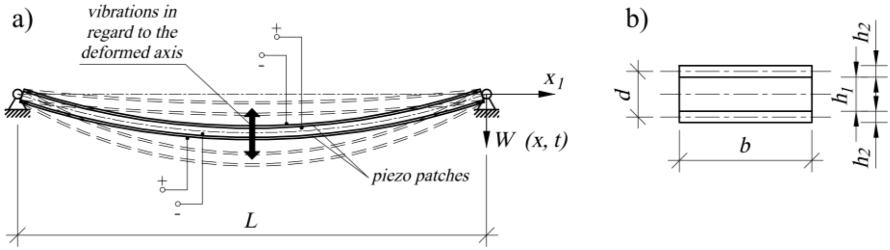

Fig. 1. Vibrations of a deformed simply supported beam via piezoelectric bending actuator (a), cross-section (b)

2. Problem statement

The main aim of this work is to investigate how different ways of piezoelectric actuation affect system deflection, which in result modifies its natural nonlinear frequency. Knowing that in slender structures the axial and bending stiffness as well as mass has a crucial influence on system dynamic response, the priority parameters are beam and piezo elements dimensions, their mechanical and electro-mechanical properties. Moreover, the level of piezoelectric forces actuation and forces induction patterns are taken under investigation.

The stated problem is formulated on the basis of Hamilton's principle and solved with the use of perturbation method. The slenderness of the system allows to classify the problem into Euler-Bernoulli beam theory. In the first sequence of numerical calculations the system geometry affected via piezoelectric actuation is investigated. Having determined static structure configuration, the dynamic response is analysed.

It is demonstrated, that the use of different piezoelectric actuation patterns has a strong influence on system deflection and its nonlinear frequency. Moreover, it is proved that for the analysed system configuration even a small change in physical or geometrical properties may lead to quantitatively and qualitatively different static and dynamic results.

References

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