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Research on the thermal characteristics of bending hybrid piezoelectric actuators under different exciting methods

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A B S T R A C T

Bending hybrid piezoelectric actuators have merits of large flexibility on dimensions as the only restriction is the symmetry in structure. Furthermore, they can be used for linear or rotary driving either, depends on the type of the rotor. This work focuses on the exciting methods for the bending hybrid vibrations, which are evaluated by the comparison between their thermal characteristics. Totally, five exciting methods are proposed and tested, they are: half pieces of PZT plates with converse polarizations, whole pieces of PZT plates with two partitions of converse polarizations, whole pieces of PZT plates with two partitions of the same polarization, whole pieces of PZT plates with four partitions of converse polarizations and whole pieces of PZT plates with four partitions of the same polarization. Five prototypes with the same dimensions are fabricated under the proposed five exciting methods, respectively. Their surface temperature changes are measured under no-load condition in time domain. The effects of the temperature on the electromechanical coupling factors are measured. This work can guide the design of piezoelectric actuators operated in bending hybrid modes.

1. Introduction

Piezoelectric actuators (PAs) have been successfully used in areas of precise actuating system, aerospace mechanism, robot, optical instrument and cell manipulation as their merits of simple structure without coils, quick response at millisecond, high precision and resolution at nanometer, low speed without reducer, self-locking in the power-off state and absence of electromagnetic radiation, etc. [1–3]. Recently, resonant type PAs using the hybrid of two vibration modes have become the research focus, which can be classified into longitudinal-longitudinal (L-L) hybrid type [4–6], longitudinal-bending (L-B) hybrid type [7–9], longitudinal-torsional (L-T) hybrid type [10–12] and bending-bending (B-B) hybrid type [13–15]. These PAs have the similar operating principle as they always drive the runner by the elliptical movement of the driving tip produced by the hybrid of two vibration modes with the same resonance frequency: the horizontal and vertical vibrations of the driving tip are generated separately with temporal shift of 90°, the vertical displacement is used to overcome the preload between the interfaces, whereas the runner is pushed by the horizontal displacement.

The three types of PAs using the hybrid vibration modes, contain L-L hybrid type, L-B hybrid type and L-T hybrid type, are limited in special structure dimensions, which means that the changes of the sizes can break the uniformity of the resonance frequencies of the two vibration modes involved. However, the B-B hybrid type PAs exhibit higher design flexibility as the two orthogonal bending modes will have the same resonance frequency under a symmetrical cross-section such as circle or square. This flexibility in the structure dimension is significant for the industrial application as the demands for size, weight, speed, force and power are always changed to satisfy the requirements of different application areas. Therefore, the bending hybrid PAs are more valuable for the aim of application, which have been verified by several previous designs. However, nearly all previous works had used half pieces of PZT plates with converse polarizations to generate the bending hybrid vibrations; the compression stresses of the PZT elements applied by the clamped bolt were not equal since the PZT plates had minute discrepancies in their thicknesses, which caused problems of heating and low efficiency.

This work focuses on the exciting methods for the bending hybrid vibrations, and five exciting methods are discussed and tested, which are: half pieces of PZT plates with converse polarizations, whole pieces of PZT plates with two partitions of converse polarizations, whole pieces of PZT plates with two partitions of the same polarization, whole pieces of PZT plates with four partitions of converse polarizations, whole pieces of PZT plates with four partitions of the same polarization. These exciting methods are evaluated by the comparison between their thermal characteristics under no-load condition. The operating principle of the bending hybrid PA is discussed shortly in Sections 2, 3

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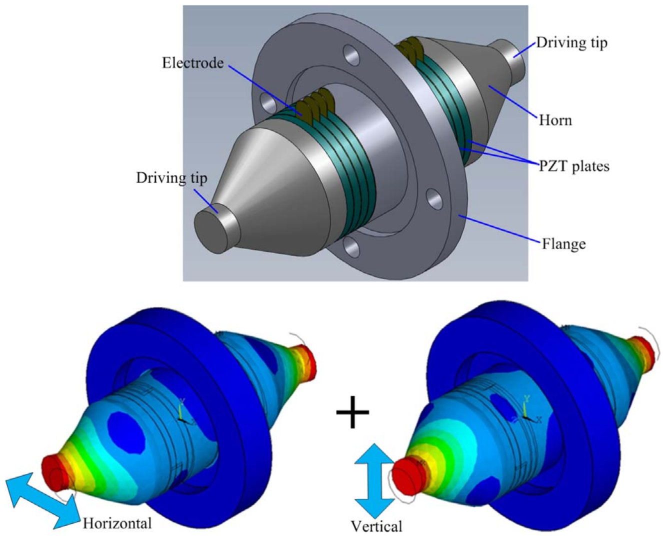

Fig. 1. Structure of the bending hybrid PA and its operating principle.

describes the five exciting methods for the bending hybrid vibrations in detail, Section 4 gives the experimental testing and results of the surface temperature changes of the prototypes in time domain, Section 5 is the conclusion.

2. Operating principle of the bending hybrid piezoelectric actuators

The three-dimensional structure and the operating principle of a PA using the bending hybrid vibration modes are shown in Fig. 1. Two orthogonal bending vibration modes are generated in the actuator with the same resonance frequency and a temporal shift of 90°; their superimposition can form elliptical trajectory movements on the two driving tips, which can be used for linear or rotary driving when a runner is pressed into contact. Piezoelectric ceramic plates and electrodes are clamped between the horn and the flange by bolt, and the end tip of the horn serves as the driving part. Usually, these piezoelectric ceramic plates are classified into two groups: the first one is responsible for the excitation of the horizontal bending, whereas the other group is used to generate the vertical bending. Circular cross-section structure is used by the proposed PA to ensure that the two bending vibration modes have the same resonance frequency.

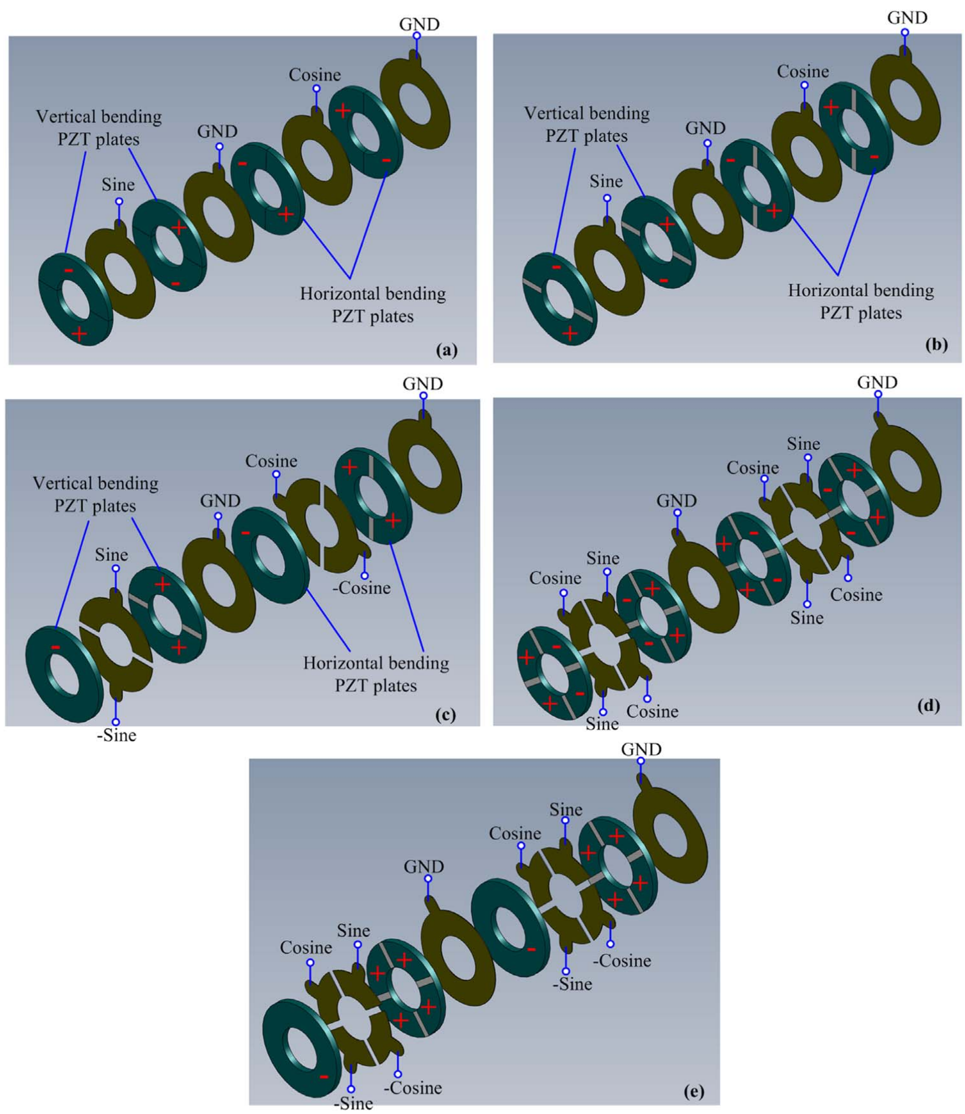

Fig. 2. The exciting methods for the bending hybrid vibrations: (a) half pieces of PZT plates with converse polarizations, (b) whole pieces of PZT plates with two partitions of converse polarizations, (c) whole pieces of PZT plates with two partitions of the same polarization, (d) whole pieces of PZT plates with four partitions of converse polarizations, (e) whole pieces of PZT plates with four partitions of the same polarization.