AN INERTIAL PIEZOELECTRIC ROTARY MOTOR BASED ON THIN SQUARE TYPE FRAME

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1. Abstract

Results of numerical and experimental investigations of a thin inertial piezoelectric rotary motor based on a square type frame is presented in the paper. The objective of investigations was to validate operation principle of the actuator and to analyse dynamic characteristics of the motor. The motor has small size and a simple design. It consist of a square type hollowed steel frame with four straight cantilevers used to move the rotor. Piezo ceramic plates are glued on the both sides of the stator and are used to excite the second in – plane bending mode of the beam. Excitation of the stator can be carried out by two saw-tooth signals with the phases shifted by π. The thickness of the stator is 1.3mm. Therefore it can be used for applications where space and mounting volume are critical parameters. Numerical and experimental investigations were performed to analyse vibration modes, resonant frequencies and to investigate dynamical and electrical characteristics of the actuator. A prototype of the motor was made and measurements of the mechanical and electrical characteristics were performed.

2. Introduction

An inertial piezoelectric motors are widely used in modern mechatronic systems and devices. These type of motors are used for the precise positioning, focus control in optical systems, scanning tunnelling microscopy and etc [1]. Wide applications of inertial piezoelectric motors are caused by the following advantages such as short response time, high resolution, self – locking, magnetic field free operation and small displacement step [2].

Inertial piezoelectric motors can be classified into two groups based on operation principle i.e. stick – slip and slip – slip [3]. In general, these operation principles of an inertial piezoelectric motors are based on different phases of acceleration at the contact point between stator and rotor. The difference of acceleration phases is caused by non – harmonic excitation signals. The most common signals used to excite an inertial piezoelectric motors are saw – tooth and square type waves [4].

The linear inertial piezoelectric motors are widely analysed and numerous different designs of these motors are presented in the literature [5, 6]. On the other hand, much less designs of the rotary inertial piezoelectric motors can be found, however demand of these motors in the market is quite high. The main advantage of inertial piezoelectric rotary motors is- a high angular resolution [7]. In most cases, inertial rotary motor operates at stick – slip.

3. Design and operation principle of the motor

Proposed inertial piezoelectric motor consist of a stator, rotor, shaft, preloading spring and clamping cylinder (Fig.1a). Stator of the motor has square shape frame with the four straight cantilevers pointed to the center of the frame. The L is defined as length and width of the stator and is equal to 25 mm (Fig. 1a). Thickness of the stator H is equal to 1.3 mm. The frame of the stator is made from DIN 1.4301 stainless steel. Sixteen lead zirconate titanate (PZT) plates are glued on the top and bottom surface of the stator. Electrodes of the PZT plates are divided into two equal sections. Polarization is of PZT plates are pointed along thickness. Plates are glued on the top and bottom surface have opposite polarization direction. Dimensions of each PZT plate is 8 x 4 mm.

Small alumina ceramic plates are glued at the end of each cantilever in order to increase contact friction between the stator and rotor. Double conical shaped rotor is placed in the centre of the stator. (Fig.1a). Spring is used to preload rotor to the stator. Adjustment of the preloading force of the spring is made by clamping cylinder that can be moved and fixed in the proper position on the shaft. M1.2 screw is used to fix clamping cylinder on the shaft.

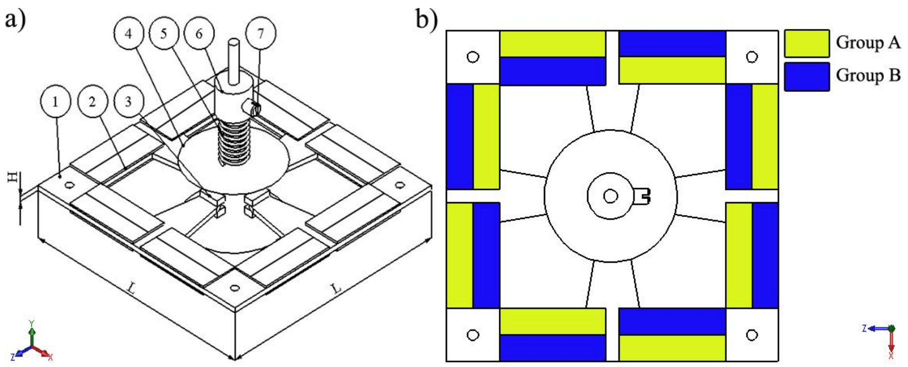

Figure 1. Principle design of the motor: a - Isometric view of the motor; 1 – stator; 2 – piezo ceramic plates; 3 – alumina ceramic plates; 4 - double conical rotor; 5 – spring; 6 – clamping cylinder; 7 – fixing screw; b – excitation scheme of the stator.

Operation of the motor is based on excitation of the 2nd in-plane bending mode of the frame. Electrodes of piezo ceramic plates were divided into two groups A and B respectively as shown in Fig.1b. Non-symmetric excitation signal with phase difference by π is applied on different groups of the electrodes. Excitation of group A expands stator while plates of group B shrinks stator. Transverse deformations of stator are obtained that excite second in-plane vibrati

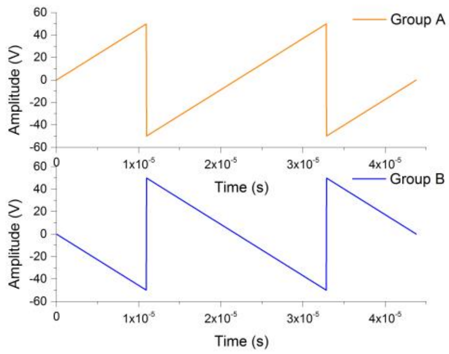

Figure 1 Shape of excitation signal

Stick – slip interaction between stator and rotor is achieved applying saw tooth excitation signal (Fig. 2). Timing of the stick - slip interaction is directly related to the shape of the excitation signal. Expansion and contraction of piezo ceramic plates is slow at the first step of excitation. Slow signal rising causes that friction force between stator and rotor is greater than inertial force of the rotor, so rotation of the rotor can be observed. However, then signals suddenly changes state inertial force becomes grater than friction force and cantilevers slips through surface of the rotor and motion is not transferred. Similar operation of the motor can be observed during its excitation by pulse shape signals.

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