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Analysis of Vibration Drives With Composite – Structure Piezoconverters

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Abstract
The paper deals with the development, analysis and application of vibration drives with composite – structure piezoconverters. The most important part of these drives is the input link made as a stack of piezoceramic elements.
For the constructed drives characteristic is simple design, high speed response, high resolving power (0,1'-0,15") and the possibility to perform micro -displacements up to ±35μm value according to the praset law of motion.

Keywords: vibration, piezoceramic, actuator

1. Introduction

In precision engineering industry among different control drives especially important are the drives with active piezoceramic elements – composite piezotransducers ie piezostarks made of piezoceramic discs or rings.

A typical pump of this type (see figure 1) would include an inlet valve, a pair of opposed pistons, and an outlet valve. The valve and piston actuators would contain stacked piezoelectric or electrostictive ceramic wafers. The voltages applied to the actuators would be phased to make them operate in a sequence to move a fluid from the inlet to the outlet. Pressure sensors in the pistons and valves would provide feedback for phase control. The pump would not leak when turned off because when no voltage was applied to the valve actuators and pistons, both valves would remain closed and the pistons would be pressed against each other or it could be made to retain the position where one valve is opened.

Stacked piezoelectric wafers would be used instead of thicker piezoelectric blocks in order to obtain useful amounts of piezoelectric contraction at applied potentials <100 V. A typical actuation range of 10 to 20 μm could be realized, the exact range depending in the piezoelectric material. In one example, the gap between the pistons would be 40 μm with full voltage applied. If the pistons were 25 mm in diameter, the displaced volume would be 19,6 mm^3 per stroke. For a pump-cycle frequency ranging from 1 to 10 kHz, the pumping rate would range from 20 to 200 cm^3/s.

In Fig.2 the schematic of piezoceramic drive for optical correction ob the wave front of laser beam is shown vibrodrives for phase correction of a wave – front of a light beem.

The vibration drive is based either on the formation of the zone of micro-displacements of the mirror surface being deformed or on the change of the slope angle of seperate segments of a segmented mirror along three coordinates by means of composite piezoceramic vibrators operating in non-resonanse regime. Such drive can exert a form up to 1000N in magnitude, can achieve the displacement precision up to 0,1 μm in the displacemen range of 0÷1mm.

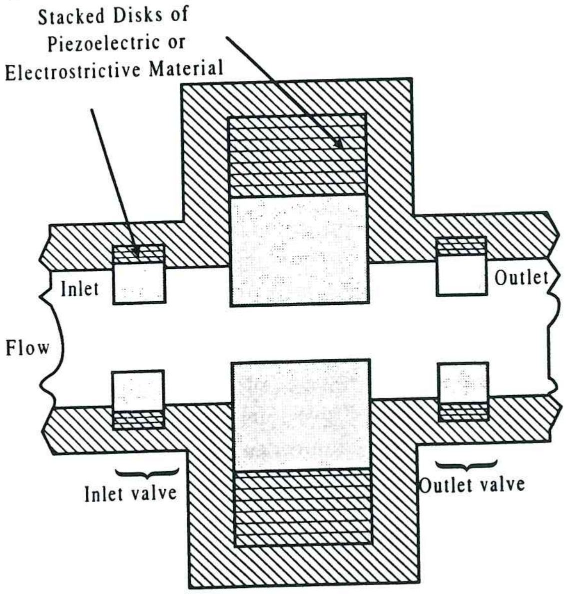

Fig. 1. Contraction and Expansion of piezoelectric valve ar piston actuators in a controlled sequence would result in pumping action

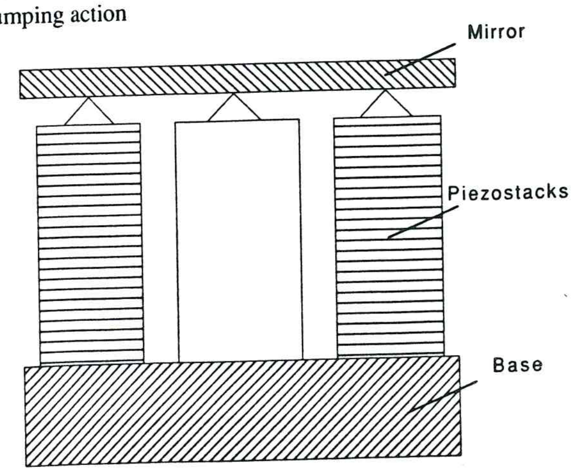

Fig. 2. Vibrodrive for optical correction of the wave front o light beam

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2. Investigaton

Vibration drives combined with composite piezoconverters are based on direct transformation of elastic strains of piezoconverter components into the motion of an output link of mechanisms. These drives are widely used in precise positioning units, optico-electromechanical instruments and the systems of adaptive optics. Their distinguishing characteristics are: minute gadgets, rigidity, absence of clearances and backlashes, simple control system, feasible motion of the operating link according to the given law of motion, high resolving power, and accuracy. The analysis of vibrodrives with ccomposite piezoconvertes made as stacks of piezoceramic elements covers the following items: the piezostack structure and materials have been optimized for maximum displacement; heterogenous nature of elastic strain distribution along piezostacks has been detected; piezocomponent number has been minimized, the influence of automatic control means on the hysteresis loop correction has been evaluated. Static characteristics of the vibrodrive are shown in Fig.3. Closed curve 1 represents the operation of a servoamplfier-vibrodrive system without electromechanical feedback. Closed curve 2 represents the operation with an electromechanical feedback. The characteristics indicate that the application of automatic control has enabled to cut down the hysteresis losses from 12-15% to 0,2% of the maximum displacement magnitude of output link, an the same time, to improve the accuracy of the preset micro-displacement. In precise measuring systems, especially in adaptive optics, the behaviour of vibrodrive under dynamic operating conditions as well as its controlability are of great importance. The family of amplitude-frequency characteristics of the system-servoamplifier-vibrodrive is shown in Fig. 4. It is evident that vibrodrive characteristics ensure the reliable operation and good controllability over the whole range of frequencies. The first resonanse points which may effect the vibrodrive operation are moved from the operating range of frequencies by an order and even higher. These vibrodrive characteristics, its high resolving power (0,11÷0,15μm), linear microdisplacement ability improved up to ±35μm and simple cotrol by varying the control voltage value make it possible to apply our vibrodrives for the solution of a number of problems in precise instrument engineering.

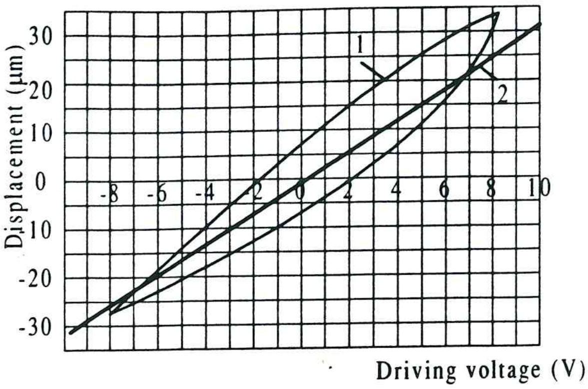

Fig. 3. Static characteristic of the vibrodrive when maximum out put voltage $U_{max\ output}$=450 V, load force F=500 N

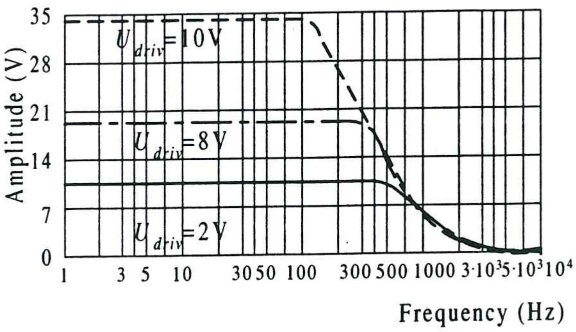

Fig. 4. Family of amplitude-frequency characteristics of the vibrodrive when driving voltage U_{driv}=2V; 6V; 10V maximum out put voltage $U_{max\ out\ put}$=450V, load force F=500N

3. Conclusions

The investigation of vibrodrives with composite piezotransducers showed what influence have the means of automatic control on the correction of hysteresis loop i.e. they reduce the error of motion variation up to 92% from maximum displacement value.

Dynamic characteristics of axial piezoceramic element stacks have been determined – such drives operate stable in a wide frequency range with an accuracy not less 0,1μm.

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