Compact Balancing Devices based on Piezoelectric Ultrasonic Motors

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Introduction

Time-varying unbalance due to e.g. tool changes or temperature gradients is increasingly complicating performance enhancement of production machines. High speed shafts are already often equipped with balancer rings (*Fig.1a,b*), but active balancing devices that compensate unbalance during machine operation are getting more and more common. The conventional electromagnetic balancer device might be improved and miniaturized by utilizing piezoelectric ultrasonic motors (PUM's) (*Fig.1c,d,e*) for actuation. PUM's have a simple mechanical structure and a low response time and they are easily combined with non-contact power supplies.

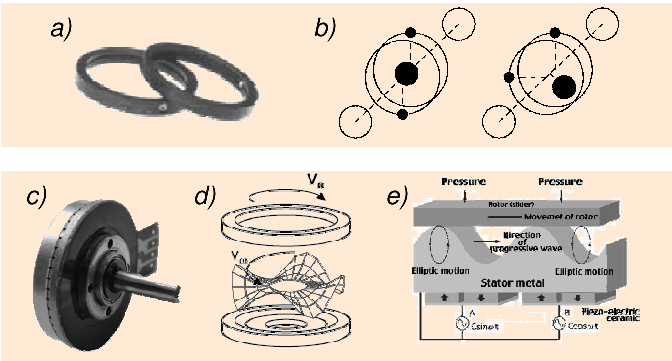

Fig.1. (a) Balancer rings with (b) working principle. (c) Shinsei rotary PUM with (d,e) working principle.

Objective

The present research aims to quantify the performance of an active balancing device which is based on two rotary piezoelectric ultrasonic motors.

Methods

A flexible shaft with a heavy disk is selected as test case. (This enables a comparison between piezoelectric mass actuators and the force actuators which were considered in previous research). Vibration at the bearings and motion of the shaft are measured with accelerometers and eddy current sensors, respectively. Two balancer rings separated by a teflon disk are mounted on the shaft between two PUM stators (*Fig.2a,b,c*). The PUM electrodes are connected to coils which are powered contact-less by stationary coils. The relative orientations of the shaft and balancer rings are obtained from key phasor signals measured with optical sensors.

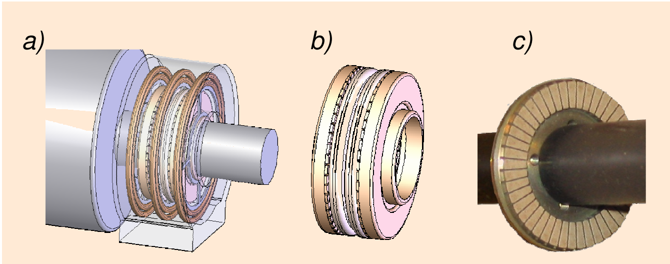

Fig.2. (a) Ring balancer device on a flexible shaft with disk (drawing). (b) Two facing PUM's (drawing). (c) Stator of a Shinsei PUM on a flexible shaft (photo).

Adaptive unbalance compensation algorithms are developed which take into account 1) stiffness and mass asymmetry of the shaft and supports, 2) transient effects which result from the varying rotor speed and motion of the balancer rings and 3) positioning hysteresis in the piezoelectric ultrasonic motors. The control algorithms are implemented on a dSpace™ system. A schematic representation of the experimental setup is shown in *Fig.3*.

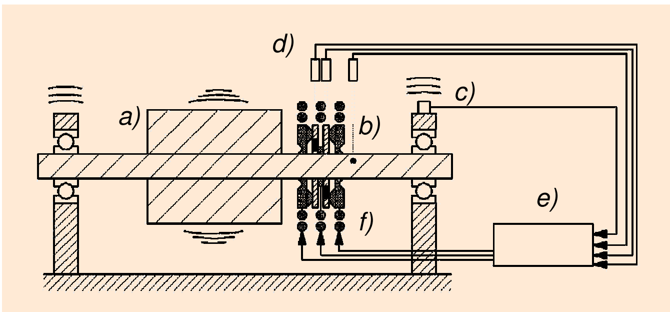

Fig.3. Experimental setup: (a) flexible shaft, (b) PUM's, (c) accelerometer, (d) phase sensors, (e) control system, (f) powering coils.

Results

In previous research, a flexible shaft with surface-mounted piezoelectric force actuators was effectively stabilized and unbalance induced vibration was reduced by 98%.