Balancing and stabilizing flexible shafts with piezoelectric materials

P.J. Sloetjes, A. de Boer

Institute of Mechanics, Processes and Control - Twente
Chair of Structural Dynamics and Acoustics, University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands
phone +31-(0)53-4893405, email p.j.sloetjes@ctw.utwente.nl

Introduction

Fastly rotating shafts in production and automotive machines often vibrate or induce vibration. Typical rotor dynamic problems are shown in *fig.*1:

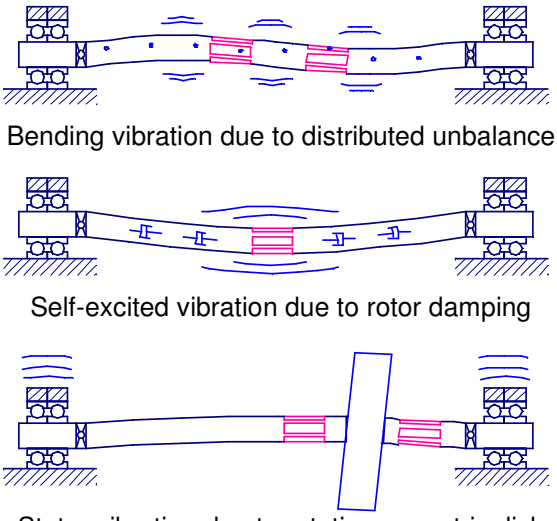

Fig.1. Typical rotor dynamic problems (actuators in red).

Objective

The present research focuses on system level solutions for active balancing and stabilization of flexible shafts using piezoelectric ceramics.

Methods

Design of smart structures is challenging because of tight constraints on sensor quality, actuator number, power consumption and processing capacity.
Solving the problems in *fig.*1 requires only few actuators. It also takes only little power, because constant actuation voltages suffice for balancing, while small forces can suppress self-excitation.
Due to the shaft's static deflection, the actuators produce charges that may power economic control systems. Less economic control systems may be powered with built-in electromagnetic generators.
Optimal control solutions are sought by combining finite element models, electronic circuit models, stability analysis and experiments. Advanced stability analysis takes nonlinearity into account.

Results

Preparatory simulations and experiments showed the effectiveness of active balancing and damping.
Active balancing was achieved by estimating rotor unbalance and correcting it by rotor shape control.
Active damping was achieved by computing control voltages as angular velocity dependent functions of modal position and velocity.
Results from the test rig in *fig.*2*a* are shown in *fig.*2b. For the indicated angular velocity profile, the maximum midshaft deflection was reduced from far more than 4000 µm to less than 150 µm.

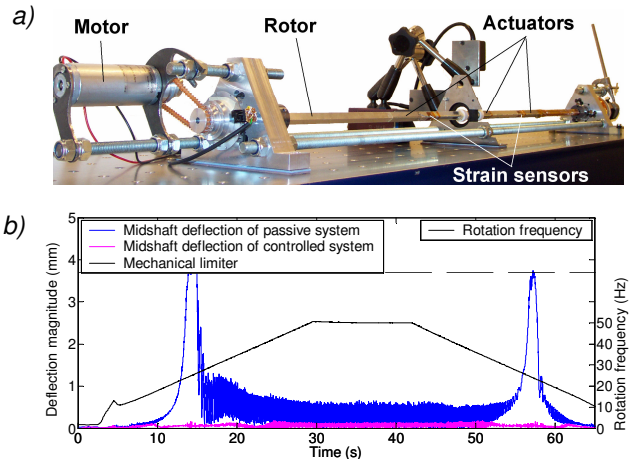

Fig.2. Deflection magnitudes for shown rotor setup.

Experiments with power harvesting indicated the feasibility of autonomous balancing devices. The high level structure of such a device is shown in *fig.*3. The low level structure is yet to be determined.

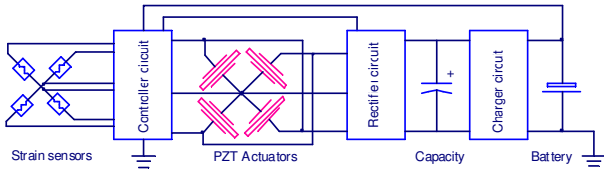

Fig.3. Circuit diagram of a self-powering balancing device

Discussion

Common rotor dynamic problems can be solved by means of rotor-fixed actuators and sensors.
Future research involves linear and nonlinear stability analysis of smart rotor systems.