Bandwidth increase of positioning tables

BANDWIDTH INCREASE OF POSITIONING TABLES

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HIGH-END MOTION SYSTEMS

In the industry of high-end manufacturing, for instance in the semiconductor market, various processing and measurement steps take place on positioning tables or stages. In these types of high-tech motion systems, the finite stiffness of mechanical components usually limits the bandwidth of the control system [1]. This can be counteracted by increasing the controller complexity, for instance by using notch filters [2]. The resonance frequencies of the non-rigid body dynamics and the amount of damping significantly affect the achievable bandwidth.

POSITIONING TABLES

The dynamical behavior of relatively flat positioning tables is mainly characterized by mode shapes with large out-of-plane displacements. These mode shapes are dominant in the transfer function in z-direction and limit the achievable control bandwidth in that direction. A square plate is used as an abstracted stage model. The plate's mode shapes are exported from FEM and a state space model is generated.

ADDING DAMPERS

A method is investigated to add damping to the out-of-plane flexible behavior of this square plate model, using tuned mass-dampers [3], also called harmonic absorbers. Very high local damping is applied to these dampers. The connections between the plate and the dampers are determined at the plate corners because these locations have relatively large vibration amplitudes. See Figure 1. The mass-spring-damper system uses the plate's displacement and velocity as input and generates a damping force that acts on the plate. The damper model is also created in state space description and a superseding model is calculated for the plate with four dampers added [4].

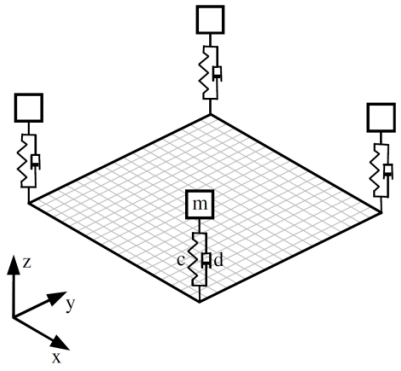

Figure 1: Model of a square plate with 4 dampers added on the corners. The DoF of the dampers is in z-direction. The four dampers have the same mass, damping and stiffness.

MODAL DAMPING INCREASE

The main result is that a significant modal damping increase is achieved over a broad band of resonances, with only a small number of dampers added. This implies a small mass increase of the overall system. Decoupled transfer functions are calculated by applying a geometrical decoupling procedure. The damper parameters are tuned to suppress the bandwidth limiting resonances and therefore achieve an as high as possible bandwidth.

BANDWIDTH IMPROVEMENT

The damping increase primarily results in a control bandwidth improvement of over 150%, with the same stability margins applied during controller design. See Figure 2. A higher controller gain can be applied. This higher open-loop gain leads to a disturbance suppression increase of over 10 times for both force and displacement disturbances.

REFERENCES

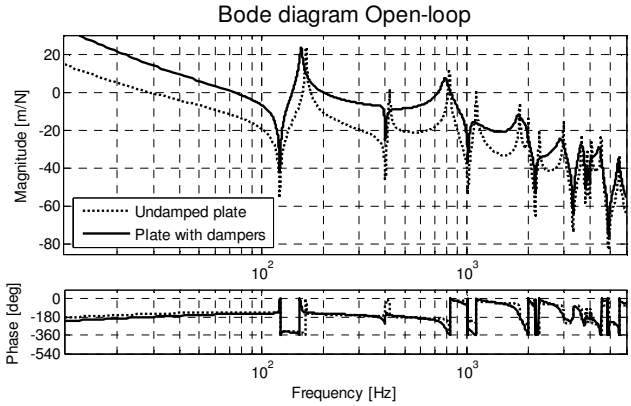

Figure 2: The dotted line represents the Bode diagram of the undamped plate and the solid line represents the transfer function of the plate with dampers.

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