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Vibration suppression and shape change of thin plate by clusters of actuators

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Presented field in this paper is vibration suppression of the plate with heavily distributed grid of the piezo actuators and sensors. Such mechatronic smart materials have potential in many different field of use. For example, morphing wing of the plane [3]. The classic wing of the aircraft uses flaps, which are mechanically positioned. The morphing wing, on the other hand, is a single element that has the ability to change its shape. This eliminates the need for gears, rods and other mechanical components. Its advantage is uniformity, which gives the wing better aerodynamic properties. There are several possibilities how to shape the wing into the desired shape. One possibility is to use smart material with active elements to clad the pliable internal structure of the wing. Another advantage of such material is the possibility of active vibration damping in the wing. One of the vibration cases studied is flutter. Flutter phenomena are seen when vibrations occurring in an aircraft match the natural frequency of the structure. If they aren't properly damped, the oscillations can increase in amplitude, leading to structural damage or even failure. Work focuses on the research of creating such a smart material that is able to suppress vibration or even change its shape. Studied way is that the base material is equipped with a uniform network of piezo sensors and actuators [4] Fig. **1**, which are divided into individual units (clusters Fig. 3). It is then possible to design a single cluster control and apply it to a large structure, such as the wing of aircraft.

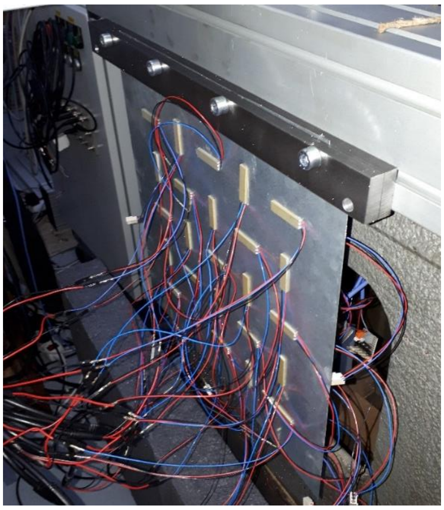

Fig. 1. Experimental structure

Simulation model (delivered by black box identification) of the plate equipped with 8 actuators (control inputs u_i) and 20 sensors (measured outputs y_i) is used for design and validation of control law. Which is designed using the H infinity structured optimization methodology [1, 2] to attenuate resonant modes of this flexible structure Fig. 2.

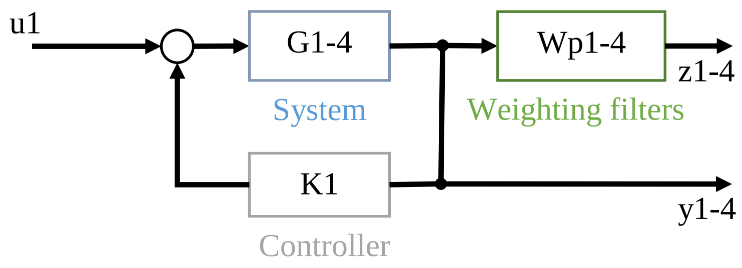

Fig. 2. Design of the controller with weighting filters

For purpose of simplify control, the clusters of sensors were used Fig. 3. For actuator 1 (ACT 1) are relevant 4 sensors (sensor 1, 2, 7, 9) with labeling cluster 1 (cl1). For another example for actuator 4 (ACT 4) are relevant sensors (sensor 4, 5, 12, 13) with labeling cluster 4 (cl4).

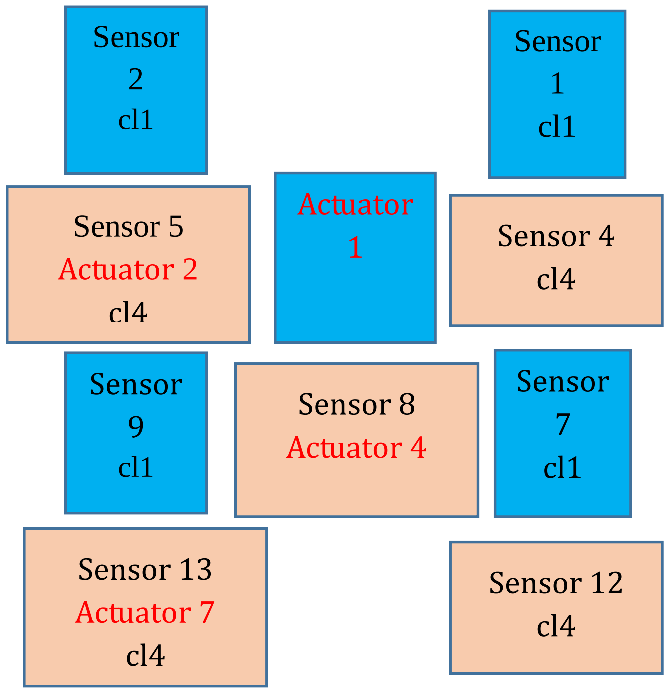

Fig. 3. Clusters

More specificaly we deal with distributed control law where the control action applied to each node depends on measured outputs at the neighboring nodes Fig. 3,

$$u_i = -k_i(y_{i-1} - y_i) - k_i(y_{i+1} - y_i). \quad (1)$$

The scenarios with constant gains throughout the structure is studied. The control system is described as a generalized LTI system with tunable components and weighting filters (Fig. 2). The *hinfstruct* function tunes those components by minimizing the closed-loop H infinity gain from the system inputs $(u_1, u_2, \ldots, u_i)$ to outputs $(z_1, z_2, \ldots, z_i)$. Weighting filters $(W_1, W_2, \ldots, W_i)$ are included for resonant frequencies penalization. The results, in the form of a transfer function, with the structure described above are satisfactory and can be seen that it dampen penalized natural frequencies well, Fig. 4.

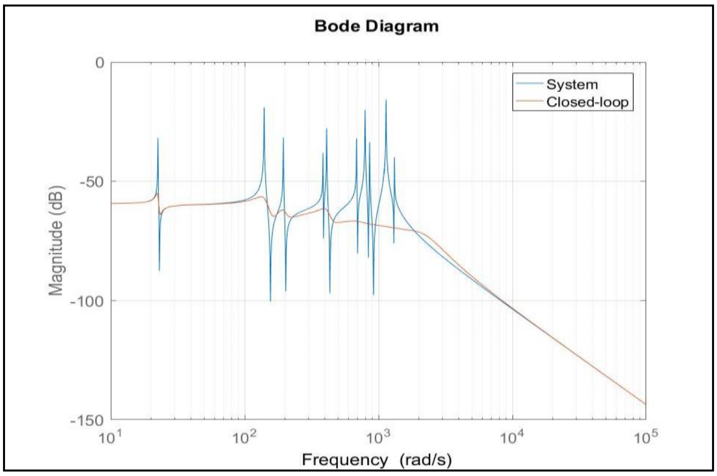

Fig. 4. Result of Hinf regulator

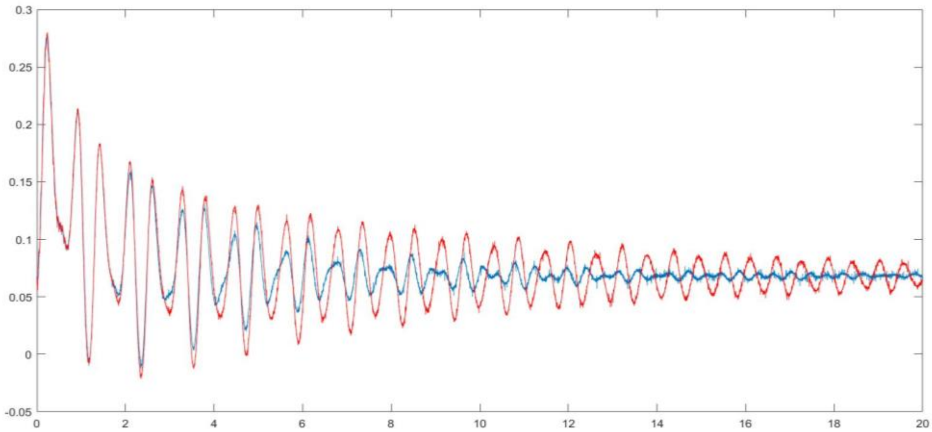

Fig. 5. Result of demonstrator

The Fig. 5 shows the results on a real demonstrator. As we can see the attenuation proceeds much faster, but the first oscillations are not damped at all. This is due to the disproportionately high excitation force that was applied to the demonstrator and the piezoelements were getting saturated. The use of proportional excitation force is the object of further study. Also simulate the form of a flatter that appears on the wings of aircraft as excitation force.

Acknowledgements

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