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Combined MIMO adaptive and decentralized controllers for broadband active noise and vibration control

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ABSTRACT

Model errors in multiple-input multiple-output adaptive controllers for reduction of broadband noise and vibrations may lead to unstable systems or increased error signals. In this paper, a combination of high-authority control (HAC) and low-authority control (LAC) is considered for improved performance in case of such model errors. A digital implementation of a control system is presented in which the HAC (adaptive MIMO control) is implemented on a CPU and in which the LAC (decentralized control) is implemented on a high-speed Field Programmable Gate Array. Experimental results are given which demonstrate that the HAC/LAC combination leads to performance advantages in terms of stabilization under parametric uncertainties and reduction of the error signal.

1. Introduction

Many algorithms used for broadband active noise control are based on the adaptive Least Mean Square (LMS) algorithm [1]. The low complexity and the relatively good robustness properties are the major advantages of the LMS algorithm. Recent algorithms solve many of the problems associated with the speed of convergence of the older algorithms. The basis for a particular class of such algorithms has been given by Elliott [2] as the preconditioned LMS algorithm. The version based on the filtered-error algorithm [3] is more efficient for multiple reference signals than the filtered-reference algorithm. A proper implementation of the filtered-error preconditioned LMS algorithm solves many of the problems associated with early implementations of the LMS algorithm, such as slow convergence due to frequency dependence of the secondary path and cross-coupling in the secondary path [4]. However, the controller is model-based and is, therefore, still sensitive for mismatch between the model and the plant. This model mismatch reduces the overall performance of the controller. Model mismatch can be caused by variations in parameters such as temperature, boundary conditions, etc. For some control schemes, online adaptation of the model is possible in principle but a large amount of additional noise has to be injected in the system for rapid changes in the model [5]. Furthermore, if the controller uses model-based preconditioning or factorization, then these time-consuming operations should be performed online as well. Robust control approaches are known [6] as well as probabilistic methods leading to frequency-dependent regularization for optimum filtering [7,8] and adaptive control [9,10]. Such algorithms can be tuned for a particular application but require additional effort in the design stage and presume that sufficient a-priori knowledge is available about the uncertainty. An alternative approach is to use a high-authority and low-authority control (HAC/LAC) architecture [11], where the goal

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of the low-authority controller is to add active damping to the structure. Active damping can be implemented using different strategies. The use of a HAC/LAC architecture yields three major advantages [11]. Firstly, the active damping extends outside the bandwidth of the HAC control loop, which reduces the settling times outside the control bandwidth. Secondly, it is easier to gain-stabilize the modes outside the bandwidth of the outer loop. And thirdly, the large damping of the modes inside the controller bandwidth makes them more robust to parametric uncertainty. In the paper by Herold et al. [12], a method using piezoelectric sensors and actuators and positive position feedback(PPF) was described. In the PPF-method, a second-order filter is used as the control filter which is combined with positive feedback. The control filter is then tuned to reduce one of the desired resonance peaks.

In the present paper, an approximately collocated and dual sensor–actuator pair is used, suitable for broadband damping as described by Elliott et al. [13]. If the actuator–sensor system is dual and collocated, a simple decentralized proportional feedback controller is sufficient to add damping due to the fact that the overall energy that is stored in the system will be reduced [11]. As such, less detailed a-priori information is required about the model uncertainty. Active damping is not very effective for frequencies that do not coincide with the poles and zeros. To gain further reductions for such frequency components a model-based controller is used such as the RMFeLMS algorithm as described in this paper. Section 2 gives a description of the panel, the control architecture, the control hardware and the particular implementation

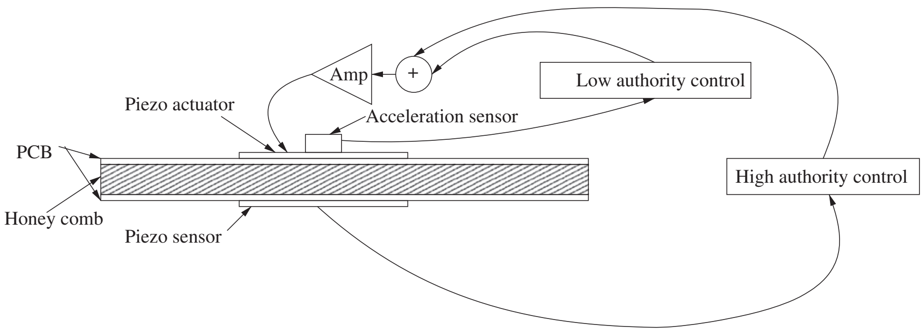

Fig. 1. Configuration of the high-authority/low-authority control architecture applied to a sandwich panel with piezoelectric patch actuators, piezoelectric patch sensors and accelerometers.

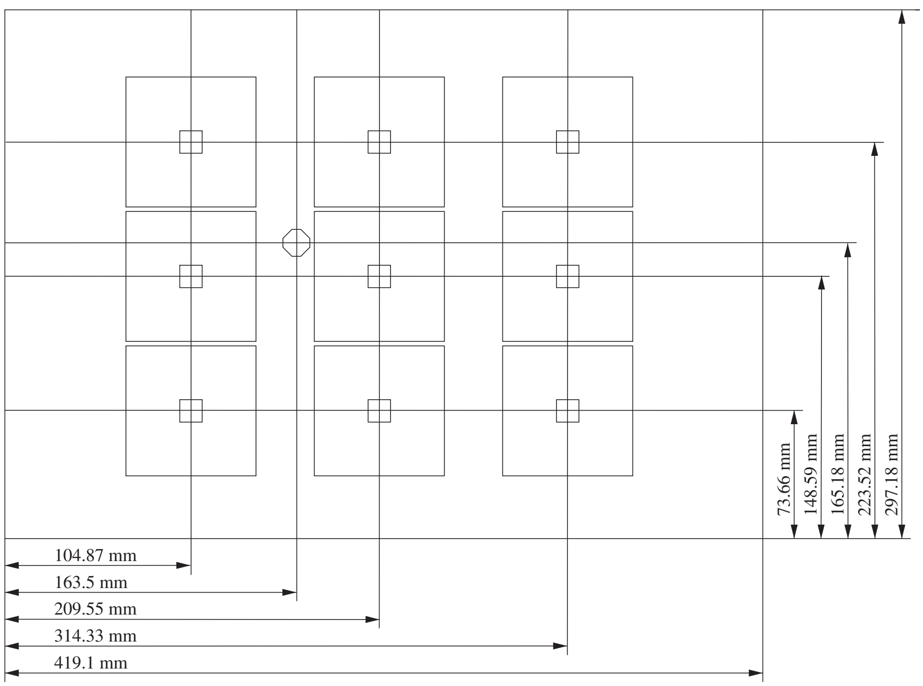

Fig. 2. Dimensions of the active panel used in the experiments. A mount with a thread was used to attach extra weight to the panel (indicated by a circle).