Title of the thesis: Active control of noise in vibro-acoustic cavities

Abstract

This thesis deals with development of efficient methods for global active noise control (ANC) in vibro-acoustic cavities, such as automotive vehicles, aircrafts and other transportation equipment, under the presence of both the acoustic and structural disturbances. First, optimal control inputs to the acoustic and structural control sources for the maximum reduction in acoustic potential energy in a vibro-acoustic cavity under the presence of both the acoustic and structural disturbances are derived and studied. Then, an adaptive feedforward control algorithm using acoustic sensing, which is applicable to irregular-shaped vibro-acoustic cavities under the presence of both acoustic and structural disturbances, is developed to realise the optimal control. Numerical study in a car-like vibro-acoustic cavity shows that the noise reduction obtained using the proposed global ANC method using acoustic sensing is very close to the maximum reduction possible with the optimal control.

A simultaneous use of both acoustic and structural control sources is required for a maximum global noise reduction under the presence of both acoustic and structural disturbances but this leads to an undesirable effect of increase in kinetic energy of the enclosing flexible structure. To address this issue, a constrained minimisation problem, in which the objective is to minimise the acoustic potential energy in the cavity subject to a constraint that the kinetic energy of the structure does not increase after control, is formulated. An adaptive feedforward algorithm, based on exterior penalty function approach in which the solution of the constrained problem is sought as the converged solution of a sequence of unconstrained minimisation problems, is developed to realise optimal control inputs in real-time. Numerical studies for tonal as well as multi-tonal noise indicate that the proposed adaptive feedforward control method ensures active noise control without increasing structural vibrations.

Modal based ANC strategies reported in the literature are in the framework of feedback control or internal modal control architecture. This work presents development of a modal based feedforward control algorithm, named as 'Modal Filtered-x Least Mean Square algorithm', for global ANC in a vibro-acoustic cavity. This is achieved by formulating the conventional FxLMS algorithm in the modal domain of the cavity which then allows focussing attention on reduction of contributions of specific acoustic modes to the acoustic potential energy. The formulation introduces concepts of 'modal secondary paths' and 'modal filtered reference signals'. A numerical study in an irregular-shaped vibro-acoustic cavity shows that the Modal FxLMS algorithm is capable of reducing contributions of the chosen acoustic modes. A variable step-size FxLMS algorithm is developed for active control of noise of continuously varying frequency. This algorithm makes an advance prediction of the continuously varying noise and uses this information for optimally adjusting the step-size. Numerical studies show an improved ANC performance with the developed algorithm over the conventional FxLMS algorithm for various rates of frequency variation.

Global ANC algorithm using acoustic sensing as well as the Modal FxLMS algorithm developed in this work are validated experimentally on a 3D rectangular box cavity with a flexible plate. The ANC methods are implemented on a dSPACE controller board. Results of the experimental study of global feedforward ANC using acoustic sensing show that the
proposed method is effective in achieving global noise control under the presence of both the structural and acoustic disturbances. Results of the experimental study of Modal FxLMS method show that the method is able to reduce modal contributions of the chosen acoustic modes to the acoustic potential energy.