A STUDY OF MODAL SOUND RADIATION

by

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The work described in this thesis is concerned with the development and verification of techniques useful for the investigation of modal sound radiation from vibrating surfaces.

For the purpose of developing and verifying techniques it has been useful to consider in detail the radiation properties of a simple model capable of exact mathematical description. For the latter purpose the clamped edge circular flat plate mounted in an infinite baffle and vibrating in one of its low order modes has been chosen for study, as it is a model that can be both simulated and mathematically described.

The general applicability of the techniques developed is demonstrated for three models which are not readily described by mathematical analysis. The models used for the latter demonstration are the clamped edge circular flat plate mounted on the end of a long tube, the same plate mounted in an infinite baffle but vibrating in a non-classical mode and the side walls of several in-line internal combustion engine blocks.

The modal responses of flat circular plates with both clamped and simply supported edge conditions are calculated using both Classical and Mindlin-Timoshenko plate theories. Numerical results for the modal resonant frequencies, mode shapes and mean square surface velocities are calculated using each theory and presented for the first seven plate modes.

The results obtained for the plate response are used to calculate the corresponding sound radiation efficiencies for each mode, where the
radiation efficiency is defined as a complex quantity with both real and imaginary parts, and may be considered as a normalised form of the surface radiation impedance. The acoustic field adjacent to the vibrating plate is described in terms of oblate spheroidal coordinates. Use of these coordinates allows matching of the acoustic velocity in the fluid adjacent to the plate with the normal plate surface velocity, enabling both real and imaginary parts of the radiation efficiency to be calculated. The predictions obtained in this way for the real part of the radiation efficiency are compared with numerical results obtained by solving the Rayleigh Integral in the acoustic far field. Excellent agreement is demonstrated.

Measurements of the real part of the circular plate modal radiation efficiencies are made using time averaged holography to determine the mean square plate surface velocity. A reverberant room is used for the direct measurement of the radiated sound power. A range of plates differing in size and thickness and vibrating in each of their six lowest order vibration modes are tested. Reasons for discrepancies between experimentally measured and theoretically predicted radiation efficiencies are suggested.

In the second part of the thesis the suitability of a reverberant room (containing a rotating diffuser) for the pure tone sound power measurements mentioned earlier is investigated. In particular the average radiation impedance presented to a number of pure tone sound sources is experimentally determined and compared with free field predictions and measurements.

The sound sources considered initially are the mouths of two impedance tubes of different diameters and a conical horn whose throat is attached to the mouth of the smaller impedance tube. The impedance
presented to the tube mouth is determined as a function of frequency and diffuser angular position and speed by sampling the sound field in the impedance tube at a suitable rate and over a suitable period of time. The impedance averaged over one complete diffuser revolution is then calculated as a function of diffuser speed and frequency and compared with the free field predictions.

Finally, several different size simply supported square plates, each vibrating in their fundamental resonant mode are used as sound sources. Both the real and imaginary parts of the radiation efficiency are measured for each plate as a function of diffuser angular position. The measurement procedure uses a time averaged hologram to store information about the velocity amplitude distribution over the vibrating surface, which may be related to a single acceleration measurement on the surface. A near field microphone scan of the vibrating surface allows determination of the amplitude and phase distribution of the acoustic pressure in the fluid adjacent to the surface, which again is related to the single acceleration measurement. A computer program is used to combine the velocity and pressure information to give the real and imaginary parts of the radiation efficiency.

Values of the measured radiation efficiency averaged over the plate surface are averaged over one complete diffuser revolution and compared with free field predictions and similar measurements in an anechoic room.

It is demonstrated that the rotating diffuser does have a significant effect on the sound power radiated by a pure tone sound source in a reverberant room and that the radiation impedances presented to the pure tone test sources, when averaged over one complete diffuser revolution, are close to the free field values.
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