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CAVITY RESONANCE, ACOUSTICAL NETWORKS AND VIOLIN ACOUSTICS

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This paper is presented in memory of Dr. R. W. B. Stephens and in gratitude for his extensive contributions to the advancement of acoustics in his own and many other countries, especially as a research supervisor who taught, inspired, guided and encouraged a generation of students.

1. INTRODUCTION

In many acoustical systems, wave motion within a cavity interacts with lumped acoustical elements such as resistances and inertances. Such systems are not readily amenable to conventional mathematical analysis especially where the geometry is complex. In principle, such complexity can always be accommodated by finite element analysis using powerful computers, but the cost is high in terms of effort and loss of contact with fundamental concepts. An appealing alternative may be appropriate where the relevant natural modes of the cavity can be identified in terms of their spatial charcteristics. It may then be possible to reduce such modes to simple lumped element acoustical networks which can readily be enlarged to include other acoustical elements. This intuitive approach, though approximate and limited in scope, is simple and can yield valuable insights into the behaviour ofthe system (1).

2. CAVITY RESONANCE IN THE VIOLIN

These ideas can be applied to the acoustics of the violin with particular reference to the primary longitudinal air mode A1 which can be compared with half-wave resonance in a simple rectangular cavity. Such a resonator can be represented by an acoustical network composed of two capacitances and an inertance whose values can be chosen to endow the network with the appropriate impedance characteristics and resonance frequency. Similarly, the upper and lower portions of the violin cavity can be represented by acoustical capacitances coupled by an inertance choosing network values that are appropriate for the A1 mode. Other inertances can then be added to represent the f-hole system taking into account the asymmetrical interaction between the system and the air cavity. The result is a six-element network which can be reduced to five elements by algebraic transformation. This simple network, with two degrees of freedom, seems to represent rather well the most important air modes in the violin: the Helmholtz mode A0 at approximately 290 Hz and the A1 mode at approximately 500 Hz.

According to this network, when the violin is at resonance in the A0 mode, the acoustic pressure in the upper volume is appreciably greater than the pressure in the lower volume. This finding has been confirmed by recent experimental work which shows that the pressure ratio is, in fact, about 1.3. Evidently, the Helmholtz mode is not quite so simple as one might suppose.

3. VIOLIN WITH RIB HOLES

Carleen Hutchins has described and demonstrated an experimental violin with acoustical characteristics that can be modified by opening varying numbers of holes in the ribs. This instrument,"Le Gruyere",has 65 such holes 5.5 mm in diameter evenly distributed around the ribs of the instrument with a matching set of corks to close the holes when not in use. Resistive plugs are also available to provide controlled acoustical damping as well as inertance in the open holes (2, 3, 4).

The five-element network representing the violin cavity and the f-hole system can readily be extended to include representation of open rib holes with and without damping. It is only necessary to add additional branches each consisting of an inertance in series with a resistance. In practice, two such branches, representing the collections of rib holes around the upper and lower volumes, are generally sufficient. The acoustical characteristics of the modified instrument can readily be calculated in terms of the acoustic impedances presented to the violin plates and the resonance frequencies and Q factors of the A0 and A1 modes. It is also possible to compare the volume velocity passing through the rib holes with that associated with the f-hole system. While no allowance can yet be made for plate vibrations, the calculated resonance frequencies and Q factors appear to be in good agreement with the available data for the experimental violin.

4. REFERENCES

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