EFFECT OF THE BULKHEAD FIXING ON THE NOISE INSIDE THE AIRPLANE CABIN

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1. DESCRIPTION OF THE PROBLEM

This paper describes one step of a research program undertaken by the authors to investigate the cabin noise of airplanes (more specifically the Challenger 601-3A made by Canadair). It focuses on the effect of fixing conditions of the Rear Pressure Bulkhead (RPB) on the internal cabin noise. The idealized modal simulating the problem is the radiation of sound from point-driven circular plates into a hard-walled cylindrical enclosure.

Two issues motivated this work. Firstly, for Challenger configuration, preliminary testings on the plane revealed that mechanical excitation is one of the main noise sources. The engines are attached through a beam-like structure to the rear part of the airplane body where the RPB is mounted. Therefore, the RPB which is a circular plate-like structure, may be a strong sound radiator. A throughout understanding of the effects of the boundary conditions of the RPB can , hopefully, help the engineer to reduce the cavity noise. Secondly, the present work is intended to deepen the existing knowledge regarding the general structure-cavity analysis. In fact the literature clearly showed a lack of general formulation and understanding of the boundary conditions effects on the induced cavity sound field.

2. OUTLINE OF THE MODEL AND THE THEORY

The model used for this study is a circular plate backed by a circular cylindrical cavity. The plate is driven by an external point-force and is elastically supported by rational and translational springs along its edge. With this model, both classical boundary conditions and intermediate cases can be easily simulated by making different combinations of the elastic constants of the spring. A variational formulation associated with a Rayleigh-Ritz approach is used in the analysis of the plate by choosing simple polynomials as trial functions. For the cavity, the hard-walled cavity modes are used as a decomposition basis of the sound pressure and also for obtaining the cavity Green's function. The resulting couplings equations, in which full interactions between the structure vibration and the internal cavity pressure field are taken into account, are then solved. Details about the formulation are available in the references given.

3. PRINCIPAL FINDINGS

1). In the theory formulated above, the plate-cavity coupled system is described in terms of the natural modes of its two uncoupled subsystems: the in vacuo plate and the acoustically hard-walled cavity. It is shown that the normal modes of the coupled system can be divided into three groups: plate-controlled modes, cavity-controlled modes and well-coupled modes, depending on whether the modes are dominated by plate vibration, cavity sound field or both. In particular the concept of so-called "pumping mode " of the free plate is put forward.

2). Taking a simple-supported plate and a free plate, both being driven by a point force, it is illustrated that the overall vibration levels of the two plates are not much affected by boundary conditions of the plates. However, except at very low frequencies, the free plate radiates much less than a simply supported one. The nuance occurs at the low frequency range, where the free plate gives a stronger sound field than a simply-supported one. This is due to the previously named pumping mode .

3). It is shown that the translational stiffness of the contour supports is a key factor in the radiation behavior of the plates into the cavity. The concept of "Radiation Efficiency into Cavity"(REC) is defined as the ratio between the acoustic energy in the cavity to the kinetic energy of the plate. This parameter represents the radiation capacity of each structural mode into the cavity.

4).Using this concept, this observed phenomenon is shown to be due to the low radiation capacity of the flexural modes of the free plates. This observation is consistent with previous one made for the far-field sound radiation from the baffled plates except that the piston motion, which is the main radiator for the free plate, is no longer true in cavity configuration. This is mainly because the flexural modes, which may generate evanescent waves in far-field radiation case, become significant contributors to the sound field within an enclosure.

5). Elastical supports of the plates are investigated, showing two interesting phenomena: Firstly, in comparison with the free cases, a limiting frequency seems to exist for each elastical support, above which the plate behaves roughly like a free plate. indicating therefore a significant reduction in induced sound pressure. Secondly, in the frequency range below this value, a softer support does not always guarantee a sound reduction. The reason is that different supporting conditions modify the structural modes, the consequence of which can further change the modal structural-cavity coupling. As a result, in some frequency ranges, the cavity sound pressure may be amplified. Combining these two observations, one concludes that the stiffer the support is, the higher is this limiting frequency and, consequently, the higher is the frequency range where the beneficial effect is expected.

6). Using the model, a prediction is made for a 1/4 scale model of the airplane mentioned at the beginning of the paper. The cabin is faithfully scaled in every respects, Whereas the rear pressure bulkhead is simulated by a 3 mm thick plate. Fig.1 illustrates the cabin noise level in one-third octave band radiated by bulkheads with three different supports in translation. Three stiffnesses chosen are respectively infinite, $100K_p$ and $1000K_p$. K_p is the aerostatic stiffness of the cavity which one can calculate easily. It is concluded that a softer translational support of this bulkhead improves significantly the cabin noise.

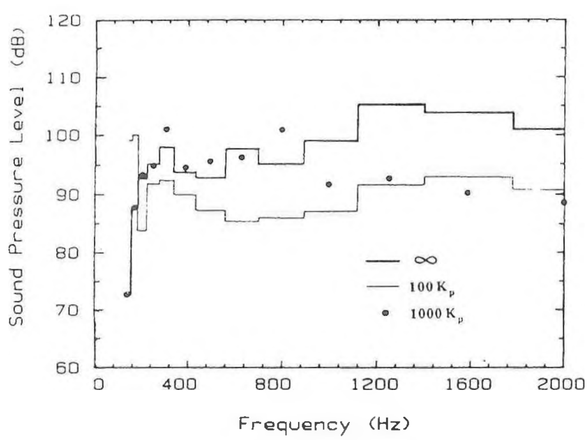

Fig. 1. Sound pressure level inside the cabin of a 1/4 scaled airplane model. Three fixing conditions of the RPB are considered

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