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ACTIVE VIBRATION CONTROL OF THE ACOUSTIC RADIATION OF A HONEYCOMB FLAT PANEL

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1. INTRODUCTION

The paper deals with a study realized as part of the BRITE RHINO project and concerns the feasibility of an active control procedure applied to the internal noise of a helicopter. The main noise is produced by the gearbox at discrete frequencies in medium and high frequency range. The analyze of acoustic measurements in the Dauphin helicopter cabin shows frequency spectra with peaks whose the magnitude is much higher than the random noise (about 10 to 30 dB) [1].The more noisy zone is situed near the back roof (mechanical deck). The use of composite structures in aeronautic domain often leads towards a degradation of the internal acoustic comfort because of their vibroacoustic behaviour. So, the reduction of the noise level can consist, not only on optimizing the characteristics of the components, but also on using an active control procedure. A lot of theoretical and experimental works have proved the interest to control the radiation of homogeneous panels using vibration actuators like shakers or piezo patches on the structure and microphones like sensors [2 to 5]. So, we are interested in the feasibility of an active noise control procedure to reduce the radiation of a thick sandwich orthotropical panel, representative structure of a helicopter ceiling, excited by a shaker (primary source). After a presentation of the experimental set-up and the primary field, the results of the active control procedure are presented for different frequencies and for 2 types of control actuators (mini shakers and piezo patches). Simulations, done outside BRITE RHINO, are also presented.

2. EXPERIMENTAL SET-UP

The tested structure is a plane panel made of a Nomex honeycomb placed between two orthotropic fiber glass laminates. It is clamped in an aperture (1,2 X 1,5 m^2) separating two soundproofing rooms. The primary shaker is pasted with cyanolit in the middle of the panel. The PCE 5 piezo patches of 30 X 30 X 0,5 mm^3 in size are supplied by amplifiers of maximum output 200 Volt. The pressure is measured, before and after the control procedure, at 5 microphones regularly spaced of 0,3 m and located at 1 m away from the panel on a horizontal line. An L.M.S algorithm [6] minimizes the pressure radiated by the panel at some located sensors (error sensors). A sinus generator represents the reference signal.

3. PRIMARY CHARACTERISTICS

To know the vibration and acoustic behaviour of the panel, a modal analyzis has been carried out on 0-1600 Hz frequency range. We have identified 23 modes between 66 and 908 Hz with a decreasing damping of 5 to 1 %. The modal model, extracted from the modal analyzis, does not take enough modes in account to allow simulations. So, a theoretical model is implemented. The formulation is adapted with clamped plane panels, made of orthotropical laminates and excited by point forces. The displacement field, identical to that introduced by Guyader [7] for simply supported panels, points out membrane, bending and shear effects with the continuity of displacements and shear stresses. The mechanical characteristics used in the model come from measurements carried out on reference beams in low frequency, and not on the tested panels. We obtain, after a slight adjustment, a discrepancy of about 3 % for the resonance frequencies. The model brings to the fore 80 modes in the experimented frequency band. The loss factors of the layers have been estimated from transfer functions measured between the primary force and accelerometers. A simulated primary pressure field, using a free-space Green's function, has been compared with a measured field as 1 m. We have noticed differences relative to the symmetric theoretical field. This can be explained by the boundary effects introduced by the mounting of the panel and by the configuration of the receiving soundproofing room. Nevertheless, the model can be used to understand the phenomena produced by the excitation on the structure.

4. ACTIVE CONTROL PROCEDURE

During the different periods of active control experiments, the tests have been carried out for many excitations and sensors configurations. Only some cases are presented below. We consider the mode (i,j) with i the number of anti-nodes along the horizontal axis and j along the vertical axes.

At 282 hz, the theoretical primary pressure field at 1 m away from the panel is mainly composed of the propagation of (3,1) mode, the other contributions coming from the (1,1) and (1,3) modes. At 615 Hz, many modes influence the field. The more energetic are the (5,1) and (1,7) modes. In the high frequency band, in our case at 1158 Hz, the modal density introduces a complex primary field, with modes of high orders (ie: order 9).

The mini-shakers lead to an increasing of mass due to the mobil mass and the rod on the panel (about 50-80 g). This can noticeably modify the behaviour of the light structure by decreasing the resonance frequencies. The theoretical model has regard for this point with the hypothesis that the modal shapes remain unchanged.

In the case of an active control procedure with mini-shakers (table), we notice that it is possible to obtain high reduction of the level globally on the 5 sensors even for complex modes and a small number of actuators (2 or 3).The reductions reach 10 to 19,9 dB. If the location of actuators is accurately chosen, the number of error sensors has not very influence on the result (ie: minimization at 615 Hz with 2 mini-shakers). So, at 682 Hz, a simulation of the reduction in a plane (1,2 X 1,5 m^2 in size) has shown a minimization on the 5 sensors of about 15,3 dB and globally about 7 dB. We have noticed an increasing of the pressure level in some limited zones but without reaching the maxima of the primary field. The homogeneity of the field after active control procedure becomes more and more difficult to realize with the increase of modal density. The minimized area decreases in size. So, the theoretical minimization at 1158 Hz reachs 8 dB for the 5 error locations but produces a global increase of 2.4 dB (surface : 1,2 X 1,5 m^2) .

In the case of piezo patches as actuators (table), because of their lower efficiency, the primary excitation level has been reduced. So, the primary field to minimize is lower (about 6 to 10 dB according to the frequencies). At 282 Hz, two patches are pasted in the same configuration than the mini-shakers. Because of a problem of gluing, the performance of a patch is reduced. That modifies the pressure field after the active control procedure (reduction of 13,3 dB instead of 15,7 dB in the case of mini-shakers). Moreover, it turns out that the used patches have a non linear behaviour above 175 volts for 10 mA, limit which is quickly obtained. So, the quality of location becomes essential to assure a good efficiency.

5. CONCLUSION

This study has shown the feasability of an active control procedure led on a panel representative of a helicopter ceiling structure. The results show noticeable reductions of pressure level even for rather high modal densities. The number of actuators and error sensors remains low and allows to look to future developments for industrial applications.

References

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Configuration	**sensor number**					
282 Hz (2 mini-shakers)	**1**	**2**	**3**	**4**	**5**	**global**
primary pressure (dB)	76	83,5	85,1	81	75	/
reduction (dB) at sensors 1,3,5	-4,1	-16,7	-22,6	-18,6	-22,3	**-14,9**
reduction (dB) at sensors 1,2,3,4,5	-4,8	-22,7	-20,7	-18,4	-15,5	**-15,7**
615 Hz (2 mini-shakers)	**1**	**2**	**3**	**4**	**5**	**global**
primary pressure (dB)	73,7	65,8	86,4	71,4	77,4	/
reduction (dB) at sensors 2,3	-8	-43	-59,7	-11,5	-18,7	**-19,9**
reduction (dB) at sensors 1,2,3,4,5	-7,1	-14,6	-34,9	-12,1	-24,6	**-19,6**
1158 Hz (3 mini-shakers)	**1**	**2**	**3**	**4**	**5**	**global**
primary pressure (dB)	85,1	75,2	85,3	81,9	84,5	
reduction (dB) at sensors 2,3,5	-6,6	-25	-20,6	-6,1	-37,6	**-10**
reduction (dB) at sensors 1,2,3,4,5	-8,8	-10,1	-14,2	-7,5	-41,1	**-11,2**
282 Hz (2 piezo patches)	**1**	**2**	**3**	**4**	**5**	**global**
primary pressure (dB)	72,4	77,1	78,7	74,7	68,6	/
reduction (dB) at sensors 1,3,5	-8	-21	-32,3	-9,4	0,7	**-10,8**
reduction (dB) at sensors 1,2,3,4,5	-6,7	-29,8	-23,4	-19,3	-2,7	**-13,3**

Results of minimization with active control procedure

Table