EXPERIMENTAL INVESTIGATION OF ACOUSTIC AND VIBROACOUSTIC CHARACTERISTICS OF COMPOSITE PANELS

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The experimental investigation results related to determining the acoustic and vibroacoustic characteristics of multilayer composite panels of various height installed in an aperture between two reverberant chambers are presented. Four panels made of carbon fiber reinforced plastics (CFRP) with number of layers 5, 9, 12 and 34 are investigated. Sound insulation and loss factors of panels are defined at various variants of their covering by damping materials.

1. Introduction

Last years in aircraft engineering obvious tendencies of using the designs executed from composite materials are observed. These designs considerably differ from metal ones not only by their elastic, inertial and dissipative characteristics, but also by essential anisotropy. The wide experience of the work which have been saved up in TsAGI at carrying out of researches with classical aviation designs [1-3], can be effectively used at carrying out of researches with modern designs from composite materials. In our acoustic and quiet aeroacoustic installations there is a possibility of carrying out of extensive assortment of experimental researches by determination vibro-acoustic and dynamic characteristics of the panels executed from composite materials: determination of sound transmission losses; determination of sound absorbing structures and materials characteristics; determination of influence of exciting fields structure on vibro-acoustic characteristics of panels, compartments and aircraft models; carrying out of parametrical tests by definition of influence of this or that parameter of a design on it vibro-acoustic and dynamic characteristics with development of recommendations about their optimization, etc. Our experience allows us to optimize designs taking into account effects of influence of space-time structure of aeroacoustic fields on an external surface of the plane or other kinds of high-speed transport – trains, cars, etc.

In this paper the experimental investigation results related to determining the sound insulation and vibroacoustic characteristics of multilayer composite panels of various height made of composite materials based on carbon fabric are presented. The estimate of efficiency of several variants of vibroabsorbing covers is obtained at excitation of a test panels by a diffuse sound field and an electrodynamics shaker, in certain extent modeling excitation of an aircraft skin by an acoustical loading from engines and a pressure fluctuations field of a turbulent boundary layer.

2. Experimental setup

The experimental research was carried out in the reverberation chambers of the acoustic stand AC-11. The stand is consists of three adjacent acoustic chambers: one anechoic chamber (AC) of 750m^3 volume and two reverberation chambers (RC1 and RC2) of 210m^3 and 220m^3 in volume. Three chambers are consecutively connected with the use of two apertures for setting test panels with dimensions 2.2x1.5m or 1.5x1.5m.

The internal surfaces of walls, floor and ceiling of reverberation chambers are executed in the form of planes, not parallel each other. The chamber walls are manufactured of monolithic reinforced concrete of 0.5m in thickness. To prevent the structure interference, the chambers are not rigidly bound to each other and to building structure. They have separate foundations and are mounted on special rubber cushions. The given feature of a construction considerably attenuates structural transfer of noise between the adjacent chambers. It leads to essential increase of dynamic range at measurements of sound insulation which varies within the limits of 45-83dB, according to the frequency.

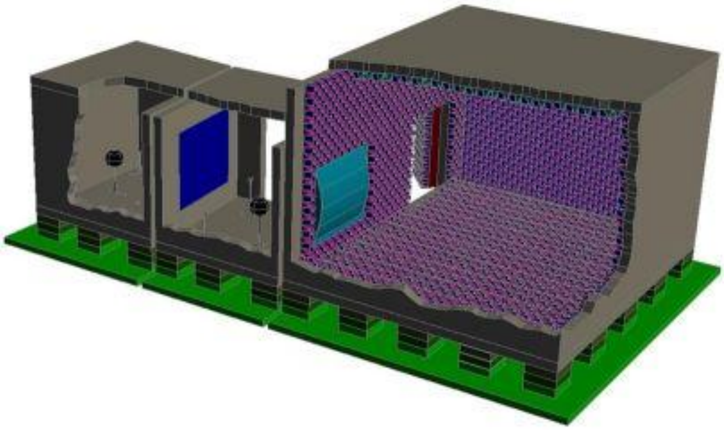

Figure 1: The scheme of acoustic stand AC-11.

In experimental researches four plain composite panels were used. These are the multilayered panels made of fabric CC600 from high-strength carbon fibre T300. Dimensions of panels are 1.7x1.7м, surface mass of one layer is 0.6 kg/m^2, a thickness of a layer is 0.6 mm. Parameters of panels are presented in Table 1.

Table 1: Parameters of composite panels (CP).

№	Name	Weight, kg	Height, mm	Number of layers	Surface mass kg/m^2
1	CP-01	12	~3.6	5	4.15
2	CP-02	20.2	~4.5	9	7.0
3	CP-03	27.5	~7.0	12	9.5
4	CP-04	81.0	~18	34	28.0

For the purposes of evaluating the effectiveness of damping covering VTP-1V vibroabsorbing materials made from thermoelastoplastic polyurethane with the thicknesses of 0.5, 1.0 and 1.5 mm and surface masses of 0.6, 1.1, 1.7 kg/m^2 have been used. Facing was made by strips of a material in width of 320 mm on all area of the panel.

3. Technique for making measurements

At the paper a sound insulation radiation loss factor and total loss factor of the panel at various variants of its covering are defined.

3.1 Technique for making acoustic measurements

The estimation of sound insulation was carried out with use of standard procedure of its determining by a method of reverberation chambers. In tests following instrumentations, auxiliaries and the software were used:

1. Microphones of diffuse field (type B&K 4942), 10 pieces;
2. Sound sources (Yamaha, type DSR115), 4 pieces;
3. Data acquisition-processing system (type B&K 3560C);
4. Software PULSE (type B&K 7700-N10).

Control system diagram at sound insulation measurements is shown in Fig.2

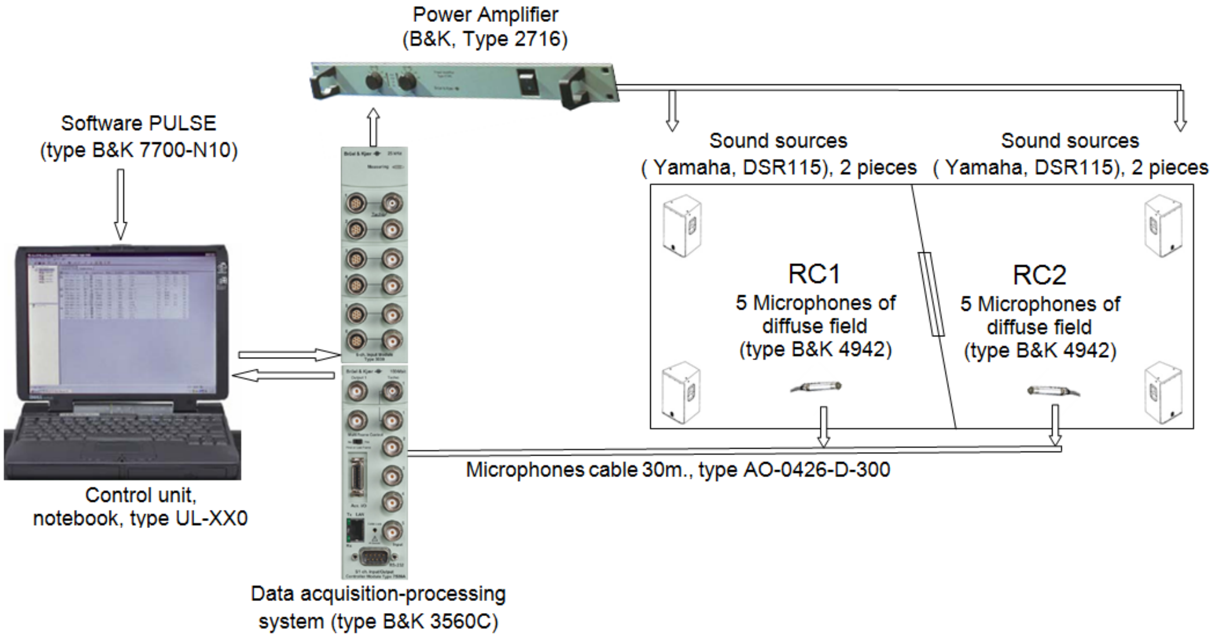

Figure 2: Control system diagram at sound insulation measurements.

Briefly the essence of procedure of sound insulation measurement of an aircraft panel is reduced to the following. The tested panel is established in an opening between reverberation chambers. Five microphones and two sound sources are placed in chamber RC1 and RC2. Definition of sound insulation value of a panel is carried out in two stages. At first the difference of average sound pressure levels between chambers RC1 and RC2 is determined. For this purpose in chamber RC1 a diffuse sound field is generated in interesting frequency bands. In chambers RC1 and RC2 average sound pressure levels and their difference are determined. After that the reverberation time is determined in RC2 in interesting frequency bands. As a result the value of sound insulation R for panel in interesting frequency bands is obtained.

$$R = \Delta L + 10\lg\left(ST/\left(0.16V_2\right)\right). \quad (1)$$

Here ΔL is the difference of average levels between RC1 and RC2, S is a radiating area, T is a reverberation time in RC2, V_2 is a volume of RC2

As a result of measurements values of sound insulation of a panel were obtained in 1/3-octave frequency bands: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000, 6300, 8000, 10000 Hz.

The effect ΔR of a vibro-absorbing material was evaluated as a difference of sound insulation of a panel with and without covering.

3.2 Technique for making vibro-acoustic measurements

At vibro-acoustic measurings the same soft-hardware complex was used, as at conducting of acoustical measurements. In addition to it the following equipment has been involved:

5. Vibration Exciter (B&K, Type 4809);
6. Power Amplifier for exciter (B&K, Type 2716);
7. Impedance Head (B&K, Type 8001);
8. Accelerometer (PCB, Type 352B10).

For conducting of vibro-acoustic tests the exciter suspension in RC1 has been made, which is shown in Fig.3. A suspension feature is the capability of excitation of any point of a panel. At the given tests the panel was excited in a point with co-ordinates (0.943; 0.63) concerning the left lower corner of a panel by "white" noise in octave frequency bands.

On the vibration exciter the impedance head has been established. With its help signals from force and acceleration sensors were fixed.

Figure 3: Vibration exciter on a suspension (view from side of RC1).

The ratio of radiation loss factors to total loss factor is measured at point excitation of a panel skin by the exciter and estimated from the relation

$$\eta_r / \eta_t = W_d / W_{in} \,, \qquad (2)$$

where W_d is the acoustical power absorbed by walls of the reverberation chamber of a low level (RC2), W_{in} is the power acting on a panel from the vibration exciter.

W_d is estimated from the relation

$$W_d = \omega\eta_2 < p^2 > V_2/\rho c^2 \quad , \tag{3}$$

where $\omega = 2\pi f$ is a circular frequency, $\eta_2 = 2.2/fT$, T is a reverberation time in RC2, $< p^2 >$ is a square of sound pressure averaged in a volume of RC2, V_2 is a volume of RC2. ρ, c are the parameters of air medium in RC2.

W_{in} is measured and controlled during tests by means of an impedance head. For its estimation the following ratio is used:

$$W_{in} = -\frac{1}{\omega} Im\, G_{aF}(\omega), \tag{4}$$

where $G_{aF}(\omega)$ is a cross spectrum of force and acceleration in an excitation point.

The radiation loss factors and total loss factor are estimated from the relations:

$$\eta_r = W_d/W_v, \tag{5}$$

$$\eta_t = W_{in}/W_v. \tag{6}$$

W_{in} is the power of panel oscillations:

$$W_v = \omega E_v \quad , \tag{7}$$

where

$$E_v = M_p < a^2 >/\omega^2 \quad . \tag{8}$$

M_p is a panel mass; $< a^2 >$ is a mean square value of the acceleration, which was estimated according to measurements in 8 observation points.

4. Results of experimental investigations

In Fig. 4 the measured values of sound insulation of four bare composite panels are resulted at their excitation by a diffuse sound field.

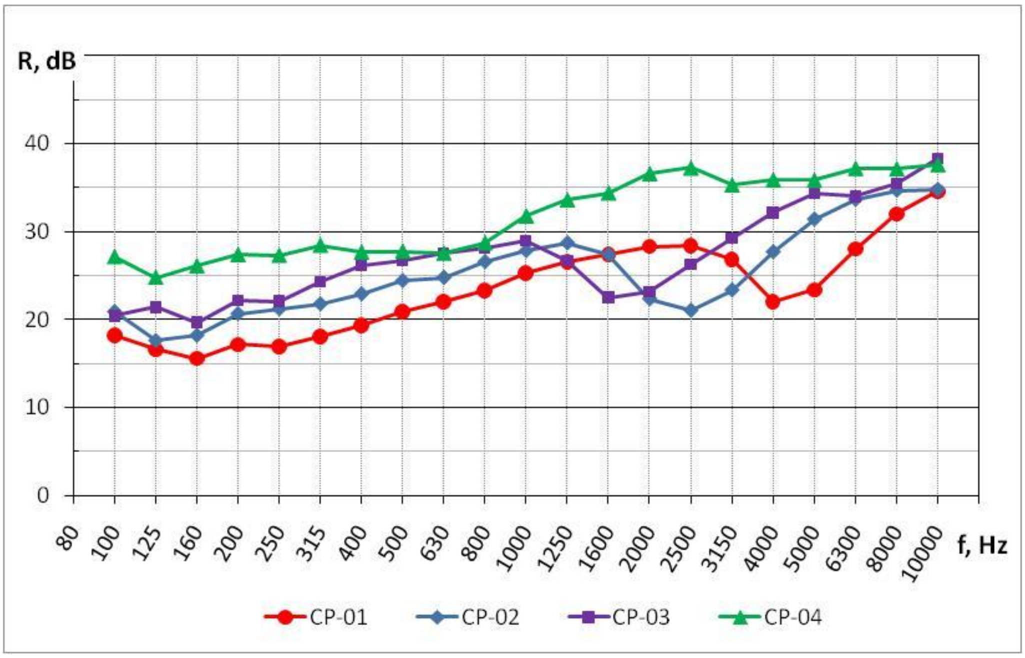

Figure 4: Sound insulation of four bare composite panels.

In Fig. 5 for three bare panels an estimation of the ratio of radiation loss factors η_r to total loss factor η_t are presented.

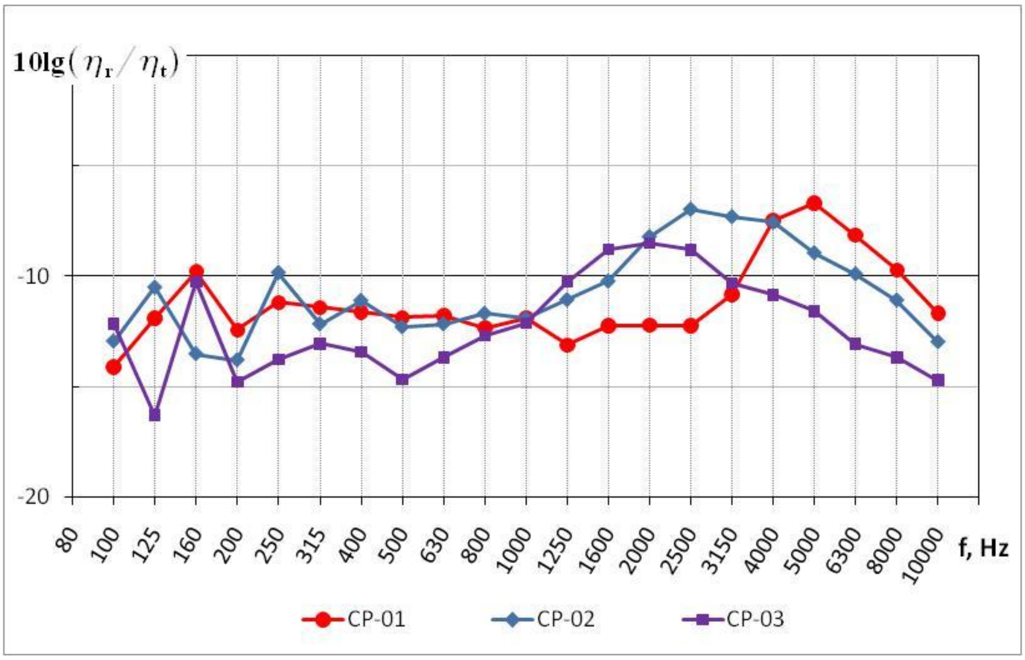

Figure 5: Ratio of radiation loss factors to total loss factor for three bare panels.

In Fig. 6 it is shown, how a covering of a panel CP-01 by vibroabsorbing material VTP-1V of various thickness influence on its sound insulation. Here are presented five curves corresponding to sound insulation of five variants of panel: without of covering and with covering by material 0.5, 1.0, 1.5 mm in thickness. Covering was glued from side of RC1. Besides here are presented a variant with sum thickness of covering 2.5 mm. This is the case of double-side covering: from side of RC1 a material of 1.0 mm was glued and from RC2 – 1.5 mm.

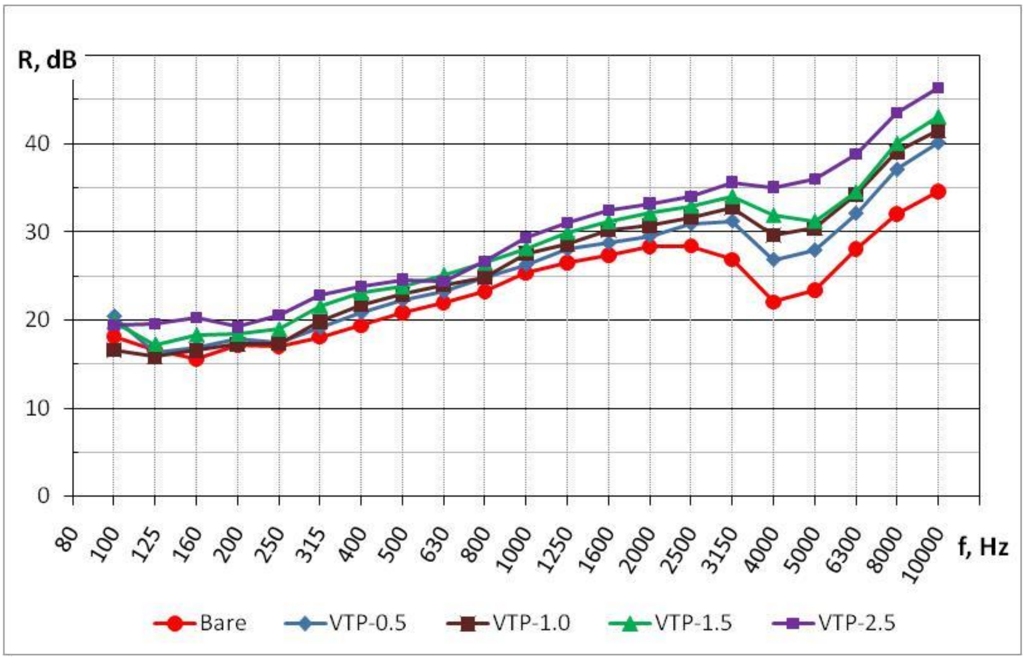

Figure 6: Sound insulation of the panel CP-01 without and with covering of various thickness.

Influence of covering thickness on ratio of radiation loss factor to total loss factor for composite panel CP-01 is shown in Fig. 7. In Fig. 8 total loss factors for the same variants of panel CP-01 are shown.

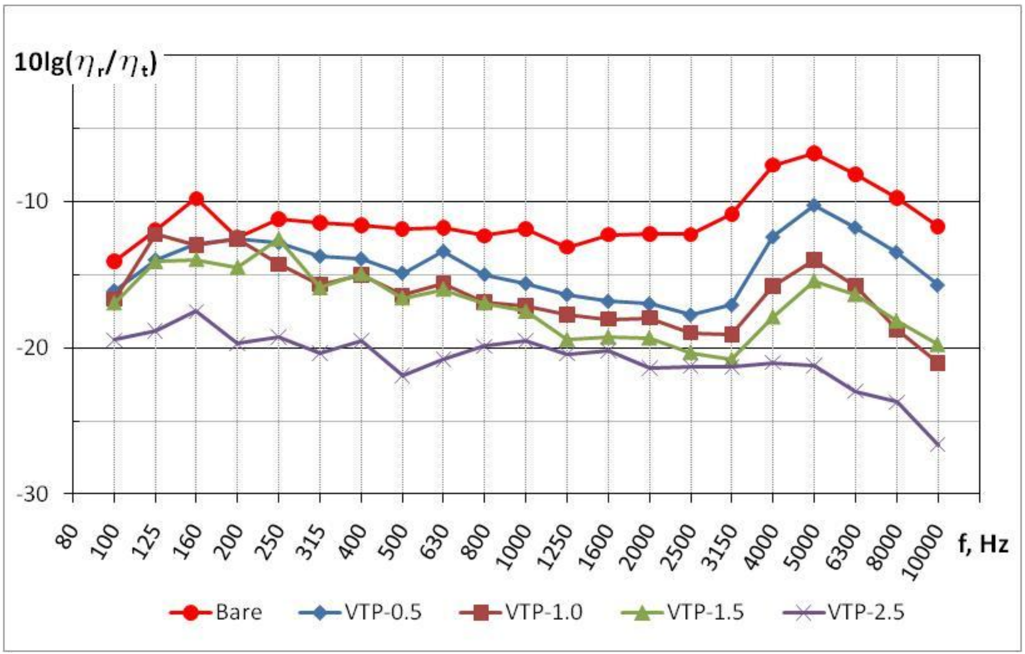

Figure 7: Ratio of radiation loss factor to total loss factor of the panel CP-01 without and with covering.

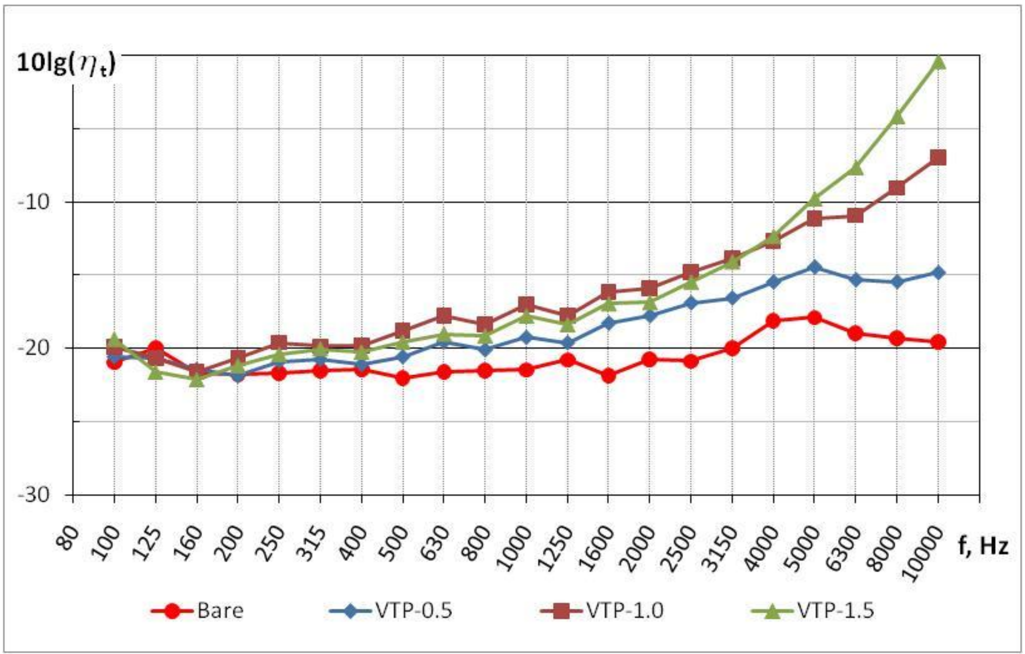

Figure 8: Total loss factor of the panel CP-01 without and with covering of various thickness.

5. Conclusions

Values of sound insulation and vibro-acoustic characteristics of composite multilayered panels of a various thickness with different number of layers are experimentally defined. Tests are spent both with bare panels, and with the panels covered by vibroabsorbing material VTP-1V of a various thickness.

Values of radiation loss factor and total factor of bare and covered panels are received.

Effects of influence of vibroabsorbing coverings on sound insulation and vibro-acoustic characteristics of panels are defined.

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