LOW-FREQUENCY VIBROISOLATION PROVIDING FOR MODERN AIRCRAFT WITH HIGH BY-PASS RATIO ENGINES

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At modern aircraft in accordance with new aircraft external noise norms (ICAO, Ch. IV) a high- and extra-high by-pass ratio engines installed. It was shown recently that such engines strongly interact with airframe and engine mounting. It lead to aircraft vibroacoustical spectrum broadening with shift to infrasound range [1]. At modern aircraft a probable noise level in cabin can achieve more than 100 dB in infrasound range. Recently Boeing aircraft published a new results of investigations at QTD-2 (Boeing-777 with GE-90-115B engines with by-pass ratio equal to 8). It was shown that infrasound components exceed a medium level over 30-40 dB [2].

Thus, a modern aircraft external noise reduction activities (and their obvious success) lead to a serious problem – a low-frequency (including infrasound) noise and vibration presence in aircraft cabin. A seriousness of this problem caused by numerous research [3-5] results which determine that infrasound is a strong negative influence factor for human organism. At long exposition and intensive impact infrasound can lead to irreversible pathological alterations in internal organs tissues. These circumstances put a question not only about passengers and crew health threat but also about flight safety for modern aviation. A situation intensified by absence of a unified norms on infrasound impact on human organism. And aviation norms functioning now didn’t correspond to new sanitary norms based on modern medical investigations.

So, a problems described lead to necessity of adequate engineering solutions for modern aircraft cabin protection from low-frequency vibroacoustical impact. Note, that a low-frequency vibroisolation problem doesn’t fully solved now. And infrasound range is a more difficult case. Particularly it caused by obsolescence of traditionally used computational models (especially in low-frequency range) [6].

Recently a dynamical model of a system «engine-attachment-airframe» was developed [7] as a multi-coupled system with taking into account a real dynamical characteristics of partial elements. Using this model an investigated system model was significantly specified in low-frequency range. Also a set of basic requirements to vibroprotection system was formulated and a possible solution

Fig. 1. Elastic characteristic (force-deflection) of nonlinear elastic element. Force normed on static one.

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of low-frequency vibroisolation problem was proposed [8].

It was proposed to use a nonlinear elastic elements based on initially deformed Euler beam for low-frequency vibroisolation [9]. Such system have a nonlinear elastic characteristic with quasi-zero slope range at large static force (fig. 1). It allow to supply a vibroisolation in wide range of dynamical force (~20% of static force) and narrow deflection range (1-3 mm at static force equal to 12 kN). A computational model for such system was constructed based on Düffing-type equation with nonlinear dissipation and bracket oscillation taking into account:

$$\ddot{x} + f_{ds}(t) + \alpha \dot{x}^3 + \beta \dot{x}(1 + a \sin \Omega t) = f(t).$$

A two models of nonlinear dissipation used – with cubic nonlinearity and with nonlinearity of \(x\dot{x}\)-type:

$$f_{ds}(t) = 2\alpha \dot{x}(1 + \delta_1 \dot{x}^2),$$

$$f_{ds}(t) = 2\alpha \dot{x}(1 + \delta_1 x).$$

It’s shown at fig. 2 an example of oscillations obtained with constructed computational model. It’s shown a sufficient oscillation amplitude decreasing in case of nonlinear vibroisolation element application.

![Fig. 2. A temporal realization of oscillations in case of linear (curve 1) and nonlinear (curve 2) vibroisolation mounts.](image)

![Fig. 3. A special rig for experimental testing.](image)
Proposed device was experimentally tested at special rig (fig. 3). It include a system which imitates a real flow (1-2), attachment system and engine flow inlet/exhaust system (3-6), engine (7) and measurement devices. A flow-generation system (1) creates a quazi-homogeneous air flow which propagates through oscillation device (2) which modulate it by adjusted oscillations. Then flow travels to engine air-inlet (3). Engine (7) attached through mounting (4) to special beam (5) installed on massive fixed platform. A flow after engine taked off through special device (6). In mounting (4) a nonlinear elastic elements installed (fig. 4). A dynamical force level in engine mounting was registered through experiment.

![Engine Mounting](image)

**Fig. 4.** An engine mounting with nonlinear elastic element.

At fig. 5 and 6 an experimental results shown. It’s clear from fig. 5 that tested mounting have a self resonanse at 4 Hz and effectively decrease oscillations in frequency range beyond 6 Hz in both of vertical (curve 1) and longitudinal (curve 2) mountings. At fig. 6 an experimentally measured elastic characteristic of vibroi solation block shown (curve 1), rotor component of dynamical force (curve 2) and low-frequency component of dynamical force (curve 3).

![Amplitude-frequency characteristic of proposed mounting](image)

**Fig. 5.** Amplitude-frequency characteristic of proposed mounting.
Section I

Fig. 6. An experimental testing results.

So, in this work a problem of low-frequency vibroisolation for modern aircraft with high-by-pass ratio engines described. An approach for this problem solution described. For this approach a computational model developed for low-frequency vibroisolation mounting and computational and experimental results considered. After experimental testing it was shown that proposed mounting supply a dynamical force level reduction on 12-14 dB in frequency range 6-80 Hz.

REFERENCES