DYNAMICS AND VIBRATION OF NEW GENERATION AVIATION ENGINES

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ABSTRACT
Strategic development of new generation airplanes goes in a direction of the further decrease in noise, emissions and increase of fuel efficiency, where the defining role belongs to engines. The rapid development of engine allows re-engineering of the most popular narrow-fuselage airplanes (type B737 and A320), occupying 80% of the park-haul aircraft and aircrafts of another popular class - B777 and A330.

Keywords: Aviation engines, turbofan, noise standards.

INTRODUCTION
The next 10 - 15 years we will have to deal with aircraft equipped with turbofan engines of high bypass ratio (8.5 - 12): Leap-1B, Leap-1A, PD-14, GE9X, TRENT 7000, TRENT 1000 TEN, XWB and family type PW1000G.

Aircraft equipped with these engines, can successfully execute future noise standards in 2017 (Chapter 14), Fig.1, ensure the reduction of harmful emissions and increase of fuel efficiency, but this is accompanied by a significant change of dynamic characteristics and vibration engines.
DISCUSSION AND PERSPECTIVES

The long-term investigations directed to dynamical characteristics definition for engine bodies (different by-pass ratio) and airframe of aircraft allow to significantly specify calculation models of modern aircraft constructions in engine’s rotor frequency range. And it allowed to determine tendency of engine’s dynamical characteristics variation with by-pass ratio increasing. If by-pass ratio is increased up to estimated 8…12 we should expect that the upper boundary of rigid-body-like dynamic behavior of the engine does not exceed 10 Hz.

Within a wide range of rotor frequencies the dynamic behavior of engine body corresponds to the model of elastic-inertial system or to an elastic-dissipative element. It differs substantially from the idealized rigid-body model of aircraft gas turbine engine both by the value of dynamic compliance module and by the type of dynamic behavior. Vibration spectrum of turbofan engines is greatly extended with a shift in the low-frequency range due to low rotor speed fan (especially in the case of the gear). Some harmonics gas duct path (for example, rotating vortex) associated with a certain ratio of the frequency of rotation of the fan, are already in the field of infrasound.

For modern aircraft airframe is characterized by the presence of several dozen natural modes in the low-frequency part of the spectrum. The interaction some of them with the perturbing action of the engine via mounting attachment may lead to the generation of high-level low-frequency noise components in the pressurized cabin. Increased bypass ratio engine not only leads to a considerable increase of acoustic power of the fan, but also a change in the spectrum of noise emitted from the front and rear hemispheres power plant.

Reducing the speed of the shaft and the number of fan blades significantly reduces the frequency of the first harmonic of the fan in the mid-frequency range.

The level of these components is mainly defined by the conditions at the fan inlet (possibility to generate aerodynamic unbalance long fan blades).

All these components will determine the spectrum of power plant dynamic effect transferred via mounting assembly (engine attachments) on airframe structure. The expected level of structural noise (from engine vibration influence) in the cockpit increases significantly in the low-frequency part of the spectrum, which is confirmed by the calculation taking into account real characteristics of the transfer functions and dynamic compliances prototypes of engines and airframes, and measurements on the aircraft - demonstrator QTD2.

With the increase in diameter of the fan blade tips rotate at supersonic speeds, generating a shock wave. Interaction of shock waves with the fan wheel forms a series of discrete components of polyharmonic around the main frequencies of blades (the first and second harmonics), The distance between components of blade frequency are equal to shaft rotation frequency. This phenomenon is called "buzz-saw noise". So the noise emitted from the engine air intakes high bypass ratio in the far field and the direction of the wall of the fuselage consists of multiple tones frequencies, which was also observed in the spectrum of the noise of the front passenger compartment of aircrafts - demonstrators QTD1 and QTD2.

Experience in operating aircraft with engines high bypass ratio shows that the level of low-frequency components structural noise in the cockpit crew may exceed the recommendations of sanitary norms and raise questions about safety, and we expect ahead second (Advance) and third (UltraFan) generations of geared engines and can be «Open Rotor».