Reducing aircraft noise continue to be relevant and form an important part of the overall problems of ensuring environmental safety. Experimental analysis of sound fields generated by an aircraft engine is one of the most important and complex problems of aviation acoustics. The main difficulty is the large number of acoustic modes emitted by the engine. The chief part of energy-efficient acoustic modes is generated by the fan of the engine. The most advanced technique for analyzing sound field generated by the fan is modal analysis in the intake and bypass of the engine. A special mathematical model is being developed in the present paper to optimize modal decomposition technique. The presented model represents a calculation of sound propagation in the engine intake using the Navier-Stokes equations and numerical schemes of high-order accuracy. The test object is a cylindrical intake duct. The entire lower surface inside the duct was used for sound field generation, setting unsteady pressure as a combination of acoustic modes. The modes were registered at the points of the ring array and at gross sections inside the duct that were located at the same distance from the bottom surface. The technique of modes registration at gross sections allows to identify all the modes generated inside the duct, because it uses complete information in the section and real experimental measurements are imitated by measurements at points. This paper presents the calculation of sound propagation in the cylindrical intake. It contains the calculation results with different combinations of modes and there is a comparison of modal decomposition based on points and gross sections measurements. In terms of the presented analysis problems in the experimental modal decomposition have been identified and the ways of their elimination have been outlined.

Keywords: modal analysis, sound propagation, air intake, engine noise.

1. Introduction

At present there are no methods for analyzing modal decomposition of sound field generated by a blade machine, which takes into account all geometric features of the engine flow section. It is necessary to create a mathematical model that allows to make an analysis of the experimental modal noise structure of the engine’s fan stage, and use it to compare calculations with experimental data. The objectives of this work are:
- Modelling of an air intake channel with a mode generator
- Calculation for a set of modes at individual frequencies
- Analysis of the pressure fields in the channel

2. Mathematical model

Nonstationary equations of motion of a viscous ideal gas were used for constructing a model. The test object is a cylindrical intake duct, see Fig. 1. Equations were solved using numerical schemes: the central difference scheme Dispersion Relation Preserving (DRP) and Low dissipation and dispersion Runge Kutta (LDDRK) [1,2] for modeling three-dimensional unsteady turbulent flows in an aircraft engine based on a graphics processing unit (GPU).

![Figure 1: Cylindrical intake duct.](image)

**External boundary**

Unreflecting boundary conditions

\[ P_{ct} = 101325Pa \]

**wall** \( V_x = V_y = V_z = 0 \)

**Sound generator**

Individual acoustic mode with amplitude = 1.

![Figure 2: Calculations results at f=1000 Hz.](image)
Structured computational meshes were used and the time step was selected from the perturbation conditions, so it was determined by the Courant number (CFL), the results for frequency 1000 Hz are shown at Fig. 2.

3. Conclusion

- The analysis of acoustic pressure fields in a special channel for testing modal analysis methods at a frequency of 1000 Hz was performed. The calculations were conducted for modes with different circumferential numbers and radial number 1.
- It was revealed that at low circumferential numbers a single mode with a minimum radial number, specified in the generator cross-section, turns into several radial modes. Moreover, the lower the circumferential mode number, the more radial modes appear as a result of the changeover of the annular channel into the cylindrical. Pressure fields were obtained that can be used for analyzing such features and forming a transition matrix for modal analysis.
- When using modal decomposition methods based on sound field measurements on the channel surface, it is necessary to take into account the redistribution of acoustic energy through the channel due to the complex geometry of the channel.

To identify the modes generated by the blade machine using decomposing into acoustic modes, one must take into account the complex geometry of the channel and use a numerical model of sound propagation in the channel.

For the analysis of propagating modes along the cylindrical (or close to it) part of the channel, an analytical model of propagation can be used.

REFERENCES