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CALCULATION OF THE NOISE CONTOURS OF A CIVIL AVIATION AIRPORT

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***Abstract**: Major issues and statistical data of the noise impact created by air transport, namely civil aviation aircraft, are analyzed. The main methods of reducing aircraft noise are considered. One of the methods of noise control and mitigation near the airports, namely 'noise contour calculations', is proposed for consideration. The description of the calculation method used and the calculation of the noise contours of the civil aviation airport are given. The civil aviation airport of one of the largest cities in Russia was chosen as a subject of research. As a result, maps of noise contours around the airport were obtained and information about the benefits of the data was provided.*

***Keywords:** noise contour, ANP database, airport, noise, sound level*

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1. INTRODUCTION

The noise created by air transport, namely civil aviation aircraft, greatly affects the health of urban residents and over the time its impact can greatly increase. Federal Law of the Russian Federation No. 52 'On the sanitary and epidemiological welfare of the population' [1] prescribes requirements for noise reduction in residential areas near airports and airfields. We can observe that the aircraft fleet is constantly updated; the latest turbojet and turboprop aircraft are appearing on the airlines. According to the company 'Boeing', the number of jet aircraft between 2000 and 2020 has increased from 14,500 units to 33,000. The number of turboprop aircraft during the period of 1990 to 2020 increased from 2,300 units to 7,000 (Fig. 1. The number of jet and turboprop aircraft that have already been produced during the period from 1990 to 2020).

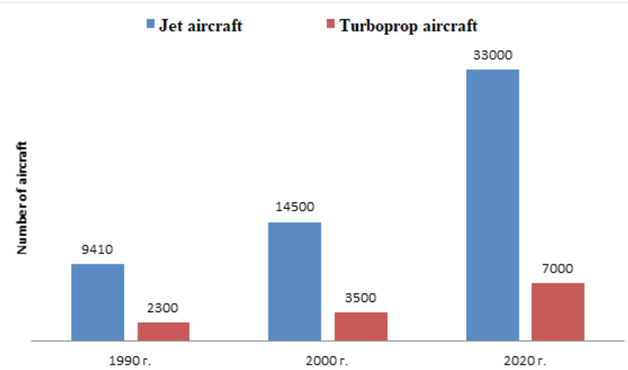

Fig. 1: The number of jet and turboprop aircraft that have already been produced for the period from 1990 to 2020

Passenger traffic and the number of cargo shipments increased significantly (Fig. 2. Passenger traffic volume for the period from 1990 to 2020).

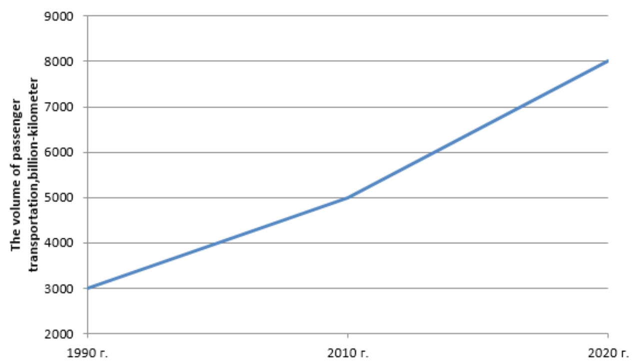

Fig. 2: Passenger traffic volume for the period from 1990 to 2020

Many airfields and airports are under construction, and the existing ones are being reconstructed. It often happens that the CA airports are located in the immediate vicinity of residential buildings, and airways pass over numerous settlements. Aviation noise significantly affects the noise regime of the territory near the airports. The noise level depends on factors, such as the direction of the runway and the aircraft flight paths, intensity of flights during the day, the time of year, the aircraft type, and so on. With the constant operation of airports, the equivalent sound levels (SL) on the residential territory in the daytime reaches 80 dBA, at night-78 dBA, the maximum SL is in the range between 92 and 108 dBA. In some Russian cities, aircraft are significantly in the lead among all noise sources in terms of noise levels and the total area of the noisy territory. A very unpleasant acoustic situation develops for residential areas when the airport is located within the city or in a nearby location from it.

The problem of reducing aircraft noise is closely related to the abundance of factors that affect it. The methods used to reduce noise can be both administrative and constructive in nature.

Main directions and methods of aircraft noise reduction:
- maintaining restrictions on the aircraft operation;
- restrictions on aircraft take-offs and landings;
- using the 'perimeter rule';
- highlighting routes with minimal noise levels;
- limiting the intensity of flights;
- offset of the runway entrance edge;
- installation of AE in the places of engines testing;
- aircraft towing;
- introduction of a fee for deviation from the established routes of the aircraft span;
- development of the sanitary protection zone (SPZ) and normally occupied area projects;
- installation of the noise-proof glazing in the nearby residential areas.

2. DESCRIPTION OF THE CALCULATION METHOD USED

The calculation of the acoustic impact of the civil aviation airport on the adjacent territory was performed using the licensed SoundPLAN software package.

The SoundPLAN software package is an advanced development of the German programmers and noise mitigation specialists and implements the calculation methods adopted as national standards for assessing noise levels in Europe and America.

The SoundPLAN software package implements the calculation methods of the international regulatory documentation, presented in the 'Guide to the recommended method for calculating noise contours around the airports. First edition - 2008' [1].

SoundPLAN software implements the segmentation method recommended in [1]. Segmentation simulation is based on a database on noise and aircraft performance that was created by aircraft manufacturers in collaboration with the authorities responsible for noise certification. The specified international database on Aircraft Noise and Performance (ANP-The Aircraft Noise and Performance) is currently available on the Internet at: http://www.aircraftnoisemodel.org [5]. The ANP database contains performance factors for aircraft and engines, as well as information on the noise-power-distance relationship for a considerable part of the civil aircraft types operated worldwide.

Segmentation is the process by means of which the noise contour model adapts the NPD (Noise Power Distance, noise-power-distance relationship database) data corresponding to an infinite trajectory and the lateral adjustment data in order to calculate the level of noise perceived by the observer generated during an uneven flight path, i.e., the trajectory along which the flight configuration changes. For the purposes of calculating the sound level during a single flight of an aircraft, the flight path is represented as a series of adjacent straight-line segments, each of them can be considered as a finite part of an infinite trajectory, for which the NPD values and lateral adjustments are known. The highest value of the corresponding values for individual segments is taken for the maximum level of this noise event. The time-integrated sound level of the entire noise event is calculated by summing the values of the noise level coming from a sufficient number of segments, i.e. from those that make a significant contribution to the total sound level of a given noise event.

In the context of simulation, a flight path (or trajectory) is a complete description of the aircraft movement in space and time. Time is taken into account through the aircraft speed value. Together with the thrust (or other noise-related power parameter), this is the information that is needed to calculate the generated noise.

The noise-power-distance (NPD) curve data contained in the ANP database determines the level of noise produced by aircraft following idealized horizontal flight paths of infinite length with a constant speed and power mode. To adapt this data to flight paths in the airport area, which are characterized by frequent changes in power and speed, each trajectory is divided into finite straight-line segments. The noise levels generated at each of these segments are then summed to obtain the corresponding parameter at the observation point.

Thus, the calculation method includes the following steps:
- determination of the flight paths based on the path lines, altitude, speed and thrust;
- determination of the sound exposure level based on the ANP and NPD database by means of correcting the data by way of making appropriate corrections;
- construction of noise contours by summing the sound exposure levels at each point of the calculated grid.

3. CALCULATION OF THE AIRPORT NOISE CONTOURS DURING THE PERIOD OF 19.08.2019-19.09.2019 (A MONTH)

The total level of sound exposure at a particular point is calculated by summing up the single exposure levels of all significant aircraft flyover noises, i.e. all flights that affect the total level.

The time-weighted equivalent sound levels, which take into account all the significant perceived sound energy of the aircraft, are determined by the formula:

$$L_{eq,W} = 10lg\left[\frac{t_0}{T_0}\sum_{i=1}^{N} 10^{(L_{E,i}+\Delta_i)/10}\right] + C \qquad (1)$$

Summation is performed for all $\boldsymbol{N}$ noise events for the time period T0. $\boldsymbol{L_{E,i}}$ represents the level of a single sound impact of the i-th noise event. The parameter $\boldsymbol{\Delta_i}$ is a weight coefficient that depends on the time of day (for the day and night periods). $\boldsymbol{\Delta i}$ is a multiplier for the number of flights completed over specific time periods. The constant $\boldsymbol{C}$ is a normalizing constant or seasonal correction.

The total noise level is calculated by adding the noise fractions from all the different aircraft types or categories using different flight routes set for a given airport.

The maximum sound level (L_{max}) is determined using the formula:

$$L_{max} = 10lg\left[\frac{1}{N}\sum_{i=1}^{N} 10^{(L_{max,i})/10}\right] \tag{2}$$

where
N is the number of noise events,
$L_{max.i}$ is the maximum sound level generated by the noise event.

Noise contours are calculated by interpolating between the values of the noise index at the points of a rectangular coordinate grid, and their accuracy depends on the selected interval between the coordinate points (or the size of the cells).

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The calculation of sound levels from a civil aviation airport in the SoundPLAN program is performed according to [1]. The advantage of the simulation methods provided by the SoundPLAN software package is considering the noise reduction during attenuation over an acoustically soft surface, taking into account the influence of terrain, and refining the calculation of noise reduction behind buildings. When estimating the noise levels at the reference points, the program takes into account the cumulative impact from all sources. The result of the simulation is a flat 2-dimensional noise map.

The area is divided into a grid with a certain step that best matches the mapping goals to calculate the noise propagation. After determining the noise levels at the reference grid points, the points with equal sound levels are connected by isolines, resulting in lines of equal sound level on the territory of the city with a certain step. For each protected area, in accordance with its purpose, the maximum permissible noise levels are set, and the excess of permissible noise levels is determined.

When making the noise map of the flight path sections, the entire territory was divided into reference points on a grid with a step of 50 m. After determining the noise levels at the reference points, the points with equal sound levels were connected with isolines, resulting in lines of equal sound level on the territory with a step of 5 dBA, which corresponds to the noise normalization conditions.

The noise contours near the civil aviation airport are given below:

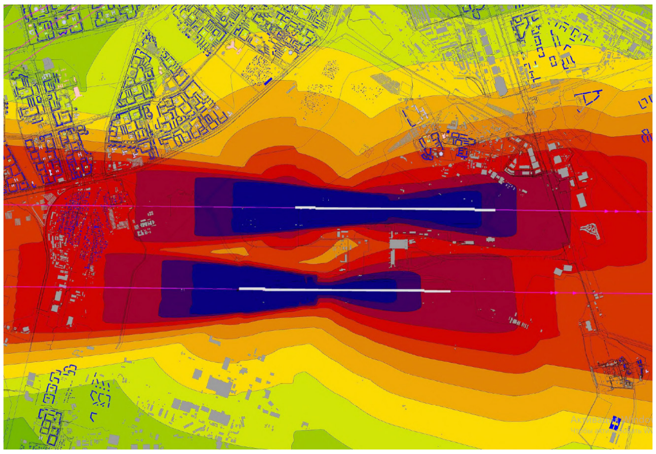

Fig. 3: Noise contours near the civil aviation airport (calculation variant 1 – maximum sound levels)

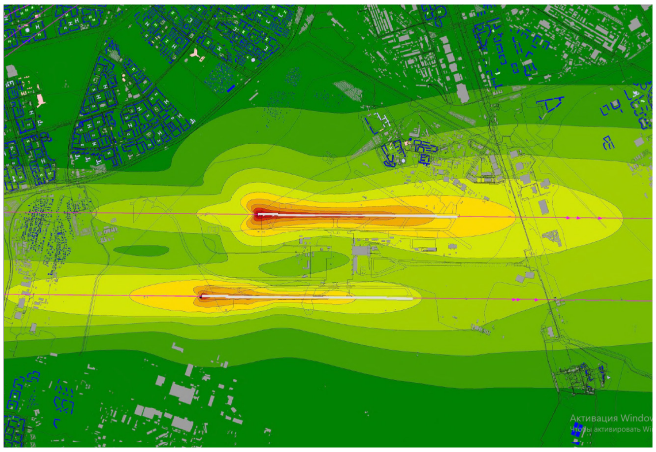

Fig. 4: Noise contours near the civil aviation airport (calculation variant 1-equivalent sound levels in the daytime)

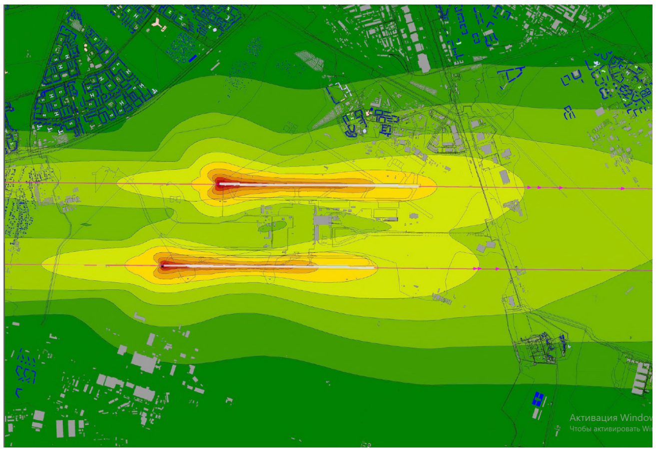

Fig. 5: Noise contours near the civil aviation airport (calculation variant 1-equivalent sound levels at night)

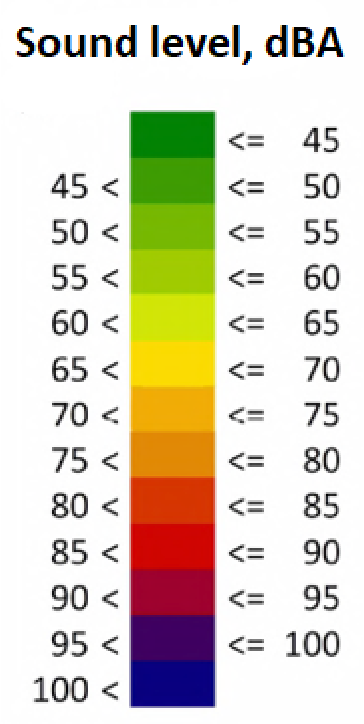

Fig. 6: Colour symbols on the noise contour map

4. CONCLUSION

According to the calculated noise contours, it is possible to assess the compliance of sound levels with the requirements of GOST 22283-2014 [2] and SN 2.2.4/2.1.8.562-96 [4]. GOST 22283-2014 establishes requirements for newly designed residential areas in vicinity of the existing airports and for existing residential areas in vicinity of the newly designed airports. Since the civil aviation airport exists, and the territory adjacent to it is the territory of the existing residential development, it is recommended to perform noise regulation according to [2]. Thus, the permissible levels of the aircraft noise are limited by the contours: for equivalent sound levels of 55 dBA during the day and 45 dBA at night, for maximum sound levels of 70 dBA during the day and 60 dBA at night.

Thus, the noise contour maps used to determine the value of a specific parameter or noise index, the level of impact and the coverage area of the aircraft noise around the airports can help determine the methods used to reduce noise in the residential area around civil aviation airports.

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