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NOISE EMISSION LEVEL VERSUS THE STRUCTURE OF THE AIRCRAFT TURBINE ENGINE

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Abstract

This article presents the problem of noise generated by turbine jet engines. It points out possible directions of noise decrease with particular emphasis upon structural changes within the engines, the task of which is to reduce the noise mission. The example of the modernization is based upon the "bypass" type of one-flow turbine jet engine. The essay contains theoretical basis of calculation of the noise emission level and the results, which graphically indicate a relative level of noise of this type of engine depending upon the amount of discharged air and the diameter of the discharge nozzle and the radius, upon the basis of which the noise level is determined. This work also includes a comparison of the relative noise level of this type of engine with regard to one-flow turbine engine equipped with the function of air discharge to the environment and with regard to two-flow turbine jet engine equipped with air stream flow mixing device. The essay ends with short conclusions.

In order to struggle with the air noise special "Environmental Protection Programmes" are prepared. Civil airports and military airports prepare new procedures for taking off and approaching planes as well as optimize the approach and take off airport flight zone corridors. Unfortunately, in the case of so big surfaces, acoustic screens would not bring desired effects, also due to costs.

Keywords: *noise of aircraft engines; the environmental impact of a jet engine turbine*

1. Introduction

Despite numerous advantages, jet engines have two basic disadvantages. The first one is the consumption of a great amount of fuel, whereas the second one is the emission of excessive noise, especially during the take off. Airports constitute surface sources of influence of many single noise sources – planes standing upon the apron with working engines as well as planes that approach and take off from the ground. The fact whether the airport is troublesome is to a great extent influenced by the noise generated by the planes as well as by the intensity and organization of air traffic – noise produced by the very airport, within the zone of flights above the airport, by planes upon take off flight zone corridors and by planes waiting for the take off Their level of noise in such situations amounts to 80-110 dB. The noise level generated by the planes depends upon their technical solutions and maximal start mass. New generations of planes are usually less noisy than the older ones. However, this observation does not apply to military planes. Provided that the area exposed to the noise at the level of 80 dB equals to approx. 150 km^2 for older types of planes, for the new ones, the so-called second generation, it equals only to 35-45 km^2. The noise emitted by taking off and approaching planes as well as the moving ones encompasses not only the premises of the airport but also makes the areas located from several to several dozen kilometres away from the airport border unsuitable for living, depending upon the location of start lanes. Cargo airports are particularly troublesome for the inhabitants, since flights frequently take place at night.

Current situation indicates the necessity to implement radical changes in order to eliminate the air noise upon the territory of the country. An analysis of the schedule of planes that take off and land upon the airport premises within the day determines their quantity (from 20 to even 130 flights within one day). It should be noticed that the share of night flights currently amounts to more than 10%. Despite the fact that the airport mainly uses light planes, the fact that they fly so low and make traffic especially in the case of training helicopters, the problems caused by the airport are numerous.

All of the attempts to eliminate the noise generated by the airports are very difficult. Currently, in order to reduce the air noise, the premises of the airports are distanced much from the areas inhabited by people. Moreover, the premises of the airports (especially the military ones) are surrounded by forest usufructs.

In order to minimize the noise emission, the airports try to modernize the planes, especially within the field of airframe and engine. The newest investments encompass new planes which emit considerably low noise level.

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Unfortunately, in the case of so big surfaces, acoustic screens would not bring desired effects, also due to costs. One protection of this type is constituted by the formation of special shafts and construction of concrete partitions (Fig. 1).

Fig. 1. Special shafts protecting against excessive noise emission

Upon the military airports one may frequently find the so-called shelters, which allow for the activation of planes, execution of ground trails, etc., the solution that also reduces the level of noise, which reaches the adjacent neighbourhoods.

Fig. 2. Plane shelter upon a military airport

In order to protect human health near the airport premises it is indispensible to use windows with high degree of acoustic insulation in connection with a proper system of mechanical ventilation of apartments, especially in the case of areas with the highest level of noise exposure. Although the authorities and organizations of any civil airports, military airports and aero clubs strive to reduce the noise level, all of the calculations have shown that the degree of difficulty connected to the existence of such airports has not been reduced. Such situation stems from the failure to observe the procedures of take offs and approaches of planes which take into consideration the necessity to protect residential areas. Therefore, not all of the technologies are completely human friendly.

Other attitude is illustrated in the interference with structures of air engines, which already at the stage of designing take into consideration the problem of noise. A frequently appearing element is constituted by the so-called mechanical noise silencers, which act based upon the rule of forcing of the intensification of mixing of fuel stream with air by disintegrating the stream or sucking up of an additional air mass from the environment. A new approach is to construct engines, the structures of which allow for the reduction of considerably significant level of noise emission. Such solution is applied, amongst other, in the design of a “bypass” type of turbine jet engine.

The concept of the “bypass” type of turbine jet engine describes a one-flow jet engine in which the air discharged from behind the compressor is supplied with external ducts to the place behind the turbine, where it is subject to mixing with the basic fuel stream. The diagram of this type of engine is presented upon Fig. 3. Apart from typical assemblies of every engine, it shows the external flow ducts supplying the air discharged from behind the compressor and supplied to the place behind the turbine.

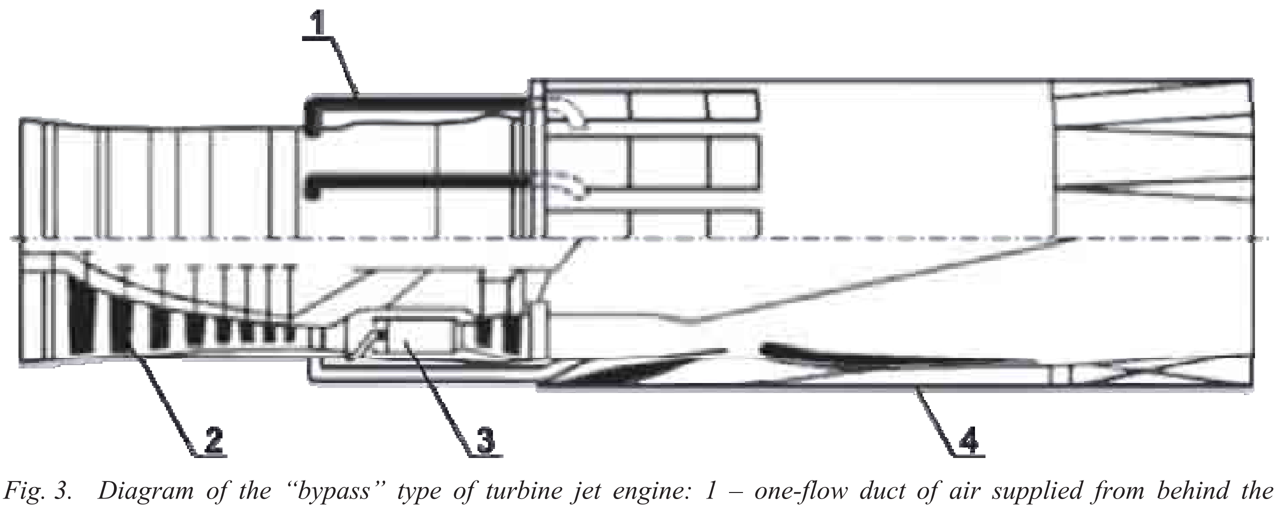

Fig. 3. Diagram of the “bypass” type of turbine jet engine: 1 – one-flow duct of air supplied from behind the compressor to the place behind the turbine, 2 – regulated compressor, 3 – combustion chamber of low level of emission of toxic components of combustion gases, 4 – discharge nozzle with a thrust reverser

The influence of this type of air discharge from behind the compressor onto the chosen work parameters of the turbine jet engine has already been presented, for example in [4] and [5]. What will be described now is the initial assessment of the noise level emitted by this type of jet engine.

As a complex sound, the noise is one of the methods to transfer the energy to the environment. The basic source of noise of the turbine jet engines is constituted by the stream of gases discharged at high speed from the discharge nozzle as well as the air stream flowing through the inlet ducts of the engines.

Additional sources consist of mechanical vibrations of the elements of drive assembly, the flow of air through the palisades of blades of the compressor and the turbines as well as of the progress of the consumption process and work of hydro-mechanical sub-assemblies of the fuel supply control.

2. Theoretical basis

The noise level may be calculated depending upon the following [3]:

$$L = 10\log\frac{I}{I_0}\ [\mathrm{dB}], \tag{1}$$

where:

$I = \dfrac{N}{2\pi r^2}$ – sound intensity upon the surface of the half-zone of the radius r, at the centre of which the noise source is located,

$N = \dfrac{\rho_5^2 D_5^2 C_5^8}{\rho_H a_H^5}$ – acoustic power of the noise emitted by the engine,

I_0 – sound intensity upon the audibility threshold,

D_5 – diameter of the diagonal cross-section of the discharge gases,

ρ_5, C_5 – respectively: density and speed of stream of discharge gases,

ρ_H, C_H – respectively: air density and sound speed inside the air.

Having taken into consideration other factors, i.e. density, temperature and pressure of the stream of discharge gases as well as the stream speed determined for the critical ratio of pressures within the engine discharge nozzle, after the proper modification the formula may receive the following form:

$$L = 10[\log F + x\log T_4^*] \tag{2}$$

where:

F - coefficient, the value of which for the engine working upon the ground is practically dependent upon the diameter of the diagonal cross-section of the discharge nozzle D_5 as well as upon the radius r (i.e. distance from the noise source to the measurement point):

$$x = \frac{2(2k-1))}{k'-1}. \tag{3}$$

3. Analysis of test results

A relative noise level of the "bypass" type of engine determined by a comparison of the noise level generated by this engine depending upon the regulation method, i.e. in accordance with the constant heat degree *=const and constant compression of the compressor π_s=const as well as the amount of air discharged from behind the compressor is presented upon Fig. 4.

It is visible that the increase of the amount of air discharged from behind the compressor to the place behind the turbine in the "bypass" type of engine results in the reduction of the relative noise level, for example for 25% of the amount of discharged air approx. 10% is added. The criterion of the engine regulation practically does not influence the change of values of obtained decrease of the relative noise level.

The value of this decrease is subject to change along with the change of the diameter of the cross-section of the discharge nozzle D5 of the engine and the radius r, upon the basis of which the noise level is determined. Such situation is presented upon Fig. 5. The increase of r radius increases the decrease of the relative noise level for the given amount of discharged air, which in consequence means that the noise level emitted by the "bypass" type of engine is silenced much earlier than the noise from the one-flow engine with no air discharge function.

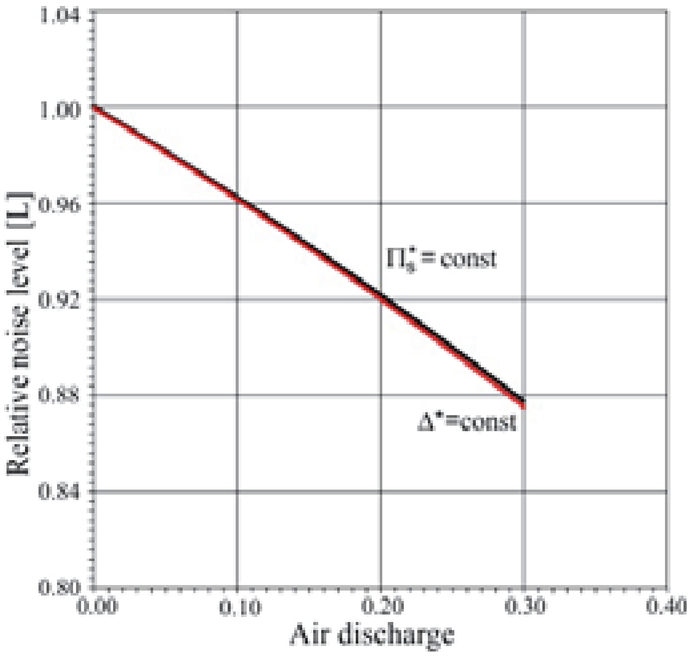

Fig. 4. Influence of air supply from behind the compressor to the place behind the turbine onto a relative level of engine noise depending upon the regulation method (D = 0.3 m, r - l m)

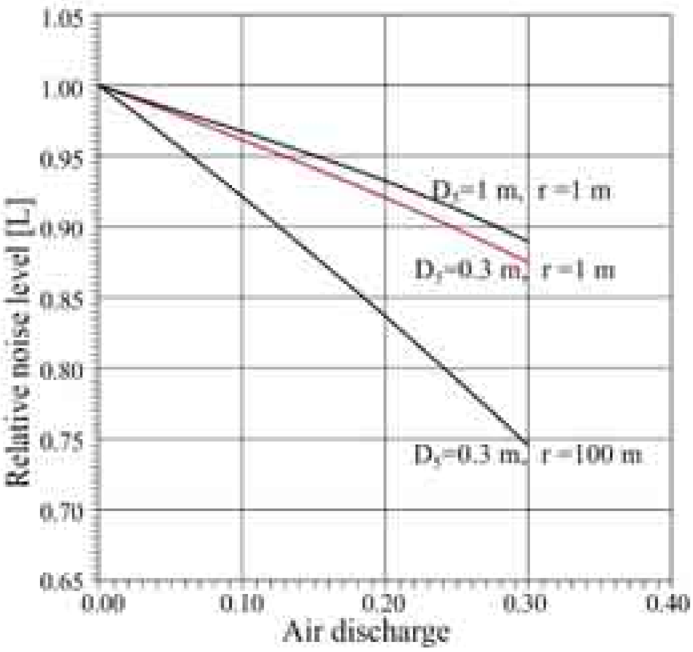

Fig. 5. Influence of air supply from behind the compressor to the place behind the turbine onto a relative noise level depending upon the diameter of the discharge nozzle D_5 and the radius r

In practice, in the turbine jet engines, the air discharged from behind the compressor is frequently used in order to ensure the static work of the compressor within the scope of low rotary speeds, as a result of which the discharged air is carried out to the environment. Therefore, the comparison of the noise level emitted by this type of engine with the "bypass" type of engine evokes much more interest. Fig. 6 presents the ratio of levels of noise emitted by the one-flow engine equipped with the air discharge function to the environment to the "bypass" type of engine, depending upon the amount of discharged air and the regulation method.

It is visible that along with the increase of the amount of discharged air, the noise level emitted by the engine equipped with the air discharge function to the environment is higher than the noise level emitted by the "bypass" type of engine. Such situation is presented upon Fig. 6 with a constant increase (above the index 1) of the curve which determines this ratio (for example for 25% of the amount of discharged air and the regulation programme in accordance with the constant heat level Δ*=const with approx. 5%).

The criterion of regulation in accordance with the constant compression of the compressor π_s=const increases this value with additional 5%. The influence of the radius r, upon the basis of which the noise level and the value of the diameter of the cross-section of the discharge nozzle D5 is determined is presented upon Fig. 5.

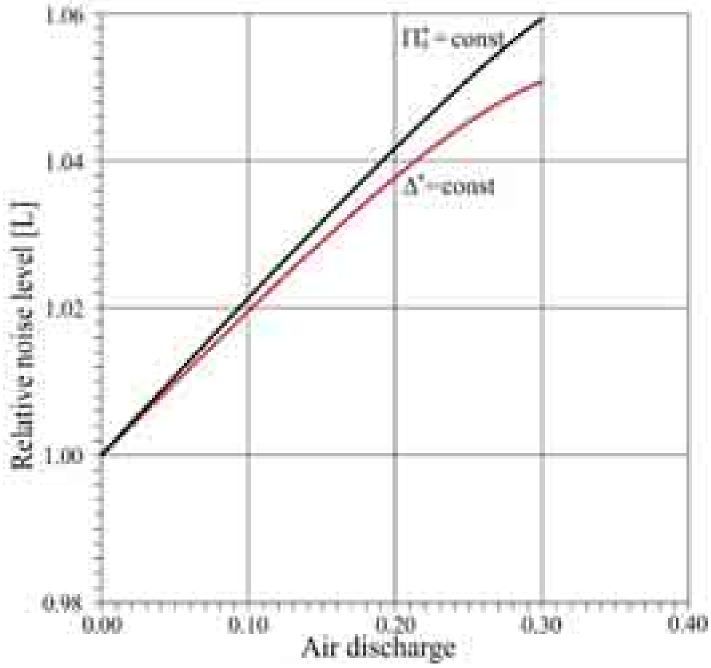

Fig. 6. Ratio of the levels of noise of the engines: one-flow engine equipped with the air discharge function to the environment and the “bypass” type of engine depending upon the amount of discharged air and the regulation method.

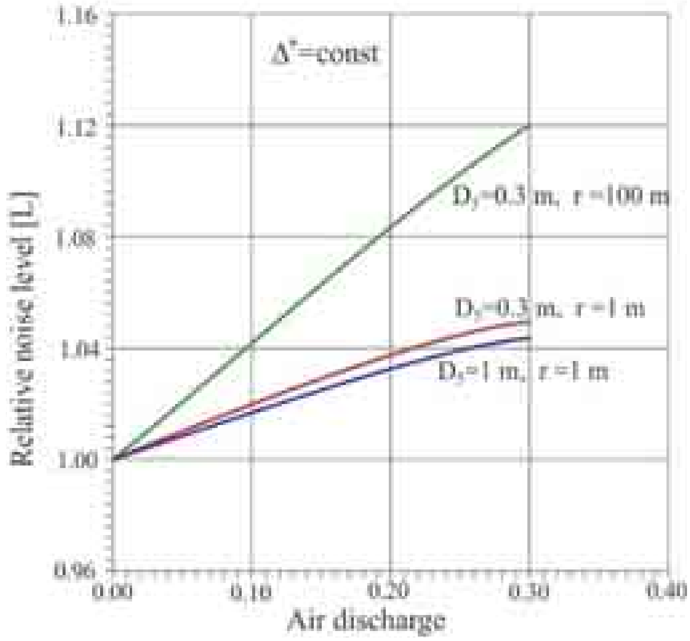

Fig. 7. Ratio of the levels of noise of the engines: one-flow engine equipped with the air discharge function to the environment and the “bypass” type of engine depending upon the amount of discharged air and the radius r as well as upon the diameter of the discharge nozzle D_5

It is visible that the increase of the radius r increases the value which determines the ratio of the noise levels emitted by the engine equipped with the air discharge function to the environment and by the "bypass" type of engine, whereas the increase of the diameter of the discharge nozzle D5 decreases it slightly. Such situation confirms that due to the emitted noise level, better effects are achieved in the engines equipped with small diameters of the discharge nozzles.

It is also interesting to compare the noise levels emitted by the two-flow engine equipped with air stream flow mixing device with the "bypass" type of engine. Fig. 8 presents the comparison, which illustrates that the increase of the amount of air flowing through the external ducts of both engines practically does not result in any changes of values of the emitted noise level. The change of the radius does not change this character, the fact that is visible upon Fig. 9.

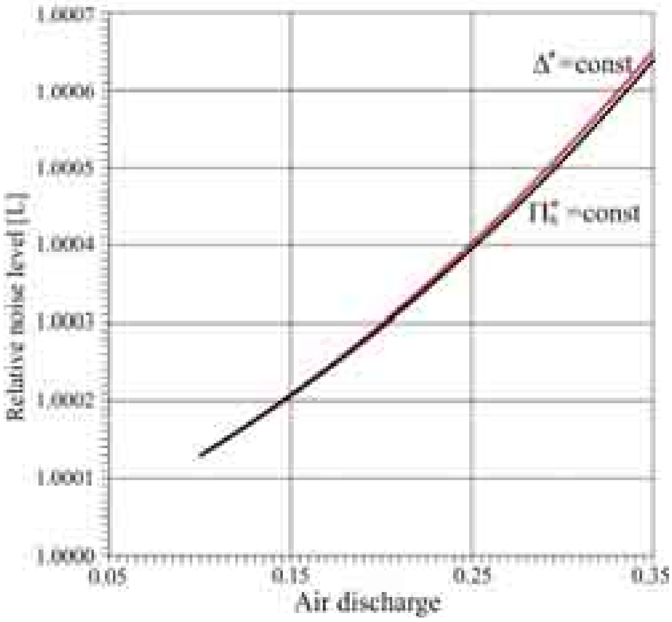

Fig. 8. Ratio of the levels of noise of the engines: two-flow engine equipped with air stream flow mixing device and the "bypass" type of engine depending upon the amount of air flowing through the external ducts of both engines and the regulation method.

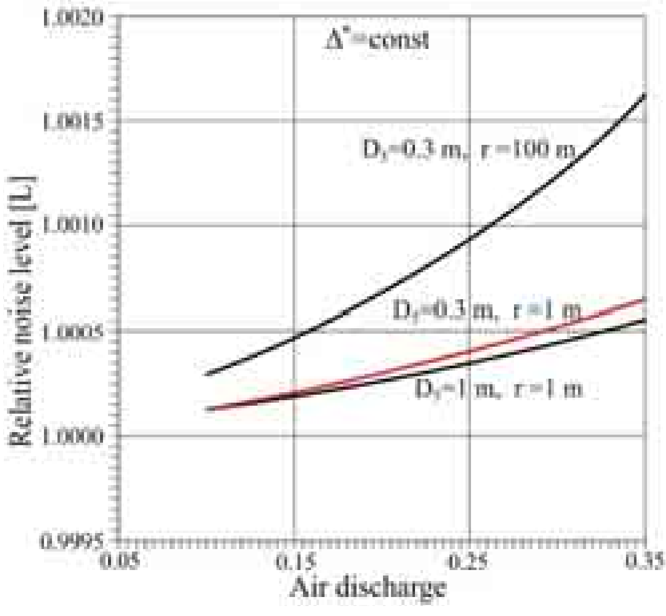

Fig. 9. Ratio of the levels of noise of the engines: two-flow engine equipped with air stream flow mixing device and the "bypass" type of engine depending upon the amount of air flowing through the external ducts of both engines and the radius r as well as upon the diameter of the discharge nozzle D_5.

4. Summary

In conclusion one may state that apart from the profits connected to the economy and drive assembly [4] (not specified herein), this type of air discharge in one-flow turbine jet engines allows for the reduction of the noise level emitted during the work of the engines, especially with regard to one-flow engines equipped with the function of air discharge to the environment.
With regard to the two-flow engines equipped with air stream flow mixing device, such solution allows for the maintenance of a similar noise level and hence enables the one-flow turbine jet engines to become competitive to two-flow engines equipped with air stream flow mixing device due to the more complex structure and production costs of the latter.

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