ABSTRACT

With the increase in the number of flights and in accordance with the expansion of airports, air traffic is becoming a serious problem of the present times. In spite of the tendency to integrate maximally air traffic into all the ecological aspects, one of the main problems today is the noise generated by aircraft engines. These engines generate vortex, exhaust gases at high speeds, whereas in supersonic aircraft there is the additional thunder due to the impact waves produced during take-off and landing of the aircraft. It is important to know the magnitude that define the noise, and the values within which they have to stay in order to comply with the valid regulations. The aircraft noise-related problems will have to be solved by certain alternatives, such as the replacement of the existing aircraft fleet by new generations of aircraft or by fitting the aircraft with hush-kits and other special parts. The solutions related to aircraft generated noise reduction can be sought also in the take-off and landing processes, navigation and adequate use of land, i.e. by creating non-populated green areas around the airports. This work deals with the impact and measuring of aircraft noise and detailed analyses of the results which may be used to determine the areas under the negative impact of noise. In this way, the endangering of the health of the population in these ecologically critical regions may be directly prevented.

KEY WORDS:
noise, ecology and the environment, airports, navigation, aircraft noise measurements

1 INTRODUCTION

Since air traffic is degrading and devastating the environment, for every project of traffic development, whether on land, in the air or on the water, the volume of its negative impact on the environment needs to be evaluated. The first steps related to aircraft noise referred to the crew and passengers within the aircraft. The entire technology was oriented to enabling as calm flight as possible and undisturbed communication on the respective flight. Although aircraft noise has always been present, in 1960 it became the main problem of air traffic, since jet engines were introduced on commercial aircraft. Today, when air traffic is constantly growing and when the number of aircraft in the world is growing fast, with the entrance of low-cost airlines onto the market, the aircraft noise represents a serious problem, which does not affect only the comfort and efficiency of a relatively small number of people in the aircraft, but affects also the population living in the vicinity of the airports. From the beginning of jet aircraft flights in 1958, the reaction of the population to the aircraft noise has been very strong. Because of constant expansion of the cities and inhabiting of the areas around the airports, there are more and more complaints regarding the impossibility of living in these regions. The complaints refer to disturbances, insomnia, and impossibilities of communications. The research has also shown that aircraft noise raises the level of stress, nervousness and generally has negative impact on the health. Negative impact of aircraft noise depends on a number of factors: sound magnitude, sound duration, direction of movement during take-off and landing, number and type of operations, operation procedures, usage of the runway systems, time of day, and meteorological conditions. The prevention of the negative impact of aircraft noise on the population is the construction of facilities equipped with high-quality noise insulation, and the distance of the constructed facilities from the airport. With the development of technology, the new generation of aircraft is much quieter.
than the previous ones, and the noise at airports has been visibly reduced. It should be noted that some airports in the world have adapted their master plan of construction, and the new runways have been oriented outside the inhabited areas (if this was technically feasible).

2 AIRCRAFT NOISE CATEGORIZED ACCORDING TO SOURCE

The primary source of aircraft noise is its powerplant, i.e. engines and planer (aerofoil). According to research, the propeller aircraft are quieter than the jet propelled aircraft. Noise caused by fans and compression exits through the air intake, and leaves the engine through the fan nozzle, whereas noise generated in the combustion chamber exits through the central engine nozzle. The fan generates during flight also an additional source of noise, which is produced by interaction of the fan blades and the stator as well as their mutual position. Unlike propeller engines of the aircraft, the jet engines influence its starting by means of air mass acceleration. In a turbo-jet engine, air is compressed by means of axle or centrifugal mechanical compressor, heated in the combustion chamber, and in turn accelerated along with the propagation through the jet aircraft nozzle.

There are three types of noise: noise of the engine input opening caused primarily as the result of the noise of compressor and aerodynamic noise, noise generated by vibrations of the engine shell, and exhaust noise. Turboprop engines are distinguished from turbojet engines in two main points. The first one is that turboprop engines contain a fan which produces thrust, whereas the other point refers to the turboprop engines that produce lower rate of jet exhaust than the aerodynamic jet noise-dominating turbo-jet engines and are therefore capable of quieter operation. The reduction of the jet exhaust noise outside the levels generated by today’s turbo-prop engines can be achieved by reducing the noise of other mechanisms such as e.g. fans, compressors, turbines or combustion processes, dominant part of the total noise spectrum.

Another element that causes noise is the planer. Noise caused by the planer is the result of the pulsing of aerodynamic forces on the wing, existence of turbulent boundary layer and vortex which occurs in the air streaming around the surface of the wing, fuselage and tailplanes, as well as because of the currents around the landing gear, flaps and various protrusions on the fuselage. In the take-off itself, the level of noise caused by the planer is negligible, whereas noise caused during approach or landing is of great importance and can be compared in intensity with the noise generated by powerplants. According to ICAO standards of ANNEX 16 category 2, the noise level of the planer has been stipulated to 8-10 EPNdB lower than the level of the total noise, and in category 3 the level is stipulated at 5-7 EPNdB of the total noise intensity.

2.1 Possibility of reducing noise in take-off and landing operations

There are limited possibilities of controlling noise in take-off and landing operations. When the aircraft is designed and in operation, the power of aircraft engines is the only modification that may be done in order to reduce the noise origin. However, modifications of flight operative procedures such as e.g. flight schedule changes (especially in case of smaller altitudes during landing and take-off) and the time of day when the aircraft flies can be highly efficient as a control procedure for noise.

2.1.1 Procedure in takeoff – FAA procedure

In aircraft takeoff there is a procedure formulated by FAA and accepted by ICAO. In the take-off procedure three segments are defined, and within each the flight parameters are defined that reduce the noise level. The first segment applies the technique of aircraft climb which flies up to 1500 ft with the takeoff thrust thus achieving faster moving away from the ground and consequently shorter duration of noise on the ground, but of higher intensity. This procedure does not require installation of any new equipment, neither onboard aircraft nor on the ground.

The example in the Figure shows three take-off paths. The first shows the biggest climb angle under full thrust. Due to the intensity of this noise points A and B are more exposed to noise. The second path is at smaller angle and at lower thrust so that in that case the noise intensity is reduced in point A, but in point B the noise is still equal. The third path shows a smaller climbing angle and the thrust in this case can be lower thus producing less noise. The noise at both points is lower.
2.1.2 Standard landing procedure

In landing i.e. approach, there is a larger number of procedures so that these can be compared with the standard procedure in approach. The standard procedure represents aircraft landing from the altitude of 1500 – 2000 ft above the airport of landing. In this flight the pilot receives first the signal of the marker bringing the aircraft to the runway axis i.e. the line that matches the runway axis. Flying in that plane the pilot accepts the dive angle signal (which is at the angle of 3 degrees in relation to the horizontal plane point A), and then starts to dive. Flying at the dive angle the pilot brings the aircraft to the runway threshold to the altitude of 15 metres, and then starts landing. During the whole flight from the moment the pilot receives the marker signal, the aircraft is in the landing procedure (extended landing gear, flaps extended, flaps fully extended). For the normal flight performance (first in level flight, then in diving) the engine thrust must be increased in order to be equal to the total aircraft drag, and the increased thrust generates a secondary phenomenon – greater noise generated by the engine itself.

2.1.3 Increasing the altitude at which the dive angle signal is received

This is a procedure which is defined first since it is most widely used and does not require installation of any special equipment on any aircraft nor on the ground. Instead of flying the aircraft at level flight at the altitude of 450 to 600 metres (1500-2000 ft), in order to receive the dive angle signal, the pilot performs the level flight at the altitude of 900 metres until receiving the dive angle signal and then the aircraft dives towards the runway. Since the flight proceeds until reaching point A at a higher altitude than the flight in standard procedure, the noise level on the ground below the flight path will be lower. It should be emphasised that in both cases the flight is performed in the same configuration. According to this procedure the noise is reduced until arrival to point A after which the flight proceeds identical to the definitions of the standard procedure so that the noise in further flight is the same as in the standard procedure.
2.1.4 Approach in two stages

This procedure started to be developed in the USA, but for its implementation the aircraft needs to be fitted with the electronic equipment and additional devices need to be installed at the airport. The same as in the previous procedure, the aircraft flies horizontally at the altitude of 900 metres (3000 ft) up to point B where the pilot receives the special dive angle signal which is set at an angle of 6 degrees and then the aircraft dives at this angle all the way to point C at approximately 300 metres (1000 ft) of altitude, where the pilot detects the signal at the standard dive angle of 3 degrees, at which the final part of approach is performed and finally landing. In previous practice the pilots landed so that they approached the runway at an angle of 3 degrees. In this procedure the pilots have to perform the first part of the approach at a double angle. Every pilot should attend additional training for such a steep approach.

2.1.5 Lufthansa procedure

The Lufthansa procedure is, from the operative point, very interesting since it does not require additional equipment neither onboard aircraft nor on the ground. The approach until detecting the dive angle signal is performed at the altitude of 900m (3000 ft) from the standard one, so that the noise generated by aircraft will be much lower until reaching the altitude of about 450 metres. Also, according to this procedure the noise will continue to be lower than in the standard procedure since the aircraft drag during flight with less extended flaps is lower, so that this requires lower thrust in approach flight, which means also less noise. Since this is the case in which the aircraft stays longer in the configuration with lower drag in relation to the standard procedure, it is called the low drag – low pressure procedure. Finally, at 40 – 50 seconds prior to the landing itself, the landing gear is extended, bringing the aircraft to the final landing configuration. From that moment there is enough time...
for the pilot to balance the flight according to the dive angle path and to finally touch the ground. This procedure brings also certain saving of the consumed fuel which gives it additional significance.

2.1.6 Selective usage of runway

The purpose of selective usage of runways (at airports that have several runways) lies in the fact that, when possible, those runways are used that allow the aircraft in the initial takeoff phase i.e. in the final approach phase to avoid noise sensitive places. It is important that the selective usage of runways should not influence the flight safety so that this method is used if:

- the chosen runway is not clean nor dry (if covered by snow, ice, water or rubber scrap);
- the meteorological conditions are such that the cloud base is at the altitude lower than 150 metres above the runway selected for landing. Also, if the takeoff and landing conditions are such that the horizontal visibility is less than 1852 m (1NM);
- for the selected runway the lateral wind component together with the wind gusts exceeds 29 km/h;
- for the selected runway the tail wind component together with wind gusts exceeds 9 km/h;
- “wind shear” is expected or bad weather which may affect the flight in approach or takeoff;
- the pilot thinks this may endanger the flight safety.

2.1.7 Approach / take-off on curved path

The use of the Microwave Landing System (MLS) makes it possible to use in approach a curved path, and only finish the approach by flying at the level of the runway axis. If there is a settlement in line with the runway axis, it is possible to avoid flying over it and thus reduce the noise in that place. This procedure needs special electronic equipment onboard the aircraft and on the ground. The situation is similar if in takeoff, instead of straight flight the turn is taken so that a settlement is avoided. This method reduces the noise in that place.
3 AIRPORT NOISE AND CONTROL THEREOF

The airport noise is generated by various operations of air and combined traffic. Apart from aircraft, that are the main source of noise, it is produced also by vehicles that move along the airport platform. Their engine power is lower, but because of greater concentrations, it could be said that it is continuous. Today, two airport noise sources are distinguished: noise generated by flight operations and noise generated by ground operations. In both cases the field of noise around a single aircraft can be calculated if the data are completely available regarding engine power and sound propagation through the atmosphere for a certain existing terrain around the airfield. The sound in stationary aircraft on the ground or from low-flying aircraft is dampened more than the noise of aircraft flying at higher altitudes. If the aircraft noise contribution is to be calculated, first the source of the total airport noise has to be determined, whereas standard meteorological conditions may be assumed. The field of noise radiated from the aircraft on the ground (engine running before take-off or engine running during maintenance) can be calculated. Depending on the type of operation (e.g. fixed position for the aircraft engine running) for the sample of individual origin, it can be assumed that it is oriented to a specific direction. For aircraft take-off or landing, the radiated noise at every point of its flight has to be considered. Extremely high amount of information is necessary to calculate noise generated from many origins at airport, including operative data such as e.g. time and type of land and flight operation, engine code and engine power, data on atmospheric dampening and usage of runway and operative airport data. For noise control and planning purpose, a detailed approach to single aircraft and approach by experience for the average energy is useful and can be combined for optimal benefit.

3.1 Reduction and control of aircraft noise in ground operations

Noise generated in ground operations refers to noise generated by aircraft origin that is produced in aircraft maintenance and during its overhaul. Although this type of noise is controlled in order to eliminate complaints of the people living in the vicinity, usually additional measures are undertaken for its control which is the main prevention in relation to personnel safety. Often the reduction of noise of 10 dB or more in certain areas in the vicinity of airports can be achieved by correct usage of certain samples of various noise sources. Moving of aircraft engine testing to areas further away from airports, and usage of any special meteorological and terrain circumstance as well as other alternatives may be practical. A certain time period is also suitable for sound propagation. Therefore, maintenance operations in these weather conditions should be avoided at night when people are sleeping.

When aircraft run in the vicinity of hangars or buildings, the effect of being sheltered by the hangar may reduce the noise level near the hangar from 10 to 25 dB. The most efficient method of noise reduction in maintaining the operation of jet aircraft engine is by using the hush kits. The portable or stationary hush kits usually enable the reduction in the sound level of 10 to 25 dB, depending on the insulation between the hush kit and the aircraft engine. Daily greater measures are undertaken in order to reduce noise. Under the pressure of the public and authorities the airports introduce additional measures to reduce negative impact of noise on the environment such as restrictions in accommodating noisy aircraft, introduction of procedures in approach and take-off for reducing noise, introduction of approach-take-off paths above less populated or unpopulated areas, by curfews, sound...
insulation of houses i.e. buildings, space zoning, moving. In order to standardize the noise intensity measurements in aircraft certification, ICAO has stipulated standard conditions and reference points in the vicinity of runways that determine the noise level in landing, i.e. take-off. These points are:

1. Take-off point (point A) – point that is located on the runway axis and 6500 metres away from the runway threshold. At this point the noise intensity in the take-off phase is measured;
2. Approach (point B) – point that is located on the runway axis and 2000 metres away from the runway threshold. At this point the noise intensity in the landing phase is measured,
3. Lateral point (point C) – point that is located at the lateral distance of 650 metres from the runway. At this point also the noise intensity in the take-off phase is measured.

3.2 Good planning and land use around airport

The aircraft noise problem is directly connected with the land use. The best solution for noise reduction is maximum distance of the airport from the populated area. If possible, the airport should be surrounded by the so-called buffer area which should consist of non-populated and forest areas, and the private land located below noisy paths should be used for activities such as agriculture, areas for motorway construction, manufacture and other activities that can be performed with such noise level. Unfortunately, the majority of airports is surrounded by buildings, schools and various structures that are sensitive to the noise level. In cities, where presence of big shopping centres, high population density and regarding town expansion, airports are becoming a part of the infrastructure, and the land around the airports reach high values.

3.3 Using sound barriers to reduce noise on the ground

Sound barriers provide the possibility of controlling the sound present on the ground such as take-off, landing, taxiing, APU and engine starting. In order to be effective, the barriers have to break through the line between the sound source and the person which is under the impact of noise. In aircraft take-off the effect of barriers is lost since its position is above them. Maximal effect of barriers is in case when the position of the barrier itself is closer to the person under impact of noise or the very source of noise. The barriers for themselves cannot be walls or soil deposits. A long building can also serve as a barrier, e.g. the terminal building. In case of aircraft with higher positioned engines, such as DC-10 the barriers located in order to prevent the visibility line reduce the noise by 5dB. If barriers against landing on the runway are installed, it is best to set them directly along the objects that have to be protected against increased noise. Every barrier must be tested to all atmospheric conditions, and has to be well fixed in order to avoid collapsing due to extremely strong winds. Regarding objects themselves and their insulation, every building in the vicinity of the airport should be insulated and this is particularly so for schools. Apart from insulation the sound within the structure should be 45dB with possible deviations of +/-5dB. Correct insulation can reduce aircraft noise by as much as 30dB.

3.4 Introduction of time restrictions at airports

Every airport has strictly defined the time limit from when and till when the aircraft are allowed to fly, and upper margins of permitted noise. At the beginning these restrictions were directed to general condition and rating of the airport and were realized only if this was in the interest of the airport. At present, the aircraft noise

Figure 7: Aircraft noise in ground operations
measurement and introduction of restrictions belong to the component of the airport operation. The developed countries have introduced also curfews which reduce or eliminate noisy operations during late night hours, when the people are most sensitive to noise. Such restrictions have high DNL since 10dB of penalties are added to the main value. These restrictions are between 22:00 and 07:00 hours during DNL. The simplest solution for airlines in preventing noisy operations is not to fly to those countries which impose restrictions on aircraft noise. Today, the world known airports and all the interesting ones have introduced restrictions in such a way that the change of fleet on the one hand or tax paying due to noise are inevitable. In evening hours this tax has to be higher, and during night hours it has to be the highest. Thus the same aircraft pays much more for the night landing, and the consequence is greater introduction of daily operations.

3.5 Noise reduction programs

There are several programs for noise reduction: take-off and landing should be done more on runways that are set towards less populated areas, construction of sound barriers and insulation of buildings, ban on landing of aircraft that are not within standards related to noise, various charges depending on the aircraft noise level. FAA in cooperation with airports designs ideal aircraft paths in order to avoid populated areas. The principle of designing such paths is based on the continuous monitoring and measuring of the airport noise and the analyses and development of maps with the contours of aircraft noise. According to these results the attempts are made to adjust the paths above the rivers, lakes, motorways, bays. The negative side is that thus more aircraft would be sent to certain runways and the capacity of a runway would be exceeded whereas the others would be hardly covered. The biggest restriction for airports is the curfew. Some airports based on FAA standards, strictly require that aircraft with noise exceeding 72 dBA in landing and 85 dBA in take-off are banned from using the airport between 22:00 – 07:00 o’clock. This noise level automatically eliminates all aircraft. Some other companies have agreements with airports and they are permitted to land within a certain hour between 22:00 – 07:00. Cleveland has banned technical landings for fuelling in the period between 22:00 – 07:00.

3.6 Influence of aircraft noise on the psychological and medical condition of population

Apart from substantial costs for the construction and maintenance of infrastructure, incident situations and high social price, pollution of air, underground water and soil, consumption of energy and natural resources as well as noise have significant responsibility regarding psychological and medical condition of the population. The effect of aircraft noise can be classified into two categories. The first category is the influence of noise on the behaviour of people, and the second is the influence of noise on the medical and psychological condition of people. The effect that is related to the behaviour of people is noticed in their mental activity, relaxation and communication. The medical effect can be reflected in the damaged or total loss of hearing, increased blood pressure or increased secretion of stress hormone.

The problem that occurs with high noise in speech is intonation. Noise generated by aircraft in the vicinity is greater than the speech between two people and there is interference in communication. This results in emphasising and loss of certain words in the conversation. At 85dB the listeners hears 95% of words, and the remaining 5% are lost. Normal conversation can be led at 65dB.

Based on research carried out in Germany, in the close vicinity of the Munich airport, the results were worrying regarding the issue of the impact of noise on the human organism. The research included 217 schoolchildren from the rural areas in the vicinity of the airport before and after its opening. About half of the children living directly beneath the approach i.e. take-off plane of the international airport have been compared to the children of similar sociological conditions living in much quieter areas. The children had their blood pressure measured as well as the stress hormones, six months before the airport was open to traffic, as well as six, i.e. eighteen months after the airport started operating. In case of children living in the noisier area a moderate, but characteristic rise of the blood pressure was noticed, as well as a significant rise in the stress hormone, whereas in case of children living in quieter areas no significant changes were noticed. Eighteen months after the airport was open to traffic, a report was made about a significant decline in the quality of living of the children in the noisy zone.

Every noise exceeding the noise of normal speech can damage the parts of the ear cochlea which converts sound signals into auditory signals of the nervous system. The primary damage of the cochlea can be only momentary, but further exposure to noise results in the permanent damage and there may be noises in hearing.
4 CONCLUSION

With the growth in the number of flights, air traffic is becoming a serious problem which has to be solved at the global level. The solution of the aircraft noise will have to be found in some alternative solutions such as replacement of the existing air-fleet which belongs to category 2, by new generation of aircraft or some current solution such as fitting the aircraft with hush-kits and some special parts, which also affects noise reduction. Also one of the solutions that can be proposed is the construction of approach and take-off runways that are not in the paths of inhabited areas. Looking at the future, this is a good solution, but with the expansion of the urban areas it is just a question of time when the re-populated areas will find themselves in approach and take-off paths. Whereas the noise is one of the factors in the series of negative ones assigned to air traffic, another negative factor should be mentioned which refers to air pollution. Aircraft engines directly pollute the air in the area of ozone and upper layer of the troposphere. In the airport areas there is greatest concentration of pollution, so that one can say that aircraft account for 45% of pollution, and road traffic at and around the airport accounts for 45%. Other pollutants (medical waste, chemicals, etc.) are in the minority but in no way negligible. The pollution of underground waters and water supply areas of big cities and other populated areas would lead to a catastrophe of huge dimensions. The solution of the mentioned problem lies in the construction of airports outside the range of the water supply areas and densely populated regions. With fast development of airports and the expansion of urban areas, resulting in big problems related to noise and air pollution, the human factor will have to find ways of harmonizing the development and modernization of air traffic and the “possible enemies” that occur as consequence of the technological development of airports.

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