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THE EVALUATION OF LOCAL ATMOSPHERIC AIR POLLUTION VIA THE ASSESSMENT OF JET ENGINES EMISSION

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Atmospheric air pollution assessment of local and regional scale on the territory of airport is being carried with estimation and so far modeling for further application of air quality strategy. Aircraft engine emission index assessment has been done by chemiluminescence's method (measurement of nitrogen oxides) inside the airport area. On the ground of measurement campaign the concentration values of NOx, CO_2, O_3 were determined in exhaust of aircraft engine for maximum operation mode. The difference between measured emission indexes and ICAO data was found due to mismatch real operational conditions with ICAO certification terms.

Keywords: Aviation, environment, pollution, ICAO, aircraft engine, aircraft, air quality, emissions.

Оцінювання місцевого та регіонального забруднення атмосферного повітря в межах аеропорту виконується шляхом вимірювання та моделювання для подальших кроків стратегії регулювання якості повітря. Виконано оцінювання індексів емісії авіаційних двигунів у реальних умовах експлуатації на території аеропорту, а також на базі хемілюмінесцентного методу (вимірювання оксидів азоту). За результатами вимірювань визначено концентрації забруднення (NO_x, CO_2 та O_3) повітря внаслідок викидів авіаційних двигунів для максимального режиму. Виявлено різницю за результатами порівняльного аналізу виміряних індексів емісії та наданих показників ICAO, зумовлену тим, що реальні експлуатаційні умови не відповідають умовам сертифікації ICAO.

Ключові слова: авіація, навколишнє середовище, забруднення, ICAO, авіаційний двигун, повітряне судно, якість атмосферного повітря, викиди.

Introduction

During last decade a lot of studies are also focusing on the aircraft emissions impact on local and regional air quality in the vicinity of airport. The basic objects of attention are NO_x and fine particle matter (PM) emissions from aircraft engine emissions as initiators of photochemical smog and regional haze, which directly impact human health [1; 2; 3; 4; 5].

This problem intensifies in connection with increasing air traffic (at a mean annual rate of 5 to 7 %) and growing public awareness of local air quality around the airports.

Emissions airport influence local air quality. The emission sources associated with a wide variety of activities at airports. The main components of aircraft emissions are NO_x/NO_2, unburned hydrocarbons and particulate substances that are known to affect negative impact on human health and the quality of the local environment. European air quality standards and national laws were designed to ensure that health impacts are within acceptable limits, and that the quality of the local environment meets certain standards.

Considering the sources of emissions airports affecting the quality of local air. Aircraft operations are a major source of emissions in most airports. In vain motion is expected to continue to grow.

Regulation of aircraft emissions is very important to reduce air pollution in the area airport due to toxic and harmful impact on human health and the environment.

Literature overview

Analysis of inventory emission results at major European (Frankfurt am Main, Heathrow, Zurich and etc.) and Ukrainian airports highlighted, that aircraft (during approach, landing, taxi, take-off and initial climb of the aircraft, engine run-ups, etc.) is the dominant source of air pollution in most cases under consideration. Also, aircraft is special source of air pollution due to following features: moving source, result in velocity, direction and acceleration of aircraft movement has been changed in within the wide limits; aircraft engine operation modes during landing take-off cycle have been changed from idle to maximum operation mode emission characterristics of aircraft engine has been also changed within the wide limits [6; 7].

So, local air pollution produced by aircraft engine emissions with taking into account meteorological conditions (temperature, humidity) and real operation conditions, to provide real input data for model of air quality, must be assessed by measurement and modelling methods, which initial information for next steps of air quality regulations (aircraft emission index and concentration of pollutant) to calculate precisely emission inventory of aircrafts and concentration field for control of sanitary hygienic zone sizes around the airport. Also determination emission index under allow to improve emission inventory of aircraft.

Aim of work

Determination of EI under operational conditions inside the airport.

Local air quality regulation

This issue of health European standards and national legislation for airquality must ensure that health risks remain within acceptable limits and the values of contaminant concentration in ambient air remain below certain standards. In order to meet air quality normatives, assessment and forecast concentrations of air pollutants is implemented by using appropriate tools: sampling instruments to measure air pollution modeling of emission inventories and air pollutants dispersion.

Local air quality regulations often regulate specific emissions species as well as the secondary pollutants that these emissions may form. As a result, regulations may vary and be tailored to the local conditions and priorities in the countries where they are applied. An example of this is the difference in emphasis that the European Union (EU) and the U.S. place on NO_2, NO_x and O_3, with many EU States more concerned with NO_2 concentrations and the U.S. and others more concerned with NO_x emissions, which is an O_3 precursor [8].

States have also historically developed their own local air quality regulations and/or guidelines, and therefore a number of national regulatory criteria exist worldwide although not comprehensive in its coverage, is included to demonstrate the variability that exists between States for a number of air pollutants.

Beyond the detail shown in the table, this variability also extends to the manner in which the numerical standards are applied. For example, some regulations are treated as maximum acceptable levels, while some specify the number of acceptable exceedances.

Also included in the table are the EU Air Quality Framework Directive and the World Health Organization (WHO) guidelines for comparison. It is noteworthy that local air quality regulations are typically in the form of micrograms per cubic metre (μg/m^3) and for a specified time frame (usually hour, day or year) by pollutant.

Emission inventory assessment for aircraft engine

Emission inventories of aircraft in the vicinity of airports are traditionally calculated by using ICAO engine exhaust emission data and the ICAO reference LTO-cycle, the latter sometimes adapted to airport specific taxi times. Initially intended for certification purposes, the LTO cycle cannot sufficiently take operational issues (de-rated take-off, climb profiles) into account.

Evaluated data suggested to have an operational LTO cycle defined with 4 phases similar to the ICAO reference cycle:

a) take-off: average thrust setting from take-off brake release to the point of main engine throttle back;

b) climb: thrust setting from the point of throttle back to the mixing height altitude;

c) approach: average thrust setting from mixing height altitude over the touch down point to the end of the rollout on the runway;

d) taxi / ground idle: average thrust setting from engine start to the point of take-off brake release for taxi-out and from the end of rollout after landing to parking and main engine turn-off for taxi-in.

Reference Conditions for Engine Certification Gaseous emissions of jet engines whose rated output is greater than 26,7 kN and whose date of manufacture is on or after 1 January 1986 are regulated under the provisions as set out in the ICAO Annex 16, Volume II, Aircraft Engines Emissions. These provisions have been established by ICAO to guarantee that engines do not exceed certain regulatory environmental limits. The engine is tested at specified thrust settings. Furthermore, the reference emissions LTO cycle for the calculation and reporting of gaseous emissions shall be represented by the following time in each operating mode Table 1.

Table 1

ICAO Reference LTO cycle

Take-off	100 % F_∞	0,7
Climb	85 % F_∞	2,2
Approach	30 % F_∞	4,0
Taxi/ground idle	7 % F_∞	26,0

The LTO cycle basically covers emissions of self-moving aircraft from the ground up to 915 m or 3,000 ft above ground. The different modes are not described in more detail.

Basic methods for evaluation of mass emissions (inventory) of pollutants from aircraft engines based on the basic formula:

$$Q = FF \times EI \times T \times n, \qquad (1)$$

where FF — fuel consumption rate, kg/s; EI — index emissions, g/kg; T — time of (work) aircraft engines, c; n — the number of engines on the aircraft [9; 10; 11].

Emissions inventory parameters. The following factors should be considered when developing an emissions inventory:

a) Inventory purpose. The use of and requirement for an emissions inventory largely determines its design. If the requirement is solely to calculate the total emissions mass, then the methodologies utilized will be simple and straightforward. If the inventory is to be utilized as part of a dispersion model, the methodologies could be different and more detailed because dispersion modelling requires spatial and more detailed temporal information. The design of the emissions inventory has to take this into account so as not to limit its future use.

b) System perimeter. The system perimeter defines the spatial and the functional area within which emissions will be calculated. The spatial area could be the airport perimeter fence, a designated height and/or access roads leading to the airport. The functional area is typically defined by emissions sources that are connected functionally to airport operations, but could be located outside the airport perimeter.

c) Updates. The frequency of inventory updates influences the design of the inventory and any applied databases or data tables. It is also important to evaluate the efforts needed and available to compile the inventory at a certain frequency.

d) Level of accuracy/complexity. The necessary accuracy level of data inputs is determined by the fidelity required for the analysis and the knowledge level of the analyst. This guidance is to be a framework for conducting analysis at various levels of complexity.

Whenever possible, guidance is given for three different levels of complexity:

1) simple approach;

2) advanced approach;

3) sophisticated approach.

As shown in Table 2, an emissions inventory can be conducted at various levels of complexity, depending on the required fidelity of the results as well as the availability of the supporting knowledge, data and other resources.

This guidance material is intended to be a framework for conducting studies at various levels of complexity. Whenever possible, guidance is given for three different levels of complexity. When conducting an analysis, the approach applied should also be stated.

Table 2

Measured emission indexes of aircraft engine under real operational conditions at International Boryspol airport

Characteristics	Simple approach	Advanced approach	Sophisticated approach
Complexity	Basic knowledge required; necessary data are easy, standardized and available; straightforward methodology	Basic knowledge required; necessary data are easy, standardized and available; straightforward methodology	In-depth knowledge, cooperation among various entities and/or access to proprietary data might be required
Accuracy	Generally conservative	Good	Very high
Confidence	Low	Medium	High

Unless required otherwise for specific legal reasons or regulatory compliance, it is recommended to make use of the best available data for creating emissions inventories while considering the level of accuracy and confidence required.

This could evolve to using advanced or sophisticated approaches rather than a simple approach. Approaches can also be combined by using one approach for one emissions source and a different approach for another emissions source in compiling the inventory. In addition, combinations of approaches could be used for the same emissions source where various parameters are needed to calculate the emissions mass.

Experimental investigation in International Boryspol

With aim to determine emission indexes under real operation conditions, the measurement campaign was organized in International Boryspol airport (IBA).

Measurement of air pollution produced by aircraft engine emissions was conducted by two stations (stationary station A and movable station B) for maximum operation mode (aircraft is accelerating on the runway or takes-off).

Stationary station A is displayed near runway (18L-36R) in east direction. Mast is located at distance of 60 m from runway axis and height of sample point installation is 3 m. Container with equipment is distance of 80 m from runway axis.

Station B (movable van) is oriented to dominant wind direction and displayed at distance 120 m from runway axis in east Fig. 1. Dominant wind direction is south-west (240–270°).

Processing and analysis results of measurement data at station “B” has highlighted that a lot of peak concentrations in jet from aircraft engine clearly correlate with operation mode of aircraft engine. So, maximum operation mode of aircraft engine (accelerating stage on the runway) is characterized by the highest value of NO_x, Fig. 2 [12].

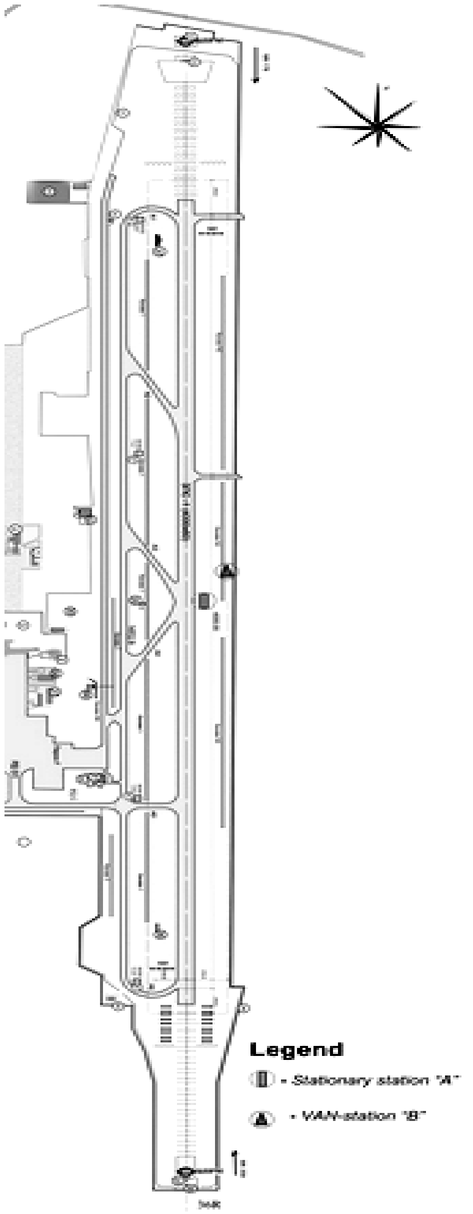

Fig. 1. Locations of stationary and mobile stationsmonitoring tool pollutant emissions from aircraft engines within the runway-1 with the dominant south-west (200–260 °) wind direction 10.09.14

The detection of NO_x concentration was implemented by chemiluminiscence method, CO_2, O_3 — by spectroscopic methods.

Emission indices were determined for a total of 5 aircraft with fifth different engines. The simultaneous occurrence of CO_2, NO and NO_x peaks, which were related to aircraft movements, allowed the calculation of the emission indices for a specific aircraft by formula:

$$EI(X) = EI(CO_2) \times \frac{M(X)}{M(CO_2)} \times \frac{Q(X)}{Q(CO_2)},$$

where M — the molecular weight; Q — concentrations (mixing ratios, column densities, etc.) of the species. $EICO_2$ = 3150 g/kg.

Determined emission indices of aircraft engines under real operation conditions were compared with ICAO values, Fig. 3, Table 3, 4.

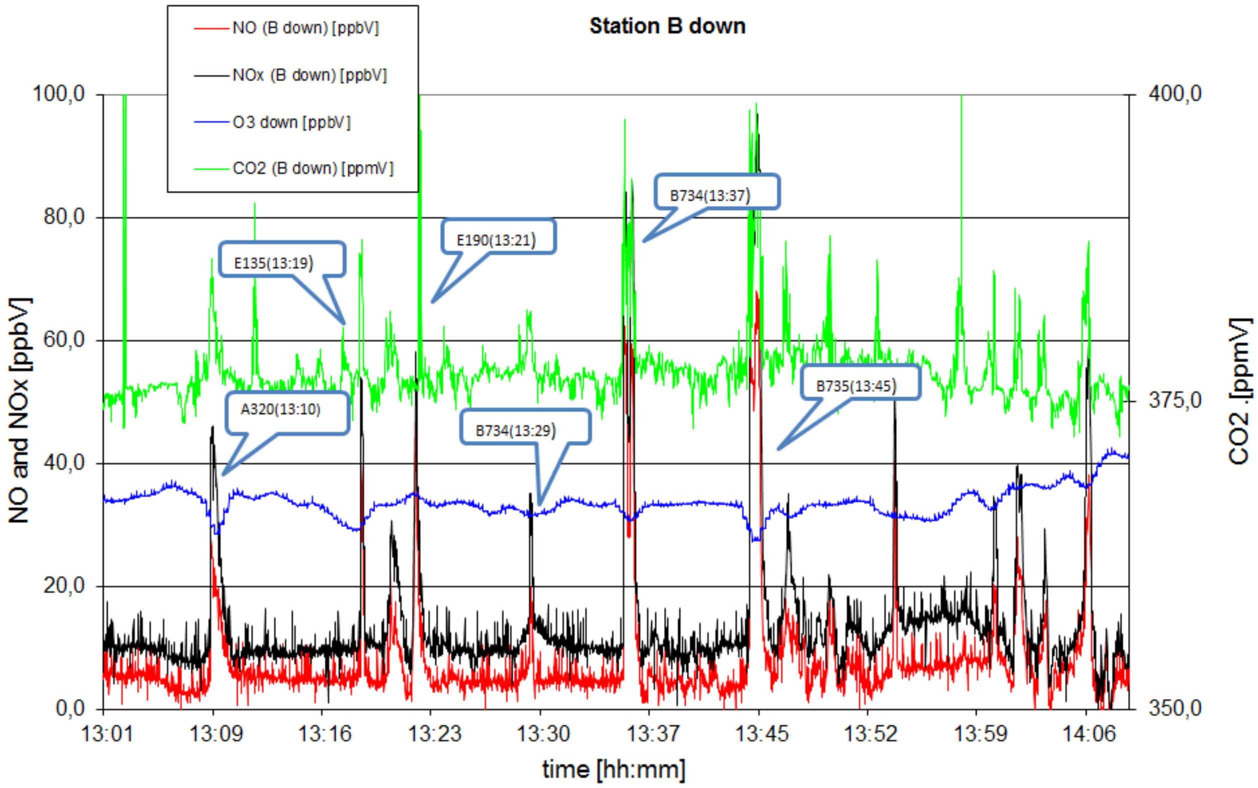

Fig. 2. Concentration of NO_x, NO, O_3, CO_2 measured in ambient air by st. B down

Table 3

Results of concentration NO, NO_x, CO_2 measurements at station B down

Aircraft	Station B down NO (ppbV)	Station B down NO_x (ppbV)	Station B down CO_2 (ppmV)
A320(13:10)	22,3	37,3	7,7
E135(13:19)	31,0	43,0	9,1
E190(13:21)	26,2	15,8	3,5
B734(13:29)	14,9	22,2	3,6
B734(13:37)	56,4	72,7	17,9
B735(13:45)	60,3	81,8	19,4

Table 4

Results EI NO_x measuredat st. B down comparison with EI NO_x ICAO

Aircraft	EI NO_x measured at st. B down (g/kg)	EI NO_x ICAO (g/kg)
A320(13:10)	15,94	24,79
E135(13:19)	15,58	17,17
E190(13:21)	14,74	18,51
B734(13:29)	20,16	20,5
B734(13:37)	13,33	20,7
B735(13:45)	13,84	19,4

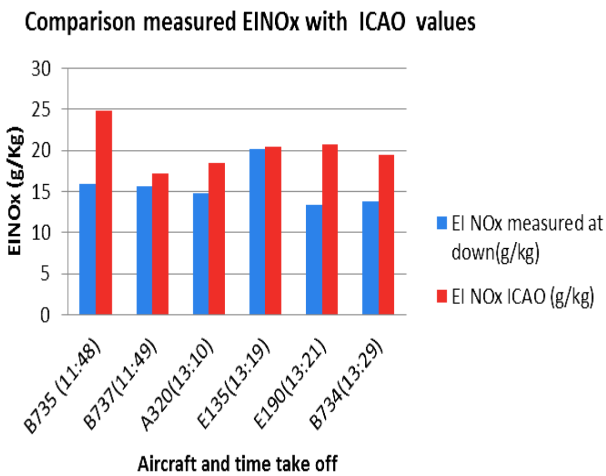

Fig. 3. Diagram measured $EINO_x$ with ICAO values

The observed variations between determined and certificated emission indexes are most likely caused by operational (thrust) and meteorological (air temperature and humidity) conditions under real circumstances which are quite different from well defined conditions during certification procedure.

Conclusion

This study was devoted to actual task, as determination emission indexes of aircraft engine under real operational conditions.

The observed variations between determined and certificated emission indexes are most likely caused by operational (thrust) and meteorological (air temperature and humidity) conditions under real circumstances which are quite different from well defined conditions during certification procedure.

Nevertheless these differences are important since the ICAO data [10] is currently used to calculate emissions from airports.

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