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Jacek PIELECHA*
Remigiusz JASIŃSKI*

THREATS OF NANOPARTICLES EMISSION IN AIRPORTS' AREAS

Particulate emission from aircraft engines represents a significant threat to human health and air traffic. Particles emitted at areas of the airports are nano-sized, which easily leak into the lungs thus giving rise to heart diseases, asthma or bronchitis. Current standards of emission caused reduction of emission of large diameter particles generated by aircraft engines. Despite this increasingly common issue at airports is smog, causing a reduction of visibility. The article presents the results of the particulate emission carried out on a jet engine. The study was divided into three phases: start-up, warm-up and stabilized operation. The first phase of operation is dominated by particles with large diameters (70-160 nm). The Warm-up phase is characterized by increase in the share of solid particles with the smallest diameter (10-40 nm) in the total emissions of PM, whereas during stabilized operation phase particles in the range of diameter of 10-70 nm are dominating.

Keywords: particulate matter, jet engine, airport

1. INTRODUCTION

Related to technical developments, observed for a few decades, advancing technical revolution is the reason for increasing demand for energy. This triggers many threats such as, first of all, those associated with effects of combustion of all kinds of fuel. During combustion are generated many chemicals which are not neutral for the environment and human life. An increase of toxic compounds of exhaust gases has a negative impact on the human body, leading to the diseases and mutagenic changes. The health hazard caused by exhaust gases from engines is high, as harmful compounds are emitted into the atmosphere in inhabited areas, where air exchange is restricted because of the buildings [1, 8].

* Institute of Combustion Engines and Transport, Poznan University of Technology.

Contamination of the atmosphere by particulate matter emitted by combustion engines has a negative impact on human health and condition of the natural environment. Particles of diameters of 10 μm or smaller can be the reason of different diseases, first of all of heart and lungs, and of the deaths caused by the diseases. Increasing number of these diseases is associated with a long-term impact of the particles in the environment. They can contribute to such diseases as asthma and bronchitis. They are also one of the reasons heart arrhythmias and heart attacks. It is estimated that because of the particulate matter, average lifespan of a European has been shortened by 8 months. The least resilience to negative impact of particulate matter is observed in people with heart and lungs diseases, elderly people and children [1, 8]. According to the reports of WHO (World Health Organization) the particles of smallest diameters can penetrate directly from the respiratory system into blood, significantly influencing human health [4, 5].

Spread of the particulate matter in different areas has a significant influence, both direct and indirect, on local and global climate. Their direct influence ensues from the same physical processes, which are responsible for deterioration of visibility [8]. However, while the deterioration of visibility is due to the spread of particles in all directions, the climate changes are the consequence of the spread of light, but in the direction towards the source. The range, within which the particles are distributed and absorb radiation, depends on their composition, optical parameters and radiation wavelength [8].

2. REVIEW OF STANDARDS

The international agreements and increasingly stringent standards concerning harmful compounds of gases indicate significant focus on actions aimed at environmental protection. Systematically tightened provisions contribute to maintaining high prices of aviation fuel and enforce the need to conduct the research and development works, the result of which are new designs of aircraft engines and modern materials used for their construction. This allows increased efficiency of the engines and significantly reduces fuel consumption, and at the same time limits emissions of carbon dioxide [13].

The fundamental international provision governing the issue of harmful emissions from the aircraft engines is second volume of 'Aircraft engines emissions' of Annex 16 'Environmental protection' of the Convention on International Civil Aviation ICAO [14]. Appendix 16 to Convention on International Civil Aviation Organization ICAO precisely defines the procedures for the LTO (Landing-Takeoff Cycle) test for measuring emissions from the gas turbine jet engines with a thrust above 26.7 kN [6, 14]. Table 1 contains standard parameters of LTO cycle.

Separate provisions concern determination of the particulate (PM). EU Directive 1999/30/EC [3] on the maximum acceptable values of sulphur dioxide and nitrogen oxides, dust emissions and lead in the air determined daily and annual limits of concentration of PM10 dust (particles of diameters up to 10 μm) in the air. In practice the provisions concern particulate matter associated with smokiness of exhaust gases, the effect of which is that influence of particulate matter on visibility in the area of the airport has been significantly limited compared to earlier years.

Table 1

Parameters of LTO cycle according to ICAO Appendix 16 [10]

Phase	STANDARD (Appendix 16 ICAO)	
	thrust [%]	operating time [min]
Start	100	0.7
Climb	85	2.2
Approach	30	4.0
Taxi/ground idle	7	26.0

Directive 2008/50/EC [2] of the European Parliament and of the Council of 21 May 2008 on air quality and cleaner air for Europe extends the provision including particles PM2.5 (particles of diameters up to 2.5 μm). Because of a significant negative effect of particles of diameters smaller than 2.5 μm on human health, along with the discussed directive have been introduced additional standards for air quality for areas of urban background in cities with over 100 000 of inhabitants and in agglomerations. For these areas was determined the acceptable value of PM2.5 in the air, which was named exposure concentration obligation, calculated on the basis of the average indicator of mean exposure for cities with number of inhabitants larger than 100 thousand and for agglomerations. In addition, each member country on the basis of national indicators of average exposure, pre-calculated on the basis of the indicator of average exposure for cities with number of inhabitants larger than 100 thousand and agglomerations, based on the criteria specified in the abovementioned directive, determined the national target of reduction of PM2.5 exposure.

In accordance with the provisions of Article 86a para. 2 of the Act of 27 April 2001. - Environmental Protection Law of the General Inspectorate of Environmental Protection calculates the value of the indicator of average PM2,5 exposure for cities with number of inhabitants larger than 100 thousand and for agglomerations and the value of the national indicator of the average exposure. These indicators are calculated in accordance with methods specified in the provision of the Minister of Environment of 13th September 2012 on the methods of calculating the indicators of average exposure and the procedure of observing the exposure concentration (Journal of Laws of 2012, pos. 1029).

3. METHODOLOGY

The aim of this study was to determine the distribution of sizes of particulate matter emitted by a jet engine in three phases of its operation: start-up, warm-up and stabilized operation. Measurements were carried out in stationary conditions. The object of tests was a combat and training aircraft, the first jet aircraft of Polish design PZL TS-11 Iskra (Fig. 1), equipped with SO-3 turbine engine [12]. The basic technical specifications of the engine:

- compressor: axial, 7 stages,
- turbine: reaction, axial, 1 stage,
- combustion chamber: annular with fuel vaporization,
- engine mass: 347 kg,
- maximum thrust: 1100 kG,
- fuel consumption: 1066 kg/h,
- dimensions: 2112/760/799 mm.

Fig. 1. View of PZL TS-11 Iskra

For measurements of values of diameters of particles was used the EEPS 3090 mass spectrometer (Engine Exhaust Particle Sizer™ Spectrometer) by TSI Incorporated [11]. It enabled measurement of the discrete range of particle diameters (from 5.6 nm to 560 nm) on the basis of their varying speed. The electric range of solid particles mobility changes exponentially, and the measurement of their size is done with a frequency of 10 Hz.

4. ANALYSIS OF THE RESULTS

Using the measurement apparatus was determined the distribution of diameters of particles. The measurements were divided into three main phases of jet engine operation: start-up, warm-up and stabilized operation.

The size distribution of particulate matter emitted by the turbine jet engine in the start-up phase (Fig. 2) shows emission of particulate matter of large diameters (ranging from 70–160 nm), formed as a result of the accumulation mechanism [9].The characteristic diameter of the obtained distribution of particles is 110 nm. There have been no particles of diameters smaller than 20 nm observed, while particles of diameters up to 40 nm have insignificant share in the total number of emitted particles.

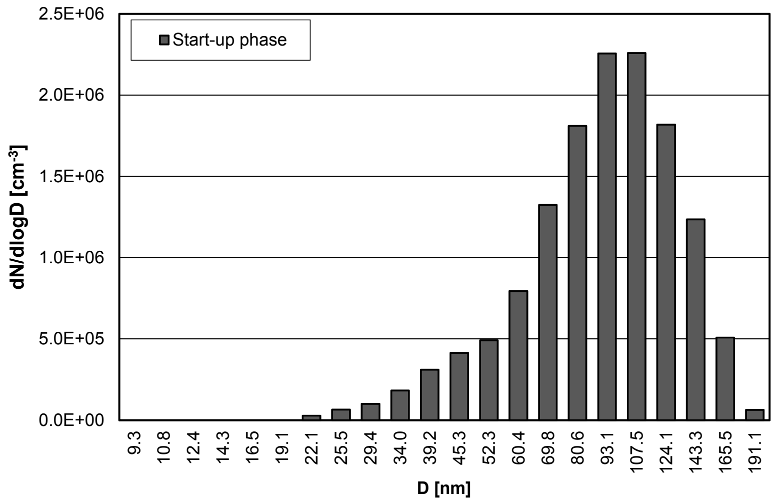

Fig. 2. Dimensional distribution of particulate matter in start-up phase

The size distribution corresponding to the warm-up phase of the engine is shown in fig. 3. There might be distinguished two diameters prevailing in the described distribution: 20 nm and 80 nm. Contrary to the size distribution of particles for the start-up phase, here dominate particles with small (ranging from 10–30 nm) and medium diameters (ranging from 60–100 nm). During successive seconds of engine operation there was observed gradual decrease in the number of particles of diameters exceeding 60 nm and increase of particles with diameters from the range 10-30 nm.

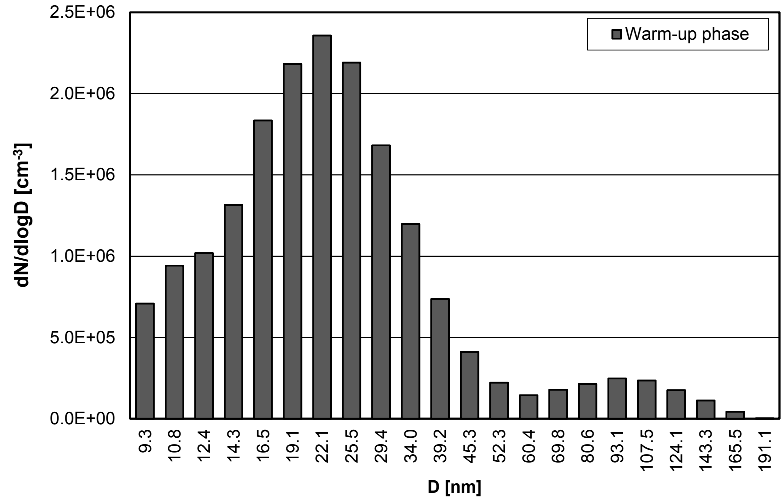

Fig. 3. Dimensional distribution of particulate matter in warm-up phase

On a chart of the size distribution of particles for stabilized jet engine operation (Fig. 4) dominate particles with diameters ranging from 20–40 nm. As characteristic for the discussed distribution, the diameter of 34 nm was accepted. There have been no particles of diameters larger than 150 nm observed. It means that the declining trend of the particles with large diameters, started in the warm-up phase of the engine, was maintained, leading to their total disappearance.

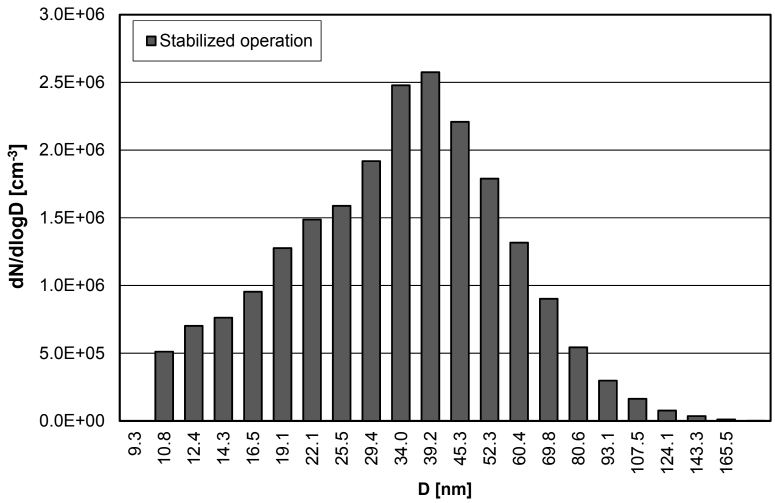

Fig. 4. Dimensional distribution of particulate matter in stabilized operation phase

5. SUMMARY

On the basis of the analysis of the size distribution of the particles it was found that during the start-up phase are emitted particles with diameters of about 100 nm, which are the soot agglomerates with absorbed SOF (soluble organic fraction) substances, generated in accordance with the accumulation mechanism.

During the warm-up, two characteristic diameters can be found, presence of which ensues from existence of two mechanisms of generating particles. Apart from particles resulting from the accumulation mechanism, are also generated particles in the form of the nucleation phase with diameters of about 30 nm, consisting of substances that form volatile fractions of SOF, small amount of carbon and metal compounds [10]. Engine stabilized operation causes an increased number of particles with characteristic diameters of about 30 nm, which prevail during further engine operation.

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ZAGROŻENIE EMISJĄ NANOCZĄSTEK NA OBSZARACH LOTNISK

Streszczenie

W artykule przedstawiono wyniki badań emisji cząstek stałych z silnika odrzutowego. Badania prowadzono w trzech fazach pracy silnika: rozruchu, nagrzewania i pracy ustabilizowanej. W pierwszej fazie dominują cząstki stałe o dużych średnicach (70–160 nm). Faza nagrzewania silnika charakteryzuje się wzrostem udziału cząstek stałych o najmniejszych średnicach (10–40nm) w całkowitej emisji cząstek stałych. Z kolei w trakcie pracy ustabilizowanej dominują cząstki o średnicach w zakresie 20–60 nm.