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THE ASSESSMENT OF OIL ADDITIVE IMPACT ON THE PARTICULATE MATTER EMISSIONS OF JET ENGINE

Particulate matter emissions from aircraft engines is the issue increasingly discussed among researchers active in the field of ecology of aviation. This fact is mainly caused by negative effects of particulate matter on human health and the latest research results, which indicate that the particle matter emitted from aircraft engines are characterized by very small dimensions. The article presents the results of studies conducted to determine the effect of oil additive to fuel on particle matter size distribution. It was found that the addition of oil reduces the concentration of PN with the increase of thrust of the jet engine. There was no significant effect of oil additive on the size distribution of particles.

Keywords: exhaust emission, turbine engine, oil additive

1. INTRODUCTION

Associated with the development of technology, observed for several decades in the world, technological revolution causes increasing demand for energy. This triggers a number of risks, which primarily include the effects of burning all kinds of fuels. Fuel combustion causes formating many kinds of compounds adverse to the environment and human life. Increased concentration of toxic compounds of exhaust has negative impact on the human body, leading to disease and mutagenic changes. Threat to public health because of the engine's exhaust emissions is high, because the harmful ingredients are thrown into the air in residential areas, where conditions of air exchange are limited because of buildings [Mazaheri 2011, Masiol 2014]. The

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existing situation contributes to stricter requirements for the environmental performance of aircraft engines.

Air polluted by particulate matter emitted from engines has a negative impact on human health and the environment. Particles characterized by diameters of 10 μm or less can cause a variety of diseases, especially the heart and lungs which may cause death [Kampa and Castanas 2008]. The severity of diseases is combined with the long-term effects of particles in the environment. They may contribute to the occurrence of diseases such as asthma and bronchitis. It is estimated that, because of the particulate average life expectancy of the European citizen decreased by 8 months. The lowest resistance to the negative impacts of particulate matter have people with diseases of the heart and lungs, the elderly and children [Merkisz and Pielecha 2015].

The spread of particle matter in different areas has a significant impact, both direct and indirect, on the development of regional and global climate [Peace et al. 2006]. Their direct impact comes from the same physical processes that are responsible for the deterioration of visibility. However, while the deterioration of visibility is caused by the spread of the particles in all directions, changes in climate are the result of the propagation of light, but in the direction of the source [Hyslop 2009]. The extent to which the particles are spread and the ability to absorption of radiation is dependent upon its composition and properties.

The impact of particulate matter on the climate is very complex and not fully understood. In global terms, particles in the atmosphere slows down atmosphere warming [Ramanathan and Feng 2006]. However, deviations from the average global values can be very large, even on a regional scale. Any assessment of local negative effects is extremely complex. Estimation of the global impact of particulates on global climate processes and local meteorological phenomena and their effects on human health is very uncertain due to the specific particle emissions at the local level.

From the standpoint of particulate emissions, very important is the chemical composition of the fuel used to power the engines [Unal et al. 2005]. Fuel for turbine aircraft engines Jet A-1 is produced from components obtained in a specific regime in the technological processes of hydrodesulphurization, hydrocracking and distillation. The components meet the established quality requirements. Fuel is enriched with additives (antioxidant and antistatic). Common in military and civil aviation is the use of oil additives to the fuel in order to ensure the proper course of thermodynamic and friction phenomena. The growing knowledge of the processes involved in the creation of air pollution from combustion engines and a dynamic development of emission measuring devices lead to the creation of new rules and conditions for the certification of aircraft engines. The influence of oil additives to aviation fuel on particulate emissions is an issue so far unexplored.

2. METHODOLOGY

2.1. Purpose of the research

The aim of the study was to determine the size distribution of particles emitted by the jet engine GTM-120 powered by aviation fuel Jet A-1 and Jet A-1 with a 3% addition of Mobil Jet Oil II. Jet Mobil Oil II is a high quality lubricant designed for aircraft gas turbine, based on a combination of highly stable synthetic base oil and a unique additive package. This combination provides excellent thermal and oxidation stability, prevent deterioration and deposit formation in both phases – both liquid and gas, as well as provide excellent resistance to foaming. Effective range of the oil is at temperatures between –40°C and 204°C.

Mobil Jet Oil II is designed for aircraft turbine engines used in commercial and military service requiring high performance. It was developed to meet the high requirements of gas aircraft turbine, operated in a wide range and in difficult operating conditions. The product has a high specific heat, in order to ensure a good heat conduction part to the motor, oil-cooled. Determination of the particles size distribution (PN) based on the used fuel mixture allowed to determine the effect of oil on the emission of the jet engine. Measurements were carried out under laboratory conditions on a prepared test stand.

2.2. Test object

The object of the study was turbine engine GTM-120 (Fig. 1) constructed of a single-stage radial compressor, driven by a single stage axial turbine. The engine start is carried out with the starter motor. During stabilization of operation parameters the engine is powered by LPG (Liquefied Petroleum Gas). The test stand allowed to measure the shaft speed, temperature of exhaust gas at the nozzle and thrust. Measurements were carried out for twelve points of engine operation in two cycles, one for each fuel mixture. Each test cycle consisted of measurements carried out in the range of thrust from 10 N to 120 N.

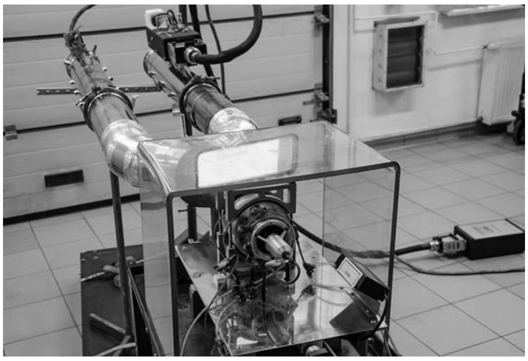

Fig. 1. View of the test stand

2.3. Measuring apparatus

For measuring size distribution of particles mass spectrometer TSI Incorporated – EEPS 3090 (engine exhaust particle sizer ™ spectrometer) was used. It enabled the measurement of a discrete particle diameter range (from 5.6 nm to 560 nm) on the basis of their different speeds. The scope of the electric mobility of the particle matter is exponentially changed, and measuring their size is at a frequency of 10 Hz. The exhaust gases are routed through the dilution system and maintaining the desired temperature to mass spectrometer. The initial filter retains particles with a diameter greater than 1 micron, which are outside of the measuring range of the device. After passing through the neutralizer the particles are directed to the charging electrode; after getting electrically charged they can be classed by their size. The particles deflected by the high-voltage electrode go to an annular slit, which is the space between the two cylinders. The gap is surrounded by a stream of clean air supplied from outside. Exhaust cylinder is built in a stack of sensitive electrodes isolated from one another and arranged in a ring. The electric field present between the cylinders causes the repulsion of particles from the positively charged electrode; then the particles are collected on the outer electrodes. When striking the electrodes, the particles generate an electric current, which is read by a processing circuit. EFM (Exhaust Flow Meter) with a diameter of 125 mm and EFM-HS (High Speed Exhaust Flow Meter) flowmeter characterized by a sampling frequency of 2500 Hz were used. The schematic of the engine workbench is shown in Fig. 2.

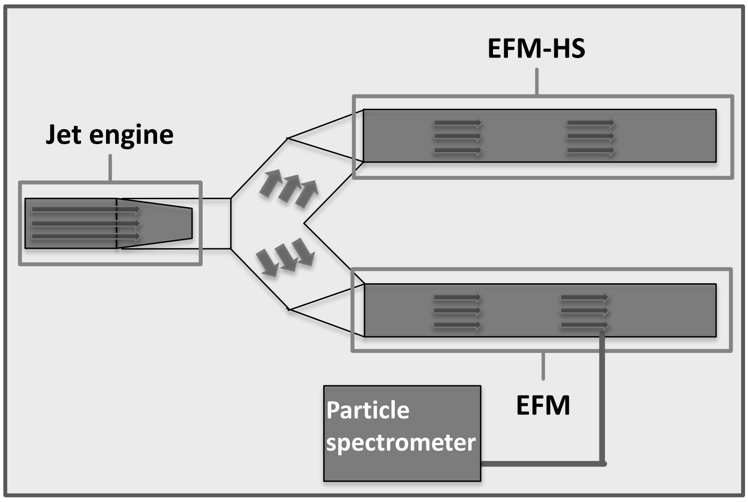

Fig. 2. Engine workbench schematic

3. MEASUREMENT RESULTS OBTAINED AND THEIR ANALYSIS

Diameter distributions of particles emitted by the engine turbine GTM-120 were determined using an apparatus for measurement of particulate emissions from combustion engines. Figures 3–8 show measurement results for each of the level of engine thrust. In the case of an engine powered by pure Jet A-1 fuel at minimum value of engine thrust (20 N) particles with diameters of 25–35 nm dominate (Fig. 3). The characteristic value of particle diameter distribution obtained from measurements was 30 nm. There were no emissions of particles with diameters greater than 100 nm.

Diametrical distribution of particles emitted in the case of an engine supplied with oil additive is similar in relation to the distribution obtained when the engine was fueled with clean Jet A-1 fuel. The main difference was twofold increase in concentration of PN resulting from the use of oil as a fuel additive.

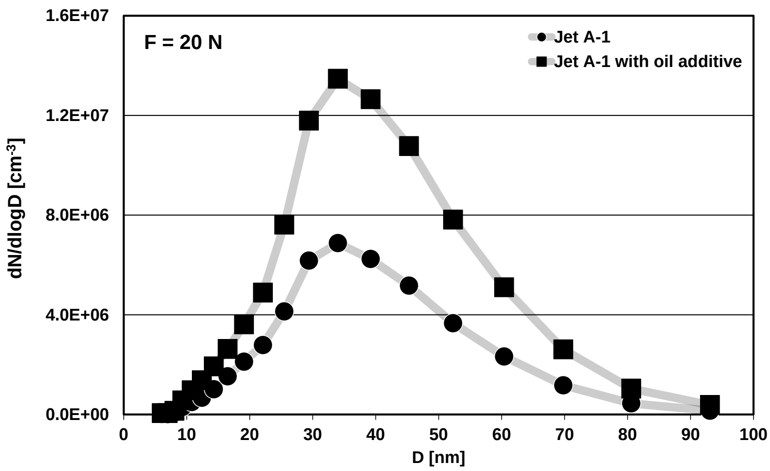

Fig. 3. Dimensional distribution of particulate matter corresponding to 20 N of jet engine thrust

The obtained diametrical distributions of particulate matter for the engine fueled with Jet A-1 and operated at 30% of maximum thrust was dominated by small particles with diameters of 20–50 nm (Fig. 4). There was no emission of particulates with diameters greater than 100 nm. As with the dimensional distribution of particulate matter for low levels of engine load, the use of oil additive increased the concentration of emitted particles.

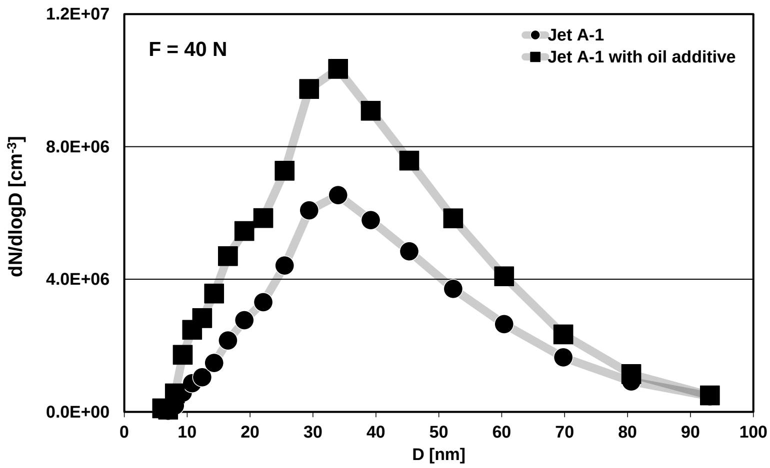

Fig. 4. Dimensional distribution of particulate matter corresponding to 40 N of jet engine thrust

The obtained diametrical distributions of particulate matter for the engine fueled with Jet A-1 and operated at medium level of engine load (Fig. 5 and 6) was dominated by small particles with diameters of 20–40 nm. There was no emission of particulates with diameters greater than 100 nm. Addition of oil to the fuel jet A-1 caused a two-fold reduction in the concentration of particulate matter in the exhaust of a jet engine (Fig. 6).

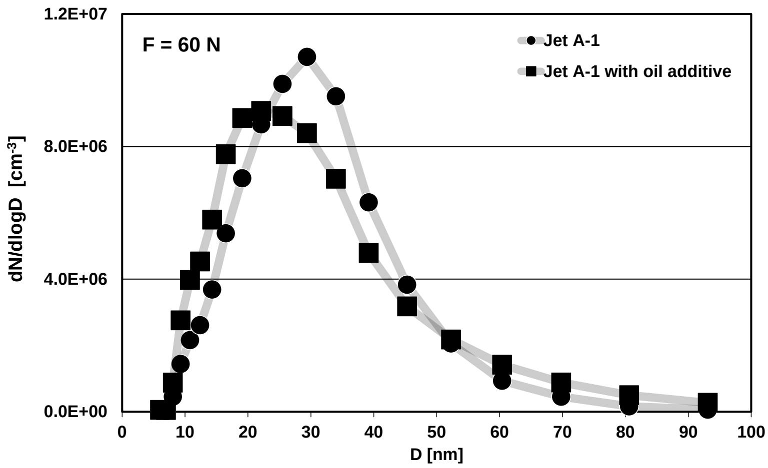

Fig. 5. Dimensional distribution of particulate matter corresponding to 60 N of jet engine thrust

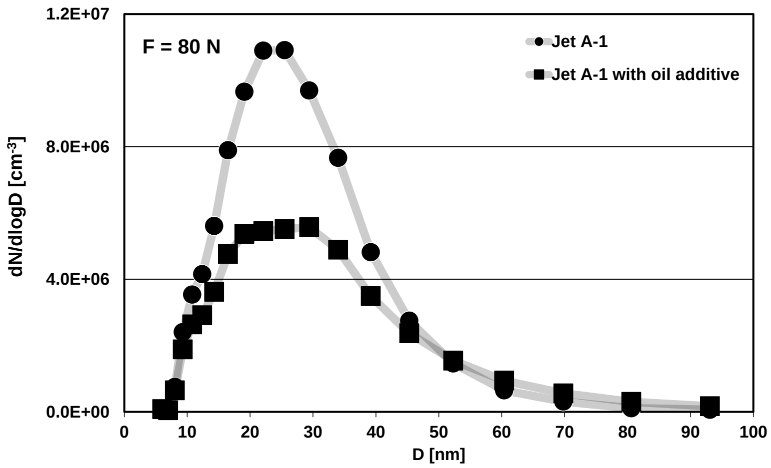

Fig. 6. Dimensional distribution of particulate matter corresponding to 80 N of jet engine thrust

Increasing the level of engine load for the engine fueled with Jet A-1 to 80–100% resulted in a reduction of the diameter of particles emitted (Fig. 7 and 8). Emissions were dominated by particles with the smallest diameters, from 20 nm to 30 nm. The use of the oil additive did not resulted in changes in the size distribution of particles compared to the distribution obtained for the particles emitted from an engine supplied with clean jet fuel. It was found that oil additive causes reduction of particulate matter concentration.

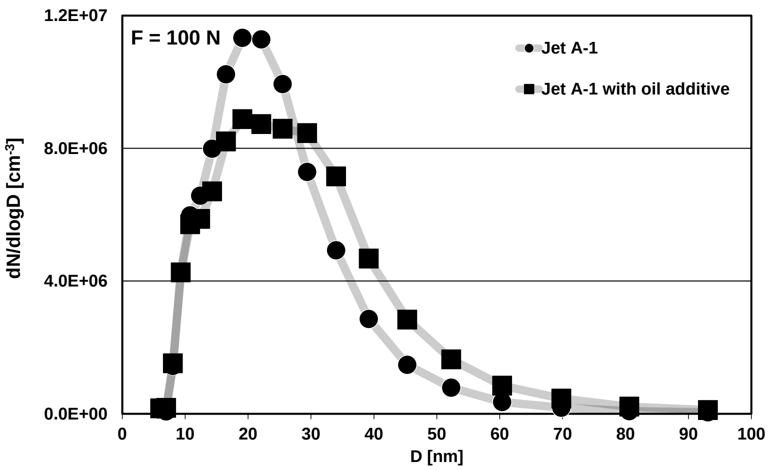

Fig. 7. Dimensional distribution of particulate matter corresponding to 100 N of jet engine thrust

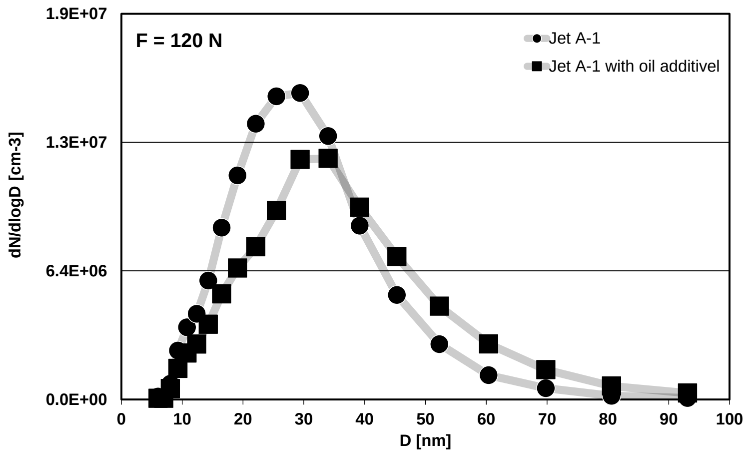

Fig. 8. Dimensional distribution of particulate matter corresponding to 120 N of jet engine thrust

4. CONCLUSIONS

In order to consider the effects of the addition oil to fuel on the intensity of the emissions of particle matter proper measurements were performed for the GTM-120 jet engine, powered with pure kerosene (Jet A-1) fuel and its blend with oil (Mobil Jet Oil II). The main result of introducing oil as an additive to jet fuel, was a change in the concentration of particles emitted by the turbine engine, in relation to the distributions recorded when using the Jet A-1 fuel without additives. In the case of a small level of thrust, oil additive causes an increase of the concentration of particulate matter in the compare to an engine powered by clean Jet A-1 fuel. There were no significant changes in the size distribution of particles emitted from the jet engine caused by the use of oil additive. Increasing turbine engine thrust resulted in a particle concentration decrease for engine fueled with oil additive. It was noticed that oil additive causes a significant reduction in the number of emitted particulates for engined operating at medium and high level of load. In the whole range of measurements the addition of oil did not result in significant changes in the size distribution of emitted particles.

REFERENCES

Hyslop N.P., 2009, Impaired visibility: the air pollution people see, Atmospheric Environment, nr 43, s. 182–195.

Kampa M., Castanas E., 2008, Human health effects of air pollution, Environmental Pollution, nr 151, s. 362–367.

Masiol M., Harrison R.M., 2014, Aircraft engine exhaust emissions and other airport-related contributions to ambient air pollution: A review, Atmospheric Environment, nr 95, s. 409–455.

Mazaheri M., Johnson G.R., Morawska L., 2011, An inventory of particle and gaseous emissions from large aircraft thrust engine operations at an airport, Atmospheric Environment, nr 45, s. 3500–3507.

Merkisz J., Pielecha J., 2015, Nanoparticle Emissions from Combustion Engines, Springer Tracts on Transportation and Traffic, New York.

Peace H., Maughan J., Owen B., Raper D., 2006, Identifying the contribution of different airport related sources to local urban air quality, Environmental Modelling & Software, nr 21, s. 532-538.

Ramanathan V., Feng Y., 2009, Air pollution, greenhouse gases and climate change: Global and regional perspectives, Atmospheric Environment, nr 43, 37–50.

Unal A., Hu Y., Chang M.E., Odman M.T., Russel A.G., 2005, Airport related emissions and impacts on air quality: Application to the Atlanta International Airport, Atmospheric Environment, nr 39, s. 5787–5798.

OCENA WPŁYWU DODATKU OLEJU NA EMISJĘ CZĄSTEK STAŁYCH Z SILNIKA ODRZUTOWEGO

Streszczenie

Emisja cząstek stałych z silników lotniczych jest zagadnieniem coraz częściej poruszanym wśród naukowców prowadzących badania w zakresie emisji związków szkodliwych z silników lotniczych. W głównej mierze spowodowane jest to faktem, że cząstki stałe emitowane z silników odrzutowych charakteryzują się bardzo małymi rozmiarami, co czyni je szczególnie niebezpiecznymi dla zdrowia człowieka. W artykule przedstawiono badania mające na celu ocenę wpływu dodatku oleju do paliwa lotniczego na emisję cząstek stałych. Stwierdzono, że dodatek oleju powoduje zmniejszenie stężenia liczby cząstek stałych wraz ze wzrostem siły ciągu silnika turbinowego. Nie stwierdzono istotnego wpływu dodatku oleju na rozkład wymiarowy emitowanych cząstek stałych.

Słowa kluczowe: emisja spalin, silnik odrzutowy, dodatek oleju