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INFLUENCE OF AIR TRANSPORT ON THE ENVIRONMENT

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Abstract. In the modern world, aviation plays an extremely important role because it allows us to cover thousands of kilometres quickly. Every year, more and more new airlines are created, trying to win the favour of passengers. Aviation serves almost all points of the globe. The main task of the industry is to ensure the rapid and sustainable development of aviation technology and infrastructure and to adapt existing capacities to new opportunities for their operation. Air transport is an integral part of the modern system of economic relations. In the conditions of the progressive international division of labour and the growth of international economic and cultural ties, its importance for the world economy is becoming increasingly significant. Air transport belongs to the branches of the world economy that develops much faster than others. Today, one of the main sources of atmospheric pollution is transport. Although aviation is significantly (approximately 15 times) inferior to road transport in terms of the pollutants emitted into the air, it affects the ecology of the upper troposphere and lower stratosphere every day. The peculiarity is that aviation affects air quality at the local, regional and global levels, unlike other forms of transport. The share of air transport in the world economy is constantly growing, which is facilitated by both technological development and the latest developments in the aviation industry, as well as globalization and ever-closer business and cultural ties between different countries of the world (Civil Code of Ukraine, 2003).

Keywords: atmospheric pollution, emissions, air transport, environment.

1. Introduction

Problem statement in general and its connection with various scientific and practical tasks. At the beginning of 2020, the aviation market of Ukraine began a gradual recovery after the coronavirus pandemic in the world. Flights are gradually resuming, and carriers are starting to work as usual.

Covid-19 significantly affected civil aviation. Many airlines could not optimize their work and thus went bankrupt. Thus, the carrier Montenegro Airlines (Montenegro) officially declared bankruptcy in 2020, Czech Airlines reorganized the company and returned to regular operations, and Ellinair (Greece) is currently awaiting financial support from the state. It is worth noting that UIA did not receive any support from the state during the pandemic and, despite this, was able to survive and continues to provide passengers with regular flights (Resolution of the Cabinet of Ministers of Ukraine, 2001; Starytska, 2009).

About three dozen airlines operate on the passenger and cargo air transportation market of Ukraine, including six leading airlines, namely Ukraine International Airlines, Azur Air Ukraine, Roza Vitriv, YanAir, Skyup, and Bees Airlines perform 95 % of the total volume of passenger transportation.

The modern system of airports is an important prerequisite for the economic development of the country and its integration into the world economy (Antonyuk, 2008).

The purpose of the work is to analyze the impact of Ukraine International Airlines PJSC on the environment. To achieve this goal, the following tasks are set:

- to analyze the carrier's aircraft fleet;
- to determine the number of flights (as of December 2021);

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• to investigate the amount of spent fuel and the impact of its combustion products on the environment.

The object of the study is Ukraine International Airlines PJSC and its impact on the environment as of December 2021.

The impact of aviation on the atmosphere is divided into acoustic (noise pollution) and chemical (aircraft engine emissions). In 1972 in Stockholm, at the United Nations Conference on the Environment, the position of the International Civil Aviation Organization (ICAO) was stated as follows: "In carrying out its role, ICAO is aware of the harmful effects on the environment that may be associated with the use of aircraft, as well as their duties and the duty of ICAO member states to achieve maximum integrity between the safe and planned development of civil aviation and the state of the environment" (Overview of the economic situation…, 2014).

According to this position, CAEP (Committee on Aviation Environmental Protection), a technical committee of the ICAO Council on environmental protection from the effects of aviation, was created in 1983. The Committee assists the Council in formulating policy and adopting new ICAO regulatory documents, Standards and Recommended Practices (SARPs) related to aviation noise, aircraft engine emissions and the more global impact of aviation on the environment. These documents are mainly drawn up in Appendix 16, "Environmental Protection" of the Convention on International Civil Aviation.

The analysis shows that civil and military aircraft affect the environmental condition of airfields and near-airfield areas. The result of this impact on the environment is the pollution of the atmosphere by combustion products of aviation, automobile and other types of fuel, pollution of soils and groundwater by fuel and lubricant materials (emergency spills of fuel from aeroplanes, leaks during refuelling, etc.), acoustic pollution and some other factors.

To protect the environment, the International Civil Aviation Organization (ICAO) has introduced certain restrictions on noise pollution from aircraft and emissions of harmful substances from aircraft engines. International standards on the ecology of civil aircraft are outlined in Volume 1, "Aviation Noise", and Volume 2, "Emissions of Aircraft Engines", Annexes 16 to the Convention on International Civil Aviation.

It is known that aircraft noise is the most disturbing factor in the negative attitude towards aviation of the population in the territories living near airports. A large number of citizens living near airports, as well as aviation workers and passengers, are affected by noise. Aviation noise negatively affects people's health (decreased or lost hearing, stress, impaired concentration, headaches).

The ICAO policy on aviation acoustic pollution includes a number of measures to mitigate noise pollution: the introduction of noise reduction technologies, the organization of flight schedules (a ban on night flights), the tightening of noise standards for the existing fleet of aircraft and the development of standards for new aircraft models. Today, radically new aircraft designs and engine concepts are being developed. Aircraft manufacturers try to work so that their products meet the highest requirements of environmental standards.

Air quality in airports. Interest in the issue of air pollution at airports began to grow in the early 1970s when the number of commercial transports using turboprop aircraft increased. Chemical pollution of the atmosphere at airports is represented by such chemical compounds as oxides of carbon (CO, CO_2), nitrogen (NOx), sulfur (SOx), hydrocarbons (HC) and suspended particles released during the operation of engines and combustion of aviation fuel. Aviation-related emission sources can spread rapidly in the atmosphere and lead to air pollution in urban areas close to airports (The State Statistics Committee of Ukraine, 2022).

Ukrainian and international air quality monitoring programs constantly require responsible aviation and government organizations to monitor air quality near airports. Particular attention is also paid to the impact of aviation on the environment, water quality, waste generation, and the impact on the local environmental condition near airports (especially the prevention of fuel leakage). Over the past decades, significant progress has been made in reducing emissions due to the improvement of the environmental friendliness of aviation fuel (partial replacement of kerosene with liquefied natural gas or biofuel) and technical improvement of aircraft engines (increasing their efficiency and reducing fuel consumption) (Resolution of the Cabinet of Ministers of Ukraine, 1999).

The burning of the main part of the aviation fuel is not carried out in the surface layer near the airports but in the high layers of the atmosphere. Scientists assume that the annually increasing emission of carbon dioxide, water and methane by aircraft engines changes the chemical and radiation balance of the atmosphere, which, together with the emission of soot sulfate aerosols, can affect the climate. Sulfur oxides and soot lead to the formation of aerosols. Aerosols and their precursors (soot and sulfates) increase cloudiness in the form of condensation trails and cirrus

clouds. Tracks from aeroplanes can remain in the sky for several minutes and sometimes hours, depending on the state of the environment. They spread several kilometres wide and resemble cirrus or high clouds.

Greenhouse gases, the emissions of which can affect the process of global warming, are of special attention among the emissions produced as a result of the burning of aviation fuel. To reduce them, airlines have two options for solving the problem:

• increase in fuel efficiency (specific fuel consumption);

• use of alternative fuels: synthetic fuels from hard coal, natural gas or biomass. Natural fuel does not contain sulfur and aromatic hydrocarbons, which significantly reduces emissions of volatile aerosols and cloud condensation nuclei, reducing the impact on the radiation balance.

In addition, studies have proven that the use of fuel purified from sulfur leads to a significant "healthiness" of the troposphere in terms of concentrations of ozone, sulfates, and nitrates.

Scientists also predict that a complete transition to biofuels could lead to the gradual destruction of tropical forests and an increase in the cost of food. In addition, its use in the long term has not been proven to reduce CO_2 emissions. However, biofuel for aviation needs is already produced in the USA, Great Britain, Germany, France, and Finland. By 2020, China, which has established fuel production from palm oil, also intends to increase the share of biofuels to one-third of the fuel used by aviation (Merkhezh, 2009).

In recent years, a number of countries fighting for ecology have been actively replacing conventional aviation fuel with cryogenic fuel (hydrogen, liquefied natural gas). When using it, the aircraft becomes more economical (fuel consumption decreases), and CO_2 emissions into the atmosphere decrease. Aviation emissions of carbon dioxide, according to various estimates, make up from 2 to 2.5 % of the total amount of anthropogenic emissions of CO_2 into the atmosphere.

From the beginning of 2020, restrictions on emissions of harmful substances were introduced, and by 2050, they plan to reduce carbon dioxide emissions by 50 % compared to the level of 2005. In addition, the European Commission insists that from 2020, the aviation industry should use about 4 % of alternative fuels. Today, hydrogen fuel is considered environmentally friendly, which emits water and a small number of nitrogen oxides during combustion (The State Statistics Committee of Ukraine, 2022).

2. Theoretical part

Analysis of recent research and publications. It is also appropriate to analyze the experience of implementing aviation standards not on the example of individual states but on the example of airlines because each of them conducts its own environmental policy and introduces its own standards. One of the leaders in the world market is the Lufthansa Group, which is an international aviation concern that includes a total of more than 550 subsidiaries and affiliated companies (Order of the State Committee of Ukraine…, 2001).

Directly, Lufthansa is one of the largest airlines, operating in 165 countries and four continents. Lufthansa employs more than 55.000 people. The company has long been committed to caring for the environment. It has one of the most technologically advanced and economical fleets in the world. The long-haul fleet consists of Boeing 747-8 and Airbus A380, two of the most environmentally friendly passenger aircraft (Aparova, 2013).

The German airline Deutsche Lufthansa AG became the first European company to have received five stars from the international rating agency Skytrax (Great Britain). Lufthansa also received an environmental award at Air Transport World magazine's award ceremony for the best achievements in the airline industry in Washington. This is reported in the press release of the airline. It received the title of ecologically oriented for the second time. In 2015, Lufthansa was awarded the Air Transport World Award for its strategic environmental protection program, according to which the airline will enter into service 263 new aircraft that meet technical requirements for fuel efficiency and CO_2 reduction by 2025. Already in the spring, the Lufthansa Group starts refuelling its planes at Oslo Airport with an ecological biogas mixture (International Airlines of Ukraine, 2018).

By comparison, total fuel consumption by commercial airlines worldwide reached 95 billion gallons in 2019, according to the International Air Transport Association, before the pandemic hit the travel industry.

The first buyer of ecological fuel will be Lufthansa, which will use it when refuelling its cargo planes at Hamburg airport. The airline has committed to annually purchase at least 25.000 litres of "green" fuel in the next five years for climate protection. In addition, passengers can buy a SAF ticket for a flight with environmentally friendly fuel, which costs significantly more than conventional fuel thanks to the

additional environmental tax. The Compensaid service was also developed in cooperation with the Lufthansa Innovation Hub. The Compensaid allows you to calculate the impact of flights and offset carbon emissions.

The Compensaid offers travellers two options: using environmentally friendly aviation fuel (SAF) or investing in climate protection projects that meet the highest standards. It is also possible to combine these two options.

Independent Ukraine, together with other states of the world, undertook international legal obligations to create an effective national legal mechanism that could reliably ensure the priority of environmental safety; ecologically safe conditions for people's life and health; implementation of precautionary measures for environmental protection, etc. (Air Code of Ukraine, 2011).

In particular, Ukraine's signing of the UN Framework Convention on Climate Change and ratification of the Kyoto Protocol should be highlighted among Ukraine's significant international achievements. With this, Ukraine has undertaken to implement a policy of reducing greenhouse gas emissions. Ukraine is among the 20 largest polluters of the planet and is forced to answer for its share of the negative consequences of economic activity. Among other types of economic activity, the activity related to the production and operation of air transport is characterized by a large-scale and ecologically harmful impact on the environment and health: civil aviation enterprises have a complex impact on the ecological state of the environment that is, simultaneously on its various components: air, land and water resources. In this regard, international organizations that consider the safety of civil aviation in general, that is, including the safety of the impact on the natural environment of the aviation activities of business entities, pay considerable attention to the analysis of the operation of air transport.

Environmental problems in aviation are related to the adverse impact of aviation on the environment. The solution to these problems is based on the current structure of the international system of environmental protection against the harmful effects of aviation.

ICAO constantly provides information to air transport companies regarding norms, standards and rules approved by the organization. Ukraine and domestic air carriers also comply with all norms and standards approved at the international level.

Summarizing the above, it is worth stating that at the current stage in Ukraine, an interdisciplinary regulatory and legal mechanism has been created. It regulates environmental factors of civil aviation safety. But, unfortunately, it needs future improvement for practical application, in particular, by developing preventive measures in this area in accordance with international requirements and standards. A positive factor is also the increase in the norms of environmental direction in the air legislation of Ukraine. But despite the priorities declared in the norms of an ecological nature, the new Air Code of Ukraine does not yet contribute to the awareness of the importance of the safety ecological component, the lack of a mechanism for bringing legal responsibility for violations of civil aviation (Forecast of the development …, 2014).

To solve the tasks, an environmental management system has been implemented and is constantly being improved, which meets the international standards of the ISO 14000 series. It ensures compliance of the company's activities with the requirements of Ukrainian and international law in this field and also helps to choose the most optimal ways to achieve the goals of environmental policy.

The Roza Vitriv airline company has implemented a system of environmental management and industrial environmental control, which includes modern environmental protection technologies and standards. The adopted Energy Saving and Environmental Efficiency Improvement Program fully complies with IATA's environmental strategy.

Aviation has its own characteristics, different from other types of transport, regarding the chemical impact on the atmosphere.

One of these features is the specific structure of exhaust gas emissions from gas turbine engines. The content of toxic components in combustion products depends significantly on the engine operation mode. Thus, at reduced modes (taxiing, landing, idling), the engine is characterized by high concentrations of carbon monoxide and hydrocarbons. And when working in the modes close to the nominal one (takeoff, altitude gain, flight mode), the content of nitrogen oxides increases significantly, and the total emission of toxic substances by aeroplanes increases.

Another feature is the emission of harmful substances. In other words, it is the emission of exhaust gases from aircraft engines, direct and by-products of fuel combustion in the atmosphere. Carbon monoxide and nitrogen oxide emissions from cars are much higher than from aircraft. However, the emission occurs in the troposphere and lower stratosphere, where ozone is present in significant quantities and

weather processes occur. That is, aviation directly affects the atmosphere (Service and technologies, 2022).

3. Results and Discussion

Private joint-stock company (PJSC) UIA is a company that works in the field of air transportation, both cargo and passengers. The company was established in 1996, and during its work, it has proven itself as a guarantor of quality, reliability and safety (Onishchenko, 2009).

Ukraine International Airlines PJSC provides air transportation on numerous Ukrainian and international routes on its own aircraft and equipment purchased under operational leasing. Today, the UIA airline has more than 40 representative offices in Ukraine and the world.

Fig. 1. Logo of UIA Airlines

Ukraine International Airlines PJSC has an extensive network of direct flights from Ukraine to Europe, the CIS countries, and the USA. The airline has signed over 100 interline and code-sharing agreements with other global carriers, including Turkish Airlines, Air Baltic, Air France, Czech Airlines, etc.

It is also worth noting that there is no air connection with Russia since the beginning of the annexation of Crimea and the military aggression in the East of Ukraine.

Ukraine International Airlines cares about the state of the environment. Therefore, it also contributed to solving the problem of global warming.

The first step towards this was the installation of winglets, and wing rings (expanded raised-end wings), which will help reduce the harmful effect of carbon emissions into the atmosphere by reducing fuel consumption.

The chemical composition of aviation fuel depends on the oil from which it is obtained and the way it is processed. Kerosene contains 20–60 % of aliphatic hydrocarbons, 20–50 % of naphthenic hydrocarbons, 5–25 % of bicyclic aromatic hydrocarbons and up to 2 % unsaturated hydrocarbons. During combustion, carbon combines with oxygen, so when burning, each kilogram of aviation fuel releases 3.15 kilograms of carbon dioxide into the atmosphere.

In addition, CO_2 easily migrates in the vertical direction, so it does not matter whether it was formed near the Earth's surface or at an altitude of 10–11 thousand meters, where most of the civil aviation corridors lie. Considering this, we can calculate that approximately 2.2 % of all anthropogenic carbon dioxide is emitted by aeroplanes into the atmosphere. Road transport accounts for about 14 %, and other types of transport - sea, rail and others emit a total of 3.8 % (Overview of the economic situation…, 2014).

Constantly increasing volumes of transportation by air transport leads to pollution of the environment by combustion products of aviation fuels. On average, one jet plane, consuming 15 tons of fuel and 625 tons of air per hour, emits the following amount of substances into the environment.

Table 1

The number of dangerous emissions into the atmosphere from the operation of the turbofan engine

Compound	Quantity
Carbon dioxide	46, 8 t
Water vapour	18 t
Carbon monoxide	635 kg
Nitrous oxide	635 kg
Sulfur oxide	15 kg
Solid particles	2,2 kg

The average duration of stay of these substances in the atmosphere is about 2 years.

3.1. Calculation of the projected number of UIA airline emissions for December 2021

To assess the environmental impact of UIA airline operations, it is necessary to understand how many flights the carrier makes per month. According to the official flight schedule presented on the airline's electronic portal, we will try to analyze the number of regular flights and their duration (Ukraviatrans, 2022).

Therefore, the total number of flights is 1084 flights for December 2021. For regular flights, the airline uses only 2 types of aircraft: Boeing 737-800 and EMBRAER-190. The total amount of time in the sky is 185260 minutes or 3087 hours.

EMBRAER-190 aircraft have a total flight time of 26,460 minutes or 441 hours in the sky, while Boeing 737-800 aircraft are used in the sky for 158.800 minutes or 2.646 hours per month. The graph also

shows the percentage value of aircraft operation, which is 85.7% for the Boeing 737-800 and 14.3 %, respectively, for the EMBRAER-190 type aircraft.

Let's try to determine how much fuel the airline plans to spend on flights and which type of aircraft is more efficient (The Derzhkomstat, 2022).

Table 2

Characteristics of aircraft

Aircraft type	Number of passengers on board	Fuel consumption	Number of hours in the sky	Number of flights	Number of passengers on 1 flight	Cruising speed
EMBRAER-190	27456	1850 km/h	441	264	104	842 km/h
Boeing 737-800	152520	2526 km/h	2646	820	186	927 km/h

So, let's try to calculate how much fuel the airline will consume in general, how much fuel is consumed per 1 flight, per passenger and which aircraft is more efficient.

To determine the total fuel consumption, we need to multiply the fuel consumption indicator by the number of hours in the sky for each of the planes.

So, for an EMBRAER-190 type aircraft, the total fuel consumption for December 2021 will be: 1.850*441=815.850 kg. The estimated distance covered during this period is determined as follows: average cruising speed*number of hours in the sky, 842*441=371,322 km.

To cover 371.322 km with an EMBRAER-190 aircraft, it is necessary to spend 815.850 kg of fuel. Let's determine how much fuel is spent per 1 km: 815.850/371.322=2.197 kg/km.

The average distance covered by one flight: 371.322/264=1,406 km.

To find out how much fuel is “consumed” by one passenger on a flight let’s multiply the average flight distance by the fuel consumption in kg/km and divide by the number of passengers on board: 1.406*2.197/104=29.70 kg of fuel is consumed per passenger on the flight. Fuel consumption per 1 passenger/km is 21.125 g/km.

We will perform a similar calculation for a Boeing 737-800 type aircraft.

The total fuel consumption for December 2021 will be 2.526*820=6, 683, 796 kg. The bearing distance covered during this period is determined as follows: average cruising speed*number of hours in the sky, 927*2.646=2.542.842 km.

To cover 2.542.842 km with a Boeing 737-800, it is necessary to consume 6.683.796 kg of fuel. To find out how much fuel is consumed per 1 km, let’s divide the total fuel consumption by mileage: 6.683.796/2.542.,842 = 2.62 kg/km.

Dividing the distance by the number of flights, we find out the average distance one flight covers: 2.542.842 /820=3.101 km.

To find out how much fuel is “consumed” by one passenger on a flight, we multiply the average flight distance by fuel consumption/km and divide by the number of passengers on board: 3.101*2.62/186=43.68 kg of fuel. Fuel consumption per 1 passenger/km is 14.08 g/km.

So, as we can see from the calculations, the Boeing 737-800 is more efficient, thanks to the plane's cabin being equipped with more passenger seats.The total fuel consumption of the UIA airline company for December 2021 is 815.850 kg + + 6.683.796 kg = 7.499.616 kg of fuel.

Our society is characterized by a high level of use of modern technical means and devices, which are designed to meet people's life needs. The equipment is becoming more automated every time, and as a result, more energy-consuming.

In the vicinity of airports, groundwater is polluted with petroleum products mostly due to leakage of liquid fuel during the refuelling of planes, as well as due to technical errors during its transportation and storage. When an aeroplane takes off and lands, a certain amount of liquid and gaseous fuel combustion products are released into the atmosphere, settle near the runway and accumulate in the soil (State Aviation Administration, 2018).

3.2. Formation of measures to reduce the impact of harmful and dangerous factors on the environment

Safety is a priority area in the work of UIA. International flight safety certificates (IATA) serve to confirm this. According to the received certificate, the level of safety of the operational activity, technical support and maintenance of aircraft, work of the crew,

as well as control of the aircraft is at a high level (The State Aviation Administration, 2022).

In the process of studying the current trends in the development of the "green" direction in the aviation industry at the global level, it can be confidently stated that they have great potential for improving productivity and efficiency. In addition, integrating the principles of "green growth" with regard to long-term strategy and technological development priorities, as well as thanks to large-scale and coordinated support at the state level, leading airlines are actively developing and implementing scientific and technical developments to radically improve various aspects of their operations. As world experience shows, the implementation of such a concept requires large investments and requires state support at all stages of system implementation and development.

Therefore, air transport causes much damage to nature and the population, and a significant share of pollution belongs to airports. At the same time, taking off, aeroplanes release thousands of tons of harmful emissions into the atmosphere, with their greatest amount occurring during takeoff and climbing, which indicates their significant concentration in the vicinity of airports.

Taking into account all of the above and considering the most important problem of modern society, the limited amount of resources, including natural, there is a need to introduce "green" technologies in air transport.

Therefore, an important stage of the introduction of "green technologies" at aviation enterprises is the formation of an effective system of environmental management.

The environmental management system is a part of the integrated management system of the airline, which is used to implement the environmental policy and manage environmental aspects. The functioning of the environmental management system is aimed at improving the environmental characteristics within the aviation enterprise through periodic analysis and assessment. The environmental management system is the necessary condition for managing the sustainable development of the aviation enterprise, which includes a complex of processes and methods that enable the enterprise to reduce its impact on the natural environment (International Airlines of Ukraine, 2022).

4. Conclusions

It was analyzed that in December 2021, the airline plans to perform 1,084 flights to various cities around the world. At the same time, the negative impact is expressed in atmospheric pollution by fuel combustion products, acoustic pollution, an increase in the greenhouse effect, and a harmful impact on the health of people who work directly at aviation enterprises and the population living near airports. Measures that will ensure effective environmental management at the enterprise are presented, in particular:

- use of alternative types of fuel;
- improvement of aircraft;
- flight schedule optimization, etc.

Today, measures that will reduce noise impact zones and the volume of emissions of pollutants into the atmosphere (despite the increase in air traffic intensity) are of crucial importance.

Thus, to reduce the emission of aircraft engines, experts suggest optimizing the aircraft flight mode (at the nominal operating mode of engines), which significantly reduces the emission of nitrogen oxides in the airport area.

Aviation ground maintenance facilities, special vehicles, repair bases, aviation fuel storage tanks and fuel and lubricant warehouses, and fuel filling and distribution systems significantly contribute to the pollution of the natural environment. Therefore, the study of the impact of aviation equipment on the state of the surface atmosphere, hydrosphere and soil, as well as the acoustic pollution of the territory, is very relevant.

2. The problem of protecting people and the natural environment from the harmful effects of aviation equipment is quite complex and should be solved by implementing a set of measures taking into account technical, financial and organizational capabilities. Local authorities are faced with the task of rational organization of these territories, taking into account their ecological state.

The methodological basis for creating an environmental management system in the application of aviation equipment is normative data for civil aviation (ICAO Convention on International Civil Aviation), state standards, etc.

As problems of building a modern decision-making support system in managing the ecological safety of the air environment, it is possible to identify the following:

1. The problem of analyzing the ecological state and directions of influence of gas turbine engines of mobile man-made objects on the state of the environment.

2. The problem of developing a scientific and methodical apparatus for determining pollutants in gas turbine engines of mobile man-made objects.

3. The problem of assessing the pollutants properties of aircraft gas turbine engines and other mobile man-made objects.

4. The problem of forecasting the condition and assessment of environmental parameters under the influence of gas turbine engines of mobile man-made objects and the development of scientific and practical recommendations for their application.

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