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INVESTIGATION OF THE CAUSES OF MALFUNCTIONS OF AI-25TL GAS TURBINE ENGINE

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Abstract: *The article analyzes the causes of malfunctions of the AI-25TL gas turbine engine based on statistical materials from its maintenance in the Bulgarian Air Force. The creation of perfect and highly economical aviation engines is inevitably associated with maintaining operating modes close to the limits of stability and strength with an optimal combination of many parameters. The complexity of fulfilling these conditions comes from the need to ensure high efficiency and reliability of aviation engines in a wide range of altitudes and flight speeds, while maintaining their operational characteristics and operating modes. Ensuring high reliability of aviation engines in the process of operation is a complex task, which arises from the diversity of factors affecting reliability, the accounting of which is often difficult due to their random nature. In this regard, in the process of operation of the AI-25TL gas turbine engine, significant attention is paid to studying the causes of the occurrence, development and possible consequences of specific malfunctions.*

Keywords: maintenance, aircraft, engine

1. Introduction

The development of aviation technology leads to the creation of new, increasingly advanced aircraft, which, regardless of external conditions, will solve important tasks in conducting combat operations. Ensuring the necessary characteristics in the use of aircraft is possible only if they have a gas turbine engine with high thrust and high operational reliability [1].

Modern aircraft engines are very responsible and complex devices, consisting of a large number of units and assemblies that are subject to the influence of various factors. Automation of control and high requirements for engine regulation processes have led to the creation of complex systems, the quality of which largely determines the achievement of the design parameters and flight safety.

The complexity of engines during their development, the increased requirements for flight safety in the conditions of constantly increasing speeds and altitudes of aircraft use, the high cost of engine production are the main reasons for the great attention paid to the problems of the reliability of aircraft engines [2].

In the process of operation, under the influence of external and internal factors, the state of the gas turbine engine (GTE) is constantly changing.

The complexity of the design of modern GTE is associated with an increase in the number of units and systems, and this in turn leads to an increase in the number and types of malfunctions.

The object of the study is the AI-25 TL double-circuit turbojet engine, which is used on the L-39ZA training aircraft.

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Figure 1: AI-25TL gas turbine engine

2. Analysis of the Malfunctions of the AI-25TL Gas Turbine Engine.

Today, the Bulgarian Air Force has 10 jet training aircraft in service L-39ZA, but only half of them have extended life and undergone major overhaul to maintain airworthiness. Bulgaria purchased a total of 36 aircraft from the former Czechoslovakia. The first batch of 18 L-39ZA was ordered in 1985. The second batch, also of 18 machines, arrived in our country in 1990. After the expiration of the originally assigned technical resource, the majority of the aircraft have been sold (including all of the first batch), and six of the remaining ones have had their service life extended in stages as they undergo overhaul by the manufacturing company.

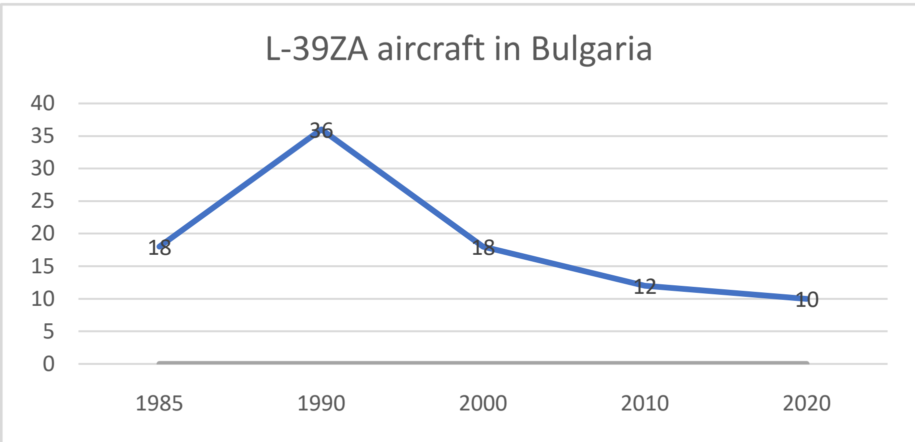

Figure 2: Number of L-39ZA aircraft

After the overhaul from 2013-2016, the machines received an extended total technical resource to 32 years and an inter-repair resource of 7.5 years and 1500 hours, whichever happened first. The extension of the resource is certified by issuing a special bulletin from Aervodohody aircraft (AVA) for the aircrafts that have undergone capital-restorative repair (in accordance with the SLEP program developed by the company). This bulletin specifically states that the life extension remains valid provided that the aircraft are operated in accordance with the manufacturer's instructions. This means that the limitations laid down in the operating documentation are followed and only new and/or refurbished spare parts approved by the manufacturer to maintain airworthiness are used when repairing the machines [4].

According to the original manufacturer, the maintenance of aircraft that have been in service for 25 years or more requires completely new approaches and repair methods designed and developed to ensure trouble-free operation of the aircraft up to the age of 40 years. Applying the original old repair methods poses a significant risk to both the aircraft and its crew [5].

The main operational requirements imposed on engines are related to their trouble-free operation to ensure flight safety. Reporting and collecting information on engine malfunctions makes it possible to establish the nature of their manifestation and the degree of their repeatability. Based on mass observations on the occurrence and manifestation of various malfunctions, measures are developed and implemented aimed at increasing the level of reliability of aircraft engines.

These measures are identified on the basis of collected, processed and analyzed statistical material on the malfunctions that occur during engine testing and operation.

Sources for collecting information on aircraft engine malfunctions are:

- fault reporting cards[8];
- monthly analyses;
- reports on the circumstances of aircraft accidents;
- complaintreports [9];
- the lists of defects found during repairs [10].

Information on the quantity and nature of malfunctions of aviation GTEs obtained during their operation is of extremely great importance in developing measures to increase their operational reliability, determine the technical resource and improve the methods of technical operation [3].

Based on the analysis of information on GTE malfunctions, the following main tasks are solved:

- the main directions of experimental and theoretical research to increase reliability are determined;
- the operational reliability of existing and incoming aviation equipment is assessed;
- the regularity of changes in the operational reliability of GTEs depending on the working hours and storage time is established;
- measures are developed to increase the operational reliability of existing and incoming aviation equipment;
- the most unreliable parts and details, design and production defects are revealed;
- additions and amendments to the current technical documentation are developed [6].

The AI-25TL engine has been operated in the Bulgarian Air Force for a sufficiently long time, and extensive experience has been gained in detecting, analyzing and eliminating operational malfunctions.

For the analysis of the most characteristic malfunctions, data on the AI-25TL engines operated in the Air Force for the period 1985 - 2020 are used.

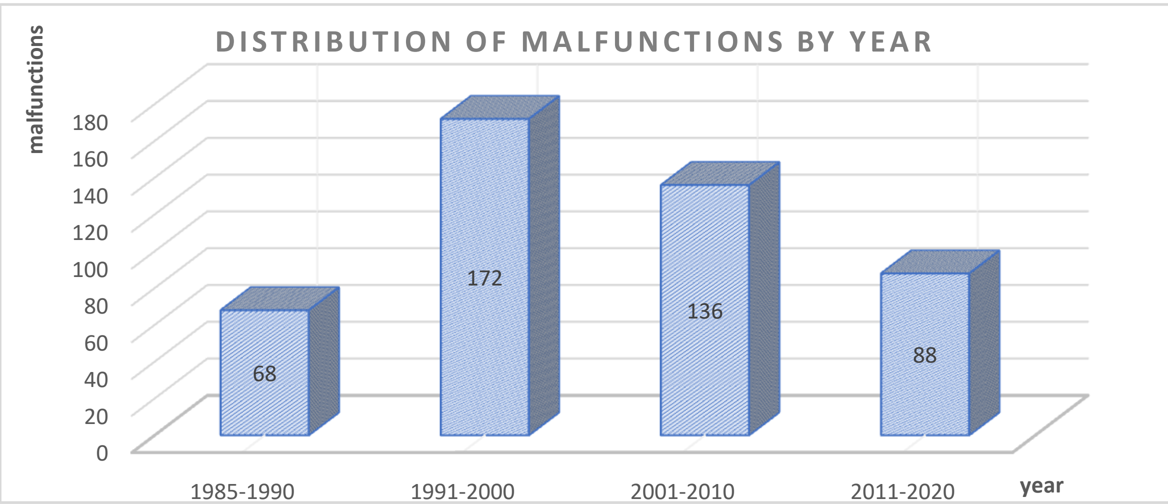

Figure 3: Distribution of malfunctions by year

Some of the most common malfunctions and their causes in the AI-25TL gas turbine engine are shown in Table 1.

Table 1: Most common malfunctions and their causes in the AI-25TL gas turbine engine

	MALFUNCTIONS	MAIN CAUSES
1	The motor rotor does not spin after pressing the "start" button.	Unfulfilled measures, according to the technical documentation for preparing the engine for start-up.
2	When the engine is started, the fuel does not ignite	When starting the engine, the fuel does not ignite.
3	During the engine start-up process, the rotor of the high-pressure compressor (HPC) is not sufficiently spun by the air starter SV-25.	The air pressure at the inlet to the air starter CB-25 is lower than the set values.
4	A sharp increase in the temperature of the gases after the turbine when starting the engine with a tendency to exceed the permissible values.	Increased fuel consumption at startup.
5	The engine randomly shuts down during startup or in any of the operating modes.	Presence of air in the fuel system.
6	The engine operating parameters do not change when the throttle is moved to increase the engine operating mode.	Temperature regulator malfunction.
7	The engine continuity time does not comply with technical standards.	The throttle packages are dirty.

The pie chart in Figure 4 shows the distribution of malfunctions across the individual engine systems.

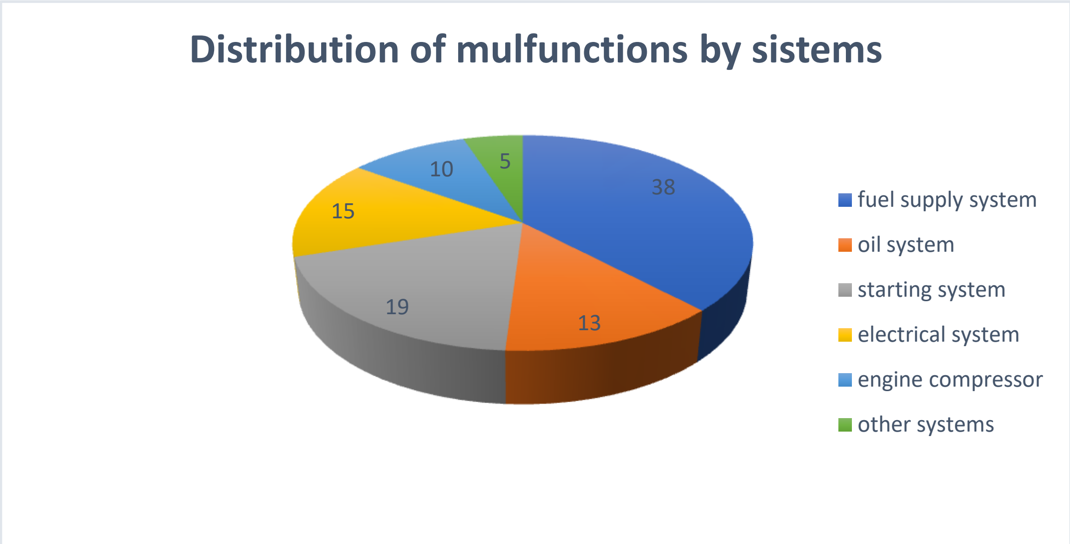

Figure 4: Distribution of malfunctions by engine systems

From Figure 4 shows that the largest share is occupied by malfunctions in the fuel system - 38%. In it, the largest number of malfunctions were registered in the fuel regulator - unit 4000.

The large volume and complexity of the functions performed by the system for regulating the fuel supplied to the engine, as well as the significant number of diverse and complex elements and units included in it, determine the large number of malfunctions in this system. These malfunctions in the fuel automation lead to non-starting, self-shutdown and engine surge, stalling and oscillation of the rotor rotation frequency, an increase in the temperature of the gases after the turbine with a tendency to exceed the permissible values. In many cases, malfunctions in the regulation system are eliminated during operation by replacing individual units or by adjustment [4].

The oil system is designed to supply oil under pressure during engine operation to its friction surfaces in order to reduce friction and remove heat generated during friction of the hottest parts. It determines the reliable operation and resource of the engine. The summarized data on the malfunctions of the AI-25TL engine make it possible to indicate the most characteristic malfunctions of the oil system:

• appearance of chips in the oil;
• increase in oil consumption;
• deviation of the oil pressure and temperature from the values specified in the operating instructions;
• fuel getting into the oil.

The main reasons for the appearance of chips in the oil are due to wear of the rotor bearings, oil seals and parts of the drive units.

One of the most likely causes of oil pressure dropping below normal values is a violation of the adjustment of the pressure reducing valve or a malfunction of the valve itself (broken spring, solid particles getting under the valve, which hold it in the open position). When the pressure oil pump or its drive is destroyed, the pressure in the system drops sharply, which leads to engine overheating.

The following contribute to an increase in oil pressure above the permissible value: malfunctions of the pressure reducing valve, contamination of oil filters and oil nozzles, which supply oil for lubricating bearings and gears. The latter malfunction is especially dangerous, since contamination of filters and nozzles leads to oil starvation of the bearings, their overheating and, subsequently, to their destruction.

The increase in oil temperature above the permissible values can be caused by an insufficient amount of oil in the tank, hot gases entering the engine oil cavities due to poor seal performance.

Increased oil consumption in the absence of external leaks indicates unsatisfactory seal performance.

In flight, hail, ice or birds may enter the engine. Depending on their mass and size, they cause damage or breakage of the working and straightening blades of the compressor and unacceptable imbalance in the engine rotors. Unstable operation of the compressor and self-shutdown of the engine are also possible. If a bird hits, the flow at the inlet to the compressor may become uneven both along the radius and circumference of the flow section, which leads to instability in the operation of the compressor. A bird hitting the AI-25TL engine would cause damage and tearing of the material of the blades of the engine impeller. This leads to premature engine retirement.

When examining the malfunctions related to engine operation by the flight and engineering staff, it is seen that they are the result of:

- improper preparation of the engines for start-up (uncleaned platforms and stands, presence of foreign objects in the inlet device and air ducts, forgotten plugs on the air intake and outlet nozzle);
- exceeding the permissible engine operating time at maximum mode and the permissible values of the rotor rotation frequency and the temperature of the gas flow after the turbine during a continuity test of the engine;
- failure to perform the absolutely necessary and mandatory engine warming up before its test and cooling the engine before bringing it to rest.

The analysis of the malfunctions related to the implementation of regulatory and repair work shows that they are a result of forgetting tools, fasteners and locking elements in the input device, as well as incorrect assembly and disassembly of parts and assemblies.

3. Conclusion

Therefore, based on the results of the statistical analysis of the malfunctions, it is concluded that the AI-25TL gas turbine engine, like any other technical object in the process of operation, deviates from the set norms for changing the parameters. Taking into account the high requirements from the point of view of flight safety, it is necessary to constantly monitor the trend of changes in the controlled parameters and prevent them from exceeding their pre-failure value. It is mandatory to comply with the requirements of the technical operating instructions and the documents regulating the repair regarding the overall operation, maintenance, storage and repair of the AI-25TL gas turbine engine.

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