ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0012.2846

DIAGNOSTICS AND ANALYSIS OF JET ENGINE MALFUNCTIONS

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Abstract

The article describes emergency situations occurring in the propulsion system of an aircraft with the jet engine used in Poland on planes such as MiG-29 or F-16. The article also presents statistics of polish aircrafts damage over the years. Due to the technological progress of turbine engines used in fighter aircraft, the authors decided to discuss the issue of monitoring emergency states in this study. In particular, efforts have been made to ensure that damage to the aircraft engine can be prevented by monitoring its operation with the equipment available on the aircraft. Counteracting phenomena that occur in the jet engine can lead to permanent damage; can lead to an increase in the safety of the pilot and the local population, but also to a reduction of costs. The authors also decided to se the threats that occur during take-off and landing, and the flight when they land outside the plane. Jet engines are almost reliable and most common cause of engine damages as the analysis shows are foreign bodies, particularly dangerous for a turbine engine on or near the runway, as well as birds, which provides to mechanical damage of engine. Securing the airport against foreign objects on the runway is one of the most important tasks of ground staff.

Keywords: *jet engine, aircraft, diagnostics, safety*

1. Introduction

The propulsion unit of the combat aircraft is a jet engine with aggregates. The purpose of the propulsion unit is to provide the necessary flight to perform the flight and the tasks performed before the aircraft. The main element of each drive unit is the engine. Over the years, due to the evolution of turbine aircraft engines, there has been a shift from single-flow engines to two-flow motors.

Three types of combat aircraft are operated by the Polish Air Force. These are F-16 multirole aircraft, and MiG-29 fighter aircraft and the SU-22 fighter-bomber plane. The basic parameters, relevant from the point of operation of the drive unit are shown in Tab. 1.

Tab. 1. Basic parameters of aircraft engines: MiG-29, F-16, Su-22 [1]

Data	RD-33	F100-PW-229	AŁ-21F
Thrust without afterburning [kN] with afterburning [kN]	2 × 50.0 2 × 82.0	79.2 129.4	76.5 109.8
Percent increase in thrust after inclusion afterburner [%]	64.0	63.4	43.5
Mass flow rate [kg/s]	2 × 77.0	120.0	104
The temperature before the high-pressure turbine [K]	1530	1675	1385
Number of compressor stages	4F+9S	3F+10S	14S
Combustion chamber	ring	ring	tubular-ring
Turbine	1 + 1	2 + 2	3
Weight [kg]	2 × 1 050	1696	1720
Max. The speed of the high-pressure compressor [rpm]	15 539	13 450	8316
Max. The speed of the low-pressure compressor [rpm]	11 000	10 400	

Schematic diagram of a gas turbine jet engine, the course of the calculated basic gas-dynamic parameters (temperature, pressure and speed) shown in Fig. 1, in which specified elements: 1 – fan, 2 – high pressure compressor, 3 – combustion chamber, 4 – high pressure turbine, 5 – low pressure turbine, 6 – afterburner.

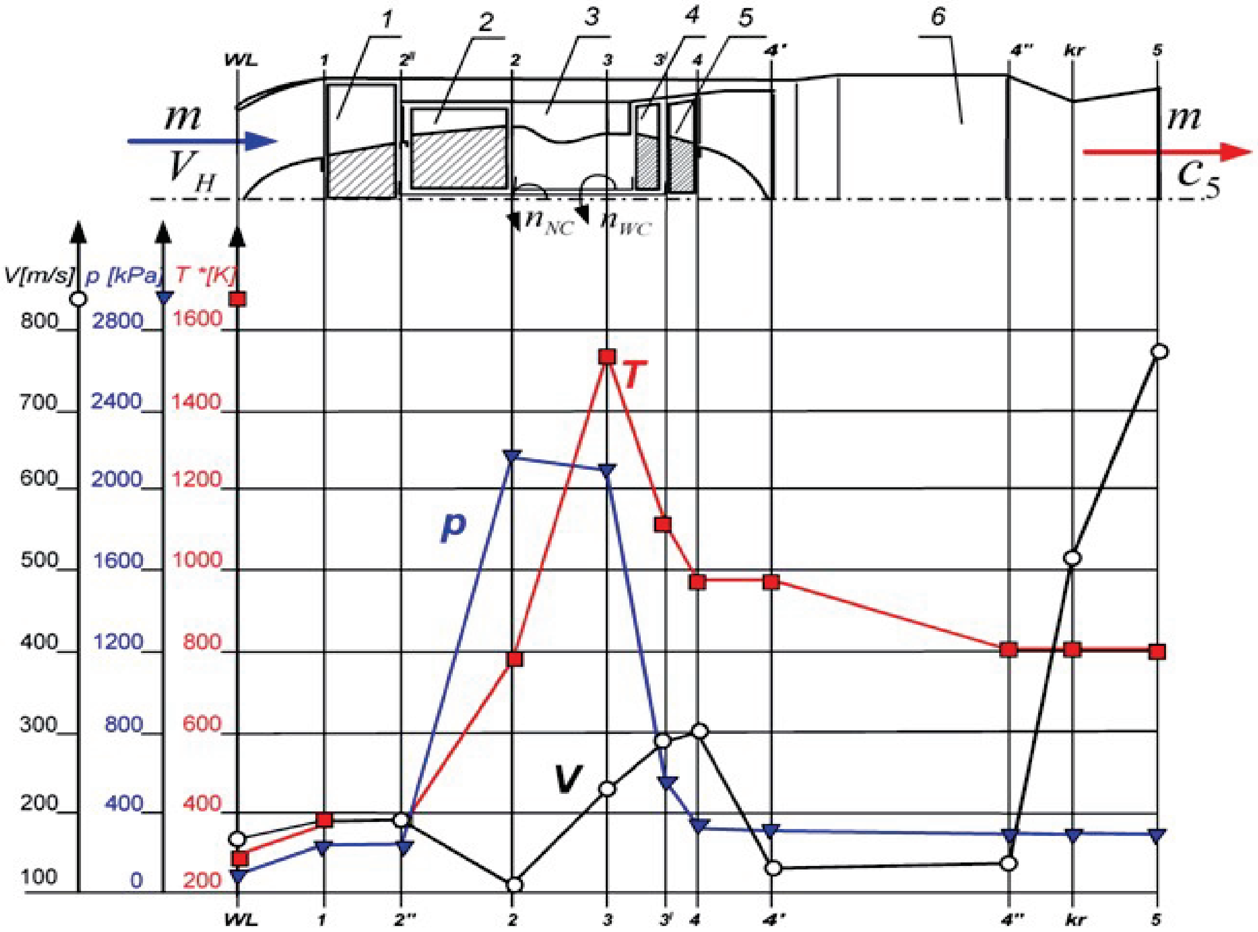

Fig. 1. Diagram of a turbofan jet engine turbine bearing course gas-dynamic changes in the basic parameters [1]

The results of the analysis of these parameters from Tab. 1 show that a single RD-33 engine gives way to the two thrust engines [4, 5, 7, 8, 11]. However, two RD-33 engines provide very good dynamic parameters (excess thrust) and double survivability on the MiG-29 aircraft.

2. Emergency states

Turbine jet engines are devices with a very complex structure, and their performance parameters depend on the performance of aircraft as well as flight safety [13]. According to statistics, if not for damage caused by suction of foreign bodies, the turbine jet engine could be described as the most reliable element of the aircraft. However, this does not mean that turbine aircraft engines are completely free of defects. Analysis of the reliability of aircraft used in the Armed Forces of the Republic of Poland in 2009-2013 shows that 9% of aviation events were caused by engine damage as shown in Fig. 2.

Over the last few years in the aviation of the Armed Forces of the Republic of Poland, a significant part of aviation events concerned RD-33 engines (Fig. 3.) used on MiG-29 aircraft [6].

Damage monitoring of the MiG-29 aircraft power unit is a continuous process carried out through proper management of the aircraft maintenance process, ongoing analysis of data from flight recorders and the use of data from on-board diagnostic systems [3].

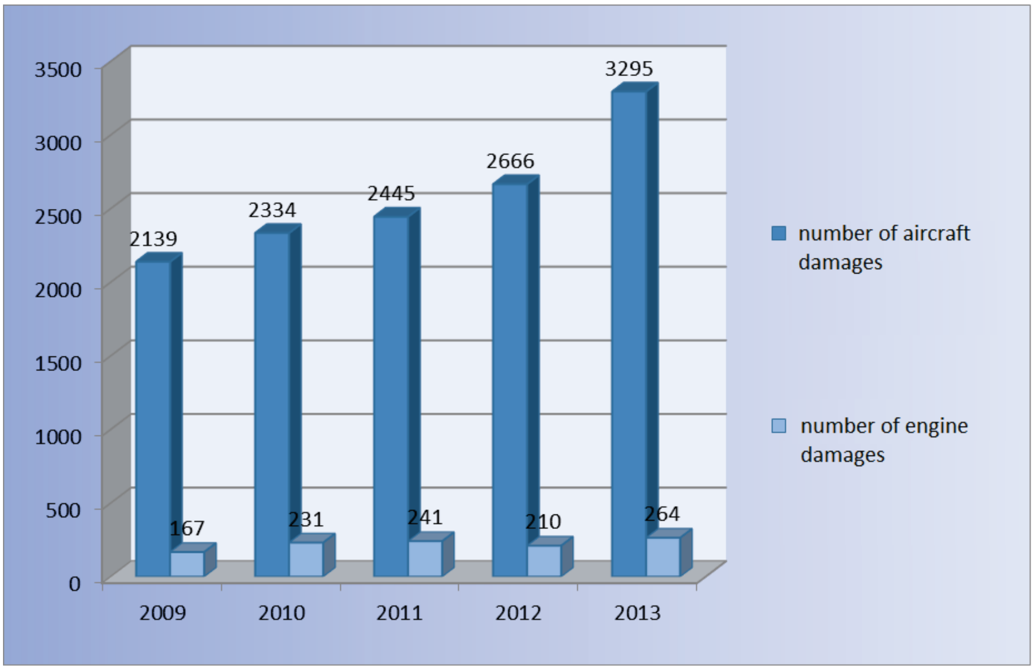

Fig. 2. Number of damage to aircraft related to the failure of the engine in the Polish Armed Forces in 2009-2013 [1]

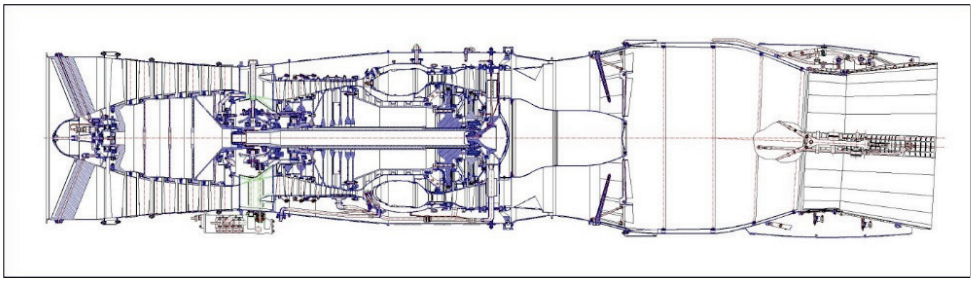

Fig. 3. Cross-section of the RD-33 engine [1]

Registration of flight parameters on the MiG-29 aircraft is carried out using the following recorders:

- TESTER U3-Ł, recorder for recording parameters: altitude, speed, linear overloads, horizontal stabilizer and aileron movements, movement of pedals and joystick, rudder stock rudder movement and DSS,
- ATM – QR6D, the on-board data recorder is an additional (operational) flight data recorder built into the MiG-29 aircraft,
- S2-3a/MiG-29, the recorder is intended for recording, during flight and on the ground, the parameters of the main systems of the airplane and its equipment.

Warning and emergency signals are provided from systems for blocks of emergency and warning signals of BAPS, which activate appropriate signalling devices with a colour filter:

- yellow, if they are warning signs,
- red, if they are emergency signals,
- green, if they are information signals.

3. Analysis of causes of propulsion failure and counteractivity

The driving unit of the MiG-29 aircraft being considered is a particularly complicated system since its core consists of two RD-33 engines [9]. Failures and inefficiencies of the drive unit can be caused by a number of different factors, which can include:

- the degree of depletion of elements and components of SP,
- failure of blocks generating signals about disability,
- errors in piloting technology,
- operational environment (condition of airport pavements and the related possibility of occurrence of FOD phenomena, the presence of wild game at the airport, the status of occurrence of birds at the airport and in its vicinity).

Failures of the power unit can take place throughout the entire exploitation process, from its launch on the ground, until the engines are shut down after landing.

The inefficiencies of the drive unit components are very difficult to rank with those that can occur on the ground and those that occur essentially in the air. The ones that happen only on the ground can include failures that prevent completion of the engine starting process in accordance with the applicable rules. The following are some cases of malfunctions related to the use of the MiG-29 aircraft by the Polish Armed Forces.

Case 1

The engines were started in the range of manual selection of the order, in the system – left, then right. After 6 minutes from the start of the left engine, the pilot received a message in the form of lighting the OIL PRESS LEFT lamp, and a message about filings in the oil. The remote control immediately moved the motor control levers to the STOP position, switching them off.

As a result of the analysis of this event, several preventive recommendations were introduced, i.e.:

- an obligation has been introduced to check and clean the engine oil filter, on RD-33 engines as part of "Special inspections and checks" after every 25 ± 5 hours of engine operation;
- the operation algorithm after the "OIL FILTER" signal has been supplemented in the Russian technical engine operation manual with the wash gasoline wash order and oil flush irrigation;
- a rule was introduced, according to which at the airports with oil consumption test sets, their operation would be carried out only by trained specialists in technical service groups;
- an order to enter in the “Engine Books” engines of the re-assembled information about the elaborate bearing's service in the plant, in the case of building this product in the second category.

Case 2

After the start of both engines, the pilot noticed on the board of emergency signals the light of the OIL PRESS RIGHT lamp and heard the command of the CHIPS RIGHT ENGINE, REDUCE RPM voice information system. The pilot informed the technician about the failure, and then turned off the engines – right and then left. As a result of the tests and expert opinions, the commission conducting the event determined that the appearance of filings in the right engine oil system was caused by the inability of the right angular drive, which in turn was the result of improperly repaired this drive in foreign contractor repair plants. In technical terms, the cause of the incident was the damage to the inner surface of the pipe shield.

Recommendations were introduced in the event of the phenomenon of filing of such assemblies as the aircraft aggregate drive box (KSA), engine aggregate drive box (KDA) and angle drives.

Case 3

During the flight, the pilot heard a single voice command from the informant LEFT VIBRATION, while not noticed information about the motor vibration on the fault indicator – SCREEN. The operating and temperature parameters of the gases of both engines were in accordance with the technical conditions. When switching off the engines after depreciation of the aircraft technician, he heard “unusual working noises" of the left engine. In performing the checking of the left-engine compressor, a crack of the oil chamber casing of the left front engine support, about 100 mm in length, was found, as well as oil traces at the point of fracture. analysis of the materials of objective control of flights coming from the MiG-29 aircraft clearly indicates that the occurrence of the phenomenon of a significant increase in the level of engine vibrations (from 15 mm / s to 25 mm / s and pulsation about 20 mm / s) began on the aircraft 15 flights back.

Case 4

After the start, the pilot made a bend collection by 180 ° and joined the leading aircraft on the left. When making a turn on the straight line, in order to make a flight over the airport, the pilot noticed the OIL PRESS RIGHT lamp lighting up, at the same time the EKRAN – OIL PRESS RIGHT system command and the OIL PRESSURE RIGHT command, REDUCE RPM E-11. Without reporting the commander of the grouping, the pilot made a departure from the formation, going to ascend and securing the speed of the aircraft. After switching off the engine, leaving the plane straight, he released the landing gear, flaps, and landing. He landed the plane properly, released the braking parachute and, after finishing the run, he turned to the parking and turned off the engine.

The reason for the disconnection of the kinematic connection of the oil aggregate with the gearbox of the motor aggregate drive was the damage to the teeth of the splines connection of the aggregate drive shaft with the gearwheel of the aggregate drive box caused by the lack of concentricity of the cooperating elements.

4. Conclusions

The parameters of aircraft and flight safety depend on the parameters of a turbine jet engine [2, 12]. According to the statistics, excluding the events involving suction of foreign bodies to the TSO inlet, the engine would be the most reliable element of the aircraft. The engine damage itself by foreign bodies can be divided into two groups:

- damage to the turbine engine through elements, particles and objects (e.g. pieces of concrete, ice, snow or construction elements "lost" from the aircraft or vehicles) loosely located on the road surfaces during the movement or stopping of the aircraft,
- damage to the turbine engine by sucking a bird during a self-flight.

Monitoring of the damage to the power unit in the changing operating conditions of the MiG-29 aircraft is an extremely complex issue that must be viewed through the prism of the multi-faceted perception of the operation of aircraft technology.

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Manuscript received 14 March 2018; approved for printing 29 June 2018