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SOME PROBLEMS OF EXPLOITATION OF JET TURBINE AIRCRAFT ENGINES 0--ETC(U)
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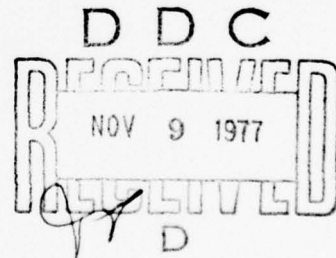
FOREIGN TECHNOLOGY DIVISION



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by

Andrzej Slodownik



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SOME PROBLEMS OF EXPLOITATION OF JET
TURBINE AIRCRAFT ENGINES OF LOT POLISH
AIR LINES

Andrzej Slodownik, M. Eng.

The article discusses the equipment of a turbine engine with control-measurement systems and the possibilities arising therefrom of evaluating the technical status of the NK-8-4 jet turbine engine with which the Il-62 airplane, used by LOT Polish Air Lines, is equipped.

The isotopic method of determining the technical status of turbine aircraft engines is also discussed.

Turbine aircraft engines which are considered the prime mover of contemporary communication airliners are characterized by great dependability of operation. Two groups of factors are involved in such large operational dependability of which, the first group concerns the very construction of the engine, and the second concerns the level of technical service. It is not necessary to argue that even the most worked on construction to fulfill the condition of a high certainty of operation demands a fitting cost of service labor, which is that much larger, the more intensive the exploitation of the device is. The most useful, in terms of exploitation, would be that solution in which, on the basis of a reading of a selected set of running parameters (recorded automatically) it would be possible to define, with a considerably high level of confidence, an anticipated period of operational dependability. In such a solution we can imagine that an installed system to

record running parameters would cooperate with an automatic data transformation system, which system would be able to work out suitable information for the airplane crew and for the ground personnel about engine status, making it possible to avoid break-down situations. Despite constant technological progress, current solutions nevertheless deviate considerably from the concept presented.

Concerned with the problem of automatization of the control process of the technical status of engines, the problem of selecting a suitable representative set of parameters must be solved, which would have to record automatically and find the functional dependence between the technical status of the engine, determined by the value and run of the selected set of parameters, and the anticipated time of dependability of operation.

The actual status of operations in this field lets us confirm that we stand at the threshold of a solution which in the near future will allow us to revolutionize the current systems of technical service. The concept of aircraft engine installation life (strictly forced upon by the manufacturer) will disappear, because the exploiter, on the basis of full knowledge of its technical status will be able to determine the period of time he can let the engine be exploited, having the certainty of its operational dependability.

According to S. Szczecinski, the proper information number on the technical status of a turbine engine and its automatic control system can be obtained only on the basis of recording the run of selected parameters under conditions of transition, i. e., during a change of rotational speed of rotors from conditions of "low gas" to limit velocity, and the reverse. Thus, desiring to evaluate objectively the technical status of an engine it would be necessary to compare the runs of selected parameters recorded under "transition" conditions with standard runs. The system recording these runs could be built up directly on the deck of the airplane.

In studies conducted to define the technical status of turbine aircraft engines the properties of radioactive isotopes were used. These studies dealt with definitions with the help of radioactive isotopes of those engine parameters, the knowledge of which has a decided influence on evaluating the technical status of the engine. The concern here is to define the degree of use of the engine rotor bearings and examining the size of turbine tip clearance. Introduction to the material out of which the bearing of the radioactive isotope is made makes it possible to evaluate directly the degree of utilization of the bearing by measuring the amount of threadbare irradiated material which was found in the installation of an oil engine.

Knowledge of the degree of utilization of bearings makes it possible to evaluate the size of the clearances in a rotor bearing system of a turbine engine. The method of determining the size of the tip clearance of a turbine by means of a radioactive isotope elaborated and practically verified in the WK-1 engine depends on the placement in the turbine casing of an irradiated graphite wheel, which as the tip clearance decreased was scraped down by the engine turbine. A decrease of the irradiated material is the basis for determining the actual tip clearance of the turbine. The above methods of determining the parameters of the technical status of the engine do not exhaust the possibility of uses for those purposes of radioactive isotopes.

An advantage of the methods mentioned is, above all, the fact that they permit tracing during exploitation of the formation of engine parameters, which is the starting point to the prognosis of the time of its operational dependability.

According to Western sources prognosis of the time of operational dependability of an engine requires knowledge of the size and run during the exploitation process of about 200 of its parameters, and with that, the size of the turbine tip clearance and the degree of use of the rotor bearings.

A service system of a turbine aircraft engine depends on what possibilities there are to evaluate the technical status of the engine by an exploitational status, and from there of necessity, contemporary service systems are a reflection of real possibilities of defining the technical status of the engine. The problem of defining the technical status of a turbine aircraft engine and connected with this, a service system, must be examined in much wider context, for the service system of an engine must be connected with the service system of an airframe and of the radio, navigational, energetic, etc., devices built up in it. What holds true here is the principle of the "weakest link," for the service system of an airplane is necessarily subordinate to a service system of a device, which to fulfill the condition of high operational dependability, demands the largest operation in a unit of time of final approach.

Contemporary aircraft engine technical service systems rely on the execution of periodic control and service functions after elaboration of a specific number of hours by the engine, and after crossing its overhaul life the engine is directed for repair.

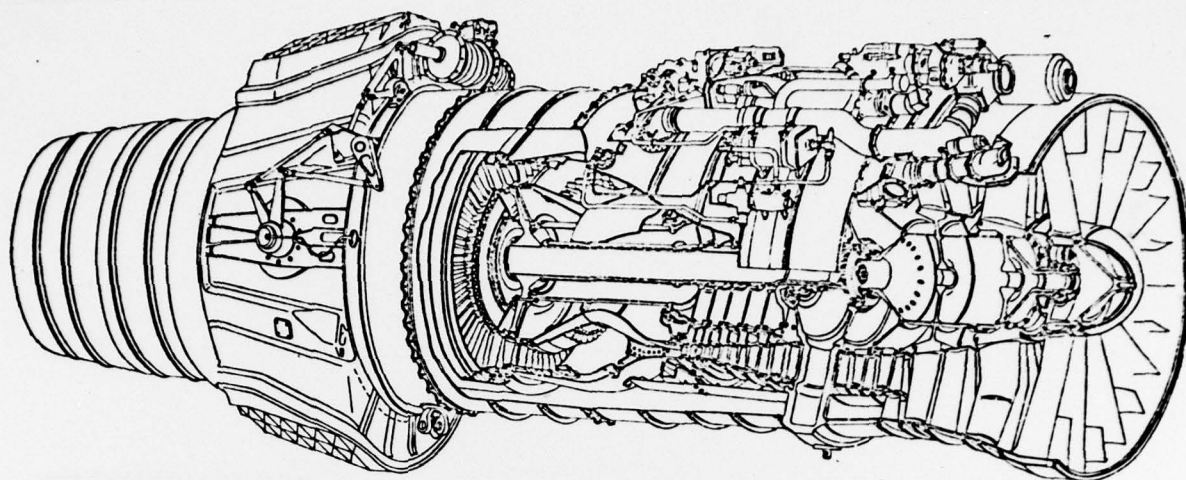
The overhaul life is fixed experimentally by the manufacturer and again and again a given copy of an engine achieves increased overhaul life to its next repair as a result of a modification introduced by the manufacturer.

At the time of routine inspections many service and control activities are performed in a scope forced upon by the manufacturer, and with that, if the inspection proves positive, the engine is committed to exploitation for an anticipated period by instruction of the manufacturer, after which time a consecutive periodic examination is performed.

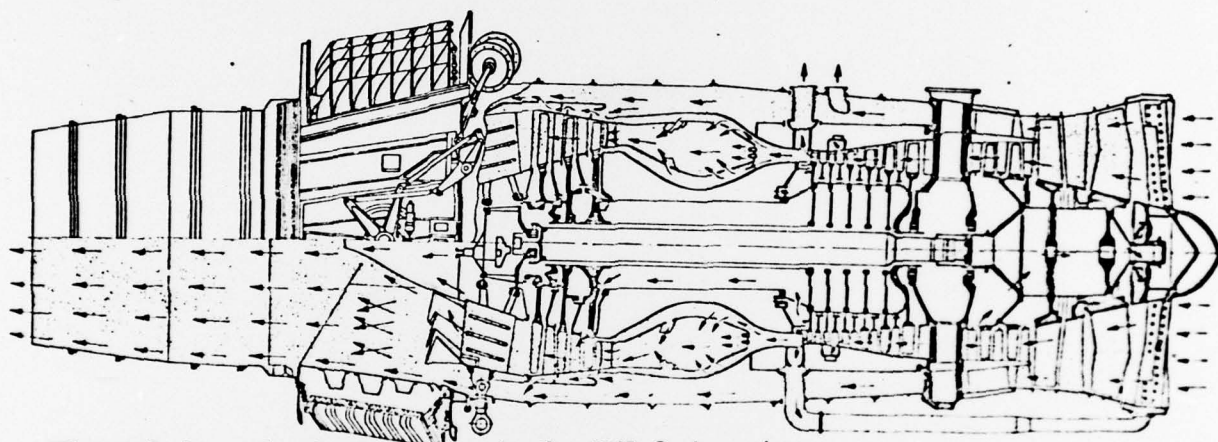
Technical service systems of aircraft engines in which the manufacturer strictly forces the ^{length} of the period between inspections and the maximal overhaul life are proper for that status of engineering, in which the exploiter on the basis of measured parameters, is not in condition to evaluate the technical status of the engine to such a degree as to be able to make a prognosis of the period of time to commit the engine to exploitation, being certain of its operational dependability.

Changeover from a system of evaluating the technical status of an engine based on flight time to a system of evaluating an engine according to its actual technical status will be an enormous jump in exploitation engineering.

Technical service of turbine engines exploited by LOT Polish Air Lines takes place in a system of routine inspections during which time much control and service work is performed. In introducing for exploitation in LOT



1. NK-8-4 engine structure



2. Flow of air and exhaust gases in the NK-8-4 engine.

Polish Air Lines new types of airplanes equipped with more and more modern prime movers, a process of equipping the engines with more and more complex control-measurement and safety devices can be observed. The degree of equipping engines used by LOT Polish Air Lines with control-measurement devices and the resultant possibilities of evaluating the technical status will be discussed later in regard to the NK-8-4 engine, with which the Il-62

airplane is outfitted.

The NK-8-4 engine is a ducted-fan tandem turbine jet engine with a capacity ratio of external to internal contour of 1:1 and developing take-off thrust (under standard conditions) equal to 10,500 kG.

Fundamental information on the status of the engine and its automatic control system furnish flight control-measurement systems which can be divided into "classical" control devices, semi-automatic control systems of engine operation, and automatic control-safety devices.

The second group of data on engine status is gathered during periodic inspections, based on examinations and measurements by manual systems.

In periods between inspections the engine is checked based on information furnished by flight control-measurement systems.

"Classical" control devices include indicators of rotational speed of high and low pressure rotors, of oil pressure and temperature, oil quantity in the installation, fuel pressure before injectors, temperature of gases behind high and low pressure turbines, fuel output, vibration level of the engine and angular position of the lever of the automatic control assembly

of the engine.

The semi-automatic control devices of the engine signal (by means of light signalling) the following states of inefficiency:

--- minimal fuel pressure behind a low pressure filter (the possibility of cavitation),

--- "plugging" of the low pressure fuel filter (fuel flows to the engine disregarding the filter),

--- minimal oil pressure (oil pressure decreased to $2.3 \pm 0.5 \text{ kg/cm}^2$ which does not assure proper lubrication of rotor bearings),

--- too high gas temperature (temperature of gas in front of the low pressure turbine increases to 870°C),

--- minimal amount of oil in the oil tank (amount of oil in the tank decreased to 5^{+2}_1),

--- filings in the oil (appearance of metal filings in the oil installation of the engine),

--- increase of engine vibration (heightened increase of vibration speed is signalled, defined at $65 \pm 10 \text{ mm/s}$ and dangerous increase of vibration speed defined at $90 \pm 15 \text{ mm/s}$),

--- engine icing,

--- angular position of transposed guide-vanes in high pressure impeller-eyes (the state of inefficiency appears when the guide-vanes do not shift from the starting position to the service position at a rotational speed

of a low pressure rotor of $43^{+3}_{-5.5}\%$ according to the conventional scale; the starting position of the guide-vanes is signalled by a light plate),

Inspection Type	Take-off		Periodic		
Inspection Name	A	B	2	2A	3
Performance Period	Before flight	7 days	200 ± 20 h flight	600 ± 40 h flight	1200 ± 80 h flight

--- position of air release valves from the high pressure compressor (the state of inefficiency occurs when the release valves fail to close at a speed of the high pressure rotor of $74.5 \pm 1.5\%$ according to the conventional scale; the closed position of the valves is signalled),

--- removal of blocking from the thrust inverter lock (the state of inefficiency occurs when automatic removal of the blocking in flight is not controlled),

--- engaging the thrust inverter (the state of inefficiency occurs when the screen of the thrust inverter does not shift after the shift of the control lever by the inverter in the "reverse thrust" position),

--- engaging the automatic control system by starting (the state of inefficiency occurs when the system does not turn on after pressing the start key).

All the mentioned semi-automatic systems signal states of engine inefficiency, but do not supply information about their cause.

In the instance of integrating the deck recorder of the exploited parameters of the engine with a ground system, making it possible to find the cause for the failure, we have to deal with the automatic control system.

The NK-8-4 engine is equipped with an automatic gas thermoregulator control system in front of the RTA-26-9-1 turbine. During engine operation the temperature of the gases in front of the low pressure turbine and the temperature of gases behind the engine turbine are controlled while in operation on the basis of the thermoscope reading.

The state of inefficiency of the RTA-26-9-1 system appearing with the crossing of a given permissible temperature of gases in front of a low pressure turbine is signalled by means of a light plate.

The on-ground tester PI-38-1 imitating the thermoelectric force of thermo-elements makes it possible to regulate the action of the RTA-26-9-1 amplifier in all ranges of operation and to check ^{the} IM-7-7 performance mechanism controlling fuel outlay depending on the proposed gas temperature.

Aside from the possibility of checking the operation of the RTA-26-9-1 system by means of the PI-38-1 tester the possibility exists to check the RTA-26-9-1 by means of its internal control system, which performs at the time of engine testing on the ground after changeover of the system to the "control" range.

In this instance the RTA-26-9-1 system fixes the controlling maximal gas temperature in front of the turbine on a level lower than the permissible gas temperature in the starting range. Therefore, shifting of the control lever by the engine in the direction of greater thrust will allow for an increase in rotational speed of the engine rotors only to that moment, in which the gas temperature in front of the low pressure turbine reaches a given control value. The RTA-26-9-1 system is efficient, if despite further shift of the control lever by the engine, the gas temperature in front of the low pressure turbine and the rotational speed of the rotors keep on an equal level.

In the case of the inefficiency of an automatic gas temperature control system in front of the turbine, as a result of which the gas temperature crossed exploited quantities, to decide what to do about further exploitation of the engine information is necessary concerning the kind of run the gas temperature had in time after crossing the exploitation quantity.

The RTA-26-9-1 System permits the obtaining of this information on the basis of temperature gauge readings. However, the designers want to make this operation automatic.

One of the solutions which can be proposed is the connecting of the temperature recording system with the recorder of the engine operation time. Such a system would record separately the engine operation time with the gas temperature in front of the turbine lower than the temperature in the take-off range and separately the engine operation time with a maximal gas temperature in the take-off range. At the same time in the case of crossing permissible temperature the system would automatically record its run in a time function.

Similar systems are already being manufactured, among others, by Smiths Industries, Ltd.

Beyond the data on the technical status of an engine, furnished by the above mentioned deck control-measurement systems, the remaining information was obtained as the result of technical inspections.

These inspections are divided into take-off and periodic and are performed according to the precepts given in the table.

In the system of these inspections the range of activities performed in case of increase of final approach, enlarges, and in connection with this the airplane lay time during inspection increases.

Data on the technical status of an engine, obtained during inspection can be divided into the following groups:

- data obtained as the result of optical verification of the external status of the engine and its installation,

- data obtained as the result of the control of fuel and oil installation filters,

- data on the degree of elaboration of several elements obtained as the result of partial dismantling of the engine,

- data on the status of turbine blades obtained as the result of checking their trailing edge by means of an induction flaw detector.

Besides the possibility of checking blades by an induction flaw detector LOT Polish Air Lines also uses an X-ray flaw detector, since considering the difficulties with the installation of the apparatus in the engine only the examination of blades of the last degree of a turbine or the first degree of a compressor is possible.

The extent of equipping an engine with control-measurement systems as discussed in the article and the possibilities arising therefrom of evaluating the technical status of an engine fully comply with the mandatory standards and regulations.

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