UDC 629.735.036.017.1

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METHODS OF DIAGNOSING MALFUNCATION GRADE OF GAS TURBINE ENGINE WORKING FUEL ATOMIZERS IN SERVICE CONDITIONS

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The subject of these document methods is substantiation of a generalized diagnostic parameter allowing diagnosing the degree of fuel atomizers coking during gas turbine engine operation.

Introduction

It is known that heat release coefficient at fuel combustion is regarded as one of diagnostic criteria of design work of aviation gas turbine engine (GTE) combustion chamber. It characterizes heat losses in the combustion chamber and shall be derived using the following equation [1]:

$$\eta_{com} = \frac{\left\lfloor Cp_g T_g^*(1+g_f) - Cp_a T_c^* \right\rfloor}{H_u} \frac{G_a}{G_{f.h}},$$

where Cp_a, Cp_g are specific thermal capacity of air behind the compressor and specific capacity of gas in front of the turbine, accordingly; T_c*, T_g* are total temperature values of air behind the compressor and gas – in front of the turbine, accordingly; g_f, $G_{f.h.}$ are relative and per-hour fuel flow rate of engine, accordingly; H_u is specific heat-producing fuel, G_a is per-second air flow rate via engine.

Methodic determination of generalized diagnostic parameter

According to the results of statistics data analysis for typical GTE regarding $\eta_{com.}$ (fig. 1) [2] behaviour, it is stated that the value of heat release completeness in the combustion chamber is poorly affected by minor deviations of temperature T_c* and air pressure P_c, as well as specific fuel flow rate C_R, which are connected with the occurrence of initial damages of engine's flow part and, as it is known, physical-chemical parameters of fuel grade do not depend upon technical condition of GTE.

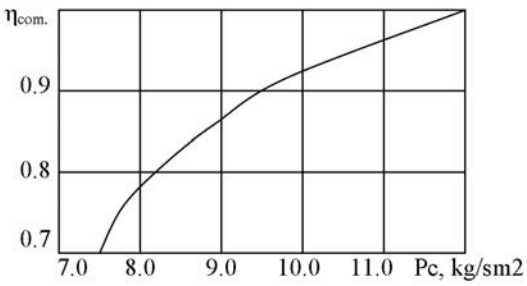

Fig. 1. The typical dependence coefficient η_{com} from air pressure P_c of be hind compressor GTE

At the same time the value η_{com} is mostly affected by fuel pressurizing difference occurring in front of working atomizers $P_{at.f}$ of the combustion chamber due to their clogging or coking, and by the change in the geometry of the combustion chamber $\Gamma_{com.ch}$ connected with its damages (burn-outs, cracks) in a heat pipe or housing.

It is very difficult to determine the dependence of value difference η_{com} from $\Gamma_{com.ch}$ and malfunctions of fuel atomizers in operation conditions of GTE. It is more reasonable and convenient to use some generalized diagnostic characteristic (parameter) as a deterioration criterium of thermodynamic combustion process which is connected both, with the damages in the heat pipe and coking (clogging) of fuel atomizers.

For this purpose the dependence of per-hour flow rate via fuel atomizers upon operational factors [3] is used:

$$G_{f.h} = \mu_{at} F_{at} \sqrt{2\rho_f P_{at.f}}\,, \qquad (1)$$

where μ_{at} is fuel flow rate coefficient characterizing atomizing capacity of fuel atomizers; F_{at} is total atomizing surface; ρ_f is fuel grade density; $P_{at.f}$ is pressure of fuel in front of atomizers in the appropriate diagnostic mode of GTE operation.

Proceeding from operational working conditions of GTE it is known that coking or clogging of atomizers' elements while preserving constant fuel flow rate via atomizers will result in pressure increase in front of atomizers. Value $P_{at.f}$ is checked by the device (pressure gauge) installed in the aircraft cockpit. At that specified malfunctions of the atomizer will result in fuel throttling in the atomizer channel itself and atomizing surface reduction. So, coking (clogging) of atomizer will lead to the change of value $\mu_{at}F_{at}$. Relative value of this change may be defined using (1) according to the equation:

$$\delta_{at} = (\mu_{at} F_{at})_{\mathrm{cur}} / (\mu_{at} F_{at})_{init}\,,$$

or

$$\delta_{at} = \frac{(G_{f.h.red})_{cur}}{(G_{f.h.red})_{init}} \sqrt{\frac{(\rho_f P_{at.f})_{init}}{(\rho_f P_{at.f})_{cur}}}\,. \qquad (2)$$

Thus, the proposed way of diagnosing malfunctions of GTE working fuel atomizers consists in the control of current values of fuel pressure in front of fuel atomizers $(P_{at.f})_{cur}$ using authorized device and analysis (or registration by flow meter) of given value of per-hour GTE fuel flow rate $(G_{f.h.red})_{cur}$ at the appropriate diagnostic GTE operation modes. These values are compared with the known initial (bench, official) values of the same parameters $(P_{at.f})_{init}$, $(G_{f.h.red})_{init}$ according to the design ratio (2). As a result the value of generalized diagnostic parameter δ_{at} characterizing relative part or grade of coking (clogging) of atomizers and allowing diagnosing technical conditions of working fuel atomizers and the combustion chamber as GTE unit in regular operating conditions is defined.

The proposed method of diagnosing was approved experimentally on the gas-dynamical stand AI-25 by means of consecutive test of engine both, including all working atomizers and consecutive cutting down one atomizer of the two ones, etc. At that values of per-hour fuel flow rate and fuel pressure in front of working atomizers were measured on the set power conditions of engine from a minimum throttle operation mode up to a nominal one. The results of experimental modeling are detailed by fig. 2.

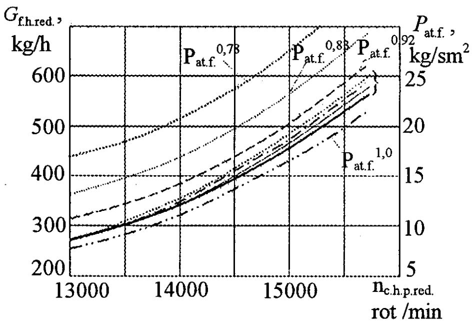

Fig. 2. Dependence of given per-hour fuel flow rate $G_{\text{f.h.red}}$ and fuel pressure $P_{\text{at.f}}$ in front of working atomizers on the engine's power conditions $n_{\text{c.h.p.red}}$ and operable conditions coefficient K_{at}: — · · — (K_{at} = 1,0); - - - - without one atomizer (K_{at} = 0,92); ········ without two atomizers (K_{at} = 0,83); ········ without three atomizers (K_{at} = 0,78)

So, for example, for cruising engine operation (0,85 nom.) the following values of controlled parameters and generalized parameter δ_{at} are registered (table).

Conclusion

On the basis of experimental research data and mathematical computer modeling of a specified kind of combustion chamber malfunction the test curve (fig. 3) showing the dependence of atomizers guaranteed coefficient ($K_{at}=K_{at}^{cond}/K_{at.\Sigma}$) upon the grade of their coking was derived for typical GTE (AI-25).

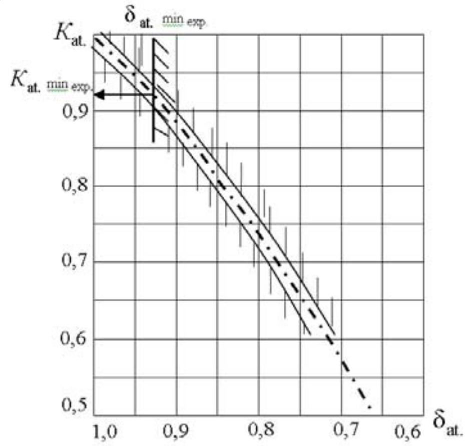

Fig. 3. Dependence of operable conditions coefficient $K_{\text{at.}}$ on the grade of their coking δ_{at} for typical engine

It may be used in operation conditions for this type of engine on the purpose of defining technical conditions of atomizers and making the decision regarding engine's design work renovation or stopping its safe operation.

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Combined data of experimental researches

Parameters	Fuel atomizers operable condition coefficient K_{at}						
	1,0	0,92	0,83	0,75	0,67	0,58	0,5
$G_{\text{f.h.red}}$ kg/h	487,5	490	496	500	504	508	511
$P_{\text{at.f}}$ kg/sm^2	18,5	21,05	24,5	29,5	34	40,0	46,0
δ_{at}	1,0	0,93	0,88	0,81	0,76	0,71	0,66

The editors received the article on 02 March 2005.

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Методика діагностування ступеня несправності паливних форсунок газотурбінних двигунів в умовах експлуатації

Розглянуто методику визначення узагальненого діагностичного параметра, який дозволяє діагностувати ступінь закоксування паливних форсунок в умовах експлуатації газотурбінних двигунів.

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Методика диагностирования степени неисправности топливных форсунок газотурбинных двигателей в условиях эксплуатации

Рассмотрена методика определения обобщенного диагностического параметра, который разрешает диагностировать степень закоксования топливных форсунок в условиях эксплуатации газотурбинных двигателей.