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Analysis on Compressor Blading Conditions of Helicopter's Gas-Turbine Engine Working in Polluted Environment

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Abstract

Working in the dusty air pollution the air-gas channel of the engine is polluted. This results in deterioration of engine power plants. In this paper we present the results of studies of mass, density, thickness and microstructure of deposits on the rotor blades of a helicopter gas-turbine engine compressor having a nominal capacity of 883 kW after working 1500 h. The researches were conducted on ten blades of each stage. The blades were weighed before and after treatment, and then the averaged sludge mass was calculated. The results show that at the latter stages of the compressor deposit density was greater than at the first ones. Mode with full manifestation of roughness for a given engine is implemented in the first six stages of the compressor. It is concluded that the characteristics of the boundary layer and the value of the coefficient of friction on the surface of the blades are mostly influenced by the size of the arithmetic average height of irregularities Rz. The resulting data is used to develop methods of purifying of the compressor flow path.

Keywords: gas turbine engine (GTE), a helicopter blade, deposits.

INTRODUCTION

Operating conditions of helicopters have a significant impact on its technical condition. Helicopter operation near industrial enterprises and ground areas brings to a significant degrade of the characteristics of their power plants. It's connected with the formation of rough deposits on the compressor blades. The mechanism of deposit formation is a complex interaction of particles of dust and soot from with a turbulent boundary layer on the blade surface (Schlichting, 1974). The secondary flow in the inter-blade channels and increased turbulence contribute to particles settling. The deposits are formed on the backside of the blades and represent a soot layer of fine dust, which degrades the quality of the surface roughness due to its growth (Golovina, 2011, 2012).

For diagnostics and calculation of losses in the compressor of impure gas turbine engine (GTE) it is necessary to take into account the effect of increasing the roughness of the boundary layer. In addition, the distribution of the thickness and deposits density on the steps of the compressor should be taken into account in the development of effective ways of cleaning its flow path (Zanun, 2007, 2010).

MATERIALS AND METHODS

In this paper we present the results of studies of the mass *m*, the density ρ, the layer thickness and the microstructure of deposits *h*, formed on the rotor blades of a helicopter turbine engine compressor with a nominal capacity of 883 kW after 1500 working hours.

Fig. 1 shows the deposits mass distribution on the rotor blades on the steps of the compressor. Measurements were carried out with the analytical balance WA-31, according to the weighing ten blades of each stage. The blades were weighed before treatment and after it, and then the averaged weight of deposits was calculated, referred to the surface area F of the airfoil backside. According to Fig. 1 we can say that the first seven stages of the compressor are the most polluted. This dependence is due to the influence of the strongest secondary flows in the early stages, the radial clearance in the working grids and intense vortex formation in the flow blades of the adjustable guide vanes.

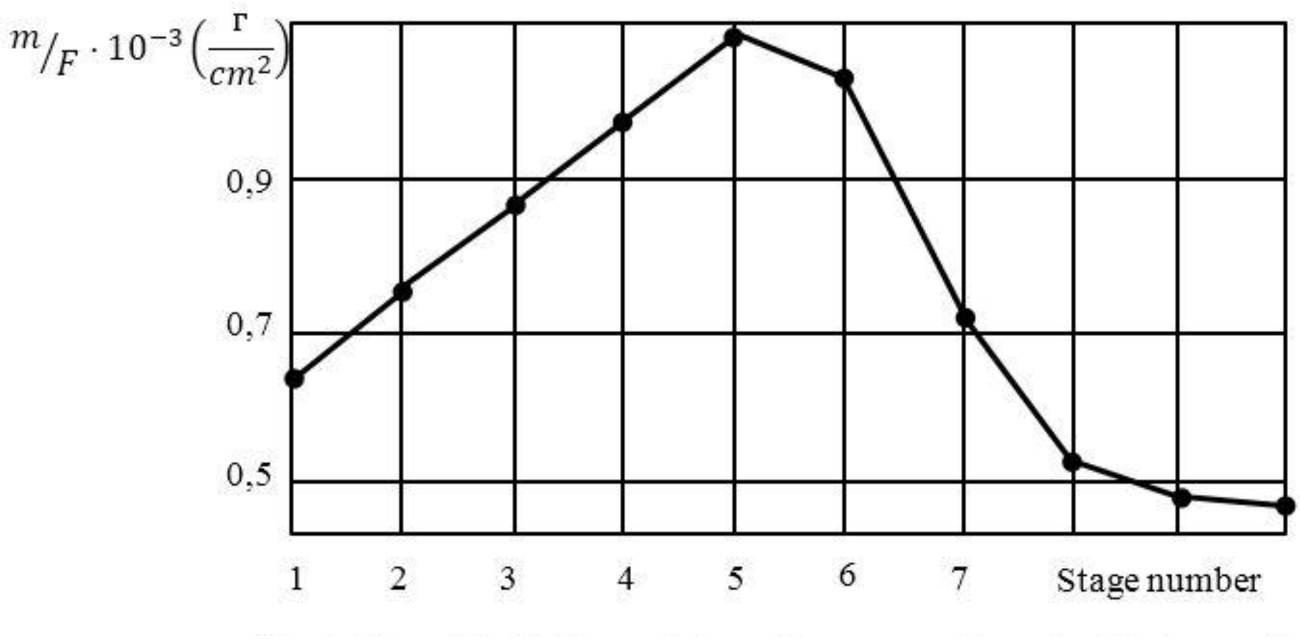

Figure 1. The distribution of deposit mass on the rotor blades on the compressor stages

Researching of deposit relief microstructure was performed on the cross-section of the blading airfoil of each stage. We analyzed photographs taken on the microscope MIM-8 at 240 times magnification. Fig. 2 shows the characteristic shape of the deposits of the deposit relief formed at the profile backside of the blading airfoil on the first rotor stage.

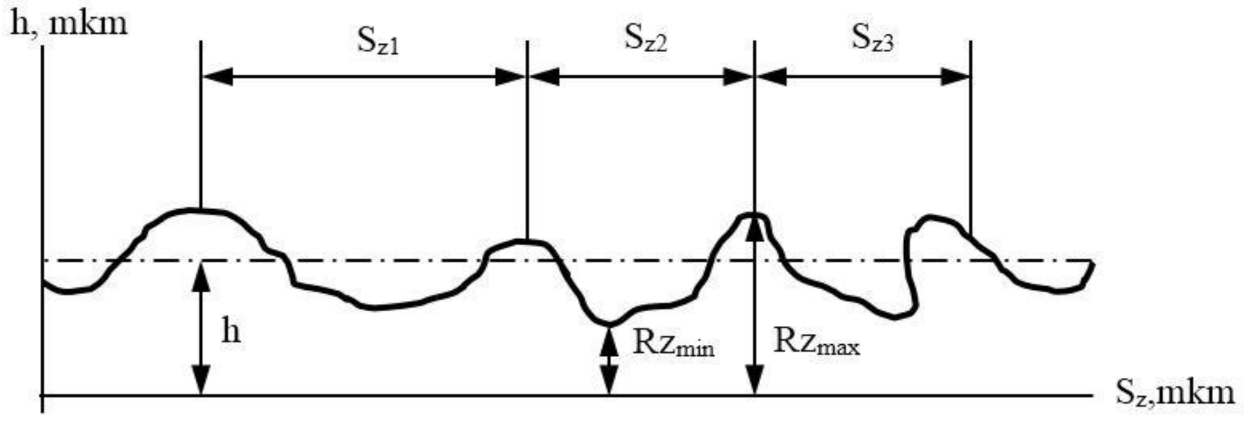

Figure 2. Deposit relief microstructure on rotor blades of the first stage (× 240)

Deposits are presented as a dark layer between the epoxy glue used in the manufacture of lap, and the blade surface. It can be seen that the deposits have a developed rough surface with a complex configuration of protrusions and depressions. Experimental data processing allows obtaining the averaged value of deposits lay thickness *h* for each stage, though its density is calculated. The results of measurements and calculated parameters are given in the table 1.

Table 1.

Parameter	*Stage number*									
	1	2	3	4	5	6	7	8	9	10
$m \cdot 10^{-3}$, г	13,6	12,1	10,1	8,30	7,60	6,00	3,50	2,40	2,00	1,60
F, cm^2	22,0	16,3	11,6	8,70	7,20	6,00	4,80	4,50	4,10	3,50
h, mkm	53,0	42,0	32,5	24,5	18,0	12,5	7,60	4,80	4,00	3,40
$m/F \cdot 10^{-3}$, g/cm^2	0,62	0,74	0,87	0,95	1,05	1,00	0,73	0,53	0,49	0,46
ρ, g/cm^3	0,12	0,18	0,27	0,38	0,58	0,80	0,96	1,10	1,23	1,33
R_z, mkm	35,0	22,0	15,1	10,4	7,10	4,80	3,20	2,20	1,60	1,30
R_{zm}, mkm	6,0	4,7	4,2	3,9	3,7	3,5	3,3	3,1	2,9	2,7
S_z, mkm	110	76	59	48	40	33	28	25	23	22
N	3,1	3,5	3,9	4,6	5,6	6,9	8,7	11,2	14,4	16,9

Analysis of changes in deposit density of the steps of the compressor leads to the conclusion that the density on the last stages is more than the density the first ones. The increase of the density takes place under the influence of high gas pressure and temperature as well as under the influence of active turbulent diffusion.

Statistical description of the roughness parameters allows us to determine an arithmetic average height Rz roughness size for each stage (see. Table 1), It is characterized by the difference between the average values of the five largest protrusions and the largest depressions on specific basis.

The surface roughness is making a significant contribution to the formation of the boundary layer, which under certain conditions can be realized in quasismooth or during operation by a full manifestation of roughness (Lomov, 2011). The roughness is not manifested until the projections of the roughness elements are recessed in the viscous laminar sublayer. It takes place until a certain critical value the Reynolds number Re_{cr}=100 is achieved, which is calculated on the value of the equivalent roughness passed parameter R_z. Using data on the flow of gas-dynamic parameters and geometric dimensions of the blades of the helicopter turbine engine, the allowable values R_z can be calculated for each stage, without any manifestation of roughness (see. Table 1).

Comparison of the calculated values R_z with estimated R_{zm} shows that mode with full manifestation of roughness for a motor having 1500 hours, is realized on the first six stages of the compressor. In this mode, the pulsating motion extracts the energy from the potential flow by the apparent stress in the boundary layer. Then this energy is converted into heat by turbulent dissipation. The friction coefficient on rough surfaces is several times larger than the hydraulically smooth.in this flow regime

The friction coefficient and the characteristics of the boundary layer on the rough surface, moreover, depend on the distance between the tops of the longitudinal elements and the distribution of roughness on its surface. The following table summarizes the parameters of the distribution of roughness elements *N*on the surface. This parameter is characterized by the ratio of the average arithmetic distance between the tops of irregularities S_z to the value of R_z.

The value of the parameter *N*, in which there are various modes and flow structures were experimentally obtained in (Belyanin, 1985). For example, when $N \leq 7$, the surface resistance is almost constant as roughness elements formed of small vortexes spinning, which remain between them, and have no influence on the gas flow away from the side. Increasing the $N > 7$ leads to an intense growth of rate amplitude and changes in the flow structure due to the separation of large vortices and their penetration into the main stream. The resistance of such a surface is increased by 2 ... 2.5. When $N > 16$, there is a gradual decrease in surface resistance due to rejoin the flow.

The table shows that the value of the parameter $N > 7$ take place on the last four stages. However, here according to the parameter R_z the flow regime corresponds to a hydraulically smooth one. It means, the structure of turbulent flow near the roughness elements corresponds to the aerodynamic interaction without trace and does not depend on the parameter *N* in all stages of the compressor.

RESULTS AND CONCLUSION

Thus, the study of the microstructure deposits relief formed on the blades of the rotor compressor of the helicopter turbine engine after 1500 hours working, shows that a parameter R_z must be considered in the calculation of the effect of roughness on the boundary layer characteristics and estimating the friction coefficient on the blade surfaces, as well as the influence by the parameter N can be neglected. The data on the distribution of the density and deposit mass on the steps of the compressor allow developing effective methods for purifying the compressor flow path.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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