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AUTOMATED SELECTION OF THE MATERIAL A FAN BLADE PS-90A

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Abstract

Database and expert system are developed. They allow to perform thermogas dynamic calculations of aircraft engines of various schemes and action principles, to create a constructive image of engine main units, to evaluate load acting on the elements of the engine air-gas channel, to perform approximate strength calculations, to carry out the selection of the main parts materials of an aircraft engine.

Introduction

Aviation gas turbine engines (GTE) – this is the most technically difficult element of the aircraft, at its development and creation are expended colossal time and labor resources. At the present time for aircraft engine (AE) imposed strict technical conditions on the parameters of the process, in terms of reliability and fault tolerance. In operation of the entire system need high optimization of the characteristics of individual elements at different regime of the engine. The high degree of balancing of individual elements in the AE is possible in the case at the design stage and the choice of its constructive scheme solve problems of structural analysis and material selection of basic parts and assembly units of air-gas channel [1, 2].

2 Programme "AM"

On the basis systems of imitating modeling aviation GTE "DVIGw" thermogas dynamic modeling created an expert system (ES) "AM", which is compose of individual structural elements (SE) for analysis, the main elements of the air-gas channel of the engine and the selection of materials for SE, covers and other types of surface preparation [3]. The structure developed by the database (DB) material for details of AE, contains basic information about materials, including composite materials (CM) to perform structural analysis design [4, 5].

Operating principles ES "AM" [3] described in [1, 5, 6]. In [2] and [7], the results of modeling presented the major parts and assembly units of the maneuverability of the modern turbofan engines for military aircraft.

3 Selection of material

In this article presented are the results of modeling and automated selection of the material rotor blade of the fan turbojet engine with a high bypass ratio PS-90A. Fig. 1 is a topological model of the PS-90A in ES "AM".
At the fan blades (SE 4, Fig. 1) of engines with a large bypass ratio circumferential speeds at the hub and the periphery section differ significantly. Is therefore at modeling of engine is accepted that at the compressor inlet air flows initially divided into inner and outer contours, and then is goes in fan (with average compression ratio pressure at take-off on the ground π_B=1.67 and at cruising flight – π_B=1.75) and booster compressor (SE 5, Fig. 1). Fan 4 and booster compressor 5 are located on the same shaft that the simulation model is shown in using SE 7, which adds power of the fan and booster stage in a single mechanical stream and transmits it to the low pressure turbine (LPT) SE 10. Bypass ratio *m* engine take-off regime is 4.5, at cruising regime – 4.4.

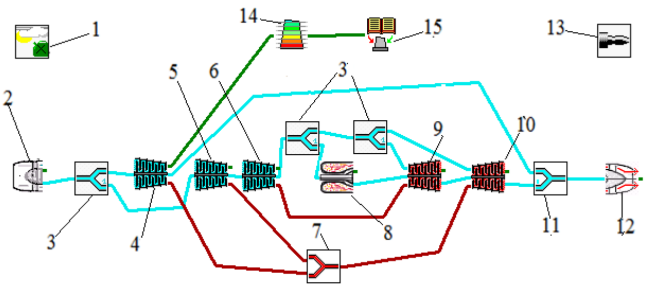

Fig. 1. Topological model PS-90A in ES "AM" for selecting of material, where *1* – SE Initial conditions; *2* – SE Input device; *3* – SE Air bleed; *4* – SE Fan; *5* – SE Booster compressor;*6* – SE High pressure compressor (HPC); *7* – SE Add power; *8* – SE Combustion chamber; *9* – SE High pressure turbine (HPT); *10* – SE Low pressure turbine (LPT); *11* – SE Mixer; *12* – SE Jet nozzle; *13* – SE General results; *14* – SE Strength compressor blades; *15* – SE Material compressor blades.

This model PS-90A engine has been identified, the main thermogas dynamic model parameters correspond to the prototype; the geometric dimensions of the flow part air-gas channel of behind main model are chosen nodes equal a characteristic size of the prototype [8, 9]. Law of calculation necessary for the simulation engine altitude-velocity performance (AVP) is given in Table 1.

Table 1. Parameters for the simulation AVP

Varies	Supported	Tabulated
π_K (Fan)	n (Fan) = = n (Add stage)	M (Initial conditions) from 0 to 0.9 in steps 0.1
π_K (HPC)	A_T (HPT)	
π_K (Booster compressor)	A_T (LPT)	H (Initial conditions) from 0 to 11 km in steps 1 km
m (Air bleed)	P_I/P_{II} (Mixer)	
G (Input device)	F (Jet nozzle)	

As the object of research is selected the first stage fan (SE 4, Fig. 2), therefore in ES "AM" to SE Fan sequentially connected SE Strength compressor blades (14) and the SE Material compressor blades. At modeling fan were set law of profiling an air-gas channel (constant average diameter), the coefficient lengthening of the rotor blade (0.64), the relative thickness of the profile (3.5%), the relative diameter of the bushing at the entrance to stage (0.3546), the exponent of profiling blade on height (1), the thickness shroud (2 mm) and the angle of the flow at the inlet of stage (90 °, since no inlet guide vanes). Fan rotation frequency (4250 rev/min) given by in the SE Fan.

In Table 2 shows a comparison of the basic geometrical parameters existing fan design and parameters obtained by means the program developed [7]. The law of profiling an air-gas channel of the fan (D_{mean}= var) is different from the selected program (D_{mean} = const), therefore, the diameter at the outlet of rotor obtained by simulation, are somewhat different from actual ones.

Table 2. The geometrical parameters of the fan stage

Parameter	Initial design	Result of modeling
Outer diameter of the at the inlet of stage, mm	1900	1900
Inner Diameter at the inlet of stage, mm	673.6	673.7
Outer diameter the output of rotor, mm	1816	1741.3
Inner diameter the output of rotor, mm	906.4	832.4
Chord of the rotor blade on the mean diameter, mm	327.9	312.1
Number of blade rows	33	33
The height of rotor blade at the inlet of stage, mm	613.2	613.2
The height of rotor blade at the outlet of stage, mm	454.8	454.4

In a result of modeling, ES determined the thermogas dynamic parameters (temperature, pressure in absolute and relative motion) and kinematic parameters (velocity and their components) the inlet and outlet of the rotor in three cross-sections of on height (at the inner, mean and outer diameters). Also defined geometric characteristics of the profile (chord, the maximum thickness of the profile, the maximum value of the deflection the midline, the angle of profile installation), number of blade rows. By these parameters ES determined the area of the blade profile in the three cross-sections, moments of inertia, the temperature of material the blade, gas unit of force acting on the blade, the bending moments from the gas forces the stress on the gas and inertial forces.

In the selection of material for the fan blades, ES provides a variety of options for enumeration materials, contained in the database, sends to the input SE Strength the compressor blades values of physical and mechanical properties of the test material, performs the calculations of the static strength of the blade and the dovetail joint blades with disc. To each material are assigned point. Then the program "AM" forms the list of five materials, received maximal number of points.

In the simulation fan blades for take-off regime (H = 0 km, M = 0) the system provides a list of the materials shown in Fig. 3a. In the simulation of the engine at cruising of flight (H = 11 km, M = 0,8) change to the parameters engine inlet (P_{H} = 34.6 kPa, T_{H} = 244.6 K), mode of operation of the engine and, accordingly, the forces acting on the rotor blade. Simulation results for the cruising of flight regime of shown in Fig. 3b.

According to the results of modeling (Fig. 3) is obtained that when modeling fan blades on the two regimes the program offers titanium and aluminum alloys. In the actual design is used titanium alloy – VT8M. Thus, the blade of an aluminum alloy (from simulation results) weighs an order 3.14 kg of a titanium alloy blade is 5.24 kg.

Place	Sequence number the material in the BD	Amount of points	Material
1	115	6.38	VD17
2	114	6.30	AK4-1
3	113	5.95	AL9-T5
4	120	4.74	VT1-0
5	122	4.30	VT5

a)

Place	Sequence number the material in the BD	Amount of points	Material
1	120	5.29	VT6
2	121	5.28	VT20
3	124	5.26	VT8
4	117	4.80	VT5
5	119	4.79	VT5L

b)

Fig. 3. The results of the selection of materials for rotor fan PS-90A, a) take-off regime of flight (H = 0 km, M = 0); b) cruising regime of flight (H = 11 km, M = 0,8)

ES "AM" also allows simulating the fan blades of the CM. For this purpose in a topological model of the engine (Fig. 2) replace the SE Material compressor blades on the SE CM for compressor blades. When selecting the CM for fan blades ES exhaustive search of fibers and the matrix material, sorting reinforcement ratio. The maximum number of points is gaining the variant of CM, which can withstand for service temperature, operating load and has a minimum specific weight [10]. When choosing a CM for blade the first stage of the fan the engine for stand conditions system offers the following list of variants CM (Fig. 4). For flight regime, the system offers a list of materials is shown in Fig. 5.

As seen from the simulation results, ES mainly provides a combination of aramid fiber with a non-metallic matrix. Optimal reinforcement ratio is 0.5. Thus this blade from composite weighs 0.30 kg (without shroud and decreasing the relative thickness of the profile up to 0.4 %) that in general considerably facilitates the entire design.

Place	Amount of points	Reinforcement ratio	Component	Material number in BD	Material
1	6.73	0.50	Matrix	3	Organic fibers
			Fiber	2	Polypropylene
2	6.69	0.55	Matrix	3	Organic fibers
			Fiber	2	Polypropylene
3	6.59	0.50	Matrix	3	Organic fibers
			Fiber	6	Polyimide binder PMR-15
4	6.54	0.45	Matrix	3	Organic fibers
			Fiber	7	SP-97
5	6.52	0.50	Matrix	3	Organic fibers
			Fiber	7	SP-97

Fig. 4. The results of the selection for the CM fan blades PS-90A (*H*= 0 km, *M*= 0)

Place	Amount of points	Reinforcement ratio	Component	Material number in BD	Material
1	6.89	0.30	Matrix	3	Organic fibers
			Fiber	2	Polypropylene
2	6.75	0.30	Matrix	1	Carbon fiber
			Fiber	2	Polypropylene
3	6.70	0.30	Matrix	3	Organic fibers
			Fiber	6	Polyimide binder PMR-15
4	6.59	0.30	Matrix	3	Organic fibers
			Fiber	7	SP-97
5	6.59	0.30	Matrix	3	Organic fibers
			Fiber	1	Epoxide resin

Fig. 5. The results of the selection for the CM fan blades PS-90A (*H*= 11 km, *M*= 0,8)

4 Conclusion

The developed DB and ES are designed to perform thermogas dynamics engine calculation, automated designing of its main units, the preliminary structural analysis, the selection of five the most possible materials of main parts and assembly units of the air-gas channel of GTE. As a result of the application of the developed ES and DB already the early stages of design GTE it is possible the optimization of structural layout and dimensions and mass characteristics of the basic units of GTE.

The simulation results of the PS-90A fan rotor blade qualitatively and quantitatively correspond to the existing construction. There are offered variants of execution the CM blades, which can replace blades used of titanium alloy, at the same time the weight of the construction will be significantly reduced (by reducing the density of the material and no midspan damper).

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