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Radial clearances influence on gas turbine engines of air and ground application main parameters.

The paper deals with gas turbine engine flow channel geometrical parameters changes due to radial clearance in the compressor and turbine during the long operation. The proposed method of assessing the impact of these changes on engines transit modes and practical measures to eliminate adverse effects.

Entry

During extended service live of gas turbine engine the process of geometric parameters changing result a shift of workflow characteristics.

Diagnosing and troubleshooting that arise due to these processes is very difficult duo to slow percolation, where gradational processes and the complexity of the altered characteristics. Despite the slow count and relative obscurity where degradation processes they take affect on almost all engine characteristics.

Problem

It is known that the most informative in terms of diagnosis, are transitional modes turbine engine.

To date, relatively little attention paid to modeling of transient gas-turbine engines. But we know that the signs of change in the workflow engine in the first place, there is in transition mode. This contradiction is explained by the fact that transiency transients prevented obtaining the necessary diagnostic information using on-board systems of accumulation and control.

The situation began to change after the emergence of digital control systems and storage media, which replaced the old on-board tools.

Get information in real time with high frequency and low poll period of processing options allows the use of dynamic models of aircraft gas turbine engines to meet the challenges of diagnosis. Improving the accuracy of the diagnosis requires consideration of factors such as changes in geometrical parameters of the flow during prolonged use.

Solution

Analysis of modified engines the same structural scheme, but with different absolute values of their parameters, shows that the relative deviation of key data on their values specifications are the same. The above enables use of statistics of different engines to establish general patterns of changes of parameters of operating time [2].

These geometric parameters as nozzle area turbine units are essential, those that directly affect the data base engine (thrust and specific fuel consumption). The value of radial clearance is not affected directly based data engine, and their impact is on defining parameters such as compressor efficiency and turbine stages.

Foreign companies and airlines, since GTE earlier generations, carefully study the impact of attrition on the performance and operational reliability of the engines. For example, the company "Pratt-Whitney" surveyed the effects of wear on the compressor motor JT3D characteristics and stability of supplies engine starting mode [3].

To determine the radial changes during operation we use exponential regression equation:

$$\Delta\delta(\tau) = Ae^{\frac{\alpha}{\tau}} \qquad (1)$$

where A and α - constant coefficient.

To find the constant coefficients A and α least-squares method to minimize the expression:

$$Q= \sum_{i=1}^{n} \left[\lg \Delta\delta(\tau) - \lg A + \alpha \frac{1}{\tau_i} \lg e \right]^2 \qquad (2)$$

After differentiation cut Equations (2) and the corresponding transformations we obtain relations for the determination of lg A and α .

$$\lg A= \frac{\sum_{i=1}^{n} \lg \Delta\Pi(\tau j)}{n - \frac{\sum_{i=1}^{n} \frac{1}{\tau j}^{2}}{\sum_{i=1}^{n} \frac{1}{\tau_i^2}}} \left[1 - \frac{\sum_{i=1}^{n} \frac{1}{\tau_i} \lg \Delta\Pi(\tau_i)}{\sum_{i=1}^{n} \lg \Delta\Pi(\tau_i)} \cdot \frac{\sum_{i=1}^{n} \frac{1}{\tau_i}}{\sum_{i=1}^{n} \frac{1}{\tau_i^1}} \right];$$

$$z=2,302 \frac{1}{\sum_{i=1}^{n} \frac{1}{\tau_i}} \left[n \lg A - \sum_{i=1}^{n-1} \lg \Delta\Pi(\tau_i) \right], \qquad (3)$$

The calculation sums the values included in equations (3), carried out by the number of experimental points n.

It is necessary to establish a link between changes in the value of radial clearance and defining parameters (efficiency compressor stages). .
To solve this problem use the dependence given in [1]

$$\delta\eta_K^* = -K_1 z_K \left(2{,}8 \frac{\left(\bar{\delta} - 0{,}01\right)}{\eta_{cn.o}^*} + \frac{\delta\varepsilon_{TP}}{K_2} \right), \qquad (4)$$

where K_1 and K_2 - coefficients of influence $[6]$; $Z_K -$ number of stages in cascade; $\bar{\delta}$ - the relative value of radial clearance; $\delta\varepsilon_{TP}$ - relative deviation ratio of losses by increasing the degree of surface roughness of blades. Value of $\delta\varepsilon_{TP}$ associated with the relative roughness of blades the following relation:

$$\delta\varepsilon_{TP} = \frac{\left(0{,}05 - 0{,}08\right)\varepsilon^{0,25}\left(\frac{b}{A}\right)}{\varepsilon_{TP.0}} - 1 , \qquad (5)$$

Where b - blade chord; A – width between blade channel; $\delta\varepsilon_{TP}$ - Initial value of the coefficient of losses.

Using formulas (4) and (5), you can continue to evaluate how changing the basic parameters of the engine and workflow options for stationary and transient conditions of GTE.

Due to the properties of materials radial gaps between the shoulder blades and stator compressor and turbine are changed as a result of heating units running of the engine.

It is important to remember that largest thermal load acting on the turbine blades and nozzle apparatus. It is very important is the development and application of methods of cooling blades and stator parts of the compressor and turbine.

However, the convective efficiency of the method is not enough high, as 90 of the last century began to use film cooling. This method of cooling air time margin is derived through the holes in the front and creates a film to avoid direct contact of hot gases from the surface of the blade.

Despite the high efficiency cooling, this method has a significant drawback: the effective thickness of the profile increases the thickness of film cooling. Consequently, the degree of efficiency decreases, which affects the fuel efficiency of the engine.

Therefore, there appropriateness of use of convective cooling method in, but at a new level: instead of 3.4 radial canals, as was the traditional method, using highly developed system of “micro-circulation” channels below the surface of the blade.

This method of cooling avoids shortcomings of traditional methods (convection and film), to provide reliable cooling blades without increasing the effective thickness profile and the resulting gain increasing efficiency of the turbine. Analytical expressions to describe the impact the efficiency of stages based on GTE working process parameters may be obtained by solving systems of equations describing the motion of the rotors and the conditions of operation elements engine transient conditions [6].

$$\frac{dn;}{dt} = \frac{N_{Tj} - N_{Kj} - \Delta N_j}{(\pi/30)^2 J_{zj} n_j};$$

$$G^{Kj} - G^{K}(j+1) - \Delta G^{Kj} = 0; \qquad (6)$$

$$G^{K.З.} + \sum_{i=j}^{N} \Delta G_{c.a.i} + \sum_{i=j+1}^{N} \Delta G_{pKi} - G^{rj}(\pi_{Tj}, \tau_{uj}) = 0;$$

$\Phi(F_C)=0$; $\Phi_1(g_n)=0$; } control laws in the transition process.

where n_j - rotational speed of the j-s rotor; N_T and N_{Kj} - power turbine and compressor rotor j- s rotor; ΔN_j - Power of the shaft shown in the j-s rotor; J_{zj} - Moment of inertia of the j-s rotor; G_{Kj} and $G_{K З}$ - air losses in compressor j-s stage and in combustion chamber; $G_{rj}(\pi_{Tj}, \tau_{uj})$ - gas losses determined by the characteristics of each turbine stage; $\Delta G_{CA.j}$ and ΔG_{pKj} - amount of air flow for cooling blades of the machine nozzle and impeller j-s stage turbine; $g_{П}$ - relative fuel consumption; F_C - area of the nozzle.

Solutions of equations are carried out after setting the initial conditions, such as options on the idle power by using a standard program of integration of differential equations.

Changes in efficiency of stages directly affect the output value of these stages, which are a system of equations (6).

Conclusions

The suggested approach allows take into account and numerically describe the result of radial clearance changing in the compressor and turbine that effects flow in GTE air channel. Integrated application of the proposed method and technical solutions allows creating the conditions for significant improvement in engine parameters during continuous operation.

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