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EXTRAS

MAIN FACTORS THAT INFLUENCE THE FILM- COOLING FLAME TUBE TEMPERATURE IN GAS TURBINE ENGINE COMBUSTION CHAMBERS

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MAIN FACTORS THAT INFLUENCE THE FILM-COOLING FLAME TUBE TEMPERATURE IN GAS TURBINE ENGINE COMBUSTION CHAMBERS

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Abstract. The paper analyzes a computing method for the gas turbo-engines flame tube temperature. It also studies the influence of pressure, temperature and film cooling air flow on the flame tube temperature.

Key words: gas turbine engine, flame tube temperature, computing method.

1. Introduction

The heat transfer processes that take place in the gas turboengine burning chamber influence essentially the efficiency of the chamber and of the engine on the whole. In order the flame tube to have a large enough life span it is compulsory to maintain the wall temperature values and the wall temperature gradient in admissible limits. At most aircraft turboengines the flame tube is kept at admissible temperatures by cooling the device with an air film. The air film flows inside the flame tube through a series of inlet rows in the tube wall. The heat exchange between the flame tube and the surrounding media is influenced by many factors, the most important being the burning chamber pressure, the air temperature at the chamber inlet and the air ratio used for cooling.

The present paper analyses the main factors that influence the film-cooling flame tube temperature in gas turbine engine burning chambers.

Each factor mentioned is analyzed irrespective of the others in our concern seen as constant.

Up to now remains unknown a theoretical model that should make possible to determine the temperature in any of the flame tube points depending on its geometry and on the flow parameters at the burning chamber inlet. However, there are several papers quoted by [1] that show experimental data concerning the influence of various factors on the flame tube temperature as well as some qualitative regards over this influence.

2. Physico-mathematical Model of the Heat Transfer in the Film-Cooling Flame Tube Case

The heat flows in which the flame tube is involved are presented in the Fig. 1. Here R_1 – heat flow exchanged by radiation from the flame to the inner surface of the flame tube; R_2 – heat flow exchanged by radiation from the flame tube to the outer cover of the combustion chamber; C_1 – heat flow exchanged by convection from the flame tube to the cooling air film; C_2 – heat flow exchanged by convection from the outer surface of the flame tube to the secondary air; K – longitudinal conduction heat flow through the flame tube's wall and K_{12} transversal conduction heat flow through the flame tube's wall.

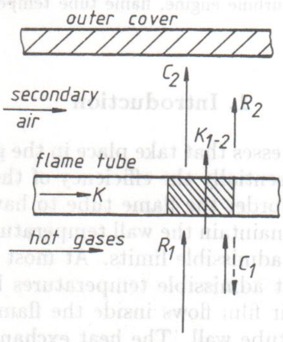

Fig. 1 Heat flows in which the flame tube is involved.

For a certain part of the flame tube the following relation takes place

$$R_1 + C_1 = R_2 + C_2 = K_{12}. \tag{1}$$

The heat exchange model that implies the film-cooling flame tube was presented in [4].

3. Numerical Solving Method

In order to find the temperatures T_{tf1} and T_{tf2} of the inner and outer flame tube wall in the given section, the nonlinear equation system (1) needs to be solved.

A way of solving is through the successive approaches method. We pick a value for T_{tf1} and calculate T_{tf2} in the first equation. The second equation is used to verify the T_{tf1} value that we have picked. If this equation does not verify, T_{tf1} requires to be modified accordingly and the calculation continues until convergence is reached.

The initial data required for the calculation are: the flame tube geometry, the air, the burning gases and the fuel properties, the air and gases flows in every section of the combustion chamber, the fuel flow, the temperature and pressure of the feeding air, the radiation properties of the materials the chamber is made of.

The mathematical model calculates the flame tube temperatures and the flows that characterize the heat exchange in every section for which the initial data are known. It is very useful to study the influence that various factors impel on the flame tube temperature.

4. Results. Interpretation

The variation of the flame tube temperature accordingly to the chamber inlet air temperature is presented in Fig. 2. As parameter was used the dimensionless length x/s between the current section and the one at the cooling air inlet (x being the length to the current section and s the inlet height through which flows the air film). The curves are drawn for $p = 3040$ kPa (value for which [1] yields the burning gases parameters).

In Fig. 3 is shown the variation of the flame tube temperature along the film-cooled section, the parameter being the air temperature at the burning chamber inlet. The curves are drawn for $p = 3040$ kPa. In Fig. 4 is shown the temperature in one of film cooled flame tube points accordingly to the pressure, for a temperature $T_a = 880$ K, as parameter being used the dimensionless length to the inlet. In Fig. 5 is shown the wall temperature dependency along the flame tube of the air flow variation for the film cooling, all remaining parameters being constant.

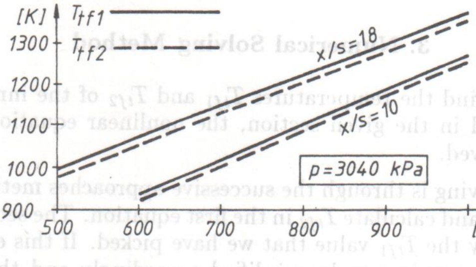

Fig. 2

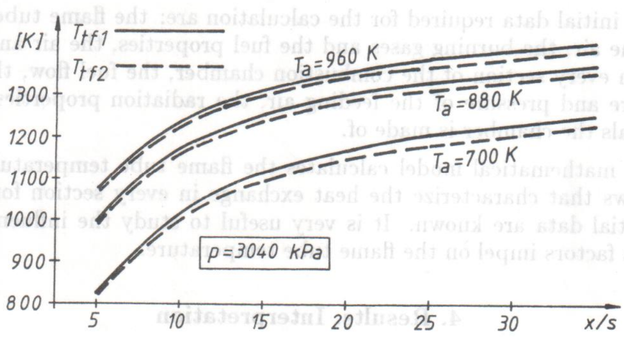

Fig. 3

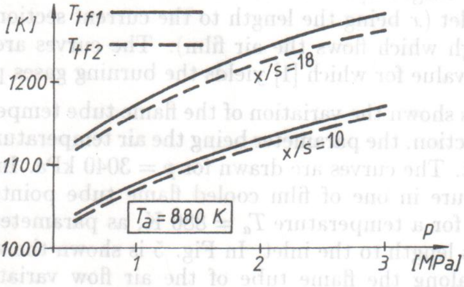

Fig. 4

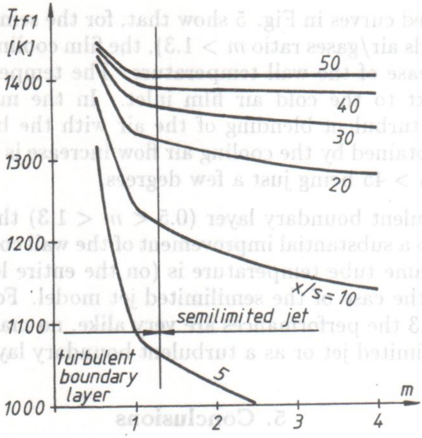

Fig. 5

It is obvious (Fig. 2) that the film cooled flame tube temperature depends almost linearly of the air temperature at the burning chamber inlet. This dependency confirms the assumption according to which the T_a increase should lead to the increase of the burning gases temperature and, consequently, to the R_1 flow increase. The T_a increase worsens the flame tube wall cooling due to the decrease of the difference between the wall and the cooling air temperatures as well.

The wall temperature dependency (Fig. 3) of the dimensionless length to the inlet reveals that just next to the air inlets the fire tube is "cold", its temperature increasing slower and slower as the x/s increases. This happens because next to the inlets the heat exchange is intense due to the great air flowing speeds and due to the great temperature gradient.

From Fig. 4 it comes out that as the burning chamber pressure increases, so does the flame tube temperature. This is justified by the fact that as the pressure increases, the flame emissivity also increases and therefore the flow R_1 increases as well. In the same time, it shows that the influence of the pressure increase by Δp is more important at lower values of it.

In which concerns the cooling air flow influence, it shows that its modification for a section of the flame tube doesn't influence at all the R_1 and

R_2 terms, strongly influencing C_1 and C_2 just a little.

The calculated curves in Fig. 5 show that, for the semilimited jet model (the masic speeds air/gases ratio $m > 1.3$), the film cooling air flow increase leads to a decrease of the wall temperature. The temperature decrease is more acute next to the cold air film inlet. In the main region of the jet, due to the turbulent blending of the air with the burning gases, the cooling effect obtained by the cooling air flow increase is much diminished, at length of $x/s > 45$ being just a few degrees.

For the turbulent boundary layer ($0.5 < m < 1.3$) the cooling air flow increase leads to a substantial improvement of the wall cooling. For smaller air flows, the flame tube temperature is (on the entire length considered) higher than in the case of the semilimited jet model. For air fl s whose m is closer to 1.3 the performances are very alike, no matter if the air film flows as a semilimited jet or as a turbulent boundary layer.

5. Conclusions

1. The mathematical model analyzed is easy to apply, it does not require a too large amount of calculations and yields conceivable results, close to the experimental results found in the literature.

2. In the close vicinity of the cooling air inlet, for $x/s \in [0...5]$, the calculation method does not work always properly, the calculated temperatures being sometimes smaller than the cooling air temperature.

3. The model allows to verify the flame tube temperatures for any functioning regime of the gas turboengine.

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FACTORII PRINCIPALI CARE INFLUENŢEAZĂ TEMPERATURA TUBULUI DE FOC DIN CAMERA DE ARDERE A TURBOMOTOARELOR CU GAZE

(Rezumat)

Se analizează un model de calcul pentru temperatura tubului de foc al turbomotoarelor cu gaze. Este studiată influenţa presiunii, temperaturii şi debitului de aer de răcire peliculară asupra temperaturii tubului de foc.