DYNAMIC CHARACTERISTICS OF THE WORKING PROCESS IN VITIATED HEATERS OF HIGH-ENTHALPY TEST RIGS

V.Yu. Aleksandrov [1], M.A. Ilchenko [2]

One of the main problems in carrying out altitude tests of high-speed ramjet engines integrated with hypersonic flying vehicle, prototypes of advanced heat-stressed combustion chambers of ramjet on ground test rig is the reproduction of air flow parameters at the entrance of engine as close as possible to flight conditions.

To generate such flow special vitiated heaters (VH) are used, in which a combustible substance (methane, hydrogen) is burned in oxygen-enriched air.

The paper presents the results of pressure pulsation signals registered in high-temperature flows in number of VH differing in design and geometric dimensions. Spectral analysis of the measured signals is performed including the representation of the amplitudes of the spectral components in the form of a function of two parameters: frequency and time (3D spectrum) using the algorithms of Fast Fourier Transform and wavelet analysis for combustion modes with fixed parameters and with their time variation.

It is established that the values of experimentally recorded frequencies of discrete spectral components of pressure pulsations in unstable combustion modes correspond to high-frequency acoustic waves propagating with the speed of sound and low-frequency entropy waves carried with the flow velocity.

Calculations of the frequencies of acoustic oscillations and entropy waves for thermophysical and gas-dynamic parameters corresponding to the chemically reacting gas mixture and boundary conditions in the initial and final sections of the VH are carried out. The existence of two different forms of acoustic oscillations is established. The discrete spectral components of the pressure pulsations in the VH can correspond to the calculated values of the resonant frequencies of the simplest acoustic resonator with lumped parameters (Helmholtz resonator) formed by the volume of an VH with a constant pressure amplitude for volume. In the other case the frequencies of the amplitudes of the discrete spectral components coincide with the frequencies of the own longitudinal acoustic modes of the VH volume with the amplitude of the pressure varying along the length of the VH.

For a more detailed study of the relationship between the pressure pulsations in the VH and in the ramjet under investigation the method of mutual synchronous spectral analysis of the pressure pulsation signals measured in them and the coherence function obtained on the basis thereof is used, which determines the quantitative measure of the linear interrelation between these signals. Analysis of the coherence function obtained as a result of the processing of the two signals indicates that a fairly pronounced relationship can be observed between the pulsations of pressure in the VH and in the ramjet under study at the frequencies of the acoustic modes of the VH. This result shows that in the case of a significant increase in the amplitudes of the discrete spectral components of the pressure pulsations in the VH an increase in the amplitudes at these frequencies in the investigated ramjet can occur, which will have a negative effect on their characteristics.

Therefore ensuring the stability of combustion in the VH and determining its dynamic characteristics are an important tasks necessary for conditioning altitude tests with imitation of extreme flight conditions, as well as meeting the reliability and performance requirements of the VH and the entire test rig as a whole.

[1] Central Institute of Aviation Motors, Russia, Moscow, Aviamotornaya, 2, aleksandrov@rtc.ciam.ru
[2] Central Institute of Aviation Motors, Russia, Moscow, Aviamotornaya, 2, 012@ciam.ru