Results of numerical modeling of combustion process in a vortex chamber

A.V. Badernikov[1], S.A. Piralishvily[2], A.I. Guryanov[2]

[1]UEC-Saturn, Rybinsk, [2]Rybinsk State Aviation Technical University

Free opposite swirling jets interference researches confirm the presence of shear mixing layers that generate high-intensity turbulence, large-scale eddies and three-dimensional vortex structures. The observed effects are used to organize intensive mixing of fuel and air components, followed by firing augmentation of the prepared fuel-air mixture with high intensity in a limited volume. The mentioned concept has developed in the designs of various reverse-flow burner units, the basis of which is the modified design of the vortex tube [1].

The research of the combustion products velocity, the distribution of the temperature inside and at the outlet of the vortex chamber, was carried out in the paper [2]. The vortex chamber with a diameter Dk = 152.5 mm ($\overline{F}_c$ = 0.12, $\overline{R}_d$ = 0.511, $\overline{L}_k$ = 2) is equipped with a quartz glass window for laser-optical measurements of the flow velocity and holes for platinum-rhodium thermocouples. The premixed mixture of air and natural gas was used as a fuel. Both ratio of the fuel components and their consumption are varied during the testing. Simplicity of configuration and a sufficiently large amount of experimental data of the paper [2] make it possible to use it as a model problem for adjusting the physical and mathematical model that correctly reflects the characteristic features inherent in the swirling flow in a vortex reverse-flow burner module, taking into account the combustion reactions.

The calculations of the combustion process in a vortex chamber [2] are given in this paper. The calculations were performed both on the original turbulence model RNG k-ε and with allowance for the curvature of streamlines [3]. For the calculations, the Eddy Dissipation Model (EDM) and the Burning Velocity Model (BVM) [4] were used, the chemical reaction kinetics was modeled by a 2-step scheme for the EDM model and a detailed kinetic mechanism containing 28 substances and 100 reactions for the BVM. The calculations were carried out both under the assumption of the vortex chamber adiabatic walls and in the formulation of the coupled heat exchange with the walls taking into account the emission. Calculations were carried out via ANSYS CFX software system. A block-structured hexahedral grid with a volume of 300,412 elements was constructed for calculations. The number of elements in the axial, radial, circumferential direction is 150x45x30, respectively.

Analysis of the calculation data indicated the following:

1) Measurement of the nonadiabaticity of the vortex chamber walls plays a significant role in the formation of the temperature field in the end part of the vortex chamber. 2) Applying the allowance for the curvature of streamlines makes it possible to predict the circumferential velocity component and the location of the flame front in the vortex chamber more accurately. 3) The calculation data on the combustion models EDM and BVM indicate close to each other results, which are in good agreement with the experiment. 4) Calculations have shown that, depending on the initial approximation, several possible stable solutions can be calculated.

The obtained results and adjustments of the physical and mathematical model will be used to calculate the vortex reverse-flow burner module.

References

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