Simulation of CO emission in the small-sized combustion chamber with liquid fuel injected by pressure swirl atomizer

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The preparation process of the air-fuel mixture is one of the most important in organizing the working process in the combustion chamber since it affects such characteristics as the combustion efficiency, the stability of the combustion process, and the emission of harmful substances. The most common type of atomizer used for combustion chambers of small size gas turbine engines is the pressure-swirl atomizer.

In this paper, a method for calculating the characteristics of liquid fuel injection by pressure swirl atomizers to set the boundary conditions for injection into the combustion chamber is proposed. In addition, the paper presents the results of CO emission simulation in a model combustion chamber with two variants for setting the boundary conditions for liquid fuel injection. A method for setting the boundary conditions for liquid fuel injection using a discrete phase model (DPM) is proposed, for which the parameters characterizing the fuel atomization are obtained as a result of two-phase flow simulation by the volume of fluid (VOF) method. For comparison, the parameters characterizing the atomization for setting the boundary conditions for fuel injection were also calculated using the pressure swirl atomizers calculation method proposed by H. Lefebvre. By comparison of two boundary conditions setting methods, it was found that the proposed method for determination of the boundary conditions for injection allows to increase the accuracy of CO emissions prediction several times compared to the classical semi-empirical pressure swirl atomizers calculation method.

As a result of determining the characteristics of liquid fuel atomization by pressure swirl atomizer, for using it as boundary conditions for fuel injection into the combustion chamber, the following results were obtained:

1. An operation scheme of a hybrid method designed to determine the parameters of the primary fuel atomization by pressure swirl atomizers that are necessary to set the boundary conditions for fuel injection into the combustion chamber for combustion processes simulation has been formed;
2. It can be seen from a comparison of two variants of the boundary conditions that the droplet tracks, the characteristics of which are determined by the semi-empirical method of A. Lefebvre, extend up to the outlet section of the combustion chamber, which can lead to overestimated values of incomplete combustion products when simulating pollutant emissions;
3. Comparing the calculated and experimental values of CO emission in the model combustion chamber, it was found that the standard deviation between the values obtained using the injection parameters determined using the developed calculation method does not exceed 15%, which is an acceptable result;

Therefore, it can be concluded that when setting the injection parameters obtained using the developed method of calculation of pressure swirl atomizers atomization characteristics, it is possible to increase the accuracy of determining CO emission by 1.5–2 times compared to the classical semi-empirical pressure swirl atomizers calculation method.

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