COMPUTATIONAL MODELING OF FLOW IN A LOW-EMISSION COMBUSTION CHAMBER OF CIAM WITH A LARGE RECIRCULATION ZONE BEHIND A CONICAL FLAME HOLDER

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Abstract: A computational study of the hydrodynamics of the flow without combustion in the compartment of a full-size low-emission combustion chamber (LECC) of CIAM of the original scheme with one large recirculation zone was carried out in order to select the least expensive method for calculating the turbulent flow, determine the optimal parameters of the design scheme, clarify the flow characteristics typical of LECC (the position of the places of maximum pressure and velocity pulsations relative to the zones where the main heat release occurs during combustion, the influence of areas adjacent to the main design zone and boundary conditions, the flow structure at the end of the recirculation zone). Calculations of the turbulent flow were performed by LES (large-eddy simulation) and SAS (scale adaptive simulation) methods in two configurations — with an input receiver and without it, for two computational meshes of varying degrees of detail. The results of calculations on the length of the recirculation zone, the level and spectral composition of pressure pulsations are compared for different computational domains and meshes with each other and with data from the previously conducted experiments. The analysis of possible reasons for the difference from the experimental results was carried out and recommendations are given to limit the degree of detail of the computational domain and mesh for the considered type of the combustion chamber. The use of the SAS method is appropriate for real combustion chambers during their design and finishing calculations.

Keywords: low-emission combustion chamber; turbulent flow; LES and SAS methods; computational domain and mesh

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Figure Captions

Figure 1 Half of the design domain of an experimental full-size LECC of CIAM with a receiver and a fuel collector: *1* — receiver; *2* — mixer with a burner; *3* — mixer confuser; *4* — swirler; *5* — conical stabilizer; *6* — diffuser; and *7* — combustion chamber

Figure 2 The structure of the basic calculation mesh on the example of a configuration with a receiver: (*a*) a coarse calculation mesh in the domain of the flow outlet from the chamber; and (*b*) a fine calculation mesh in the vicinity of the receiver, mixer, and flame stabilizer

Figure 3 Shape of the recirculation zone (RZ) boundary

Figure 4 Comparison of the shapes of the RZ boundaries, SAS method: *1* — with receiver; and *2* — with receiver and a corrected swirler. Dimensions are in millimeters

Figure 5 The change in the RZ length with the quality of the calculation mesh in the combustion chamber for a configuration without receiver using two methods: *1* — LES; and *2* — SAS

Figure 6 The change in the RZ length with the completeness of the calculation domain for the basic calculation mesh by two calculation methods: *1* – LES; and *2* — SAS

Figure 7 Fields of averaged pressure pulsations P_{rms} (*a*) and averaged velocity pulsations V_{rms} (*b*)

Figure 8 The influence of the computational domain on the field of the velocity module (top — with receiver, mixer, and front device; and bottom — without). The basic quality of the calculation mesh, SAS method

Figure 9 The effect of mesh quality on the distribution of pressure pulsations along the axis of the chamber; without receiver; SAS method: *1* — basic mesh; and *2* — fine mesh

Figure 10 Distribution of pressure pulsations along the axis of the chamber; without receiver, basic mesh. Comparison of LES (*1*) and SAS (*2*) methods

Figure 11 Distribution of pressure pulsations along the axis of the chamber for various configurations of the computational domain: *1* — without receiver; *2* — with receiver; *3* — with receiver and a corrected swirler; and *4* — experiment. Meshes of basic quality; SAS method

Figure 12 The boundaries of the RZ (top) and the field of averaged pressure pulsations (bottom); configuration with the receiver; SAS method

Figure 13 The spectrum of pressure pulsations on the axis of the chamber at $x = 200$ (*a*), 400 (*b*), and 500 mm (*c*); without receiver; LES method; basic mesh; at the end of the main calculation period

Figure 14 The spectrum of pressure pulsations on the axis of the chamber at the end of the RZ at $x = 400$ mm; without receiver; LES method; basic mesh; at the end of the additional calculation period with a duration of 0.45 s

Figure 15 Comparison of the SAS method (*1*) with LES method (*2*) in terms of the ability to create the spectral content of the stream; for the points on the chamber axis at the end of the RZ without receiver; basic mesh

Figure 16 Influence of the configurations of the computational domain on the spectrum of pressure pulsations on the axis of the chamber at the end of the RZ; SAS method; basic mesh: *1* — without receiver; *2* — with receiver; and *3* — with receiver and a corrected swirler

Table Caption

The length of the recirculation zone obtained in the calculations

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