

більш сприятливу зону циклу та покращенні параметра CA50. Разом з тим збільшення рівня водневої добавки обмежується зростанням швидкості наростання тиску в циліндрі. Отже, використання водню в режимі мікродобавок може бути ефективним засобом підвищення досконалості робочого процесу дизеля без суттєвої зміни його конструкції.

Література

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CFD MODELING OF HYDROGEN LEAKAGE IN THE FUEL SYSTEM OF AN AIRCRAFT HYDROGEN ENGINE

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The use of liquid hydrogen as a fuel for aviation is an important step towards decarbonizing emissions. In addition to environmental friendliness, hydrogen has a high heat of combustion, provides high heat transfer coefficients, and its reserves as a chemical element are virtually unlimited. Along with the issues of creating economically feasible H₂ technologies, technical implementation of H₂ engines, on-board H₂ storage and supply systems, the key problem is safety at all stages of use [1].

Hydrogen is easily flammable and has a wide range of flammability in air. Therefore, its leaks pose a danger to any variant of the hydrogen fuel system configuration both in ground transport and in aviation. Emergency leaks of hydrogen from pipelines, tanks or other elements of the fuel system can lead to catastrophic consequences both on the ground and during flight. In recent years, special attention has been paid to safety issues and various scenarios of hydrogen leaks and its mixing with air are being considered. CFD modeling is a key tool for predicting such processes [2]. Despite a fairly large number of modern studies in the field of modeling hydrogen leaks and the features of its mixing with air, today there is no universal and reliable approach to solving such problems. Cases of hydrogen leaks on board an aircraft are especially poorly studied, taking into account the extensive system of pipelines, complex design and compact arrangement of fuel system elements.

The aim of this study is to calculate the flow distribution of hydrogen in air, the change in the volumetric concentration of hydrogen over time, and the identification of areas with an explosive concentration of hydrogen in the event of an emergency hydrogen leak in the fuel system of a hydrogen aircraft engine.

One of the most dangerous scenarios when hydrogen leaks into the enclosed airspace of an aircraft wing or fuselage through a damaged fuel system element is considered. The developed model also allows to calculate the processes of mixing flows during hydrogen leakage from fuel tanks located inside the aircraft. The studied computational domain is a volume of air space 2.8 m x 1.2 m x 0.8 m, in which an element 2 m long and 0.4 m in diameter is placed. On the surface in the center of this element is a source of hydrogen leakage with a diameter of 10 mm. Hydrogen mass flow rates of 0.1...1 g/s are considered for cases with ventilation and in its absence.

The problem was solved in a three-dimensional formulation using CFD modeling. The process of mixing flows was modeled by solving a system of mass, momentum, and energy conservation equations with the addition of a convective-diffusion equation within the Species Transport model. The Realizable k-e model was used to describe turbulence. The Pressure-Based Solver in a transient formulation was used as a solver for such a system of equations. Based on the results of the mesh convergence analysis, a hybrid mesh with a total number of elements of 0.83 million was selected. The hydrogen leakage model was validated by comparing calculations for different turbulence models with experimental data from other authors. The calculation error did not exceed 10%.

Based on the results of the calculations, the regularities of the hydrogen flow distribution in the air space around the fuel system elements, the change in the volume fraction of hydrogen over time, and the areas with explosive hydrogen concentrations and the conditions of their occurrence were determined.

Conclusion

Analysis of the results showed the maximum concentration of hydrogen in the air is observed in the core of the hydrogen flow and is about 90% by volume. The

diameter of such a core for the case without ventilation is almost independent of the hydrogen flow rate and in the range of hydrogen mass flows of 0.1...1 g/s is about 0.15 m. For the case of hydrogen leakage with a mass flow rate of 1 g/s and without ventilation, the explosive concentration of hydrogen in the air in the entire calculation area is reached very quickly. After 10 seconds, it occupies about 20% of the total volume, and after 60 seconds it is 60%. The explosive concentration of hydrogen in the air is established mainly in the first 60 seconds from the beginning of the leak for the case without ventilation and in its presence with air velocities of 0.5 m/s. In the case of ventilation in a horizontal direction with an air velocity of 1 m/s, hydrogen does not accumulate in the volume; it is all blown away by the air flow.

The results obtained allow for more accurate prediction of the consequences of an emergency hydrogen leak in the fuel systems of hydrogen aircraft engines, and for developing effective ways to identify hydrogen leaks, which will increase the reliability and safety of hydrogen systems in general.

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