Numerical simulation of a swirling flow of water vapor with aluminum micro- and nanoparticles and a heating source

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Currently, significant interest is being shown in research on the creation of environmentally friendly energy sources, in particular, autonomous installations for the production of hydrogen and thermal energy.

A relatively complete kinetic scheme of plasma-chemical reactions in a discharge in water vapor in the presence of metal micro- and nanoparticles includes a significant number of reactions. Therefore, simplified kinetic schemes are usually developed that make it possible to calculate the parameters of discharges and flows.

The work took into account the heterogeneity of the working mixture of water vapor/aluminum powder. An analysis of experimental work showed that the ignition temperature of particles ~1 μm in size is about 1500 K. In turn, the simplified kinetic scheme of chemical reactions takes into account that aluminum oxide Al_2O_3 does not exist in the gas phase and very quickly decomposes into sub-oxides.

The rate constants are obtained from a number of works and the US National Institute of Standards and Technology database. The thermodynamic parameters of the substances involved in the reactions were calculated using NASA seven-coefficient polynomials.

Based on the solution of the system of Reynolds-averaged Navier-Stokes equations, a three-dimensional multicomponent flow in the PVR was studied, accompanied by the combustion of aluminum supplied in the form of powder. The turbulence model SST k-ω was used to close the system. At the inlets of the swirler, a constant mass flow rate of the mixture, the mass fraction of the metal, and its temperature were set.

The calculations were carried out with varying power of the heat source, which simulated the heating of the mixture in the discharge region, and the mass fraction of supplied aluminum. Within the framework of the scheme used, an increase in the maximum concentration of both atomic and molecular hydrogen was demonstrated with increasing heating and increasing the concentration of the supplied metal, Fig. 1

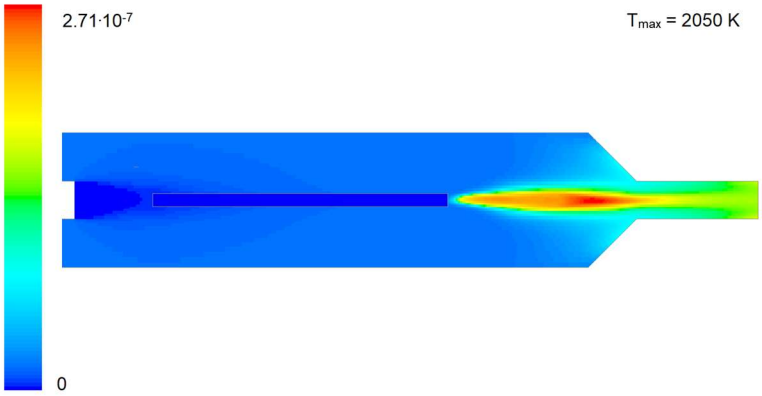

Fig.1. Distribution of the molar concentration of atomic hydrogen (H) at the maximum temperature T_{max} = 2050 K, mol/cm^3

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