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Experience of Using CFD Models for Development of High-Temperature Furnace Equipment for Fabrication of Mixed Nitride Uranium-Plutonium Fuel Pellets

CFD modeling was extensively used for the development of high-temperature furnaces for the carbothermal synthesis of uranium and plutonium nitrides and a furnace for the sintering of mixed nitride uranium-plutonium fuel pellets. This equipment is intended for use at the Pilot Demonstration Energy Complex (PDEC) being constructed in Seversk, Russia. The CFD-model of the carbothermal synthesis furnace was developed with the SolidWorks Flow Simulation software to obtain a three-dimensional temperature distribution both inside the furnace and in the bulk material charged, as well as typical gas flow patterns and a gas velocity distribution throughout the furnace. The CFD model was verified using experimental data on the temperature profile at three points inside the furnace measured during heating, isothermal exposure, and cooling within a temperature range from 20 to 1650 °C during acceptance tests of the manufactured equipment. The CFD model was used to verify the engineering solutions selected and formulate recommendations on operation modes of the furnace. In particular, the modeling results demonstrated a wide range of process parameters, such as the heater temperature, the gas temperature and flow rate, that ensure a temperature of 1650±50 °C throughout the bulk material required for the carbothermal synthesis of uranium and plutonium nitrides. It is shown that the maximum difference in temperature throughout the bulk material does not exceed 62 °C.
A horizontal pusher-type sintering furnace was developed, wherein mixed nitride uranium-plutonium fuel pellets successively move through heating, sintering, and cooling zones with different gas media. The CFD model of the furnace channel was developed with the Ansys Fluent software and underwent benchmark testing on a specifically built bench for gas-dynamic investigations using a full-size channel model. The engineering solutions were proved to ensure the sustainable operation of three gas zones (argon-nitrogen-argon) in the furnace channel at a sintering temperature of ~1950 ℃.
Application of the CFD models reduced the time of developing the high-temperature furnace equipment and facilitated the justification of the engineering solutions. The developed models allow simulations of various operation modes including possible emergencies and will be used to support the operation of the high-temperature furnaces.

Country/Int. organization

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