APPROXIMATE ESTIMATES FOR THE NONLINEAR STATIONARY RADIAL HEAT CONDUCTION IN THE CERAMICAL NUCLEAR FUEL PELLETS

Romashov Yu. V., Chibisov D. O.
National Technical University «Kharkiv Polytechnic Institute», Kharkiv

It is clearly understood that the temperature state of the ceramic nuclear fuel pellets used in the fuel rods of nuclear reactors is significantly depended on the thermo-physical properties of their material. It is well-known, the heat conductivity of the ceramic nuclear fission materials for fuels is very small and has very noticeable depending on the temperature such as increasing the temperature leads to decreasing the thermal conductivity. At the same time, the most of the known proposed approximate assessments of the temperature state of the nuclear fuel pellets made from ceramic materials are based on the linear heat conduction grounding on the averaged value of the thermal conductivity. It is naturally, that these linear assessments of the temperature state of the ceramic nuclear fuel have some discrepancies due to neglecting of depending on the temperature of the heat conductivity. The purpose of this research is to obtain of estimations of discrepancies in the results for the temperature state of the ceramic nuclear fuel pellets as consequence the linearization the initially nonlinear heat conduction equation.

The mathematical formulation of the stationary heat conduction in the form of two group of equations including the heat balance equation and the Fourier's Law of the heat conduction connecting the temperature and the heat flow vector is used for approximate assessment of the nonlinear radial heat conduction of the ceramic nuclear fuel pellets instead traditional approaches based on single heat conduction equation for the temperature. Using such mathematical formulation allows excluding the derivative on the temperature of the thermal conductivity coefficient from the solving equations when the temperature state of the ceramic nuclear fuel pellets is researched. Due to that circumstance, we have regularization of the thermal conductivity coefficient representing only by values corresponding to the some given temperatures. Besides, due to that circumstance it is possible to represent the thermal conductivity coefficient as sum of the constant and the temperature dependent terms and use the Picard's method for iterative solving the nonlinear heat conduction differential equations with necessary boundary conditions.

Using proposed approach, the stationary radial nonlinear heat conduction in the cylindrical ceramic nuclear fuel pellet, which is typical for the nuclear fuel rods of the most modern nuclear reactors, including the VVER-1000 type nuclear reactors, is considered. The state of zeros heat flow thru the inner surface of the fuel pellet and the heat transfer thru the outer surface of the fuel pellets are considered as the boundary conditions. Using the computational simulations, it is shown that taking into account the temperature dependence of the thermal conduction coefficient lead to higher temperature estimations comparing with the corresponding results on the ground of linearization.