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Modeling of radiative cooling of disperse flows of the low-grade heat rejection frameless systems in space

For solving some urgent problems of the use of space it is necessary to essentially raise the power-to-weight ratio of space vehicles. The most problem constituent of their power systems is the low-grade heat rejection system. Micrometeorite vulnerability of conventional panel radiators and those out of heat pipes increases quickly with increasing rejecting power (and the surface area along with it). Armoring of radiators surfaces inadmissibly raises the space vehicle mass. The use of the frameless systems of low-grade heat rejection may be a way out. The idea of droplet cooler-radiator (DCR) involves the heat rejection with the aid of the heated droplet flow. The droplet generator disperses the heated heat-transfer agent, the collector picks up the cooled droplet flow.

The problem of the thermal design of high-temperature DGR was widely discussed in literature. It has been revealed that the droplet flow emissive capacity, equal to the instantaneous loss of heat, referred to the instantaneous average temperature to the fourth power, depends only on the optical thickness of the flow and the dissipation albedo. In so doing, the flow emissive capacity differs essentially from the case with the zero temperature gradient.. This regularity becomes true after the initial transient period, in the course of which the agreement of the temperature distribution and the dissipation source function takes place. The duration of the transient period for high-temperature CDR (T>600K) is negligibly small. At the same time, for low-grade CDR (T<500K) the time to reach the steady-state process may exceed the droplet transit time in a sheet. And so, for the thermal design of the low-grade CDR it is necessary to obtain a solution of the problem of radiative cooling of the structured droplet sheet, describing the transient processes.

The paper deals with the calculation results of processes of establishment of the temperature profiles in the structured droplet flows of arbitrary optical thickness. The problem is solved with expansion of the temperature field in the flow by a system of eigenfunctions of the overradiation process of the disperse flow structural elements. The method is based on consideration of the disperse flow as a whole. Analytic dependences, describing the process of establishment of the temperature profile in the droplet flow, were obtained. The problem made it possible to determine the temperature field and the thermal power of the low-grade CDR. The computer program for research of progress of nonstationary heat-exchange processes in the CDR droplet flow was created. Numerical and approximate analytic results were compared. The resistance of the droplet flow cooling process to disturbances of the temperature field in the flow in different conditions, including at the available external radiation, were analyzed. A method for designing the droplet flow structure, that is optimum for the operation of the space vehicle power system, was proposed.