STUDY OF CATALYTIC HEATING EFFECTS ON METALS AND QUARTZ FOR EXOMARS ENTRY CONDITIONS

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This work has been carried out in the framework of SACOMAR Project (7^{th} Framework Programme of EC). The scope of the paper: (1) to perform heat transfer tests in CO_2 and $97\%CO_2$ + $3\%N_2$ plasma flows by 100-kW RF-plasmatron in accordance with specified EXOMARS vehicle entry conditions, (2) rebuilding subsonic high-enthalpy free stream conditions in the facility and (3) to determine recombination coefficients γ_{wO} and γ_{wCO} for water-cooled surfaces of some metals and quartz.

For EXOMARS vehicle entry conditions subsonic heat transfer tests with pure CO_2 and $97\%CO_2$ + $3\%N_2$ plasmas have been performed. The water-cooled cylindrical nozzle was used, and generator power, pressure in test chamber, and distance from model surface to the nozzle were altered in order to meet requirements of the test plan. The four tests regimes were selected and realized according the test matrix at the specified enthalpy (9 and 13.8 MJ/kg) and stagnation pressure (80 and 40 hPa).

Measurements of the heat flux rates to the 50-mm diameter model with the reference probe with silver surface in wide range of the RF-generator power and stagnation pressures have been performed. Evidence of silver surface oxidation was observed. The time history of the stagnation point heat flux to the silver wall was registered. The saturation time for reaching maximum heat flux is found to be about 20 min.

Indirect numerical rebuilding CO_2 flow enthalpy by GAMMA CFD code through calculated heat flux rates to cooled fully catalytic wall and comparison with the data of stagnation point heat fluxes to oxidized stable silver surface and measured dynamic pressure was carried out.

Measurements of the stagnation heat flux to silver, copper, stainless steel (T_w = 300 K) and quartz (T_w = 500 – 755 K) surfaces at the pressures 80 and 40hPa have been performed. In subsonic $97\%CO_2$ + $3\%N_2$ and pure CO_2 flows the materials are arranged in the order Ag $>$ Cu $>$ stainless steel $>$ SiO_2 in terms of stagnation point heat fluxes.

Subsonic ICP flow parameters in IPG-4 segmented discharge channel with conical nozzle are calculated by Alpha code on the basis of Navier-Stokes and simplified Maxwell equations for the four IPG-4 test regimes realized for $97\%CO_2+3\%N_2$ working gas according test matrix. Parameters of equilibrium reacting subsonic jet flow over euromodel are calculated by Beta code on the basis of Navier-Stokes equations for the same test conditions.

One-dimensional 5-species (CO_2, O_2, CO, O, C) flow in nonequilibrium dissociated boundary layer with finite thickness near the model stagnation point was calculated by Gamma code to determine heat flux envelopes for the IPG-4 test regimes with CO_2 working gas. The calculations were made for the standard (Goulard's like) and the novel self consisted model of surface catalysis for O-atoms and CO-molecules recombination.

CO recombination coefficients γ_{wCO} are determined by the novel model for quartz and stainless steel for the four test regimes with use of the following fixed values of γ_{wO}: γ_{wO} =2e-3 for quartz and γ_{wO} =2.6e-3 for steel according available literature data. Comparison of the effective recombination coefficient $\gamma_w = \gamma_{wO} = \gamma_{wCO}$ obtained by the standard model with the newly obtained catalytic efficiencies γ_{wO} and γ_{wCO} is presented.