THREE DIMENSIONAL RADIATION IN MARTIAN ATMOSPHERE

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It has been long time understood that there is a strong necessity in accurate and time efficient method of radiative heat transfer prediction during planetary entry. These requirements are defined by strong radiative-gasdynamic interaction which takes place between hypersonic inlet flow and thermal protection capsule of descent space vehicle.

An experience of past space probe missions and present-day calculations show that during capsule entering in Martian atmosphere it experiences heating by strong CO_2 and CO bands. On the other hand, the radiative part of complex radiative-gasdynamic solvers can take significant (up to 90%) of total time. The order of temperature entering velocity is such to influence on gasdynamic parameters of inlet flow. The trajectory of probe is considered to be under non zero angle of attack, so the flow field is essentially three dimensional.

This paper presents a high time efficient computational platform for three dimensional spectral radiation transfer calculation.

The governing system of equations is solved by program code NERAT-3D.

The radiative heat transfer is described by the P_1-approximation of spherical harmonics method. The P_1-approximation is an accurate and powerful method for radiation calculation in strong absorbing media. Considering the extremely strong absorption in infrared and UV part of spectrum in Martian atmosphere, the P_1-approximation seems to be good enough to describe radiative heat transfer. The media is considered to be absorbing and emitting.

The multigroup spectral model (100 spectral groups) is chosen to describe optical properties of Martian atmosphere. 10 species model (C, N, O, C_2, N_2, O_2, CN, CO, NO, CO_2) and 37 reactions are used to describe chemical properties of inlet flow.

The computational platform performs with multiblock structured and unstructured grids. This fact allows calculating radiative heating of complex shape bodies. Two types of three dimensional capsules are used: spherical body with radius 66 cm and the body, similar to Pathfinder shape with radius 120 cm. Such blunt cone at front shield and truncated cone at back shield shape is typical for capsule of new ESA mission EXOMARS.

Radiative heating parameters are obtained for point of MSRO trajectory where thermal protection system experiences maximum of radiative heating. The parameters of inlet flow are P_∞ =2.462x10^0 erg/cm^3, ρ_∞ = 1.01x10^{-8} g/cm^3, T_∞ = 129 K, V_∞ =7.49x10^5 cm/s. These parameters correspond to the 42^{nd} second of MSRO flight. The altitude is 50 km approximately.

The spectral and integral heating calculation along the whole body surface is presented. The verification against tangent slab approximation and ray-tracing method is demonstrated. The volumetric radiative heat release in the whole computational domain is also obtained. The adequate accuracy of P_1-approximation is demonstrated.

The efficient strategy of P_1-approximation method in case of small optical thickness is proposed. This step of optimization allows dramatically decrease the time consuming factor of P_1-approximation comparing with ray-tracing method. The summarizing table of P_1-approximation, tangent slab approximation and ray-tracing method time efficiency presented.

In the conclusion, some general recommendations for efficient coupling radiative and gasdynamic solvers are suggested.