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NUMERICAL SIMULATION OF RADIATION TRANSPORT PROBLEM AROUND REENTRY VEHICLE

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ABSTRACT

There are many active space research programs concerned with regular space launches. They include launches of interplanetary stations (NASA "Phoenix Mars Lander 2007" program) and International Space Station flights. The problem of thermal protection development for space vehicles remains very important. It requires accurate prediction of the heating environment.

Numerical investigations of radiation transport problem around a reentry vehicle are carried out using the model of the diffusion approximation. The model was coupled with the gas dynamics part including radiation flux in the energy equation. The quasi gas dynamics equations [1] were used to compute gas dynamic flows. A radiation database has been developed in order to use the values of the absorption coefficients for the problem [2,3].

High performance multiprocessor computing systems with distributed memory were used for the calculations. Parallel algorithm and parallel code have been developed. The parallel algorithm is based on the method of splitting of computational domain on space and splitting of spectrum. The equations of radiation gas dynamics are solved on a "pipe-line" or "grid" topology of processors.

The described technique is implemented to model two dimensional flows around body with 0.5035 m radius. It is the maximal radius of the body. For calculations some shapes of the body were applied: rectangular, bullet and egg. The hybrid irregular grids were used for calculations [4]. They consist of rectangular and triangular cells.

The diffusion equations consume more than 90 % of total calculation time. Each group contributes to radiation field only if the temperature and pressure of environment fall within some range of values. Influence of radiation is not essential if the temperature is less than 600-700K. For each time step we need to determine whether or not to include in calculations particular group. Application of dynamic loading algorithm of the processors to distribute the frequency groups on the computing system is necessary. As a result the volume of the calculations of the radiation block substantially diminishes. Efficiency of load balancing of processors is approximately 10% at the initial stage of calculations (low temperatures), and approximately 60-80% during next periods.

The examples of calculations on the hybrid grid for Mach number 12 are presented. At Figure1 red color reflects high temperature in the shock layer. For this example the temperature is equal to 9310K. Temperature distribution with radiation is shown in Figure 2. The maximum value of the temperature with radiation is lower than without radiation (7714K).

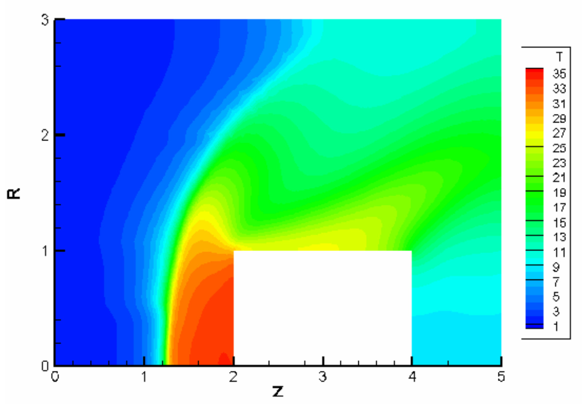

Figure 1. Distribution of temperature without radiation

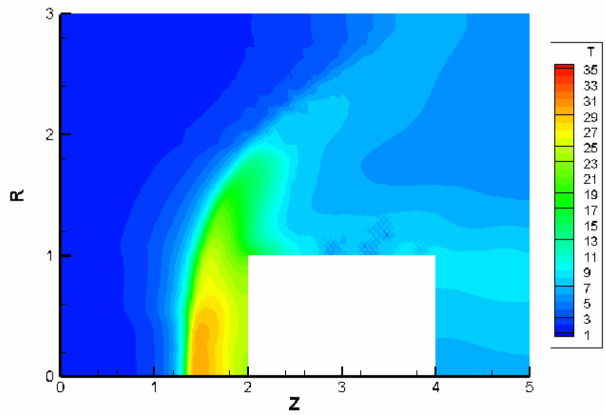

Figure 2. Distribution of temperature with radiation

The calculations reflect an essential difference between a variant with radiation and without radiation. Numerical results show that the radiation heat transfer processes are very important for accurate prediction of gas dynamics fields around reentry vehicles.

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