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Test Particle Monte Carlo Simulation of Return Flux on Various geometric surfaces due to Ambient Scatter of Outgassing Molecules

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Abstract

The test particle Monte Carlo (TPMC) method is delineated by taking the molecular return flux problem for the flow past a complete sphere as an example and the return flux on a variety of geometric surfaces, including a complete sphere, a circle flat plate, a convex and concave hemisphere, due to ambient scatter of outgassing molecules is simulated by this method. The return flux ratio (RFR) obtained here for the flow past a sphere is in good agreement with previous results. Then, effects of various outgassing and freestream conditions on RFR for flows past three geometric bodies, including a circle flat plate, a convex and concave hemisphere, have been investigated and compared. Moreover, heuristic arguments about geometric, outgassing and freestream governing parameters provide theoretical references for the evaluation and control of return flux contamination.

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Keywords: outgassing molecules; ambient scatter; return flux; test particle Monte Carlo; hemisphere.

1. Introduction

Gases are emitted from space vehicles as a result of outgassing from the surface materials, control jet efflux, and waste discharge [1]. However, emitted molecules that would otherwise escape from the vehicle may return because of the scattering caused by collisions with other molecules. Therefore, the return flux is formed. The physical quantity describing the magnitude of return flux is return flux ration (RFR), which is defined as the fraction of molecules that return to the outgassing surface. Return flux is divided into the ambient-scattered flux due to

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collisions between emitted molecules with ambient or freestream molecules, and the self-scattered flux due to intermolecular collisions entirely within the outgassing gas cloud. Generally, the latter is much less than the former in magnitude, so we only consider the former here. As a general rule, the RFR is extremely small. However, it has a significant effect on performances of sensitive equipment on spacecraft such as solar arrays, mirrors and lenses [2], and in most cases, the performance of optical equipment determines the overall performance of the satellite mission. Thus, an accurate estimation of contamination is an essential issue in the design of satellites.

Return flux contamination by backscattering has been considered difficult to handle due to the strong directional anisotropy of backscattering flux. Common analysis methods such as the Bhatnagar-Gross-Krook model and the direct simulation Monte Carlo (DSMC) technique are rather inefficient because they are complicated or take a long time for simulation [3]. The TPMC method was put forward by Davis [4], which is suited to collisionless and near free molecular gas flows. Its distinguishing feature is that the representative molecular trajectories are generated serially rather than simultaneously [5]. Consequently, it doesn't require too large storage capacity. In 1993, Fan et al. [2] applied the TPMC method to the molecular return flux problem due to self- and ambient-scatter of outgassing molecules. Guo and Liaw [6] concluded that the TPMC method can reduce a large amount of computer time compared with the DSMC method and its results are more accurate than the solutions of BGK equations. Therefore, TPMC is more practical than the DSMC and BGK method for the predictions of spacecraft contamination.

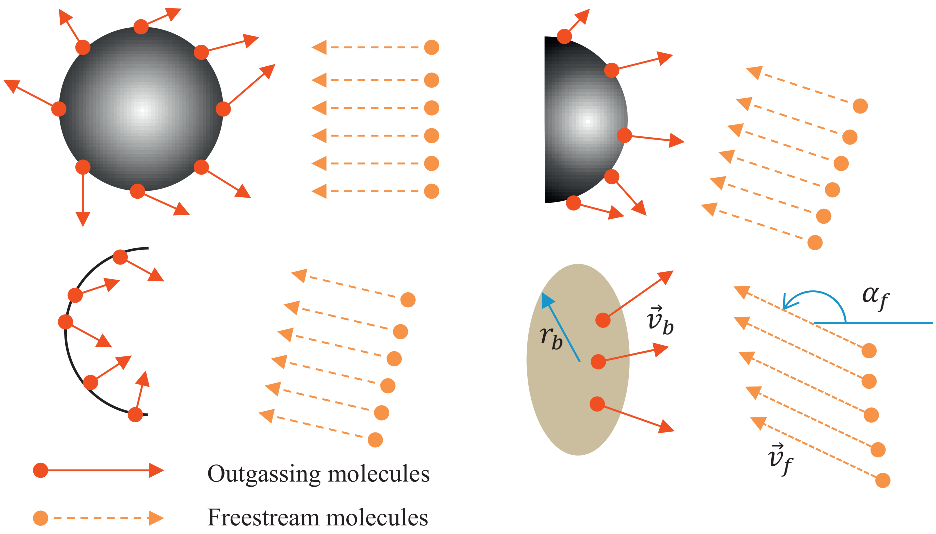

Fig. 1. Schematic of flows (Flows past a sphere, a convex and a concave hemisphere and a circular flat plate)

The present work will deal with the molecular return flux on a variety of geometric surfaces (Fig. 1) due to ambient-scatter of outgassing molecules. After the RFR results for the flow past a complete sphere are validated by comparing with previous DSMC results [1], Then, effects of various outgassing and freestream parameters, including the outgassing molecular mass, the temperature of outgassing surfaces, and the freestream molecular mass, velocity and molecular number density, on RFR for flows past three geometric bodies, including a circle flat plate, a convex and concave hemisphere, have been investigated and compared. In addition, heuristic arguments about geometric governing parameters, provide theoretical references for the evaluation and control of return flux contamination.

2. Test particle Monte Carlo method

The main TPMC procedure for present return flux problems is summarized as follows. Firstly, construct a control volume and generate a test particle on the outgassing surface. Secondly, keep on tracking and simulating its