NUMERICAL SIMULATION OF LIQUID APOGEE ENGINE PLUME FOR GEO SATELLITE USING PARALLEL DSMC METHOD

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Summary. The present abstract introduces the plume flow simulation of liquid apogee engine for geostationary satellite is investigated using parallel DSMC method.

1 INTRODUCTION

The geostationary Earth orbit (GEO) is a widely used mission orbit for communications and weather monitoring satellites[1]. As an altitude of GEO is about 36,000 km from the Earth's surface, the launch vehicle first places the GEO satellite into a transfer orbit with an altitude of about 200 km. Then, the GEO satellite fires its onboard liquid apogee engine (LAE) for several times to get sufficient velocity increment to reach its final mission orbit as shown in Figure 1[1].

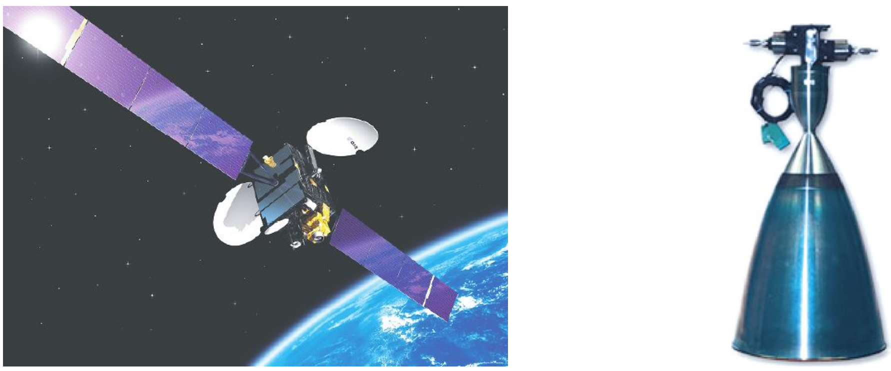

Figure 1: Configuration examples of GEO satellite and LAE[1]

As a thrust level of several hundreds of newton is usually utilized for the LAE, a considerable amount of a high-temperature and high-pressure plume flow is ejected during the operation of the LAE and also expands freely in a space environment along all directions. Due to a high vacuum effect, severe plume backflow collides directly with the satellite surfaces and eventually causes severe heating and contamination on exposed satellite components, which can degrade optical properties and performance of solar panel especially. Therefore, accurate predictions of the LAE plume flow and assessments of its influences on the GEO satellite need to be conducted from the initial design phase of the satellite. There are several researches which deal with the plume influences of the small newton thrusters for an attitude control of the satellite, however, the plume simulation of LAE with several hundreds newton thrust has been rarely reported in previous literatures.

Thus, the objective of the present paper is to investigate numerically a plume flow influence of the liquid apogee engine during the orbit raising sequence of the GEO satellite using parallel DSMC method.

2 PARALLEL DSMC METHOD

To deal with the complex plume flow regimes of stagnation, continuum, and rarefied conditions efficiently, the combined approach of the computational fluid dynamics (CFD) and the parallel Direct Simulation Monte Carlo (DSMC)[2] were used depending on the flow conditions. The parallel DSMC method was applied with a three-dimensional unstructured grid system to simplify geometrical complexities of the GEO satellite configuration. The simulated particles were traced and calculated using about 40 CPU cores. Parallel processing was made by dividing the computational domain into several subdomains by using the MeTiS library, which was based on the k-way, n-partitioning technique by Karypis. After each time step advancement, information about the particles and their properties was exchanged through the subdomain boundary by using the MPI (Message Passing Interface) library.

3 RESULTS AND CONCLUSIONS

In Figure 2, unstructured three dimensional computational grid of a GEO satellite configuration is given with a box-shaped structure. A single-winged solar panel is installed on only one panel of the satellite. To simulate the orbit raising phase, a half-deployed configuration of the solar panel is considered in the present study. A size of computational domain is set to 8 m in width (x), 12 m in length (y) and 13 m in height (z) each. Also, one LAE of 400 N grade thrust is installed on the bottom platform of the GEO satellite. Some representative results are summarized in Figure 3. It can be observed that the exhausted plume flow from the LAE spread in the calculation domain. Also, the plume backflow was occurred behind the LAE nozzle exit due to the high vacuum effect. As a result, a severe collision of the plume flow was predicted over the satellite bottom platform and components including the solar panel and two antennas. Thus, such impingement by the LAE plume could eventually result in undesirable effects on the GEO satellite performance such as a disturbing force/torque, a heat load, and a contamination of sensitive components.

Throughout the numerical simulations using the present parallel DSMC method, the overall behaviors of the plume flow exhausted from LAE and its influence on the GEO satellite were investigated. Consequently, the present investigation results would be expected to provide useful information on the verification of the GEO satellite design quantitatively.

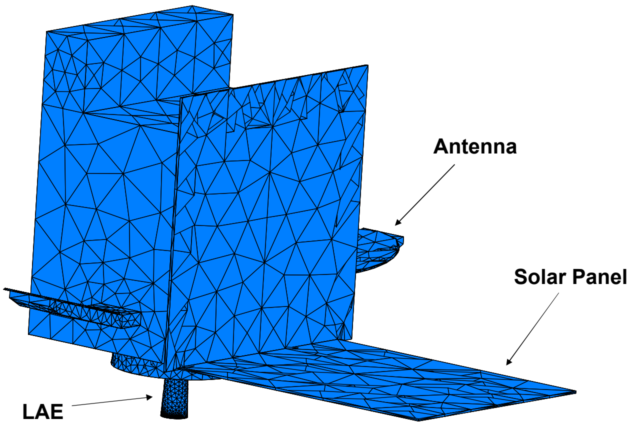

Figure 2: Configuration of GEO satellite

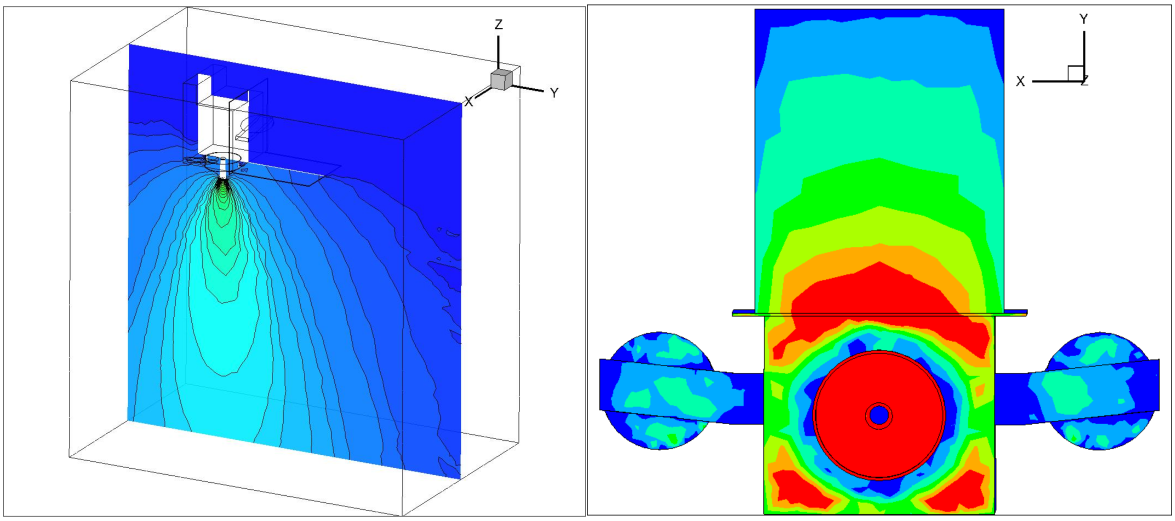

Figure 3: Density and number flux distributions of LAE plume flow

REFERENCES ACKNOWLEDGMENTS

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