A coupled DSMC-SPH solver to study atmospheric entry ablation in presence of a rarefied gas phase

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ABSTRACT

Debris from launcher stages and satellites at end-of-life is increasingly becoming a threat for humans when remains, that have not fully disintegrated during descent, impact the ground. The development of prediction tools for space debris demise and risk assessment requires a description of the entrainment of the molten layer into the hypersonic rarefied flow, where the different fluid phases cannot be described by the same models. On the contrary, the solid and liquid can be treated as continuous media, whereas a kinetic treatment is needed for the gas.

In our approach, both phases are simulated by particle schemes: the Direct Simulation Monte Carlo (DSMC) [1] for the gas phase and the Smoothed Particle Hydrodynamics (SPH) [2] for the solid and liquid phases. While DSMC is the dominant technique for rarefied gas flows simulations, SPH has been selected, among other numerical techniques, because of its mesh-free Lagrangian nature which allows dealing with free surfaces naturally. Thermal and dynamic coupling between the gas and the condensed phase is obtained by applying classical kinetic boundary conditions for the vapour, at interfaces. Momentum and energy are exchanged between liquid and gas after the interaction of the latter with the free surface.

In this work, we present the details of the coupling methodology, along with some verification test cases, e.g. a slab of material melting under the effect of a supersonic Couette flow, for which a semi-analytical solution can be found in slip regime. Finally, we consider the melting of a solid cylinder immersed in a hypersonic stream. The dynamics of the formed molten layer under the influence of the rarefied flow is analysed.

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REFERENCES

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