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Title

Modeling of polyatomic gas flows within a kinetic Fokker-Planck approach using a direct modeling method

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Abstract

The modeling of gas flows as for re-entry vehicles or jet plume expansion faces a large range of the Knudsen number. With Birds DSMC method [1], the Boltzmann equation, describing the evolution of the system by a probability density function, can be solved accurately. However, the computational expenses become unfeasable for small Knudsen numbers due to the complexity of the Boltzmann collision operator with the large amount of collisions. Therefore, the complex collision operator in the Boltzmann equation is approximated by a Fokker-Planck (FP) operator in velocity space. While DSMC models pairwise collisions, the collisions by the FP operator are modeled by local drift and diffusion coefficients, that are matched to reproduce the production terms of the Boltzmann collision operator in the continuum limit [2]. Both methods use computational particles. This way, a hybrid modeling approach can be set up where FP can be used in regions of high densities and small Knudsen numbers, while DSMC is used for rarefied flow regions and large Knudsen numbers [3].
In contrast to monatomic gas flows, polyatomic molecules can take up a significant amount of energy in internal modes like rotational and vibrational, which have a large influence on the entire flow field. An extension of the FP operator to a diatomic modeling has been approached using two methods: the Master-equation ansatz [4] and a direct modeling approach [5]. In the meantime, the Master-equation ansatz has been extended to a polyatomic model [6], while a polyatomic extension of the direct modeling approach will be presented in this paper.
Comparisons with the Master-equation ansatz in terms of the quality of the flow field and flow properties as well as the overall performance are made. Finally, temporal relaxations of energies are investigated.

References

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