

# NUMERICAL SIMULATION OF THE HIGH-ALTITUDE HYPERSONIC FLOW OF A BODY UNDER SHOCK-WAVE INTERACTION

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The paper considers problems of simulation of interaction of the fourth-type waves typical for the high-altitude hypersonic flow of flight vehicles.

The key target of the paper is to identify the most effective and promising numerical methods for the considered area of problems.

The complete validation of a method asks for a huge amount of work, to simplify the task the paper considers 2D axisymmetric problems of flow without separation on the windward side of blunted bodies.

Three cases are selected: • the ONERA experiment on hypersonic flow of a cylinder under the shock-wave interaction in front of it with incident shock [1], • reproduced data of the OREX flight vehicle for a point of its trajectory at  $H = 92.4$  km [2], • the hypersonic flow of a two-component cone with a separated-flow region at the interface [3].

The math methods are based on the widely used numerical schemes: • DSMC–Monte-Carlo simulation (direct statistical simulation) implemented with the SMILE software, • method of finite volumes (AUSM+ scheme)—Godunov-type method implemented with the ANSYS Fluent software, • method of finite volumes (Kurganov–Tadmor scheme)—central-upwind scheme implemented with the OpenFOAM software.

A series of calculations using the above methods are made for each case. Upon analysis of the results conclusions are drawn on applicability of a numerical method to settle problems of this type. In particular, the Kurganov–Tadmor scheme combines high accuracy and low computational cost, is good for the engineering analyses. While the DSMC with its practically unlimited accuracy is good for academic research.

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1. Moss J.N., Pot T., Chanetz B., Lefebvre M. DSMC Simulation of Shock / Shock Interactions: Emphasis on Type IV Interactions
  2. Yamamoto Y. CFD and FEM Coupling Analysis of OREX Aerothermodynamic Flight Data // AIAA Thermophysics Conference, June 19–22, 1995, San Diego, California.
  3. Chanetz B., Pot T., Benay R., Moss J. New Test Cases in Low Density Hypersonic Flow // Rarefield Gas Dynamics: 23rd Interbational Symposium, 2003.