DSMC Simulations of Shock-Vortex Interactions

T. P. Koehler, M. A. Gallis, J. R. Torczynski

Engineering Sciences Center
Sandia National Laboratories
MS 0840, Department 1513
Albuquerque, NM 87185-0840 USA
tkoehle@sandia.gov

Although turbulence is typically studied at the hydrodynamic or continuum level, there are cases in which the Kolmogorov length and time scales are comparable to the mean free path and collision times [1] and a molecular-level approach is required to fully examine the non-equilibrium physics. A practical example is the two-dimensional, unsteady, compressible interaction of a shock wave with a vortex. Traditionally, this interaction has been studied numerically at the continuum level [2] although more recent efforts have used non-continuum techniques [3] to show that non-continuum effects are present. Herein, the shock-vortex interaction is simulated using the Direct Simulation Monte Carlo (DSMC) method of Bird [4] as implemented in Sandia's SPARTA code [5] to study the non-continuum effects on the flow field for various vortex sizes and shock strengths.

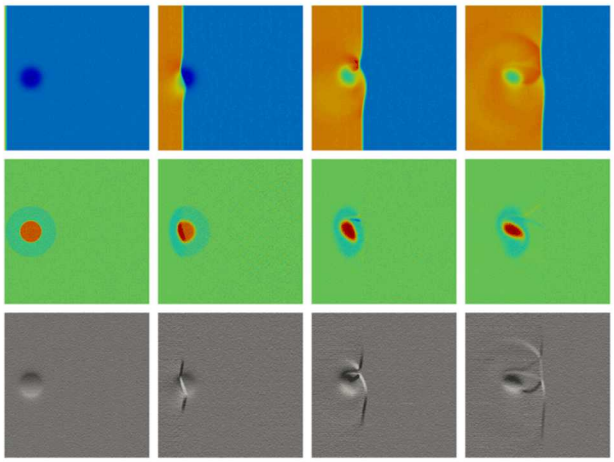

Figure 1. Temporal evolution of the interaction of a Mach 1.5 shock with a Mach 0.7 vortex. Number density (top), vorticity (middle), and numerical Schlieren (bottom) are shown.

[1] M. A. Gallis, N. P. Bitter, T. P. Koehler, J. R. Torczynski, S. J. Plimpton, and G. Papadakis, "Molecular-Level Simulations of Turbulence and Its Decay," *Physical Review Letters*, **118**, 064501 (2017).
[2] O. Inoue and Y. Hattori, "Sound generation by shock-vortex interactions," *Journal of Fluid Mechanics*, **380**, 81-116 (1999).
[3] K. Koffi, Y. Andreopoulos, and C. B. Watkins, "Dynamics of microscale shock/vortex interaction," *Physics of Fluids*, **20**(12), 126102 (2008).
[4] G. A. Bird, *Molecular Gas Dynamics and the Direct Simulation of Gas Flows*, Oxford University Press, Oxford, UK (1994).
[5] S. J. Plimpton, S. G. Moore, A. Borner, A. K. Stagg, T. P. Koehler, J. R. Torczynski, and M. A. Gallis, "Direct simulation Monte Carlo on petaflop supercomputers and beyond," *Physics of Fluids*, **31**, in press (2019).

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