Abstract #
Preferred Topics: AEROFLIPHY / CFDMPS
Corresponding author: KHALIDOV Iskander A.
e-mail of corresponding author: iskander.khalidov@gmail.com
Type: Oral
Status of corresponding author: Regular

Title

Simulation of Rarefied Gas Flow in a Channel Applying Artificial Neuron Network

Authors

*Olga A. AKSENOVA[1], Iskander A. KHALIDOV [2]**

** Corresponding author*
[1] St.Petersburg Naval Polytechnic University, Dept. of Mathematics,17/1 Ushakovskaya Quai, 197045, St.Petersburg, Russia, olga.a.aksenova@gmail.com
[2] Peter the Great St.Petersburg Polytechnic University, Dept. of Mathematics, 195251, Polytechnicheskaya ul., 29, St.Petersburg, Russia, iskander.khalidov@gmail.com

Abstract

Simulation of rarefied gas flow in a channel is considered in our previous papers [1]–[4] applying different methods including ANN (Artificial Neuron Network). The purpose of the present paper is to confirm numerically applying ANN our algorithm for transitional flow between continuum and free-molecular flow. The main advantage of this approach is substantial computing time economy compared to usual DSMC procedure.

To minimize calculation time we apply artificial neuron network (ANN) in its basic form – multilayer perceptron which consists of several layers of nonlinearly-activating nodes [5]. Each node in any layer connects with a certain weight to every node in the following layer. The learning of ANN (changing connection weights after each piece of data is processed corresponding to the minimum value of error) is based on relative simple test flows, analytic solutions in limit cases, calculations by LBM method [6] and on comparatively few Monte Carlo simulations. Near the free-molecular regime our previous results have been applied, obtained for large Knudsen numbers under conditions where the flow has shown the properties of unstable nonlinear dynamic system [1]–[4]. The scattering function V is supposed to be ray-diffuse, i.e. it is the mixture of ray reflection and diffuse scattering. The ray model [7] could be regarded as the generalized specular reflection, where the velocities of incident and reflected gas particles are connected by Dirac delta function under some restrictions to ensure that V satisfies the known criteria on wall collision kernels. The ray-diffuse model has better experimental confirmation in comparison with the specular-diffuse model widely applied in practical DSMC calculations [3], [8]. Simulated test flow of Nitrogen in a microchannel with aspect ratio ($L/h = 20$) and by pressure ratio ($1.84 < \Pi < 4.14$) considered in [6] has shown a good coincidence of ANN and DSMC calculations under different conditions even if only s small part of original DSMC computation has been applied for learning ANN (hence, computing time is reduced up to 10 times).

References

[1] O. A. Aksenova and I. A. Khalidov, “Simulation of Unstable Rarefied Gas Flows in a Channel for Different Knudsen Numbers”, in *Rarefied Gas Dynamics*, AIP Conference Proceedings 2132(1), 180009 (2019), pp. 1800091–1800098; doi: https://doi.org/10.1063/1.5119667
[2] I. A. Khalidov and R. N. Miroshin, *Local Methods in Continuum Mechanics*, (St.-Petersburg University Publishers, St.-Petersburg, 2002, in Russian), pp. 1–202.
[3] O. A. Aksenova and I. A. Khalidov, “Unstable Rarefied Gas Flow Conditions in a Channel”, in *Rarefied Gas Dynamics*, AIP Conference Proceedings 1786, 100009 (2016), pp. 1000091–1000096.
[4] O. A. Aksenova, I. A. Khalidov, *Moscow Aviation Institute Vestnik*, **16**, No.7, pp. 11–14 (2009, in Russian).

[5] D. A. Tarkhov. Neuron network models and algorithms. Reference book. Radiotekhnika Publishers, Moscow (2014), pp. 1–350 (in Russian).
[6] Dulikravich S., Gokaltun S., Skudarnov P., Sukop M. “Statistical Modeling of Rarefied Gas Flows in Microchannels” in *AIAA Paper* 2007: Proc. Of 18th AIAA Computational Fluid Dynamics Conference (2007), pp. 1–14.
[7] O. A. Aksenova and I. A. Khalidov, *Surface Roughness in Rarefied Gas Aerodynamics: Statistical and Fractal Models*, (St.-Petersburg, St.-Petersburg University Publishers, 2004, in Russian), pp. 1–120.
[8] C. Cercignani, *Theory and Application of the Boltzmann Equation*, (Scottish Academic Press, Edinburgh, London, (1975), pp. 1–456.
[4] M. Litvak and V. Malyugin, Journal of Technical Physics **82**, No.4, pp. 99–107 (2012, in Russian).
[5] A. I. Erofeev, O. G. Friedlander *et al*., “The Influence of Roughness of the Surface on the Interchange of Momentum between Gas Flow and Solid Surface”, in *Rarefied Gas Dynamics*, AIP Conference Proceedings 1501, edited by M. Mareschal, (Melville, NY, 2012), pp. 1168–1174.
[6] A.I. Erofeev, A.P. Nikiforov, S.B. Nesterov, R.A. Nezhmetdinova, in *TSAGI Journal*, **47**, 4, pp. 12–27 (2016).
[7] G. Markelov, , S. Stefanov, “Statistical simulation of gas flows through short rough microchannels” in *Rarefied Gas Dynamics*, AIP Conference Proceedings 1404, (Melville, NY, 2011).
[8] N. E. Gimelshein, T. C. Lilly, S. F. Gimelshein, A. D. Ketsdever and I. J. Wysong, “Surface Roughness Effects in Low Reynolds Number Nozzle Flows”, in *Rarefied Gas Dynamics*, edited by M. S. Ivanov and A. K. Rebrov, (Novosibirsk: Siberian Branch of RAS, 2007), pp. 695–702.