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ON THE UNSTEADY VORTEX SHEDDING BEHIND A CYLINDER

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KEY WORDS

Direct Simulation Monte Carlo (DSMC), Vortex shedding, Simplified Bernoulli Trials on transient adaptive subcells (SBT-TAS), Nearest Neighbor (NN).

ABSTRACT

In this work, the accuracy of a newly suggested collision scheme in the DSMC method, Simplified Bernoulli Trials [1] over transient adaptive subcells, SBT-TAS, for prediction of vortex shedding of a rarefied flow past a cylinder is calculated. Results of SBT-TAS are compared with the SBT solution on uniform grid, and conventional/sophisticated collision models, e.g. no time counter (NTC) and the nearest neighbor (NN) with respect to their accuracy on predicting vortex formation and shedding frequency behind a two-dimensional cylinder in subsonic flow (Mach 0.6) regime [2]. In this work "time-averaging" approach is used for performing unsteady sampling procedures. This approach perform averaging during a number of time steps over an interval centered in the sampling time. The approach requires only one simulation run [3]. The Knudsen number based on free-stream conditions was 0.00833, the flow and cylinder surface temperature was kept at 300 K and flow Reynolds number was 80. The simulation domain and boundary conditions are shown in Fig. 1. In this condition, as Fig. 2 shows, the SBT and NTC collisions schemes on the same grid and with the same number of particles per cell (PPC) predicts the vortex behind the cylinder quite weak and the structure of vortices are quite smeared out. On the other hand, the SBT-TAS and NN collisions schemes predicted the strength of the vortices and their oscillation with the same level of accuracy, see Fig. 2.

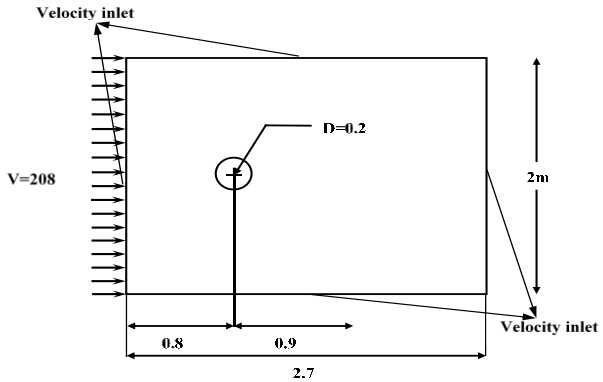

Fig. 1. Geometry of cylinder considered for simulation of unsteady vortex

Our results demonstrated that SBT-TAS provided the most accurate solution if subcells are adapted to PPC=3. Further decreasing the PPC resulted in a decrease in the SOF, which is the ratio of the mean

collision spacing to the mean free path, see Table 1, however, this decreases is not accompanied with an enhanced solution accuracy. The Strouhal number (f×D/U) for SBT-TAS and NN schemes are calculated as 0.160 and 0.164, respectively. The value reported experimentally by Roshko [4] at the continuum limit is 0.156. The SBT and NTC solutions do not show any periodic vortical behavior.

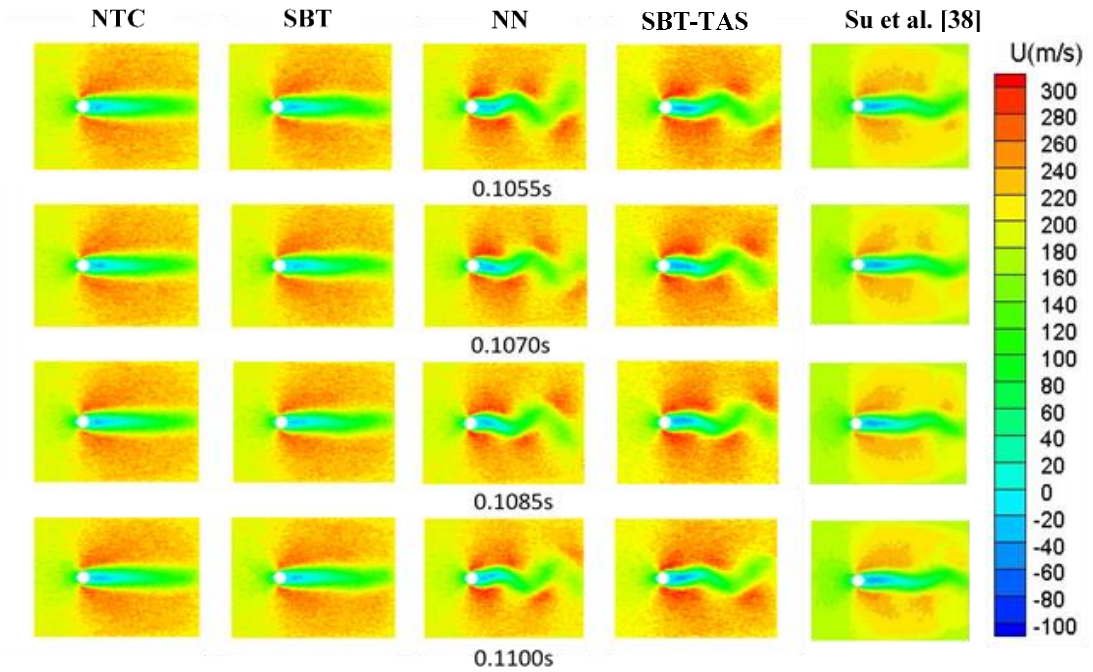

Figure 2: Contours of stream-wise velocity (m/s) at different times for the vortex shedding behind a cylinder using 4×10^6 total initial number of particles and division size equal to 200×150 cell for all NTC, SBT, NN, SB-TAS (PPSC=3) collision schemes. The last column corresponds to Su et al. work [2] obtained using NTC-TAS.

Table 1: Comparison of the SOF (MCS/λ) value between all DSMC collision schemes.

scheme	Divisions size	Total initial number of particles	Initial PPC	SOF (MCS/λ)	PPSC adaptation in TAS
NN	200*150	$4*10^6$	32	0.43	-
SBT-TAS				**0.24**	1
SBT-TAS				0.47	2
SBT-TAS				0.66	3
NTC				2.08	-
SBT				2.08	-

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