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ON THE EFFICIENT CONFIGURATIONS FOR RADIOMETRIC PUMPS

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KEYWORDS

Thermally driven flows, radiometric flow, DSMC, diffusive walls.

ABSTRACT

Utilization of thermally driven flows in the gap between periodically structured surfaces has been studied in the previous works. Donkov et al. [1] considered a ratchet channel with the temperature gradient applied between the opposing walls. Mixed diffuse and specular reflection boundary conditions were applied to the ratchet surface. They showed that flow could be induced in the gap between the surfaces. Shahabi et. al [2] investigated the physical mechanisms of the flow field and studied the effect of geometrical parameters in ratchet channel with diffuse and specular walls. They showed that suitable fin structures need to break the reflection symmetry and a purely geometrical symmetry breaking based on diffusively reflecting walls is not sufficient. Chen et al. [3] analyzed a novel configuration consisting of two facing isothermal ratchet surfaces at different temperatures using DSMC method and studied the effect of accommodation coefficient and miss-alignment distance.

The main motivation of this work is to study the pumping performance of various geometrical configurations of the radiometric pumps using the direct simulation Monte Carlo (DSMC) method with transient adaptive subcells for collision partner selection. We employed the DSMC solver of the OpenFOAM software package, i.e., *dsmcFoamStrath*. The key parameter determining the flow regime is the Knudsen number (Kn) which is defined as the ratio of the mean free path (λ) of gas molecules to a characteristic length (L_{ch}). In this study, we considered some alternative configurations with fully diffusive boundary conditions for the walls of vane/fins but with different temperatures and computed the flow and the temperature field of the rarefied gas. All solid surfaces considered at T_{cold}= 300K expect the left side of the vane or ratchet which is held at T_{hot}=600K. Fig. 1 shows isolines of the normalized temperature for various configurations. Right-angled triangle (case 1), vane (case 2), isosceles triangle (case 3), and two isosceles triangles (case 4) sitting aside each other were considered as four main configurations. The average temperature of the flow field is higher for case 1 but temperature gradient around the tip which results in flow induction around the tip is pretty higher in case 4.

Velocity streamlines plotted over iso-contours of flow speed are depicted in Fig. 2. The flow is induced in the negative x-direction, as expected from the momentum exchange of particles and the vane/ratchet configuration. The region of maximum velocity is around the tip and it is higher for case 4. Table 1 shows different characteristic of the flow field, i.e, maximum and averaged velocity, normalized pressure, mass flux and force ratio. It can be concluded that the performance of the ratchet is better than a vane and using a series of the ratchet increases the induced mass flow rate.

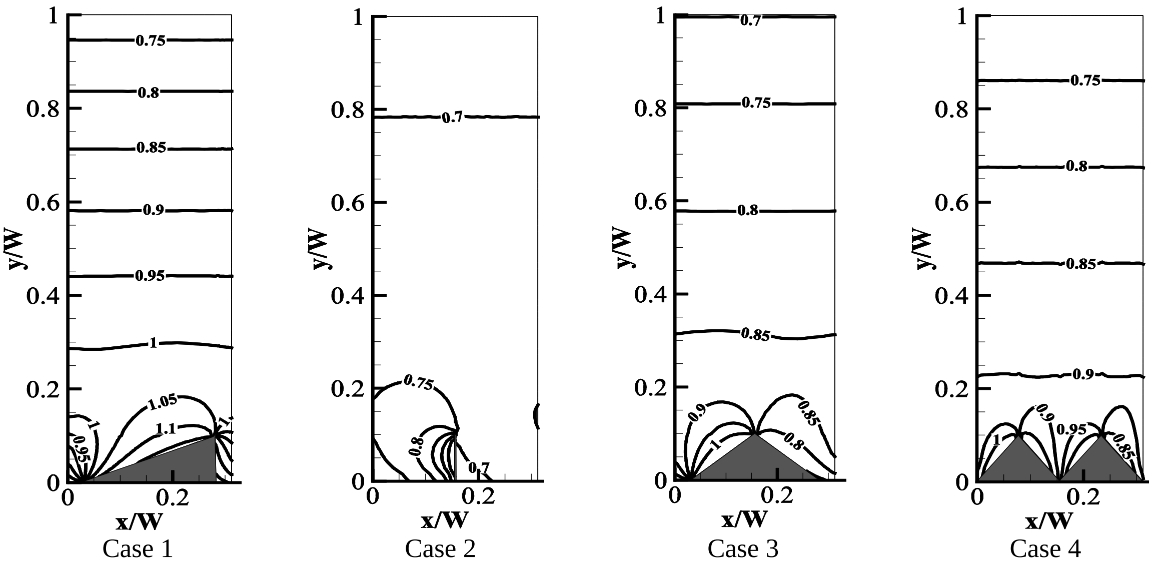

Figure 1: Isolines of the normalized temperature $T/Tavg\,, Tavg = (T_{cold} + T_{hot})/2$

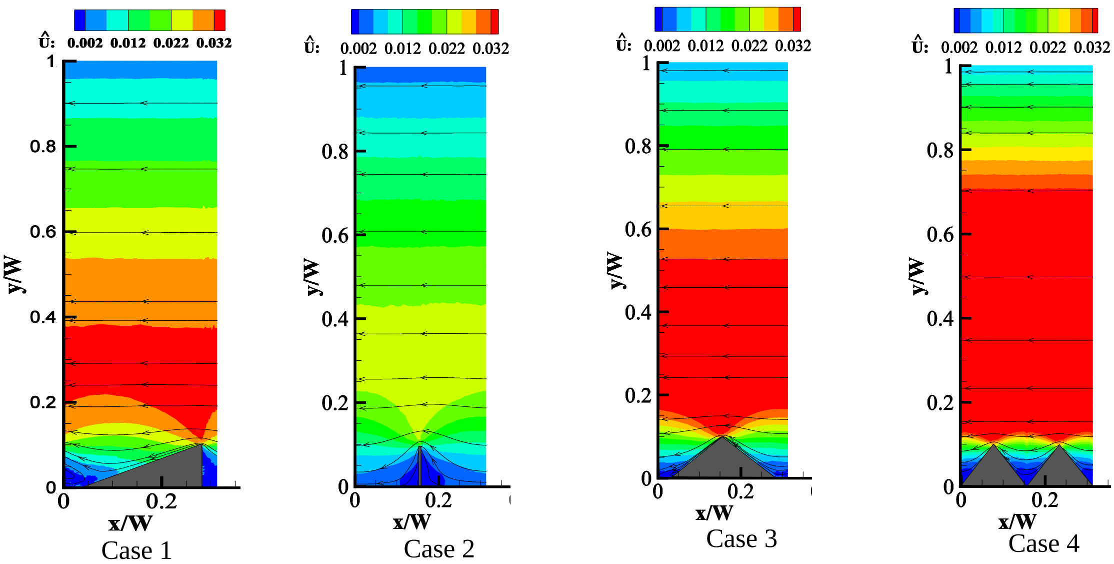

Figure 2: Isolines of the normalized velocity magnitude and streamlines, $\widehat{U} = U/U_0\,, U_0 = \sqrt{2RT_{avg}}$

Case	U_{max} (m/s)	U_{avg} (m/s)	T_{avg} (K)	$\dot{m}$ (kg/s)	q_{left} (W/m^2)	q_{right} (W/m^2)	F_x	F_x/F_y
1	-17	-6.83	236	6.72e-06	-2.8616	2.6356	-1.6404e-04	-6.936e-03
2	-12	-4.01	162	4.80e-06	-4.1565	0.5816	-1.0453e-04	-5.795e-03
3	-18	-6.73	181	7.96e-06	-3.6549	1.5748	-1.8001e-04	-8.577e-03
4	-26	-9.05	186	1.07E-05	-3.9443	2.3777	-2.5325e-04	-1.156e-02

Table 1: Different properties of the flow field for investigated cases.

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