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DSMC Modeling of Rarefied Flow through Micro/ Nano Backward-Facing Steps

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Abstract

In this study we use direct simulation Monte Carlo (DSMC) method to simulate subsonic nitrogen flow through micro/nanoscale backward-facing step. This paper investigates the effect of Knudsen number on the fluid and thermal behavior of the step geometry. We observed that increasing the Knudsen number makes remarkable variations in flow behavior such as decreasing in average flow Mach number and increasing in average flow temperature. Our results showed that variations in flow and thermal field properties are more sensible at low Knudsen number. Also the results show that increasing Knudsen number decrease the length of separation zone behind the step. Additionally, gas flow becomes more uniform at higher flow Knudsen number.

Introduction

Over the last several decades the improvements in performance and shrinkage of device size have been dominant driving forces in micro/ nano electronics to promote scientific and economic progress. [1]

One of the conventional geometry in microscale is step geometry. This geometry is conventional in micro fluidic devices and medical instruments. For a dilute gas there exist more efficient particle-based simulation algorithms. A popular method is direct simulation Mont Carlo (DSMC), introduced by Bird in early 1970s [2].

Results and discussion

At first We performed a grid independency activity to finalize the suitable grid sizes in our simulations. You can see figure 1 which shows grid study. We consider four test cases. These cases are different in Knudsen number. They are named case1, 2, 3and 4 for Kn=0.01, 0.1, 1 and 10. Figure 2 exhibits velocity profile on lower wall which determine separation length. Figure 3 shows the effect of Kn number on mach number of channel at the end of channel (X/L=1). Also this trend is shown in figure 5. It shows the Mach number at whole of the nano step geometry.

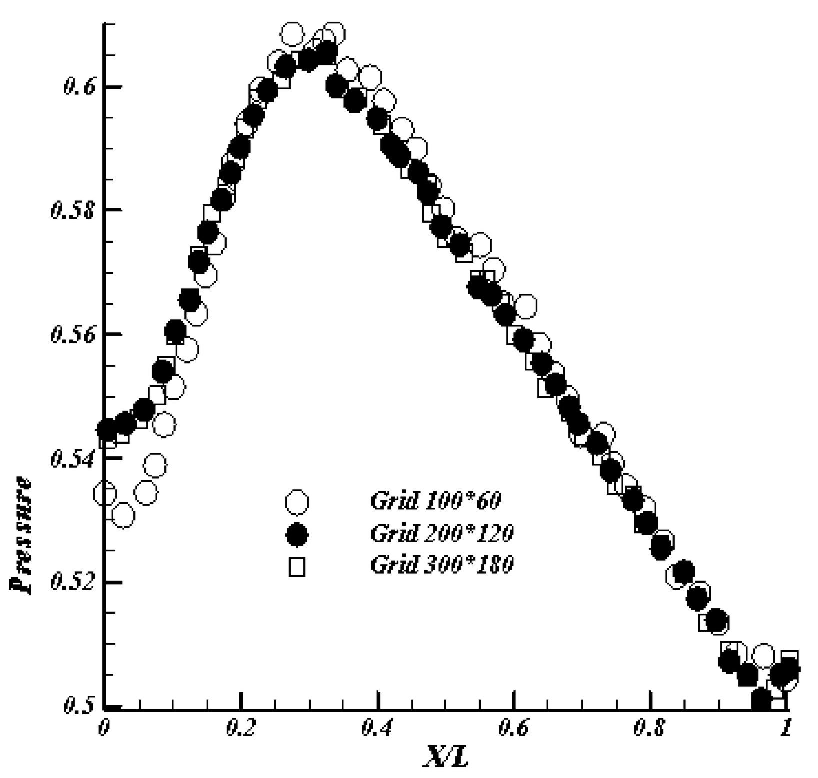

Fig.1 : Grid study

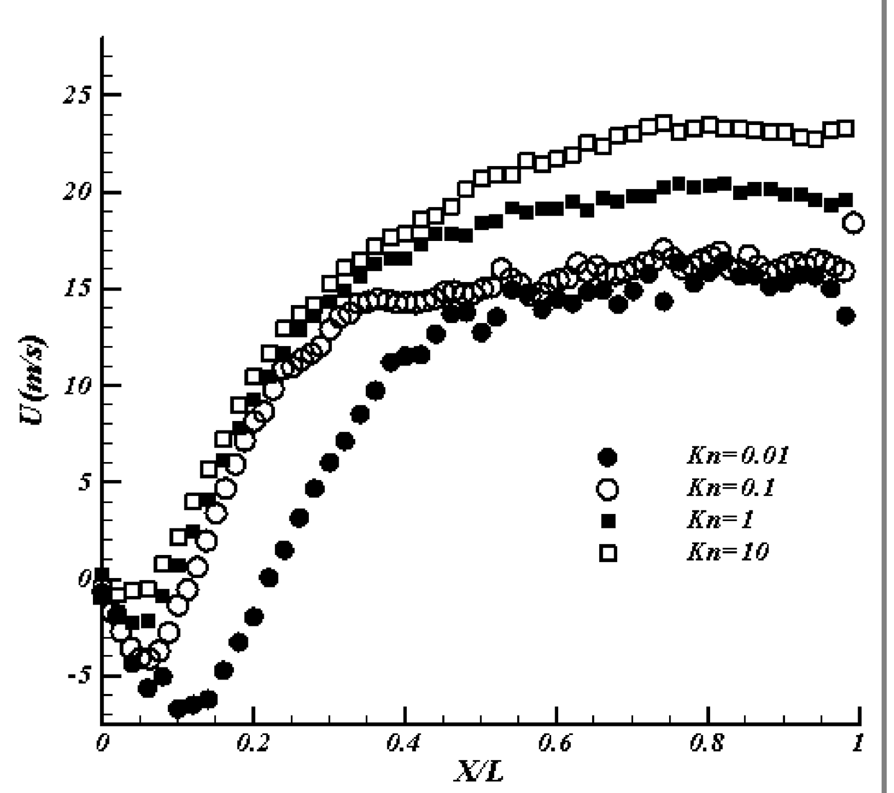

Fig.2: velocity profile over the lower wall

Figure 4 shows the temperature contour at X/L=0.3. As it shown at high Knudsen number the flow regime is more uniform and it is obvious that high Knudsen number can not affect temperature profile. You can see the same behavior at all of the geometry in the figure 6.

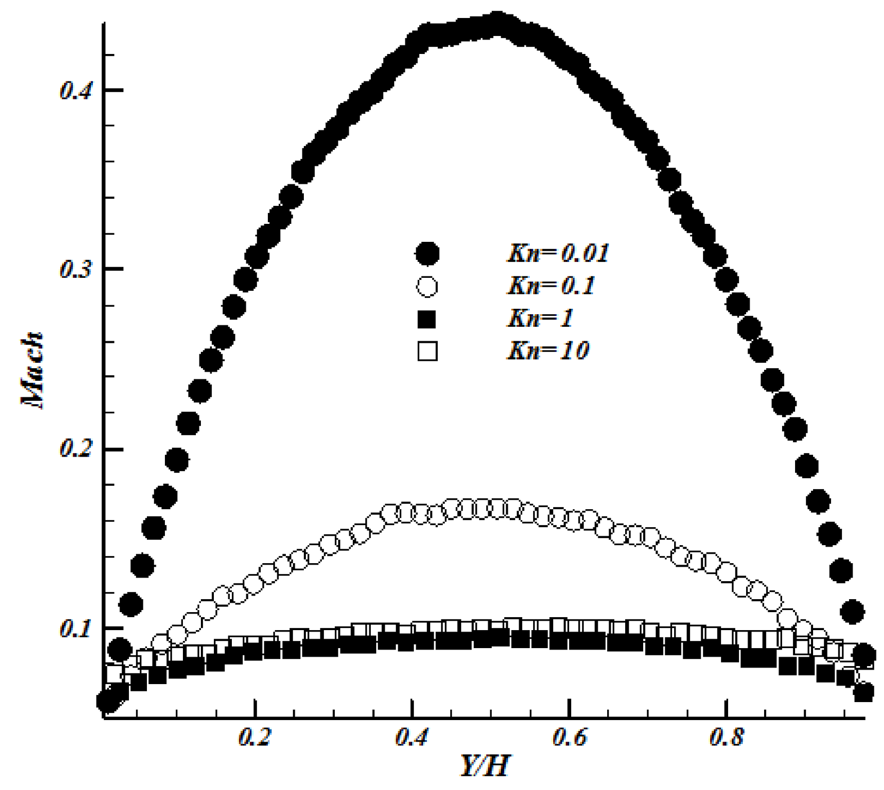

Fig.3: Mach number at X/L=1

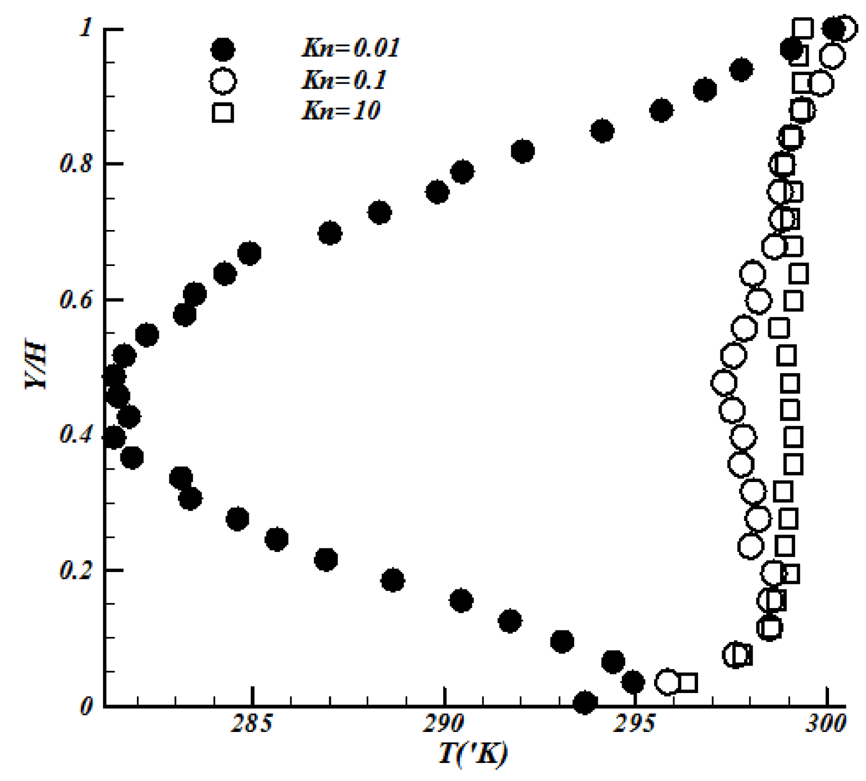

Fig.4: Temperature profile at X/L=1

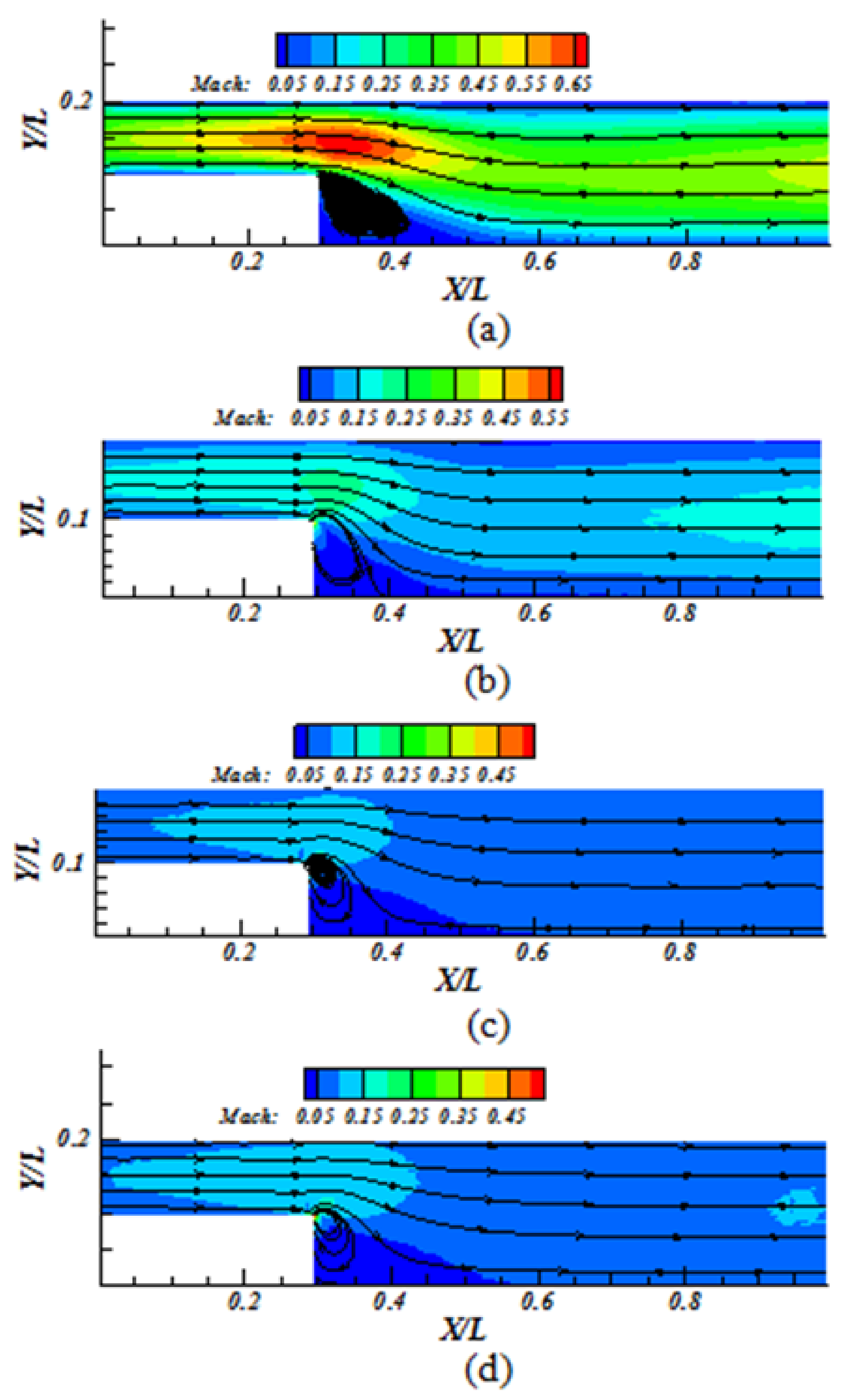

Fig.5: Mach number contours

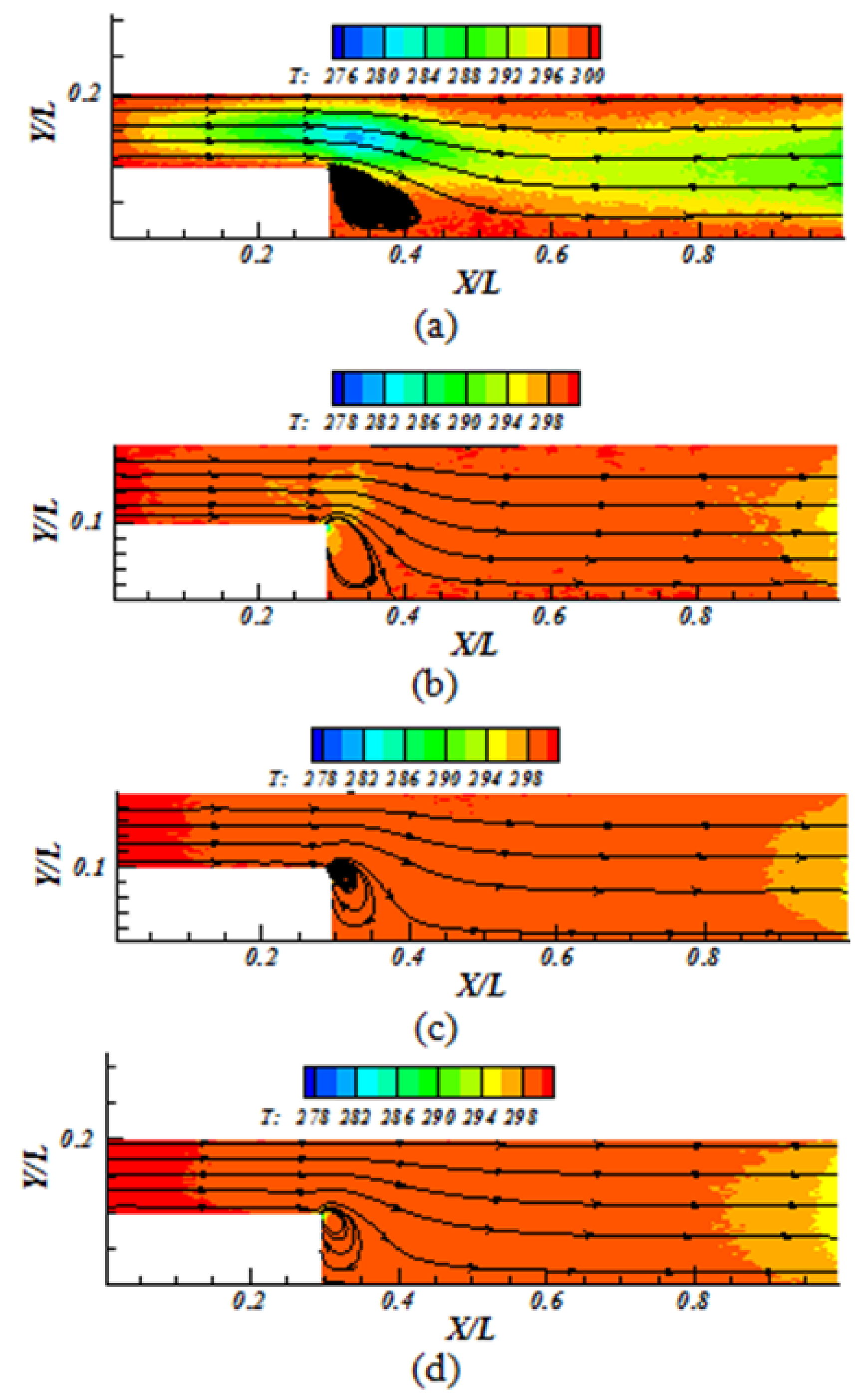

Fig.6: Temperature contours

a) Kn=0.01 b)Kn=0.1 c)Kn=1 d)Kn=10

Conclusion

In this paper we survey the effect of the Knudsen number in some of specifications of the flow such as the velocity and temperature contours. Additionally we investigated the effect of Kn number on separation zone. These effects are not so sensible at high Knudsen number. Our results showed that increasing Knudsen number cause nitrogen gas more uniformly and there are not a really big gradient at high Knudsen number.

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