Research of Gas Flowing Characteristics in Knudsen Pump

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Introduction

Micro Electro Mechanical System(MEMS) is a popular interdisciplinary study, with its miniaturization, low-cost mass production, highly integration, easy expansion and other advantages, which can be widely used in information, electronics, communication, military, biomedical, aerospace and other fields. Therefore, the drive and control of fluid in MEMS is one of the problems that must be solved when researching microfluidic devices. For developing and improving the microfluidic devices, micro-pumps, the drive control engine, are the most important point. The Knudsen pump was first proposed by Danish physicist Martin Knudsen in 1909. Compared to other micro-pumps, it is highly favored in the microfluidic devices application because of the advantages: no complex moving parts, simple structure, long service life, easy mass production, easy expansion, wide energy sources and low energy consumption.

Gas can flow in the channel since the gradient temperature field in the dilute gas, and the functional mechanism of the Knudsen pump is thermal induction flow. The classic Knudsen pump consists of a series of connecting fat and thin channels. Thermal creep effect is based on the gradient temperature which parallels to the wall of channel, which can drive gas flow from the low temperature to the high temperature side.

Methods

In this paper, the classical Knudsen Pump in rectangular channel model is studied. We analyze the flow characteristics of single gas (Ar, N_2, O_2) respectively and mixed gas (N_2 and O_2) in the pump channels by using Direct Simulation Monte Carlo (DSMC) method based on dsmcFoam solver of OpenFOAM . In addition, how these three different molecular models (Hard-Sphere (HS) model, Variable Hard Sphere (VHS) model, and Variable Soft Sphere (VSS) model) affect the gas flow is also researched by applying self compiling code of Binary Collision Model.

Results & Discussion

Fig.1

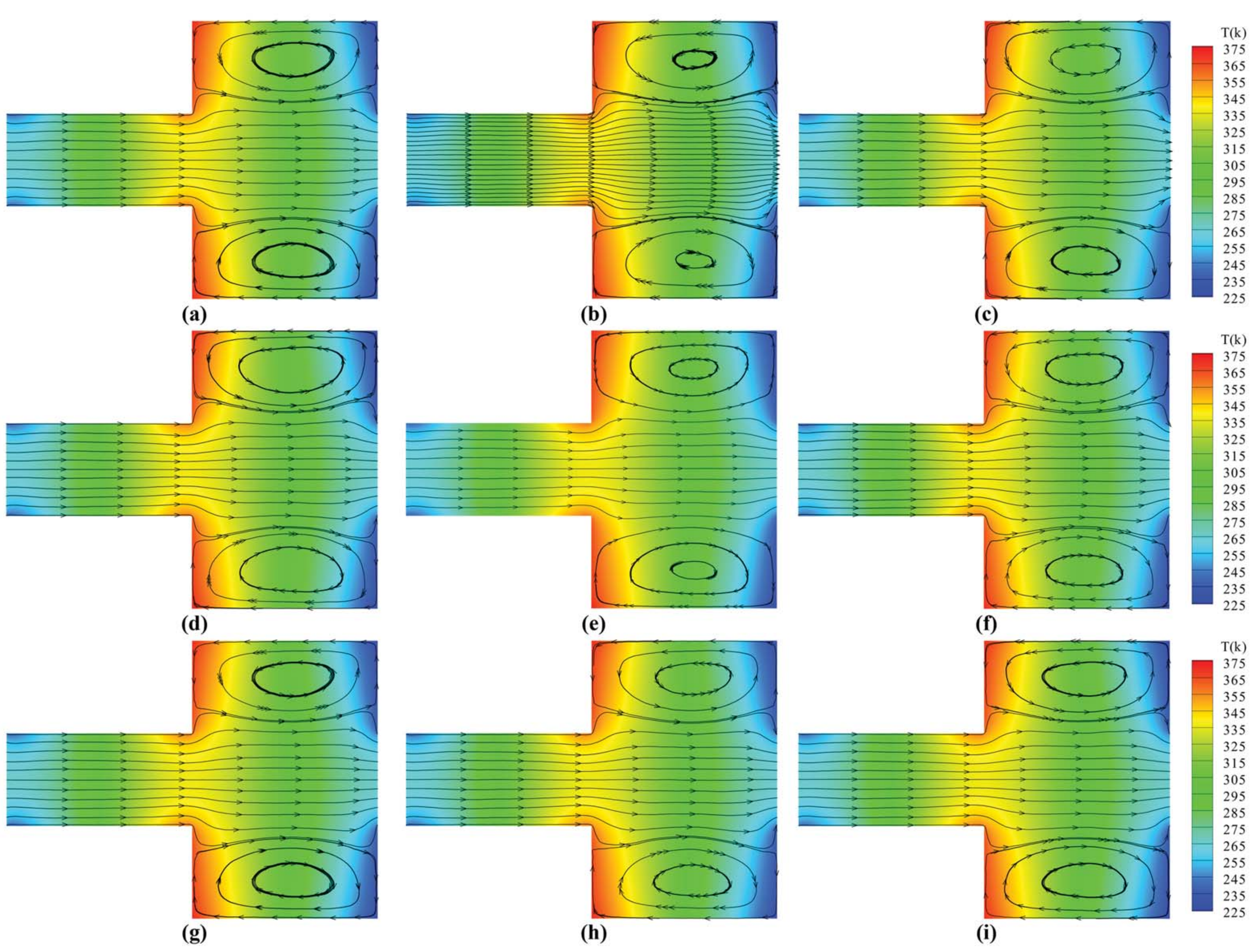

Fig.1.Streamlines and temperature contours for different gas compositions : (a)Ar; (b)N_2; (c)O_2; (d)N_2&O_2=4:1;(e)N_2&O_2=1:1; (f)N_2&O_2=1:4 and different molecular models: (g)HS model; (h)VHS model; (i)VSS model under atmospheric pressure.

The results indicate that changes in gas compositions, species, and molecular models do not affect the overall distribution and variation of the field in the channels.

Fig.2

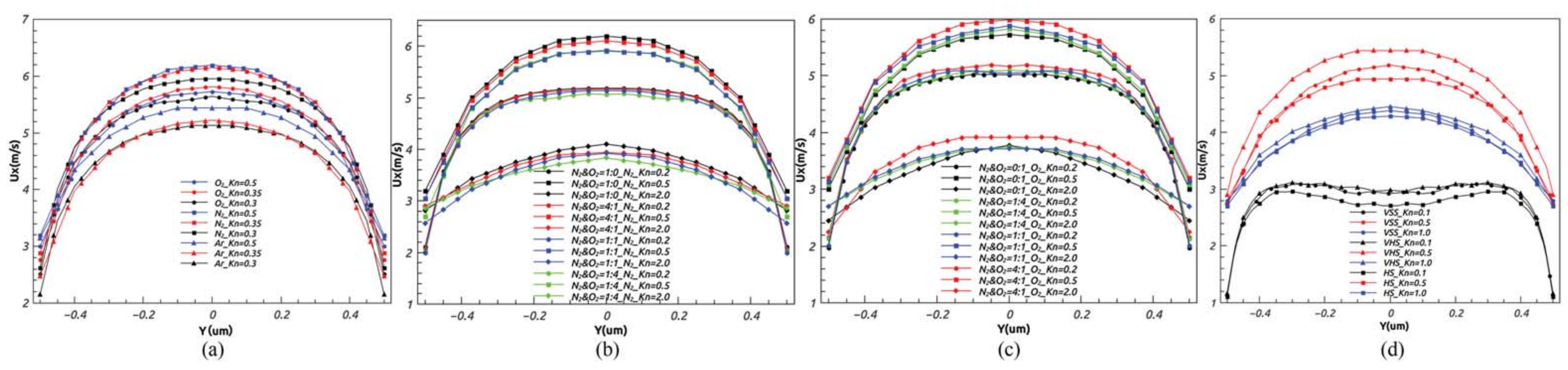

Fig.2.Velocity of different gas flow at X=1um. The thermal creep effect shows a trend of increasing first and then decreasing as the increasing of Kn number; gas N_2 has the strongest thermal creep effect; when the proportion of N_2 increases in the mixed gas, it can not only enhance the thermal creep effect but also promote the forward movement of the heavier gas; Variable Hard Sphere (VHS) model shows the strongest thermal creep effect among these three molecular models.

Fig.3

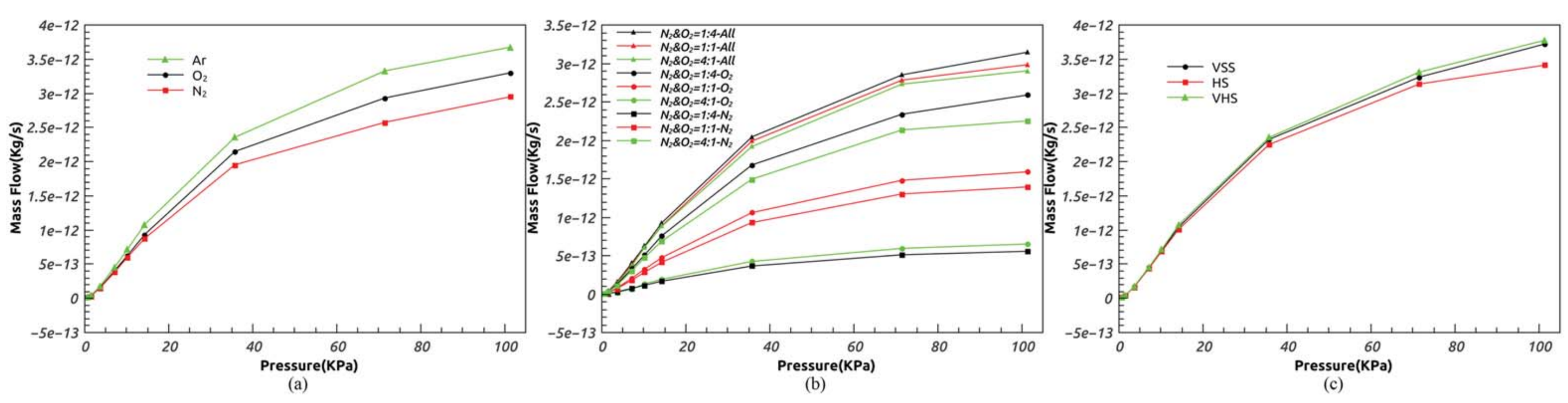

Fig.3.Mass flow versus pressure for different gas flows. Mass flow increases with the increasing of gas molecular weight; compared with the VSS model that can more practically reflect the movement of gas, the HS model will underestimate the actual performance of the pump, while the VHS model will overestimate the actual performance. When the Kn number is larger, the movement rule of the VSS model is more consistent with that of HS model. On the contrary, while the pressure is higher, the VSS model movement rule is closer to that of VHS model.

Conclusions

1.Changes of physical properties of the gas flow do not affect the overall distribution and variation of the field in the channels;
2.The lighter the gas molecular weight is, the stronger the thermal creep effect is;
3.The lighter gas can promote the forward movement of the heavier one;
4.Thermal creep effect increases with the increasing of gas molecular diameter.

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