Reexamination of the Lift on a Circular Cylinder in Uniform Shear Flow

Tongqing Chen, Qinghe Zhang
School of Civil Engineering, Tianjin University & Key Laboratory of Harbor and Ocean Engineering, Ministry of Education, P. R. China
Tianjin, China

ABSTRACT

The lift on a circular cylinder in uniform shear flow is numerically investigated based on the lattice Boltzmann method. The flow asymmetry will cause a non-zero mean lift force, whose direction is shown differently in previous studies. The influence of shear parameter, grid resolution and blockage ratio on the lift force is discussed in this paper. It is found that there probably exists a critical value of Reynolds number for the direction change of the mean lift force. When the shear parameter is 0.1, the critical Reynolds number is around unit.

KEY WORDS: lift force; circular cylinder; uniform shear flow.

INTRODUCTION

The uniform flow past a circular cylinder has received comprehensive studies in the past. However, in practice, many structures are not immersed in uniform flows but in shear flows, such as the pipelines near the seabed. The simplest typical case of shear flow is the uniform shear flow as illustrated in Fig.1, in which the velocity has a linear distribution along the transverse direction, also called linear shear flow in the literatures.

The flow pattern of the uniform shear flow past a circular cylinder mainly depends on two parameters, Reynolds number Re and shear parameter K, which are defined as $Re = U_c D/\nu$ and $K = GD/U_c$, where $U_c$ is approaching velocity at the cylinder center; $D$ is cylinder diameter; $G$ is transverse velocity gradient; and $\nu$ is kinematic viscosity (Lei et al., 2000; Sumner and Akosile, 2003).

The mean lift force on a circular cylinder in uniform shear flow will not be zero because of asymmetry of the flow. Previous researches show different results on the direction of mean lift force. Part of previous studies has been summarized by Kang (2006). The numerical results of Tamura et al. (1980) at $Re=40$, 80 and those of Yoshino and Hayashi (1984) at $Re=80$ show that the direction of mean lift force is from the low velocity side to the high velocity side, whereas it is shown in the opposite direction by the results of Jordan and Fromm (1972) at $Re=400$ and those of Lei et al. (2000) at $80 \leq Re \leq 1000$, which are confirmed by the numerical results by Kang (2006) at $50 \leq Re \leq 160$ and $0 \leq K \leq 0.2$. The experimental data of Sumner and Akosile (2003) at $4.0 \times 10^4 \leq Re \leq 9.0 \times 10^4$ indicate that the mean lift force acts from high velocity side to low velocity side. Wu and Chen (2000) claim that it depends on the magnitude of the free stream shear. Similarly, previous studies about the lift on a square cylinder and a sphere in uniform shear flow also show different results. The numerical results of Hwang and Sue (1997) and Lankadusu and Vengadesan (2009) show that the mean lift on a square cylinder acts from the low velocity side to the high velocity side, however the numerical results of Cheng et al. (2007) reveal that it is in the opposite direction. In terms of uniform shear flow past a stationary sphere, the direction of lift force is from low velocity side to high velocity side according to the approximate expressions by Saffman (1965), McLaughlin (1991) and Mei (1992) and the numerical results by Dandy and Dwyer (1990). The numerical results of Kurose and Komori (1999) and Hölzer and Sommerfeld (2009) show that there exist a critical value of Reynolds number for the lift force, which change direction at approximately $Re=60$ in the work of Kurose and Komori (1999) and at approximately $Re=50$ in the work of Hölzer and Sommerfeld (2009). An experiment is also carried out by Kurose and Komori (1999) to confirm the negative lift force at high Reynolds number.

The discrepancy of previous studies mentioned above motivates us to conduct the present work to get further insight into what can influence the direction of the mean lift force on a circular cylinder in laminar flow with uniform planar shear. Numerical simulations are performed at ranges of $0.5 \leq Re \leq 200$ and $0 \leq K \leq 0.1$. The influence of shear parameter, grid resolution and blockage ratio on the lift force will be discussed in this paper.

$U_c + G(y-y_c)$

Fig.1 Sketch of the uniform shear flow past a circular cylinder