

Influence of Inclination of Bluff Body in Flowmeters

Yaoying Lin Volker Hans

Institute of Measurement and Control, University of Duisburg-Essen, Schuetzenbahn 70, 45117 Essen, Germany

Abstract This paper studies a factor which might influence the Strouhal number, that is, the inclination of the bluff body. The inclination of the bluff body happens in flow industry when the bluff body is inclined relative to its pipe parallel axis. Triangular bluff bodies are thoroughly discussed in this paper. Normally, the flat side is facing the inflow which is called conventional setup. It is turned around with 180 degrees facing the sharp side to the inflow, which is called unconventional setup in this paper. The inclination of bluff body has different influences in each setup. This paper shows that the flowmeter with bluff body in conventional setup makes lower Strouhal number but has more robustness to the inclination. On the contrary, it makes higher Strouhal number but less robustness. With fixed width, the different length of the triangular bluff body also causes influence to the Strouhal. In addition, the inclination of a rectangular plate bluff body is studied.

Keywords: ultrasonic vortex flowmeter; Strouhal number; bluff body; setup; inclination

1. Introduction

The vortex flowmeter is widely used in flow measurement industry. This kind of flowmeter is based on the Karman vortex street. The vortex shedding frequency is proportional to the flow velocity. The frequency is generally detected by counting vortices. This paper uses ultrasound to detect the shedding frequency.

Many factors can influence the shedding frequency in the flowmeter. From the equation provided by the Karman street, they can be such factors as flow velocity, width of bluff body and so on. These eventually influence the Strouhal number[1]. The authors in literature[1,2] this paper referred to have studied some factors influencing the Strouhal number.

This paper, taking the triangular bluff body and rectangle bluff body as two examples, thoroughly studies the inclination of bluff body which is believed to cause influence on the Strouhal number.

2. Basic measurement principle

2.1. Fluid dynamic background

The operating principle of the vortex meter is based on the natural phenomenon of vortex shedding. The frequency of vortex shedding is directly proportional to the flow velocity, thus providing the basis of a flowmeter. The well known relation between the shedding frequency f_v and flow velocity u_m is described by

$$S_r = \frac{f_v \cdot d}{u_m}, \quad (1)$$

where S_r is the Strouhal number and d is the width of bluff body[3].

2.2. Measurement equipment

As shown in Fig.1, the bluff body is rotated around the point O with a certain angle until $\theta = \alpha$ for

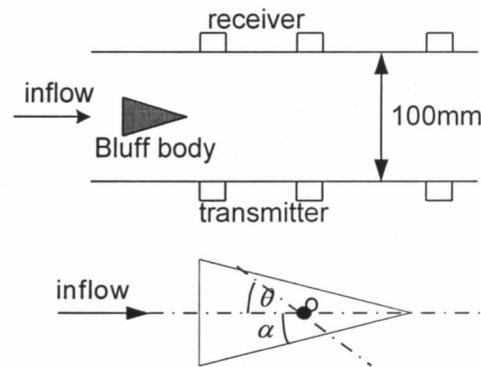


Fig.1 Ultrasonic vortex flowmeter and inclination of bluff body

triangular bluff bodies so that one side is parallel to the flow. Point O is the middle point of the bluff body symmetrical axis. Experiments have shown that the frequency of the vortices changes at different angles even at the same velocity. Since the width d is constant for the same bluff body, the vortex frequency should be always the same according to equation (1). But measurements do not confirm this effect.

In the flow meter market, the triangular bluff body is normally positioned with the flat side facing the inflow, shown in Fig.2, which is called conventional setup. It is called unconventional setup when facing the sharp side to the inflow as illustrated in Fig.3.

Triangular bluff bodies with different ratios between width d and length l defined in Fig.4 have been tested. The ratios studied in this work are $l/d=1, 2, 3$, respectively. The performances in both conventional setup and unconventional setup are also studied which will be described later.

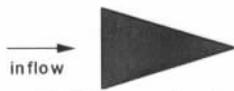


Fig. 2 Conventional



Fig. 3 Unconventional

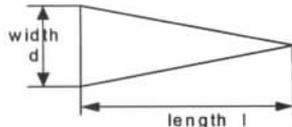


Fig. 4 Definition of ratio l/d

3. Results

3.1. Conventional setup

Fig. 5 shows the changes of Strouhal number with inclination of bluff body in conventional setup at

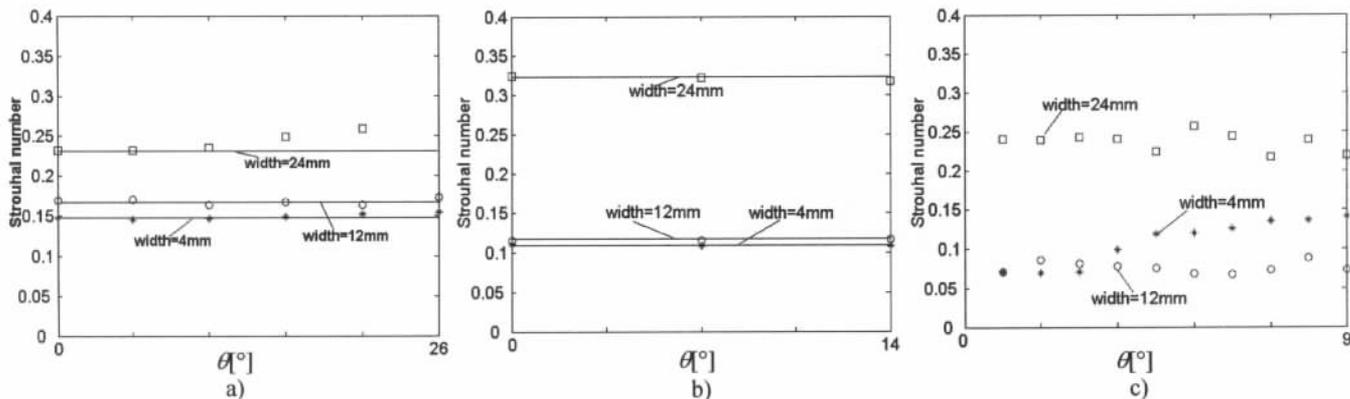


Fig. 5 Strouhal number changes with the inclination of bluff body in conventional setup
a) ratio=1 b) ratio=2 c) ratio=3

different ratios. It can be seen that in general the inclination results in tiny influence on the Strouhal number, which shows strong robustness. Except the bluff body with ratio 3, the Strouhal number has more fluctuation during the process of inclination. This indicates the triangular bluff body with ratio 3 possesses relative weak robustness. In the case of

ratio 3, the bluff body shape changes more dramatically relative to the inflow with the inclination. This is the basic reason that Strouhal number changes. The more the shape changes, the more the Strouhal number changes. In conventional setup the flow meter possesses high robustness which is good for the measurement precision.

3.2. Unconventional setup

As shown in Fig. 6, when the width of the bluff body is small, the inclination has a big influence on the Strouhal number. The bluff bodies with width of 4 mm and 12mm have the same tendency of Strouhal number changing with the inclination of the bluff body. But the bluff body with width of 24 mm is very robust. The Strouhal number does not change so much with the inclination no matter which ratio the bluff body is. This is because of the big size of bluff body which causes wall effect. The wall effect

exists all the time and changes little during the inclination process, which can not be detected.

In general, in unconventional setup, the Strouhal number is higher than that in conventional setups. It decreases with the increasing inclination angle of the triangular bluff body except that with width of 24mm as illustrated in Fig. 6. The Strouhal number

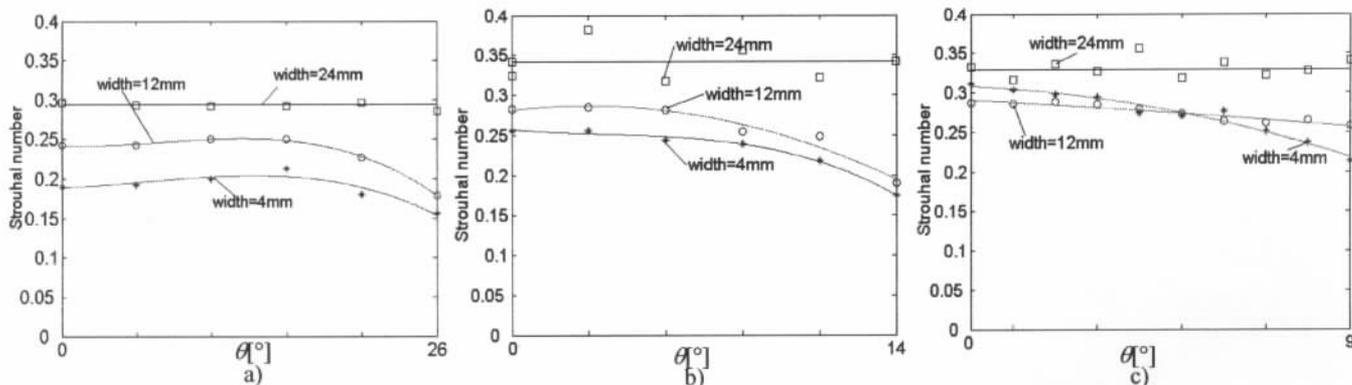


Fig. 6 Strouhal number changes with the inclination of bluff body in unconventional setup
a) ratio=1 b) ratio=2 c) ratio=3

decreases from angle zero to critical angle for each bluff body in unconventional setup.

Besides, it has been discovered from experiments that for a fixed width, different length leads to the difference in Strouhal number, which is shown in

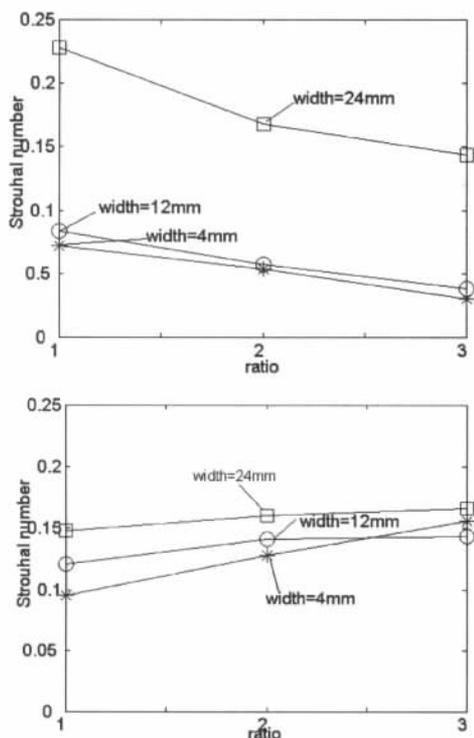


Fig. 7 Strouhal number changes with the width of bluff body in conventional setup(upper) and unconventional setup(lower)

Fig.7. Fig.7 indicates that the smaller the width of the bluff body is, the stronger is the influence of the length on the sensitivity. But the influence of the length in different setups is quite different. The Strouhal number decreases with the increasing length in conventional setup. In unconventional setup, the tendency is completely contrary. The Strouhal number increases with the increasing length of the bluff body for a fixed width. The change of the Strouhal number due to the different length is mainly caused by the difference in different shapes of bluff body.

3.3. Rectangular bluff body

The rectangular plate is installed in the pipe as shown in Fig.8. The plate whose width is 10mm and

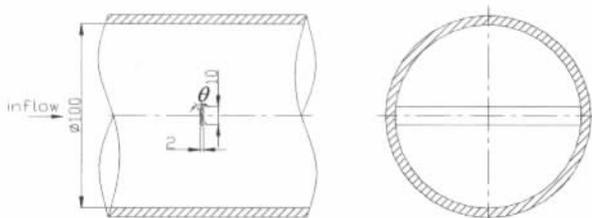


Fig.8 View from front and view from left (unit: mm)

length is 2mm is rotated from 0 degree to 90 degrees to see the changes in Strouhal number.

From Fig.9, it can be seen that the inclination causes strong influence on the Strouhal number which can

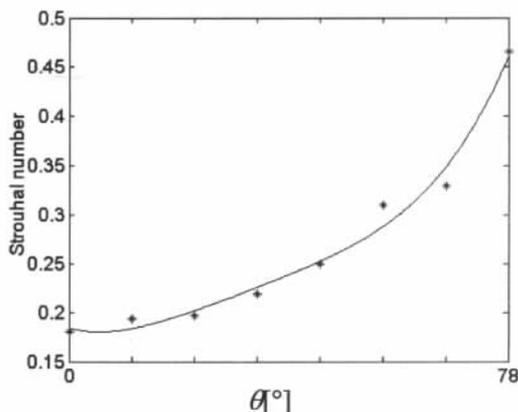


Fig. 9 Strouhal number changes versus inclination angle

be explained by the form of the characteristic width. With the inclination, the characteristic width decreases, the shedding frequency increases, and the Strouhal number increases.

Only the angle from 0 to 78 degrees are listed because bigger angles show no stability. Beyond 78 degrees, the sensitivity decreases dramatically due to the much too small characteristic width, defined in Fig.10, of the bluff body. There is almost no vortex generated behind the bluff body with too small characteristic width because the thin rectangular plate is almost parallel to the flow. As known, when the rectangular plate is aligned parallel to the flow, there is almost no separation from the boundary[4].

4. Conclusion and Discussion

Large amount of experiments indicate the inclination of bluff body is one of the factors influencing the Strouhal number. Bluff bodies in unconventional setup are more sensitive to inclination than in conventional setup. The smaller bluff bodies are more sensitive than bigger ones.

There are still a lot to be further studied and discussed. The real physical reason for the change of Strouhal number especially in unconventional setup as well as the existence of the characteristic width of bluff body need to be further studied and firmly proved.

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