Review Paper on Vortex Flow meter

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***Abstract*- The vortex flow meter is a device that works on the principle of shedding of vortices behind a bluff body placed in the flow. In the fifteenth century the great Italian painter Leonardo Da Vinci described and drew accurately the vortices behind cylindrical body.Later in 1878 Strouhal based on his observation published a relation for the vortex shedding frequency. This relation later represented in dimensionless form as: St= (f *d/Um)**

The first theoretical investigation on this subject was reported in1911. Von Karman derived the geometrical pattern of the vortices behind a circular cylinder based on linear stability analysis. He also established a theoretical link between the vortex street structure and drag experienced by the body. In the early stage there was a lot of discrepancy in the literature related to the choice of appropriate characteristic length for defining the non-dimensional Strouhal number.

Index terms- Flow Separation, Strouhal Number, Vortex Shedding, wake width

I. INTRODUCTION

The vortex flow meter is based on the well-known von Karman vortex street phenomenon. This phenomenon consists on a double row of line vortices in a fluid. Under certain conditions a Karman vortex street is shed in the wake of bluff cylindrical bodies when the relative fluid velocity is perpendicular to the generators of the cylinder (Figure 1.1). This periodic shedding of eddies occurs first from one side of the body and then from the other, an unusual phenomenon because the oncoming flow may be perfectly steady. Vortex streets can often be seen, for example, in rivers downstream of the columns supporting a bridge. They can be created by steady winds blowing past smokestacks, transmission lines, bridges, missiles about to be launched vertically, and

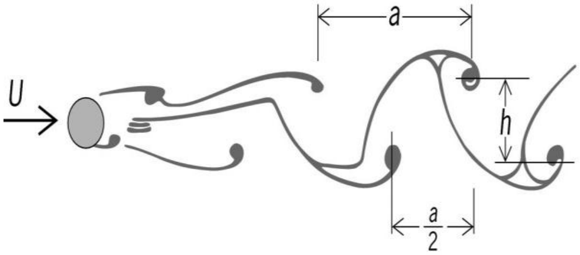

Figure 1.1: Karman Vortex street phenomenon

It is obvious, that each successful meter design is determined by comprehensive understanding of applied physical phenomena. Von Karman vortex street phenomenon is very complex and sensitive on numerous physical factors. Hence, the necessity of investigations with application of miscellaneous methods. The vortex flow meter remains very attractive for industrial applications due to its high accuracy, insensitivity to the physical properties of the medium and linear dependence on frequency versus flow rate. The frequency of generated vortices is directly proportional to the flow velocity:

$$f = \mathrm{St}\left(\frac{v}{d}\right) \qquad (1)$$

Where, ST is the Strouhal number, v the fluid velocity and d is the bluff body diameter.

The Strouhal number ST is constant over a very wide range of flow velocities. In spite of the very simple equation, which describes the behaviour of the vortex flow meter, the phenomena appearing in the meter are very complicated, and many unidentified factors may influence the vortex shedding. Hence, a complete description of these phenomena is not feasible, necessitating further research. Various research methods must be applied to obtain a more complete understanding of the phenomena, with each method elucidating partial information.

II. LITERATURE REVIEW

Vortex shedding was first observed by Bernard (1908) who observed alternate precision of eddies behind a circular cylinder in water, based on visible dimples on water surface [1].

Leonardo Da Vinci (1911) sat by the river side and observed the vortices shedding on the sharp edges turning up in the river. Later work carried out by von Karman was supported by flow visualization experiments. For instance, Hiementz's observations led von Karman to the theoretical description of the vortex street [2].

Bearman et al. (1969) has examined, the flow around a circular cylinder over the Reynolds number range 105 to 7.5 x105, Reynolds number being based on cylinder diameter. Narrow-band vortex shedding has been observed up to a Reynolds number of 5.5 x 105, i.e. well into the critical regime. At this Reynolds number the Strouhal number reached the unusually high value of 0.46. Spectra of the velocity fluctuations measured in the wake are presented for several values of Reynolds number [3].

P. W. Bearman (1973) described how the flows around two circular cylinders, displaced in a plane normal to the free stream, interact as the two bodies are brought close together. Surface pressure measurements at a Reynolds number of 2.5 x 104, based on the diameter of a single cylinder, show the presence of a mean repulsive force between the cylinders. An in stability of the flow was found when the gap between the cylinders was in the range between one diameter and about 0.1 of a diameter. Correlation measurements of hot-wire outputs indicate how mutual interference influences the formation of vortex streets from the two cylinders. Span wise correlation measurements show that the correlation length doubles as the cylinders are brought into contact [4]

C. J. Baker (1974) has investigated experimentally the formation of horseshoe vortex around the base of a cylinder by a separating laminar boundary layer. Smoke flow visualization shows that both steady and unsteady vortex systems exist. Pressure distributions beneath both types of vortex system have been measured and the variation of the horseshoe vortex position on the plane of symmetry upstream of the cylinder has been determined. Unsteady horseshoe vortex systems are shown to have a complex oscillatory behaviour and the nature of this oscillatory behaviour is described. Using smoke flow visualization techniques some measurements have been made of the velocity distributions within horseshoe vortex systems [5].

Igarashi et al (1978) experimentally investigates on the flow characteristics around a circular cylinder with a slit have been carried out. Flow visualization, hot-wire measurement of the wake flow and the distribution of the static pressure coefficients around the cylinder have been made. The experiments were carried out in the Reynold's number region of 13800 to 52000 for two slit ratios of s/d= 0.080 and 0.185. Three different typical flow patterns were found for the inclination of the slit B. For 400≤ β≤600, the effect of the slit was little. For 600≤β≤900, boundary layer suction was observed periodically with a period of the shed vortices. In this case, the base pressure coefficient dropped and the shedding frequency decreased [6].

Sadeh and Brauer (1980) conducted a diagnostic visualization study of turbulence in stagnation flow around a circular cylinder to gain physical insight into the coherent structure of turbulence in flow around a bluff body advanced by the vortices-amplification theory. The visualization was conducted at a cylinder-diameter Reynolds number of 8 x103 utilizing titanium dioxide white smokes for an approaching flow containing turbulence at scales larger than the neutral wavelength of the stagnation flow. Analyses of the flow events focused on tracing out the temporal and spatial evolution of a cross-vortex tube outlined by the entrained smoke filaments from its emergence near the stagnation zone through its penetration into the cylinder boundary layer. The selective stretching of cross-vortex tubes, their stream-wise tilting, the emergence of an organized turbulent flow pattern near the stagnation zone, the interaction of the amplified vortices with the body laminar boundary layer and the growth of a turbulent boundary layer were revealed by the visualization. In particular, the visualization indicated that the cross-vortex tubes conveyed by the diverging stagnation flow constitute a coherent substructure within the overall turbulent flow that is triggered to its fullest manifestation by the stretching mechanism [7].

The frequency of vortex shedding from a circular cylinder in a uniform shear flow and the flow patterns around it were experimentally investigated by Kiya et al. (1980). The Reynolds number Re, which was defined in terms of the cylinder diameter and the approaching velocity at its centre, ranged from 35 to 1500. The shear parameter, which is the transverse velocity gradient of the shear flow non-dimensionalized by the above two quantities, was varied from 0 to 0.25. The critical Reynolds number beyond which vortex shedding from the cylinder occurred was found to be higher than that for a uniform stream and increased approximately linearly with increasing shear parameter when it was larger than about 0.06. In the Reynolds-number range 43 < Re< 220, the vortex shedding disappeared for sufficiently large shear parameters. Moreover, in the Reynolds-number range 100 < Re < 1000, the Stronhal number increased as the shear parameter increased beyond about 0.1 [8].

Gerich (1981) investigates whether the cylinder end boundaries (end plates or simple free ends) alter the vortex-shedding mechanism near these boundaries. This effect has in the past usually been overlooked. In a region near an end plate or a free end (ranging from 6 to 15 cylinder diameters in length), the shedding frequency f2 is found to be 10-15 % less than the regular Strouhal frequency fs. The latter frequency is observed over the remaining cylinder length. The simultaneous occurrence of two frequencies results in a beat frequency, which is best, observed at the junction of the two regions characterized by fs and f2 respectively. A third frequency f3 with fs > f3 > f2 is observed over the entire cylinder length when the cylinder is bounded by two end plates less than 20 to 30 cylinder diameters apart. Here the critical Reynolds number for the onset of shedding is shifted to about 60 and the laminar Reynolds-number range is extended from about 150 to about 250 [9].

Igarashi (1982) experimentally investigated on the effect of boundary layer suction for a circular cylinder with a two dimensional slit placed along with a two-dimensional slit placed along a diameter have been carried out. Flow characteristics around the cylinder for cases of intermittent boundary layer suction (Pattern I), alternate boundary layer suction and blowing (Pattern II) and transition regions were clarified. Particularly, the mechanism of the boundary layer suction, fluid flows in the slit and rear surface of the cylinder and the mechanism of the vortex formation in the wake were clarified [10].

Szepessy And Bearman (1990) have studied aspect ratio effects on the vortex shedding flow from a circular cylinder by using moveable end plates. Experiments were carried out to measure fluctuating forces, shedding frequency and span wise correlation whilst varying end plate separation and Reynolds number. The aspect ratio (0.25-12) was found to have a most striking effect on the fluctuating lift. Within a certain range of Reynolds number an increase of the sectional fluctuating lift was obtained for reduced aspect ratio, and showed a maximum for an aspect ratio of 1, where the fluctuating lift could be almost twice the value for very large aspect ratios [11].

M. W. Johnson (1990) used a computational technique for unsteady incompressible viscid flow applicable to any 2-dimensional flow geometry is presented. The method adopts a stream function vortices approach and uses an Alternate Direction Implicit Technique to march the vortices in time, and a successive over-relaxation technique to obtain the stream function at each time level. Initial calculations are presented for the vortex shedding from a circular cylinder where the 5trouhal number is computed to within 10% of the empirical value over a range of Reynolds numbers up to1250. The flow within a commercial vortex-shedding meter is also computed and results indicate how the design of the bluff body affects the strength of the shed vortices and they also highlight the best locations for the frequency detector. [12]

K. El Wahed (1991)the results of an experimental investigation into the influence of the cross-sectional bluff body (shedder) shape on the performance of an electrostatic vortex shedding flow meter are presented. This flow meter uses the modulated signal of the electrostatic charge deposited on an electrode as a means of registering vortex shedding frequency. In this study, the dimensionless signal to Noise ratio was used to assess the performance of each bluff body and various electrode configurations. The results indicate that the meter incorporating a Rectangular electrode positioned on the front face of a T-shaped shedder produces. The best signal quality and best meter performance. [13]

III. CONCLUSION

Flow visualization supported by the image processing appears as very useful couple of methods for von Karman vortex street investigations. Due to the flow visualization the observation of the whole flow area at that very moment is feasible. Hence such important phenomena like the occurrence of the stagnation region can be evaluated.

Quantitative information concerned visualized phenomena is feasible due to the digital image processing of obtained pictures. Identification of vortices as separate objects enables determination of the distance between consecutive vortices.

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