BENARD VON KARMAN VORTEX STREET DEVELOPMENT BEHIND A HEATED CYLINDER

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ABSTRACT

The alteration of the bi-dimensional wake behind a heated circular cylinder was previously investigated when buoyancy effects were added to the viscous ones. Velocimetry and thermocouples pointed out the configurations of forced and natural convection with respect to a critical heat input, and how they rule the wake when it is dominated on the one hand by the viscosity and on the other hand by the gravity (Michaux-Leblond 1994 [1]). The experimental results reported in this paper concern the three dimensional effects created by the ends of the cylinder (walls of the test section), how they spread all over the cylinder and how they affect the flow in a median plan when the vortex street is completely developped (Re = 199) behind a small length to diameter ratio cylinder (L/d = 6.84).
The temporal and spatial resolutions were respectively privileged by the use of an Ultrasonic Doppler Velocimeter (V.D.U.) and a Laser Doppler Velocimeter (V.D.L.).

I - INTRODUCTION

The present paper deals with the control of the vortex formation and shedding behind a circular cylinder. We particularly want to exhibit in which way the walls of the test section alter the characteristics of the wake.
What we know at this time is that the critical Reynolds number increases as far as the length to diameter ratio decreases (Shair *and al.* [2] and Nishioka *and al* [3]). The length of the recirculating region follows a linear and growing variation with the Reynolds number (Taneda [4]). The recent studies of Le Masson [5] and Michaux-Leblond [1] put in clearness the presence of a threshold beyond which the position of the wake stagnation point decreases. Like the evolution of the Reynolds number, the point location is strongly dependant on the length to diameter ratio. If we consider that the cylinder is bounded at its ends by the walls of the test section, the closeness of the walls stabilises the wake. The cylinder end boundaries, whatever they may be, end plates or simple free ends, alter the vortex shedding mechanism near these boundaries and introduce three dimensional structures in the core of the flow, inherent in boundary layers created by the plates. In the past, this effect has usually been neglected. Studies were then accomplished with cylinder which length to diameter ratio sufficiently large to neglect the end-boundaries influence.

II - WORKING PRINCIPLE

The working principle of the Ultrasonic Doppler Velocimeter is to detect and process the echoes of ultrasonic pulses reflected by the microparticles contained in a flowing liquid. A single transducer emits the ultrasonic pulses and receives the echoes. All moving particles contained in the measured liquid introduce a frequency shift in the echo due to the Doppler effect. The velocity information is extracted by measuring these frequency shifts. The measurement of time lapse between the emission and reception of the pulse gives the position of the scattering volume. By measuring the Doppler frequency shift at different times after the emission of the pulse, it is possible to obtain a velocity profile after a number of ultrasonic emissions. The axis resolution is a function of emitted pulse. If the time between two pulses decreases, the spatial resolution may improve but the echoes energy decreases.

III - EXPERIMENTAL CONFIGURATION

When the waves cross the walls of the test section, several reflections and diffractions appear, that are characterised by fixed echoes. These ones depend espacially on the Doppler angle, the composition and the thickness of the wall and the transducer power supplied and will influence the velocity information quality near the walls but they can be easily filtered by a adapted treatment. Besides, this technical requires the use of particles with a minimum diameter so that the flow was sowed by corn starch particles. The ultrasonic pulsed wave used for this experimental configuration was governed by the flow regime previously investigated [1], [6].

In the same way, the U velocity field measurements were made by using an one component Laser Doppler Velocimeter operating in the forward scattering. The light supply comes from a 15 mW Helium-Neon Laser.

Measurements were made in an open loop water tunnel which test section is 80x300 mm² in cross section and 1000 mm long. This apparatus presents two main features such as a vertical test section and an ascensional flow : the preoccupation is here to hold in position a symmetrical vortex shedding despite of the cylinder heating, and viscosity and buoyancy actions in a single direction. A detailed description of the apparatus working as well as its kinematics and geometrical characteristics are found in the reference [1].

The schematic diagrams of the transducer disposition and the reference system are presented respectively in figure 1 and 2.

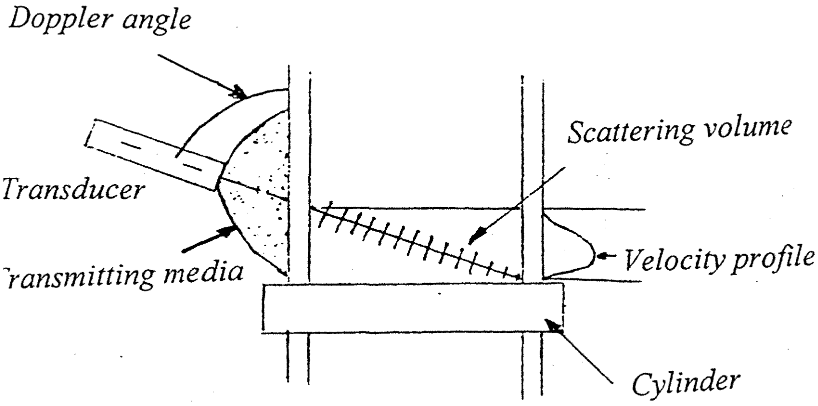


Figure 1 : ***Experimental apparatus***

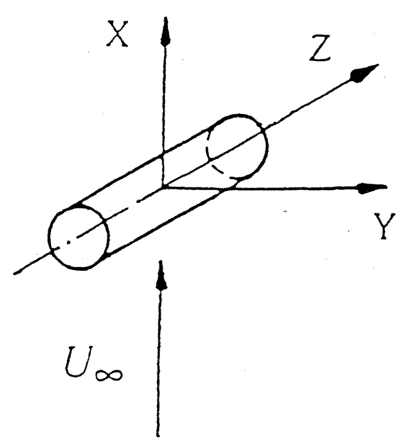


Figure 2 : ***Reference system***

The origin of the coordinate system is situated on the revolution axis of the cylinder at half way of the walls of the test section.

IV - RESULTS

IV- 1. Isothermal wake

The first results concern the 3D isothermal wake for x/d = 1.35 when the vortex street is completely developed (Re = 199). The data represented in figures 3, 4 and 5 were respectively obtained by V.D.U. (figure 3 and 4) and V.D.L (figure 5).

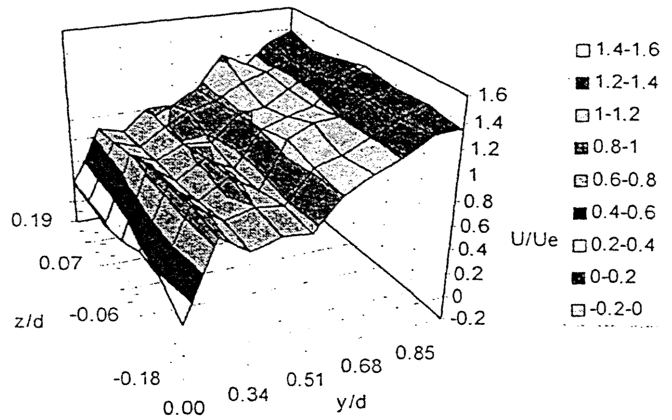


Figure 3 : ***Velocity profiles - V.D.U.***
Re = 199 - x/d = 1.35 - 0.19 < z/d < 0.19

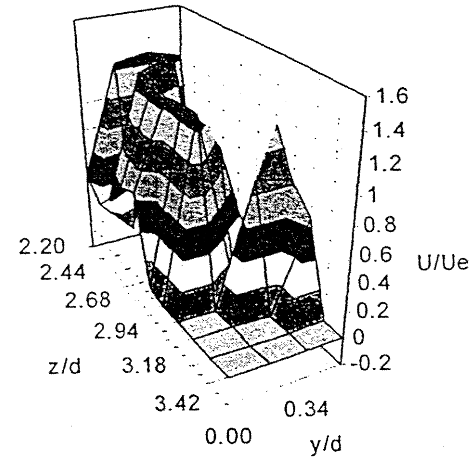


Figure 4 : ***Velocity profiles - V.D.U.***
Re = 199 - x/d = 1.35 - 0 < z/d < 2.2

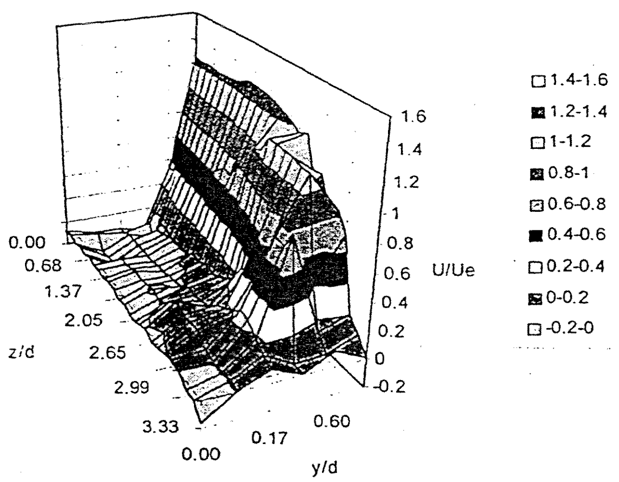
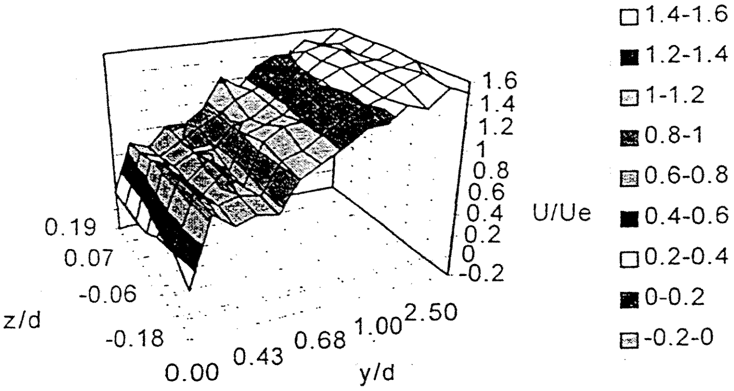


Figure 5 : ***Velocity profiles - V.D.L - Re****= 199 - x/d = 1.35 - 0 < z/d < 3.33*

Near the walls of the test section, a wide peak appear, strongly marked by the V.D.U. technical whereas, in the median part of the cylinder, the spatial resolution difference that characterises the two investigation methods does no more persist.
The further informations given by V.D.U. pointed out a temporal evolution of the spatial structures created by the walls of the test section.

IV- 2. Non isothermal wake
The figures 6, 7 and 8 represent the velocity field obtained by V.D.U. for Re = 199 and x/d = 1.35 when the cylinder is progressively heated.
For P/L = 0 W/m, the velocity field is relatively uniform. The heating of the cylinder creates fluctuations that spread over the cylinder axis and increase with the heat. However, these transverse structures are reduced in the cylinder recirculation area.



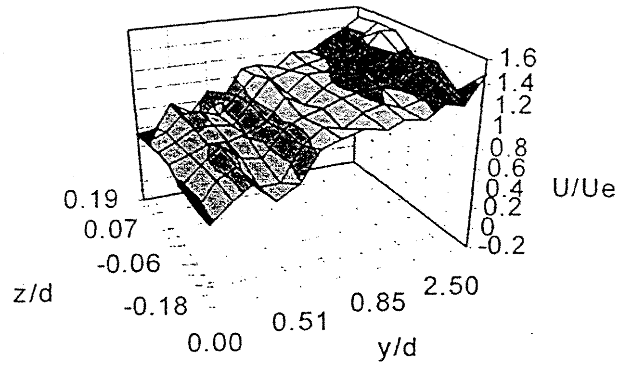


Figure 6 : *Velocity profiles - V.D.U.*
Re = 199 - x/d = 1.35 - P/L = 0 W/m

Figure 7 : *Velocity profiles - V.D.U.*
Re = 199 - x/d = 1.35 - P/L = 25 W/m

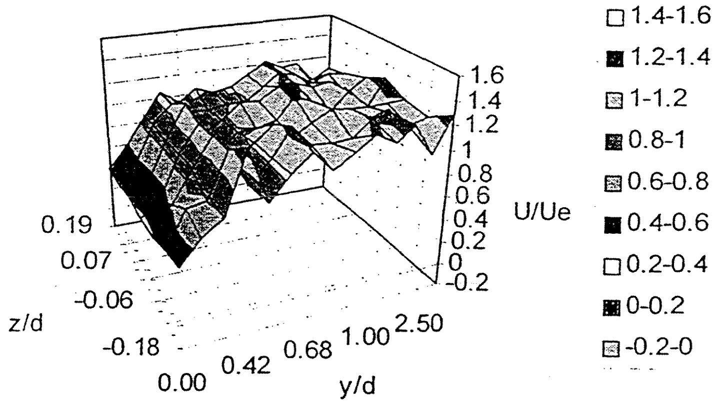


Figure 8 : *Velocity profiles - V.D.U - Re= 199 - x/d = 1.35 - P/L = 93.75 W/m*

V - CONCLUSION

The results obtained respectively by V.D.U. and V.D.L. pointed out the parts of the wake dominated by 3D structures.
The cylinder heating creates perturbations outside the recirculation area that are amplified as far as the heat input increases.

VI - REFERENCES

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