EXPERIMENTAL STUDY BY PIV OF DISPERSION IN THE NEAR WAKE OF IDEALIZED CAR MODEL.

[1]B.PATTE-ROULAND, [2]D.BALOU, [3]E.VARÉA, [4]P.PARANTHOËN

Université Rouen Normandie, CORIA UMR 6614, 76801 Saint-Etienne du Rouvray
Beatrice.patte-rouland@univ-rouen.fr

Abstract - The objective of this work is to study the dispersion of pollutants in the wake of car model and thus to understand the influence of the flow on the pollutant. This experimental study is carried out in a closed circuit subsonic wind tunnel. The vehicle is assimilated to a body of Ahmed at the scale of 0.19. This work breaks down into two parts: in the first one we are interested in the characterization of the flow without taking into account the pollutant; the second part looks at the distribution of the pollutant in the wake of the flow. The velocity of the flow is measured by Particle Image Velocimetry (PIV).The statistical analysis makes it possible to apprehend the physical phenomena taking place in the wake of idealized car model.

Index Terms - Ahmed model, Separated turbulent flow, Dispersion, Particle Image Velocimetry.

I. INTRODUCTION

Pollutants emitted by motor vehicles mainly contribute to the degradation of air quality in urban cities or near highways. For this reason, air-quality regulations concerning automobiles emissions are becoming more stringent in controlling the composition and quantity of exhaust gases. Vehicular emissions of concern include both primary and secondary reactive or non-reactive gases (CO2, CO, NOX, SO2, HC, COV) and ultrafine particles (0.05–1 um).

In order to comply with the next strict air pollution standards, automobile manufacturers try to find out new solutions to reduce aerodynamic drag and limit fuel consumption. In this context, a large number of studies have recently been carried out to measure or simulate the complex 3D velocity field in the wake of a ground vehicle.

Most of these works use the ‘‘Ahmed model’’ due to its geometric simplicity and availability of experimental results (Ahmed et al. 1984; Morel 1978; Gillieron and Chometon 1999; Lienhart et al. 2000; Howard and Pourquie 2002; Beaudoin et al. 2004).
In the current note, we present and discuss some recent experimental results concerning velocity in the near wake of a simplified model car (Ahmed model with a rear slant angle of 25 °). Measurement of the velocity field allows us to understand the dispersive and mixing characters. Results show the existence of a transition of the flow regime from 2D to 3D resulting in a significant change of the effluent field. The statistical analysis makes it possible to apprehend the physical phenomena taking place in the wake of the vehicle.

II. EXPERIMENTAL SET UP

A. Model car

The model car is an ‘‘Ahmed model’’ with a rear slant angle of 0 to 35 degree. Fig.1 is a schematic of the Ahmed model. This model was mounted on the adiabatic flat plate of a 2D wall jet and aligned with the exit velocity. The velocity of this jet was 13.9 m s^{-1}.
As shown in Fig. 1, the origin of the reference system was located at the rear of the model. The x-axis was oriented in the direction of the main flow, the y-axis was vertical and the z-axis was perpendicular both to the model side wall and the main flow.

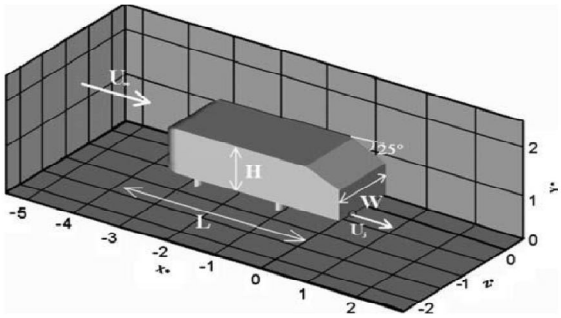


Fig. 1. Schematic of the car model (Ahmed body)

B. Subsonic blower

The experiments were led in a subsonic blower. The quality of a blower is determined by its capacity to generate a stable flow in time and homogeneous in space. The top view of the blower is described on Fig. 2. It is here a blower of type closed circuit, the square trial section measures 40 centimeter of quoted. Fig.2. highlights a number of components. This subsonic blower generates speeds of going flow 16 m/s what corresponds at the speed of vehicle driving to 60 kilometer per hour.

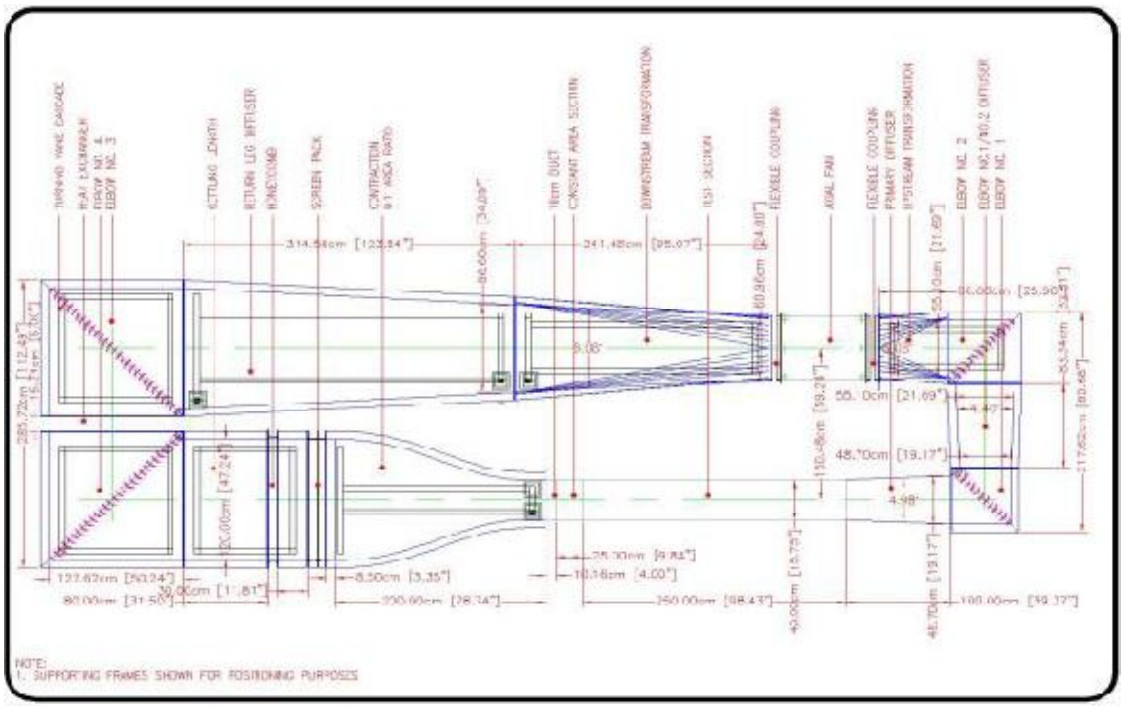


Fig. 2. Experimental set up subsonic blower

C. PIV SET UP

The measurement consists in velocity fields and scalar field measurements by PIV. The flow dynamics and the scalar fields will be studied on the central horizontal and vertical planes. The signal emitted by the particles is collected by cameras CCD (Charge-Coupled Device). In the case of our study, we opted for a classical PIV (2D2C), it allows to observe the flow in a plane, therefore to obtain two speed components. We use a double cavity Nd: YAG laser that emits beam at 532 nm with an energy of 121 mJ per pulse at a frequency of 10 Hz.The time between two laser pulses is 12.10-6s. The laser takes place along the vertical of the movement bench. To create the laser slice we used a plane mirror that we put at 45 ° from the beam emitted by the laser, a divergent cylindrical lens of focal lengt f0 = - 40mm and a lens spherical convergent focal length f = 1000mm. To increase the size of beam of light emitted by the laser, we put a beam expander to some centimetres from the laser exit. The thickness of the generated slice is of the order of 1 mm. The visualization of the seeded flow was done using the camera HiSense Neo from DANTEC Dynamics of 2560 * 2160 pixels with dynamics of 12 bits. The exposure time of the camera is 20 ms, the time interval between the shots of the two successive images is 2.10^{-6}s.

This camera is mounted perpendicular to the seeded flow plane. The synchronization of the laser and the camera is done thanks to a BNC box which generates TTL signals for triggering the camera and the laser. To secure the camera we connected BNC instruments case (TTi) which is in triggered mode, in back it drives the camera and the laser.

The particles of oil of glycerin are introduced into the reservoir of the smoke machine FOGBURST1500, consequently, the flow of particles is injected in the selling via the crack of the trial vein.



Fig. 3. PIV set up.



Fig. 4. Smoke machine FOGBURST1500

III.RESULTS

A. TRANSITION 2D-3D

As the angle of inclination increases, the flow becomes strongly three-dimensional. In contrast, for important angles of inclination the Fluid takes off between the ridge of the roof and the rear window and then collects on the central surface of the telescope. Through their work, Ahmed et al. have shown that the wake is also characterized by the presence of two contrarotating vortices from the

edges of the rear window. They also observe an area recirculation downstream of the pellet and a development of the two edge swirls, as well as the presence of separation bubbles. These results are in good agreement with those of Gillieron and Chometon [5].

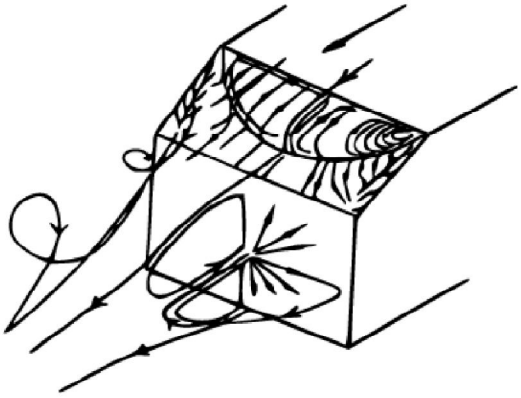


Fig. 4. two contrarotating vortices from the edges of the rear window

For an angle a=25°, they show the existence of a transition in the flow regime at a critical Reynolds number Relc. As shown in Fig.5, under Relc, the structure of the flow is 2D and characterized by a separation over the rear slant [13][14].

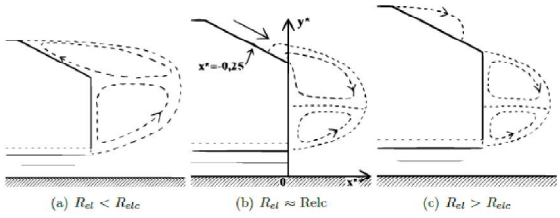
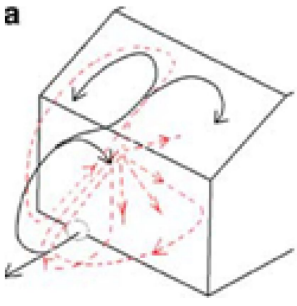


Fig.5 transition in the flow regime at a critical Reynolds number Re_{lc}

In this case, a part of the heated fluid injected by the exhaust pipe is trapped by the lower anticlockwise vortex, pulled back towards the base of the model and drawn by the upper clockwise vortex. This explains the presence of heated fluid within the zone located just above the slanted wall [13][14]. This scenario is close to the one proposed by Richards et al. (2000) to analyse the initial behavior of exhaust gases in the near wake of a fastback type vehicle. Above ReLc, the structure of the flow is 3D. As shown in Fig. 6a and b, the flow separates over the whole of the rear end and occasionally reattaches near the bottom end as shown by Howard and Pourquie (2002).



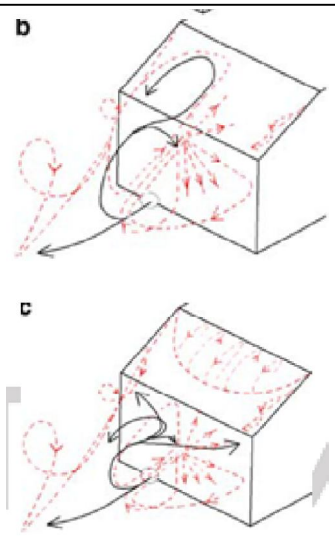


Fig.6 Structure of the flow

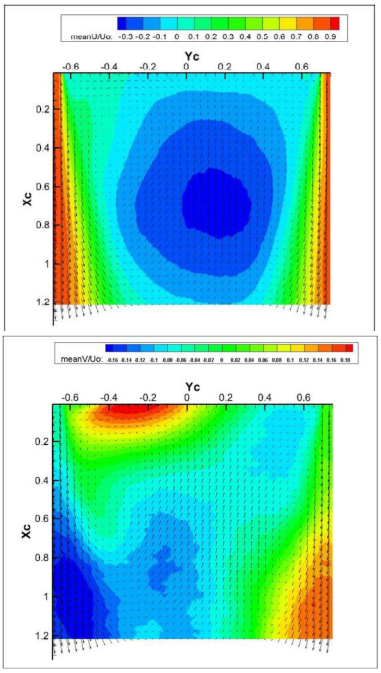
B. PIV RESULTS

we present the average and instantaneous velocity components obtained by PIV.

B. 1 Rear slant angle of 0°

By placing in x = 35 mm, y = 0 mm and z = 25 mm. We obtain the images below.

On the average velocity fields downstream of the right pellet, we observe many structures swirling, counter-rotating in the near wake following the component longitudinal. These structures are in line with those described in the bibliography. Moreover, the longitudinal vortices observed are not symmetrical; certainly because of the bad location of the model car. These structures informs about the trajectory that will follow the passive scalar in the recirculation zone.



B.2 Rear slant angle of 25°

For this body, it is placed in x = 74 mm, y = 0 mm and z = 20 mm. The results obtained are illustrated by the images below

We observe the presence of two contrarotating vortices from the edges as we can see in Fig.8. These results are in good agreement with the works of Ahmed [1] or those of Gillieron and Chometon [5].

B.3 Rear slant angle of 35°

We calculated the two speed components by setting x = 72 mm, y = 0 and z = 30 mm. The results obtained are represented by the images below.

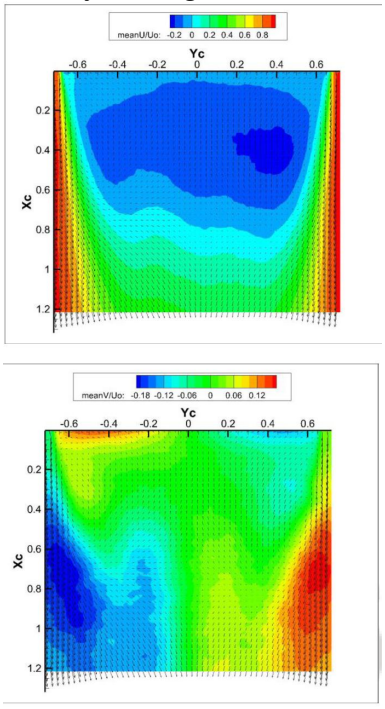


Fig.9 Component of longitudinal mean velocity (a) and transverse velocity (b).

In Figure 9, we can see that the longitudinal vortices are disappearing

CONCLUSION

To conclude, we have studied experimentally the velocity in the near wake of a simplified model car. This model is an Ahmed model with a rear slant angle of 0, 25° or 35°. The objective of this study was to understand the different phenomena (dispersion, mixing) of the pollutant due to the influence of the turbulence of the ambient flow created by the wake of the vehicle. The bibliographic study we has allowed to have a global view on the various works. Indeed, a large number of experimental studies have been devoted to measuring pollutants without taking into account the influence of turbulence or the characterization of the flow without pollutant. This is how we opted for this experimental study in the interest of describe the pollutant taking into account the turbulence. The results obtained are in agreement with the literature. The velocity fields measured for the three inclination angles showed that dynamic field of the near wake strongly depends on the vehicle geometry. Results show too that the thermal fields are strongly dependent on angle in relation with the corresponding flow fields.

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