

Ventilation Characteristics of Modeled Compact Car Part 1 Airflow Velocity Measurement with PIV

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ABSTRACT

In the present study, a model experiment is performed in order to clarify the ventilation characteristics of car cabin. This study also provides high precision data for benchmark test. As a first step, the ventilation mode is tested, which is one of the representative air-distribution modes. Part 1 describes the properties of the flow field in the cabin obtained by the experiment. Part 2 describes the ventilation efficiencies such as the age of air by using trace gas method. The properties of flow field are measured using particle image velocimetry (PIV). The mean velocity profiles, the standard deviation distribution, and the turbulence intensity distribution are discussed. The brief comparison between experiments and predictions of computational fluid dynamics (CFD) is also presented. In the comparison between experiment and CFD, the results showed similar flow field.

1. INTRODUCTION

Ensuring a comfortable atmosphere within a car is important problem for passenger. Creating such a comfortable atmosphere requires for the development of a technique that accurately predicts the atmosphere in the car, coupled with improvements to the existing air-

conditioning system. At present, as a means of predicting the atmosphere inside the car, experimentation and CFD are generally used.

Concerning the atmosphere in automobiles, several studies have already been carried out. Batterman et al.¹⁾ proposed using tracer gas techniques to accurately measure concentrations of Volatile Organic Compounds (VOC) in homes and vehicles, and discussed the usefulness of the techniques. Lin et al.²⁾ investigated the effects of HVAC design parameters on passenger thermal comfort. The exit vent location was found to be an important factor for the flow distribution in the rear compartment. Dag et al.³⁾ measured airflow velocity in real car, Volvo S80 and compared with CFD results. In the study, PIV was used for the velocity measurements as well as our experiments. However, the turbulent intensity inside the cabin was not investigated. Kataoka et al.⁴⁾ used a three-dimensional laser flow meter to measure the airflow distribution in a simple car model and carried out a benchmark test for CFD analysis. On the basis of the test results, the thermal sensations of the passengers are also measured. The real car is set to be the target for study in these works. There is individual difference among the real car.

In the present study, a standard car model as half-scale is created to make a comprehensive experimental study of the atmosphere in a vehicle. The purpose of this report is to provide data to examine the accuracy of CFD analysis by means of a high precision experiment using PIV. The ventilation characteristics such as the mean velocity profiles, the standard deviation distribution, and the turbulence intensity distribution are also discussed. The experimental data is to be shared as a standard model to assess the atmosphere in cars and for use in CFD benchmark tests in the development of automobile air conditioning. As a result, it should become possible to accurately predict the atmosphere in vehicles using CFD and design high-quality air conditioning. In the next report, the efficiency of internal automotive ventilation are measured using a flame ionization detector (FID) and the implications on the quality of air breathed by the passengers are discussed.

2. EXPERIMENTAL METHOD

2.1 OUTLINE OF CAR MODEL

In the present study, a PIV experiment using the scale car model is carried out as shown in Figs. 1 and 2. The model is made of transparent acrylic resin and measures 1,450 mm × 700 mm × 900 mm. The top of the model can be opened and closed so as to permit manipulation of the experimental devices, etc. from above. Ducts can be connected to the model from the front to supply air to its interior. The model is symmetrical with respect to the centerline.

As shown in Figs. 3 and 4, the model is provided with four supply openings in the front for internal air conditioning. A rectangular duct coupled with a flexible duct is connected to each of the supply openings to supply air via a fan. The supply opening dimensions are 50 mm × 60 mm, and the supply angle is 20 degrees. The air in the model interior is exhausted by fans from two exhaust openings to the rear of the model. The amount of air supplied (exhausted) is controlled to a preset value by adjusting the electric power supplied to the fans. The flow rate of air is measured with an orifice tube and the amount of air is regulated with a fan.

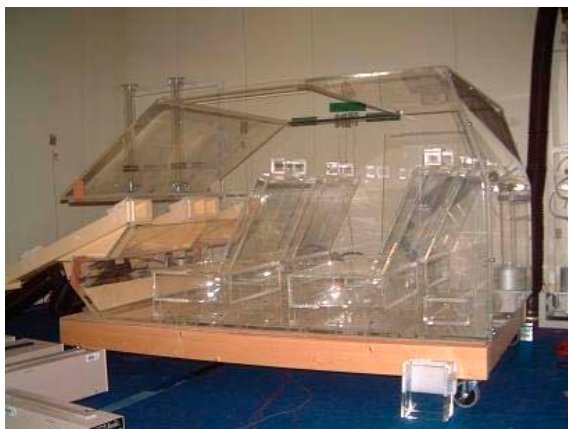


Figure 1. Half-scale car model

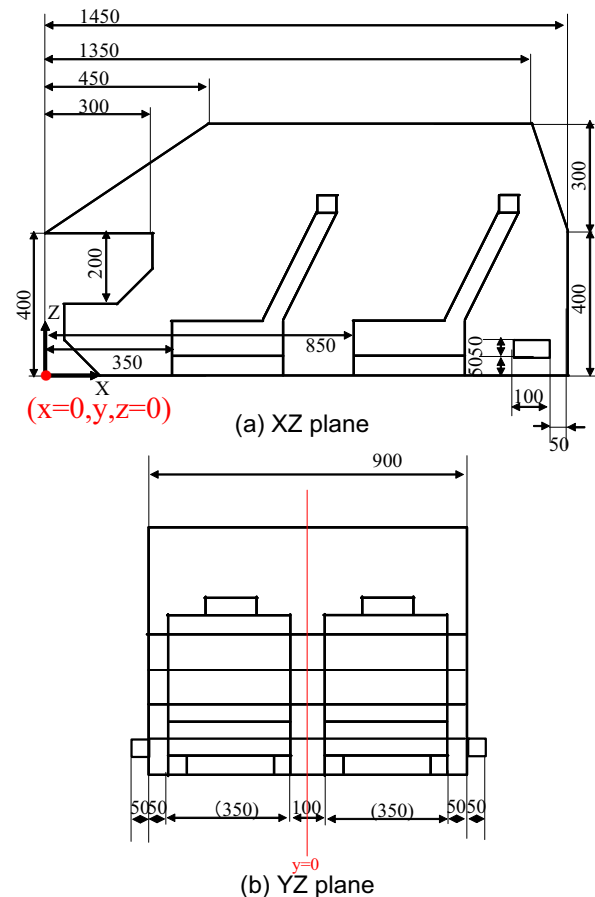


Figure 2. Size of the model (unit:mm)

2.2 OUTLINE OF CLIMATE CHAMBER

The scale model was installed in a thermostatic chamber measuring 3 m × 3.5 m × 2.5 m. This chamber is capable of supplying air from the entire floor and exhausting air from the entire ceiling. The difference in temperature between the top and the bottom can be controlled within 0.1°C. Once the temperature inside the chamber is constant, the air in the chamber is drawn in by fans and supplied to the model interior as air for the air conditioning.

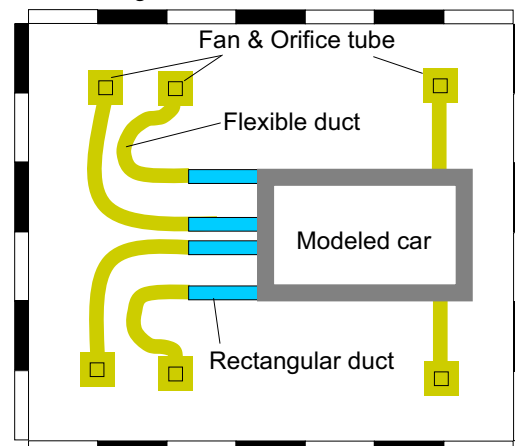


Figure 3. Floor plan of the chamber

2.3 EXPERIMENTAL SET-UP

1) Particle Image Velocimetry (PIV)

The PIV system (Dantec PIV-HUB, FlowSense M2 10 bit; NewWave Nd: YAG Laser) used in the present study is designed to measure two-dimensional airflow velocity distribution. In order to measure airflow velocity by PIV, tracer particles (oil-based particles $0.25\ \mu\text{m}$ to $60\ \mu\text{m}$ in diameter), which provide ample scattered light, are sprinkled around the fan used to air condition of the model so that they are fed into the model first. Then, images of particles shot at two different times are input as digital data by a CCD camera synchronized with the pulse laser. In each of the inspection regions, the distance traveled by the particles in micro time units is obtained by numerical processes⁵⁾, such as Fourier transformation and correlation, and a velocity vector diagram is calculated.

2) Orifice tube

The orifice tubes (Fig. 5) used in the present experiment were made from transparent acrylic resin in accordance with JIS Z8762-1995. The orifice tube for regulating the flow rate of air supplied to the model is $0.06\ \text{m}$ in diameter (throttle nozzle diameter: $0.03\ \text{m}$), and the orifice tube for regulating the flow rate of air exhausted from the model is $0.06\ \text{m}$ in diameter (throttle nozzle diameter: $0.04\ \text{m}$). It is expected that these orifice tubes are capable of accurately measuring the flow rate of air (error within approximately 1%), although this depends more or less on the accuracy of the measuring instrument used. The performance test of the orifice tubes was done for measuring the flow rates at an air temperature of 300K . Therefore, the temperature inside the thermostatic chamber was also maintained at 300K throughout the experiment.

3) Pressure gauge

In order to measure the flow rate of air using an orifice tube, the difference in pressure in front of and behind the throttle nozzle of the orifice tube is measured first, and then the flow rate of air is estimated from the relation obtained by the orifice tube performance test. The BARATRON pressure gauge shown in Fig. 6 is used to measure the difference in pressure in front of and behind the throttle nozzle of the orifice tube. In addition, an NR-2000 made by KEYENCE is used to collect and analyze the electrical signals obtained from the pressure gauges.

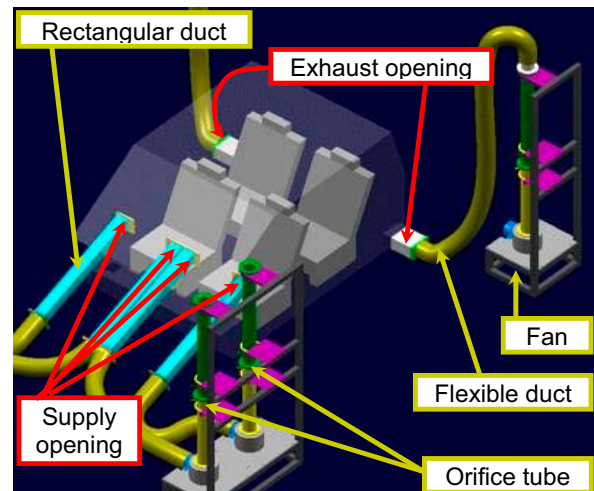


Figure 4. Experimental set-up

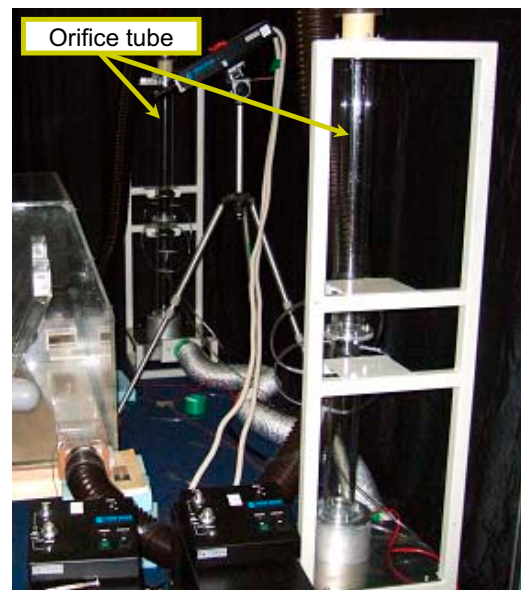


Figure 5. Orifice tube



Figure 6. Pressure gauge