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AIRFLOW AND THERMAL COMFORT OF THE BUS PASSENGERS

Abstract: *Nowadays, the thermal comfort in the means of transport is an important field of research, which have a positive impact on the health of the passengers and the driver. The latest research, results and methods, to determining the comfort in means of transport are presented in the first part of the paper. The thermal comfort study is carried out on an existing bus geometry. The bus geometry is modelled in SolidWorks using blueprints available on the web. The simulation is done for three cases: the first case where the ventilation system is open at maximum capacity, the second case where the ventilation system works at maximum capacity whit the air deflectors mounted for a better distribution of the air and the last case when the bus velocity is 14m/s whit two rear windows opened. The results of the first simulations are analysed and a location of deflectors is proposed for an optimal distribution of air inside the bus. In the last part of the paper we compare the obtained results, highlighting the conclusions of this study.*

Key words: *Thermal comfort, CFD, bus, airflow, PVM, PPD.*

1. INTRODUCTION

Nowadays the bus has become an indispensable part of our lives [6]. The comfort of the bus passengers requires a special attention because they spent many hours a day using the bus to commuting between cities. Lately the HVAC tools have been used in order to generate the optimal geometry and comfort of the room space.

The CFD simulation software reduces greatly the development and manufacturing of the HVAC system, having a significant contribution to optimizing the comfort in the buses. In the past few years, most of the specialized software for CAD design has developed the CFD solver integrated into simulation software module. Thus, with a single software package, all the process for modelling, simulation, optimization and 3D printing can be realized.

A study designed to optimize the thermal comfort of a passenger’s car is CFD simulated in Ansys Fluent module [3]. PMV and PPD scales are considered as reference for calculating the thermal comfort of the passengers and driver in the vehicles.

Another analysis of the bus ventilation system is studied in [9]. The bus geometry is modelled in SolidWorks 2015 and the CFD simulation is solved in Ansys Fluent. A detailed thermal comfort study for car passenger according the ISO 7730 is described in [5], where is simulated two cases for each passenger and driver, at the different temperature.

The examining effects of the passenger load factor in the vehicle is studied in [6]. The experimental test at the environment temperature about 35°C and a relative humidity of 40% have been done in two phases, on the Renault E7J [2]. A thermal comfort study is done on the surface public transport from Bucharest, during the summer period when the thermal comfort decrease, on the seven transport vehicles models [4].

Using numerical simulation in [7] the thermal comfort evaluation is done. The simulation of the process shows the influence of the bus air distribution.

For the thermal comfort estimation on the vehicles, the PMV index is used to predict the thermal response of the bus passengers, driver and the baby passengers, according to ASHARE standard. In table 1 is presented the comfort sensation values of the PMV (Predicted Mean Vote) index [3].

Table 1

Comfort sensation value [9].

Hot	Warm	Slightly warm	Comf. / Neutral	Slightly cool	Cool	Cold
3	2	1	0	-1	-2	-3

PPD (Predicted Percent Dissatisfied) index is the quantitative measure of the group of people at a particular environment [10].

2. CAD MODEL

Recently, computerized graphical methods have replaced the classic graphical methods for solving various metric problems in engineering design [1]. The bus model chosen for CFD simulation is Urbino 15 Solaris, production of 2014. The basic CAD geometry of the bus is modelled in SolidWorks software [12] using blueprints image [11]. For generate the three-dimensional model are used the front, rear, right and inside projection picture. The picture of the inside is useful to view and generate de seats location and geometry. In Fig. 1 is presented the blueprints pictures.

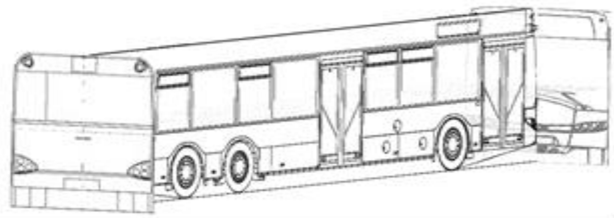

Fig. 1 Blueprints picture of the bus body [9].

Using advanced modelling techniques, the bus model is generated. The overall dimension of the CAD model is in concordance with the real model of the bus. The internal space and the seats of the bus are basic modelled to reduce the simulation time. In Fig. 2 the front view and the right view of the CAD model of the bus with overall dimensions is represented.

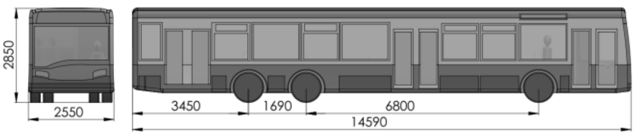

Fig. 2 The bus model.

3. CFD SIMULATION

In this case, the aim of the CFD simulation is to determine the thermal comfort of the bus passengers. The flowchart of the iterative CFD process is presented in Fig. 3.

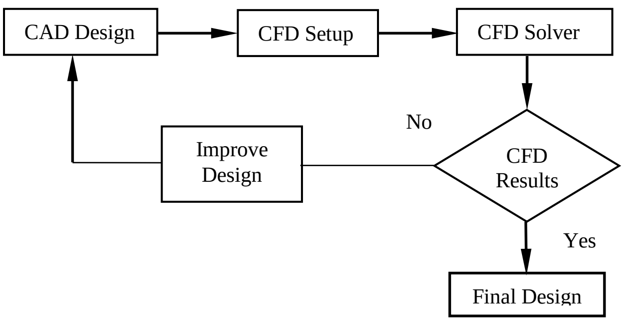

Fig. 3 Flowchart of the iterative CFD process

In the first step of the flowchart is generated the basic design of the bus, using CAD modelling techniques. The load case of the simulation is created in second step of the CFD process. The value of the result decides if the design is feasible. If the results no satisfy the requirements, the design of the bus must be improved. This iterative process enters in a closed loop until the requirements are accomplished.

The CFD simulations of this paper are made in SolidWorks Flow Simulation module.

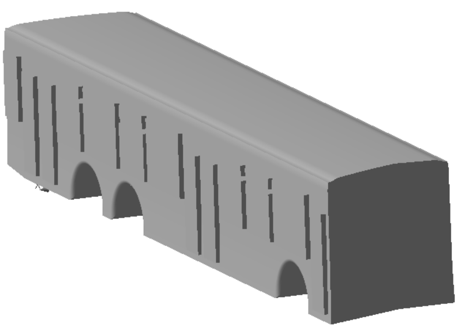

Fig. 4 CFD computational volume.

The simulation is done just to the passenger volume space. In Fig. 4 can be observed the computational volume, generated inside the bus geometry.

3. 1. CFD setup

The CFD simulation from this study are realised for three cases: the first case where the ventilation system is open at maximum capacity, the second case where the ventilation system works at maximum capacity with the air deflectors mounted for a better distribution of the air and in the last case when the bus velocity is 14m/s whit two windows opened.

3. 2. Case 1

In the first case the air conditioner sistem is opened. The air temperature of the sistem is 17 °C and the inlet volume flow is 0.01 m^3/s for each. The air temperature of the inside bus is 20 °C. All windows of the bus are closed.

The results of the simulation are presented in the next pictures. In Fig. 5 can be observed the longitudinal section of the air velocity distribution inside the bus passenger compartient.

The passenger from the first, third and the rear seats on the bus are partialy afected by the velocity of the air.

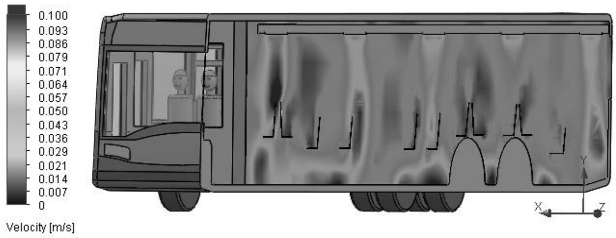

Fig. 5 Velocity of the air distribution.

In Fig. 6 is presented the temperature distribution inside on the bus. Can be observed that the passenger placed above the evacuation of the air conditioner is affected by the lower temperature almost 17°C.

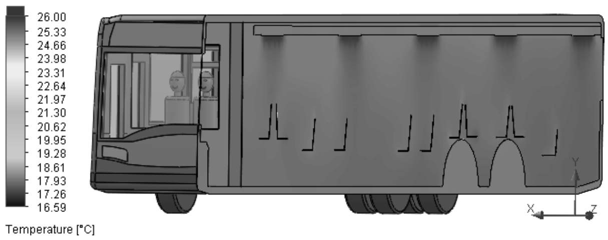

Fig. 6 Temperature distribution on the bus inside.

The value of the PMV analysed for this case is presented in Fig. 7. The comfort sensation values are in the range -1.71 and -0.86. This interval shows that the passengers are partially affected when the all air conditioner device are opened.

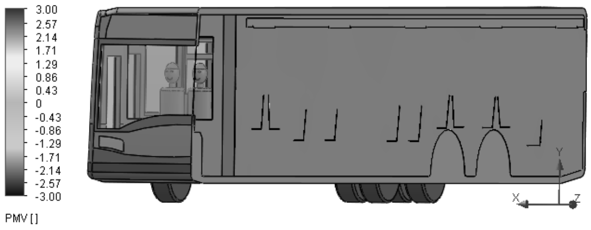

Fig. 7 PMV index -comfort sensation values - case 1.

In the figure 8 is presented the percent of the Predicted Percent Dissatisfied (PPD).

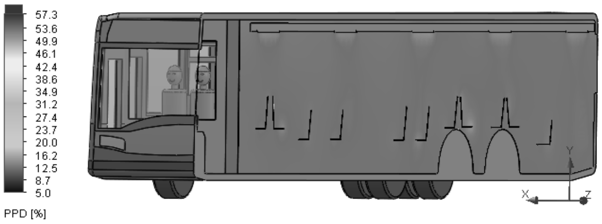

Fig. 8 Predicted Percent Dissatisfied (PPD).

3. 3. Case 2

In the second simulation case, are modeled two air deflectors placed bellow on the air evacuation. The air temperature remain same as in the first case. These deflectors are built to uniformize of the air distribution inside the bus.

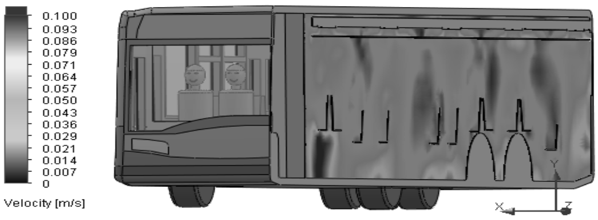

Fig. 9 Velocity of the air distribution.

In Fig. 9 is presented the longitudinal section of the bus. It can be observed the air velocity distribution inside the bus.

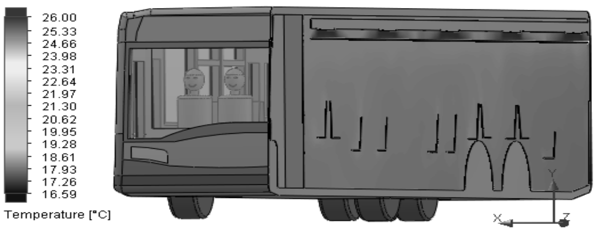

Fig. 10 Air temperature distribution.

The air temperature distribution is presented in Fig. 10. It can be observed that the distribution of the temperature is almost uniform in all the internal volume of the bus.

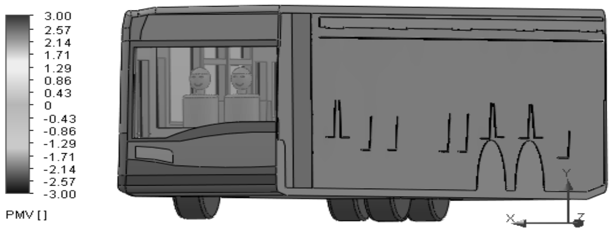

Fig. 11 PMV index -comfort sensation values - case 2.

In Fig. 11 is presented the PMV index. The confort interval value is between 1.28 and 0. It can be observed that the thermal comfort inside the bus increase.

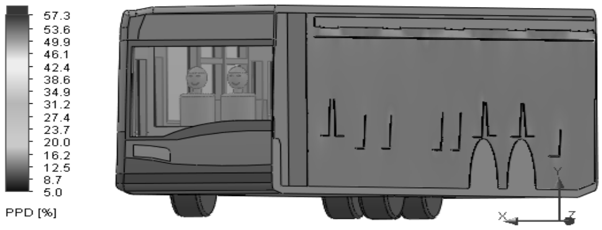

Fig. 12 Predicted Percent Dissatisfied (PPD).

In Fig. 12 is presented the rocent of the PPD index.

3. 4. Case 3

In this case in which the bus velocity is 14 m/s, is closed all air conditioner system and two windows is open in rear side on the bus. In Fig. 13 can be observed the opened windows of the bus.

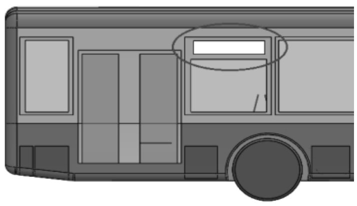

Fig. 13 Opened windows on the rear side of the bus.

After the simulation running it can be observed in Fig. 14 the PMV index values. The thermal comfort values are between -2.14 and -0.43. In this case it can be seen that the thermal comfort is lower in the rear side of the bus.

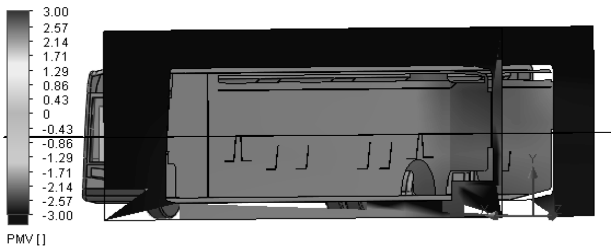

Fig. 14 Opened windows on the rear side of the bus.

In the Fig. 15 is presented the distribution of the thermal comfort using the PPD index procent.

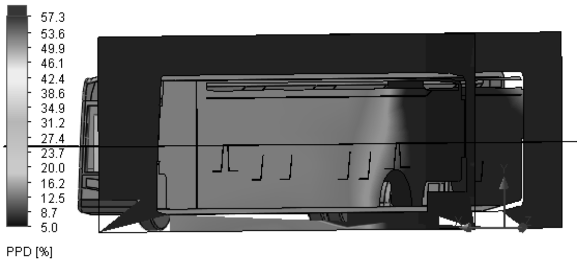

Fig. 15 Distribution of the thermal comfort – PPD index.

All the CAD models and CFD simulations presented on this paper are made on a graphical workstation HP Z400, Intel Xeon processor, 16 GB RAM and Nvidia Quadro Graphical card.

4. CONCLUSIONS

In this paper is presented three CFD simulation case. In first simulation case can be observed that the passengers on the bus are partially affected by the ventilation system. In second case the thermal comfort of the passengers is improved by using two the air deflector. In the last simulation case, the thermal comfort of the passenger from the rear side of the bus is affected by the outside air that entering from the rear side on the bus.

Numerical CFD simulation offers the optimal solutions in fluid volume flow.

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