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NUMERICAL ANALYSIS OF VOLATILE ORGANIC COMPOUNDS CONCENTRATION IN A E SEGMENT VEHICLE INTERIOR

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Abstract

Constantly increasing amount of cars causes significant deterioration of air quality. Emission of harmful substances such as aromatic hydrocarbons or soot has negative influence for human health, especially for the respiratory system. Pollutants from engine vehicles are emitted at the people living height and, especially in cities, could cumulated because of weak ventilation among the street canyons made by buildings and infrastructure. Dynamic development of motorization and people lifestyle make the time spent inside the car is getting longer. Fumes and other air pollutants can get into the car cabin, what is extremely dangerous for driver and passengers. The pollutants inside the vehicle can also accumulate and if cabin is not well ventilated, the concentrations of them could be really high. It cause changing the microclimate inside the car cabin and has negative influence on the people staying inside the car, such as lowering of comfort and focus of driver and health effects. Previous studies have shown that the highest concentration of most of the pollutants in the vehicle cabin is located at the height of the driver's head. Of course, it depends on many factors like type (category) of vehicle or geometry of nozzles in the ventilation system. The study aim was to define concentration of volatile organic compounds in an E segment vehicle cabin by using computational fluid dynamic simulation.

Keywords: *volatile organic compounds, computional fluids dynamics*

1. Introduction

Human health at risk of becoming a larger amount of hazardous substances. Air quality in the cities is decreasing because beside centres of cities is concentrated industrial sources of pollutant. Directly in the centre of city is increasing amount of individual heating systems.

Number of vehicles in the city is increasing as well. Much more car than has been predicted when rods in the cities were designed caused many traffic jams. Low speed of car movement is causing big concentration of hazardous substances in the city space. It entails increase of fuel consumption and consequently leads to the forming of smog [1, 2].

Interior of car is depend on the outdoor air quality. Traffic jams are increasing and it is causing, that people are spending more and more time in vehicle. [3]

Research of amount of volatile organic compounds (VOCs) is allow to define amount of harmful substances in the cabin and identify and describe the factors which impact on micro – atmosphere quality in the car interior [4]. If amount of VOCs is known is possible to describe micro – atmosphere in vehicle cabin by using computational fluid dynamics (CFD) [5, 6].

2. Simulation

Simulation was based on simplified three-dimensional geometry of passenger's vehicle interior (inside E segment car) presented in Fig. 1. In Fig. 2 side view of tested car was depict.

Domain of car interior was made in Ansys ICEM software. Numerical mesh was based on tetra mesh elements.

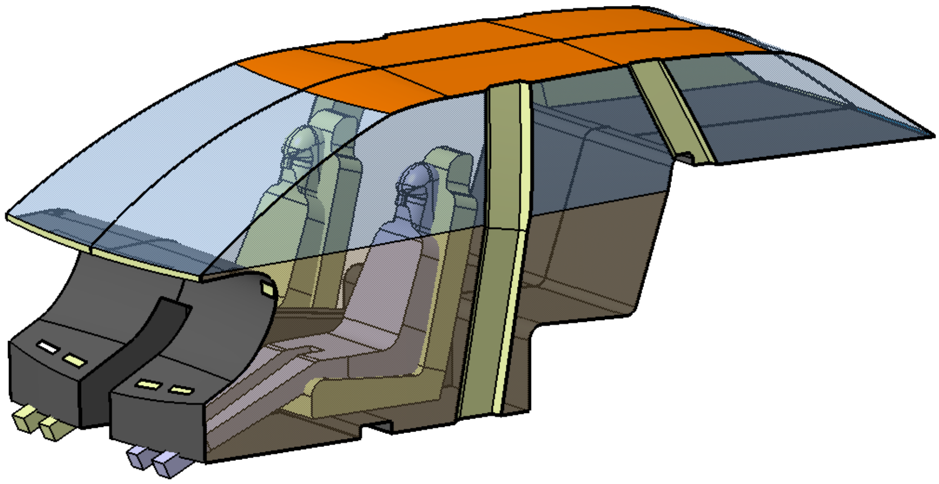

Fig. 1. Vehicle geometry

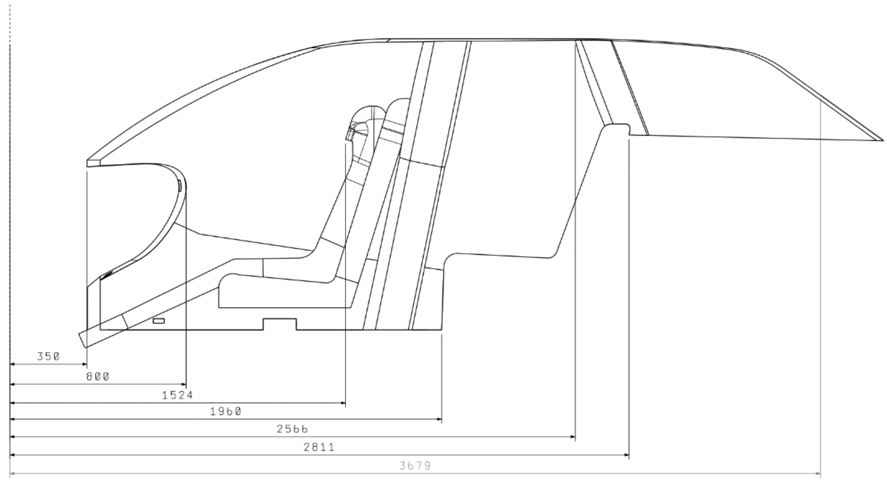

Fig. 2. Dimension of vehicle

The calculation was made in Ansys Fluent software. In the simulation k-ε, turbulent model was used to define airflow turbulences and airflow behaviour. To solve VOCs multi-flow, Eulerian model was applied.

Simulation was carried out for three-ventilation setting. Velocity of inlet flow was measured by an anemometer for minimal airflow setting (results are presented in Tab. 1). Position of inlet nozzles and outflows are shown in Fig. 3.

Fig. 3. Position of nozzles inlet and outlets

Tab. 1. Velocity of flow inlet to the cabin

No.	Inlet velocity	
1	Front window nozzle (1)	1.85 m/s
	Side window nozzle (2)	2.00 m/s
2	Central middle nozzle (3)	1.60 m/s
	Side middle nozzle (4)	2.40 m/s
3	Front legs nozzle (5)	2.70 m/s
	Front legs side nozzle (6)	1.55 m/s
	Rear legs nozzle (7)	0.50 m/s

Concentration of benzene, toluene, xylene (BTX) in the inlet air to the interior of vehicle was measured on the test bench (chassis dynamometer). During this test traffic drive were simulated with average speed of vehicle 60 km/h. To the simulation was used vehicle with gasoline engine, 1.0 ecotec – pollution source. Behind car which was emitted fumes was standing in the length 0.9 m vehicle were concentration of BTX was measured (Fig. 4). Before test, simulated traffic drive interior atmosphere background in the tested car was measure to achieve reference level.

Fig. 4. Vehicles setting in the test bench

The active carbon sample was placed in the interior of tested vehicle presented in the Fig. 5 according to the norm ISO/DIS 12219-1. Outdoor of the car (next to airflow inlet to the cabin) was placed active carbon sample as well. VOCs sample was untaken by ASP II aspirator for 3 hours. The flow intensity was equal 30 dm^3/h.

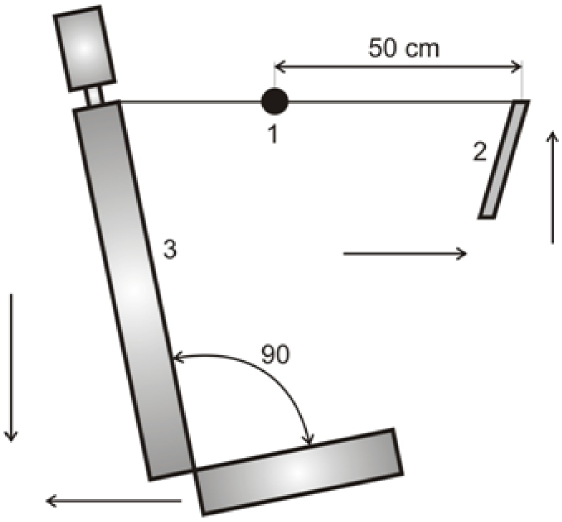

Fig. 5. Active carbon sample position

Results of VOCs concentration in the interior after chromatographic analysis are shown in Tab. 2.

Tab. 2. Identified VOCs concentration in tested vehicle interior

Voltaire organic compounds	
n-pentane	0.0018%
toluene	0.00024%

Results of chemical analysis was applied as boundary conditions for CFD simulation

3. Research and discussion

The results of the simulation are presented in figures below. In Fig. 6 to Fig. 8, streamlines for chosen ventilation sets (Tab. 1) are shown.

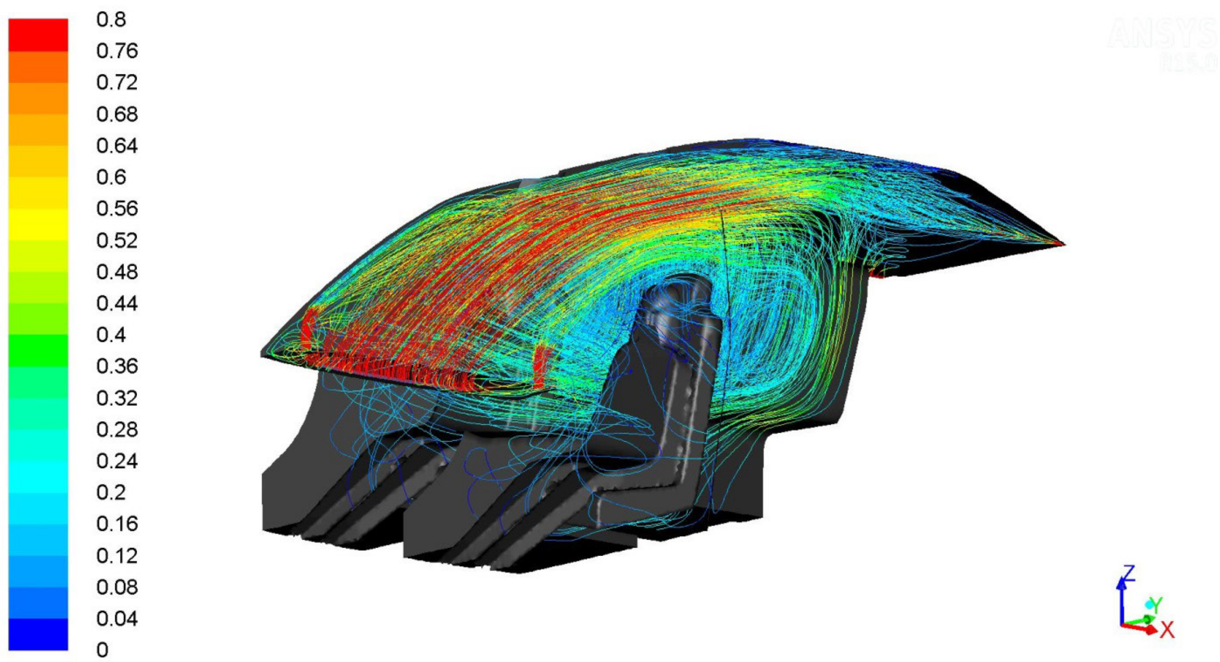

Fig. 6. Streamlines of velocity, m/s, front and side window vent (No. 1 in Tab. 1)

In the Fig. 6 is depict streamlines of velocity in the cabin at front and side window of ventilation system set. The highest intensity of air stream is appeared next to the ventilation nozzle. Air is flowing next to the front window and roof. Some of air portion is delivered to the space between rear and front seats.

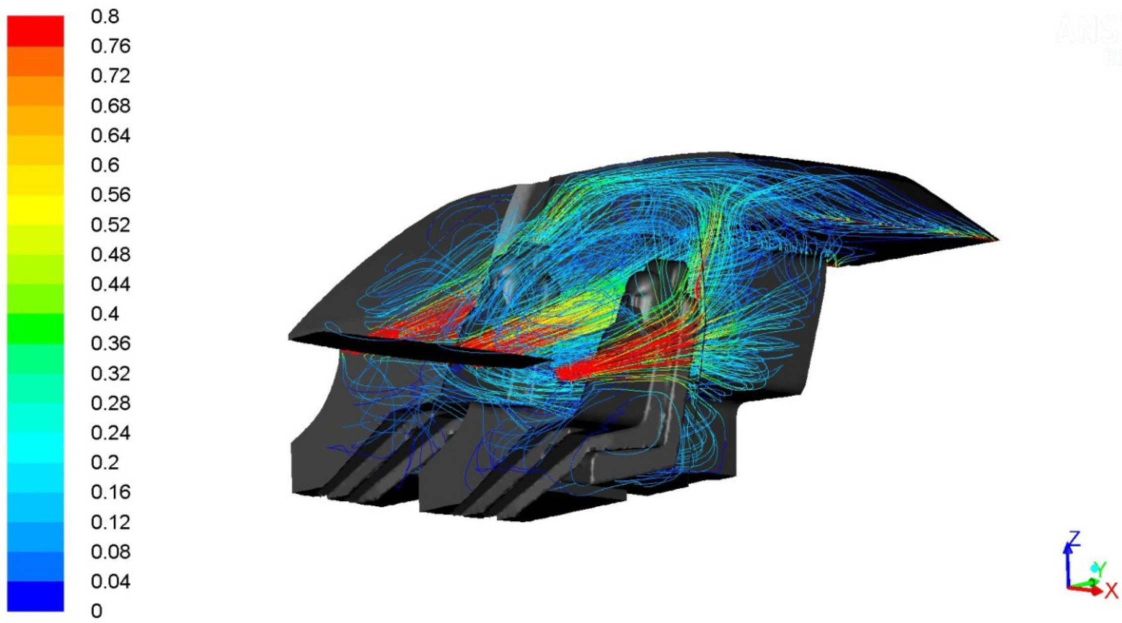

Fig. 7. Streamlines of velocity, m/s, central and side middle vent (No. 2 in Tab. 1)

In the Fig. 7 is depict streamlines of velocity in the cabin at central and side middle of ventilation system set. Air is flowing directly to the free space between front seats.

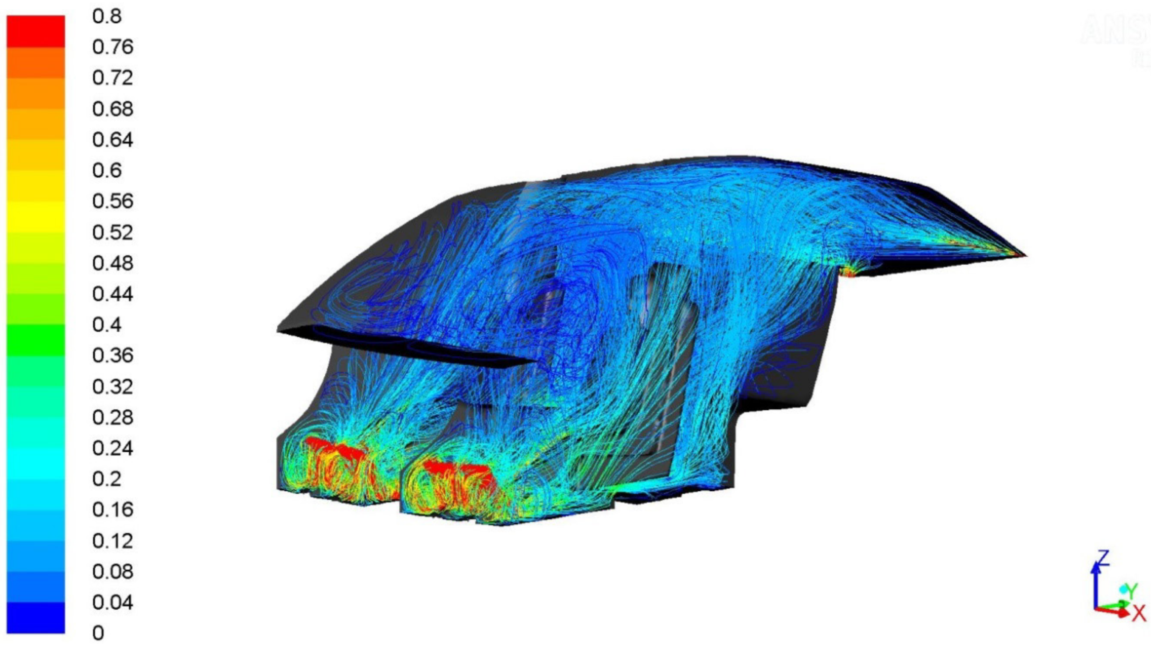

Fig. 8. Streamlines of velocity, m/s, front and rear bottom vent (No. 3 in Tab. 1)

In the Fig. 8 is depict streamlines of velocity in the cabin at front and rear bottom of ventilation system set. Air is filling whole cabin. The maximum concentration of streamline is visible on the bottom of car interior.

The highest intensity of streamlines on driver position was observed on middle and window vent sets.

The results of simulation on a driver cross-section are presented in Fig. 9-11 for n-pentane content and at Fig. 12-14 for toluene content.

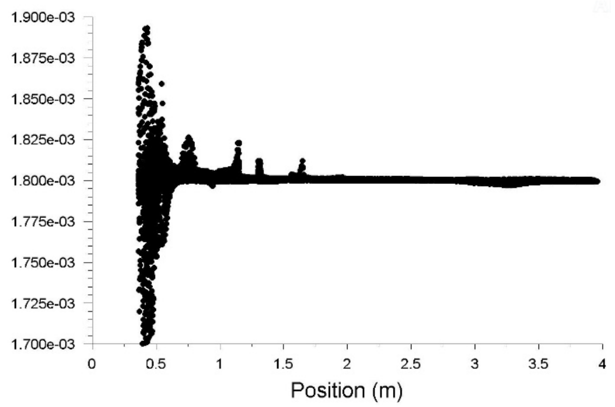

Fig. 9. n-pentane concentration, % on driver position cross-section (No. 1 in Tab. 1)

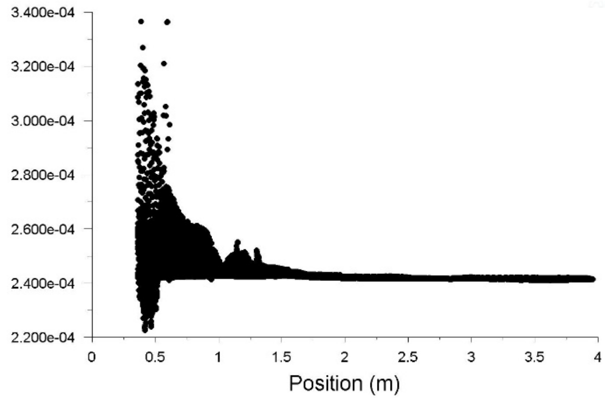

Fig. 10. n-pentane concentration, % on driver position cross-section (No. 2 in Tab. 1)

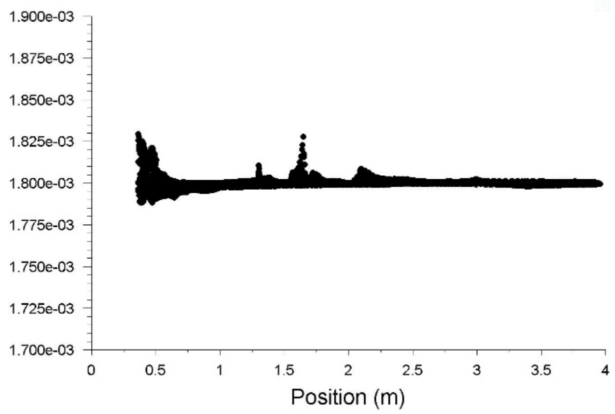

Fig. 11. n-pentane concentration, % on driver position cross-section (No. 3 in Tab. 1)

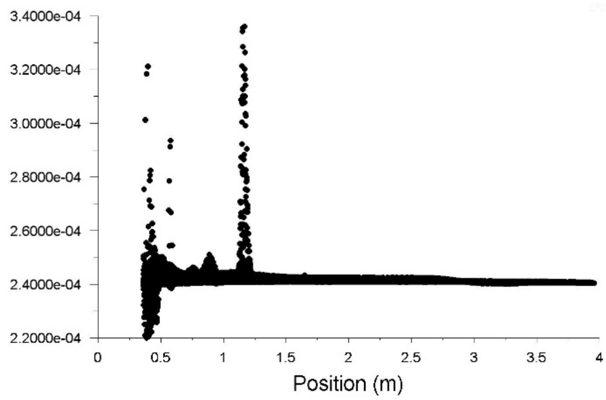

Fig. 12.,Toluene concentration, % on driver position cross-section (No. 1 in Tab. 1)

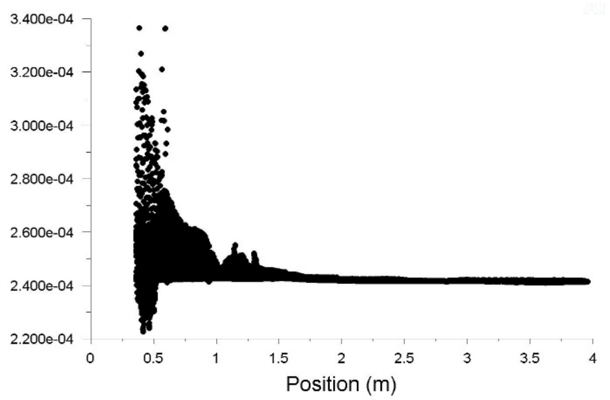

Fig. 13. Toluene concentration, % on driver position cross-section (No. 2 in Tab. 1)

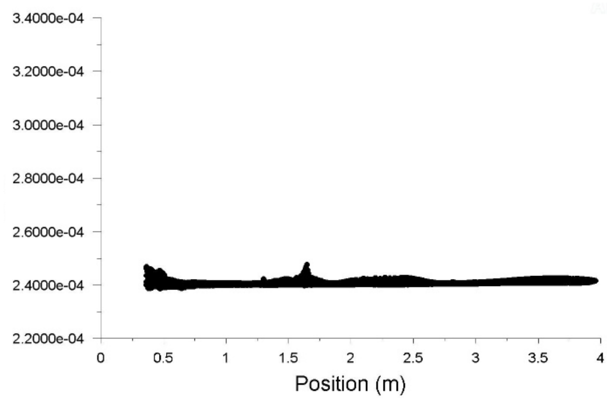

Fig. 14. Toluene concentration, % on driver position cross-section (No. 3 in Tab. 1)

Maximum concentration next to the driver head is notice for window and middle vent sets. Content of toluene and xylene (visible in Fig. 9-14) in the front and rear of vehicle is appeared that in the rear seats concentration is the lowest. For legs ventilation system set content of VOCs is on the same level. It is possible to see that content pics are located under front window and behind the front seat.

4. Summary and conclusions

Computational Fluid Dynamics method application enables to simulate physical parameters like airflow intensity, temperature and pressure in interior of vehicle cabin. This method allows predicting pollutants concentration distribution in vehicle interior in function of ventilation systems settings.

According to the results, it is possible to predict concentration of hazardous substances in vehicle cabin. It is possible to create map of places with maximum content of VOCs to prevent vehicle user exposure.

After simulation is possible to define the most preferred setting of vehicle ventilation system for human health. Legs setting of ventilation nozzle are the most benefit. Concentration of VOCs in whole vehicle interior is the lowest and it is settle on the similar level. On rear seats harmful substance are not cumulated.

Acknowledgment

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