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EXPERIMENTAL INVESTIGATIONS ON POLLUTANT CONTENT INSIDE THE CAR IN RELATION TO POLLEN FILTER IMPROVEMENTS

BY

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Abstract. In urban traffic, exhaust gases penetrate the passenger compartment through the ventilation system and expose the occupants of the vehicle to a high degree of pollution. The pollen cabin filter located in the air inlet that penetrates into the passenger compartment acts as a barrier between the contaminated environment and cars’ occupants. There are many studies evaluating the air filtration capacity inside the car which show that the active carbon pollen filters greatly reduces the pollution in the passenger compartment. Other studies show a fifteen times increased concentration inside cars compared to the roadside. It was clearly proven that such particles (dust, pollen and soot) originated exclusively from vehicle exhaust. The system implemented by these researchers uses a quartz fiber filter. Taking this background into account, our paper aims to study the experimental investigations that have been carried out in order to determine the air quality in the passenger compartment.

Keywords: carbon layer; polyphenol; air quality sensor; quartz; cabin filter.

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1. Introduction

Atmospheric air is an important element for maintaining life, so its quality depends on the quality of life.

Air pollution consists in changing the composition in terms of the proportion of its constituents or the appearance of new constituents with harmful effects on humans. From the point of view of the action of polluting substances in the atmosphere on organisms and the environment can be: with direct effect and indirect effect. Pollutants with direct effects are carbon monoxide, sulfur dioxide, nitrogen oxides and particulate matter (PM2.5, PM10). The most important source of CO from the general air pollution (60%) is produced by the exhaust gases of the vehicles. It has been estimated that 80% of the CO is produced in the first 2 minutes of engine operation and represents 11% of the total exhaust gas. Vehicle pollutant emissions have two great features. First, the disposal is very close to the soil, leading to high concentrations at very low heights. Second, the emissions are made on the entire area of the locality, the differences in concentrations depending on the traffic intensity (Munteanu, 2016).

During the journey, the car absorbs the outside air. Thus, exhaust gases of cars running in front, fine particles of dust, pollen and bacteria, ozone and nitrous oxide can enter the passenger compartment through the ventilation system (Autolatest, 2010). Car equipment with air conditioning systems has become a standard feature for car manufacturers. The air conditioning system must be seen as a system that improves the overall active safety of the car not only the caloric comfort of the occupants (E-automobile, 2015).

Most of the cars are equipped with passenger compartment filters that protect passengers against pollutant emissions from the air in the vehicle. Air conditioning machines, for example, are always equipped with a passenger compartment filter. If the filters are worn out due to the harmful substances they get, they can no longer perform their filtering function. In addition, harmful substances stored in the passenger compartment filter lead to the development of mold and bacteria. The filtered particles are, in this case, released with the air distributed inside the car.

Over a relatively long operating period, the heating/air-conditioning system creates the condition for a favourable habitat for bacteria and other micro-organisms due to air humidity being continually condensed at the evaporator. Together with dirt that is introduced via fresh air or even recirculated air, this may lead to microbial contamination of the evaporator and, as a result, may lead to a mouldy odour, for example (BMW – AIR).

For this reason, most car manufacturers recommend changing the passenger compartment filter to 15000 km in order to provide a fresh and healthy air inside the vehicle. Air quality is essential because it directly affects the driver's ability to concentrate (Autolatest, 2010).

2. Air Conditioning Systems Improvements

The first manufacturer who includes a pollen filter to clean the ventilation system was Nash Motors "Weather Eye" (the first fully ventilated system) introduced in 1940. This system was a successful implementation of circulation in safety and comfort (Wikipedia, 2018).

In the 1990s, Volvo began the testing process to create a clean environment in the car's interior, especially for sensitive people. In 1998, the Volvo S80 received the first efficient air filtration system to enter the passenger compartment. In recent years, the improvement of air quality inside the car has been achieved by introducing a larger multi-filter. This filter contains a layer of active carbon. The manufacturer's recommendation is to change the multi-filter once a year. The Indoor Air Quality System (IAQS) also contains a sensor that monitors the air quality inside the car. New Volvo models were fitted with a display that allows the user to find out the level of air quality in the passenger compartment. The air quality icon changes its blue color, the symbol for optimum conditions, to gray when the filtered air enters the passenger compartment or the air quality sensor is turned off. The system developed by Volvo is called CleanZone (Volvo Cars, 2017).

The purpose of the study established by a Sweden research in 1999 is to compare the efficiency of different pollen filters in stopping the particles of diesel exhaust and reduce biomedical effects on passengers. The study used a special designed exposure chamber and had as reference earlier studies of exposure to diesel exhaust. Thirty two non-smoking subjects take part in the study and sixteen of them had allergy to grass or tree pollen. Fourteen of the subjects were bus drivers and 18 were students. Each participant was exposed six times: once to air, once to unfiltered diesel exhausts, and once to filtered to diesel exhausts with the four types of cabin filters. The exposure lasted for one hour in a special designed chamber and the participants were sitting on a chair to imitate a driving position. The chamber is shown bellow in the Fig.1 (Rudell *et al*., 1999).The first time the subjects have been tested on air and then on diesel exhaust gases. The interval of each test was six days. Through the test they were monitored the levels of NO_2, NO, CO, HCs and the particles collected by every filter.

A computer was connected to a water loaded engine dynamometer controlled by the engine. The cabin filter was made out of a composition of a pre-filter and an absolute filter with a particle reduction of 99.99% for 0.3 µm particles. A fan with variable flow was mounted to feed the air and meet the pressure drops from the different pollen filters. Additional was installed a diaphragm to keep a constant flow of 70 l/s through the four filters. There was no pollen filter mounted to the chamber when the test was performed with air or with diesel exhaust gases (Rudell *et al*., 1999).

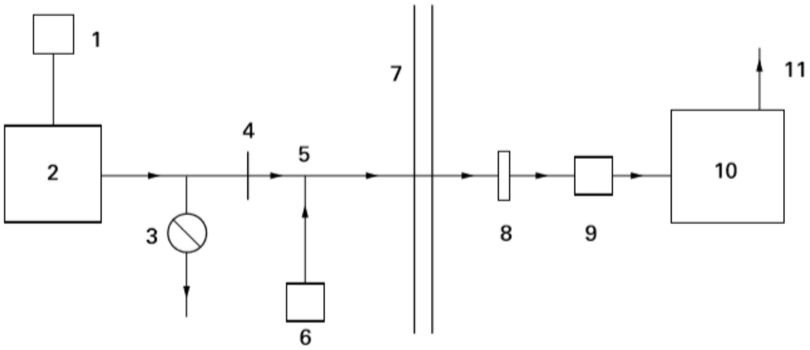

Fig. 1 – Experimental diesel exhaust system: 1 – water loaded engine dynamometer; 2 – diesel engine; 3 – exhaust shunt with the valve; 4 – flexible diaphragm; 5 – mixing of diesel exhaust and filtered air; 6 – outdoor air inlet and particle filters; 7 – wall between machinery hall and exposure hall; 8 – iris diaphragm for adjusting the flow; 9 – filter frame and cabin air filter to be studied; 10 – exposure chamber; 11 – chamber evacuation.

The engine used was a Volvo TD 45 from 1991. It was connected to a water loaded engine dynamometer and was maintained at 1400 rpm (50% speed) and 30.6 kW (50% load).

Table 1
Test Situations

Test	Inlet of fresh filtered air	Addition of diluted diesel exhaust	Cabin filter or filter combination	Comments
Air	Yes	No	No	Negative control
DDE	Yes	Yes	No	Positive control
Filter 1	Yes	Yes	Yes	7A (particle filter)
Filter 2	Yes	Yes	Yes	6C (particle filter)
Filter 3	Yes	Yes	Yes	6C (particle filter) + 7C (charcoal filter)
Filter 4	Yes	Yes	Yes	6C (particle filter) + 8A (charcoal filter)

The engine was an inline four cylinder, four strokes and a direct injected turbocharger. The fuel used was a standard diesel with a high concentration of sulphur. During the test with diesel exhaust through one of the four filters, if the flow was reduced by the accumulation of the filter, the fan speed was modified to keep the constant air flow. A new filter was used for each subject of this test. All four filters presented in Table 1 (Rudell *et al*., 1999) reduced the concentration of particles and total aromatics compared to test with diesel exhaust gases. With the filter 4 (combination of particle filter and charcoal filter) the concentration of total aromatics (benzene, toluene) and aliphatics hydrocarbons (result of incomplete combustion) were the same as in the air test. The filter 3 and 4 reduced the NO_2 concentration significantly. The charcoal active filters reduce hydrocarbons and the odour of diesel exhaust gases confirmed by the subjects of the study (Rudell *et al*., 1999).

The Swiss researchers experiment shows that the filters now used in ventilation systems remove pollen from visible particles, and this needs to be improved. The developed system is a retrofit to the original ventilation system of the car. The air conditioning system of the car is not altered, but the air recirculation mode is used to prevent air entrances from being filtered by the original car's ventilation system (Mayer *et al*., 2018).

Various filters were tested for the retrofit, but a quartz filter was chosen. The test solution is shown in Fig. 2 (Mayer *et al*., 2018). The system uses a pre-filter to increase the lifetime of the high-performance filter and operates at an air flow of 30 m^3/h and can withstand pressures up to 2000 Pa (Mayer *et al*., 2018).

Due to the performance of the car, the two-filter system has been tested on school buses. Filter replacement takes place after 100000 km of use (Mayer *et al*., 2018).

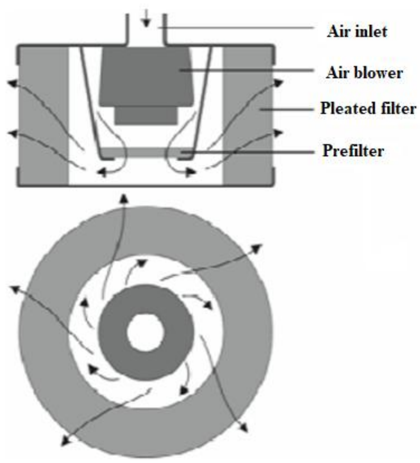

Fig. 2 – Prototype with prefilter.

3. Conclusions

For this paper we have proposed a review of the studies conducted so far to improve air quality in the passenger compartment. The paper covers both studies by researchers from other countries and other areas, as well as innovative systems introduced by car manufacturers. Test results show that the use of active carbon pollen filters improves air quality in the passenger compartment. It is useful to know the existing research and its results in order to make new studies. For future work, we propose conducting air quality studies in Iasi and a driver awareness campaign on the timely change of the passenger compartment filter. The studies will be conducted in the car interior, both in urban traffic and during extra-urban travel. Different pollen filters will be studied at the microscope to see the degree of loading of the filter paper after 15000 km.

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STUDIU EXPERIMENTAL PRIVIND CONȚINUTUL DE GAZE POLUANTE ÎN INTERIORUL MAȘINII ÎN CORELAȚIE CU ÎMBUNĂTĂȚIRILE ADUSE FILTRELOR DE POLEN

(Rezumat)

În traficul urban, gazele de evacuare pătrund în habitaclul mașinii prin sistemul de ventilație. Gazele poluante îi expun pe ocupanții vehiculului unui grad ridicat de poluare. Filtru de polen/filtrul de habitaclu funcționează ca o barieră între aerul contaminat din exterior şi pasagerii autoturismului. Există multe studii care evaluează capacitatea de filtrare a aerului din habitaclu. Rezultatele testelor ne arată că filtrele de polen cu strat de cărbune activ reduc semnificativ gradul de poluare din interiorul autoturismului. Alte lucrări ne arată o concentare de poluanți de cincisprezece ori mai mare în interiorul mașinii comparativ cu mediul exterior. S-a demonstrat că aceste particule (praf, polen si funingine) provin de la sistemul de evacuare al mașinilor. Sistemul implementat de cercetători folosește un filtru cu fibră de cuarț. Luând în considerare aceste date, lucrarea noastră își propune studierea experimentelor efectuate pentru determinarea calității aerului din habitaclu.