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The road test of car cabin filter in Japan

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Abstract

The car cabin filters in Japan can be classified into the groups of filters installed in the HVAC unit and filters installed in the air purifier. In this study, the road test results of car cabin filters manufactured by JVC and installed in the HVAC are presented and compared to some commercial filters of other companies.

The new combination filters for the dust removal and for the odor removal were tested as well as particulate filters.

Introduction

The car cabin filter has been popular in automobiles for safe and comfortable driving in Japan. The ambient air is taken in through the HVAC unit to the car cabin. However, the ambient air in the urban area contains both toxic particles and gases which have a strong possibility of harming human health.

On the other hand, buildings in Japan have been widely installed with high efficiency air filters in the air conditioners, in accordance with the so-called "Building Maintenance Law" in Japan. Already in Europe, most automobiles are equipped with high efficiency filters for protecting human health. And recently, the Japanese automobiles have started to be equipped with air filters, although, most of them are low performance filters.

Airborne dust concentrations on the road side is 0.14 mg/m^3 per day mean value in Tokyo, and 0.19 mg/m^3 at the most polluted district in Tokyo,1993. The Environmental Standard [1] states that the concentration of suspended particulate matter (SPM) should he less than 0.1 mg/m^3 per day in mean value. However, there are no districts in Tokyo which pass this standard.

Gas concentrations on the road side were also measured by the Japanese Environment Agency and distributed as follows.

		Mean value per year (ppm)
SO_2	National average	0.007
	Maximum	0.013
NO_2	National average	0.040
	Maximum	0.056
HC	National average	0.43 (ppmC)
	Maximum	0.96 (ppmC)

Test filters

The particulate and combination filters were tested for dust and odor removal. Filters manufactured by JVC were compared to commercial filters which were supplied by other companies and available in Japan.

Our dust removal filters are constructed with two layers, a prefilter layer and a microfiber layer. The prefilter is mainly composed of polyester fiber and synthetic binder, having stiffness for pleating, and having durability for longtime use. The fiber layer is composed of meltblown polypropylene, having high dust removal efficiency. The two layers of the prefilter and the microfiber filter are laminated and bonded with pin point ultrasonic to prevent the delamination. We used two kinds of dust removal filters, the high efficiency filter (I) and the long lifetime filter (II).

Our combination filters are made of four layers, which are combined with two layers for dust removal and of two layers for odor removal. The dust removal layer is the same material as the former dust removal filter. The odor removal filters are made of the special activated carbon layer and a polyester spunbonded backing layer. The activated carbon granules are formed evenly on the backing layer and combined with each other by a thermoplastic powder to maximize the carbon amount at a relatively low pressure drop.

As compared with our test filters, we tested four commercial filters supplied by other companies; two filters are for domestic passenger cars (I, II) and the others are for imported passenger cars (III, IV). The filter (I) is pleated with a single odor removal layer. The filters (II, III) are combined with a pleated dust removal layer and a panel shaped activated carbon layer. The filter (IV) is pleated with dust removal and activated carbon layer.

All tested filters were set in a plastic frame in the size of 223 mm width by 200 mm height by 30mm depth. The commercial filters were cut to fit the frame size and then put in the plastic frame.

The filter specifications are shown in Table 1. The pressure drop and the dust removal efficiency at 0.3 – 0.5 µm in particles were measured in our laboratory. Filter were tested with an atmospheric dust at the flow rate - of 240 m^3/h.

Test Filters			Filter Depth [mm]	Pleat Spacing [mm]	Δ P at 450 m³/h [Pa]	Efficiency For 0.3 μm at 240 m³/h
Our Filters	Particulate	I	30	4.0	103	45
	Particulate	II	30	4.0	85	22
	Combination	I	30	9.0	243	49
	Combination	II	30	9.0	147	23
Commercial Filters	Odor	I	19	3.8	61	1
	Combination	II	12	4.0	330	3
	Combination	III	30	6.5	635	21
	Combination	IV	30	12.0	477	28

Table 1: The specifications of test filters

The road test conditions

The test filter was installed in the front of the evaporator at the HVAC unit in our passenger car during the driving test. We used a middle class passenger car (1600 cc) driven on the actual road in Saitama near Tokyo. In order to conduct the road test at the constant condition, we determined the driving course at the same route, and at the usual jammed route with trucks and passenger cars.

For the measuring equipment, we used a set of two dust monitors, Laser Dust Monitor "LD - 1", from Sibata Scientific Technology ltd., which can measure the instantaneous relative dust concentrations consecutively, but not the particle diameter. The principle is based on measuring the intensity of laser beam scattered by dust. The air sampling was conducted simultaneously upstream and downstream of the test filter.

The odor subjective test was conducted by three panelists including a driver. The odor perceiving intensity was evaluated with the following six level classifications:

0: No odor
1: Slight odor (possible to recognize the existence of odor)
2: Mild odor (possible to recognize the kind of odor)
3: Easily perceiving odor
4: Strong odor
5: Intense odor

Panelists counted the odor perceiving frequency. The test samples were replaced in turn per about half a hour. The blower switch was set the low-medium during the drive test.

Test results

The dust concentrations upstream of the test filter varied widely from 0 up to 1 mg/m³. The maximum dust concentrations were measured frequently but they disappeared within a short time about 10 seconds. It was clearly observed that the peaked values were caused by the exhaust gas coming out of driving vehicles in front of the test car, especially trucks, busses and limousines. The panelists perceived the odor when the peaked dust concentrations were measured. The dependency between the odor perceiving and the peaked dust concentrations was strongly observed.

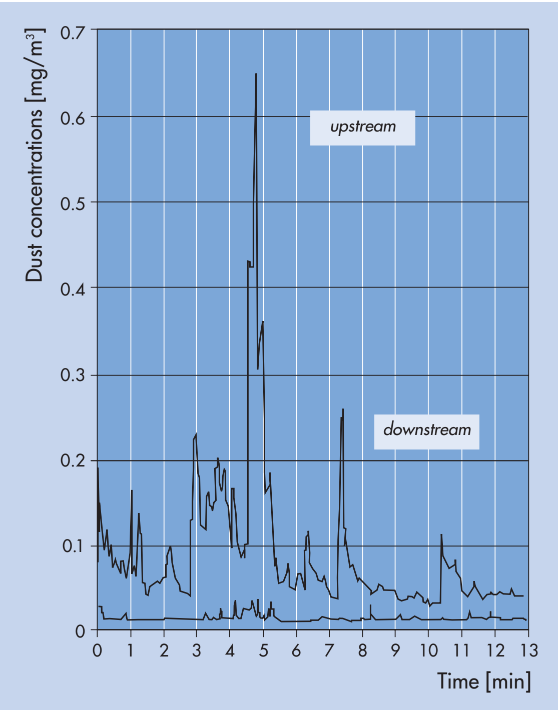

Fig. 1: Dust concentration upstream and downstream of our filters

Figure 1 shows an example of the recorded data of the dust concentration in the relation of the passage time. A large amount of the peaks on the dust concentrations can be seen in the figure. The peaks at downstream of test filter have a bit of time lag and correlate with the peaks of upstream.

The correlative peaked data of dust upstream and downstream concentrations are shown in Figure 2a and 2b. The dust concentration downstream can be regarded as being in proportion to the dust concentration upstream.

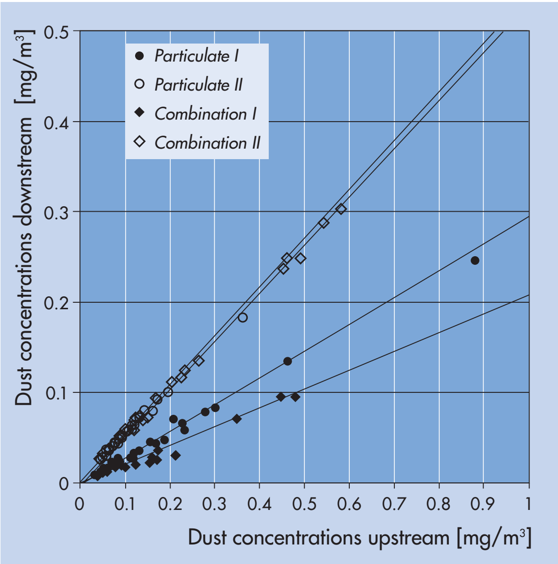

Fig. 2a: Dust concentration upstream and downstream of our filters

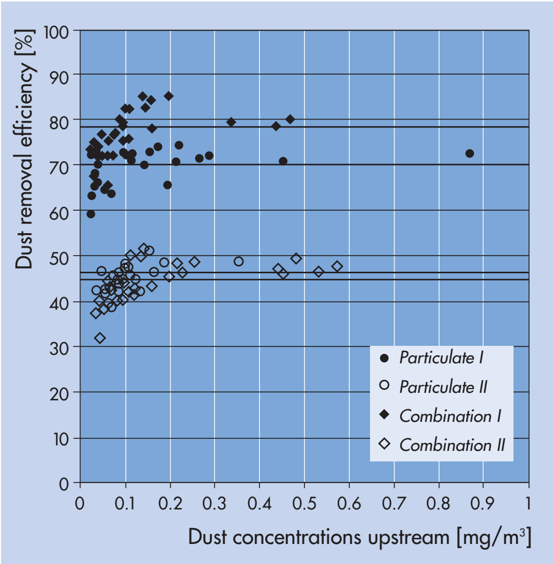

Fig. 3a: Dust removal efficiency of our filters

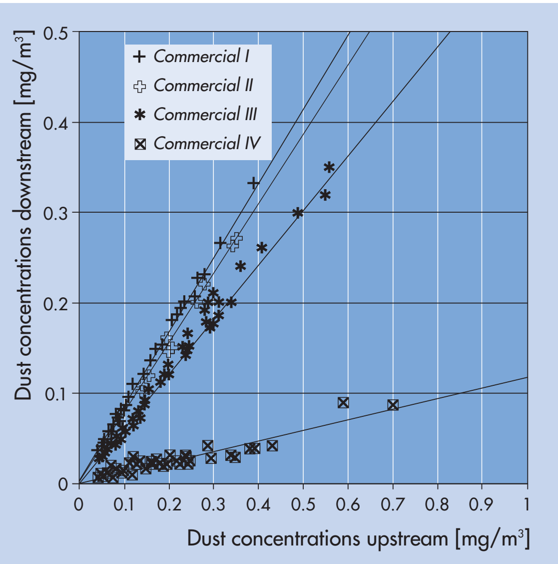

Fig. 2b: Dust concentration upstream and downstream of commercial filters

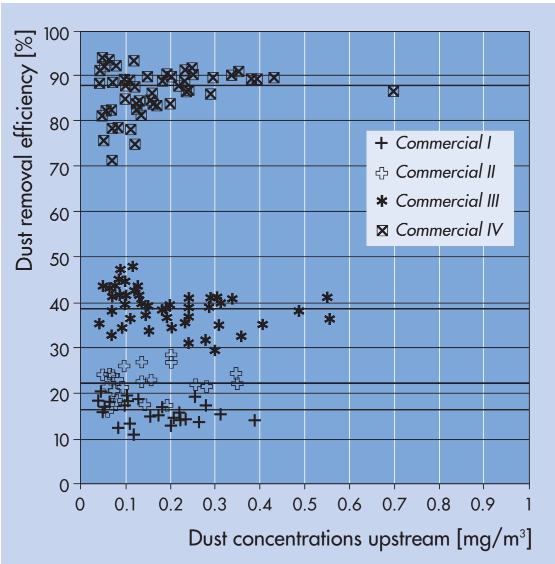

Fig. 3b: Dust removal efficiency of commercial filters

The dust removal efficiency was calculated with the following formula:

Efficiency (%) = (1 – Concentration downstream/Concentration upstream) x 100

The efficiencies versus the upstream dust concentration are shown in Figures 3a and 3b.

The efficiencies showed a constant value by each test filter but being deviated. The mean efficiencies are as follows:

Our filters	Average Efficiency (%)
Particulate I	70
Particulate II	45
Combination I	79
Combination II	46

Other Companies	Average Efficiency (%)
Combination I	16
Combination II	23
Combination III	39
Combination IV	88

Odor level	0	1	2	3	4	5	AI
Test filters	Odor perceived frequency						
Particulate I	0	0	5	1	1	0	2.4
Particulate II	0	0	3	2	0	0	2.4
Combination I	13	0	4	0	0	0	0.5
Combination II	5	0	2	0	0	0	0.6
Commercial I	0	0	0	0	3	2	4.4
Commercial II	0	1	1	4	0	0	2.5
Commercial III	0	0	4	1	0	0	2.2
Commercial IV	0	0	5	1	0	0	2.2
No filter	0	0	0	0	2	5	4.7

Table 2: The odor subjective test result

Our filter has higher efficiency than that of commercial filters, however, the commercial filter IV shows the highest efficiency in spite of lower efficiency for 0.3 μm of atmospheric dust. The reason is not clear.

In the table 2, the odor perceiving frequency are sorted by the odor intensity. These data were measured at the time of the dust concentration peaked, since we

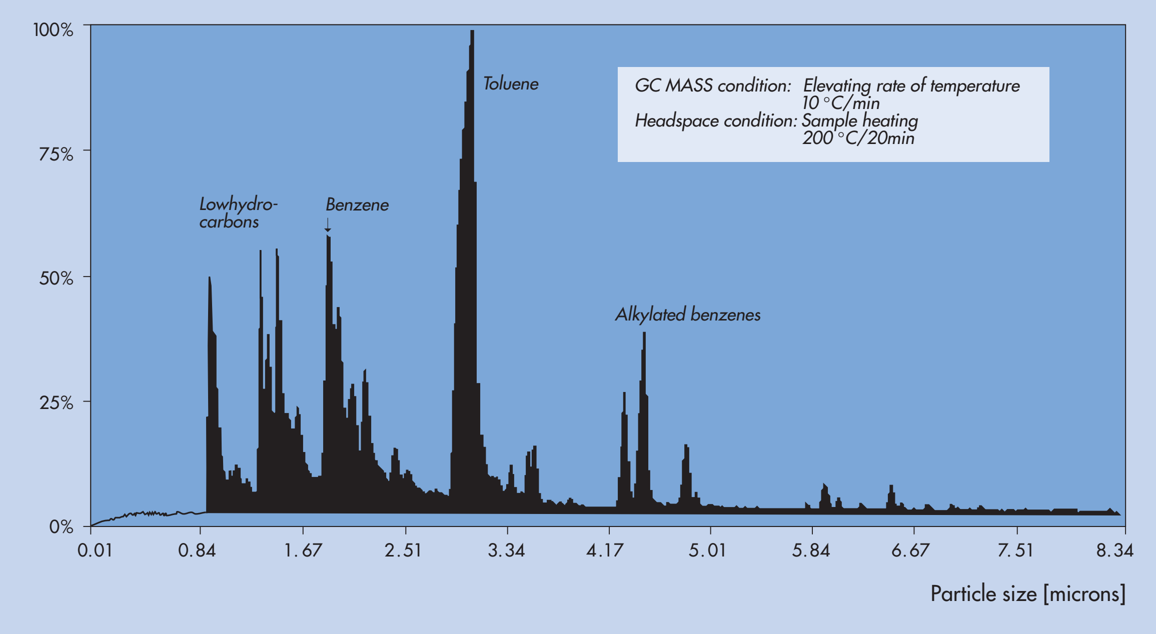

Fig. 4: GC MASS analysis result

have experienced that the odor usually comes into the car cabin in presence of a peak dust concentration. The mean odor level of three panelists was used for the odor intensity and AI value, means the average odor intensity, was calculated with the following formula:

$$AI = \sum (\text{Frequency} \times \text{Odor intensity level}) / \sum \text{Frequency}$$

We can see that particulate filters have a strong influence on odor removal by removing dust. And our combination filters are able to almost completely remove the odor coming from the outside air, mainly the diesel exhaust gas. The commercial filters have less effect than our combination filters.
The headspace and GC-MASS spectro analysis of our combination filters (II) which had been used for three month, 4000 km driven in Tokyo, is resulted in Figure 4. There are many kinds of adsorbed gases composed of low hydrocarbons and toluene, alkylated benzenes and so on.

Furthermore, we extracted the gaseous substances out of the test sample into the hot water, and analyzed the inorganic substances with the Ion Chromatograph analysis. The results are shown in Table 3.

	The extracted amount per a test filter (mg)
NO_3^-	84.7
SO_4^-	604.8

Table 3: The Ion cromatograph analysis

Conclusions

- Our new combination filter shows a superior filter performances of dust and odor removal on the road test in Japan.
- The dust removal effect can be measured with the Instrument based on the laser beam scattering method on the road test.
- The odor removal effect can be evaluated with the odor perceiving test by panelists during the car driven.
- The amount of gaseous substances adsorbed in the test filter can be analyzed with the instrument of the headspace and GC-MASS spectro analysis, and the Ion Cromatograph.

Acknowledgements

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References

[1] Environmental Agency of Japan; The state of air pollution near the road. March, 1995

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