特集 Development of Deodorant Filter for Diesel Odor*

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With regard to the desire for more passenger comfort there is a special need for an efficient deodorant filter. Since customers are becoming so sensitive about cabin odor, the development of a more effective deodorant filter is strongly required. Outside of the vehicle, diesel odor is the most obnoxious, therefore, analysis of this diesel gas and the conducting of an investigation to identity the main ingredient responsible for the strong odor were executed. Acetaldehyde gas was established as the main culprit.

Therefore, identification of a chemical that could be impregnated in activated carbon and adsorb acetaldehyde gas was required, since activated carbon itself does not have the ability to adsorb acetaldehyde gas. Finally vitamin Bx was found to be the appropriate chemical. At the end of this report, a sensory evaluation result by twenty panelists with regard to deodorant type cabin air filters impregnated with vitamin Bx and their efficiency in filtering will be delivered.

Key words : Deodorant filter, Diesel odor, Acetaldehyde gas, Vitamin Bx

1. INTRODUCTION

"Air Refiner" is our product name for the air conditioner filter of a vehicle, which serves to purify cabin air, and is assembled in the air conditioning system (**Fig. 1**).

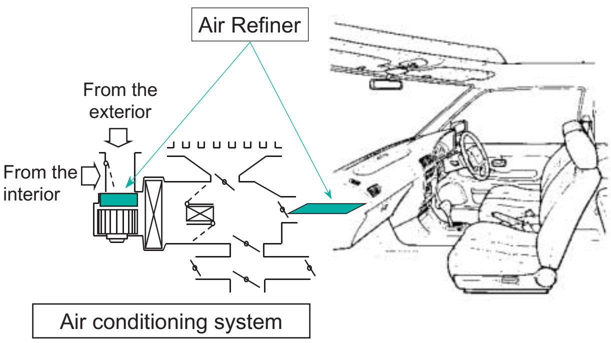


Fig. 1 Air Refiner and air conditioning system

The Air Refiner cleans the air coming in from outside and introduces clean air into the cabin, therefore, keeping the airflow resistance low is necessary for it not to have an adverse affect on the air conditioning quality. The critical points regarding the air refiner's development are maintainment of high quality and low pressure.

2. DUST REMOVING FILTER

The dust removing mechanism can be divided into the "physical filtration type" and "electrostatic filtration type". The physical filtration type physically captures the dust employing fiber, and is highly efficient vis-à-vis relatively large particles of micron size, while inefficient with regard to smaller particles of submicron size (**Fig. 2**). The electrostatic filtration type is inefficient vis-à-vis relatively large particles because of powerful inertia force, but is highly efficient with regard to smaller particles of submicron size, because this type of filter is capable of capturing the dust utilizing Coulomb force with electrostatic fiber (**Fig. 3**).

We have three types of dust adsorbing filters, namely, the "large particles type", "long life type" and "high efficiency type". The large particles type is pure fabric and has the advantage of a high airflow rate due to low pressure, and the long life type has the ability to lessen rising airflow resistance because it is lightweight and its electret qualities are high. The high efficiency type is highly efficient regarding both large and small particles (as its name suggests), but the pressure is high and also easily accumulate dust.

3. TARGET OF DEODORANT FILTER

Recently, customers are getting more sensitive regarding unpleasant odors, and the development of a more effective deodorant filter is required. Therefore, in order to define the target it is necessary to judge whether a certain odor is acceptable or not, and to develop a deodorant filter based

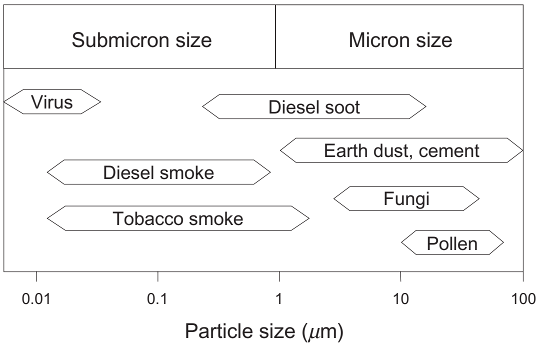


Fig. 2　Types of environmental dust

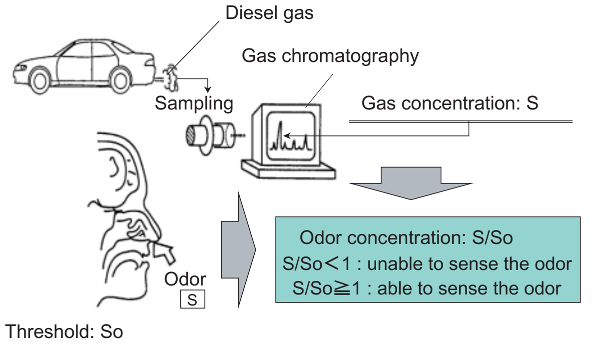


Fig. 4　Diesel gases analysis procedure

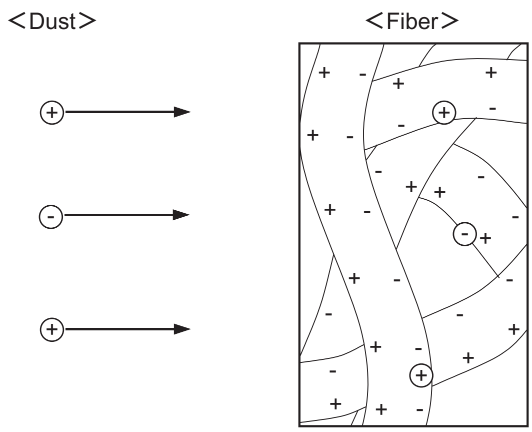


Fig. 3　Dust removing methods of electrostatic type

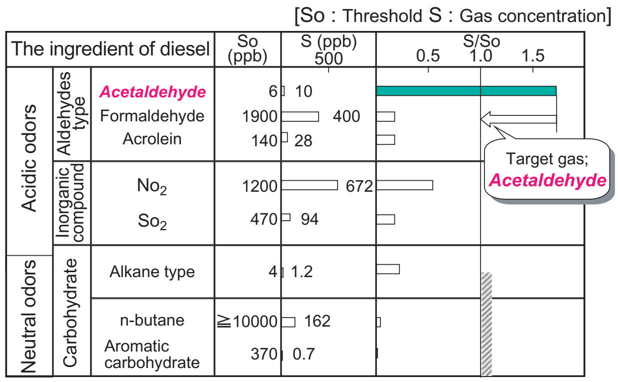


Fig. 5　Analysis result of diesel odor

on that judgment. The main cause of unpleasant odors in the cabin is diesel odor entering from outside of the vehicle. Because of this, an investigation was conducted into diesel and the development of a deodorant filter to eliminate diesel odor was initiated, and the procedure undertaken is outlined in the following chapters.

4. THE ANALYSIS OF DIESEL ODOR

First of all, a diesel gas analysis was conducted (**Fig. 4**). Some samples of diesel gas were obtained, and the constituents of the diesel gas were measured employing gas chromatography. "S" represents gas concentration, and "S_0" represents the threshold. If $S/S_0 < 1$, man is not able to sense any odor, however if $S/S_0 \geqq 1$, man is able to sense the odor. Please refer to **Fig. 5** - the analysis result of diesel odor. Only Acetaldehyde was $S/S_0 \geqq 1$, the remainder were $S/S_0 < 1$. By calculating the result from this formula, we can see that acetaldehyde is the cause of strong diesel odor. Therefore, it is necessary to develop a deodorant filter to remove acetaldehyde in particular.

5. TECHNOLOGY TO ADSORB ACETALDEHYDE

Generally, deodorizing is conducted through gas adsorption employing activated carbon, and the gas adsorption is divided into physical adsorption and chemical adsorption (**Fig. 6**). Activated carbon is porous in nature (micropores, macropores), and the specific surface area ranges over 1000 m^2/g. Physical adsorption represents a mechanism whereby the odor molecules are captured within the pores. Physical adsorption is efficient with regard to neutral gases, such as toluene and butane, but is not very efficient vis-à-vis strong polarity gases, such as aldehyde and ammonia. Accordingly, the surface of activated carbon is impregnated with chemicals, and the impregnated activated carbon is able to capture polarity gases through a chemical reaction (chemical adsorption), e.g. impregnated activated carbon with acidic agent carboxylic acid has an effect on the basic gases such as ammonia, and impregnated activated carbon with basic agents including the amino group has an effect on the acidic gases such as acetaldehyde.

Therefore, impregnated activated carbon containing the

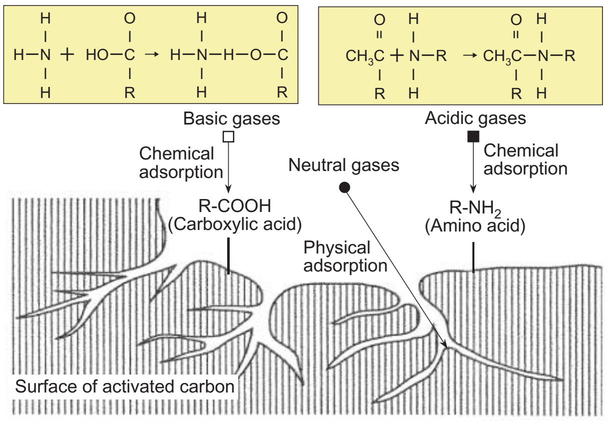


Fig. 6　Deodorant mechanism

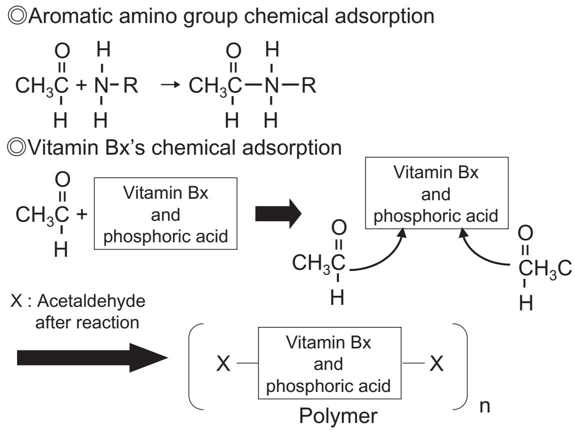


Fig. 7　Chemical adsorption of acetaldehyde

amino group is a necessity for the adsorbtion of acetaldehyde, At the beginning of the study, the aromatic amino group was tested, however, the impregnated activated carbon with the aromatic amino group exhibited poor deodorizing performance. Over a long period, its efficiency decreased, necessitating the discovery of a more suitable material that would enable a greater deodorant efficiency in the adsorption of acetaldehyde over a longer period. Vitamin Bx and phosphoric acid were chosen to fit this requirement. Vitamin Bx is a safe material that can be found in yeast and spinach etc., and whose chemical name is para-amino benzoic acid. Using vitamin Bx by itself did not react to acetaldehyde, however, a combination of vitamin Bx and phosphoric acid, which formed acid salt, had a dramatic effect on the aldehyde gases. Normally, one molecule of the aromatic amino group chemically bonds to only one molecule of acetaldehyde. On the other hand, one combined molecule of vitamin Bx and phosphoric acid enabled chemical bonding to multiple molecules of acetaldehyde, and formed synthesized polymer (**Fig. 7**). Therefore, the impregnated activated carbon with vitamin Bx and phosphoric acid will adsorb acetaldehyde more effectively than current impregnated filters employing the aromatic amino group.

6. COMPARISON OF VITAMIN Bx FILTERS AND CURRENT FILTERS BY LABORATORY TESTING

An experiment to compare a filter impregnated with vitamin Bx with a current filter (impregnated with aromatic amino group) to compare the adsorption performance of both, vis-à-vis acetaldehyde was conducted. Activated carbon was impregnated with vitamin Bx and phosphoric acid for the “vitamin Bx filter”, and activated carbon was impregnated with the aromatic amino group for the “current filter”. The picture and structure of the deodorant filter used for the test is shown in **Fig. 8**. The filter size, mass and type of activated carbon are the same. The efficiency and

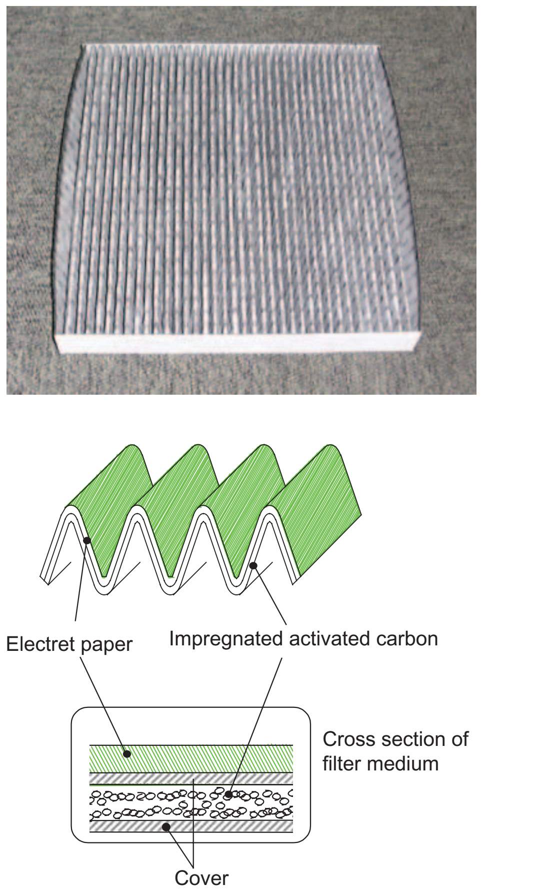


Fig. 8　The picture and structure of deodorant filter

capacity of the filter were measured with the test equipment (**Fig. 9**). Acetaldehyde gas used for evaluation was a diluted acetaldehyde solution with air. Acetaldehyde gas was measured employing gas chromatography. The airflow velocity of the filter was 1.4 m/s.

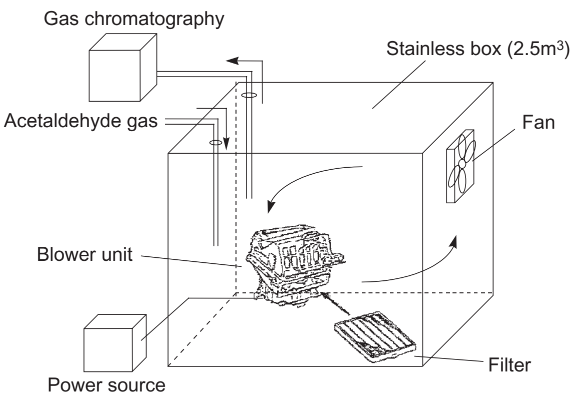


Fig. 9　Test equipment

6.1　Analysis method of filter efficiency

The analysis method used for the adsorption efficiency of the filter was as follows.

(1) Place a blower unit with no filter into a stainless box. Adjust acetaldehyde concentration in the stainless box to 3 ppm, and operate the blower unit for 30 minutes. The natural damping ratio is measured by this method, and the formula for η_0 is "1-(acetaldehyde concentration after 30 minutes operation/ acetaldehyde concentration at the outset)".

(2) Place blower unit with filter into a stainless box. Adjust acetaldehyde concentration in the stainless box to 3 ppm, and operate the blower unit for 30 minutes. While operating the blower unit, measure acetaldehyde concentration in the stainless box several times.

(3) Filter adsorption efficiency is calculated at t=1 by following the Filter Adsorption Efficiency Formula.

$$\eta = \ln\left(C_0/(C_t + C_0 * h_0 * t/30)\right)/t * V/Q$$

η : filter adsorption efficiency (%)
C_0 : gas concentration at the outset (ppm)
C_t : gas concentration after t minutes (ppm)
t : time (min)
V : volume of box (m^3)
Q : air flow volume (m^3/min)
η_0 : natural damping ratio (%)

6.2　Analysis method of filter capacity

The analysis method used for the adsorption capacity of the filter was conducted as follows.

(1) After the above items (1) and (2) of "Analysis method of filter efficiency" were conducted, filter adsorption capacity was calculated using the Filter Adsorption Capacity Formula.

$$W = M * V/(22.4*(273+T)/273)*C_0*(\eta - \eta_0)$$

W : filter adsorption capacity (mg)
M : molecular weight of gas
V : volume of box (m^3)
T : temperature (ºC)
C_0 : gas concentration at the outset (ppm)
η : concentration damping ratio at 30 minutes (%)
η_0 : natural damping ratio (%)

(2) Item (2) of "Analysis method of filter efficiency" above is repeated until $\eta = \eta_0$, when "concentration damping ratio" became equal to "natural damping ratio" (until the limit of the filter capacity), and total filter adsorption capacity (full filter life capacity) is calculated.

6.3　Examining results of acetaldehyde gas adsorption

The relationship between filter efficiency and filter capacity of acetaldehyde gas is shown in **Fig. 10**. As you can see from that, the vitamin Bx filter adsorbs 3 times or more acetaldehyde than the current filter. **Figure 11** shows the relationship between filter efficiency and the quantity of acetaldehyde that passed through the filter. At first glance, it is clear that the period of efficiency regarding acetaldehyde adsorption of vitamin Bx filter is much longer than the current filter. The vitamin Bx filter maintains excellent efficiency vis-à-vis acetaldehyde adsorption.

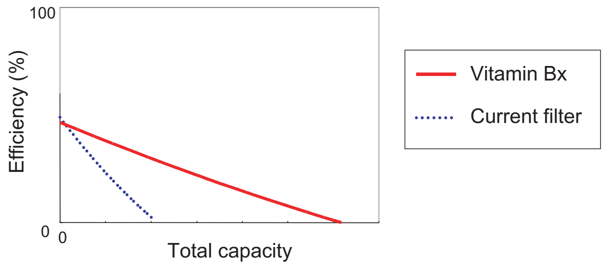


Fig. 10　Deodorant quality regarding acetaldehyde (1)

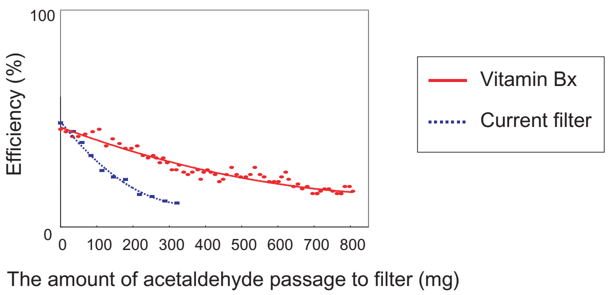


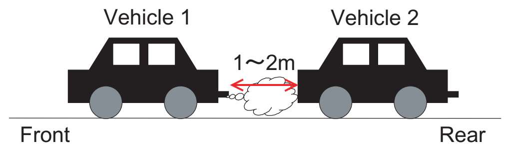
Fig. 11　Deodorant quality regarding acetaldehyde (2)

7. COMPARISON BETWEEN VITAMIN Bx FILTER AND CURRENT FILTER BY SENSE EVALUATION

Regarding the deodorization effect, in a laboratory experiment it was established that the vitamin Bx filter is superior to the current filter. Then it became necessary to also prove that the vitamin Bx filter excels in performance over the current filter in an actual environment. Firstly, a vitamin Bx filter and a current filter were prepared. Each of these filter's size and activated carbon quantity were adjusted to be equal. The filters were fitted into the air conditioner of a vehicle, and were used as an "air refiner". Sense evaluation for diesel odor was conducted at mileages of 1,000 km, 5,000 km and 10,000 km.

Figure 12 shows the sense evaluation method. Vehicle 1 is a diesel car, and Vehicle 2 is situated one to two meters behind vehicle 1. During one minute idling of Vehicle 1, panelists in Vehicle 2 began sniffing the cabin air, and ranked the odor based on **Fig. 13**.

Figure 14 shows the result of sense evaluation, also the relationship between the level of sense evaluation for odor and odometer of a vehicle where a filter had been affixed. As for the vitamin Bx filter, the result shows that the deodorizing efficiency regarding diesel odor of the filter continues longer than for that of the current filter.



Vehicle 1 : Diesel car.
Idle Vehicle 1 for about one minute.
Vehicle 2 : Filter is installed in air conditioner of Vehicle 2.
Air flow strength of air conditioner is medium.
During idling of Vehicle 1, panelists take a sniff and order based on Fig.13.

Fig. 12　Sense evaluation method

5 : stronger odor
4 : strong odor
3 : odor easily sensed (by panelist)
2 : what type of odor sensed (by panelist)
1 : odor barely sensed
0 : no odor

Fig. 13　Odor intensity rank

Therefore, the activated carbon filter impregnated with vitamin Bx and phosphoric acid is the best deodorant filter for diesel gases.

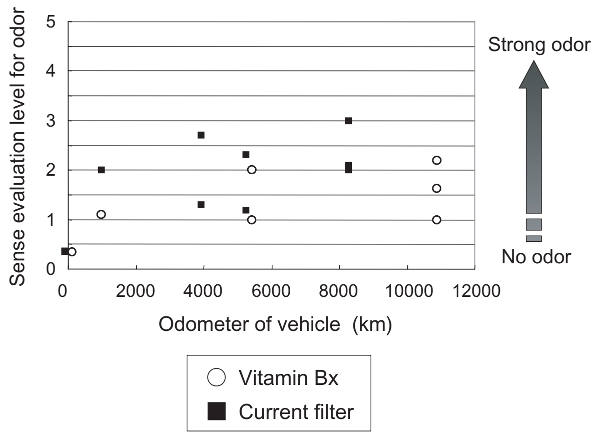


Fig. 14　Result of sense evaluation

8. CONCLUSION

The deodorant filter has been developed focusing on diesel odor during this experiment. The deodorant filter exhibits efficiency not only in the laboratory but also in an actual environment. Now, improvement regarding the quality of the deodorant filter is our new target for further development.

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