Estimating the service life time of the cabin air filters used in automobiles based on tests of loading capacity and filtration efficiency

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The cabin air filter is an essential component of the ventilation system of an automobile to remove air pollutants, especially PM. However, guidelines for the filter life time under different conditions are still lacking, because the loading characteristics may depend on the particle properties and ambient conditions. This study is focused on testing the performance of the cabin air filters under different simulated driving conditions and proposes a quantitative method to estimate the service life time of the cabin air filters based on the experimental results.

The experiments were conducted in a wind tunnel compatible with EN DIN 779 standard. Two types of commercial cabin air filters were tested and compared with each other, which were normal fibrous filters (NF) and activated carbon coated filters (CF). Both the Arizona road dust (ARD) and soot particles were used to load the filters, which represented the mineral road dust and automobile exhaust, respectively. The relative humidity inside of the wind tunnel was set to vary between 30% RH and 80% RH which were typical values of normal and rainy weather. The experimental conditions were listed in Table 1.The pressure drop across the tested filters and the filtration efficiency of the filters were monitored continuously during the whole loading process

Table 1. Summary of the six sets of experimental conditions.

	I	II	III	IV	V	VI
RH(%)	30	30	30	80	80	80
Loaded dust	ARD	Soot, ARD	ARD	ARD	Soot, ARD	ARD
Filter type	NF	NF	CF	NF	NF	CF

The obtained loading curves of the filters are shown in Figure 1.

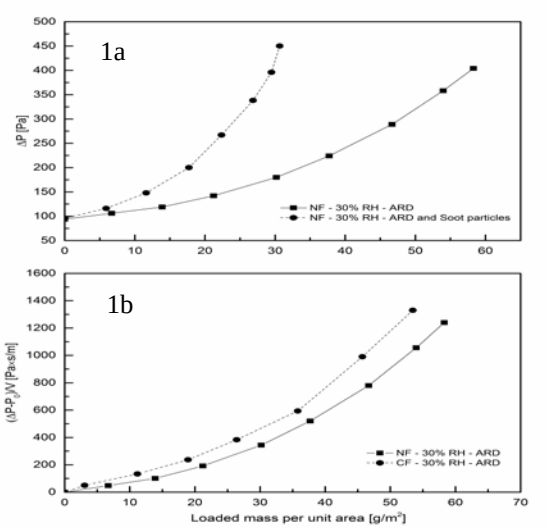

Figure 1. Loading curves under different conditions: (1a) NF loaded by ARD and ARD with soot particles, respectively; (1b) comparison between NF and CF

Equation 1 is utilized to estimate the service life time of the filters

$$W=\Delta P\times Q \quad [1],$$

where W is the power of the fan for ventilation system (W); ΔP is the pressure drop caused by the cabin air filter (Pa); Q is the air flow rate (m3/s). In practice, the power of the motor should be kept lower than the rated power, otherwise the motor is damaged in short time.

If the flow rate (Q) is kept constant to maintain a stable ventilation condition, the power (W) will be linearly proportional to the pressure drop (ΔP) and increase gradually due to the increasing ΔP caused by continually loaded particles. In practice, when the rated power of the motor and the average flow rate are known, based on the loading curves in Figure 1, the corresponding loaded mass of the filters can be obtained and the service life time of the filters can be estimated according to the air quality on the road.

In conclusion, the proposed method provides a new way for the automobile manufacturers to improve the design of the ventilation system based on the quantitative measurements.