Design of a filtering car air purifier

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Abstract. Aiming at serious air pollution in the passenger car, in this paper, a filtering car air purifier is designed. This paper mainly consists of selection of the fan, design of the filter, design of the shell, processing of all parts, assembly of the complete machine, usage, operation process, and usage. Finally, through the detection of the filtering car air purifier designed in this paper, the test shows that this filtering air purifier can remove harmful substances, such as formaldehyde, in the car.

1. Introduction
With the popularization of cars, air pollution in the car attracts more and more attention. Pollutants in the car are mainly produced by the release of harmful substances in equipment and decorating materials in the car, and these materials in the car have large quantity of toxic gases, including benzene, formaldehyde, xylene, etc [1]. The concentration of toxic gases in new cars leave factory is excessively high, and the volatilization time can last more than 6 months. These harmful substances can unconsciously poison people who will then have symptoms such as headaches, nausea, fatigue, coughing, sneezing, or even cause serious diseases such as leukemia. In addition to materials in the passenger car, the leakage, evaporation of fuel, lubricants, and refrigerants, and mildew and nicotine produced by the air-conditioning system are the main sources of air pollution in the car. At current, there have been many methods on the market to purify the air in the car, such as, fragrance deodorants and activated carbon bags, but most of them have some hidden safety hazards or low cost performance. Therefore, it is necessary to actively develop a set of air quality improvement devices in the passenger car so as to improve the air environment quality. After studying the purification methods, this paper designs and develops an efficient, low-powered passenger car air purifier with no side effects, so as to provide the drivers and passengers with comfortable and safe riding environment.

2. Product design
Now, there are many types of car air purifier sold on the market, and according to the principles, there are mainly four types, namely, filtering car air purifier, dust-accumulated car air purifier, ozone car air purifier, and negative oxygen ion car air purifier [2]. The air purifier designed in this paper is a filtering car air purifier. In general, the filtering car air purifier is composed by a shell, a fan (air supply system), and filter (purification system) [3]. In terms of its principle, it mainly uses the fan for forced ventilation, and adopts porous filter materials, such as non-woven fabrics, fibers, and foam, to adsorb and decompose suspended particles and harmful gases in the air, thus purifying the air in the car. The structure diagram of the air purifier is shown in Figure 1.
2.1. Selection of the fan

The selection of the fan shall take the wind speed, wind pressure and resistance into account. There is not too much pollution gases produced in the general passenger car per unit time. With comprehensive consideration of the volume and effect of the filter designed, this design will adopt the German EBM external-rotor axial flow fan with ultra-high performance. This fan has a rated voltage of 12V, 24V and 48V, and it is featured by compact structure, low noise and good heat dissipation effect. Integrating external electronic equipment, it can efficiently adjust the air flow through precise open-loop or closed-loop control, and at the same time, it has signal alarm, Lin / PWM output, and open-loop control and bus interface depending on temperature or flow. The schematic diagram of the fan is shown in Figure 2:
2.2. Design of the filter
The filtering effect of the filter is not only related to the wind speed, wind pressure, and resistance, but also directly related to the material and area selected [3]. The selection shall mainly consider adsorption capacity, residence time, service life and adsorb ability.

2.2.1. Selection of filter layer materials. The adsorption media designed and selected in this paper mainly take various purification materials with different adsorption functions, such as granular active carbon and activated alumina, as the base materials.

The high efficiency filter is filled with PIA and N4G1, and the chemical filter is filled with PCM. PIA is mainly composed of spherical activated alumina and potassium permanganate, and the main gases it can remove are H2S, NO, formaldehyde, ethylene, organic acids, amines, etc.; N4G1 is mainly composed of cylindrical broad-spectrum activated carbon, and the main gases it can remove are hydrogen compounds, benzene, acetone, chlorine, ozone, smoking odor, garbage odor, etc.; PCM is a compound of 50% PIA and 50% N4G1, and the main gases it can remove are formaldehyde, hydrogen sulfide, mercaptans, acetaldehyde, acetic acid, nitrogen oxides, ozone, VOCs, etc.

2.2.2. Parameter design of the filter. The filter is composed by a primary filter and a high efficiency filter. The primary filter is a layer of rectangular foam to be installed with the high efficiency filter which is installed at the air inlet. Both are designed as cuboids. Considering the service life, specific structure and site conditions, etc. of the filter, the parameters of the filter are designed as follows: The cuboid has a length of 200mm, a width of 158mm and a height of 30mm. Considering the dust removal effect, the interior is made into folds to increase the contact area of the catalyst with pollutants. The structure diagram is shown in Figure 3:

![Figure 3. Primary and high efficiency filters.](image)

The chemical compound filter is composed by a metal filter (three layers), a chemical filter, and a post filter.

Considering the size of the fan selected, the internal structure of the reactor must ensure the full contact of the catalyst with pollutants, and the flow rate of the polluted air flow through the purifier. The e
The chemical compound filter is initially designed as a rectangular frame with the outer diameter of 82 cm, the width of 73 cm, the height is 40 mm, and the thickness is 15 mm. The structure diagram is shown in Figure 4.

2.3. Design of the shell

2.3.1. Selection of shell materials. In order to reduce weight and costs, the shell material adopts ABS plastic with high strength, good toughness, and low price [4].

2.3.2. Parameter design of the shell. The space in a family car is about 2-3 m³, and due to the mall space, the purifier cannot be too large. Considering that it is necessary to ensure the full contact of the catalyst with pollutants, and the flow rate of the polluted air flow through the purifier, the shell is designed to be composed by an upper cover, a middle shell, and a base. The size of the upper cover is 205 mm * 163 * 40 mm, and the size of the middle shell and the base is 250 mm * 200 mm * 40 mm, with the wall thickness of 8 mm. The upper cover is provided with a vent which allows the polluted air enter the reaction chamber of the air purifier under the driving effects of the fan. The base is used to install the fan and chemical compound filter, and there are protruded grooves on it to fix the chemical filter. The structure diagram of the upper cover, middle shell and base is shown in Figure 5:

![Figure 4. Chemical compound filter.](image)

![Figure 5. Schematic diagram of the shell.](image)
2.4. Design of other parts

2.4.1. Protective screening. In order to protect the high efficiency filter from abrasion and prolong its life, a layer of protective screening is installed to the outer and inner sides of the high efficiency filter. The inner screening height is 44mm and the outer screening height is 46mm, as shown in Figure 6:

![Figure 6. Schematic diagram of the protective screening.](image)

2.4.2. Anti-slip mat. The anti-slip mat is installed at the bottom of the lower shell. Its material is heat-resistant rubber, and its main function is to fix the purifier firmly to the back of the seat, so as to prevent friction for bump between the purifier and the seat. The parts drawing of the anti-slip mat is shown in Figure 7:

![Figure 7. Schematic diagram of anti-slip mat.](image)
3. Assembly of the purifier
After processing of dimension parameters and selected materials of all parts, the purifier is assembled according to the assembly steps. The process is as follows:

1. Fix the fan in the center of the base, and connect the fan to the power adapter connector with a wire.
2. Put the chemical compound filter into the base, and note to keep the end with the power socket aligned with the end of the filter with a gap bench to prevent air leakage.
3. Install the upper cover, primary and high efficiency filters, middle shell, chemical compound filter, and rear seat with fan according to the direction of gas flow in order as shown in Figure 8:

![Installation drawing](image)

**Figure 8.** Installation drawing.

The three-dimensional and physical map are shown in Figure 9:

![Three-dimensional and physical map](image)

(a) Three-dimensional map (b) Physical map

**Figure 9.** Three-dimensional and physical map of the air purifier.

4. Usage and operation process

4.1. Usage
1. Tie the built-in belts to the back of the seat.
2. Connect one end of the cable of the cigarette lighter to the purifier, and the other end to the car lighter socket. The machine starts to work, and disconnect the power when not in use.

4.2. Operation process of the air purifier
1. The polluted air is absorbed into the air purifier through the strong negative pressure generated by the fan, and suspended solids such as inhalable particulate matter and dust with larger particle size are removed by the primary filter.
(2) The air filtered by the primary filter passes through the HEPA filter to remove dust mites, dust (bacteria clumps), and fine dust particles larger than 0.3 micrometers, to complete the high-efficiency filtering;

(3) The air highly filtered will pass through the chemical compound filter which is composed by the metal filter (three layers), the chemical filter, and the post filter. The metal filter can remove the charged ions in the air, and completely removes the charged ions floating in the air; The chemical filter is composed of composite adsorption and decomposition materials with no toxic and side effects, and mainly removes odors and toxic organic volatiles produced by decorative materials, breathing, smoke, and chemicals in the air; The post filter can block particles that may be produced in the filtering process so as to ensure the freshness of the air entering the car through the purifier. Finally, clean air is discharged from the air outlet.

5. Detection

5.1. Detection methods
Currently, the method that can evaluate the purification efficiency of air purifiers more objectively is clean air delivery rate (CADR) which is proposed with reference to American standards. As a performance index which is related to the use feature of air purifiers and can reflect the purifying capacity, it is not only applicable to evaluate the ability of air purifiers to remove suspended particle, but also applicable to evaluate the ability to remove other air pollutants [9]. Due to the restrictions, this paper just tests formaldehyde.

5.2. Detection of closed testing device and test steps
Currently, the method that can evaluate the purification efficiency of air purifiers more objectively is clean air delivery rate (CADR) [5].

(1) Evaluation device and conditions
The volume of the closed testing chamber is 1m³, and the chamber is equipped with a circulating fan. The temperature in the testing chamber is maintained at (21 ± 2.5) degrees, and the relative humidity is (50 ± 5) %.

(2) Test steps
Place the air purifier to be tested in the middle of the testing chamber and adjust the air purifier to the operation state of the test. The detection is normal. Inject formaldehyde gas (concentration: 20mg / m³) into the testing chamber at a flow rate of 5L / min (formaldehyde diluent) for 10min. Test the formaldehyde concentration in the testing chamber with air purifier turned on and off within 140 minutes. The sampling port flow rate is 0.5L / min, and the sampling time is 20min.

![Figure 10. Purification effect of purifier on formaldehyde gas.](image)
5.3. Test results
It can be seen from Figure 10 that the purification effect of the air purifier is significant. For formaldehyde gas with an initial concentration of 1.2 mg / m³, the removal efficiency of formaldehyde is over 90% after the air purifier is operated for 140 minutes.

6. Conclusions
Aiming at the current situation of air pollution in the passenger car, this paper designs a filtering car air purifier. Based on the test analysis, the air purifier designed in this paper can effectively improve harmful substances, such as formaldehyde, in the car. The improvement of air quality in the car is a long-term work, and the use of air purifiers for the improvement is only a small measure. To make sure people enjoy the pleasure of driving and not harmed by air pollution, the relevant government departments, enterprises for car research and development, and automotive interiors materials enterprises must reach a consensus and do a good job of preventing pollution in the car.

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