Study on method of HEPA filter recycling by CFD & Physical treatment

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Abstract. To find out the best method to recycle the filter, this article used both CFD simulation and Physical treatment to clean the filter. This article shows how the air travel through the filter and how the pollution particles attracted on the filter and what would be the possible way to remove the particles, by using CFD simulation, the result will be shown in the following graphic. Found out the most efficiency physical treatment is Ultrasonic, by measuring the transmittance of the liquid after the ultrasonic treatment.

Keywords: filter recycle, CFD, velocity field, aerodynamics, filtration process

1. Introduction
Nowadays human pay more attentions on the resource we have been using, more and more product will be consider to be recyclable and environment friendly before it is produce. To figure out the best way to recycle the filter (in this article we choose HEPA filter) this article used CFD to simulate the filter during filtration, and then analyze the condition of filter during filtration find out the badly polluted area, at last clean the filter. In order to clean the filter this article have done a certain Physical treatment such as Ultrasonic, Microwave, Heat, Electrophoresis etc. Above all the treatment the best is regard as Ultrasonic, which is the best cleaning method for the filter paper. In this article we measured transmittance of the water as the valuation to judge wether the treatment is efficiency. The demonstration will be shown in the
following sections.

2. Structure of the filter & the experiment

The filter will be design as an A4 paper size filter paper with some pattern distribute on the surface[figure,1], and deal to the computing ability of the computer as well as the actual condition of the filter, this article used “porous media method” instead of drawing the exact structure of the filter. This method not only can reduce the computing stress of the computer (specially when the computer can not Handel heavy calculation duty) but also can reduce the drawing steps , which usually need a long time to restructure the fine filter structure into software.

![Figure 1 Filter](image)

The porous media is wildly used in actual life , which is always the best solution for many condition such as filtration process and the separation process. Porous media is a common space occupied by multiphase materials, and it is also a combination of multiphase materials. The part of the space without a solid framework is called pores. It is occupied by liquid or gas or gas-liquid. In terms of phase, the other phases are dispersed in it, and the solid phase is used as the solid framework, and some voids that constitute the void space are connected to each other. The equation that used will be show as follow:

\[
S_t = (\sum_{j=1}^{3} D_{ij} \cdot u_{ij} \cdot v_{ij} + \sum_{j=1}^{3} c_{ij} \cdot 1/2 \cdot p) |v| |v_{ij}|
\]  

(1)

When the porous media is continuous we can simplify the equation into:

\[
S_t = (\mu \cdot v_{ij} + C \cdot 1/2 \cdot |v| |v_{ij}|
\]  

(2)

The computing software separate the CFD simulation process into three steps: intake fluent; porous media; output fluent .the equation above will be apply on the porous media part.
Also after we analyze the velocity of how the air flow apply on the filter, can we find out which parts of the filter paper is heavy duty during the filtration process. Then we can design the cleaning project which specially apply on the heavy duty area. In this article we only tried to put the filter paper into the boiling water and Ultrasonic treatment. We used the transmittance value of the liquid solution to evaluate the cleaning process, as the transmittance value became lower means the more effective cleaning process is.

In the cleaning project we shave the filter into a small size paper as 12x6 cm then set separately into 6 sets of experiments three is boiling water and the rest are Ultrasonic treatment. After the treatment we take the water to test the transmittance.

3. CDF modeling & cleaning treatment

The size and the filter structure will be show in the Figure 1, simulate size is 20cm x 30cm x 5 cm thick filter paper with porous media, this article used the air as the simulation object (under room temperature and standard air pressure).

In this article we define an intake air speed as variable. The variable value in this article are shown in Table 1

| No. | Intake | Output | Resistance |
|-----|--------|--------|------------|
| 1   | 5      | 4.98   | 0.996      |
| 2   | 10     | 9.96   | 0.996      |
| 3   | 15     | 14.95  | 0.972      |

The following cleaning experiences will be show as table 2. In this experiments the variable will be the time length of the treatment. we take 5,7,10 mins to boil the water which contain filter paper as well as Ultrasonic treatment. Each numbers of experiences will be repeat in three times. The transmittance experiments used purefied water as the base line 100% then used the sample to compare with base line. We used the lamber-beer law $lgT = -sdC$

| No. | Times/min | Boiling water | Ultrasonic |
|-----|-----------|---------------|------------|
| 1   | 5         |               |            |
| 2   | 7         |               |            |
4. Results and discussions

Simulation of filter paper’s pressure field and velocity field demonstrate as follow figure.3 figure.4

Figure 3 Instantaneous pressure field when air speed is 5 10 15

Figure 4 Instantaneous contours of vorticity when air speed is 10 15 20 m/s
The measured transmittance is showed as follow Table 3 in this table.

**Table 3** Average transmittance value

| No. | Boiling water/% | Ultrasonic /% |
|-----|-----------------|---------------|
| 1   | 49              | 30            |
| 2   | 43              | 27            |
| 3   | 40              | 18            |

As the simulation shows that the surface value of the filter is not equal no matter pressure or velocity. We will take intake air speed 5m/s as an example, in figure.4 we can see there are both high and low pressure area on the same intake surface, compare it with velocity field we found out that the velocity is almost equal on the surface, which means the pollution particle flow constantly and average though the filter paper. but on the other figure pressure field showed the filter paper have particularly high pressure in some area as well as the low pressure area. Which means the high pressure area can be possibly block the air flow or not easy to attract pollution particle on it and the filter paper will more likely to be broken when strong pressure of air apply on the tiny paper. On the other side low pressure area means more likely to attract particles and pollution this area will usually full with pollution. As the time pass at first more and more air flow will be pass though the low pressure area, after those area was full the air flow will be average separate on the surface of the filter paper.

**5. Conclusions**

From the simulation data, we can know that some areas are subject to high pressure and some areas are subject to low pressure. The high-pressure area means that the filter is more easily damaged, while the low-pressure area means that more airflow will collect a lot of pollutants.

And the washing project shows that the most effective way to clean the filter paper is Ultrasonic treatment the longer time it takes the more effective it became.

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**References**

[1] Li P, Wang C, Zhang Y, et al. Air filtration in the free molecular flow regime: a review of high-efficiency particulate air filters based on carbon nanotubes[J]. Small, 2014, 10(22): 4543-4561.

[2] Mader B T, Pankow J F. Gas/solid partitioning of semivolatile organic compounds (SOCs) to air filters. 3. An analysis of gas adsorption artifacts in measurements of atmospheric SOCs and organic carbon (OC) when using
Teflon membrane filters and quartz fiber filters[J]. Environmental science & technology, 2001, 35(17): 3422-3432.
[3] Thakur R, Das D, Das A. Electret air filters[J]. Separation & Purification Reviews, 2013, 42(2): 87-129.
[4] Zhang R, Liu C, Hsu P C, et al. Nanofiber air filters with high-temperature stability for efficient PM2. 5 removal from the pollution sources[J]. Nano letters, 2016, 16(6): 3642-3649.
[5] Zuo F, Zhang S, Liu H, et al. Free-standing polyurethane nanofiber/nets air filters for effective PM capture[J]. Small, 2017, 13(46): 1702139.
[6] Endo Y, Chen D R, Pui D Y H. Effects of particle polydispersity and shape factor during dust cake loading on air filters[J]. Powder technology, 1998, 98(3): 241-249. fluctuating forces on a circular cylinder [J]. Journal of Wind
[7] Cheng L, Zhang Z, Zhao X, et al. Study on the stirred blade mounting height-to-liquid level-ratio related to the law of flow field inside the stirred reactor[C]/IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2019, 569(2): 022039.
[8] Cheng L, Zhang Z, Zhao X, et al. Simulation of fluid around parallel-column by LES[J]. MS&E, 2020, 740(1): 012186.