Increasing the Single-Pass Efficiency of an Air-Purifier

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Abstract - . We need to preserve the world we are in. Air-pollution comes in direct contact with the human and it spreads easily. Hence, there is a need to take drastic measures. One of these drastic measures can be taken by curing the air with the help of air-purifiers. Companies like Zn1.0era space, Honeywell, rabbit air are going to be the leading air-purifier companies in the near future. These companies are taking initiative.

But, as the environment health is deteriorating there is going to be a time when purifying need will be on the edge. Therefore, we here, are going to customize an air-purifier which decreases the time to bring the designated room to a state of clean equilibrium.

Our customized air-purifier can suck the air faster as well as throw it faster making the place clean faster. This property, nay, better single-pass efficiency of our air-purifier will be used in many places of emergencies. This review covers how we are going to achieve this state as well as the problems we are going to encounter while achieving this state.

Keywords: Single-pass efficiency, Pre-filter, Air purifier, HEPA, Photocatalytic, Activated carbon, AHU, Ionizer, Clean Air Delivery Rate, ELPI, VOCs, SVOCs, Formaldehyde, Acetaldehyde.

I. INTRODUCTION

Although they may seem like a new innovation, air purifiers have been around for more than 200 years. What started as protective masks for fireman, air purifiers have now evolved the ability to protect you and your family from airborne pollutants. The commercially graded air purifiers are manufactured as either small stand-alone units or larger units that can be affixed to an air handling unit (AHU) or to an HVAC unit found in the medical, industrial and commercial industries.

The demand of air-purifiers has been increasing in day-to-day life. Soon a day will be imminent when air-purifiers will be a need. The ever-increasing pollution from vehicles, nay, any type of transport vehicle, industries, etc. have given rise to this curing measure called air purifiers. As the source of pollution problems can be categorized differently, air-purifiers for the same also can be. The important types which are available today are discussed about are as follows:

A) HEPA filters: Basically, a trapping particles mesh removing at least 99.97% of articles that are 3 micrometres in diameter, and efficiently remove both larger and smaller particles.

B) Photocatalytic Oxidation (PCO) system are able to completely oxidize and degrade organic contaminants. For example, volatile organic compounds found law concentrations within a few hundred ppbv (parts per billion volume) or less are the most likely to be completely oxidized.

II. TYPES OF AIR-PURIFIERS

A) HEPA filters: High efficiency particulate air (HEPA), originally called high-efficiency particulate absorber but also sometimes called high-efficiency particulate arresting or high efficiency particulate arrestance, is a type of air filter. Filters meeting the HEPA standard have many applications, including use in clean rooms for IC fabrication, medical facilities, automobiles, aircraft and homes. The filter must satisfy certain standards of efficiency such as those set by the United States Department of Energy (DOE). To qualify as HEPA by industry standards, an air filter must remove (from the air that passes through) 99.97% of particles that have a size greater-than-or-equal-to 0.3 µm. Although the ASME industry standard is not published by any government, it is recognized as an authoritative standard by many governments. Key factors affecting its functions are fibre diameter, filter thickness, and face velocity. The air space between HEPA filter fibres is typically much greater than 0.3µm. The common assumption that a HEPA filter acts like a sieve where particles smaller than the largest opening can pass through is incorrect and impractical.

Unlike membrane filters at this pore size, where particles as wide as the largest opening or distance between fibres cannot pass in between them at all, HEPA filters are designed to target much smaller pollutants and particles. Gas filtration: HEPA filters are designed to arrest very fine particles effectively, but they do not filter out gasses and odour molecules.

The specification usually used in the European Union is the European Norm EN 1822:2009. It defines several classes of HEPA filters by their retention at the given most penetrating particle size (MPPS):

Fig 1. HEPA Air Purifier [10]

Table 1. Different classes of HEPA filters

HEPA class	retention (total)	retention (local)
E10	> 85%	---
E11	> 95%	---
E12	> 99.5%	---
H13	> 99.95%	> 99.75%
H14	> 99.995%	> 99.975%
U15	> 99.9995%	> 99.9975%
U16	> 99.99995%	> 99.99975%
U17	> 99.999995%	> 99.9999%

B) Photocatalytic air-purifiers: In photocatalytic air purifiers, the catalyst that cleans the air is typically titanium dioxide (sometimes called titania) and it's energized by ultraviolet (UV) light. UV is the short-wavelength light just beyond the blue/violet part of the electromagnetic spectrum that our eyes can detect. The bad thing about it is that it gives you sunburn. The good thing is that it has much more energy than ordinary, visible light—and exactly the right amount of energy to get titanium dioxide excited. Titanium

dioxide is a semiconductor (a bit like materials such as silicon, used in integrated circuits). You don't actually need much titanium dioxide: just a thin film covering the surface of a backing material called a substrate, which is usually made from a ceramic or a piece of metal (such as aluminium). Here's how the titanium dioxide catalyst in an air purifier breaks apart molecules of air pollution:

i) When UV light (the big yellow arrow shown here) shines on the titanium dioxide, electrons (the tiny, negatively charged particles inside atoms) are released at its surface. It's the electrons that do the useful work for us.

ii) The electrons interact with water molecules (H2O) in the air, breaking them up into hydroxyl radicals (OH·), which are highly reactive, short-lived, uncharged forms of hydroxide ions.

iii) These small, agile hydroxyl radicals then attack bigger organic (carbon-based) pollutant molecules, breaking apart their chemical bonds and turning them into harmless substances such as carbon dioxide and water. This is an example of oxidation—and that's why air purifiers that work this way are sometimes also described as PCO (photocatalytic oxidation) air cleaners.

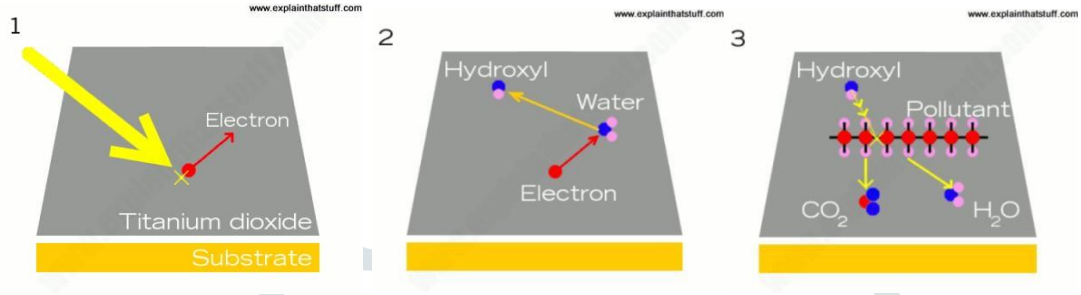

Fig 2. Photocatalytic Oxidation [11]

C) Activated carbon: It is a porous material that can adsorb volatile chemicals on a molecular basis, but does not remove larger particles. The adsorption process when using activated carbon must reach equilibrium thus it may be difficult to completely remove contaminants. Activated carbon, also called activated charcoal, is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. Activated is sometimes substituted with active. Due to its high degree of micro porosity, one gram of activated carbon has a surface area in excess of 3,000 m2 (32,000 sq ft.) as determined by gas adsorption. An activation level sufficient for useful application may be obtained solely from high surface area. Further chemical treatment often enhances adsorption properties. Activated carbon is usually derived from charcoal and is sometimes used as bio char. When derived from coal or corn, it is referred to as activated coal. Activated coke is derived from coke. Activated carbon is merely a process of changing contaminants from a gaseous phase to a solid phase, when aggravated or disturbed contaminants can be regenerated in indoor air sources. Activated carbon can be used at room temperature and has a long history of commercial use. It is normally used in conjunction with other filter technologies, especially with HEPA. Other materials can also absorb chemicals, but at higher cost.Filters with activated carbon are usually used in compressed air and gas purification to remove oil vapours, odour, and other hydrocarbons from the air. The most common designs use a 1-stage or 2 stage filtration principle in which activated carbon is embedded inside the filter media. Activated carbon is also used in spacesuit Primary Life Support Systems. Activated carbon filters are used to retain radioactive gases within the air vacuumed from a nuclear boiling water reactor turbine condenser. The large charcoal beds adsorb these gases and retain them while they rapidly decay to non-radioactive solid species. The solids are trapped in the charcoal particles, while the filtered air passes through.

Fig 3. Activated Carbon [12]

D) *Ionizer purifiers*: It use charged electrical surfaces or needles to generate electrically charged air or gas ions. These ions attach to airborne particles which are then electrostatically attracted to a charged collector plate. This mechanism produces trace amounts of ozone and other oxidants as by-products. Most ionizers produce less than 0.05 ppm of ozone, an industrial safety standard. There are two major subdivisions: the fan-less ionizer and fan based ionizer. Fan-less ionizers are noiseless and use little power, but are less efficient at air purification. Fan-based ionizers clean and distribute air much faster. Permanently mounted home and industrial ionizer purifiers are called electrostatic precipitators. Air ionizers are used in air purifiers to remove particles from air. Airborne particles become charged as they attract charged ions from the ionizer by electrostatic attraction. The particles in turn are then attracted to any nearby earthed conductors, either deliberate plates within an air cleaner, or simply the nearest walls and ceilings. The frequency of nosocomial infections in British hospitals prompted the National Health Service (NHS) to research the effectiveness of anions for air purification, finding that repeated airborne acinetobacter infections in a ward were eliminated by the installation of a negative air ionizer—the infection rate fell to zero, an unexpected result. Positive and negative ions produced by air conditioning systems have also been found by a manufacturer to inactivate viruses including influenza. However, a 2013 comprehensive review of 80 years of research into air ions and respiratory function outcomes found that there was no clear support for any beneficial role in respiratory function, nor evidence for significant detrimental effect. In conclusion, "exposure to negative or positive air ions does not appear to play an appreciable role in respiratory function." The SARS epidemic fueled the desire for personal ionizers in East Asia, including Japan (where many products have been specialized to contain negative ion generators, including toothbrushes, refrigerators, air conditioners, air cleaners, and washing machines). There are no specific standards for these devices.

Fig.4. Air Ionizer [13]

Need for selection and placing

i) Each air purifier has a different purpose to fulfil besides purifying the air and different in other reasons.

ii) Each type of purifier has a different principle. Some work with the help of activated carbon some with electrostatic precipitator and some with UV light.

iii) Noises made due to blade passage frequency (BPF) Hence, selection of an air purifier is important for the right purpose.

iv) Single pass efficiency is the efficiency given in a single pass of an amount of particulate matter. It differs from CADR.

v) Placing is as important as selection of purifier. In fact, point blankly slightly more than selection. The reasons upholding the prior sentence is that wrong positioning may lead to irregular fashion circular but not done with the place.

III. NEED OF A MODIFIED AIR PURIFIER

The ever-increasing perennial pollution has become a real problem. People from all ages have been suffering from this problem. Especially, the aged people's immune is not strong enough to withstand the damage. Children and even pregnant women need a comfortable environment so as to stay away from health problems and in today's world it is getting difficult to stay in places like these. That is why air-purifiers are about to become a necessity.

Air-purifiers have gained a good efficiency. The air-purifier's efficiency can reach up to 99.96%. Any normal air-purifier can reach almost the same efficiency irrespective of the size of the room. Now, when it comes to the size of the room the time required to gain the optimum efficiency varies. This is where one of our most important problem lies.

For example, Delhi, the capital of India was going through a pollution phase where even a day in this smog equals 21 cigarettes. It was that harmful. As you can see, this is an issue where as soon as you can clear the fog the better. Being the capital, it needs to be more of a concern. At times like these, single pass efficiency would have played an important role. Single pass efficiency is the efficiency given in a single pass of an amount of particulate matter. The time required will be less in such cases and hence, it can become of large importance. People's health was and is an urgent matter there.

In future, there might be emergencies like these. But even if there weren't any emergencies like these, wouldn't a faster resulting engine be better than a slower one?

Also, the rotor will prove as a guidance. The turbulence created by these two fans prove as nuisance. Decreasing it as much as possible is a problem. As without decreasing turbulence, the whole idea is zilch. As discussed earlier the importance of time in air-purifiers, we need to concentrate on the single pass efficiency. A normal air-purifier takes about half an hour for an average sized room. This customized air-purifier will take lesser time. Hence, the very first aim is to improve the single pass efficiency.

When the air-purifiers' fans are started. A turbulence is created by the two fans. The turbulence will then prove as a nuisance. The aim itself will not be served. Hence, to serve the basic purpose the turbulence should be taken care of. This is done by using the rotor which is used to guide. The proper guidance is one of the most important aims. In the bigger picture, time is the spotlight. Because of the single-pass efficiency increase, we also can increase the area of the air-purifier. This can also lead to the increase in CADR rates. Hence, large air-purifiers can be manufactured. The ever-increasing air pollution also can be reduced on a commercialized scale in public places if these CADR rates and single-pass efficiency get increased.

IV INCREASING THE SINGLE PASS EFFICIENCY AIR PURIFIER

As per statistics and experiments, these types work very well ideally as well as practically too. Most of them have an efficiency rate above 70% up to 99.96%. The area of efficiency has been well-defined. This project takes heart not about an air-purifier's efficiency but its single-pass efficiency. "Single pass efficiency" can be defined as the efficiency which is attained when a specific volume of air passes once through the system. In the bigger picture, single pass efficiency is a function of time. It, hence, decreases the time required to attain equilibrium of a given room. An engine with good speed is subconsciously considered as a good engine.

The air-purifier we are going to customize mainly concentrates on single pass efficiency. Generally, an air-purifier consists of one fan used for blowing out the filtered air which also works as a sucker. What we are doing is we are introducing two fans one used for sucking and one for blowing. This concept is not used anywhere in air-purifiers. As vanilla as the quid pro quo sounds, turbulence is what we get in result as the flow is too high. For this reason, we are going to use a stage which will be the same as pressure compounding used in turbines. This is where our project gets unique. In turbines, rotors are being used for mainly two purposes. These rotors are nothing but blades mounted on the shaft. The two purposes are:

A) Reducing the pressure in turbines as the pressure is too much than the required condition.

B) Guiding the fluid

There are many rotors like these and each rotor is called a stage. Here, the turbulence created by these two fans is reduced by a single rotor stage. The rotor blades in the shape of air foil is used in guidance i.e. giving it proper direction to flow through. The pressure compounding itself is used for a different purpose mainly i.e. reducing the pressure but we are going to concentrate on its secondary purpose and use it, the steps are as follows:

i) The fluid goes through pre-filter

ii) The fluid goes through the sucker.

iii) It goes through the second filter.

iv) It goes through the rotor.

v) It goes the third filter.

vi) It goes through the blower.

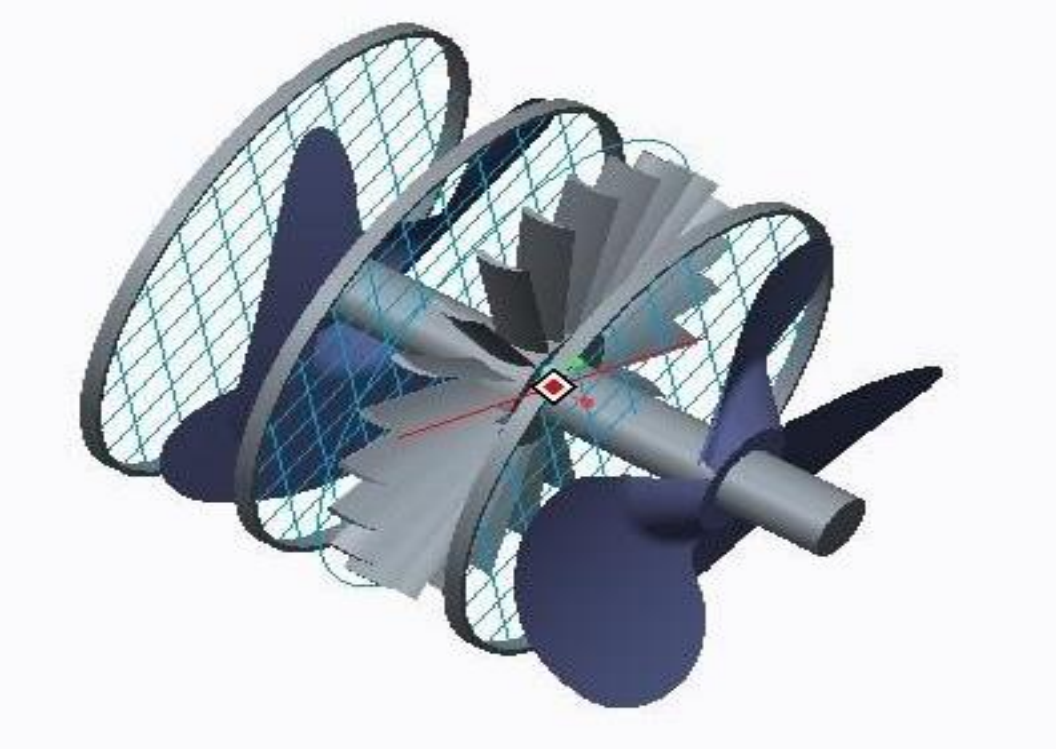

Fig. 5. Model Made in Creo

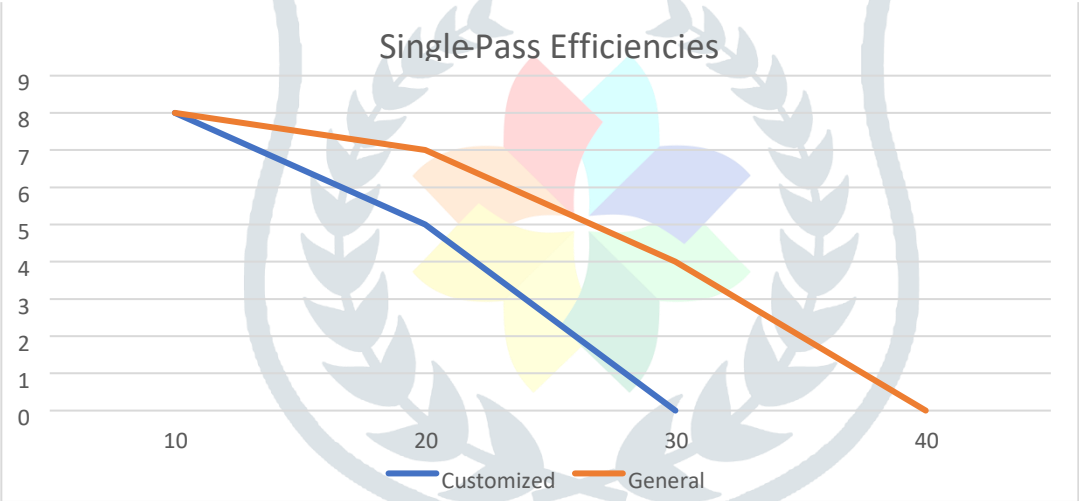

Fig. 6. Single-Pass Efficiency of the Customized Air-Purifier and a General Air-Purifier.

Detailing and Progress:

1. *FAN:*

MOC: *METAL (IRON)*

DIAMETER: *9 INCHES*

RPM: *1350RPM*

SWEEP: *225MM*

VOLT: *230V/50HZ*

i) SHAFT:

MOC: *IRON ROD*

DIAMETER: *0.314 INCHES (0.8CM)*

Fig 7. Shaft and Motor

2. FILTER:

i. TYPE OF FILTER: *SUPER HEPA FILTER*

GRADE OF HEPA FILTER: *EU-13*

MOC: *ALUMINIUM*

IPD: *25MM*

NO. OF PLEATS: *45-48FT*

TEMPERATURE: *AMBIENT*

Fig 8. Super HEPA filter [14]

H x W x D:11 x 17 x 5INCHES

CFM: 325

TEMPERATURE: AMBIENT

ii. TYPE OF FILTER: PREFILTER

MESH TYPE: HONEYCOMB

3. CENTRIFUGAL FAN:

RPM: 2800RPM

VOLT: 230V/50HZ

i. SHAFT:

MOC: IRON ROD

DIAMETER: 0.314 INCHES (0.8CM)

ii. IMPELLER:

MOC: PLASTIC

iii. FAN CASING:

MOC: PLASTIC

CFM: 75

Fig 9. Centrifugal Fan [15]

4. CASING OF THE PURIFIER

MOC: PLASTIC

H x W x D: 11 x 17 x 16INCHES

Modifications:

1) Earlier it was decided that two normal fans will be used so that single-pass efficiencies are improved. It was found out by research that the air-purifier's efficiency as well as single-pass efficiency will be much better if a centrifugal fan will be used instead of a normal wall fan. Hence a centrifugal fan was chosen for blowing out. It was chosen for blowing out because the pressure drop after the HEPA filter cannot be avoided. Also, the temperature is comparatively cooler if used after the HEPA filter.

2)Instead of 1 shaft, 2 shafts will be used. One which will be attached to the top of the casing and one to the bottom of the casing. The reason for this will be that the motor needed with specific RPM will not be able to bear the load; and as for the synchronization of the two fans, the pressure drop after the filter will create some turbulence. Therefore, synchronization is only possible if an axial compressor is used which has a cylindrical HEPA filter around it.

3) The bottom of the air-purifier will be having the pre-filter as the suction will be done from the bottom.

4) There will not be a rotor as there is not one readily available in the market of varying sizes. This when ordered separately will cost highly.

Calculations for CFM:

Step 1

Measure the room's width and length. Also measure the height of the room from the ceiling to the floor. Step 2

Multiply the three measurements from step 1 to determine the cubic footage of the room.

19 x 19 x 25 = 2256.25 cubic feet

Step 3

Multiply the cubic volume of the room by the number of times you want the air to turn over or exchange in an hour.

2256.25 x 2= 4512.5

Step 4

Divide your answer from step 3 by 60 to calculate CFM.

$$\frac{4512.5}{60} = 75.2083 \; or \; 75$$

IV. CONCLUSION

Today, the necessity is to cope up with a fast-paced life. In this sprint, we forget to look around and see what the nature has sacrificed. Day by day as the life of environment is deteriorating, it has become critical to live a healthy life. When the day arrives when cleaning the environment, we live in will be more prior than our fast-paced life is the time when the air-purifier will be taken heart. That day air-purifiers of today will not be able to clean the massive pollution. Efficiency and speed that our customized air-purifier provides will be of great importance at that time.

1) People will be having weaker immune system. Air-purifiers will help our following hierarchy to live in this critical condition.

•On an industrial scale, it will prove to be a boon as the industries and the space taken by them are increasing exponentially and with them are increasing the ever-increasing pollution from them. This is not only about cleaning the air waste but cleaning them with no time.

Isolate places like mines, caves where breathing with solace is a problem, air-purifiers can provide immediate air as well as breathable air. This can be achieved as the sucking and throwing power is doubled in this modified air-purifier.

No matter the altitude in plus or minus, we can receive the air well.

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