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Surface Functionalized 3D Printed Structures for Air Purification System

Vishal Francis[1], Khushal Jumde[2], Minal Nimje[2], Munjaji Bokhare[2]and Nitesh Goyal[2]
[1]*Lovely Professional University, Phagwara, India*
[2]*G H Raisoni College of Engineering, Nagpur, India*

Abstract

In India air pollution is increasing day by day and due to which the ill effects of it can be seen on the entire ecosystem.Cardiovascular and respiratory disease and even mortality rate attributed to fine particulate matter ($PM_{2.5}$) have risen over the past decades.To combat the problem, one of the strategy can be the usage of air purifying system/devices inside schools, offices and homes. The present paper aims to design and develop a device for purifying air using 3D printed patterned structures coated with activated carbon. The surface functionalized structures werefabricated using fused filament fabricationtechnique for adsorption of dust particles and toxins.The system consists of three stage air filtration including high-efficiency particulate air (HEPA) filter and surface functionalized printed structures.

Keywords: 3D printing, fused filament fabrication,activated carbon, air purifier.

Introduction

India has seen a rapid pace of economic and industrial development since few decades. However, along with this growth the menace of pollution to our urban centers has also increased. The increase in energy consumption,thermal power plants and industrial fumes have made the situation even worse. Moreover, the exhausts emanating from the increased number of vehicles on our roads have added to the problem of pollution [1-10]. For example, every year the onset of winters engulfs the national capital – Delhi in a thick smog cover, and the attempts made by government to curb this pollution are yet to showveritable results. Rising health problems in children, adults and seniors have been

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reported in major Indian cities like Delhi, Mumbai and Bangalore. Air pollution remains a contributing factor.Moreover, the situation is made worse in urban homes due to use of energy efficiency methods and improper ventilation which blocks the recycling of indoor air. This has led to indoor air pollution rising 10 times the number of outdoor air pollution under extreme scenarios.

Problemslike industrial air pollutions, cars CO_2 emission, burning of coal in thermal power plant, etc. have increased day by day. Due to which health issues such like lungs cancer, asthma, breathing problem are encountered [11-15].Given the current scenario, an air purifier is a must to have in homes for urban homeowners in India.

Measures have to be taken to combat this situation by finding alternative solutions to the energy sources which causes the problem. Also, it has to be ensured that the quality of the air should be purified. One of the ways to ensure purity of air in indoor arenas like school, offices and homes is to use the air purification systems. However, till date it has not become a common practice partially due to lack of awareness and partially due to unavailability of economicalpurifying systems.In this regard, attempt has been made to develop an economical air purifying system which uses surface functionalized 3D printed structures, and filters that can be utilized for indoor air purification.

Major components of the system

The 3D printed air purifier is a concept used to design a system for removing the polluted air from the indoor space. A surface functionalized 3D printed structures are utilized which have a coating of activated carbon. The system work on the concept of air filtration rather than air ionization. Air filtration permanently removes pollutants from the ambient air, whereas air ionizers only bring down the airborne particles and stick them to surfaces. The major components of the system consists of HEPA filter, activated carbon filters, guided air vent, blower, sensors and AC supply.

Air purifier’s works by sucking the air inside through fans which is passed through filter or a series of filters. As the air passes through the filters, the airborne particles such as bacteria, dust and other pollutants are removed and the purified air is circulated.

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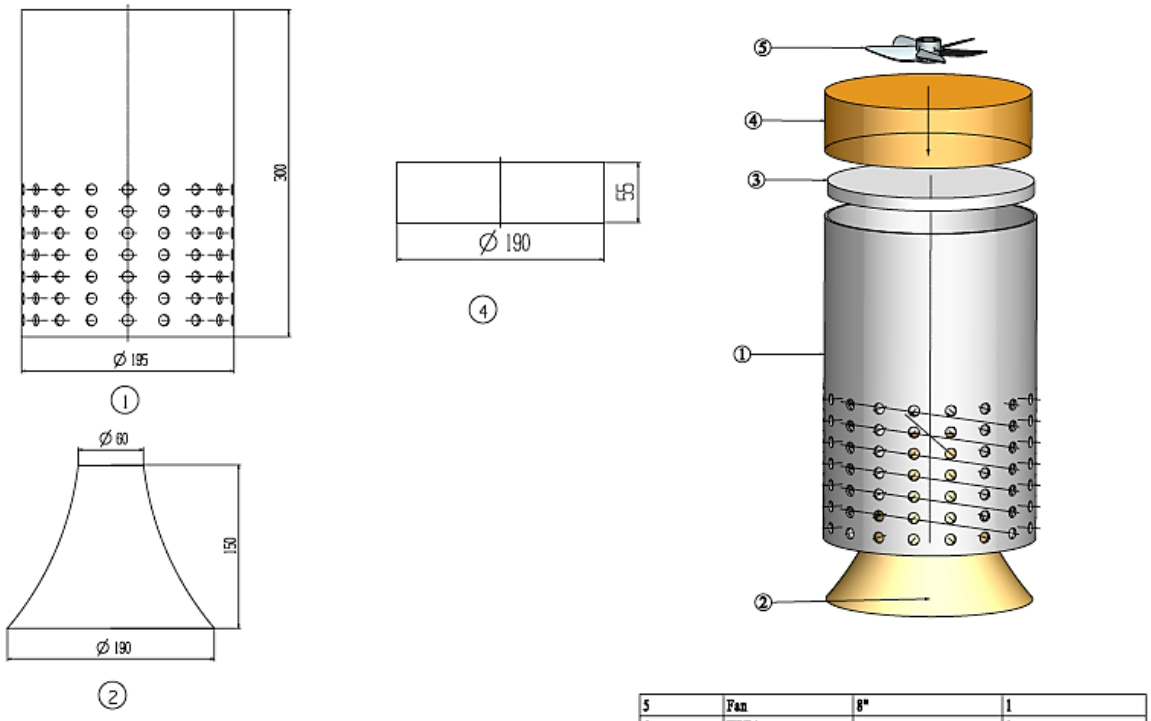
The air enters from outside through the holes and the air vent guide the air in upper direction which then passes through the stacked filter which is 3D printed and coated with activated carbon.Then the air passes through the HEPA filter and then the blower is mounted above the HEPA filter to extract the air outside. The system consist ofsurface functionalized 3 – stage filter fabricated with FFF process using ABS polymer and then post-processed with activated carbon for adsorption of dust particles and toxins. Figure 1 illustrates the components of the proposed air purifying system.



Part No.	Part Name	Material	Quantity
5	Fan	8"	1
4	HPEA		1
3	Stack	ABS	1
2	Airvent	ABS	1
1	Cover	GI	1

Figure 1 major components of the proposed air purifying system

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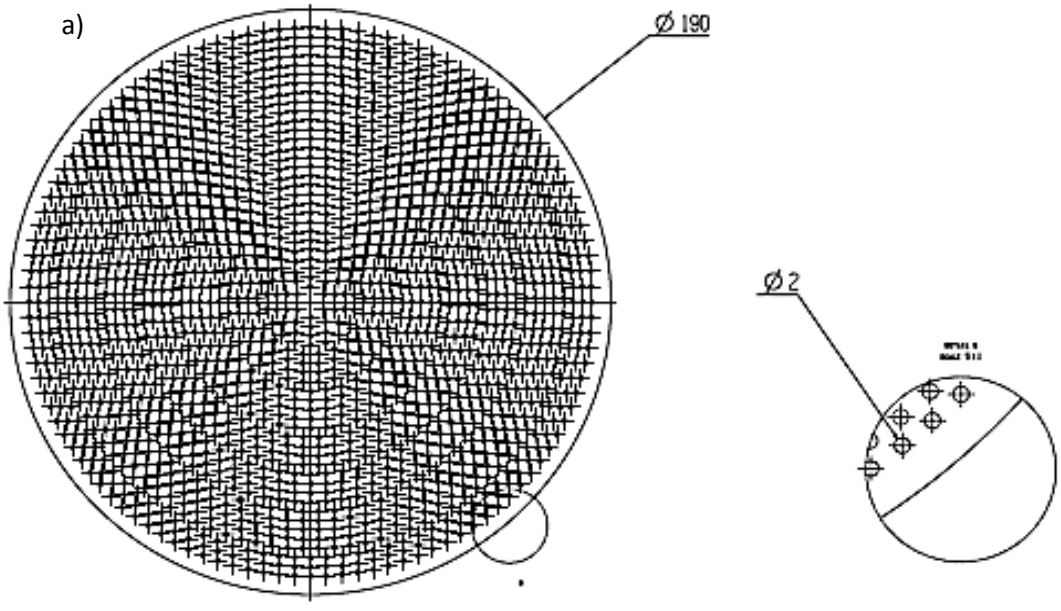
Surface functionalized 3D printed structures

The 3D printed structures were fabricated using FFF technique. ABS polymer was used to print the structures. The parametric settings of the printer were taken as per the machine manufacturer recommendations.Figure 2 a) and b) illustrates the details of the patterned structures fabricated.The disc shaped structures contains pores of circular and honeycomb shaped. The discs were arranged in such a way that the pores of two discs mismatches.So as to ensure the air passing through the firstshould come in contact with the surface of the second disc.The patterns were 3D printed and coated with activated carbon using acetone solvent



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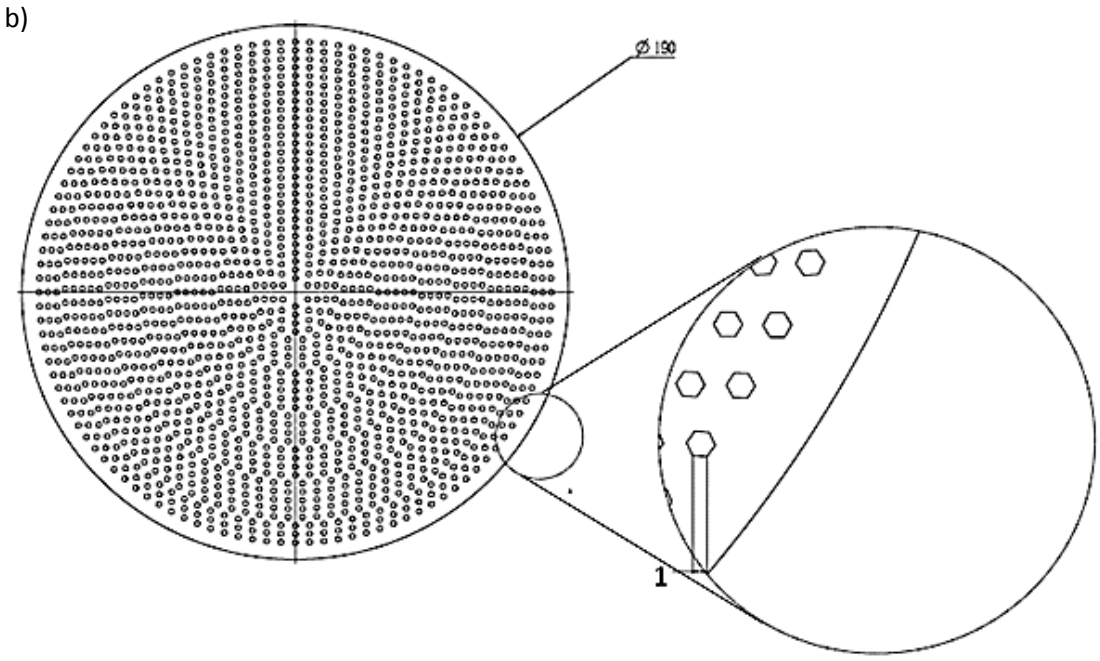

Figure 2 Porous structures for filters a) circular pores and b) honeycomb shaped pores

. Dip coating was adopted and the concentration of the activated carbon and dipping time was adjusted based on the preliminary experiments. The structures were printed in two halves due to the constraints of machine size and then afterwards assembled. The CAD model and printed parts after coating with activated carbon is demonstrated in Figure 3.

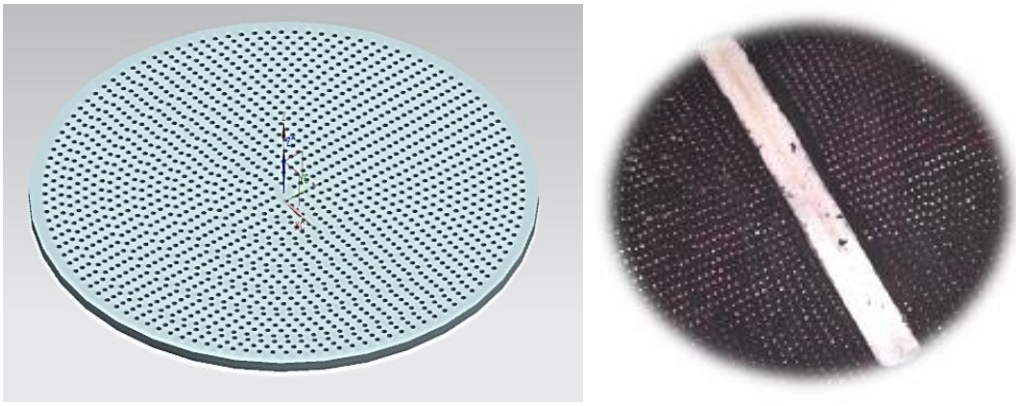

Figure 3 CAD model (left) and printed structure after coating with activated carbon (right)

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Integration of sensors and testing of the system

For testing of the proposed system, sharp dust sensor were installed as an integrated unit of the system. The dust sensor is an optical based sensor which senses the air quality. The presence of air borne fine particlesare detected by the photo detector as the dust particles reflects the light emitted by the infrared emitting diode (Figure 4).The intensity of the scattered light increases with the increase of the dust particles in the air [16]. The sensor was placed at the top of the system and interfaced with arduinouno microcontroller board. Readings were taken with and without running the air purifying system to compare the difference between the air qualities. The developed prototype was tested in a room of 12 × 8 × 9ft. in Nagpur city.On observing the readings without running the air purifying system, the average dust density was observed to be 0.01598 μg/m^3.After running the system the dust density reduced in few seconds. The observed average dust density value was to be 0.01598 μg/m^3.Figure 5 shows the observed values of dust density in running and non-running conditions for the purifying system. The system was capable of reducing approximately 68% of air borne particles from the room.

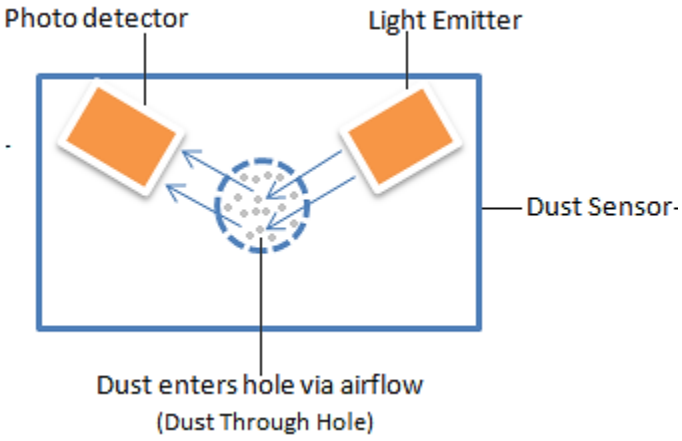

Figure 4 Illustration showing the detection of air borne particles

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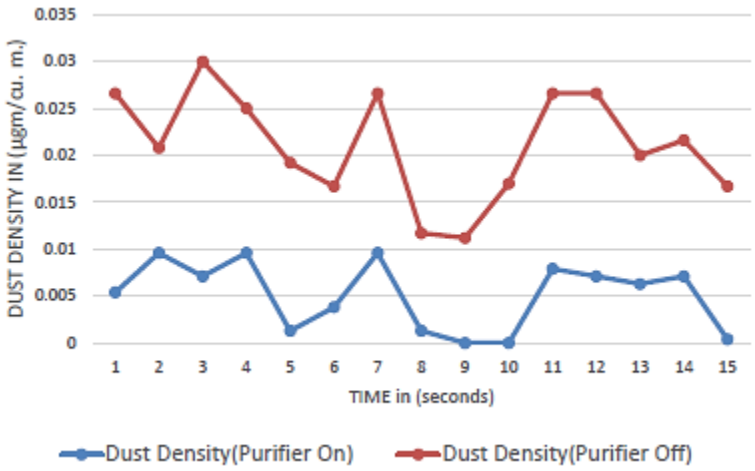

Figure 5 Reduction in dust density

Conclusion

The paper presents an approach to prototype an air purifying system. The issue of air pollution in India is critical and needs to be addressed.One of the ways to ensure good air quality in indoor arenas is to use the air purifying systems. In this work an attempt has been made to prototype a system with 3D printed surface functionalized structures. The structures were coated with activated carbon and used along the HEPA filters. The system is equipped with a dust sensor and is capable to reduce the air borne particles from the air.

68% reduction in dust density was achieved using the proposed system.

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