Journal of the Korea Academia-Industrial cooperation Society
Vol. 24, No. 3 pp. 402-408, 2023

https://doi.org/10.5762/KAIS.2023.24.3.402
ISSN 1975-4701 / eISSN 2288-4688

A Study on The Evaluation of The Concentration of Dust According to The 3D Print Open Shape

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3D 프린트 개방 형태에 따른 미세입자 농도 평가에 관한 연구

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Abstract Commonly used 3D printers are known to harm the health of users due to the emission of fine particles. This study was undertaken to determine the concentration of fine particles by evaluating the open form and work process of 3D printers. The 3D printers were classified into open type, closed type, and exhaust type, and the total fine dust emissions were measured using a fine particle meter. Compared to the closed type, the open type had twice the amount of total fine dust, and the measured value when the output was removed was 83% of the closed type. The exhaust type showed the highest measured value immediately after the removal of the output, and was determined to be 53% of the closed type. Our results indicate that the open type has a high risk of health hazards caused by fine particles, whereas the closed type and the exhaust type require management after the output is removed. We propose the necessity to develop recommendations based on number concentration standards for safety evaluation. Furthermore, workers require sufficient ventilation and need to wear protective gear for a certain period when working with 3D printers.

요 약 우리에게 친숙한 3D프린터는 미세입자 방출에 따라 사용자의 건강에 위해가 발생하게 된다. 이에 3D 프린터 개방 형태 및 작업 과정에 따른 미세입자의 수농도 측정을 평가하였다. 개방형, 밀폐형, 배기형으로 구분하여 미세입자 측정기를 이용하여 측정한 결과 총 미세먼지는 개방형이 밀폐형의 2배로 가장 높았으며, 출력물 제거 시 측정값은 밀폐형의 83% 수준이었다. 배기형은 가장 높은 측정값을 나타낸 시간은 출력물 제거 직후로 밀폐형의 53% 수준이었다. 따라서 개방형이 미세입자에 의한 건강상 위해 위험성이 높으며, 밀폐형 및 배기형은 출력물 제거 이후부터 관리가 필요하다. 다만, 안정성 평가를 위해 수농도 기준의 권고안 개발이 필요하며 3D프린터 작업 시 작업자는 충분한 환기와 일정 시간 이상의 방호구 착용이 필요할 것이다.

Keywords : 3D Print, Dust, Open Type, Sealed Type, Exhaust Type

1. Introduction

3D printing refers to the activity of outputting a 3D shape in 3D using an automated system. 3D printing technology developed since 1983 is designed using CAD (Computer Aided Design), 3D scanner, etc., and saved in STL file format, G-code is generated and output[1]. The resolution of 3D

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Received January 18, 2023 Revised February 21, 2023
Accepted March 3, 2023 Published March 31, 2023

printing is expressed as the thickness of a particle or layer, and generally has a diameter of 50 to 100 ㎛, but may be 16 μm in high resolution[2]. 3D printing methods exist in various ways as defined by the International Organization for Standardization (ISO) American Society for Testing and Materials (ASTM) 52900[3]. The advantage of 3D printing is that the process is not only short, but also that the number of parts can be reduced due to the high degree of freedom as no cutting work is required, reducing work time and cost, and ensuring safety[4]. On the other hand, there are disadvantages such as long manufacturing time for each part, high initial investment cost[5], and the need to select a material and understand its characteristics[6]. The biggest disadvantage of the 3D printing process is that it affects the health of workers[7].

During the 3D printing process, dust is generated in the process of disassembling and reassembling the filament for the product process, which affects the human body. Such dust refers to floating dust having a dust size of 10 ㎛ or less. Classification according to dust size is important because the smaller the dust size, the greater the risk to the human body[8]. Representative classification standards include Total Suspended Particles (TSP), which is the total amount of dust with a diameter of 50 ㎛ or less, PM10 with a diameter of 10 ㎛ or less, PM2.5 with a diameter of 2.5 ㎛ or less, and ultrafine dust[9]. It has been reported that exposure to fine dust is associated with an increase in mortality as well as respiratory and cardiovascular diseases[10-12]. In particular, in the case of PM10, it is mainly deposited in the upper respiratory tract or bronchi[13] and is known to be a major cause of cardiovascular diseases such as decreased lung function[14], vascular dysfunction, and thrombosis. In patients suffering from lung diseases such as asthma[15]. In toxicological studies, it has been reported that dust has stronger toxicological side effects than coarse particles[16], and it has been reported that the mortality rate increases whenever the concentration of PM10 in indoor air increases[17]. Normal 3D printing operations do not have serious and lasting health side effects[18], but exposure should be reduced to a minimum given the acute respiratory symptoms associated with long-term use[19].

Therefore, there is a need to evaluate the fine dust generated during the 3D printing process to recognize the user's risk, and to provide basic data on the fine dust of 3D printing. To this end, mass concentration and number concentration are generally used to evaluate fine dust in the air[20]. In the case of fine dust, it is known that the mass concentration is low, but the number concentration is relatively high. Therefore, it is necessary to evaluate using water concentration for the research evaluation of fine dust in the air. However, it is a reality that many researchers apply mass concentration rather than number concentration in the process of evaluating the effects of particulate matter on the human body[21,22].

In order to evaluate the harmful effects on human health caused by the use of 3D printing[23], it is necessary to first evaluate the overall exposure to dust[24]. In the case of a previous study, it was reported that the concentration of dust varies depending on various factors such as temperature, work speed, and type of filament[25]. In the case of low-cost 3D printing of the ME method, which is mainly used by the general public, a form in which all four sides are open or sealed during operation is often applied[26]. In addition, 3D printing has been developed in an unopened form that is opened after exhausting with an exhaust system installed after the work is finished. Therefore, in this study, the effect of dust according to the type of filament and the lapse of time was evaluated by dividing into open type, closed type, and exhaust type.

2. Materials and Methods

The research subject applied 3D printing of open type, closed type, and exhaust type. Ender-3 pro (Creality 3D, China) was used for the open type, and Creator3 (FlashForge, China) was used for the closed type. And the exhaust method was Ghost 5 (Flying Bear, China). The filament applied at this time was NC-PLA-1.75-500 (NorthCube, China), which is Poly Lactic Acid(PLA), and a Dust Particle Counter (TC-8200, China) was used to measure the number concentration. At this time, the dust measurement range of the Dist Particle Counter is 0.3 to 10 ㎛ (6-channel), the mass concentration range of PM 2.5 is 1000 ㎍/㎥, and the accuracy is ±10 %.

To produce the same rectangular cylindrical tube structure with three types of 3D printers, insert filament and set the temperature to 220 ° C. The location of the measuring device was measured at a distance of 1 m from the front of the 3D printer and at a height of 20 ㎝ from the bottom of the printer. At this time, the structure of the measurement site was 4.3 m wide, 8.0 m long, and 3.4 m high, and the 3D print was placed on a table with a height of 1.0 m in the center. And there is no structure on the front of the 3D printer except for the front door, and desks and monitors are placed at a distance of about 100 ㎝ at the rear.

For evaluation over time, a total of 19 measurements were taken at 5-minute intervals, from 10 minutes before printing to 80 minutes after printing, as shown in Fig. 2. The fine dust collection time was measured for 1 minute and the maximum value was recorded. At this time, the required printing time is 40 minutes, and the +40 min measurement was performed simultaneously with the removal of the printed material. And in the case of the exhaust type, the operation starts immediately after the output is finished, and it was operated until the last measurement time of +80 min. In order to reduce the error between measurements, a total of 3 repetitions were conducted, and the measurement interval had an interval of more than 6 hours under sufficient ventilation conditions.

Fig. 1. Measuring tools

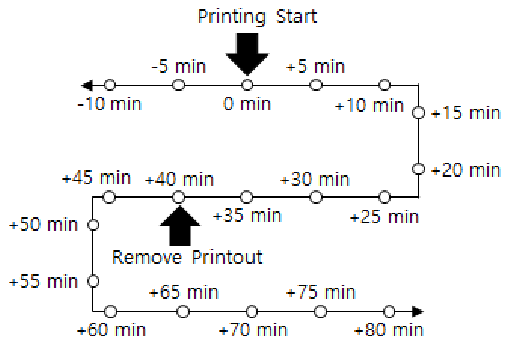

Fig. 2. Measurement time according to 3D printer operation

3. Results

3.1 Comparison of water concentration by opening and closing type

The average number concentration comparison result according to the opening and closing form of the 3D printer was shown in Fig. 3. As a result of comparing the average sum of the number concentration values measured according to the opening and closing types of the 3D printer, the open type showed a minimum of 42.6 to a maximum of 428.0 particles/㎤ depending on the size of the dust, and the sealed type showed a minimum of 23.4 to a maximum of 245.1 particles/㎤. , in the case of the exhaust type, a minimum of 8.6 and a maximum of 104.9 particles/㎤ were obtained.

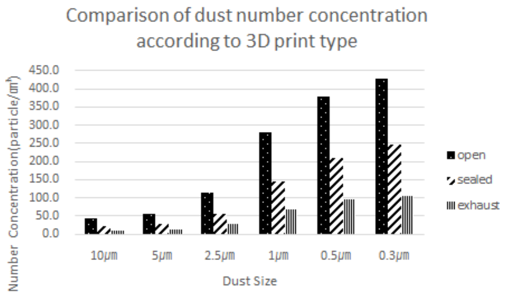

Fig. 3. Total measured amount of dust number concentration according to opening/closing type

3.2 Comparison of number concentration over time

The average number concentration results over time for each opening and closing type were shown in Fig. 4 through 6. In the case of the open type, the measured value at +35 min was the highest at 2,038 particles/㎤, and in the case of the sealed type, the measured value at +40 min was the highest at 2,372 particles/㎤. Finally, in the case of the exhaust type, the measured value at +40 min was the highest at 1,254 particles/㎤.

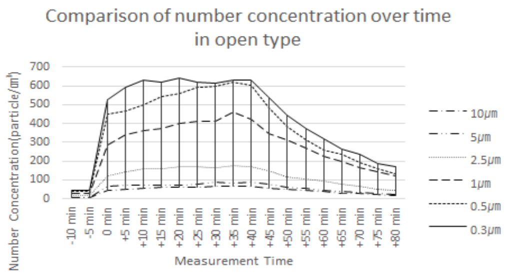

Fig. 4. Dust number concentration over time in open type

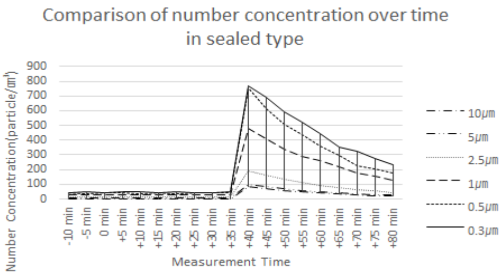

Fig. 5. Dust number concentration over time in sealed type

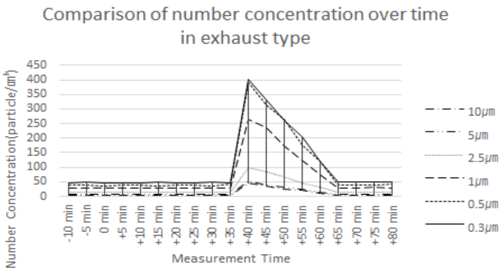

Fig. 6. Dust number concentration over time in exhaust type

4. Discussion

3D printing technology is applied in various fields and is being continuously researched, and is used in various places such as educational institutions, hobbies, and industries. Recently, news about the occurrence of lung diseases in users due to the use of 3D printers has been reported, but as various types of 3D printers have been developed, the research has been conducted as basic data for research on the generation of fine dust for each model. What is noteworthy is that the measured value of +40 min in the case of the seaded type increased from a minimum of about 1.09 times to a maximum of about 1.26 times compared to the open type. This is because, in the case of the sealed type, the outflow of fine dust increases as the window is opened to remove the output. However, in the comparison of the total number of fine dust over time, the open type showed a minimum increase of about 1.75 times and a maximum of 2.02 times compared to the sealed type. Therefore, it can be said that the exposure of workers to fine dust is higher in the open type. In addition, in the measurement, it was found that the smaller the diameter of the dust, the larger the number of dust emitted. However, more diverse environments should be considered as the research progresses, but it is limited and additional research is needed in the future. In particular, the dust emission tendency may vary depending on the type and temperature of the filament, and it is determined that there will be a change due to various factors such as temperature, humidity, atmospheric pressure, and wind speed at the measurement site.

Comparing the results of this study, compared to sealed type printers, open type printers do not trap or filter generated dust within the printer, so from the start of printing, higher dust emissions than sealed type printers are shown. However, in the case of the sealed type, there was no significant change in the amount of fine dust emitted before and during printing, while a large amount of concentrated fine dust was released when the window was opened to remove the print, resulting in a higher fine dust measurement value after the end of printing. Even in the case of the exhaust type, the amount of fine dust emitted by the removal of the output increased, but the measured value was lower than that of the open or sealed type. This is because the fine dust is kept below a certain level by the automatic exhaust system, so even if the window is opened, the fine dust emitted is reduced.

In order to evaluate the attenuation to the stable level for fine dust measurement values, the recommended standards should be reflected. However, the domestic fine dust recommendation standard is 50 ㎍/㎥ per year for PM10, 100 ㎍/㎥ for 24 hours, 15 ㎍/㎥ for PM2.5, and 35 ㎍/㎥ for 24 hours[27,28]. Concentration is recommended. Therefore, the recommended standard for number concentration has not yet been presented, and the time required for stabilization should be evaluated and reflected based on the initial measurement value, which is the background value. In other words, it can be said that the stable level is restored after about 1 hour after the end of output in case of open type and sealed type, and about 25 minutes after end of output in case of exhaust type.

5. Conclusion

Dust emissions from 3D printers cause harm to the health of users. In order to solve this problem, as shown in the research results, an exhaust type 3D printer must be used. In actual research results, as a result of comparing the total concentration of fine dust according to the opening and closing type, it was confirmed that the exhaust type has a fine dust reduction effect from a minimum of 3.93 times to a maximum of 4.95 times. In addition, in the results over time, in the case of the open type, a maximum of 14.45 times in the measurement before removal of the output, in the case of the sealed type, a maximum of 7.33 times when the output is removed, and in the case of the exhaust type, a maximum of 9.15 times when the output is removed. Through this, it was found that the risk of fine dust appeared the highest when the output was removed. However, according to the opening/closing type, the open type showed a continuous increasing trend, while the remaining types showed a rapid increase when the output was removed. However, for a more precise evaluation in the future, a detailed evaluation is required in consideration of the type of filament used, application temperature, and workroom environment. In addition, considering the reduction in the concentration of fine dust by type, care should be taken not to cause harm to the user's health by wearing protective gear along with ventilation for a sufficient time. As a result of inference based on the research results, the tendency to decrease after measuring the maximum value of fine dust showed a decrease of at least 8.08% and a maximum of 29.14% per hour depending on the particle size, although there were some differences depending on the shape. The reduction rate of PM10 was high, whereas the reduction rate was the lowest in the case of PM5 and PM2.5. Through this, in order to reduce the user's health hazard due to fine dust, it will be necessary to wear protective equipment that can filter up to PM2.5 as much as possible. It is hoped that this research will serve as an opportunity to improve the awareness of 3D printer users and secure health safety, and hope that additional research will be used as basic data for the safe use of new technologies in the future.

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