The Effect of High-Pressure Cooling Systems in FDM 3D Printers on VOC and PM Emissions

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Abstract—3D printing has undergone many changes since its inception and has found its place in industry, education and increasingly in the home. However advantages, that are low cost and shorter time of production compared with traditional methods, the 3D printing is accompanied by emissions of particulate matter (PM) and volatile organic compounds (VOCs), which can negatively affect health and environment. This article is focused on the analysis of creation of PM and VOC during 3D print with high-speed cooling. We examine the effect of this cooling to of prints and the amount of emissions produced based on available literature and knowledge. We suggest possible ways to reduce emissions, including the use of filters and optimising print settings, to minimise the impact on users and the environment.

Keywords—Cooling system, 3D printers, emissions, high pressure cooling

I. INTRODUCTION

Nowadays, the availability of 3d printers is higher than ever. High-quality 3D printers can be obtained at relatively low cost, leading to their growing popularity not only in industry and education, but also in the home. However, this increase, there is also growing interest in the safety of 3D printing for human and environment. During process of printing printer releases particulate matter (PM) and volatile organic compounds (VOCs) into the air. This can negatively affect air quality and this can be health risk, e.g. by entering the lungs or brain.

Modern 3D printers, for example PRUSA HT90 or community projects of 3D printers VORON and VZBOT, that are equipped high-speed fans enabling high-speed printing. This shift in speed can affect not only the quality of the prints but also the amount of emissions produced. Prints printed at high speeds often exhibit a rough or dull surface, which can be caused by high temperatures or by material micro-particles breaking off due to high airflow pressures.

The aim of this work is to investigate the effect of high-speed cooling on the formation of VOCs and PM particles during 3D printing. Based on the analysis of available literature and knowledge, we will focus on understanding the mechanisms of emission formation and propose possible ways to reduce the amount of emissions. This includes the use of different types of filters and modification of printing settings to minimize negative impacts on both users and the environment.

II. PM AND VOC

Particulate Matter are small solid particles or droplets, which are pollute the air and can serious problems for human health and the environment.

A. Division

1. PM10 – particles up to 10µm in size
2. PM2.5 – particles up to 10µm in size
3. PM1 - particles up to 1µm in size. These particles are the most dangerous because they penetrate deep into the lungs and bloodstream

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B. Risks of PM

- PM2.5 and PM10 can cause respiratory and cardiovascular problems
- They penetrate the airways, causing inflammation, asthma etc.
- The mostly dangerous are for children, seniors and people, which heath and lungs illnesses

C. VOC

Volatile organic compounds are hazardous substances that are easily released into the air at the room temperature and can originate from natural or human activies:

- Natural origin - plants or decomposition of organic material
- Human activity - exhaust fumes, paints, varnishes, detergents or fuel combustion

D. Risks of VOC

- Short-term exposure – eye, nose, throat or headache irritation
- Long-term exposure – damage to the liver, kidneys nervous system and increased risk of cancer

From a 3D printing perspective, the risks of PM and VOC particles are a significant concern, as the printing process itself generates small particles such as PM2.5 and PM1, and VOC gases such as styrene and formaldehyde, the amount of which depends on the material chosen. Research has shown that ABS and ASA filament printing in particular results in significantly higher emissions, with nozzle temperatures above 240°C amplifying this effect.

III. HIGH-SPEED COOLING TECHNOLOGY

In recent years, 3D printing has been developing rapidly, with one of the main goals being to increase print speed without compromising print quality. Traditional cooling methods, such as passive or slightly active cooling, are often not sufficient for high-speed printing. That's why high-pressure air cooling is coming to the fore.

A. Use of turbo blowers and CPAP tubes

High-pressure cooling in 3D printing uses turbochargers capable of generating a powerful airflow. Originally designed for medical devices such as CPAP (Continuous Positive Airway Pressure) machines for the treatment of sleep apnea, these turbochargers have been adapted for the needs of 3D printing. This innovative adaptation allows for more efficient heat removal from the material being extruded. Flexible tubing from the CPAP systems ensures precise routing of air to specific locations, increasing the quality and accuracy of the resulting prints.

B. Advantages of high-pressure cooling

- Faster material solidification: a strong airflow accelerates the cooling of the material being extruded, which is crucial for high-speed printing
- Reduced deformation: efficient cooling minimizes the risk of deformation and improves the mechanical properties of the prints
- Increased productivity: the ability to print faster without sacrificing quality increases the overall efficiency of the process

C. Disadvantages of high-pressure cooling

- Rough, matt surface of prints: Intense airflow can cause mechanical detachment of material particles, resulting in a rough and matt surface
- Increased temperature: Improperly adjusted cooling can paradoxically lead to increased temperatures in certain areas, negatively affecting print quality

- Noise and power consumption: turbo blowers can be noisy and power-hungry, which can be a disadvantage in certain environments

D. High-pressure cooling systems at 3D printing laboratory FRI UNIZA

At Faculty of management science and informatics, we use two FDM 3D printers, the vzbot 330 and vzbot 235, equipped with high-pressure cooling systems utilizing WS7040 24V V200 fans.

IV. Introduction to VzBot 330 and VzBot 235 3D Printing Projects (6,7)

In our workplace, we utilize two advanced 3D printers: the VzBot 330 and the VzBot 235, both equipped with high-pressure cooling systems using WS7040 24V V200 fans. These printers are designed to meet the demanding needs of high-speed and high-precision 3D printing projects.

A. VzBot 330

The VzBot 330 is a high-speed, moderately sized 3D printer originally based on the TronXY X5SA frame. It features a build volume of 330x330 mm, making it suitable for larger prints. The VzBot 330 is known for its robust construction and ability to handle high-speed printing . The integration of high-pressure cooling systems ensures efficient cooling, which is crucial for maintaining print quality and preventing warping, especially with materials like PLA.

B. VzBot 235

The VzBot 235 is a smaller, more compact version of the VzBot 330, with a build volume of 235x235 mm. Despite its smaller size, the VzBot 235 is equipped with the same high-performance features, including the high-pressure cooling system. This printer is ideal for projects that require precision and speed, and its compact size makes it a versatile addition to our 3D printing capabilities.

C. High-Pressure Cooling Systems

Both the VzBot 330 and VzBot 235 are equipped with WS7040 24V V200 fans, which provide high-pressure cooling. This system is essential for high-speed printing as it helps to quickly solidify the extruded filament, reducing the risk of defects and improving overall print quality. The high-pressure cooling is particularly beneficial for materials like PLA, which require efficient cooling to maintain their structural integrity.

The combination of the VzBot 330 and VzBot 235 with high-pressure cooling systems allows us to tackle a wide range of 3D printing projects with precision and efficiency. These printers are not only capable of producing high-quality prints at high speeds but also offer the flexibility needed for various applications in both professional and advanced hobbyist settings.

D. Example of Specification of WS7040-24-V200 fan.

The WS7040-24-V200 is a high-performance centrifugal blower fan designed for various industrial applications. Here are its key features (5):

- **Motor Type**: Three-phase DC brushless motor.
- **Bearing Type**: NMB ball bearings, ensuring a long lifespan with a Mean Time To Failure (MTTF) of over 20,000 hours at 25°C.
- **Voltage**: 24V DC.
- **Airflow**: Maximum airflow of 25.5 m^3/h at 0 kPa pressure.
- **Static Pressure**: Can achieve a maximum static pressure of 6.5 kPa.
- **Speed**: Operates at a speed of up to 45,000 RPM.
- **Noise Level**: Approximately 70 dBA.

- **Housing Material**: Made from durable plastic (PC).
- **Weight**: 85 grams.
- **Dimensions**: Diameter of 70 mm and height of 40 mm.
- **Protection Class**: IP20, suitable for indoor use.
- **Operating Temperature Range**: -20°C to +60°C.

E. Applications

The WS7040-24-V200 is in general suitable for use in:

- Air cushion machines
- CPAP machines
- SMD soldering rework stations
- Other industrial and medical equipment requiring efficient air movement.

F. Advantages

- **Durability**: Long lifespan due to high-quality bearings and brushless motor.
- **Efficiency**: High airflow and static pressure capabilities.
- **Versatility**: Suitable for a wide range of applications.

Based on our experience, the WS7040 fans are extremely effective for high-speed printing and scenarios requiring intensive cooling, such as with PLA material. However, potential drawbacks include high noise levels at maximum airflow, high minimum airflow rates for certain materials like ABS, and significant delays in response to sudden changes in airflow compare to the higher dynamics of print head movement in high-speed printing. These issues can be addressed, for example, by the PRUSA HT using a servo valve to control the throughput of the fan.

In general, the use of the WS7040 can be the powerful solution for the most demanding applications for advanced hobby enthusiasts or in the professional 3D printing sector.

When using maximum airflow of the fan, we observe a matte and rough surface on prints at typical speeds and accelerations (below 100mm/s and 2000mm/s²). It is well known that excessive cooling can lead to poor layer adhesion due to overcooling. Our hypothesis to verify is that high-pressure cooling can also dislodge material particles, contributing to higher emissions of VOCs and PM.

Picture: comparison 0% vs 100% airflow effect on the surface of the 3D printed model.

V. Conclusion

In future work, we propose to test VOC and PM emissions using sensors to study the dependency on the amount of cooling. We suggest investigating the impact of high-pressure cooling on the concentration of PM and VOC particles in the air during printing with high-pressure cooling. For this purpose, sensors such as the **TSI DustTrak II** for PM measurements and the **Aeroqual Series 500** for VOC detection can be utilized. These sensors will help quantify the emissions and provide insights into how cooling intensity affects air quality in the printing environment. Additionally, as shown in the images where we demonstrated the surface differences based on fan airflow, it is crucial to understand how varying cooling rates can influence both the print quality and emission levels.

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