KEEPING WORKPLACES FREE FROM AIRBORNE EMISSIONS

Joshua Evans shows how portable fume and dust extraction technology can help to maintain a healthy and productive environment in additive manufacturing and 3D printing settings

Over the last 12 months the Covid-19 pandemic has brought to the fore the value of additive manufacturing (AM) and 3D printing processes as efficient and cost-effective methods of manufacturing.

AM has been used for a long time in advanced manufacturing across many sectors, including automotive, aerospace, defence, medical devices and electronics, thanks to its ability to shorten production cycles, reduce tooling costs and waste material. However, the wider public became much more aware of the benefits of AM at the start of the pandemic in 2020, when advanced manufacturers, as well as 3D printing hobbyists, became critical parts of the supply chain, mass producing products for frontline health and care services.

Less visible are the enabling technologies that keep these operations working. For example, BOFA's fume and dust extraction systems played a vital role in keeping production lines moving by ensuring workplaces were free from airborne emissions that could be harmful to human health and might also interfere with production quality.

CONTINUOUS MONITORING

It is this twin imperative that drives AM businesses to undertake continuous monitoring of their extraction systems, particularly where there is a range of materials being worked.

This is important, not just for productivity reasons, but to ensure that operations meet the rigorous occupational exposure limits for airborne contaminants specified by different regulatory regimes around the world including Control of Substances Hazardous to Health (COSHH) in the UK.

Some health, safety and environment legislation and guidance has been re-purposed to accommodate this evolving industry, as many studies confirm the presence of fume, gases and particulate in AM processes, highlighting the need for effective extraction systems to capture potentially harmful emissions.

PBF AND DIRECTED ENERGY DEPOSITION

For example, powder bed fusion (PBF) and directed energy deposition processes use a high energy source to melt specific areas of material. This can be in the form of a powder bed or solid wire in a variety of different materials from polymers all the way to titanium.

When the high energy source hits the material, a very fine emission of particles can result. An example would be the laser from a PBF process hitting a metal powder bed. The ablation mechanism from the laser will instantaneously boil and then condense the metal powder, creating a cloud of ultra-fine particulate.

To keep these processes controlled, typically the atmosphere inside the printer is sealed and sometimes composed of an inert gas. Where this isn't viable, an inert source is aimed at the target area for deposition.

Due to the enclosed nature of the process, the risk to user health during printing is substantially decreased; however, particulate residue on equipment can result, which can compromise quality. Additionally, any build-up of particulate can lead to premature durability concerns and a risk to the user after printing when handling any finished component. Similar risks can be present when post processing, for example de-powdering.

> *"BOFA's fume and dust extraction systems played a vital role in keeping production lines moving"*

VAT POLYMERISATION AND MATERIAL JETTING

In another example, vat polymerisation and material jetting typically use either UV light or digital light processing to cure photopolymer resin. The resin is photoreactive, which then hardens as it is hit by the light.

This process presents several opportunities for gaseous release. Firstly, there is the resin itself, which may contain some compounds which cannot wait to evaporate, even at room temperature. Then, some printers heat the resin which obviously elevates the temperature and provides more energy for other noxious gases to make their escape. Finally, there is the photoreaction itself where even more energy being applied can lead to further unwanted chemical by-products (A. B. Stefaniaka, 2019).[1]

Some of these released gases, such as acrylic acid and cumene hydroperoxide can be hazardous to humans and are categorised as a mild irritant and others as fully toxic, leading to a wide range of effects from headaches to much more serious health conditions.

In material extrusion, material is forced through a heating nozzle so it becomes pliable and the printer then layers the molten

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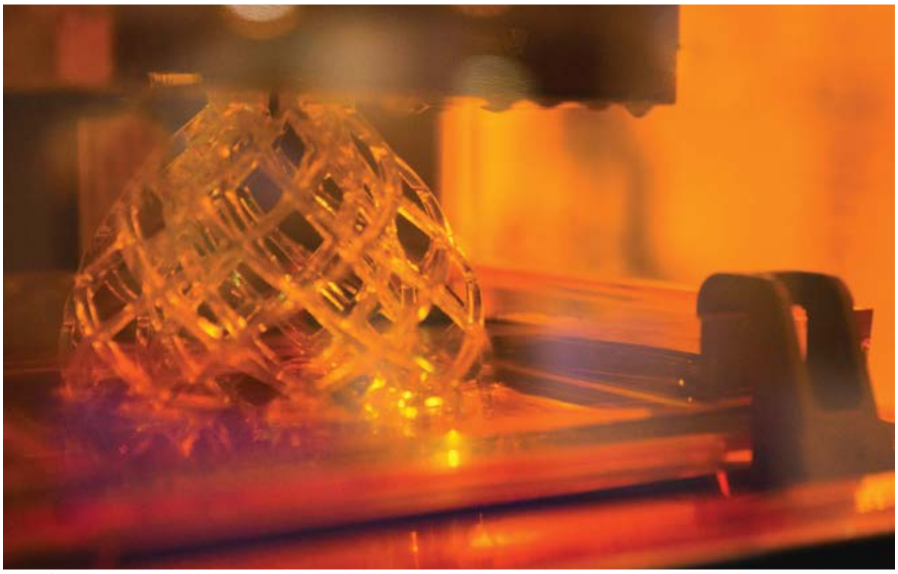
Fused deposition modelling



Vat polymerisation

material until the final object is complete. The combined shear force and heating process of polymers breaks down the material but, unfortunately, emits a fume which presents a health risk to operatives. The particle sizes emitted are very small, well below 1 micron (Health and Safety Executive, 2019)[2], and the emission rate of particulate increases with nozzle temperature.

PARTICLE SIZE

This highlights a critical factor that AM users need to take into account when looking at extraction systems – the size of particles emitted from the process. This is key to understanding the potential impact on health, notably how far into the human body any given airborne contaminate can penetrate.

> *"Size of particles emitted from the process is key to understanding the potential impact on health"*

Particles of 30 microns are roughly what you can see with the human eye; at 10 microns particles enter your mouth and nasal cavity; at 5 microns particles enter your respiratory tract; at 2.5 microns they can enter your lungs; and particles around 1 micron will reach the extremities of your lungs (Praznikar, 2012).[3]

Nanoparticles are worthy of special mention because, if not captured in an extraction process, they possess the ability to pass through membranes into the human body (Ostiguy C, 2008)[4].

CHOOSING A FUME EXTRACTION SYSTEM

The key point here is to specify extraction technology that can demonstrably capture fumes, particulate and nanoparticles associated with the materials being worked, for example by reference to data sheets. In addition, the volume of airborne particulate being generated must be taken into account when researching and identifying the filtration system best suited to the application.

Remember, not controlling particulate can also negatively impact AM printer efficiency and increase the risk of product contamination, for example through a build-up of sticky plastic droplets on critical components. This can lead to quality and reliability issues, costly unscheduled downtime and, in a worst-case scenario, the need to replace equipment.

So, with these risks in mind, I would urge manufacturers to choose a fume extraction system that incorporates the following:

1) A pre-filter (to remove larger particulate and, therefore, protect the more expensive main filter).
2) A HEPA filter (to remove nanoparticles).
3) An activated carbon filter (to remove vapours and gases).
4) Smart operating systems which can regulate airflow and monitor filter condition to optimise filter life and ensure timely exchange.

It is also worth considering the high temperatures involved in some AM processes. Here, a sealed filter exchange design

> *"Some of these released gases can be hazardous to humans"*

can remove the risk of thermal events in pyrophoric material operations. And, under certain circumstances, manufacturers might also consider whether an application would benefit from fire-resistant materials for casings and filters, a spark arrestor and thermal cut-out protection to mitigate the risk of burning particulate entering the extraction system. ■

1 *A. B. Stefaniaka, L. N. (2019). Particle and vapor emissions from vat polymerization desktopscale 3-dimensional printers.*

2 *Health and Safety Executive. (2019). RR1146 - Measuring and controlling emissions from polymer filament desktop 3D printers. London: Crown.*

3 *Praznikar. (2012). The effects of particulate matter air pollution on respiratory health and on the cardiovascular system.*

4 *Ostiguy C, S. B. (2008). Health Effects of Nanoparticles.*

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