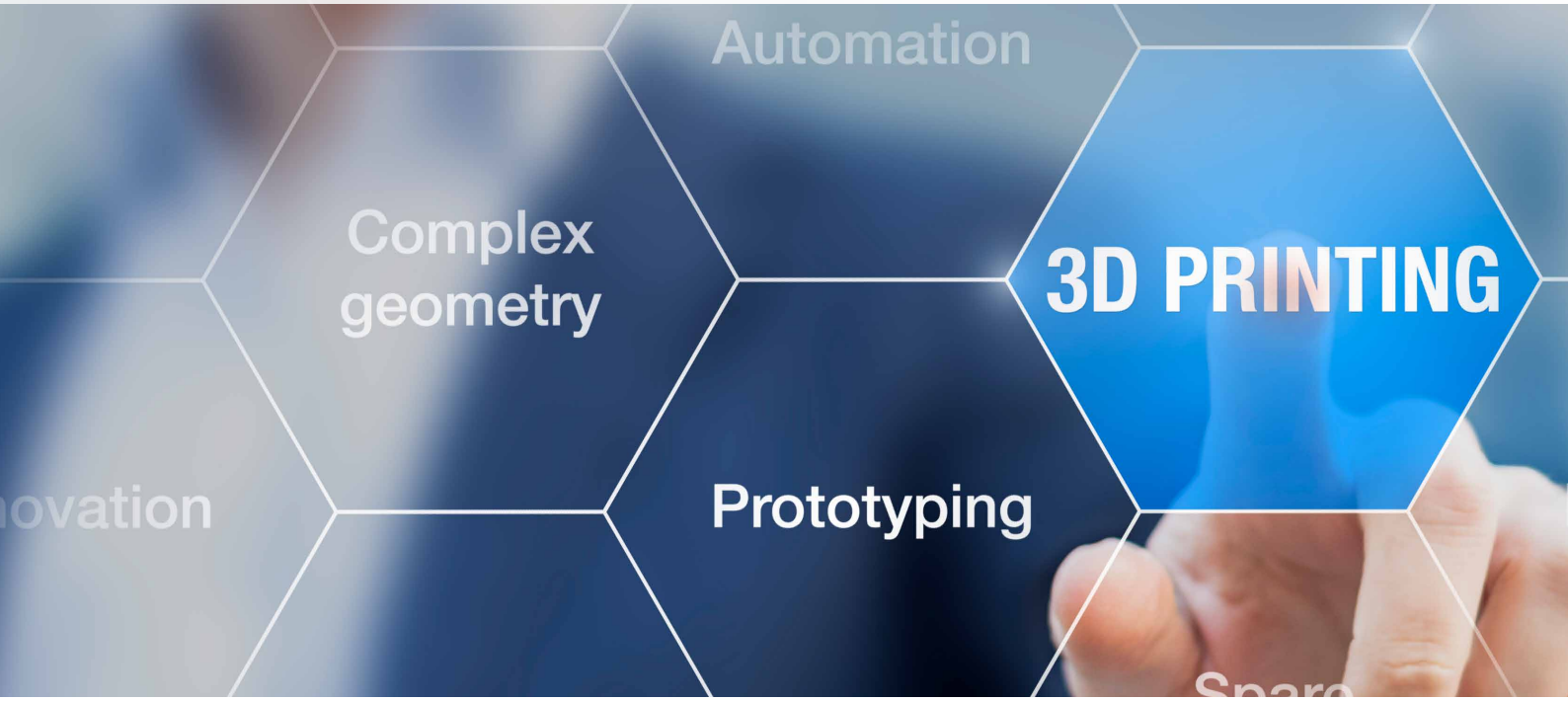

FOCUS ARTICLE

Additive Manufacturing and Related Combustible Dust Hazards

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and Steven J. Luzik PE, CFEI, Senior Process Safety Specialist

Over the last few years we have witnessed the expansion of additive manufacturing using 3D printers, from their utilization as a prototyping tool to increasing implementation on the plant floor. The rapid evolution of this technology and its applications has created new challenges for process safety. These challenges involve understanding powder combustibility properties and how best to implement reliable measures to prevent fires and explosions during powder processing and handling.

If you are involved in purchasing a 3D printer or a building official charged with reviewing and approving its use in your community, you need to be aware of certain hazards and what to do about them.

Risks in The Process of Additive Manufacturing

Materials used in additive manufacturing cover a very wide range, from plastics such as nylon, ABS, high density polyethylene, polyethylene terephthalate and others, to metals such as stainless steel, titanium, aluminum and their alloys or even gold or silver. Most of these materials are combustible and, therefore, explosive as dusts. The 3D printing process itself generates dust; in fact, it can produce very small particles (even in the nanoparticle range). Some metals such as titanium and aluminum can burn very fast and produce extremely high temperatures and pressures, necessitating extra caution. Some metals, like titanium, require a special mention for their high explosion index.

The degree of hazard linked to dust is heavily dependent on the

amount of material in question, and its behavior in that quantity. A dust explosion is caused by the rapid combustion of particles suspended in air in an enclosed space. When these particles come into contact with a spark, an open fire, an overheated surface or electrical discharge from machinery, an explosion can occur. The image below, used by OSHA and other agencies to communicate the risks of powder handling, illustrates how fire and explosion result from a combination of conditions. As shown, when handling combustible dust or powder in ambient

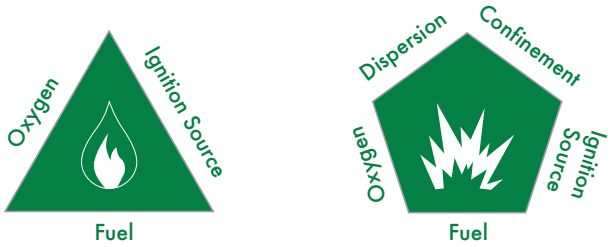

Figure 1. Fire triangle and explosion pentagon. Users of additive manufacturing are often working with fuel and oxygen, so ignition sources need to be avoided to prevent fires or explosions.

atmospheres, all that is needed is a suitable ignition source to initiate a fire. If this occurs in the presence of a dust cloud with many particles dispersed in a contained area, it could lead to a larger, more damaging explosion in a matter of milliseconds. Preventing metal dust clouds from forming is therefore of paramount importance.

What to Do About These Risks?

Management of the hazards posed by combustible dusts has been regulated in the last decades. For instance, the so-called ATEX Directives and ISO standards (mainly ISO 60079) apply in the European Union and some other countries. In the United States, National Fire Protection Association standards (mainly **NFPA 652**, 654 and specifically for metallic dusts, NFPA 484) aim to reduce combustible dust hazards.

These standards and regulations require measures to be taken to capture and contain fugitive dust generated during machining activities. The standards outline prescriptive requirements for these dust collection systems that govern the design and construction of the containment equipment, or call for explosion venting or explosion suppression systems. In lieu of prescriptive requirements, performance-based approaches can also be considered in order to manage these hazards. These approaches typically may be scrutinized by Authorities Having Jurisdiction (AHJ's). While there are standards for metal dusts in general, specific questions may arise when it comes to additive manufacturing, such as requiring the electrical equipment inside the printers to be classified for use in hazardous areas, explosion or deflagration venting, and limitations on the handling and storage of materials, all of which can significantly influence the cost of installing a 3D metal printer.

We suggest you formulate your combustible dust fire and explosion management program to include the following steps before you implement a 3D printing process on your premises:

Developing a Dust Sampling and Testing Program – to identify and test materials present in the process to determine the explosibility and ignitability characteristics necessary to complete the analysis;

Dust Hazard Analysis (DHA) – to identify potential unsafe operating conditions and potential risks in the design and to provide recommendations for appropriate process safety measures, including engineering controls, equipment and procedures;

Development of Written Safety Procedures – to detail the procedures and operational guidelines necessary for the safe operation of the facility;

Fundamentals of Combustible Dust Training Program – to train your personnel on-site.

DEKRA Process Safety has several senior process safety specialists with extensive knowledge and experience in additive manufacturing processes involving combustible dusts.

Effective risk management requires an understanding of the specific hazards associated with these powders/dusts and of the risks that may be present at your particular facility based on its likelihood and severity parameters. Our experts have worked with many clients on these issues and can assist you in developing strategies to ensure safety, including housekeeping, dust control and separation and segregation. We offer comprehensive testing in the areas of **combustible dust explosibility** and ignitibility properties, **electrostatics**, and **thermal stability**.

DR. ARTURO TRUJILLO

Dr. Arturo Trujillo is Global Director of Process Safety Consulting. His main areas of expertise are diverse types of process hazard analysis (HAZOP, What-if, HAZID), consequence analysis and quantitative risk analysis. He has been involved in many projects over the last 25 years, especially in the oil & gas, energy, chemicals and pharmaceutical industries.

STEVEN J. LUZIK

Steven J. Luzik, PE, CFEI is a Senior Process Safety Specialist at DEKRA Process Safety with over 30 years experience in the area of fire and explosion hazards including gas/vapor explosions, dust explosions and fire and explosion protection strategies. He graduated from the University of Notre Dame with a BS degree in Chemical Engineering. He is a registered Professional Engineer in the State of Pennsylvania and a Certified Fire and Explosion Investigator (CFEI) with the National Association of Fire Investigators (NAFI). As a former Mine Safety and Health Administration [MSHA] manager and technical specialist, he has investigated a multitude of incidents involving flammable vapors, gases and dusts that have included surface and underground mining facilities and industrial facilities where fires and explosions have occurred. He has conducted dust explosion hazard assessment at several coal-fired power plants. He also has served as a moderator of a flammability and dust explosibility laboratory, processing requests from MSHA and other Federal agencies for testing to determine the flammability and explosibility properties of solids, liquids, dusts and vapors. In this capacity, he has been called upon to provide expert testimony on the explosibility hazards associated with the manufacturing, processing and handling of these materials. He is a member of the American Society for testing and Materials (ASTM) E-27 Committee on Hazardous Properties of Chemicals, the National Association of Fire Investigators (NAFI) and the National fire Protection Association (NFPA). He has authored numerous publications in the areas of fire and explosion prevention, protection and investigation.

DEKRA Process Safety and Chemical Safety

The breadth and depth of expertise in process safety makes us globally recognised specialists and trusted advisors. We help our clients to understand and evaluate their risks, and work together to develop pragmatic solutions. Our value-adding and practical approach integrates specialist process safety management, engineering and testing. We seek to educate and grow client competence to provide sustainable performance improvement. Partnering with our clients we combine technical expertise with a passion for life preservation, harm reduction and asset protection. As a part of the world's leading expert organisation DEKRA, we are the global partner for a safe world.

Process Safety Management (PSM) Programmes

> Design and creation of relevant PSM Programmes
> Support the implementation, monitoring, and sustainability of PSM Programmes
> Audit existing PSM Programmes, comparing with best practices around the world
> Correct and improve deficient Programmes

Process Safety Information/Data (Laboratory Testing)

> Flammability/combustibility properties of dusts, gases, vapours, mists, and hybrid atmospheres
> Chemical reaction hazards and chemical process optimisation (reaction and adiabatic calorimetry RC1, ARC, VSP, Dewar)
> Thermal instability (DSC, DTA, and powder specific tests)
> Energetic materials, explosives, propellants, pyrotechnics to DOT, UN, etc. protocols
> Regulatory testing: REACH, UN, CLP, ADR, OSHA, DOT
> Electrostatic testing for powders, liquids, process equipment, liners, shoes, FIBCs

Specialist Consulting (Technical/Engineering)

> Dust, gas, and vapour flash fire and explosion hazards
> Electrostatic hazards, problems, and applications
> Reactive chemical, self-heating, and thermal instability hazards
> Hazardous area classification
> Mechanical equipment ignition risk assessment
> Transport & classification of dangerous goods

We have offices throughout North America, Europe, and Asia.
For more information, visit **www.dekra.com/process-safety**
To contact us: **process-safety@dekra.com**

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