Emissions from metallic additive manufacturing
An occupational and environmental perspective

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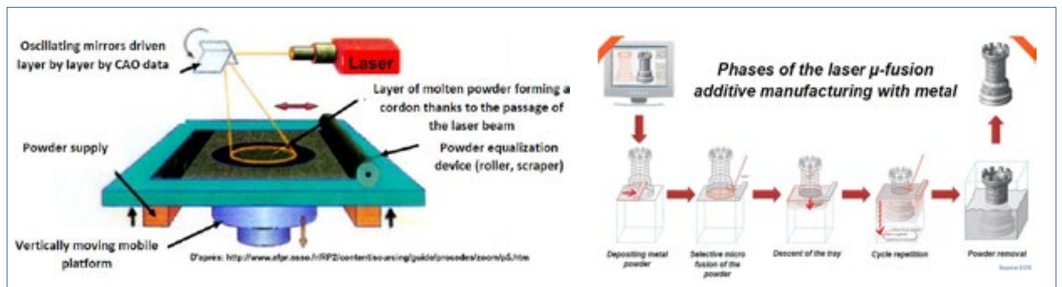
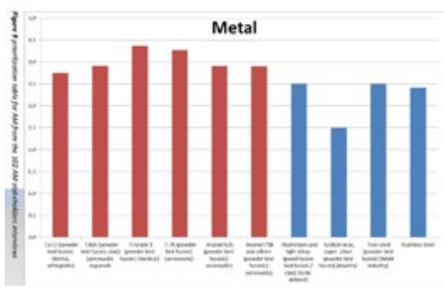
Context

The French project CaRPE (“Characterization and Reduction of Emissions from Metal Powder Processes”) aims at developing a methodological framework emissions from metallic additive manufacturing processes in an occupational and environmental perspective so as to propose emission management strategies and/or identify suitable safe(r) by design alternatives.
The framework is structured through a multi-tier approach. Main features are presented in this work as well as the operational approach and future perspective.

Metallic Additive Manufacturing



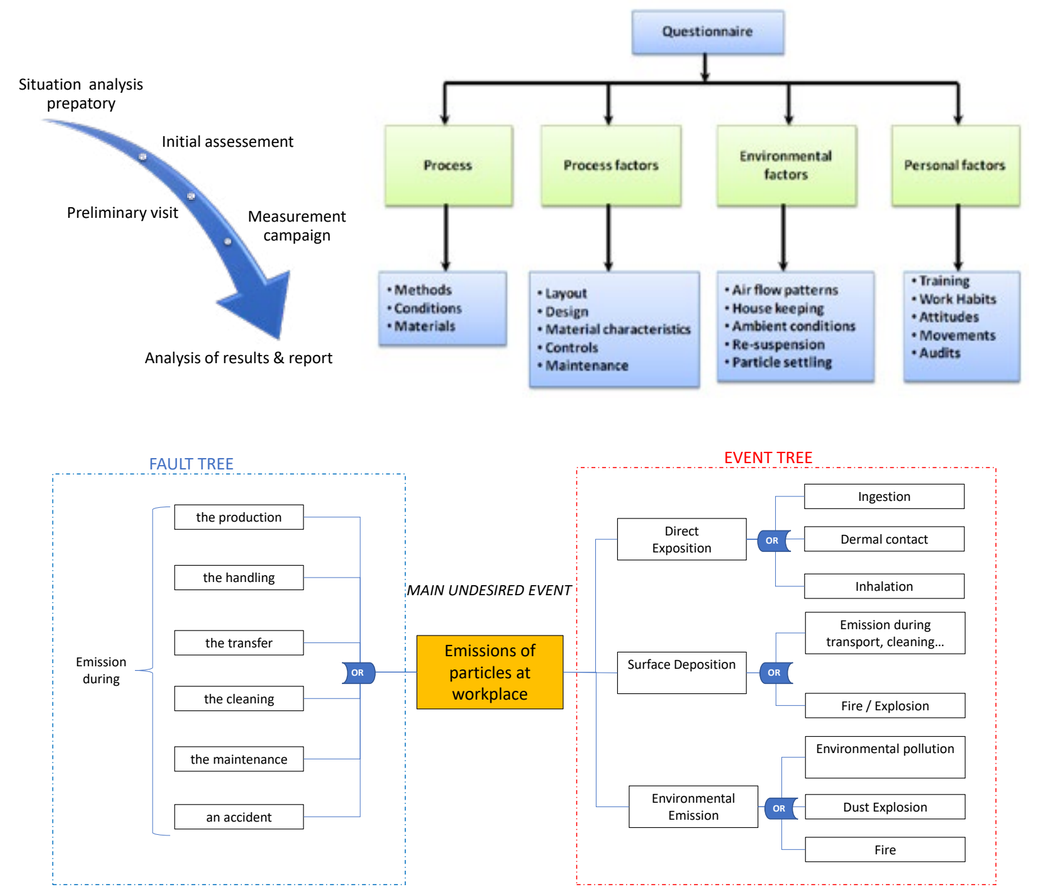


Several emissions concerns :

- Environmental emissions
- Occupationnal emissions
- Fire and explosion risks
- Waste management

https://www.rm-platform.com/downloads2/send/50-strategic-research-agenda/608-sasam-standardisation-roadmap-open-june-2015

A Multi-tiered Approach

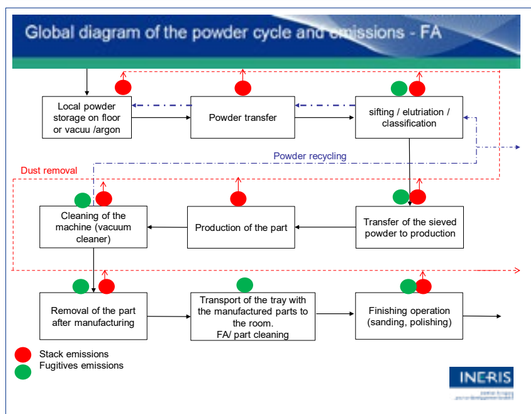


Standards (published and under development)

XP E67-006 (juillet 2020) : Additive manufacturing — Safety, hygiene and environment — Requirements for metallic materials

ISO/ASTM CD 52931 Additive manufacturing — Environmental health and safety — Standard guideline for use of metallic materials (under development)

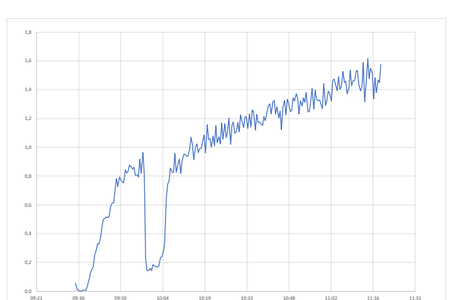
Case Study



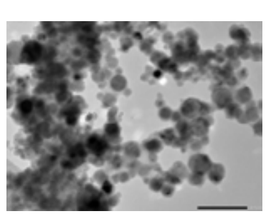
- Two FA Machines considered, both equipped with a filtration system (H13 type terminal filter)
- Powder considered : **15 to 40 µm** / compound : 70% Fe, 18% Cr and 13% Ni
- Comparison of the concentration levels in number the nature and the morphology of the particles emitted at the output of each machine.
- Measurements of the particles carried out at the level of atmospheric emissions after the filtration system.
- Real-time measurement during on-site measurement campaign and sampling for microscopy analysis (APS, CPC, TEM)

A Few Features

Machine A has particle emissions in the whole size range (micron, submicron), but at a concentration level lower than that of machine B and in this case low. Level of concentration at the outlet showed the need to think about a check of the system (possible sealing problem) or even an improvement).

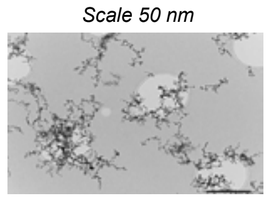


Machine A : Temporal monitoring of the concentration in number (p/cm^3) measured by APS particle size analyzer in the production phase

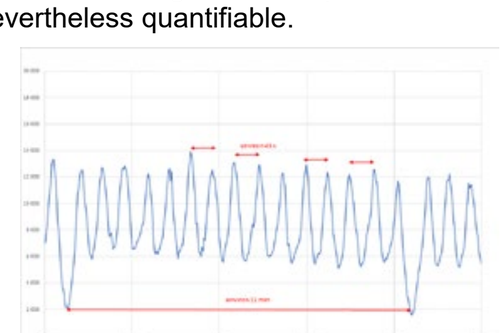


Scale 1 µm

Scale 50 nm



Machine B has ducted particle emissions of **less than 0.1 µm**. Their structure is nanometric and their elemental composition corresponds to the three species dominating the raw material used by the process (Fe, Cr, Ni): These are oxidized metals, resulting from the process. The level of concentration is moderate but nevertheless quantifiable.



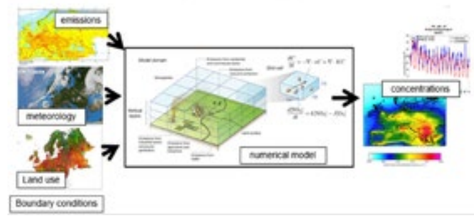
Cyclical production fluctuations

Machine B *: Short cycle of about 45 s, and a longer cycle of 11 minutes, which correspond to production characteristics: the short cycle would be attributed to the realization of a layer; the longer cycle would correspond to the "reference taking of the scanning head" which occurs every 15 layers.*

Conclusion

- **The micronic powder initially** used generates channeled emissions composed not only of fine particles, but also of **nanostructured particles of less than 0,1mm**
- Elemental composition corresponds to three metal species (oxide form) originally present in the metal powder used for additive manufacturing (e.g. Fe, Cr, Ni).
- The level of concentration at the outlet of the filtration system is moderate but significant.
- This work enabled to propose recommendations to improve the efficiency of ventilation systems so that to minimize diffuse emissions in the plant buildings (i.e. avoid emissions inside buildings) as well as the design of filtration systems to reduce channeled environmental emissions.

Future perspectives



Concept of Eulerian chemistry-transport model

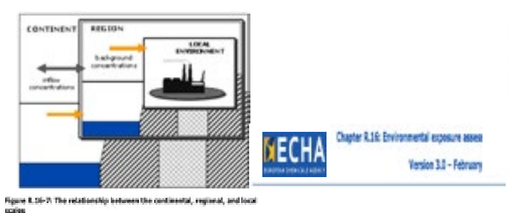


Figure R.16-7: The relationship between the continental, regional, and local scales

ALLOUL-MARMOR, 2002

Partenaires