

Additive Manufacturing – Understanding the implications and opportunities of novel manufacturing techniques on the Electrical Power Sector

Additive manufacturing (AM), also known as Additive Layer Manufacturing (ALM) is the industrial name for 3D printing technology. This is a computer-controlled manufacturing process, which creates 3D objects by subsequent deposition of layers. AM has developed rapidly over the past decade, but there is a lack of relevant work in the field of electrical power engineering, as much of the published work focuses on mechanical, thermal and chemical properties.



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— Technical challenges – inherent layer structure

In contrast to conventional manufacturing methods, such as injection moulding or extrusion moulding, AM deposits a material layer by layer on a build plate, which then results in a different material structure. A solid block of AM prepared polymer would, for example, still have noticeable layers as the polymer of the previous layer would cool down and potentially crystallise before the next layer would be deposited in the same location. Below is a simplified illustration on the type of structure that can form from such an approach and how the size of the nozzle used for deposition can affect the size of pores. A larger nozzle of course increases the throughput, but will increase the size and number of pores.

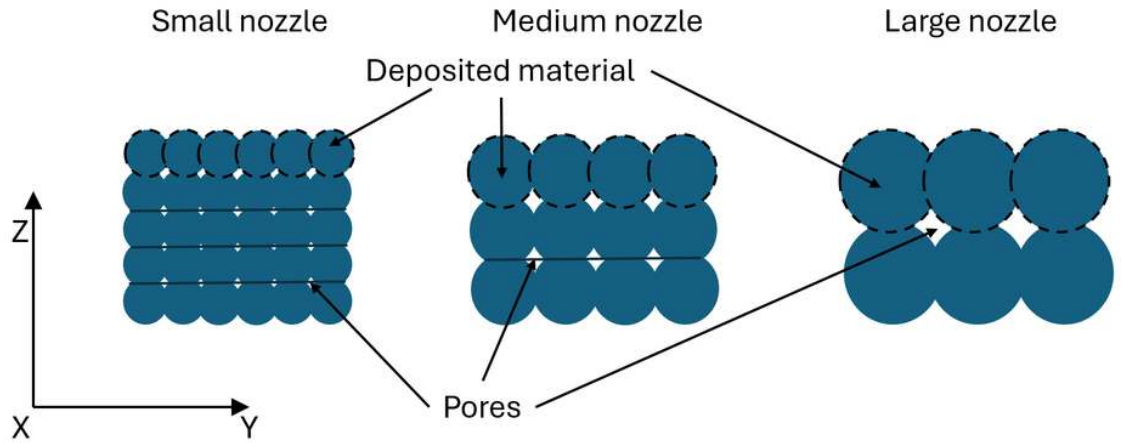


Figure 1 - Illustration of the layer structure that can form from ALM

Various parameters affect the parts created by AM, such as nozzle size, printing speed, patterning, processing temperature etc. Much of the existing literature on AM focuses on processing and mechanical properties, where micrometre-sized gaps are not always of concern. But while micrometric voids might have limited effect on mechanical properties, they are potentially critical once high electric fields are applied. AM is of course not limited to insulators or polymers; the first examples of AM in the power industry were to print metals. Since 2019, a number of examples of AM to aid maintenance and repair have been presented at CIGRE sessions and symposia, with Eletrobras in particular being at the forefront of using this new technology.

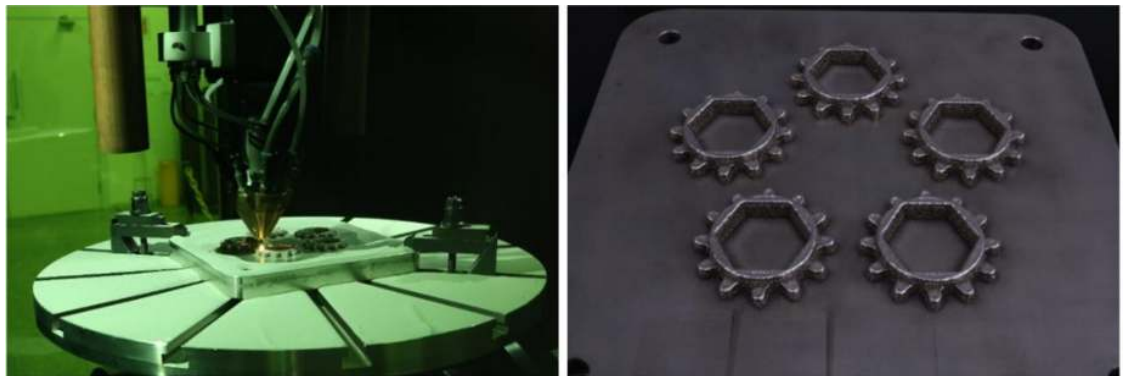


Figure 2 - Preparing gears by laser-directed energy deposition (L-DED) presented at 2024 Paris session [1]

— Opportunities

Assuming the void formation can be controlled, the use of AM opens a number of radically new design approaches, such as printing layers with different conductivity or permittivity, in order to create more effective field grading materials for HVDC and HVAC applications respectively [2]. A major cost factor for every new component is tooling, which is where AM can drastically reduce the upfront costs for any new design, since the same machine can be used to create a wide range of different designs, with combinations of different materials. Many universities and other educational institutions have already adopted AM to some extent in their teaching and

project work. Thus, new graduates have now become familiar with this technology, meaning the first generation of high voltage and electrical engineers with hands-on experience with AM as part of their education has already joined the workforce.

— Non-technical challenges

Initial discussions with stakeholders about the potential of AM technologies also highlighted several issues that arise that are not technical in nature and relate to standardisation and intellectual property rights. For example, if a manufacturer has local centres for printing spare parts for their high voltage equipment, how can they ensure that all parts are of the same quality. Only a few standards make specific reference to the means by which a component is manufactured, and instead set out means to test if these components are suitable for the use case for which they were designed and manufactured.

— The contribution of D1 on this path

Other industries, from aerospace or formula 1 teams to footwear manufacturers have adopted AM as a new tool in their toolboxes. The introduction of such new technologies in the field of high voltage and power engineering must be accompanied by an extensive and systematic testing regime, including type-, routine- and onsite tests to ensure components prepared with AM enable the same reliability as we have today. SC D1 is well placed to develop both the understanding of the physical mechanisms that might limit their application, as well as the necessary test procedures to give users confidence that parts created by this novel method are predictable, consistent and reliable.



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— The importance of understanding the effect of AM on material properties

To summarise the state of the art of AM and its potential for our sector, a new working group D1.81 “Additive Manufacturing/3D Printing in Service of the Electrical Power Industry” was launched by D1. This WG proposes to review the state of the art of AM and highlight existing work focussing on dielectric and electrical properties. It will further highlight some of the potential of AM as technology for the power industry, such as manufacturing complex geometries and opening the possibility of new field grading materials. Along with 3D scanning techniques, AM could simplify the maintenance and repair of older assets in the network, by making replacement parts that would otherwise be difficult to acquire for a variety of reasons.

Subject to relevant experience on the WG, it is proposed to include experimental work on materials created by AM that will be compared with conventionally prepared materials and compare their properties with a variety of methods.

The final brochure aims to summarise the potential for AM/3D printing for the electrical power industry and inform on the opportunities and current limitations of the technology. This should help engineers in the future understand the performance and limitations of AM prepared equipment. This WG is the first within CIGRE that is dedicated to this novel manufacturing technique.

— References

1. Alexandre Pinhel, Rodrigo Maia, Gabriel Vieira, Anselmo Thiesen, “Advancing Circuit Breaker Maintenance and Repair through Metal Additive Manufacturing Technology” CIGRE Session Paris - Reference: [A3-10709-2024](#)  - 2024.
2. Muneaki Kurimoto, Yuya Manabe, Shinichi Mitsumoto, Yasuo Suzuoki, “Layer interface effects on dielectric breakdown strength of 3D printed rubber insulator using stereolithography”, in Additive Manufacturing, 46, 2021,102069, ISSN 2214-8604, <https://doi.org/10.1016/j.addma.2021.102069>.

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