Making our world more productive

Can additive manufacturing contribute to the sustainability equation?

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Additive manufacturing's role in more sustainable production practices

The risks of climate change now need little introduction. We are already starting to live with the impacts of a changing climate on communities, businesses and supply chains. The most recent Intergovernmental Panel on Climate Change (IPCC) report delivered the unnerving news that the world is likely to overshoot the critical 1.5 °C mark by 2030, exposing many of us to potentially serious impacts to our way of life.

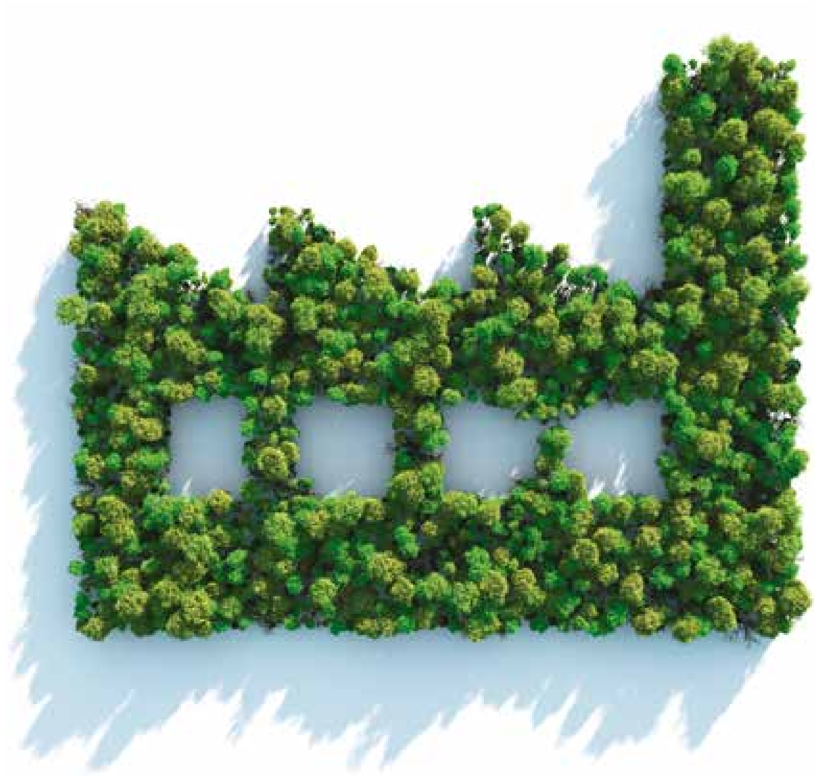
In the face of global warming and climate change, companies are becoming increasingly aware that they must rethink their business practices and pursue sustainable development. Today there is an increasing understanding that financial profitability needs to go hand-in-hand with environmental integrity.

When it comes to manufacturing, sustainability refers to the production and fabrication of manufactured products through economically sound processes that minimise negative environmental impacts while conserving energy and natural resources.

However, implementing sustainability principles in manufacturing is a complex challenge, forcing companies to confront dilemmas and make decisions with conflicting objectives and values.

Additive manufacturing can build complex components that would typically be very challenging, if not impossible, with more traditional subtractive manufacturing methods. The advantages of additive manufacturing are numerous – including greater design freedom and customisation, improved product strength and functionality, reduced assembly time for complex components, localised production, rapid time to market, mitigation of wastage, reduced obsolescence, decreased reliance on traditional suppliers and even the creation of new materials with unique mechanical and behavioural properties.

In addition to all these advantages, despite the technology being at a relatively early stage of adoption, it is also showing signs of delivering potential environmental benefits.



With some already claiming it as a green technology , additive manufacturing holds significant potential to decrease the volume of natural resources typically utilised; increase materials efficiency; reduce stock obsolescence and material waste; improve functionality and extend product life; enable ease of access to spare parts; reduce weight of key components; mitigate the need for special tooling in part fabrication and reduce emissions through less transportation required.

Light-weighting is for many manufacturers – particularly those in the transportation industries – an ultimate goal to reduce fuel consumption and in turn, reduce their carbon footprint. Additive manufacturing allows for the design of considerably lighter components, as well as enabling several components to be integrated into a single part, so potentially reducing the total number of parts required to be welded together at assembly stage. It also allows for highly innovative designs of parts with both greater functionality that can often be too intricate to be cast. Some of the most advanced engine parts aimed at significantly reducing weight and fuel consumption can now be successfully produced thanks to additive manufacturing.

The more complex a printed part, the more advantageous it is to use additive manufacturing, as the cost and energy for printing is not dependent on component complexity. Components can also be redesigned to provide additional functionality – for example improved cooling by integrating cooling channels into the structure to enhance energy efficiency and performance of the entire product. Specialised parts can be produced quickly and on demand, enabling more or less immediate access to spare parts for repairs which can not only extend the life of a product, but can mitigate the need for extensive storage and inventory – all of which needs space and energy to become operational. And if printing takes place on-site, with no transportation needed, emissions from vehicles can also be avoided. Furthermore, an additive rather than subtractive approach to manufacturing means that more of the resource material will end up in the printed part, so reducing material waste . When the greatest share of a product's environmental impact comes from producing its feedstock, minimising its waste is critical.

It is estimated that the amount of feedstock waste created by subtractive manufacturing could be reduced by as much as 90% using an additive manufacturing method.   In addition to feedstock waste, conventional manufacturing also consumes other resources such as coolants, lubricants and tooling which are not needed for additive manufacturing.

However, this does not mean that additive manufacturing generates no waste at all. This includes, for example, some material powders that are no longer recyclable, scraps generated by unexpected defects and the support structures created for printing components with overhanging parts.

Printing time = energy consumption

The success of any additive manufactured process can be determined by the mechanical properties of a finished product. When those properties are below par, resource material wastage and re-work are normally the result. And when wastage and re-work are required, more energy is consumed than is optimally required.

The properties of any perfectly printed part are not only highly dependent upon the printing process itself, but the characteristics of the feedstock. This is especially the case when using metal powders in laser powder-bed fusion (L-PBF), for example. The quality of metal powders used is critically important as it can impact on the physical and chemical properties of the finished product, including tensile strength, brittleness, impact resistance, heat tolerance and resistance to corrosion. Powder quality also plays a vital part in consistency and production repeatability.

Metal powder for use in additive manufacturing

High sphericity of the metal particles is needed so that the metal powder flows smoothly and evenly inside the printer and gas atomisation is the most effective approach to metal powder production due to the superior geometrical properties achieved. It requires not only a large supply of inert gases such as argon and nitrogen, but the gas molecule expertise to help manufacturers fine tune the atomisation process to further improve powder characteristics and eliminate rejects. Additionally, to protect the melt during atomisation, blanketing with liquid argon will protect the metal powder from oxidisation, reducing scrap and the need for expensive crucible maintenance. When considering these various gas atomisation applications, it is important to work with a specialised partner, such as Linde, with extensive know-how in high pressure gas supply solutions.

The choice of gas and the supply mode are also crucial ingredients to the success of your process and can affect the atomising flow and melt rates, pressure and overall batch time – impacting on both quality and productivity.

Once the metal powders have been produced, it is essential to maintain the correct atmosphere during their storage in order to avoid humidity. While this is less important when powders are first delivered in their hermetically sealed packaging, once opened, the powder can be at risk of exposure to oxygen which can age the powder, reducing its quality or rendering it unusable. Linde has developed an innovative and very compact solution to resolving this storage challenge – the ADDvance® powder cabinet. The powder cabinet works with a moisture control and monitoring unit to continuously measure humidity levels, triggering a high-volume purge gas flow as soon as the doors are closed to rapidly remove moisture in the air. It then applies a lower stream of gas to ensure a consistently low level of humidity, ensuring the quality of the valuable, sensitive metal powders is retained.

Beyond metal powder storage optimisation, atmospheric gases play an even more important role in the core printing process.

While additive manufacturing can optimise production of printed parts, ensuring high-quality repeatability of the process and requiring less post-print finishing, the atmosphere in the printing chamber needs to be optimal and reproducible.

Although the atmosphere in the chamber is purged with high-purity inert gases such as argon and nitrogen to rid it of oxygen, impurities can still remain present due to incomplete purging, via loose connections or even within the metal powder itself. Even extremely small variations in oxygen content can impair the mechanical or chemical properties of metals sensitive to oxygen – such as titanium

ADDvance® powder cabinet for storage of atmosphere sensitive powders

and aluminium alloys – and can affect the composition of the end product resulting in negative physical characteristics such as discolouration and even poor fatigue resistance.

Linde is dedicated to developing pioneering technology to overcome these atmospheric impurities to give manufacturers optimal printing conditions. The result – ADDvance® O_2 precision – provides continuous analysis of the gas atmosphere, detecting oxygen levels with high precision without cross-sensitivity. Recognising O_2 concentrations as low as 10 parts per million (ppm), the unit automatically initiates a purging process to maintain the atmosphere as pure as needed.

ADDvance® O_2 precision – ensuring the atmosphere of the printing chamber is correct

Linde is also a leader in the research, development and supply of bespoke gases uniquely tailored to a customer's specific AM process and project application, such as its advanced argon-hydrogen mixture, ADDvance® Sinter250, to optimise atmospheric conditions in sintering furnaces and its most recent argon-helium test mixture to optimise the production of complex, latticed parts during L-PBF.

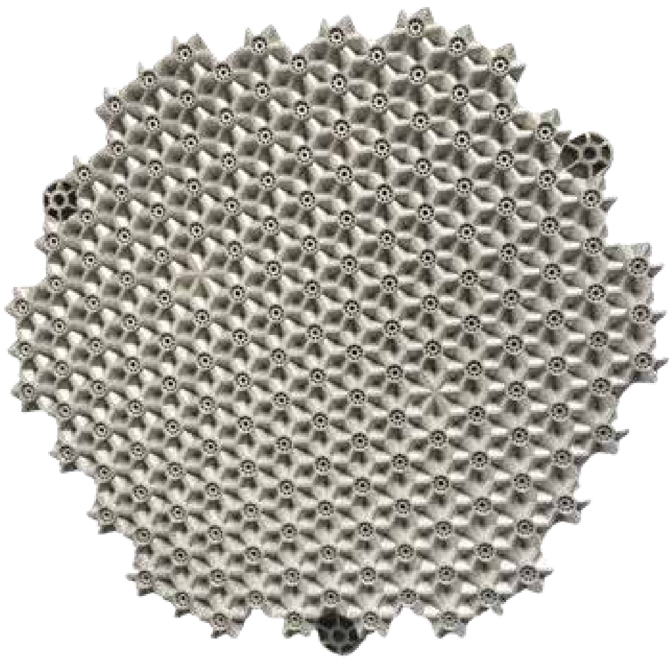
The fly in the printing chamber

The biggest potential drawback to additive manufacturing not achieving its full potential as a more sustainable production method is energy usage – both in the type and volume of energy it consumes. To achieve the future potential environmental benefits, it is important that the process benefits as much as possible from the energy transition to renewable power. The developed world has a goal to achieve Net Zero by 2050 and while policies, incentives and sustainability initiatives are largely in place, the delivery of a fully renewable electrified industrial environment is still some way off.

In the interim, however, it will be important to try to minimise the amount of current energy sources used to support the additive manufacturing process. One activity to help manage energy consumption that can be implemented relatively quickly is to ensure the additive manufacturing process itself is optimised, thereby mitigating potential re-starts and re-work in the event of defective parts. There are several aspects to the process that once enhanced, can help prevent false starts. While no one solution can claim to make additive manufacturing more sustainable than traditional production methods, through a combination of technologies – particularly associated to the use of atmospheric gases – the process can be assured to have more reliable, repeatable quality outcomes. Once this is achieved, the advantages of additive manufacturing are, at the very least given the potential to contribute to more sustainable production methods.

The end game

As we shift from conventional manufacturing methods to additive manufacturing, we also need to shift from a linear to a circular economy. Although waste from additive manufacturing is significantly less than from subtractive manufacturing methods, it still generates some waste. This is now being addressed by innovative start-ups developing processes for melting and atomising scrap metal into suitable metal powders which can be re-used. It is thought that, in principle, these small recycling facilities could be distributed across the globe, situated in additive manufacturing hubs to give scrap metal new life as additive manufacturing feedstock.



LINDOFLAMM® burner built using AM technology

Conclusion

While it may be coincidence that these two individual but major manufacturing themes have emerged and become key concerns independently of each other, it is clear that given the opportunity to coalesce, they present a significant ability to re-enforce each other's potential. As demand for more sustainable products continues to grow, the manufacturing landscape must adapt. As additive manufacturing becomes increasing scalable, more localised, resource-efficient and circular, it is not impossible for it to make a significant contribution to the sustainability agenda in the not-too-distant future.

References

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Getting ahead through innovation

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages, and greater profitability.
Each concept is tailored specifically to meet our customers' requirements – offering standardized as well as customized solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow's competition, you need a partner by your side for whom top quality, process optimization, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde – ideas become solutions.

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