Making our world more productive

Adopting Additive Manufacturing: as much mind-set change as technological

Contents

Introduction

Companies putting manufacturing at the heart of their business are under mounting pressure, both from global competition and the rapid rise in technological advancements that are changing the way goods are manufactured. With mass production having largely shifted to developing economies, Western companies are moving towards lower volume production of high-added value, innovative, customisable and more sustainable products. They also continue to seek out ways to improve cycle times, reduce waste and maximise work flow. To compete in this new environment, manufacturers have sought new fabrication approaches to support economic low volume production. One such emerging technology is Additive Manufacturing (AM). Capable of producing fully dense components layer by layer from computer aided 3D modelling, the technology removes many of the limitations of manufacturing techniques based on traditional subtractive methods.

AM consists of various technologies to process versatile materials – from laser powder-bed fusion, directed energy deposition (using a laser or an arc), electron beam melting, to binder and material jetting – and once destined primarily for prototyping, AM is now employed increasingly for the development of spare parts, small series production and tooling.

Adoption of AM has seen the greatest uptake in industries where its relatively higher production costs can be outweighed by the advantages AM can deliver, particularly in highly innovative, leading-edge industries such as aerospace, defence, medical and automotive. Such advantages include greater design freedom and customisation, removal of tooling requirements, 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.

As a disruptive technology, it challenges the foundations upon which much of traditional manufacturing understanding, practices and experience is based. From design, quality inspection and even supply chain operations, AM confronts generally accepted notions of manufacturing for the production engineers involved, presenting considerable needed changes in mind-set. For many, overcoming resistance has as much to do with change management as it does with overcoming the unfamiliar technical landscape.

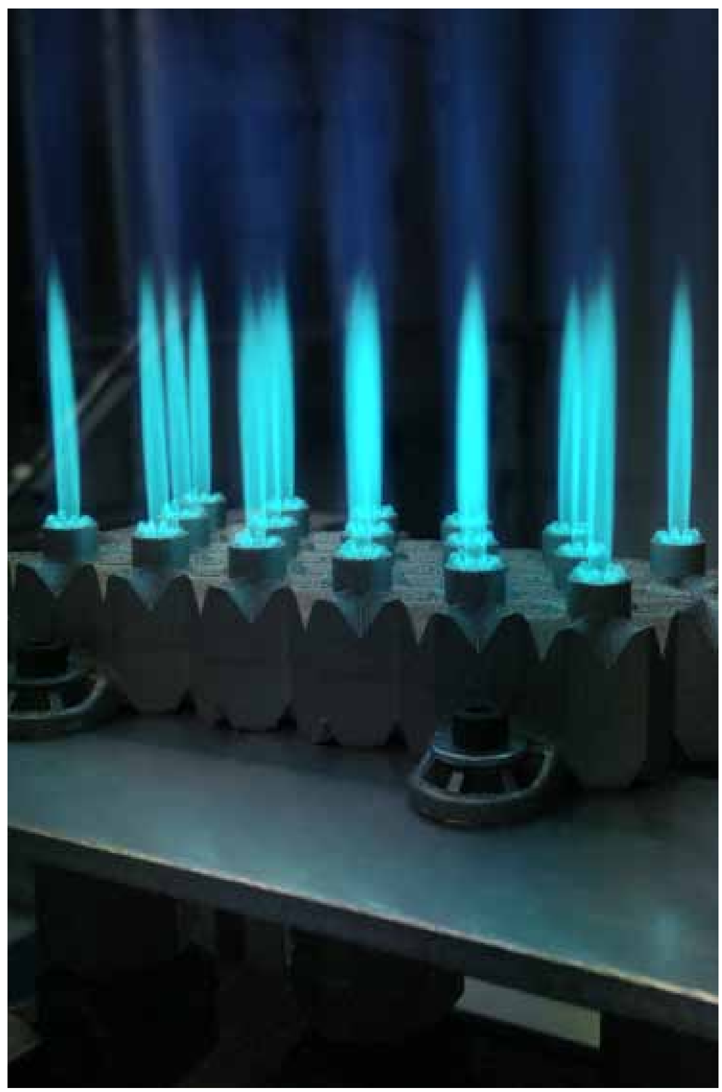
Linde is a leader in pioneering gas technology to optimise the additive manufacturing process, overcoming the challenge posed by atmospheric impurities in order to give manufacturers optimal printing conditions. Through leveraging its own technologies and expertise in the area, Linde recently embarked on a research project to advance manufacturing techniques of industrial burners using AM. However, its learnings were far from limited to the actual AM process itself, resulting in an appreciation of the mind-set adaptation needed to successfully transition from traditional manufacturing to AM.

The burners in question

Burners are made from multiple metal components typically produced by subtractive manufacturing methods in which the parts are machined from large masses of premium grade brass, copper or steel. Added to this process is milling, the many multi-directional holes to be drilled, brazed or welded, the cutting of threads, nozzle tips to be screwed and the brazing or welding of other connections. The process step of pre- or post-heating with burners is an essential operation for many process industries and the burners are often tailor made for the specific application, requiring up to 20 components or more. The burners must also ensure an even, homogeneous flame distribution, requiring highly skilled manufacturing. Such customisation and specialist proficiency can make the end-to-end process of burner manufacture complex, expensive and lengthy.

For the Linde AM research project, the burners in question were Linde's own LINDOFLAMM® acetylene burners for pre- and post-heating of welded components, though theoretically the process steps and learnings could be applied to other burners for varying applications and industries.

While reduced labour costs, production time and wastage were key goals, it was recognised that the AM process could enable additional, highly valuable functionality to the burners – for example, facilitating a cooling layer to protect the burner in order to reduce thermal stress. However, this is very challenging to incorporate through traditional manufacturing techniques – and for cooling over curved surfaces, almost impossible.



AM printed LINDOFLAMM burner in action

The project

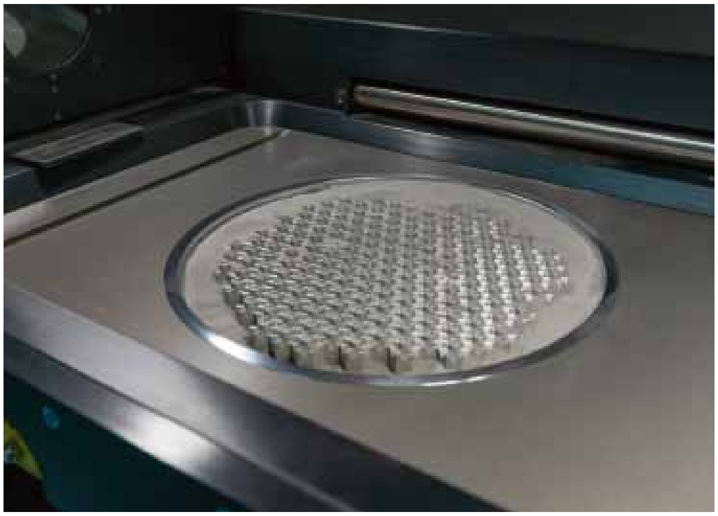
The project initially arose out of a goal within Linde to promote AM methods across its own manufacturing product portfolio. Linde undertook an ideation workshop to understand how they could benefit from the technology – and what adjustments would be needed in order to undertake successful prototyping. One of the most significant adjustments was the idea of a complete re-design of the burner for production in a printing chamber. While the engineering team undertook basic AM training and had the support of Linde's AM specialists, a key learning was that there is no replacement for direct experience. Adopting a 'fail fast and learn' approach, the team operated a series of learning 'loops': component modelling via computer aided design (CAD); component printing; sub-optimal results; back to the drawing board; redesign; try again.

One of the early challenges – but also an important learning from the project – was that the original component design was not precise enough and showed microgaps in the model, leading to poor contours and issues with porosity, resulting in leakage of the burner. Through trial and error and further collaboration with the AM team, the engineers learned what specifications and factors needed to be prioritised in AM.

Change management

While the excitement over AM continues unabated, on initiating AM production many manufacturers find their early efforts less than optimal. Sometimes it is a lack of understanding of the technology: the wrong AM process or material selected, sub-optimised atmospheric conditions within the print chamber, incorrect positioning or inappropriate post processing treatments. Or that the specific component design was more suited to a conventional technology and not adapted sufficiently to AM capabilities. While there are enormous benefits to be gained from AM, expectations need to be set in terms of the many potential snags and challenges a company may experience to create the perfect part.

As manufacturers begin to adopt AM technology, companies need to consider the human challenges beyond the strategic and technical ones. These can include how to develop know-how within manufacturing engineering teams and, perhaps more fundamentally, how to overcome resistance to this innovative technology.



3D printed LINDOFLAMM burner

Conclusion

AM necessitates a change of mind-set on the part of those involved. Until very recently designers and engineers have been taught to think in subtractional terms. In the voice of one key engineer at Linde, “Our university education to learn engineering via subtractive methods needs to be essentially eradicated from our brains. We need to re-educate ourselves in terms of design”.

Engineers now need to take into consideration the limitations of old technical feasibilities and the potential – and also restrictions – of new AM-enabled ones. For example, instead of internal geometries of components being created with complex individual parts through intensive assembly processes, engineers can now produce almost all geometries in a single print phase, enabling design of parts according to their function. However, this recalibration in thinking – even among the most experienced and lauded engineers – can take time. As such, it is equally a case of change management as it is about learning new models and approaches to manufacturing engineering. According to one of Linde’s lead engineers, “One of the targets of the project was to make this new way of thinking second nature.”

Linde has successfully developed an additive manufactured prototype of its market-leading LINDOFLAMM® burners, with the value-added capability of delivering an excellent cooling layer in the burner and providing optimal flame homogeneity. Next phases of the project include testing of the new prototype burners with customers to ensure they meet exact requirements and reliability, and then scaled up production for product launch in 2020.

Implemented properly, AM can encourage manufacturing engineers to think beyond the boundaries of traditional manufacturing methods to reduce the number of production steps, material wastage, inventory held, and the overall parts needed to be manufactured for assembly. But an implementation framework covering both technical education and change management strategies are needed to make it work.

LINDOFLAMM conventionally manufactured vs. 3D printed burner

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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