Atmospheric gases: enablers behind the additive manufacturing future

Gases for a diverse manufacturing landscape

The AM technology landscape is a diverse one, with various technologies developed to meet different production requirements including materials used, surface finish and cost. What remains constant is the need for high quality atmospheric gases and the pioneering technologies enabling their application to optimise both the process and resultant product.

Inert gas, typically argon or nitrogen, is central to the function of metal AM as well as peripheral AM processes including pre- and post-production activities, and is the media most often used for quenching during the vacuum heat-treating process. Argon gas is the third most common gas in the Earth's atmosphere, with its name coming from a Greek word meaning 'inactive' as the gas lacks chemical reactions. Colourless, odourless, tasteless, and non-toxic, argon is 38% more dense than air and it can displace the oxygen in an enclosed area.

In the AM process, argon gas is used in laser powder-bed fusion as it creates the perfect environment for the process. A major challenge in metal AM is building components in a controlled environment and minimising the introduction of any possible impurities. Inerting is also critical for proper management of the combustible dust arising from the powder metal and printing process.

For AM methods such as laser powder-bed fusion, inert gases are introduced into the sealed printing chamber to create a highly controlled atmosphere, but there are other atmospheric gases used in a variety of applications vital to the AM process. These include processes such as Laser Directed Energy Deposition (L-DED), Selective Laser Sintering (SLS) and other AM processes using gas-metal arc welding (MIG/MAG) and plasma welding techniques to melt metal filler to form a 3D component layer by layer.

Pioneering technology for atmospheric control

As is well understood and established earlier here, the core AM process takes place within a closed chamber filled with high-purity inert gases such as argon and nitrogen. What is less well understood is that even after the atmosphere is purged, impurities can remain present in the chamber due to incomplete purging or via access through loose connections or the metal powder itself. Even extremely small variations in oxygen content can impair the mechanical or chemical properties of alloys sensitive to oxygen like titanium or aluminium and can affect the composition of the end product, resulting in negative physical characteristics such as discolouration and even poor fatigue resistance. For industries at the forefront of AM adoption such as aerospace, automotive and medical, such negative production outcomes are critically important to avoid.

Linde Gases, a world-leading industrial gases company, has dedicated the past 3 years to developing pioneering technology to overcome these atmospheric impurities in order 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. The technology is already in use at companies at the vanguard of AM including Liebherr Aerospace in France, leading car manufacturers in Germany as well as other partners – both industrial and academic.

Metal powder: the beginnings

The mechanical properties of a finished product are not only highly dependent upon the AM process itself, but the initial characteristics of the powder used in that process. The quality of metal powders used in AM is critically important as it can impact on the physical properties of the finished product, including tensile strength, brittleness, impact resistance, heat tolerance and resistance to corrosion. For delivery of much needed powder excellence, atmospheric gases play an essential role. It is essential to maintain the correct atmosphere during storage in order to avoid humidity. Humidity will lower the flowability of the powder and will increase the amount of O_2 during printing. The latest addition to Linde's AM solutions now includes Linde's ADDvance® powder cabinet to ensure optimal conditions for powder storage.

Enhanced post-processing: the final touch

Most AM components require a heat treatment step to reduce stress with atmospheric gases at the heart of the process – either via hot isostatic pressing (HIP) - an advanced material heat treatment process utilising elevated temperatures in a contained high-pressure atmosphere to eliminate internal porosity and voids within cast metal materials and components or sintering after the binder jetting process.

Binder jetting is an additive manufacturing process in which a liquid binding agent is selectively deposited to join powder particles and is applied in alternate layers with the material to be bonded. The build is done under air and once completed, the object separated from the build plate – called a "green component" - has poor mechanical strength and high porosity. This can be rectified by the sintering process, with the part being fed slowly through a special high-temperature furnace to bond the metal particles together. For this process an inert gas such as argon or even a special reactive gas mixture including some hydrogen or methane is needed.

During any of the AM processes, blast powder residue or unfused powder can build up on the part being printed. Removing particles from holes and cavities can represent a particular challenge in the case of small, elaborate parts and components with complex geometries, especially as melting metal residue requires potentially damaging high temperatures. Depending on the application in question, a number of different surface finishing treatments can be applied to remove or reduce the surface roughness of AM parts including barrel finishing, abrasive flow machining, plasma polishing, micro machining and electrochemical polishing.

Linde Spokesperson Bios

Christian Bruch

A member of the Linde Executive Board since 2015, Christian Bruch is responsible for both the Engineering Division and the Corporate & Support Function Technology &Innovation, Digitalisation. Joining Linde in 2004, he has held roles in both the engineering and gases divisions spanning areas including air separation plants and tonnage. He was also previously a member of the management board. Prior to joining Linde, Mr Bruch held roles at RWE Fuel Cells GmbH, RWE Power AG and the Swiss Institute of Technology (ETH). He holds a PhD in Engineering from ETH and an BSc in Mechanical Engineering from University Hanover, Germany.

Christoph Laumen

Christoph Laumen, 47, is a senior level German engineer who joined Linde in 2006. Having held various roles including in Sweden and China, he now leads Linde’s Application Technology function in EMEA covering all relevant market segments including Additive Manufacturing. He is responsible for setting strategic direction for all gas application related research and development activities globally and for coordination of EMEA market networks, which facilitate the fast transfer of technology and innovation to partners and end-customers.

Prior to this Christoph held roles at Lothar Huck GmbH in Germany, Hilti Aktiengesellschaft in Liechtenstein and AGA in Sweden, now Linde’s Swedish subsidiary. He holds an MSc in materials technology from University of Giessen, Germany, and an executive General Management certificate from INSEAD Business School.

Pierre Forêt

Pierre Forêt, 37, is a French engineer who joined Linde in 2009. He is currently Senior Expert Additive Manufacturing and oversees the Global Development Center for Additive Manufacturing in Munich, leading a team developing new solutions – from powder production to laser powder-bed fusion / wire arc to post processes such as heat treatment and HIPing. He holds an MSc in Material Science from, Ecole Européenne d’Ingénieurs en Génie des Matériaux (EEIGM), France.