VACUUM HEAT TREATMENT

FOR ADDITIVE MANUFACTURING

Figure 2: Detail of a TAV furnace hot chamber in molybdenum.

Vacuum heat treatment is a necessary post process step when specific components and materials processed with SLM technology are taken into consideration.

By ALESSANDRO FIORESE

Additive manufacturing means any technology capable of obtaining a final component starting from a 3D CAD file and adding material layer by layer. At a theoretical level, additive manufacturing only coincides with the 3D-part construction phase. In reality, in order to fully understand this technology, a series of other preprinting and postprinting activities must be considered, which constitute the entire supply chain of additive manufacturing.

In this article we will analyze the activities that precede and follow 3D printing, paying particular attention to the requirements of the materials and the processes necessary to obtain a high quality production.

THE PREPRINTING PHASE

If we limit the field of additive manufacturing to the single and more widespread powder bed technology selective laser melting (SLM), during the entire supply chain it is essential to take care of the atmosphere that surrounds the material in all its production steps.

For example, considering the production of powders as a preprinting phase, it is necessary to pay a lot of attention to how they are produced. If the powders were obtained through an atomization process in an unsuitable atmosphere, we could find, in the printing phase, oxidized powders, which could be particularly difficult to melt or could melt generating defects inside the material of the molded component.

Assuming that the starting point of the powders is optimal, that is that the powders have been produced correctly in terms of geometry and absence of oxides, even during the process of 3D printing it is essential to control the atmosphere inside the accretion chamber. This is easily understood since 3D SLM printing can be compared to a continuous welding process in which the fused pool must be continuously protected by inert gas. Despite the inertization of the interface between the molten pool and the chamber environment, small residues of oxygen or slight impurities contained in the gas, not perfectly pure, can result in unwanted inclusions within the final piece with consequent unacceptable colors and a deterioration of mechanical performance in a future use.

Also, the postprinting phase is important to optimize the mechanical properties of the components. TAV Vacuum Furnaces has achieved some interesting results in the lab using vacuum heat treatments.

THE POSTPRINTING PHASE

After 3D printing, most of the materials that can be printed with SLM technology always need a heat treatment. This heat treatment can be de-tensioning (to release most of the internal tensions accumulated in the material during the printing phase) or of another type (to try to optimize the mechanical properties of the component according to its specific application).

Usually these treatments are carried out in air or in a controlled atmosphere.

In reality, TAV Vacuum Furnaces has experimented in its internal

Figure 1: The TAV Vacuum Furnaces R&D Laboratory.

Figure 3: SLM samples in 316 L steel before heat treatment. The samples were printed by SAIEM and analyzed by the University of Genoa (DCCI).

Figure 4: SLM samples in 316 L steel after heat treatment. The samples were printed by SAIEM.

Figure 5: SLM samples in Ti6Al4V before heat treatment printed at the CNR, Institute of Chemistry of Condensed Materials and Energy Technologies, CNR ICMATE, Lecco site.

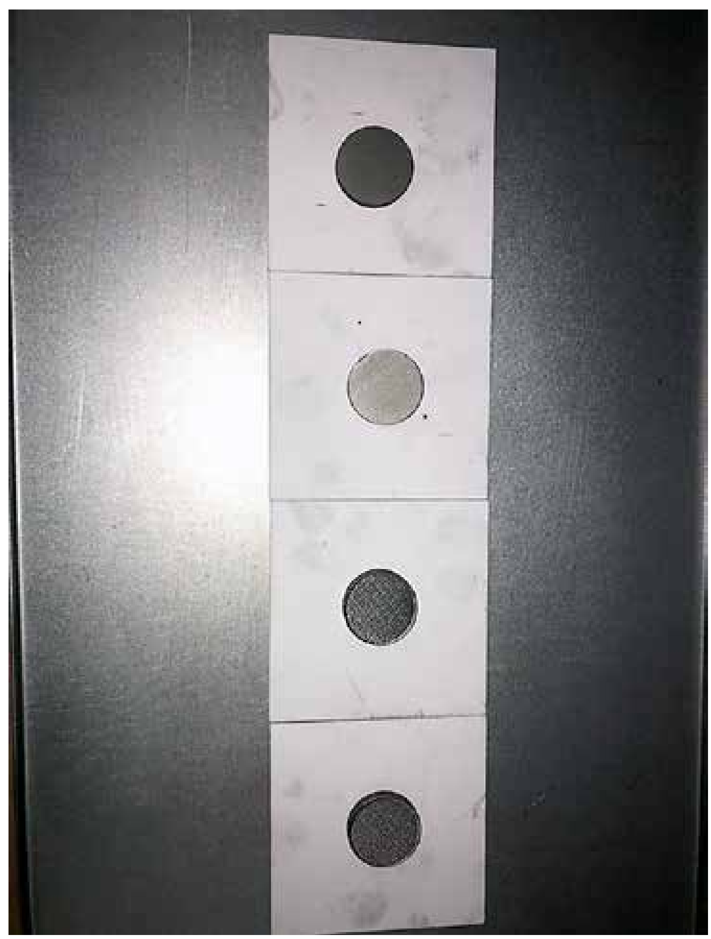

Figure 6: SLM samples in Ti6Al4V after heat treatment printed at the CNR, Institute of Chemistry of Condensed Materials and Technologies for Energy, CNR ICMATE, Lecco site.

If we limit the field of additive manufacturing to the single and more widespread powder bed technology selective laser melting (SLM), during the entire supply chain it is essential to take care of the atmosphere that surrounds the material in all its production steps.

Figure 7: SLM samples in Ti6Al4V for pre-heat treatment fatigue tests.

Figure 8: SLM samples in Ti6Al4V for post-heat treatment fatigue tests.

laboratory (Figures 1 and 2) that on specific components and materials, such as stainless steel (Figures 3 and 4), titanium superalloys (Figures 5, 6, 7 and 8), superalloys of nickel and CoCr alloys, the use of vacuum is required.

In the case of titanium, even a low vacuum level around 10-3 mbar is not sufficient.

CONCLUSIONS

Our experience, resulting from collaborations with our customers and different universities, teaches us that vacuum is able to:

› Minimize surface contamination at high heat treatment temperatures, leading to a consequent improvement in the mechanical response of the component.

› Make mechanical and corrosion verification tests of the various printed components extremely repeatable.

› In some cases, it can clean up the samples surfaces contaminated by printing processes, making them shine, that, as we have already seen, take place in a controlled atmosphere but not in total absence of oxygen.

In addition to these benefits, there is also the fact that the materials mentioned are mostly used for aerospace and medical applications, in which very strict rules must be respected to reduce surface contamination and to maximize mechanical properties.

For what has been presented so far, the vacuum heat treatment turns out to be a mandatory post process step when specific components and materials processed with SLM technology are taken into consideration.

ABOUT THE AUTHOR

Alessandro Fiorese is R&D Chief Engineer at TAV Vacuum Furnaces SPA. He attended the Engineering University at the Politecnico of Milan. There he developed theoretical knowledge in the field of materials (cementitious materials, composites, metals, polymers, ceramics, and advanced ceramics) and nanotechnologies. In 2017, a research and development laboratory was set up at TAV, which involved the installation of the following machines: a vacuum furnace, a PVD coater, a durometer, and an optical microscope. Fiorese's current role is to encourage, through collaborations, the scientific exchange between TAV and various research centers, universities, and companies to develop knowledge in the field of new technologies (e.g. additive manufacturing) and vacuum heat-treatment processes.