Metallurgical Ascpects of the Additive Manufacturing of Metallic Materials - Microstructure/Mechanical Properties/Heat Treatment

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The basic principle of the 3D printing of metallic materials with respect to conventional shape treatment, where we arrive at the final shape by drilling, milling, cutting, casting, etc., and using the principle of removal of the material, is that of adding material with nearly no losses. Additive manufacturing (AM) technologies make possible the production of metallic parts with complicated geometrical shapes by using the layer-wise consolidation of feedstock materials in the form of powders. Selective laser melting is one of most advanced and most promising AM technologies, which uses a laser to melt the powders.

However, during the AM process the material is several times remelted and rapidly solidified. The microstructure depends on the temperature gradient and the solidification velocity and, therefore, the AM microstructure is very different to traditionally obtained microstructures based on solidification and deformation processes. It is very common to observe a strong texture, depending on the additive manufacturing direction. The microstructure consists of a micro cast structure with smaller phases, less segregation, fewer precipitates and higher concentrations of defects, like dislocations, stacking faults, nano oxides, etc. Furthermore, to obtain the desired properties, AM materials must have the proper microstructure with the right phases, the correct grain size, the proper grain boundaries and grain-boundary distribution. Therefore, any heat treatment has to be adapted to the AM process and is expected to be different from the prescribed heat-treatment process for individual materials quality.

Using scanning electron microscopy with electron back-scattered diffraction and high-resolution transmission electron microscopy with energy-dispersive X-ray spectroscopy and electron-energy-loss spectroscopy we were able to explain some defects in the microstructure. It has been observed in several cases that on the nano level structure, due to rapid solidification, there are dendrite structures showing chemical nano inhomogeneity. It will be shown that in some cases we have to customize the heat treatment in order to maximize the mechanical properties.