Optimization of alloy microstructure in additive manufacturing process

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Additive manufacturing（AM）is a novel conception in manufacturing process in which the coating techniques are used to build, layer by layer, a stereo component directly in 3D via a piling up philosophy with computer control system. In many of metal material AM processes the raw materials, usually the metallic powders, are melted by a high-energy beam, laser for example, and solidified like welding process. Due to this superior characteristic, AM is capable to produce components with almost any complicate shapes and structures near-net-shape and waste-less. This has great potentials in the manufacture of areo- and astronauts- components, and attracts massive attentions from both of the material processing and manufacture industries.

Although AM has significant technology superiority, its core, the melting-solidification process, still lacks a sufficient control method to realize the structure tailoring, porous and other defects eliminating, fully equiaxed grains, and thus optimize the product's performance. The essential process of AM is melting the powder by a laser, or another powder, beam and then the melt solidified rapidly due to the strong cooling from the metal substrate or the previous layer. The solidification mechanism is the combination of epitaxy growth and nucleation, which is controlled by the laser heating and cooling condition. Up to now, the main approaches to control the solidification in SLM is relied on the "thermo-manner", that is, adjusting the heat source power, rate of heating, and cooling from the substrate or the previous layer of the alloy. This means the further effective solidification control methods are expected.

In this thesis work, an electromagnetic field will applied on the AM process to optimize the microstructure during the solidification.

Application of electromagnetic field opens perhaps a new route for controlling the solidification and thus obtaining the homogeneous refined solid structure. It has been widely accepted that electromagnetic stirring and electromagnetic vibration can refine the grains efficiently, and have been broadly applied to control the solidification in practice. Besides, during the last two decades, novel knowledge about the effects of static magnetic field on solidification has been achieved based on extensive research works. This provides a new opportunity to control the solidification of alloys in the AM. The alternative magnetic field is capable to refine the grains and thus eliminate the porous and other defects in the components manufactured. The static magnetic field coupling with the extreme high temperature gradient caused by the laser heating could produce strong thermoelectric magnetic force that may influence the flow field inside the molten pool and fracture the dendrite arms to induce columnar to equiaxed transition. This has a potential to refine and homogenize the crystal structure. Therefore, conducting the study on controlling solidification process in AM via applying magnetic field has both significant application meaning and theoretic values.

This project will focused on the basic metallurgy of melting and solidification in the laser melting additive manufacture (LMAM), the fundamentals and mechanisms of the influence of magnetic fields(both AC and DC) on the melting and solidification of several alloys in the LMAM will be investigated. The nucleation of the crystals, epitaxy growth, the interface morphology, dendrite fracture, porous, orientation of crystals, residual stress and deformation in the alloys under the magnetic fields (both AC and DC) and temperature field will be examined in detail. The thermoelectric properties and magnetic properties of the alloys will be measured in various temperatures. The basic knowledge on the solidification structure and properties of the alloys in SLM will be gained.