Spatial Beam Shaping in Laser Powder Bed Fusion for enhancing the Processability of E-Mobility Alloys

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Active fiber lasers are extensively used in manufacturing for cutting, welding, and additive manufacturing. The introduction of multiple-core fiber lasers has enabled dynamic beam shaping, shifting the Power Density Distribution (PDD) from Gaussian to more complex ring shapes. This flexibility allows better control over temperature fields during laser powder bed fusion (LPBF), crucial for manipulating material microstructure and properties. The ability to manipulate the PDD shapes dynamically opens new avenues for optimizing the microstructure and mechanical properties of materials. In this work, we present the results of the study on the effect of spatial beam shaping on two materials widely used in the electric mobility sector: a ferro-silicon soft magnetic alloy (Fe-2.9wt.%Si) and an aluminum alloy (AlSi7Mg0.6). The study was made possible by a non-commercial L-BPF system, assembled at Politecnico di Milano, equipped with a fiber laser source with dynamic beam shaping capabilities.

Regarding the Fe-2.9wt.% alloy, experiments with Gaussian and ring profiles allowed for the manipulation of grain size and shape, resulting in a transition from columnar to equiaxed structures. This approach showed potential in altering the microstructure without changing the scan strategy, although it introduced new complexities in process parameters and mechanical property analysis.

In the case of the aluminum alloy AlSi7Mg0.6, experiments focused on the effect of different beam shapes on melt pool geometry. By using beam diameters ranging from 47 µm to 144 µm, it was found that peak irradiance and ring intensity influenced the melt pool aspect ratio and depth. The study demonstrated that all conditions produced adequately dense parts (>99.5%) and that the mechanical properties correlated with the melt pool geometry.

This work underscores the potential of dynamic beam shaping in optimizing material properties in LPBF processes.