Powder Particle Velocity at the Nozzle Outlet in Directed Energy Deposition

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Metal-based additive manufacturing (AM) is challenging the conventional manufacturing approaches by enabling the production of complex structures with extremely favourable strength-to-weigth ratio. Nowere is this more crucial than in aerospace technology, where powder bed-based AM is already quickly being adopted. It is however the Directed Energy Deposition (DED) that is considered the truly disruptive variation of AM for the space industry. With no fundamental limitation on the size of the manuctured products and the ability to operate in microgravity conditions it could enable in-orbital manufacturing and repairs. However, before the latter can be employed, the quality of the manufactured products as well as predictability of the process needs to be significantly improved. Both ends could be achieved through high-fidelity numerical models.

Many of the shortcomings of DED originate in poor understanding and control of the powder delivery. We have developed a state-of-the-art model of powder stream where the powder phase and gas phase are modelled by using a fully coupled combination of Discrete Element method (DEM) and Computational Fluid Dynamics (CFD). This approach however neccessitates an accurate boundary condition for the powder at the nozzle outlet. An original approach was developed where powder particle velocity distributions are measured at the nozzle outlet using a pair of high-speed cameras. Using this novel experimental technique, we were able to show that the powder velocities depend heavily on the particle size. Moreover, contrary to widespread assumptions, smaller powder particles were found to move through the nozlle faster than the average carrier gas speed by concentrating the center area of the nozzle.