In-process inspection of laser metal deposition specimens using a laser ultrasonic system embedded on a robotic arm

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Laser metal deposition process (LMD) is one of the metallic additive manufacturing (AM) technique where the successive layers of an object are built by a laser beam forming a pool of melted metal onto substrate, while metal powder is injected by a coaxial nozzle through a gas flow. During 3D printing, variation of the process parameters (like the hatch parameter) could give rise to small defects that can be critical for the mechanical properties of the component. We will present the first results of a new robotized laser-ultrasonic system composed of commercial and specific parts, deployed through the French FUI project "I Am Sure", to monitor continuously the quality of the metal layers during process. The laser ultrasonic head has been designed to be able to perform measurements on scattering or rough surfaces encountered with the process, taking into account that defects, microstructural and surface roughness characteristics are close to the acoustic wavelengths. Two configurations were tested; one uses surface waves and required the design of a specific optical head favouring high frequency Rayleigh waves [1], the other uses zero-group velocity (ZGV) modes [2] and takes advantage of the possibility of generating and record resonances in the parts with thin walls which characterize parts built with the DED process. To carry out the control during manufacture, and follow the movements of the 5-axis robots of the DED machine, a specific 6-axis robot carrying the probe has been installed in the enclosure. The synchronization of the trajectories of the probe robot (digital twin) with the robot supporting the additive manufacturing machine allowing a follow-up to be carried out. We will describe the developed device and present measurement results obtained by intentionally varying the manufacturing parameters (hatch and laser power) in order to vary the porosity rate of parts. Then correlation methods will be used to distinguish the nature of the different defects detected. [1] C. Million, PhD thesis (in french), 'Contribution to the inspection of metal additive manufacturing parts by Rayleigh waves using laser ultrasonic technique', Conservatoire National des Arts et Métiers, (2018), C. Millon et al., Welding in the World 62(3), 653-661, (2018) [2] C. Prada, O. Balogun, and T. Murray, Appl. Phys. Lett., 87(19), (2005), C. Prada, D. Clorennec, and D. Royer, J. Acoust. Soc. Am., 124 (1), 203-212, (2008), J. Laurent, D. Royer, T. Hussain, F. Ahmad, and C. Prada, J. Acoust. Soc. Am. 137(6), (2015), F. Bruno, J. Laurent, P. Jehanno, D. Royer, C. Prada, J. Acoust. Soc. Am., 140 (4), 2829-2838, (2016)