Development of Laser Beam Modulation Assets for Process Productivity Improvement of Selective Laser Melting

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Nowadays, rapid prototyping and additive manufacturing methods are developing very intensively. Selective laser melting is one most promising method for solid growing. SLM is important in such industries as auto and aircraft industry as well as individual medical applications [1]. The main principle of the method is layer-by-layer growing of solids by remelting of powders with a laser beam in accordance with 3D models [2, 3]. Still there are some unsolved problems concerning the productivity of the method. With enlarged laser source power, the productivity problem could not be resolved directly [4]. The optical diagnostics of the process showed while processing that there are consequences of the thermal hit in the melting pool as powder granules' escape, interruption of the powder layer equability, Marangoni effect, active chemical interaction with camera environment, overheat, and dynamic effects in the melting pool [5]. The described problems could be connected with the features of temperature gradients in the melting pool [6], which are the result of the power density distribution (TEM00). To create a smoother temperature gradient and the optimal conditions for the heat and mass transfer in the melting pool, a test installation for SLM-processing with a laser beam power density distribution modulation system was built (Figure 1). The installation was provided with an optical diagnostics system for on-line control of the negative effects in the melting pool. All received single tracks were studied with optical and SEM microscopy.

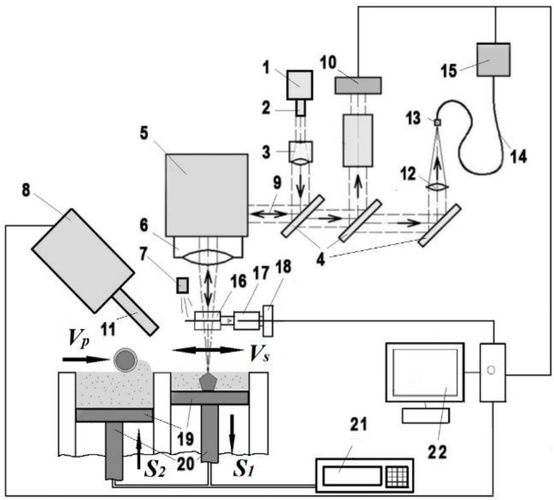

Figure 1: Test installation schematic diagram: 1, ytterbium fiber laser; 2, optical collimator; 3, pi-shaper; 4, mirrors; 5, scanning head; 6, F-theta focusing lens; 7, laser backlight; 8, Photron SA5 high-speed camera; 9, laser beam optical path; 10, IR camera; 11, NAVITAR 6000 macro lens; 12, pyrometer lens; 13, signal receiver; 14, optical cable; 15, pyrometer; 16, BCube optical mirror; 17, optical attenuator; 18, LaserCam-HRTM CCD camera; 19, platforms; 20, movable pistons; 21, micrometer; 22, PC; V_p , powder feed velocity; V_s , laser scanning velocity; S_1 , working platform feed velocity; S_2 , powder dosage feed velocity.

The main difference between tracks was found when studying the free powder consolidation zone, which is reduced from Gaussian to donut laser beam profile and which can give visible results in the improvement of productivity in the further work. It indirectly shows the reduction of the negative effects such as the granule emission from the melting pool. The study shows that the non-Gaussian laser beam distribution significantly reduces the width of the free powder consolidation zone, which is considered to be the main cause of irregularity for single tracks for the laser power of more than 150W. The single track obtained by Gaussian laser beam profile shows a deeper remelted zone in the center of the track than on its periphery.

The flat-top laser beam profile shows a more regular character for the melting zone, which demonstrates more homogenized metallurgical bonding. Both of these facts show a significant influence of the laser beam energy distribution on the energy loss at selective laser melting, especially for high-power laser sources. Optical diagnostics by high-velocity camera (HVC) also gives important data about the stability of the process.

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