Mechanical properties of the samples produced by volume powder cladding of stainless steel using a continuous fiber laser

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Abstract. Samples for tensile tests were manufactured by using one of the additive technologies – direct laser material deposition. Investigations were carried out at the facility Huffman HC-205 equipped with a fiber laser with a power up to 3.5 kW. Various strategies of layering metallic powder of stainless steel 316L were considered to optimize the modes of constructing the samples. We measured the stress-strain state of the produced samples by the method of digital image correlation. It is found that the nominal tensile strength of the samples produced by the direct growing using laser powder of 316L steel is of high level - 767 MPa.

1. Introduction

The technology of direct laser deposition of metal powder allows to produce parts layer-by-layer on a pre-programmed path. It is possible to make prototypes and operating samples for further industrial applications [1–3]. However, widespread implementation of this technology is difficult, because dependences of the obtained product properties on the technological mode of their preparation as well as the creating strategy are yet poorly understood. Primarily, this process is characterized by a large number of different parameters. However, the following basic ones should be emphasized since they have the greatest impact on the final quality of the product microstructure. They are power of the laser source, powder feed rate, the scanning speed of the laser beam and the strategy of processing the alloyed product layer by laser beam [4, 5].

2. Materials and equipment

In our experiments we used Höganäs 316L powder with a particle size of 20–53 μm and its chemical composition shown in table 1.

Table 1. The chemical composition of steel grade 316L powder.

The content of alloying elements, masses, %						
Cr	N	Mo	Mn	Si	C	Fe
17.0	12.0	2.5	1.5	0.8	<0.03	Balance

Experiments were carried out in the industrial apparatus Huffman HC-205, equipped with a high-power fiber laser LS-3.5, the coordinate system with five degrees of freedom, and a powder feeding

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system. The mixture powder was transported by inert –argon gas and focused into the treatment zone via a coaxial nozzle. Protection of the cladding area was simultaneously produced by the same gas.

3. Results of experiments

The samples were created in the form of double-sided blades for tensile testing. The following process parameters were varied during operation in this process: laser power, scanning speed, powder flow rate, the gap between the nozzle and the deposited layer, as well as the direction of the powder coating and subsequent melting. Two directions were chosen for double-sided cladding of blades: parallel to the direction of tension (figure 1) and perpendicular one (figure 2). If the cladding direction is parallel, the contour of the blade 1 would be deposited first, and then it would be the inner part, consisting of several regions, numbered 2–5. Perpendicular deposition consists in drawing the contour, and then filling it with consistent cladding tracks. Also, the start peaks of cladding were alternated to improve thickness uniformity of the sample. After the cladding of two layers with different deposition directions of rolls starting at point A, the nozzle moves to point B, from where the cladding of two layers is made as well. Next, the operation is repeated starting from points C and D. Table 2 summarizes the process modes to obtain the samples. It should be noted that deposited layer for some of the samples was remelted to reduce the roughness and improve layer stability.

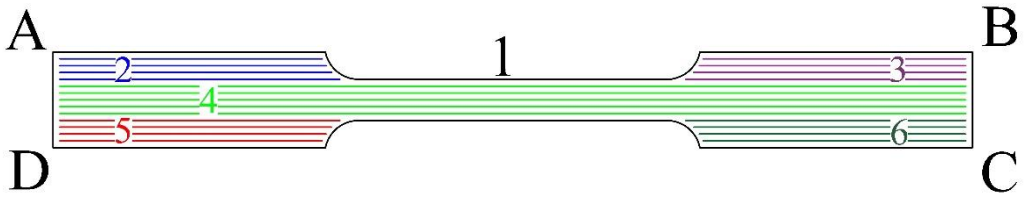


Figure 1. Scheme of cladding of rollers in a longitudinal direction.

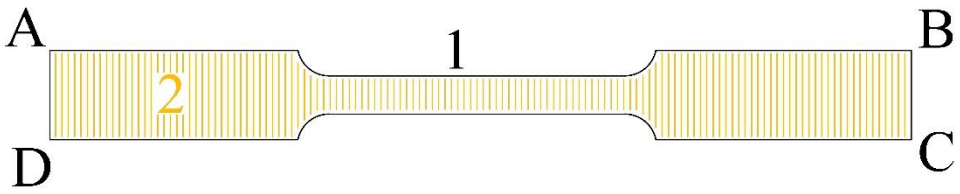


Figure 2. Scheme of cladding of rollers in a transverse direction.

Table 2. Modes of volume formation samples laser cladding method for tensile testing.

№	Cladding					Remelting	
	Power, W	Speed, cm/min	Powder federate, g/min	Gap, mm	Gap change after each layer, mm	Power, W	Speed, cm/min
1	200	100	0.8	3	0.13	100	127
2	200	100	1.1	3	0.2	100	127
3	300	100	1.1	4	0.2	-	-
4	250	100	0.8	3	0.2	-	-
5	350	100	0.8	3	0.2	-	-
6	250	100	0.8	3	0.2	-	-

Samples no. 1–6 using EDM wire cutting were divided into separate 1 mm thick bilateral blades. Tests to determine the mechanical properties of the samples were carried out on a tensile testing machine Instron. The results are shown in figure 3.

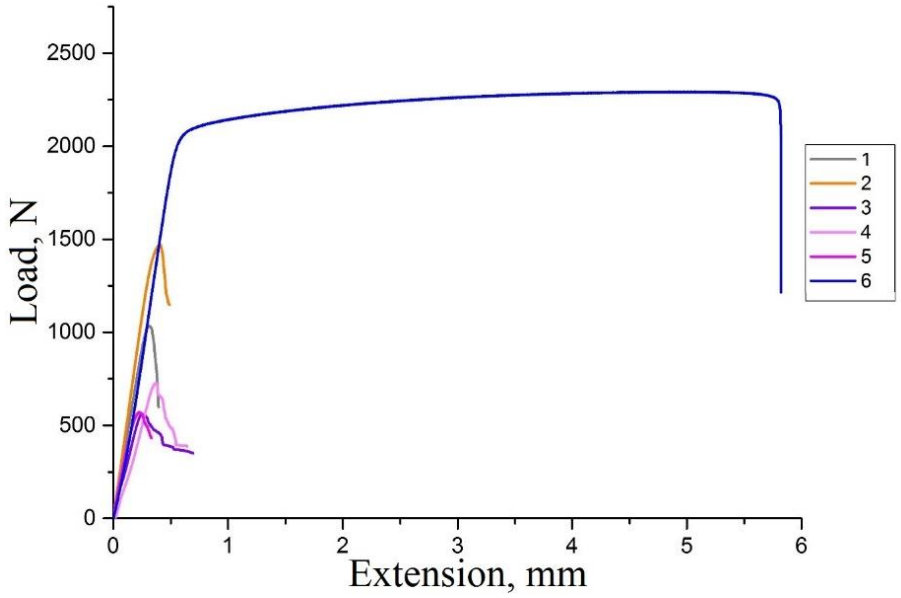


Figure 3. Load-displacement diagram for samples no. 1–6.

These results demonstrate that the sample no. 6, which had the largest height stability, and most smooth side surface, weathered larger load compared to samples no. 1–5. Tensile strength of the obtained sample is equal to 767 MPa. It should be noted that for the used steel grade 316L tensile strength after quenching and tempering is equal to 780 MPa.

Three samples in a parallelepiped form were created in the regime no. 6 with different deposition directions of layers: sample no. 7 was created with the direction of the track along the extension line, sample no. 8 – with the track across the extension line, and sample no. 9 was formed in the crossed directions.

Samples no. 7–9 were also cut into 1 mm thick plates, and then were laser cut in a pattern similar in size tono. 6 blades. This was done to study the mechanical properties depending on the direction of sample cladding and the defects on the boundary. Samples no. 7–9 were also tensile tested, and the results are shown in figure 4.

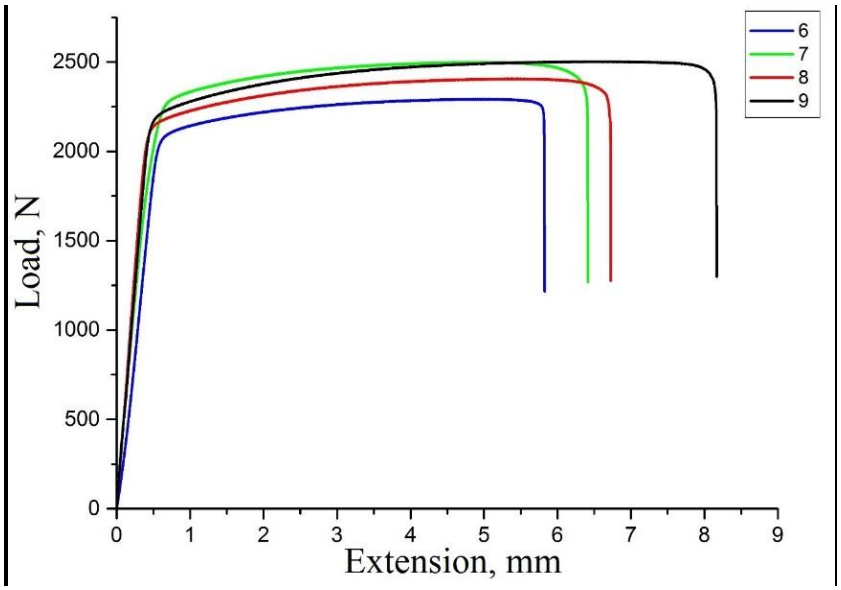


Figure 4. Load-displacement diagram for samples no. 6–9.

Results show that the samples no. 7–9 obtained by direct laser deposition of a blank followed by laser cutting withstand higher loads compared with the sample no. 6 obtained by direct laser deposition without post processing. Sample no. 9 with the tracks cladded in crossed directions withstands higher load than the samples cladded both in parallel (no. 7) and perpendicular (no. 8) directions. More uniform distribution of the internal stress after the deposition can be a possible reason for this. It is necessary to conduct more detailed studies of the microstructure of the samples.

4. Conclusion

The paper demonstrates the strategy of the optimal mode selection for obtaining products by direct laser deposition. The optimal mode is characterized by a small height of single layer providing its uniformity, and not using the layer re-melting to reduce the heating of the sample. The laser power was 250 W, the gap between the nozzle and the deposited layer was 3 mm, the scanning speed was 100 cm/min, and the powder flow was 0.8 g/min. It is also shown, that defects at the edges, for example, splashes and bumps on the sidewalls, strongly affect the mechanical properties of the sample, reducing the maximum load a sample can withstand.

Acknowledgments

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