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Evaluation of the quality of the internal microstructure of fused components during laser fusion

In today's world of rapid development of scientific and innovative technologies, it is impossible to imagine any industry of the world's leading countries without the use of laser technology. Such a universal tool as a laser can perform many technological operations and be used by many modern technologies, one of which is "Rapid Prototyping" technology, rapid prototyping of products. In the implementation of the technological process of laser fusion of the powder composition according to the scheme of injecting the powder into the area of focused laser radiation, one of the main roles is played by the level of the dispersed phase of the gas-powder mixture in the laser area. Existing means of delivery of powder material to the laser treatment area, namely coaxial nozzles form the dispersed composition of the gas powder jet due to its aerodynamic characteristics and in most cases by means of dosing systems (dispensers) that regulate the mass flow of powder material [1]. The proposed principle of regulating the dispersed composition of the powder material in the laser treatment zone, which is considered in this article is based on controlling the shape of the gas powder jet, due to the design features of the coaxial nozzle, namely a set of interchangeable nozzles with different angles, which greatly simplifies of the dispersed phase in the area of focused laser radiation [2].

Methods of mathematical statistics were used to study the integrity (as one of the main quality criteria) of the internal microstructure of fused fragments in the implementation of the process of laser fusion of powder material PGSR-3. Namely, a non-compositional Box-Benken plan for 4 technological factors was chosen, which has good statistical characteristics and is realized by the regression equation (1) of the second order [3].

$$y = b_0 + \sum_{i=1}^{i=k} b_i x_i + \sum_{i \le j}^{i=k} b_{ij} x_i x_j + \sum_{ii=1}^{i=k} b_{ii} x_i^2 \qquad (1)$$

where k is the number of technological factors;
b_0, b_i, b_{ij}, b_{ii}-coefficients of the regression equation;
x_i, x_j-technological factors.

The continuity of the internal microstructure of the fused fragments (W) was used as a response function. As technological factors influencing the integrity of the internal microstructure in the implementation of the process of laser fusion of the powder composition (previously defined), subject to stabilization of the factors of laser beam diameter, density and power of laser radiation were used geometry of nozzle angles, mass powder consumption, the speed of movement of the substrate, the position of the substrate relative to the cut nozzle. The coefficients of the regression equation (1) were calculated using the mathematical apparatus of linear algebra [3]. The degree of statistical significance of each of the technological factors on the function of the continuity response (*W*) is shown in the ranking diagram (fig. 1).

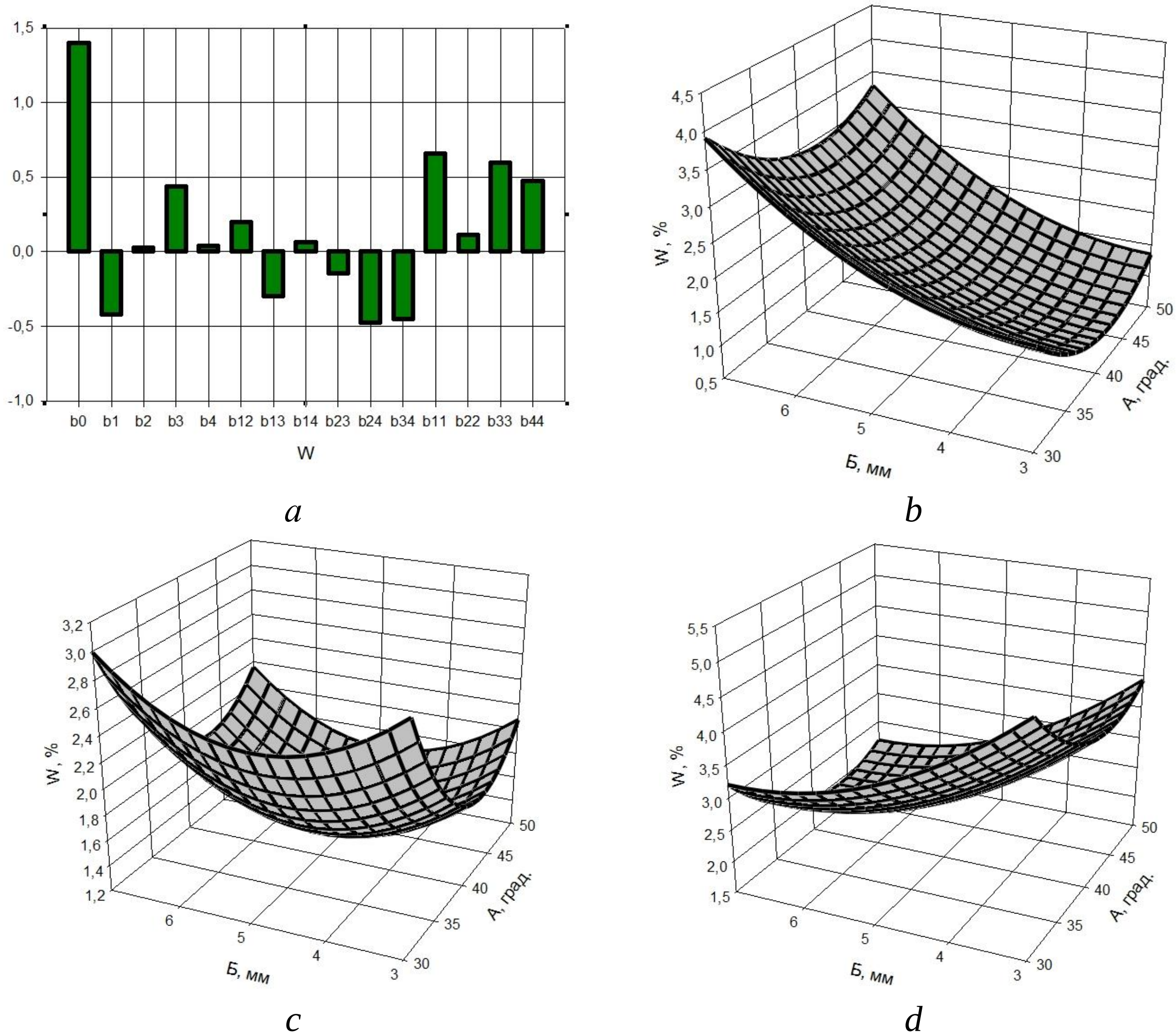
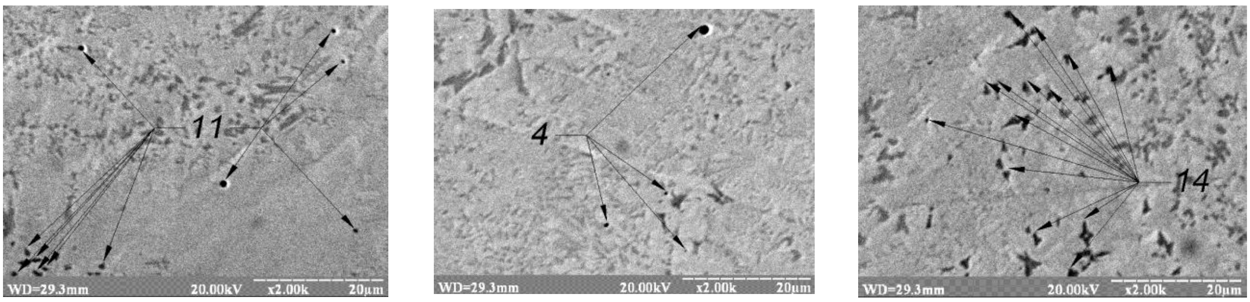


Fig. 1. Rank diagram of the degree of statistical significance of technological factors on the response function (*W*) (a) and the dependence of the continuity of the fused fragment (*W*) on the geometry of the angles forming nozzles (*A*) for different

positions of the substrate (*B*) with mass consumption of powder composition 0,1-0,3 g/s and the speed of movement of the substrate 1 mm / s (*b-d*).

The best indicators of continuity of about 1,2% are observed at angles of geometry forming 40° for the speed of movement of the substrate 2 mm/s, mass flow rate of powder material 0,3 g/s, and the distance from the nozzle cut 5 mm (fig. 1, d), The main factor in the formation of fragments close to the ideal microstructure of the fused fragment is the coincidence of the position of the substrate with the position of "focus" of the gas powder jet, due to which the laser radiation occurs in the area with the maximum transverse concentration the content of the dispersed phase in the treatment zone, these conditions lead to the formation of fragments with a dense solid microstructure. Similar indicators of continuity of approximately 4% (fig. 1, d), such as in the case (fig. 1, b) are observed for geometry angles of 30°, the speed of movement of the substrate 3 mm/s, the mass flow rate of the powder material 0,4 g/s, and the position of the substrate from the nozzle cut 3 mm (fig. 1, b), this is mainly due to the small distance of the substrate from the nozzle cut 3 mm above the position of the "focus" of the gas powder jet, and high speed of the substrate 3 mm/s leads to the formation of a gas-powder jet with a large cross-sectional area and a low concentration of the dispersed phase in the gas stream, due to which fragments of the fused powder composition with a sufficiently high content of voids are formed. In fig. 2, a)-c) as an example, photographs of the surface of the microsections of fused fragments for the three angles of geometry forming a coaxial nozzle 30°, 40 ° and 50°, indicating the total number of hollow fragments, optical magnification of 2000 times (fig. 3, a).



a) b) c)

Fig. 2. General view of the microsections of the internal microstructure of the fused fragments with a total number of hollow sections:

a)-angles of geometry forming nozzles 30°;

b)-angles of geometry forming the nozzle 40°;

c)-angles of geometry forming the nozzle 50°.

As can be seen from the photographic material (fig. 2, a-c), the change in the angles of the geometry of the forming nozzles affects the quantitative indicators of the continuity of the internal microstructure of the fused fragments, namely the maximum quantitative indicators of the continuity of the internal microstructure of the rolls are observed 30° and 50° (fig. 3, a), c) 11, 14 pcs. respectively) the minimum value corresponds to the nozzle with the angles of geometry forming 40° (fig. 3, b 4 pcs.).

Conclusions

1. The optimal modes of the process of laser fusion of powder material, which provide the maximum continuity of the internal microstructure of the fused fragments *W*=1,2% (percentage of hollow fragments, shells, micro cracks).

2. The obtained mathematical model of the continuity of the internal microstructure of the fused fragments, which can then be used as a calculation of controlled effects aimed at maintaining a constant level of quality of future products.

3. The adequacy of theoretical calculations on the possibility of using mathematical models of the process of laser fusion of powder material for their further use in the implementation of "Rapid Prototyping" technology has been confirmed.

References

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