The influence of the pause time between the passages, when Stellite 6 is deposited on the turbine wheel blades of the MAR-M200 alloy

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Abstract. Repair of blades from the MAR-M200 alloy is of great interest, since this procedure is much more profitable than manufacturing new products. At the same time, there are great difficulties associated with the fact that this alloy does not tolerate the high temperature [1], the high speed cooling and thermal cycling [3,4] that accompany the laser surfacing process. In this regard, an important study will examine the deposition regimes with pauses between the passages, designed to reduce the cooling speed and, as a consequence, the temperature drop. The article presents the results of the influence of the duration of a pause between passages on the structure and properties of samples obtained by laser cladding. Four variants of pause-0, 25, 50 and 100 seconds were investigated.

1. Introduction
The method of laser cladding provides a unique combination of high accuracy and a zone with low heat transfer, which is attractive for repair of expensive in repairing products, such as turbine wheel blades. Cobalt alloys are widely used in aircraft engines because of their high mechanical properties in operations at high temperatures. Repairing or manufacturing these products by laser cladding requires an understanding of the influence of many parameters, so controlling the process plays an important role. This work is focused on the study of properties of deposition based on Stellite 6. The presented results show how the pauses between the passages during the cladding affect the microstructure and properties of the samples obtained by laser cladding.

2. Materials and methods of research
Technological studies were carried out on an automated laser welding complex, developed directly for restorative laser cladding of crests, shrouds and ends of turbine blades. The main components of the complex are: ytterbium fiber laser LC-700, IRE-Polis, robot LR Mate 200 iD / 7L, Fanuc, laser cladding head D30, IPG, cladding nozzle Coax 40, ILT, Powder feeder PF 2 / 1LC, Plakart.
Process parameters: laser power 250 W, laser scan speed 5 mm/s, Powder feeding speed 2.6 g/min, beam offset dz 0.325 mm, pause time 0, 25, 50 and 100 seconds. Stellite 6 powder was used as the building material.
Metallographic studies of the samples were carried out on a DMI 5000 (Leica) microscope with the Tixomet software. The hardness was measured on microhardness tester Future-tech FM-310 with the Tixomet software.

Table 1. Parameters of surfacing mode

| №  | Basis material | Building material | Beam diameter, mm | Quantity steps | Power, W | Speed, mm/s | Powder consumption, g/min | Step, mm | Pause, s |
|----|----------------|-------------------|-------------------|----------------|---------|-------------|---------------------------|---------|---------|
| 1  |                |                   |                   |                |         |             |                           |         |         |
| 2  | MAR-M200 Stellite 6 | 0,9               | 6                 | 250            | 5       | 2,6         | 0,325                     |         |         |
| 3  | MAR-M200 Stellite 6 | 0,9               | 6                 | 250            | 5       | 2,6         | 0,325                     | 50      |         |
| 4  |                |                   |                   |                |         |             |                           | 100     |         |

3. Metallographic research

3.1. Microstructure research

From the blades with Stellite 6 surfacing microsections were made. To study the microstructure, the sections were etched. The figure 1 shows photographs of the microstructure of the blades with overlays produced by different modes. On the photographs of microstructures, the presence of defects, the types of structures, the distances between the dendrites and the angle of inclination of their axes were determined. The results are shown in Table 2.
Figure 1. Microstructure of the samples was made: a) without pauses; b) with 25 seconds pauses; c) with 50 seconds pauses; d) with 100 seconds pauses.

Table 2. Parameters of microstructure

| №  | Pause, s | Type of structure | Distance between dendrites, µm | Angle of inclination of dendrites, ° | Defects |
|----|----------|-------------------|-------------------------------|--------------------------------------|---------|
| 1  | 0        | dendritic         | 8,4                           | 51,8                                 | -       |
| 2  | 25       | dendritic         | 7,2                           | 52,3                                 | -       |
| 3  | 50       | dendritic         | 9,3                           | 62,1                                 | -       |
| 4  | 100      | dendritic         | 10,3                          | 59,6                                 | -       |
It can be seen from the table that, with increasing pauses between the passages, the distance between the axes of the dendrites increases, as well as the angle of inclination of their axes, which indicates a decrease in the speed of crystallization, and, correspondingly, a decrease in thermal cycling. Reducing thermal cycling, to a large extent, reduces the risk of cracking, which is very important for the MAR-M200 superalloy.

3.2. Mechanical properties research
Further, the hardness of the blades was measured in height from the base to the site of surfacing, to determine the effect of the surfacing process on the blade metal. The results of hardness measurements are presented in table 3.

Table 3. The hardness of the blades

| №  | 1 (0), HV | 2 (25), HV | 3 (50), HV | 4 (100), HV |
|----|-----------|-----------|-----------|-----------|
| 1  | 461       | 501       | 435       | 458       |
| 2  | 450       | 469       | 451       | 468       |
| 3  | 458       | 469       | 436       | 463       |
| 4  | 448       | 461       | 450       | 441       |
| 5  | 454       | 477       | 437       | 465       |
| 6  | 431       | 504       | 447       | 432       |
| 7  | 440       | 464       | 478       | 438       |
| 8  | 481       | 506       | 437       | 477       |

Figure 2. Hardness graphs of blades in height from the base to the site of surfacing: 1) without pauses; 2) with 25 seconds pauses; 3) with 50 seconds pauses; 4) with 100 seconds pauses.

Further, the hardness of the surfacing was measured from the substrate, as the blade protrudes, to the upper edge of the surfacing. The results of hardness measurements are presented in table 4.
Table 4. The hardness of the surfacing

| №  | 1 (0), HV | 2 (25), HV | 3 (50), HV | 4 (100), HV |
|----|-----------|------------|------------|-------------|
| 1  | 486       | 440        | 421        | 404         |
| 2  | 455       | 403        | 400        | 422         |
| 3  | 470       | 492        | 511        | 514         |
| 4  | 549       | 543        | 564        | 565         |
| 5  | 594       | 597        | 588        | 597         |
| 6  | 692       | 643        | 566        | 687         |

mean 541 519,6667 508,3333 531,5

Figure 3. Hardness graphs of layers of surfacing: a) without pauses; b) with 25 seconds pauses; c) with 50 seconds pauses; d) with 100 seconds pauses.

4. Results and conclusions

As a result of the metallographic research, images of the microstructures of the samples were obtained. The distribution of hardness in the zone of surfacing, thermal action, and also the base metal is determined. The samples showed no defects, including cold or hot cracks, which may result from thermal cycling. On the hardness of the blade, the thermal mode of the surfacing process affected slightly. As for the hardness of surfacing, no pause effects, and it evenly grows with the height of surfacing. All this confirms the possibility of using surfacing technology with pauses of different exposures. This technology can be used to mitigate thermal cycling or excessive overheating, as well as to perform successive layer surfacing on a large number of blades using an automated complex.
References

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