Research of the absorption of laser radiation by powder materials

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Abstract. In this paper, various approaches to the change in the absorption capacity of granules of various powder materials are considered, and the absorption capacity of various powder materials is also investigated. Investigation of the efficiency of absorption of laser radiation was carried out with the help of a continuous laser. Graphs of the laser power versus the powder surface temperature were obtained.

1. Introduction

The technology of selective laser melting is a complex process of forming parts from ultrafine powder composition. Obtaining a part that meets all the necessary requirements is the result of choosing the right value of the characteristics of the material and the parameters of exposure to laser radiation. There are a number of major problems in the manufacture of parts using selective laser melting. When laser radiation is applied to low-melting and fine-dispersed components, intense gas formation occurs, which contributes to the formation of pores (due to sharp temperature differences, cracking is possible). There is also the problem of creating complex alloys with homogeneously distributed components [1]. Some powder materials require less energy during processing, which leads to melting, so it is reasonable to use approaches that somehow reduce their ability to absorb incident laser radiation. The absorption capacity of the powder layer depends not only on the physicochemical properties of the powder material, but also on its particle size distribution, on the bulk density of the powder [2]. The radiation also passes through the voids between the particles of the powder and interacts with the underlying particles. The distribution of heat in the depth of the powder layer is determined by the usual mechanism of heat transfer. The intensity of laser radiation decreases with its penetration into the powder layer [3, 4]. To reduce the absorption capacity of granules of the powder material, it is possible to use larger particles, apply reflective coatings [5, 6], and also polish the granules of the powder composition. The study of the absorption coefficient of laser radiation by particles of powder materials will make it possible to expand the range of alloying additives into metals [7], the use of which is limited by different melting points of the powder material. To measure the absorption coefficient, calorimetric methods are...
commonly used, based on an increase in the sample temperature during the absorption of part of the laser radiation incident on it [8–10]. In this paper, we consider various approaches to the change in the absorption capacity of granules of aluminum-based powder materials, as well as the absorption capacity of aluminum powder materials.

2. Experimental work

The following samples were used: powders: initial Al and aluminum, modified in two ways. Carbon saturation of the surface of powder materials was carried out by joint grinding in a planetary mill. Composite powders were specially prepared as follows: aluminum powder was loaded into a planetary mill together with a modifying powder (in the first case - corundum, in the second - graphite) and spherical grinding bodies with hardness exceeding the hardness of the components being processed. The powder was subjected to mechanical action of both grinding bodies and metal granules, which contributes to its grinding. After processing, the powders were passed through sieves, which screened out the powder particles with a size greater than 30 μm.

A fiber laser operating in a continuous generation mode with a power up to 200 W and a wavelength of 1064 nm was used as a radiation source. The laser beam emerging from the collimator passed through the beam expander, then fell on the surface of the powder material, the laser beam diameter on the surface of the powder material was about 25 mm. In the substrate, on the surface of which the powder layer was deposited, 2 thermocouples were fixed: one in the marginal region, the other in the central one. This was done to improve the accuracy of measurement and calibration of the photodetector. The measurement of temperature sensors was carried out through an analog-to-digital converter. Measurement of temperature values during irradiation with laser radiation was carried out using a photopyrometer and thermocouples. The scheme of the experiment is shown in Figure 1.

![Figure 1. Diagram of an experiment to study the efficiency of absorption of laser radiation: 1 - Laser system; 2 - Beam Expander; 3 - Laser beam; 4 - Powder material; 5 - Thermocouple; 6 - Analog digital converter; 7 - PC; 8 - Photopyrometer](image)

The study of the absorptive capacity of the powder material was carried out as follows: a layer of powder material was applied onto a substrate with thermocouples, the surface formed was leveled with a roller, similar to the process of powder placement during layer-by-layer laser melting. The surface formed was exposed to laser radiation. The impact area was larger than the area from which
the photo of the pyrometer was taken. Pyrometer readings were controlled by integrated thermocouple readings. This is necessary in view of the violation of the correctness of the photo pyrometer readings caused by temperature distortions and changes in the reflective properties of the surface. The increase in the area of impact was achieved through the use of a beam expander, thus it was possible to carry out uniform heating of the surface of the powder material excluding changes in the state of aggregation of materials, melting, boiling, gas formation.

Before starting measurements, it is necessary to achieve thermal equilibrium. The range of variation of the laser power was chosen in such a way as to eliminate melting, evaporation, and other changes in the state of aggregation powders. A measurement protocol was created in which the detected dependences of the absorption coefficient both on the power of the incident energy and on the temperature of the sample being measured are indicated. The measurement protocol includes the sample temperature $T(t)$ and laser power $P(t)$.

3. Research

The surface morphology and particle size distribution of the powders after mechanical processing in a ball mill were examined using scanning electron microscopy. Figure 2 shows the images of the original and processed powder materials.

![Figure 2. Methods of modification of powder materials: 1 – Laser radiation; 2 – A particle of metal powder; 3 – Particles of absorbing materials; 4 – Reflection of laser radiation; 5 – Absorption of laser radiation.](image)

In the first method to change the absorption capacity of the granules, the material was processed by mechanical action of the abrasive material on the metal base of the powder. As a result of grinding the powder composition in a planetary mill, the surface and shape of the granules was greatly changed, a developed microstructure was formed, which absorbs energy much more efficiently than the original powder. The rough surface of powder materials is a large number of microscopic areas, oriented at different angles to the direction of incidence of the light wave, characterized by different values of the reflection coefficient. The second method of preparation of the powder material is the use of absorbing
coatings, this approach allows you to equalize the energy threshold leading to the melting of certain granules. Carbon materials were used as a coating of microgranules, and as photoabsorbing granules. Figure 3 shows the graphs of the laser power versus the temperature of the powder surface.

Aluminum pure powder heats up much slower than powders that have undergone special modifying preparation. This confirms the possibility of increasing the absorption capacity of the aluminum granules of the powder composition using highly absorbent materials.

4. Conclusion

In this paper, we studied the absorption capacity of aluminum powder materials. An experimental setup was created to measure the absorption capacity of powder materials. An experimentally confirmed increase in the absorption capacity of aluminum powder material with the help of additives of highly absorbing materials. Such an approach will allow leveling the energy threshold leading to the melting of certain granules. It is reasonable to use the proposed approaches for modifying granules for processing powder materials that require significantly more heat compared to the base material, namely, large granules or more refractory materials.

5. Bibliography

[1] Yan S. J. et al. 2014 *Materials Science and Engineering: A.* 612 440-444
[2] Smurov I Yu et al. 2011 *Vestnik MGTU Stankin* 2 (4) 144-146
[3] Bashkirov E R et al. 2017 *Fundamentalnye issledovaniya* 3 (9)-14
[4] Kostritsky V V et al. 2013 *Bulletin of Polotsk State University. Series B, Industry. Applied Science* 3 97-101
[5] Voznesenskaya A et al. 2018 *Scientific and Technical Journal of the Volga region* 1 50-52
[6] Voznesenskaya A et al 2018 *J. Phys.: Conf. Ser.* 1109 012056
[7] Grigoriants A G et al 1987 *Laser technology and technology: In 7 books. Book 3. Methods of surface laser treatment* (Moskow: Higher School) 159
[8] Kostenkov S N et al 2011 *Bulletin of Udmurt University. Physics and Chemistry Series* 13-23
[9] Jordan V I 2013 *Proceedings of the Altai State University* 1-1 (77) 167-171
[10] Delone N.B. 1989 *Interaction of laser radiation with matter - Course Lectures* (Moskow: Science) 280