Processing of products with pulsed laser radiation

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Abstract. This article is devoted to experimental studies of pulsed cutting of B93 aluminum alloy of holes, grooves in combustion chambers and the inlet fairing of a gas turbine engine, which were carried out with the change of the following parameters: laser power, cutting speed, frequency and duration of pulses, deepening of the focal spot into the material. The dependences of the cutting speed, laser radiation power on the cutting width and surface roughness were obtained, the results show an increase in the quality of cutting with the use of compressed air and an increase in the quality of processing.

1. Introduction. A number of processes for the separation of materials based on electrochemical, electrophysical, and physicochemical effects have become widespread in industry. Acetylene-oxy-fuel cutting, plasma cutting, penetrating arc and other physicochemical separation methods provide an increase in productivity compared to mechanical methods, but do not provide high accuracy and cleanliness of the cut surfaces and require in most cases subsequent machining [1]. Development of fundamentally new technological processes - the implementation of the idea in the early 60s of the XX century. Obtaining induced coherent monochromatic radiation and creating a laser. This event served as a powerful stimulus for the development of devices and processes using laser radiation and found application both in the field of fundamental and applied sciences, as well as in areas related to industrial applications of lasers and the development of fundamentally new processes. One of such processes is the laser technology of materials processing - the ability of a laser radiation formed in a certain way to cause a fairly rapid local heating, melting and evaporation of the material.

Laser radiation can be organized in time in the form of single or a series of pulses of a given shape with a certain duration, repetition rate and peak power. Such a possibility is presented when using repetitively pulsed lasers with appropriate Q-switches and other optoelectronic devices. This makes it possible, by setting the required heating rates and the residence time of the material at high temperatures, to choose the optimal ones in terms of the process efficiency and minimal structural changes in the operating mode.

Laser radiation, as an electromagnetic wave in the optical range, also has such an important technological quality as inertia-freeness. Taking into account the mass of photons disappearing and the high speed of light, the time of turning on and off the beam, the change in the direction of movement of the beam relative to the part is determined only by the speed of the corresponding device (optical shutter, mechanism for moving the mirror or coordinate table).
Laser cutting can be carried out both with through cutting of the material, and in the form of obtaining grooves and tracks. Laser cutting includes the following operations:

- processing of dielectric, cermet and oxide films to adjust the values of resistors and capacitors in microcircuits, the frequency of quartz resonators;
- obtaining patterns on thin films, applied to dielectric substrates of microcircuits, which is carried out both by direct evaporation and by scanning the beam using special marks;
- engraving and marking of parts;
- separating through cutting of materials to obtain parts of finished configurations.

Drilling holes includes the following operations:

- obtaining blind holes in order to balance some products,
- perforation or stitching of holes.

The least energy-consuming separation method is based on thermal cleavage of brittle materials due to the creation of thermal stresses in the irradiation zone exceeding the ultimate strength of the material [2].

The quality of laser cutting is characterized by the width of the cut, the deviation of the side surfaces of the cut from the perpendicularity to the plane of the sheet, the value of the roughness of the surface of the sheet and the absence or presence of burrs (solidified drops of melt on the lower edge of the cut).

The nature of the interaction of laser radiation with metals depends on its power, absorption and reflectivity of metals, as well as on their thermophysical properties [3].

There is an urgent need for the development and mastering of cutting methods for modern structural materials that combine high performance both in process productivity and in the accuracy and quality of cutting surfaces. Laser cutting of metals is one of such promising processes for separating materials.

The use of an auxiliary gas makes it possible to significantly reduce the specific consumption of radiation energy due to a more intensive removal of destruction products from a narrow cut slot. When cutting metals, oxygen is mainly used [4]. Pulsed laser cutting of aluminum alloy is preferable not only for a turbojet engine, but also for the fuselage, wing and empennage [5].
2. Main part.

Figure 1 shows the dependence of the pulse repetition rate $n$ of duralumin 3.5 mm thick on the speed of the pulsed laser $V_c$.

The curve is described by the equation:

$$y = 240783x^2 - 2395.1x + 1049.7$$

with a correlation coefficient $R^2 = 0.7674$.

Figure 1 shows the dependence of the pulse laser speed $V_c$ on the pulse repetition rate $n$ of duralumin with a thickness of 3.5 mm, where it can be seen that with an increase in the pulse frequency, the speed increases.
Figure 2. Dependence of the pulse repetition rate $n$ of duralumin 5 mm thick on the speed of the pulsed laser $V_c$

Figure 2 shows the dependence of the pulse repetition rate $n$ of duralumin with a thickness of 5 mm on the speed of the pulsed laser $V_c$, where a gradient curve is shown, showing the correspondence of a low frequency of 800 Hz to a relatively low speed of 0.013 m/s.

In Figure 2, line 1 corresponds to the optimal trajectory of the laser cut, therefore, to the optimal cutting modes at a thickness of 5 mm with a LaserCut 3015 fiber laser in the pulsed mode of the equipment.
Figure 3 shows the dependence of the pulse duration $\tau$ of 7 mm thick duralumin on the pulse laser speed $V_c$. The figure shows that with an increase in the pulse duration $\tau$ and the cutting speed also increases.

In Figure 3, the dotted line shows the optimal boundaries of the laser cut. Lines 2,3 correspond to the upper and lower boundaries of the cut, respectively, where no pulsed laser cutting is carried out outside of it (a non-cut is formed). Line 1 corresponds to the optimal trajectory of the laser cut, therefore, to the optimal cutting modes at a thickness of 7 mm with the LaserCut 3015 fiber laser in the pulsed mode of the equipment.

References

[1] Physical processes in laser cutting of metals. - https://helpiks.org/4-97078.html
[2] Laser technology and technology. In 7 books. Book. 4. Laser processing of non-metallic materials: Textbook. manual for universities / A.G. Grigoryants, A.A. Sokolov; Ed. A.G. Grigoryants. - M.: Higher school 1988.-- 191 p.: ill.
[3] Orishich A.M. Actual problems of physics of laser cutting of metals / A.M. Orishich, V.M. Fomin; otv. Ed. A.M. Shalagin; Institute of Theoretical and Applied Mechanics. S.A. Khristianovich SB RAS. - Novosibirsk: Publishing house of the SB RAS, 2012.-176 p.
[4] Golubev VS, On the mechanisms of removal of melt in gas laser cutting of materials // Shatura. IPLIT RAS. 2004.
[5] Makashev N.K. ,, Asmolov E.S., Buzykin O.G. Pulse-periodic gas-laser cutting of metals with oxygen-containing gas // Quantum Electronics, Vol. 19. No. 9. S.910-915. 1996
Mingazov B.G. GTE combustion chambers. Kazan, publishing house of KSTU, 2006, 216.