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PHYSICAL AND TECHNOLOGICAL ASPECTS OF PRECISION LASER TREATMENT OF CERAMIC MATERIALS. EFFECT OF TREATMENT REGIME

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A geometric model is constructed of the complete profile for a cavity cut in Al_2O_3–TiC ceramic specimens. The effect is established for the main production parameters of a pulsed laser treatment regime on geometric characteristics of cavities cut in ceramic specimens.

Keywords: pulsed laser treatment, Al_2O_3–TiC-ceramic, morphology, bead, fin, crack.

INTRODUCTION

The present article is a continuation of work for studying pulsed laser cutting of cavities in Al_2O_3–TiC ceramic specimens [1] The aim of the present stage of the work is a study of the effect of production parameters of a pulsed laser treatment regime on geometric characteristics of cavities cut in ceramic specimens. The importance of revealing these correlations is determined from conclusions from work in [2 – 5].

Research was conducted in two stages. In the first stage a geometric model was constructed of the complete profile of a cut cavity in Al_2O_3–TiC ceramic specimens on the basis of conclusions formulated previously [1]. According to these conclusions cavities cut in ceramic specimens consist of outer and inner regions, whose sizes are connected with parameters of the pulsed laser action cutting regime. In the second stage with use of results of experimental studies the effect of the main production parameters of the pulsed laser treatment regime on geometric characteristics of cavities cut in ceramic specimens have been established. Regimes for performing these experiments are provided in Table 1.

Measurement of the geometric characteristics of cut cavities was conducted in their central section of a length of 1.5 mm with a pitch of 0.3 mm. A MarSurf LD120 contour-polygraph (tracing force 0.01 N, speed 0.02 mm/min) and a VEGA 3 LMH scanning electron microscope were used. The average value of geometric characteristics for each cavity was calculated from the results of 36 measurements (6 measurements for each side of a cavity ×2 sides in each specimen ×3 of a duplicate specimen).

RESULTS AND DISCUSSION

The marked effect of production parameters of pulsed laser treatment cutting regime on the shape and dimensions of

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TABLE 1.

Parameter	Experiment number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P, W	2.5	5	15	5	5	5	5	5	5	5	5	5	5	5	5
s, μm	20	20	20	8	20	50	20	20	20	20	20	20	20	20	20
N, passes	5	5	5	5	5	5	2	5	8	10	50	100	1	1	1
n	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	500	800

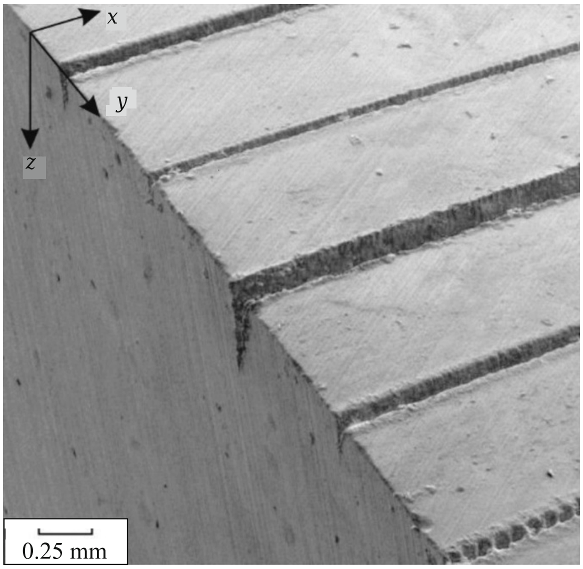

Fig. 1. General view of cavities cut in Al_2O_3–TiC-ceramic specimens with different regimes.

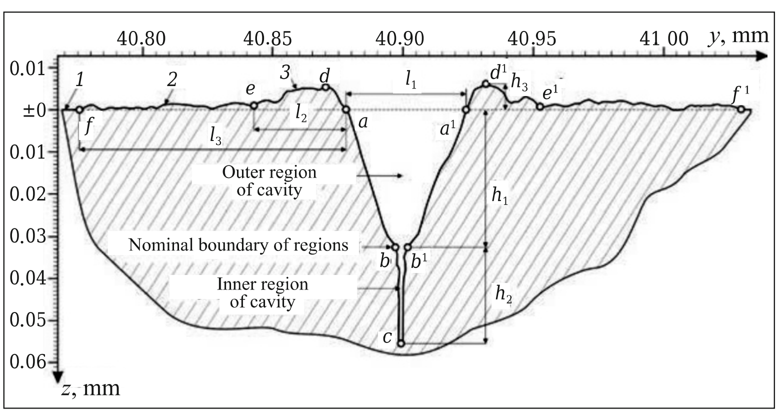

Fig. 2. Geometric model of complete profile of a cut cavity in Al_2O_3–TiC-ceramic specimens.

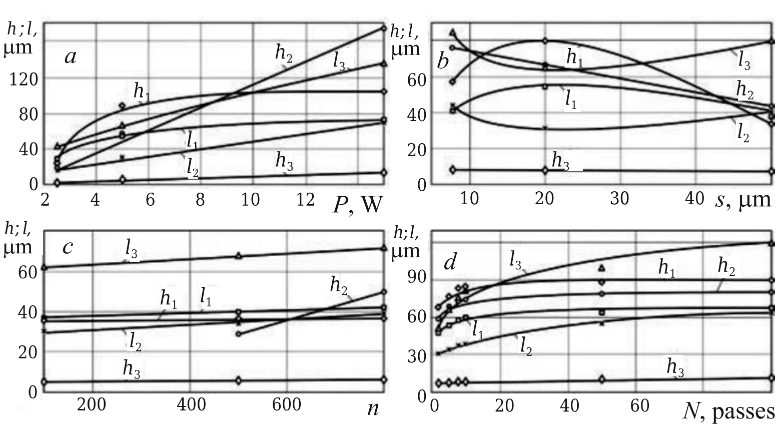

Fig. 3. Effect of main production parameters of pulsed laser treatment regime on geometric characteristics of cavities cut in Al_2O_3–TiC-ceramic specimens.

cavities, cut in Al_2O_3–TiC ceramic specimens is shown in Fig. 1. It is seen that the width and depth of cavities varies over a wide range, and during cutting of a cavity with a pitch of laser beam movement exceeding the diameter of its spot in a treated surface there is only formation of a collection of craters.

On the basis of studying the general features of the cavity cutting process in specimens of Al_2O_3–TiC ceramic [1] a geometric model has been constricted for the complete cavity profile (Fig. 2). This model includes the outer and inner regions of a cavity, which are separated by a conditional boundary. The form of the outer region of a cavity $fedabcb^1a^1c^1d^1e^1f^1$ is determined by the following geometric characteristics: depth of the outer region h_1, bead height h_3, cavity with l_1, bead width l_2, and excrescence width l_3. The inner region of a cavity bcb^1 is specified by channel depth h_2. The geometric characteristics of a cavity are connected into a system with use of an original surface 1, excrescence surface 2, bead surface 3, and bottom of the outer region of a cavity and channel bottom.

With use of research procedures developed [1] the effect of production parameters of the pulsed laser treatment regime on geometric characteristics of cavities in Al_2O_3–TiC ceramic specimens was revealed. The main results of these studies are shown in Fig. 3. It should be noted that in intensive regimes there is an increase in stochastic nature of the process of reaction of pulsed laser radiation with a hard and brittle ceramic, as a result of which there is an increase in scatter of measured values of geometric parameters of cut cavities.

It has been established that the effect of laser pulse power on cavity geometric characteristics is identical, i.e., with an increase in P there is an increase in h_1, h_2, h_3, l_1, l_2, and l_3, although the nature of this effect is different for each dependence (see Fig. 3*a*). The greatest effect appears on channel depth, forming the inner cavity, and the least on bead height. On $P - h_1$ and $P - l_1$ curves there are two characteristic sections. In the first section (P increases from 2.5 to 5 W) h_1 and l_1 increase sharply, and in the second section (P increases from 5 to 15 W) h_1 and l_1 increase smoothly and in the range 12 – 15 W they are almost unchanged. For example, an increase in the value of h_1 in the first section of the corresponding curve, obtained during treatment with s = 20 μm, n = 1000, and N = 5 passes, comprises a factor of 3.5, and in the second section a factor of 1.3. Simultaneously with this depth h_2 in the first section of the corresponding curve increases from 21 to 66 μm (increase by a factor of 3.1), and in the second section from 66 to 175 μm (increase by a factor of 2.7).

The effect is shown in Fig. 3 of the pitch of a moving laser beam s (P = 5 W, n = 1000, and

$N = 5$ passes) on the dimensions of the cavity profile. It is seen that the effect of movement pitch of a laser beam on geometric characteristics of a cavity is more complex compared with its power. With an increase in s in the range 8 – 20 μm h_1 increases from 58 to 81 μm and l_1 increases from 41 to 54 μm. A further increase in s from 20 to 50 μm leads to a reduction in h_1 and l_1. In contrast to this effect, l_2 and l_3 initially decrease and then increase. The most simple effect of laser beam movement pitch s appears on depth of the inner cavity h_2 and excrescence width h_3. Curves $s – h_2$ and $s – h_3$ have a linear character and with an increase in s in the range 8 – 50 μm h_2 and h_3 decrease by 42 and 10%.

The effect of number of pulses in a package n ($P = 5$ W, $s = 20$ μm, and $N = 1$ pass) on geometric parameters of a cavity is shown in Fig. 3*a*. It has been established that with an increase in the number of pulses is a package in the range from 100 to 1000 the values of h_1, h_2, h_3, l_1, l_2, and l_3 increase linearly, and the greatest effect of n appears in a change in h_2 and least in h_3. With an increase in n from 100 to 1000 values of h_1, h_3, l_1, l_2, and l_3 increase from 33 to 53, from 4.4 to 5.9, 34 to 40, from 6 to 9, and from 19 to 27 μm respectively. It should be noted that in cutting cavities with a number of pulses in a package of 1000, channels forming the inner surface of a cavity are not formed. Formation of these channels is recorded during treatment in a regime with a number of pulses in a package of 500 or more.

Dependences specifying the effect of number of passes in a cycle N ($P = 5$ W, $n = 1000$ pul, $s = 20$ μm) on the dimensions of the cavity profile are shown in Fig. 3*d*. It has been established that with a change in N from 2 to 100 passes the cavity profile dimensions increase, and the degree of the effect varies. The greatest effect of number of pulses during laser cutting of cavities appears in l_2 and l_3, and the least in h_3. On curves $N – h_1$, $N – l_1$, $N – h_2$, $N – l_2$, $N – l_3$, specifying cavity dimensions, there are two characteristic sections. In the first section (N increases from 2 to 10 passes) h_1, l_1, h_2, l_2, and l_3, increase sharply. In the second section h_1 increases from 68 to 86 (increase by a factor of 1.3), h_2 from 59 to 74 (increase by a factor of 1.3), h_3 from 6.4 to 8.3 (increase by a factor of 1.3), l_1 from 48 to 60 (increase by a factor of 1.3), l_2 from 31 – 38 (increase by a factor of 1.2), and l_3 from 49 to 83 (increase by a factor of 1.7). In the second section (N from 10 to 1000 passes) h_1, h_2, h_3, l_1, l_2 increase on average by 10%, and l_3 increases by a factor of 1.5.

CONCLUSION

As a result of these studies a correlation has been revealed for production parameters of a pulsed laser treatment regime with geometric characteristics of cavities cut in Al_2O_3–TiC-ceramic specimens. It has been established that intensification of a pulsed laser action regime increases instability of the process and in the majority of cases leads to an increase in cavity profile dimensions. An exception is a change in the pitch of laser beam movement: an increase in this production parameter in the range from 8 to 50 μm leads to a reduction in channel depth h_2, and in the range from 20 to 50 μm a reduction is recorded in the depth of outer region h_1 and cavity width l_1. The depth of the inner region of cut cavities may exceed the depth of their outer region in more intensive treatment regimes. In the case of a low number of pulses in a laser radiation package a cut cavity is only specified by the outer region with absence of an inner region.

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