Study of the combined laser-plasma effect on metals

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Abstract: Interaction processes of laser radiation with the metal surface layer during laser effect, and the main factors influencing the absorption capacity of the metal with a surface processing by a laser beam are considered. The method is proposed for increasing the absorption capacity of laser radiation by plasmatron pre-heating of the material. The results of the combined laser-plasma effect are presented.

1. Introduction:

The development of modern production necessitates the ever-increasing introduction of high technologies, in particular, of laser processing of materials. This processing is one of the technologies that determine the present level of production in the industrialized countries. The use of laser processing of materials ensures high quality of produced parts, specified productivity of the processes, ecological purity, as well as saving human and material resources.

At present the use of laser technologies in the instrument-making production is extremely diverse. Such technologies include welding, heat hardening, alloying, welding, cutting, dimensional processing, marking, engraving, precision micro-welding and many others [1-2]. In some cases, radiation technologies has been ahead of the competition, as using lasers can obtain technical and economic results that cannot be achieved by other technical means.

Problem of laser processing of materials is transferring the maximum amount of laser radiation energy into the material. In any case, the laser thermal effect on the material is important, not just the power of laser radiation, but the power absorbed by the material and used to getting for a beneficial result. The absorption capacity in one form or another appears in all laser processes.

Several methods are known for increasing the absorption capacity of metals [3, 4]: change in the surface roughness, the formation of oxide films during processing in an oxidizing environment, specific absorbing coating, pre-heating etc. The application of increasing roughness and applying of various coatings is not always appropriate due to an increase processing time and change the surface properties of the material.

It is known [1] that the lowest of the absorption coefficient is characterized by radiation effect of technologically advanced C02 lasers. The low level of the absorption creates at first sight a hopeless situation with the possibility to use of C02-radiation for processing of metals. However, the decisive factor is the substantial increase of absorption capacity by an increase in the temperature of the processed surface. The absorption capacity of the non-oxidized metal surface at the wavelength of laser radiation \( \lambda = 10,6 \mu m \) can be determined by the equation of Hagen-Rubens:

\[
A = 112,2(\sigma^{-1})^{1/2}
\]
where A - absorptive capacity of the metal; $\sigma_0$ - conductivity of the metal at a constant current value, 1 / ($\Omega \cdot m$). At high temperature, the electrical conductivity of metals decreases and the absorption coefficient increases.

2. Experimental studies

This study offers a method to increase the absorption capacity of laser radiation by pre-heating of the material with a linear plasmatron of indirect action a small capacity. The use of plasmatrons of direct action can lead to melting of the surface and the deterioration of its quality parameters [5-11].

Experimental studies have been conducted by using the developed laser-plasma hybrid installation. The samples of steels: 45, 09Г2C, 08KII, were processed. For comparison, this samples were treated only by first laser radiation, and then the combined laser-plasma effect (Fig. 1). Modes of laser radiation in the course of the study have been changing in the ranges: $t=1.5...2.5$ ms, $E=5.3...1.4$ J, $dp=2$ mm (where $t$ is the time of the pulse, $E$-pulse energy, $dp$ - the diameter of the focused radiation).

A microstructure of the samples studies were conducted by means of the metallographic inverted microscope called Labomed –I (Fig. 1).

![Figure1. The results of metallographic: samples after the laser (a) and a laser-plasma (b) effect, treatment conditions: $t = 2$ms, $E = 5.2$ J, $dp = 2$ mm, an increase: $\times 80$.](image)

After processing the micro-hardness was measured using the method of Vickers at 100gs load on the digital hardness testing model HVS-1000. The metallographic samples cut along a track and maximally close to points of the track, were prepared for the measurements. Some micro-hardness measurements are presented in Figure 2.

Under the combined effect of plasma and laser radiation, there is an increase of microhardness by 30-40% compared to laser.

Metallographic studies of 45 steel in the field of laser and laser-plasma effect (Fig. 1 and Fig. 2) showed that the thermal effect zone of the plasma jet has the shape of a segment. When heating, by the plasma jet a metal surface heats the surface layer to different temperatures, so it has a layered structure. Depending on the microstructure and micro-hardness of steel 45 in the depth formed three layers: the melting zone, the quenching from the solid phase and the transition zone.
Figure 2 - Distribution of micro-hardness in depth, sample of steel 45, the processing modes: • • • - Laser t = 2ms, E = 3 J, dp = 2 mm; - - - - Laser t = 2ms, E = 5,2 J, dp = 2 mm; - - - - Laser + plasma t = 2ms, E = 3 J, dp = 2mm - - Laser + plasma t = 2ms, E = 5,2 J, dp = 2mm.

3. The conclusion

Tests of the designed installation were conducted to check the performance of the laser-plasma hybrid installation as compared to the laser installation on different samples. As a result of these tests, it was determined that the pre-heating of the plasma samples increases the effectiveness of laser radiation effect.

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