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Study of Cu-Zn alloy objects vibration characteristics during laser-induced nanopores formation

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Abstract

The study of the vibration characteristics of Cu-Zn alloy objects has been performed during laser-induced nanopores formation. It was determined that in the near-surface layer the pulse-periodic laser action forms a nanoporous structure ~100 nm wide. Pulse-periodic laser action was used to determine the samples' responses to external vibroexcitation and their wave forms were registered. As the analysis' result of the samples' responses to this external vibroexcitation, it was found that the vibration rate increases in the case of frequencies that are divisible by the frequency of initial oscillation, during the amplitude decrease and the frequency increase. It was concluded that a very important condition for the development of generic thermodynamic moving force which could intensify the formation of nanoporous structure in a metallic material, is the non-permanent elastic deformation, which was caused by high-powered external action.

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Keywords: laser action; formation; nanoporous structure; vibration characteristics

1. Introduction

The application of a pulse-periodic laser is a promising trend in the formation of nanoporous structures in metallic materials. In [1–3] the conditions for the formation of such structures in Cu-Zn alloys have been determined. Single and branched channel nanopores appeared in metallic materials as a result of laser action. Nanopores are uniformly distributed on the area [4, 5]. In this case the laser pulse-periodic action forms a persistent stress condition on the surface of the samples. The cause of the material structure change is a non-permanent local

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deformation which is caused by high-powered external action [6–8]. This is a condition for the intensification of mass transfer in the solid phase of metallic materials [9–11]. The temperature increase is an effective method to increase the mobility of atoms, because the diffusion coefficient is related to the temperature with an exponential dependence [12–15]. Thus, a persistent stress condition on the surface of the samples is caused by laser action with pulse-periodic radiation [16, 17]. The main purpose of this research is to define the conditions for the formation of nanoporous structure in metallic materials via pulse-periodic laser action.

2. Study of Cu-Zn alloy objects vibration characteristics during formation of nanoporous structures

In this research samples of two-component Cu–Zn alloy brass L62 with a 60.5–63.5 % content of copper were studied. The samples were 25x35 mm in size with a thickness of 50 μm. For this research a CO_2 slab laser ROFIN DC 010 was used. The wavelength of this laser was 10.6 μm, the pulse frequency was 2–5000 Hz and the adjustment range of the output power was 100–1000 W. The pulse-periodic laser action was performed with frequencies of 3, 100, 500 and 5000 Hz. Using the laser interferometry principle measurement of the three orthogonal components of the vibration rate was carried out. Fig. 1 shows a general view of the experimental stand for studying the vibration characteristics of the objects during the laser-induced nanopores formation. The pulse-periodic laser action was used to determine the samples' responses to external vibroexcitation and their wave forms were registered. For the study of the vibration characteristics of the samples the use of contact methods was not applicable because of their fairly small size and mass. In this case, the mass of the vibration sensor would be much greater than the mass of the object. For a non-contact determination of the vibration characteristics, the Polytec scanning vibrometer PSV-3D was used.

Fig. 1. A general view of the experimental stand for studying the vibration characteristics of objects during the laser-induced nanopores formation: 1 - CO_2-laser ROFIN DC 010 with a diffusion-cooled high-frequency pumping; 2 - three-axis scanning laser vibrometer Polytec® PSV-400-3D; 3 - optical system; 4 - Polytec PDV 100 two-coordinate measuring instrument; 5 - non-contact thermometer "Kelvin LCM-1300"; 6 – the sample of brass L62.

Fig. 2 shows a typical range of the vibration rate of the sample during the laser action with a pulse frequency of 3 Hz. The analysis result of the samples' responses to the described external vibroexcitation, it was found that the vibration rate increases in the case of frequencies that are divisible by the frequency of initial oscillation, during the amplitude decrease and the frequency increase. The study of the fine structure was performed with a scanning