LASER ABLATION WITH ULTRASHORT LASER PULSES - THE APPLICATION OF SEALSAND PUMP ELEMENTS

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Surface texturing is more and more frequently used in modern machines to attain such aims as lubrication enhancement, heat flow intensification and micro-flow stimulation. The development of technologies using concentrated energy flux, e.g. laser technology, has contributed to it. Pumps contain a lot of elements where textured surfaces can be used. The article concentrates on the selection of operating parameters of a picoseconds laser used to produce texturing in elements made of steel, bronze and silicon carbide.

Keywords: *laser texturing, mechanical seals, bearings.*

Introduction. Although pumps are fluid-flow machines, mechanical losses, friction losses in particular, are a substantial factor affecting their total efficiency. Friction losses (including friction losses of rotating disks) are reported to be 4% in impeller pumps of proper construction [4]. Friction losses are from 5 to 12% in displacement pumps [3,5]. Apart from friction losses affecting the general efficiency of hydraulic machines, the life of tribological pairs is of great importance. Friction pairs in hydraulic machines are generally designed so as to make them work under conditions of fluid friction and, therefore, their wear is negligible. In some specific situations the operation under conditions of mixed, boundary and even dry friction occurs and in such circumstances wear can be as considerable as to be decisive for the service life of parts. Such specific situations include starting and running a machine as well as the operational instability of rotating elements caused by vibrations or other disturbances. Unsatisfactory performance of seals makes another problem affecting pump efficiency. As a result, losses can even be 10% [4]. The texturing of working surfaces of mating elements of a pump can improve friction conditions and performance of seals.

Texturing and its Importance to Friction Pairs. The concept of forming textured surfaces (Fig.1) is widely used starting with taking up heat and finishing in processes of protection and raising the life of the most loaded surfaces of machine parts. Numerous patents offer details of technical solutions of designing such surface textures whereas available scientific publications give only general information. Textured surfaces mean surfaces possessing isolated regular areas that can be described by geometrical, physicomechanical and physicochemical properties which are other than those used for the rest of the layer. Areas making up texture are formed as a result of using a different technology or materials different from those used for the rest of the surface. Areas making up texture can spread over the surface (surface texture) or into it (volume texture). The whole material of which a detail is made can have texture as well as the surface layer it possesses. Texture can be a characteristic natural feature of a given material or can result from a special process aimed at forming texture. To produce texture in surface layers most of the well-known surface engineering technologies can be used, but those whose action is based on the use of concentrated energy flux, i.e. beam technologies, are of particular interest.

They can include electron, laser, electric discharge, ion implantation and heat spraying technologies. In the most general case surface textures can be formed by [1,2]:

- Systems of cavities on surfaces of machine parts which are important because of the role they play, e.g. Grooves, channels, shaped pits made by milling, eroding, etching, laser shaping, etc.,
- Areas distinguishable by different physicochemical and mechanical properties, e.g. Surfaces of partly diversified hardness and mechanical strength obtained by local surface treatment or local surface hardening (laser, electronic or surface thermo-chemical treatment),
- Areas of diversified surface microgeometry, e.g. Pointwise eroded areas (laser and electroerosive treatment) or possessing formed surface microgeometry in the sphere of, for example, assumed directive tendency of ridges or surface load capacity (laser and electro eroding technologies),
- multilayer and gradient coatings.

Regularity of areas of distinguishable properties is characteristic of texture. This regularity provides recurrence of phenomena connected with friction, medium flow through the slot and heat dissipation for the whole thrust bearing, for example, or seal. The role of surface texturing in the form of regularly distributed cavities on the surface of friction resolves itself into the following issues:

– possibility of accumulating a medium forming a lubricant,

– possibility of producing hydrodynamic effects increasing the load capacity of a sliding pair,

– generation of ‘favorable’ flows in the slot (carrying heat away, cleaning the gap of wear particles, reducing leakage from the seal), possibility of eliminating wear products from the friction zone.

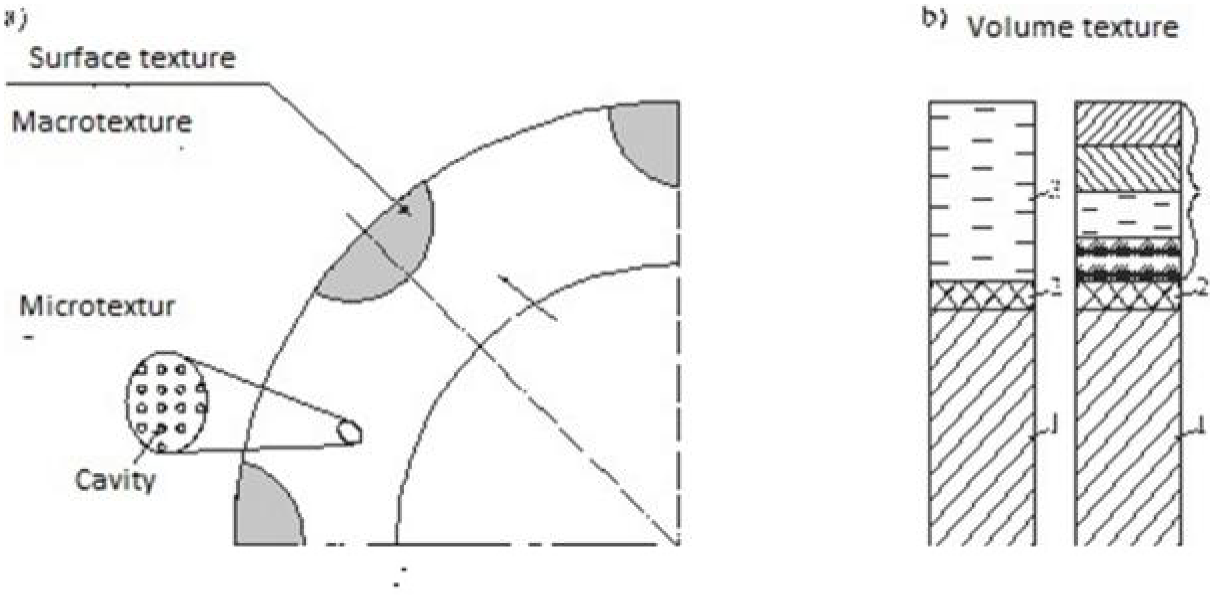


Fig.1. Model of textured surface layer: a) surface texture, b) volume texture;
1 – base, 2 – transitory layer, 3 – specific layers [5]

Interference in slot and surface phenomena is justified in numerous construction joints of hydraulic machines. Apart from bearings and seals mentioned in the title of the article, balance disks in multi-stage pumps, seals of a rotor neck, surfaces of valve faces and piston rings of displacement pumps (Fig.2) should be mentioned here. The effective action of a texture is determined by the accuracy of its production which depends on parameters of a technological process.

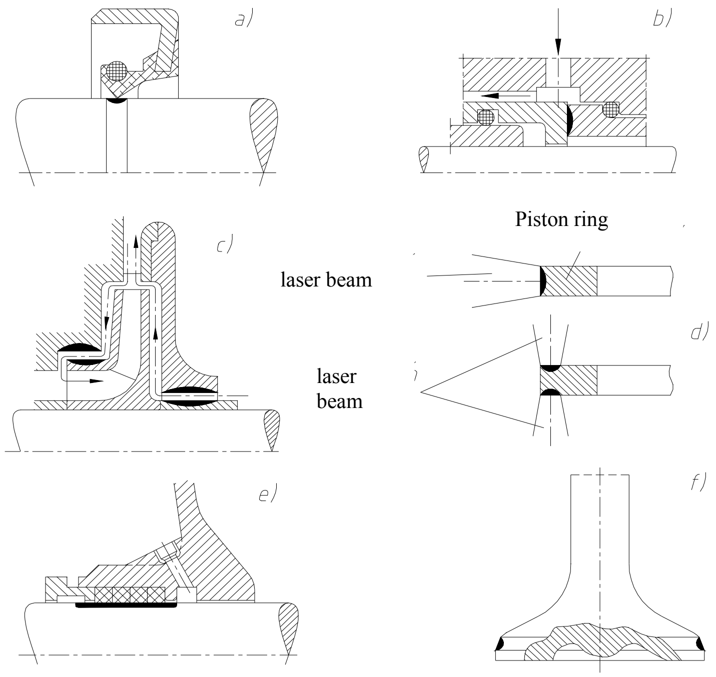


Fig. 2. Examples of using laser texturing in sealing technology (blackened places of laser treatment):
a) pair with elastomeric seal, b) face seal, c) seal of a pump impeller, d) piston rings of piston pumps,
e) sleeve of gland seal, f) faces of piston pump valves

Selection of Parameters of Laser Micromachining. The focus of investigations is on micromachining with the use of a laser emitting ultraviolet radiation of the wavelength of 344 nm in ultra-short pulses lasting several picoseconds. Considering the extreme interaction intensity, non-linear phenomena concerning a lot of photons are of importance to ultra-short pulses in absorption. With such short pulses, energy cannot be immediately transferred with electron gas to the ion network. Processes occurring under such conditions result in the formation of very high pressures, temperature concentration, changes in density, ionization and in the formation of plasma. Owing to such short time, a material cannot continuously evaporate whereas a liquid material is brought to the state of liquid superheating. These phenomena together with high pressure produce a rapidly growing cloud of droplets of liquid and steam, which is described as a phase explosion in the literature [1,5]. In such a complex process the selection of optimal parameters of micromachining is experimentally carried out. In the investigations conducted the selection was made for constructional steel 45, bronze B101 and silicon carbide SiC.

The experiment consisted in comparing the effects of the impact of laser pulses on the material under investigation with a change in pulse frequency, their duration and laser power. The assessment was based on observations of the shape and the form of the visible trace of the impact of a laser beam on the material, and on the identification of such processes as the melting of the material, loss without signs of melting and the explosion of the material. According to these observations, parameters providing maximum performance with acceptable quality were chosen.

A TruMicro 5235c laser of the average power 5 W generating pulses of laser radiation of the 343 μm wavelength and the frequency from 6.25 kHz to 400 kHz was used in the experiment conducted. The energy value of a single pulse was at 100% power 12.6 μJ. Exposure times were used in the range from 12.5 ms to 250 ms. The result is a change in the number of individual pulses acting on the sample in the range of N =78 to N = 100 000 (Table 1). During the processing samples were placed in the focal point of the laser beam and the treatment zone was shielded with argon.

Table 1. Number of individual pulses made during the exposure to a sample of bronze, steel and SiC

N - number of pulses	12.5 ms	25 ms	62.5 ms	125 ms	250 ms
400 kHz	5 000	10 000	25 000	50 000	100 000
200 kHz	2 500	5 000	12 500	25 000	50 000
100 kHz	1 250	2 500	6 250	12 500	25 000
50 kHz	625	1 250	3 125	6 250	12 500
25 kHz	312	625	1 562	3 125	6 250
12.5 kHz	156	312	781	1562	3 125
6.25 kHz	78	156	390	781	1 562

Results and Conclusions.

Figs 3, 4 and 5 give examples of the results in the form of microphotographs of the treatment effects taken by a Joel scanning microscope. The analysis shows that with a small number of pulses, weak effects of a laser beam are observed. They are visible in the central part of the trace and have the form described as the phase explosion. With an increase in the number of pulses from 390 to 1 562, a shaped cavity whose diameter and depth grow with a number of pulses is more and more visible. Products of the explosion in the form of fine particles appear on the edges of cavities. With a further increase in the number of pulses from 1 562 to 3 125, the expansion of the explosion from the surface in the centre of the trace into the interior of the cavity formed is observed. With a greater number of pulses, the cavity takes the form of a regular hopper. This form persists even when interactions contain 100 000 pulses. With an increase in the number of pulses, the depth of the hopper grows as well and changes on the walls of this hopper are visible. With an increase in the number of pulses, the walls of the hopper become corrugated. This reflects the growing share of phenomena of thermal character involved in ablation. The folds are formed as a result of melting thewalls of the hopper, which occurs in the channel formed as a result of reflections and the scattering of laser pulses. Cavities have the shape of a tapering hopper because more and more products of the phase explosion do not come out and are often ‘hit’ by another laser pulse. Considering interactions of fixed frequency, with an increase in the number of pulses, an increased number of fine particles (products of the explosion) on the edges of the cavity that are subject to partial melting creating a kind of flash can be observed. The present description is almost identical for all materials involved in the experiment. The differences only concern the parameters that can be considered critical and that determine the achievement of the satisfactory quality of treatment. According to the described analysis of images of treatment traces, in order to achieve the best quality and efficiency, it is recommended that the procedure should be followed using in a single act of exposure the following parameters:

- for bronze 50 kHz frequency and the number of pulses from 6250 to 12500
- for steel 400 kHz frequency and the number of pulses from 6250 to 1250,
- for SiC 50 kHz frequency and the number of pulses from 3125 to 6250.

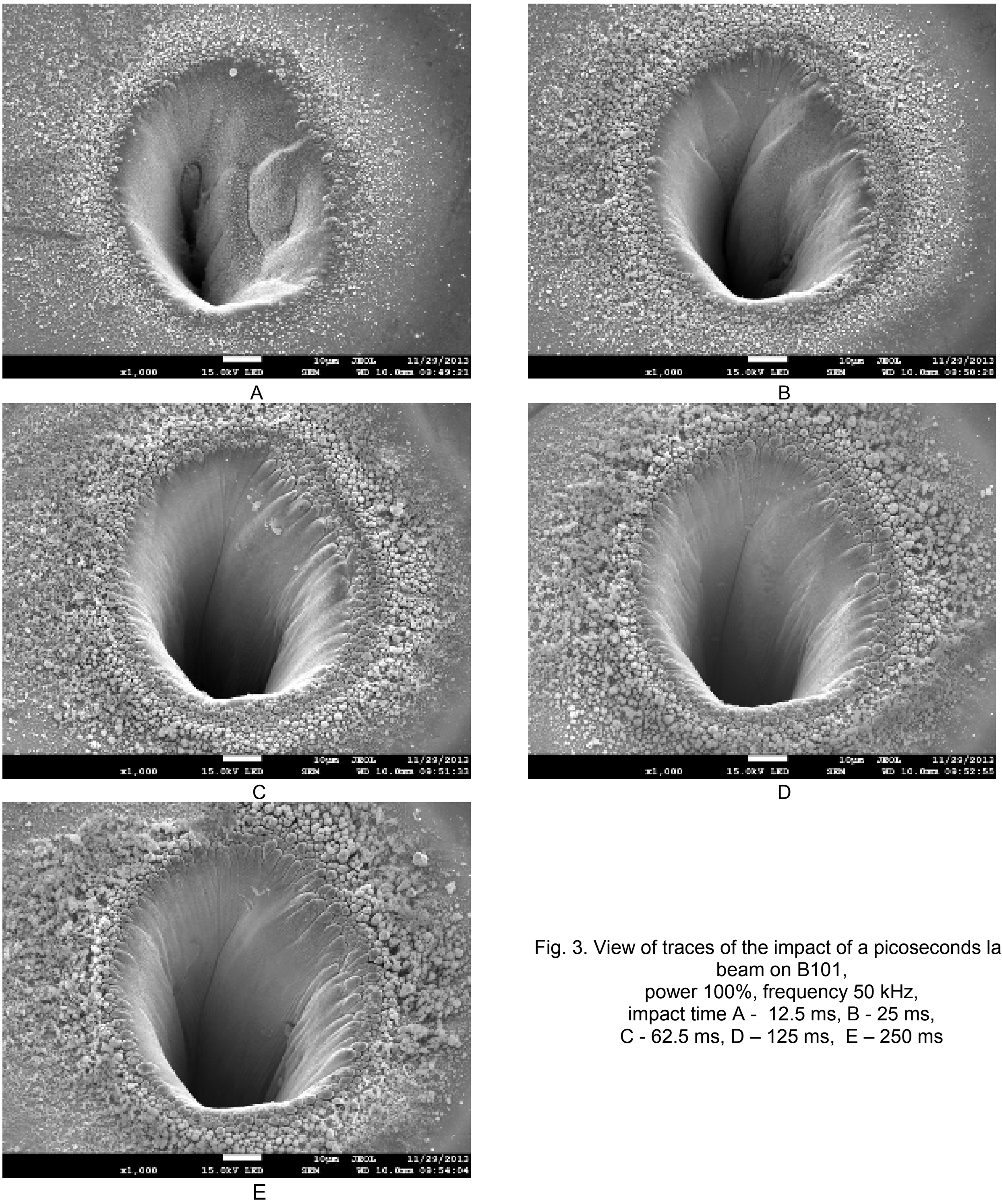
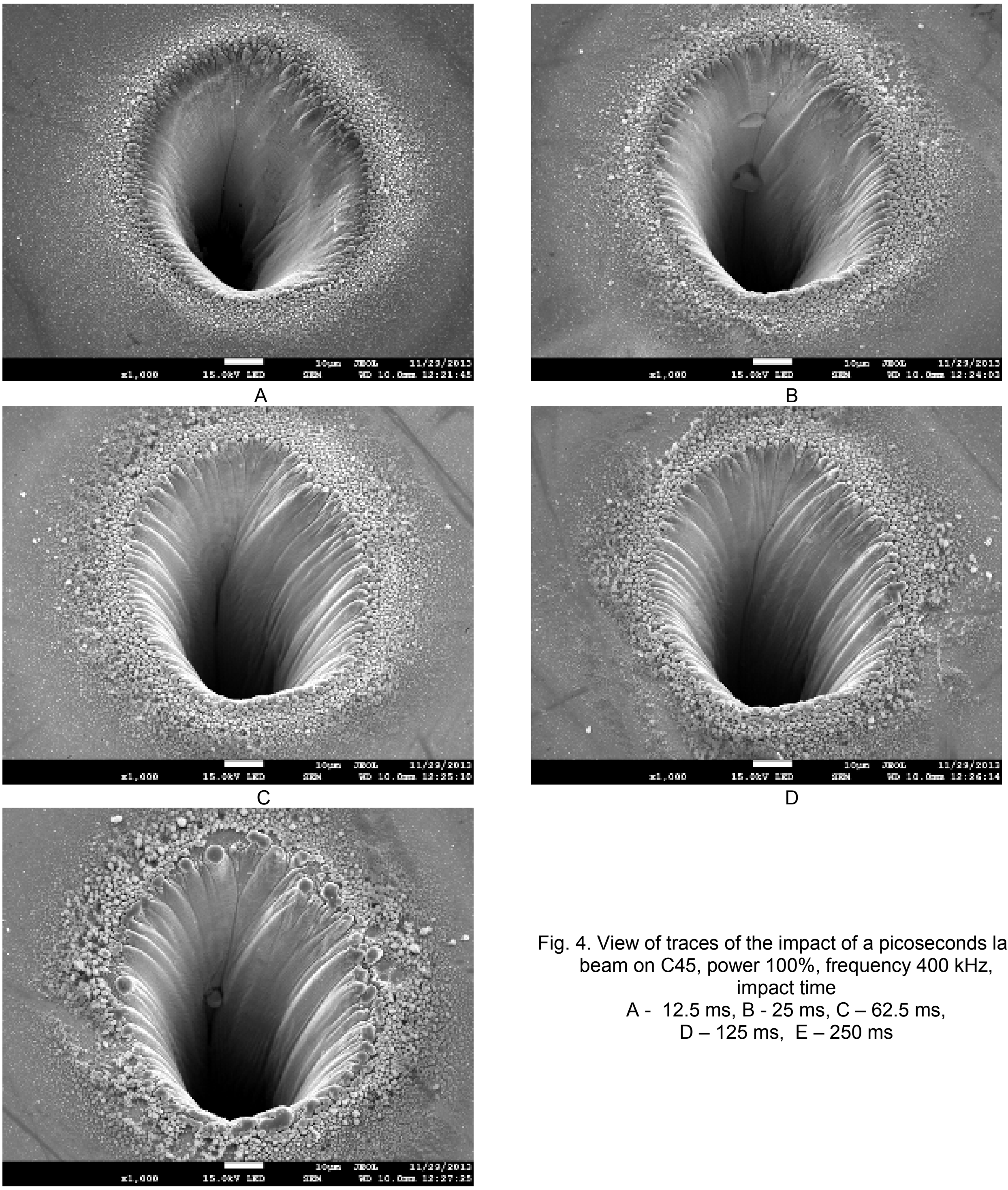


Fig. 3. View of traces of the impact of a picoseconds laser beam on B101,
power 100%, frequency 50 kHz,
impact time A - 12.5 ms, B - 25 ms,
C - 62.5 ms, D – 125 ms, E – 250 ms



A

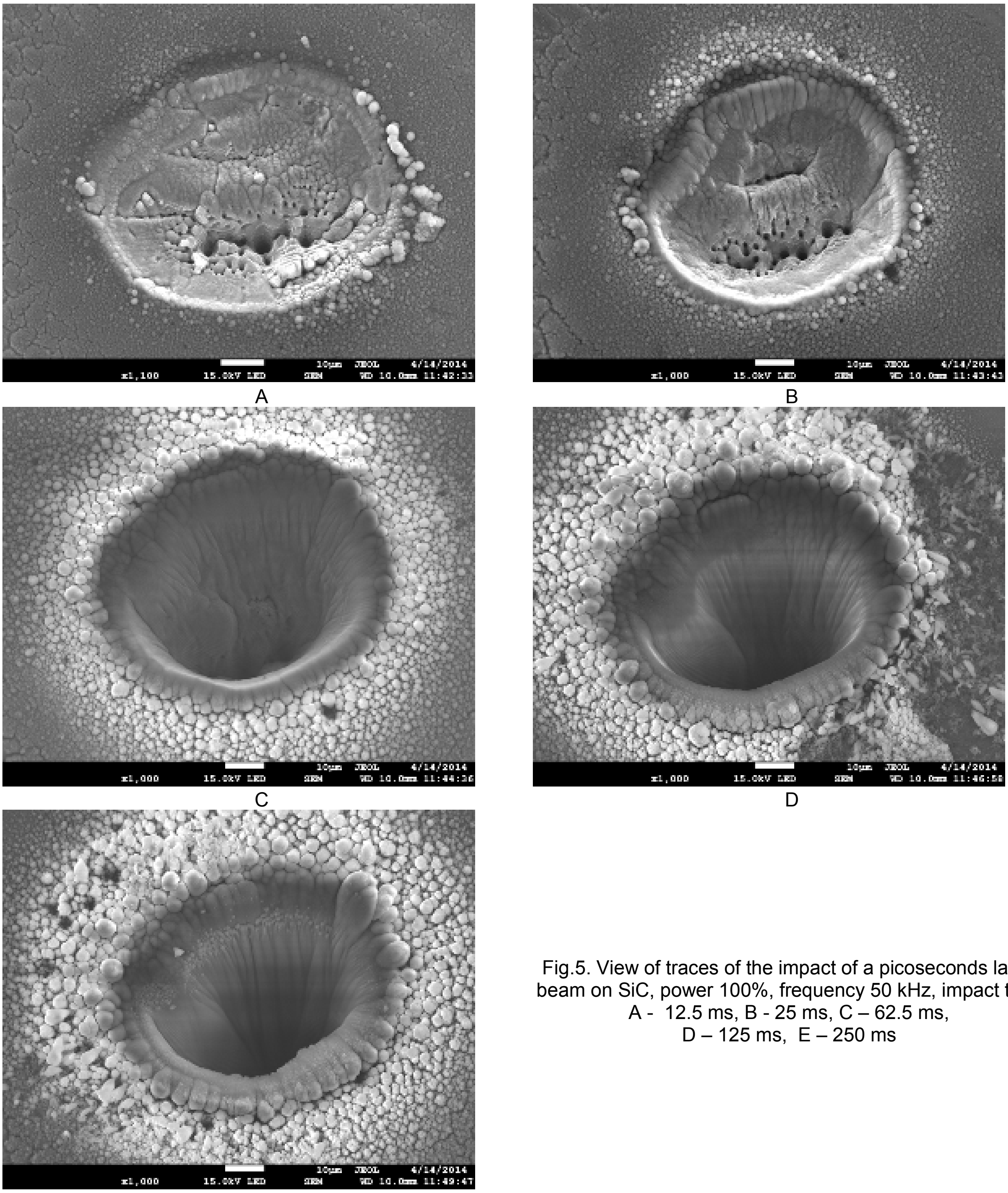
B

C

D

E

Fig. 4. View of traces of the impact of a picoseconds laser beam on C45, power 100%, frequency 400 kHz, impact time
A - 12.5 ms, B - 25 ms, C – 62.5 ms,
D – 125 ms, E – 250 ms



A B C D E

Fig.5. View of traces of the impact of a picoseconds laser beam on SiC, power 100%, frequency 50 kHz, impact time A - 12.5 ms, B - 25 ms, C – 62.5 ms, D – 125 ms, E – 250 ms

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Антошевский Б., ТарельникВ.Б. Лазерная абляция сверх короткими импульсами торцевых элементов насосов

Поверхностное текстурирование все чаще используется в современных машинах для достижения таких целей, как улучшение смазывания, интенсификации теплового потока и стимулирование микропотока. Формирование текстурированных поверхностей возможно при использовании концентрированного потока энергии, например, лазерного излучения. В насосах есть много деталей, где могут быть использованы текстурированные поверхности. Статья посвящена выбору параметров работы пикосекундного лазера, используемого для получения текстур в элементах, изготовленных из стали, бронзы и карбида кремния.

Ключевые слова: *лазерное текстурирование, механические уплотнения, подшипники.*

Антошевський Б., ТарельникВ.Б. Лазерна абляція надкороткими імпульсами торцьових елементів насосів

Поверхневе текстурування все частіше використовується в сучасних машинах для досягнення таких цілей, як поліпшення змащення, інтенсифікації теплового потоку і стимулювання мікропотоку. Формування текстурованих поверхонь можливе при використанні концентрованого потоку енергії, наприклад, лазерного випромінювання. У насосах є багато деталей, де можуть бути використані текстуровані поверхні. Стаття присвячена вибору параметрів роботи пикосекундного лазера, використовуваного для одержання текстур в елементах, виготовлених із сталі, бронзи і карбіду кремнію.

Ключові слова: *лазерне текстурування, механічні ущільнення, підшипники.*

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