

THE APPLICATION OF LASER TEXTURING IN SURFACE LAYER PATTERNING OF THE COMBUSTION ENGINES ELEMENTS

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Abstract

In this paper, selected examples of the laser texturing of the surface layer patterning of the elements of the combustion engines were presented. A laser oil micro-container fabrication method was presented. Finishing cylinder liner, spigot of the camshaft, spigot of the crankshaft, rod and piston pin of the combustions engine were patterned. Laser patterning was done with the Nd: YAG laser with wavelength of $\lambda=1064$ nm.

The manufactured micro-containers provide better lubrication of the friction associations. The conducted experiments allowed obtaining very regular surface texture what was found to be advantageous to the tribological processes and decrease of the wear of the frictional association in the combustions engines. Micro-bowls and micro-grooves were formed on the selected elements of the crank-piston elements and timing gear elements, including: the main spigots and rod spigots of the crankshaft, side surfaces of the base and the connecting rod head, piston pin and peg of the camshaft of the ZI type 126A1 engine. Textured elements of the piston-rod system and the camshaft were then successfully applied in a real object in so-called "cold ignitions" in low temperature chamber. With the use of laser ablation texturing, at optimized experimental parameters, it is possible to form on the piston-rod and timing gear elements oil micro-containers with varied shapes and surface coverage. It allows improving the association conditions in these systems, especially due to the formation of oil microfilm, which efficiently separates mentioned elements even while under high thermal, heat and mechanical load.

Keywords: laser ablation micro-treatment, surface layer, microstructure, micro-oil containers, laser texturing

1. Introduction

The utilitarian properties of numerous products and their elements rely on the structure and properties of the surface layer, not only on the ability of mechanical load transmission in the whole cross-section [5]. The economy points out that application of surface layer providing desired properties with simultaneous use of possibly inexpensive materials on the core are demanded [1, 2].

Because of certain applications, among the textured surface layer one can distinguish *inter alia*: ones with specific physical properties assuring desired mechanical properties, wear resistance, increased electrical conductivity, with controlled heat transfer, high resistance in high temperature environments etc. [3]. The piston-cylinder and piston rings-cylinder (T-P-C) associations are ones of the most important systems in the combustion engine. The system works usually under boundary friction or mixed friction. The boundary friction is usually while the association elements are being lapped, during ignition, stop and overload of the elements [4, 6].

2. Laser texturing of the combustion engine elements

2.1. The cylinder liner

With the use of preliminary research, concerning the laser micro-treatment process optimization, the laser texturing was performed on the elements of Fiat 126p type 126A1 engine.

The research was conducted on the typical, exploitation elements of the piston rod (UTK) elements and the camshaft. Selected effects of the laser texturing technology are shown in Fig. 1-9. Therefore, prepared elements were installed in the engine and were subjected so call “cold ignitions” tests in low temperature chamber. Texturing is a laser ablation micro-treatment, which allows forming periodic concaves on the surface of the treated material. The concaves may serve as oil micro-containers substituting on the working surface of i.e. finishing cylinder liner deep honing scratches. The diameter of the concaves should be in the range of 50 to 80 μm and deepness of ca. 10 μm , covering ca. 8-25% of total surface.

Such surface patterning provides wear and abrasive resistance increase of the T-P-C system elements while the amount of lubricant is insufficient.

At the optimized laser micro-treatment parameters, the oil micro-containers (micro-channels) were done in the upper zone of the cylinder sleeve (Fig. 1a, b). The surface topography of the cylinder wall was also treated and also here the micro-bowls were formed (Fig. 1c, d). The only difference between these two cases is the geometry of the formed array of the oil micro-containers.

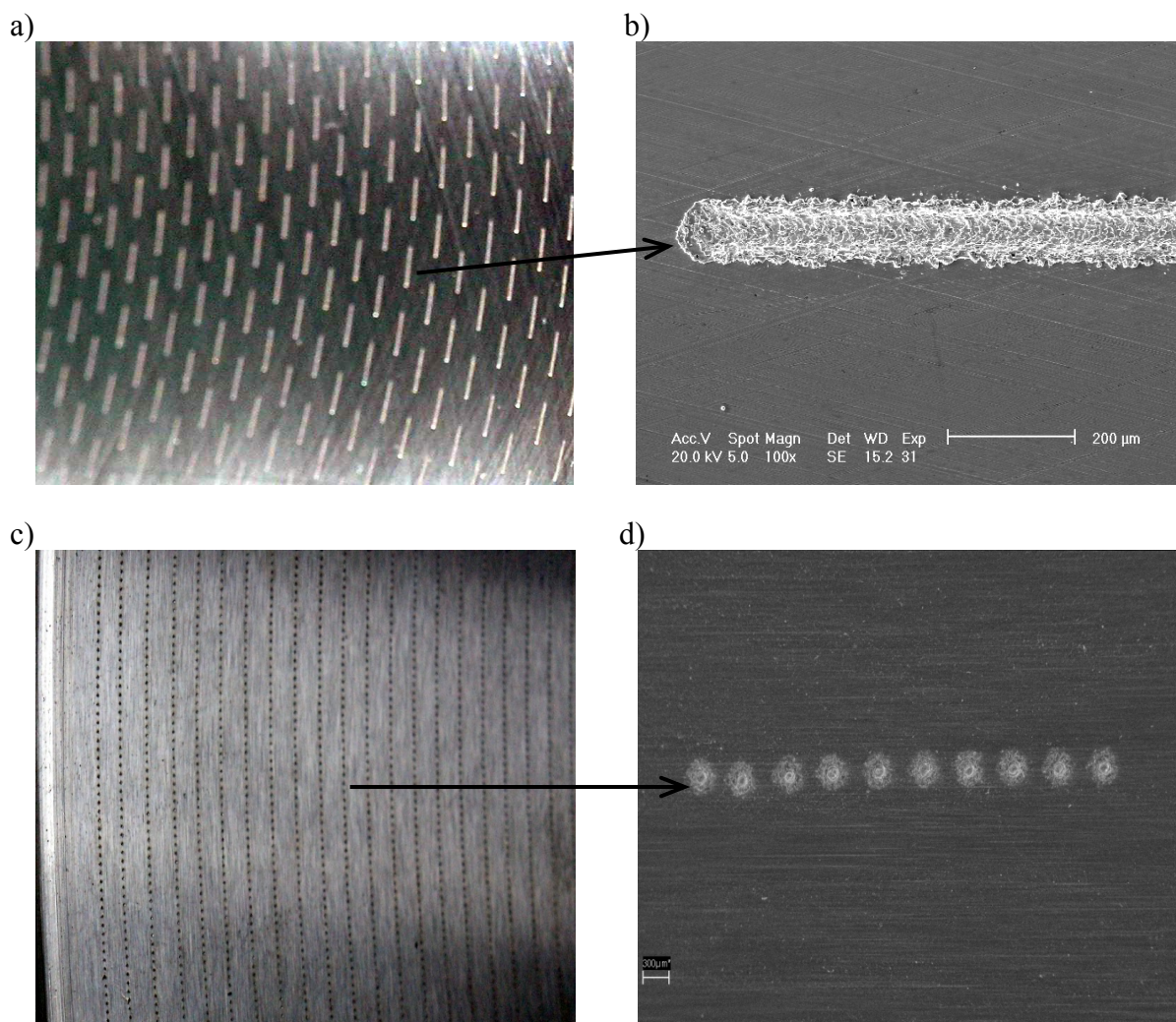


Fig. 1. Topography of the surface of a glow nitrided cylinder sleeve after laser processing: a, b) micro-channel-shaped micro containers (c, d) micro-bowls micro-containers [6]

2.2. The Crankshaft

Micro-bowl shaped oil micro-containers, covering 25% of the surface (Fig. 3) were formed on the surface of main and rod spigots of the 126A1 engine (Fig. 2).

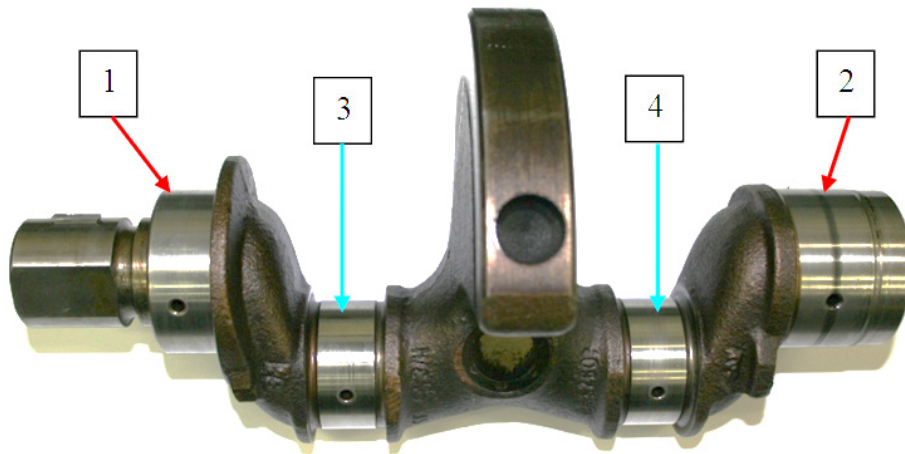


Fig. 2. View of the 126A1 engine crankshaft made of grey, spheroid cast iron: 1 end 2 – the main spigots; 3 end 4 – rod spigots, the zones with micro-bowl micro-containers. No. 1 and 3 [7]

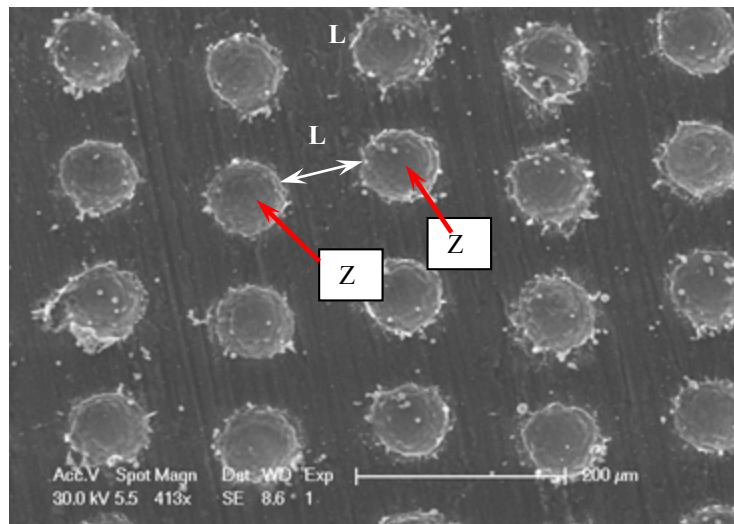


Fig. 3. The array of oil micro-bowl micro-containers; covering degree ca. 25%, distance between the containers $L = 80 \mu\text{m}$, Z -micro-containers [7]

Laser ablation texturing was applied on the whole width of the crankshaft spigot, which is the association zone with the sliding bearings. Micro-extrusions obtained as the side effect during the laser micro-treatment were removed by finishing grinding.

The array of the oil micro-containers (Fig. 3) and surface topography proves the repetitiveness of the process. Shape and geometry of the containers are repetitive as well and in accordance with the assumptions (diameter and deepness in the range of from 50 to 80 μm and from 3 to 10 μm respectively).

2.3. The Rod

Side surface of the base of the rod (Fig. 4) is exposed to the abrasive wear while the engine has high mileage and the looseness in the UTK system are increased. In such engines, the side layers of the base and head tend to be exploited intensively, up to blurring in the association with the side surface of the crank arm of the crankshaft and with the side surface of the piston hub. However, the main cause of the laser modification was the imperfectness of the surface layer topography of the base side and head of the rod, which were manufactured with the use of traditional mechanical treatment.

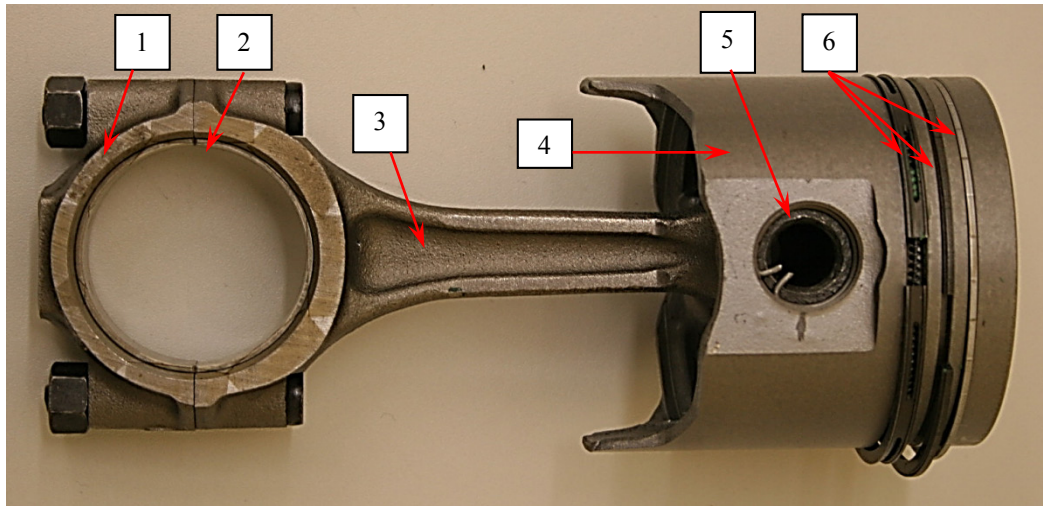
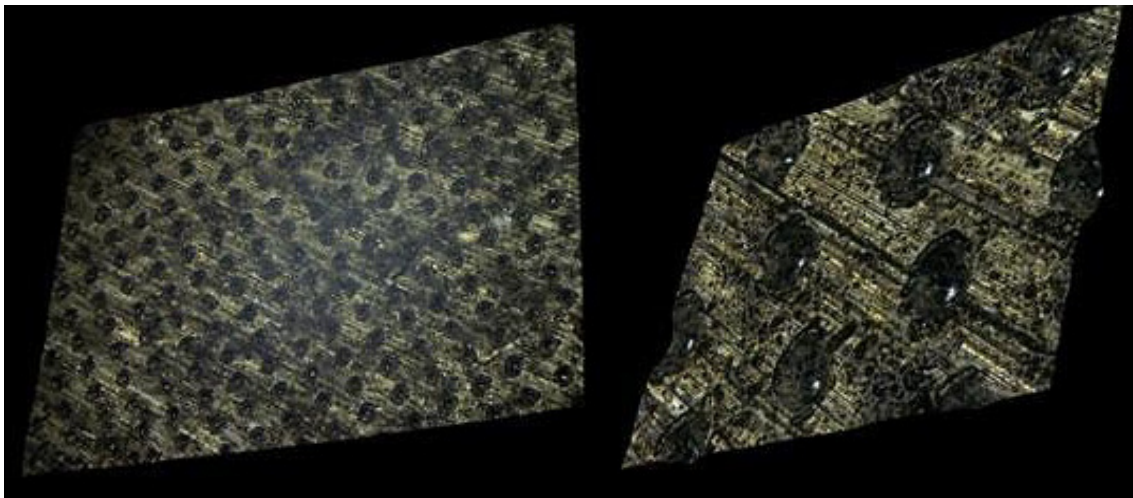


Fig. 4. The piston-rod system of 126A1 engine: 1 – textured side surface of the base of the rod, 2 – slide bearing 3 – rod, 4 – piston, 5 – bolt of the piston, 6 – piston rings [2]

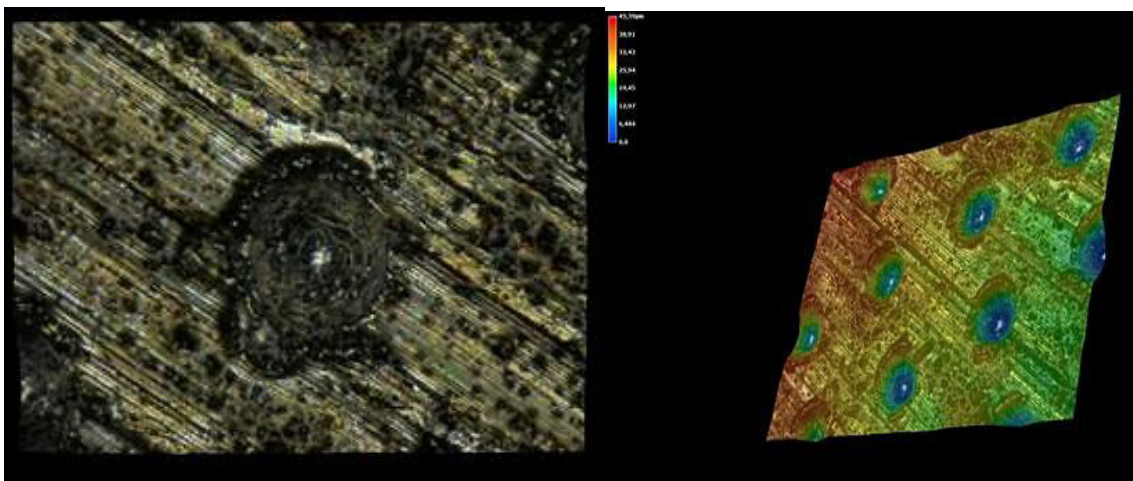
Taking into account, the imperfectness mentioned above, it seems to be essential to modify the current surfaces and researching alternative ways of surface treatment of the structural materials, improving the exploitation parameters.

To manufacture additional oil micro-containers on the side surfaces of the rod, previously optimized parameters of the treatment were used (Fig. 5) to cover ca. 25% of the treated surface.

a)



b)



c)

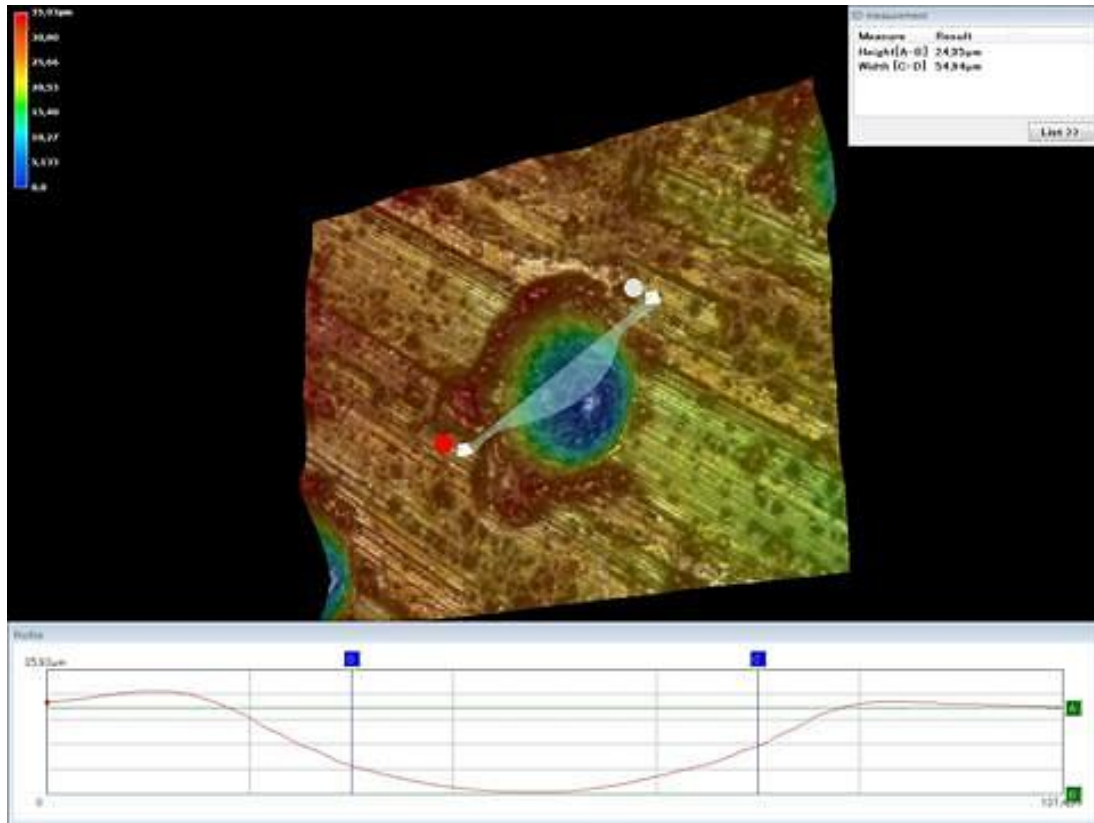


Fig. 5. The proposed array of the micro-bowl oil micro-containers on the side surface of the rod: a) texture of the surface of the base formed with laser ablation texturing, b) unique array of the bowl-type micro-containers c) topography and profiles of the side surface of the base and representative micro-container [2]

2.4. Pistons bolt

Due to the sampling limitations in the real-life elements (126A1 engine of Fiat 126p has only two piston bolts), finally on the exploited surface (Fig. 6, zones A and C) of the piston bolt, associating with inner surfaces of the hub bearings openings and surface associating with the slide bearing of the rods head (Fig. 6, zone B) the bowl-shaped oil micro-containers with the use of laser ablation micro-treatment were formed, to cover ca. 25% of the surface.

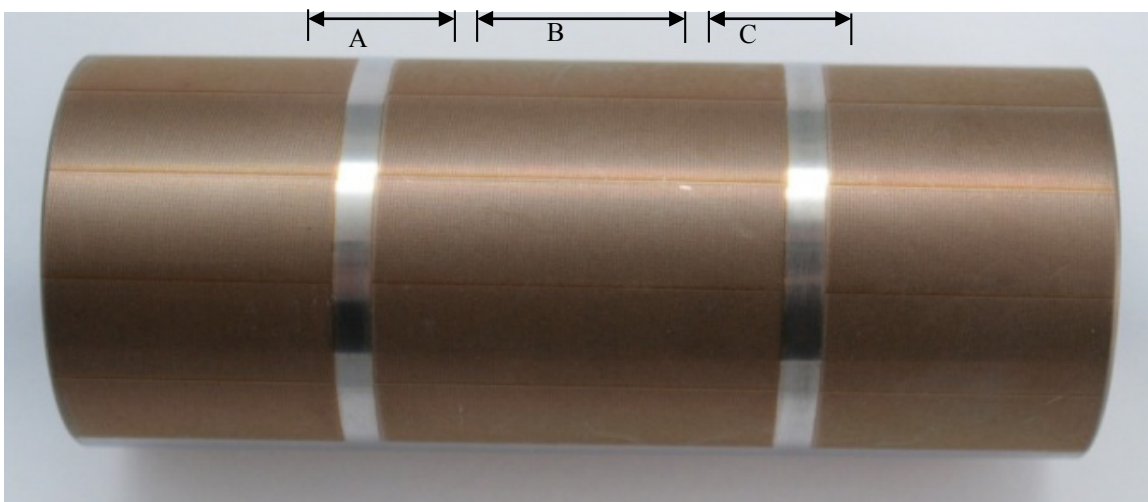


Fig. 6. The pistons bolt with A, B, C zones after laser texturing [8]

Exemplary topography and profile of the pistons bolt after laser ablation texturing presents Fig. 7.

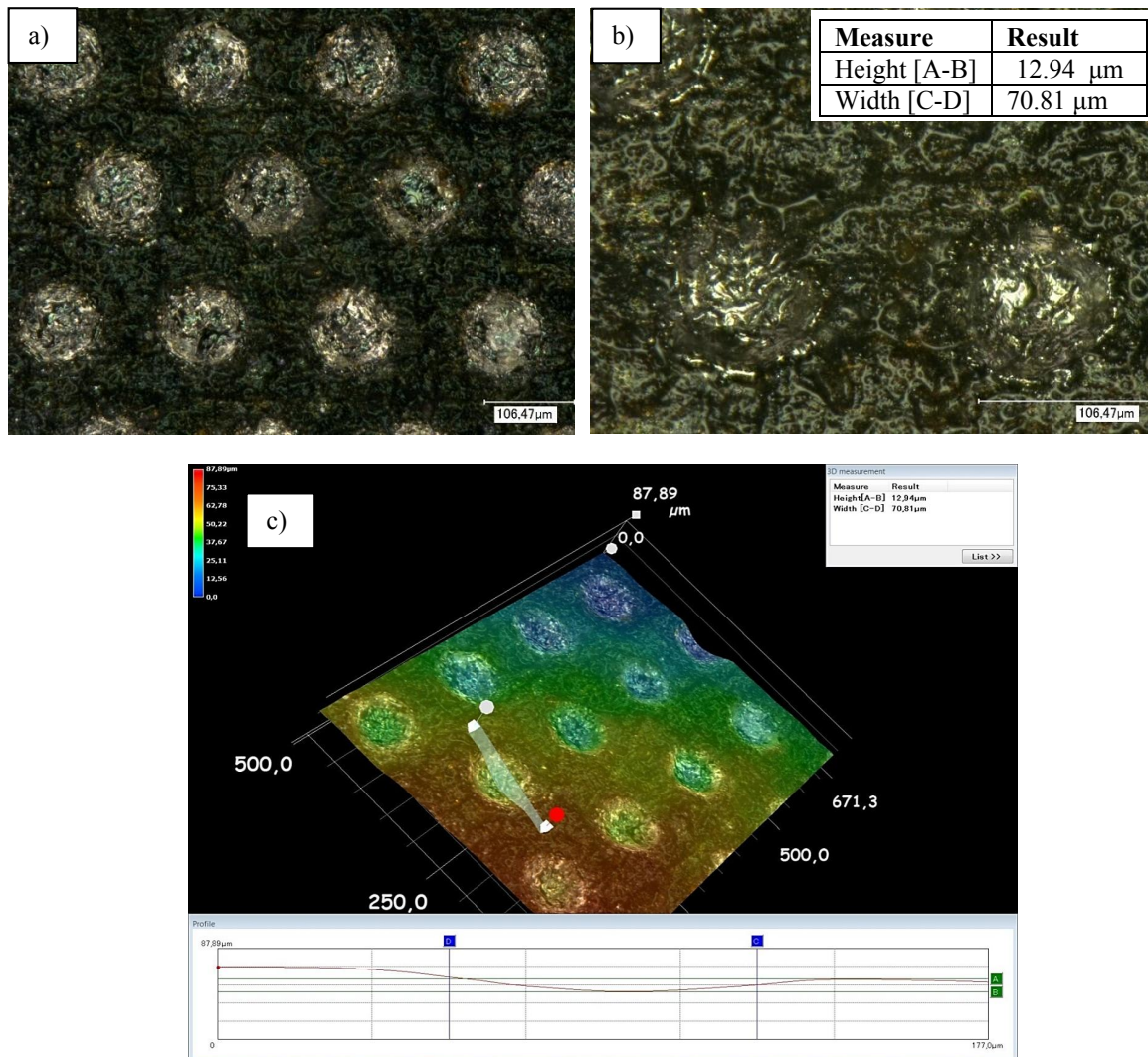


Fig. 7. Surface topography (a, b) and profile (c) of the working surface of the pistons bolt after laser ablation texturing [8]

2.5. Camshaft

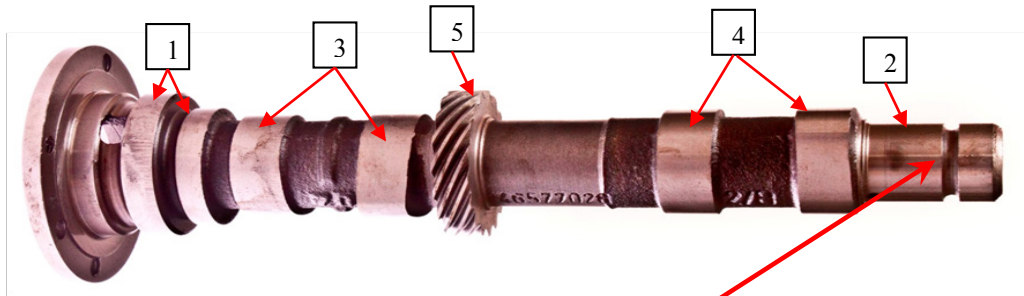
To improve the durability of the surface layer of the camshafts spigots (sufficient load surface and maintaining oil in the association are strongly demanded), experiments employing laser ablation experiments were carried out. However, there is a belief that preliminary smoothness of the camshafts spigot does not have significant impact on the engine exploitation, but the way of the treatment decides about the timing of the reaching out as well as required exploitation to create sufficiently high bearing surface of the spigot associated with the bearings track. From this point of view, it is not ambivalent what type of geometry is on the surface layer of the camshafts spigot.

Significant differences in the spigots smoothness, proposed by various manufacturers are mainly result of the type and destination of the engines, their planned durability and recommended reaching out timing. It is known that increased requirements of the surface topography parameters of the spigots of the camshaft increase, usually highly, the costs of the engines production.

Due to the limited sampling of the real-life engine elements, finally on the surface of one of the spigot of the camshaft associating with inner surface of the opening in the trunk made of AK84M

alloy, an array of bowl-shaped micro-containers was formed with the covering of ca. 25% surface with the use of laser ablation micro-treatment.

a)



b)



Fig. 8. Camshaft of the 126A1 engine and its elements: a) 1 and 2 – main spigots; 3 and 4 – cams, 5 – gear of the drive the ignition device; b) spigot after laser ablation texturing – bowl-shaped micro-containers, magn. 12x [4]

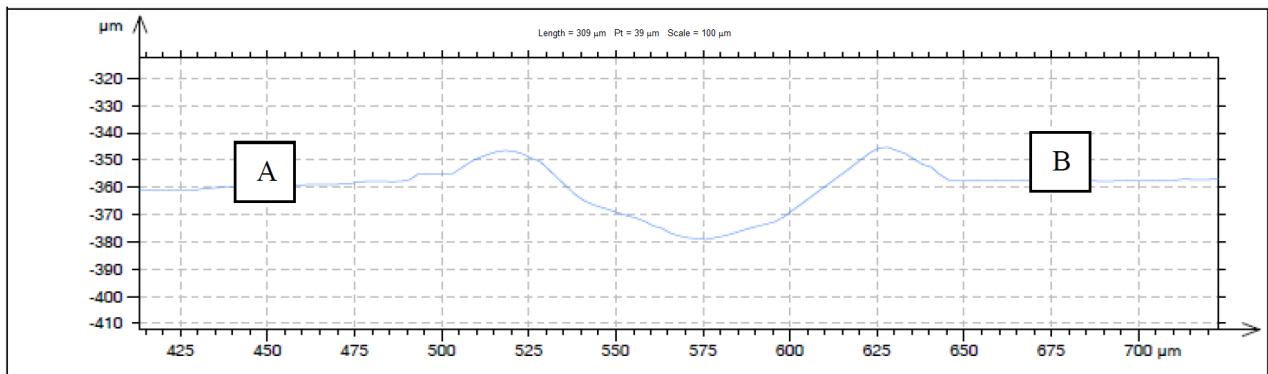
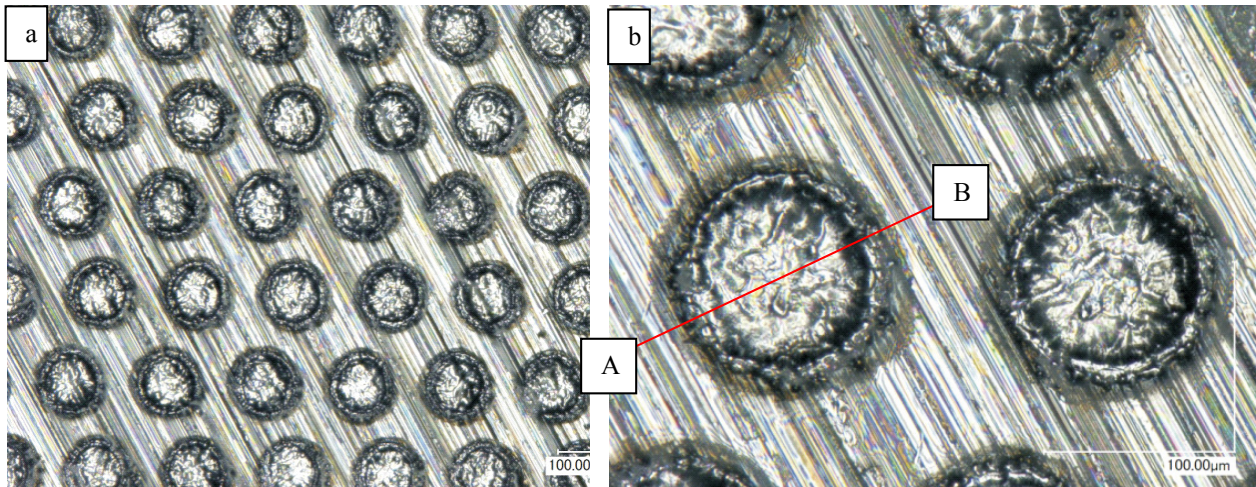


Fig. 9. Topography (a, b) and profile (c) of the surface of the spigot of the camshaft after laser ablation texturing [4]

3. Summary and final conclusions

1. Current laser technologies provide new opportunities in up to date impossible technological processes carrying out. Nowadays precise laser texturing is possible and in use. The laser techniques influence positively the quality of the completely produced element, even while these are only minor part of the technological processing.
2. Laser modification enables precise texturing of the surface by i.e. fabrication of micro-containers. These micro-bowl-shaped and micro-groove-shaped containers may be formed in crucial zones of the piston rod and timing gear systems.
3. As the part of the conducted research bowl-shaped and groove-shaped oil, micro-containers were formed on the selected elements of piston rod and timing gear systems, including: main and rod spigots of the crankshaft, side surfaces of base and head of the rod, piston bolt, pin crankshaft of the spark ignition engine, type 126A1.
4. With the use of laser ablation texturing, at optimized experimental parameters, it is possible to form on the piston-rod and timing gear elements oil micro-containers with varied shapes and surface coverage. It allows improving the association conditions in these systems, especially due to the formation of oil microfilm, which efficiently separates mentioned elements even while under high thermal, heat and mechanical load.
5. Presented elements of the piston rod and timing gear elements were preliminary positively verified on the real-life object – spark ignition engine, type 126A1 in so-called “cold ignition” tests in low temperature chamber. It allows concluding that the application of the laser ablation texturing technology allows increasing durability and reliability of the elements and will imply decrease of the emission of toxic chemicals into the atmosphere.

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