Quality evaluation of the surface shaped by laser and EDM (electrical discharge machining*)*

Ocena jakości powierzchni kształtowanych laserowo i elektrodrążeniem

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Article presents the impact of steel surface texturing, done with laser or EDM, on quality of the product. Taken into account were changes in the top layer of the material, created depending on the processing parameters, affecting the performance characteristics and accuracy of shape mapping.
KEYWORDS: laser ablation, EDM, texturing steel, layer of white

W artykule zaprezentowano wpływ, teksturowania powierzchni stali wykonanej laserem oraz elektrodrążeniem, na jakość wykonania wzoru. Uwzględniono zmiany struktury w warstwie wierzchniej materiału powstające zależnie od parametrów obróbki, wpływające na właściwości eksploatacyjne wyrobów oraz dokładność odwzorowania kształtu.
SŁOWA KLUCZOWE: ablacja laserowa, elektrodrążenie, teksturowanie stali, warstwa biała

Surface texturing is suitable for masking surface defects, decorating the surface (e.g. giving it wood texture), facilitating grip, enhancing lubrication, increasing chemical activity of the surface. Depending on the intended use, surface should have an appropriate structure, pattern repeatability and accuracy of the shape. Receiving proper texture was made possible due to development of laser micro-machining and EDM.

■ **Laser texturing.** Laser micro-machining is one of the most effective surface shaping technologies. It consists of a local and short lived laser beam use on material surface, heating micro-volume, melting and evaporating [1].The impact of the laser beam onto the materials surface absorbs heat energy and as a result causes melting of the surface layer, as well as heat transfer into the material, and as a consequence a large temperature gradient between the melted layer and non-melted basis. Large temperature gradient affects the rapid solidification of the melted and mixed material of the surface layer. Laser melting of the surface layer is accompanied by the formation of plasma and materials evaporation. Plasma formation may cause shielding of the laser beam and its reflection and dispersion. Thermal processes affect the state of the surface layer of the material, as well as defects in its shape, e.g. in the form of a flash on the edge of the melting area. Essential for the formation of various effects are processing parameters, e.g. possibility of focusing the laser beam and physical properties of the material [2, 3].

■ **EDM texturing.** Electrical Discharge Machining is an important method of surface texturing. This method, being a thermal technology, may incorporate changes in the surface layer of the material, e.g. an unfavorable structure, micro-cracks especially occurring in the white layer [4, 5].

The cause of their formation are thermal stresses produced in the process. As a result of cooling and solidification of the melted layer contortion is formed, which is counteracted by the core material and, as a consequence, generated are tensile stresses of the surface layer.

Exceeding the maximum tensile strength of the material is therefore the basis for the creation of micro-cracks [6]. Micro-cracks reduce fatigue limit, corrosion resistance. Micro-cracks in most cases spread deeper in between layers edges, sometimes even deeper into the base material [7].

Construction of the surface layer, similarly to laser texturing, is dependent on the used processing parameters. These are mainly: the duration of the electrical pulses, current, power density, type of the electrode. Increase in the amount of the eroded material increases the amount of not removed metal from the crater, which forms a white layer while solidifying [6, 8].

Laser texturing, test results

The material used for testing is hot work alloy tool steel X40CrMoV5-1 after heat treating. On the prepared sample it is to be produced texture having dimensions of 15 × 15 mm and a depth of 0.4 mm.
Assumed machining parameters (using laser Agie-Charmilles 1000 5A x 50 W): laser power of 100%, frequency of 50 Hz, speed of laser beam shifting 1000 mm/s, a single layer collected 226 µm. Texture created with mentioned above parameters is shown in Fig. 1, the time of the sample is 21 min.

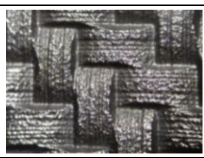

Fig. 1. Texture created on the steel surface

Laser texturing reflect assumed shape in a very high detail, if the texture is observed at the macro scale. The edges of the texture were analyzed for the size of the flash between the plane surface and the beginning of the texture profile. Measurements were made using Profilometer Form Talysurf Series. Carried out measurements have shown lift of the material onto the surface 25 to 30 µm (Fig. 2). It is a disadvantage that later in the process must be removed, if it is for example a closing element or is using interfaces e.g. rotatably.

Structure observation on the cross section of the treated layer shows a significant amount of the white layer, unevenly distributed on the edges (Fig. 3*a*). Lack of the white layer in the recesses may indicate that melted metal were thrown

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onto the higher positions, where it cooled and not evaporated.

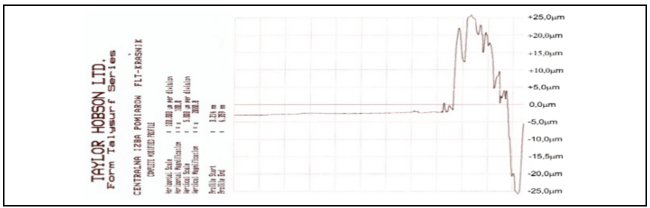

Fig. 2. Measurement of the flash at the transition between grinded surface and onset of laser-machined texture

To evaluate the accuracy of the texture, measured was profile using the optical profilometer in 3D technology (Fig. 3*b*). Optical measurement described the depth of the textures profile as 378.4 µm (400 µm were assumed).

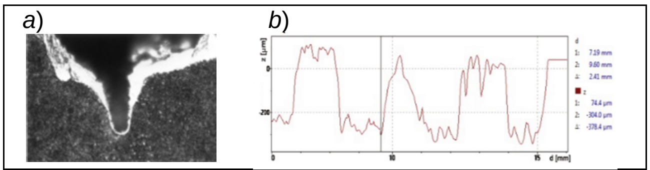

Fig. 3. *a*) Surface layer after texturing, *b*) measurement of the texture with marked profile section line

The process of laser ablation produces a white layer associated with assumed parameters of laser use. To reduce the formation of the white layer may be important to increase material removal rate, thus use of a high energy pulse. Favorable might be low frequency parameters, allowing additionally smaller share of the energy lost by the thermal conductivity.

EDM texturing, test results

Creating the texture with copper electrode requires electro-erosion machine, which is able to provide low electrode wear and due to the pointed texture profile, programmable generator parameters allowing machining at very low power. Used was EDM machine FORM 400 vP with iQ module and TECFORM program automatically generating technology, including type of work surface, drilling speed, minimal electrode wear, maximum accuracy, minimal white layer. For EDM texturing used was copper electrode (Fig. 4).

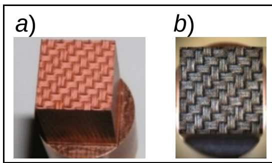

Fig. 4. Electrode used for texturing: *a*) the surface of the copper electrode before EDM, laser-made, *b*) electrode surface after EDM

The edges of the end of the texture were analysed on the size of the flash. Measurements showed material lift on the surface 3 to 5 µm (Fig. 5). In comparison to the laser treatment, the size of the flash is very small. Assumed texture depth in the electrical discharge machining have been determined as in laser texturing to 400 µm. Obtaining the proper depth is associated with the wear of the electrode.

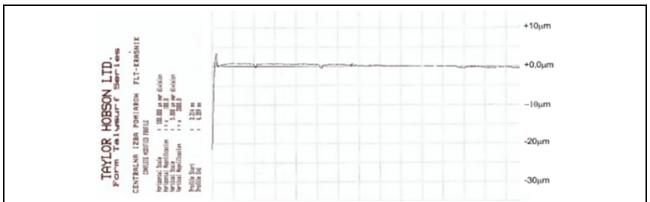

Fig. 5. Measurement of the flash at the transition between grinded surface and onset of EDM-machined texture

Carried out texture measurement using the optical scanner, highlights the initial electrode wear and obtaining a depth profile of 291.4 µm (Fig. 6).

Shape of the prepared electrode was scanned using optical scanner in 3D. After the texturing, electrode was measured again. After superimposing two scanned objects, it's possible to visualize profile change of the electrode after the machining (Fig. 7).

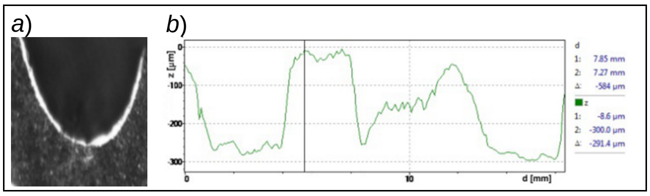

Fig. 6. *a*) Surface layer after texturing, *b*) measurement of the texture with marked profile section line

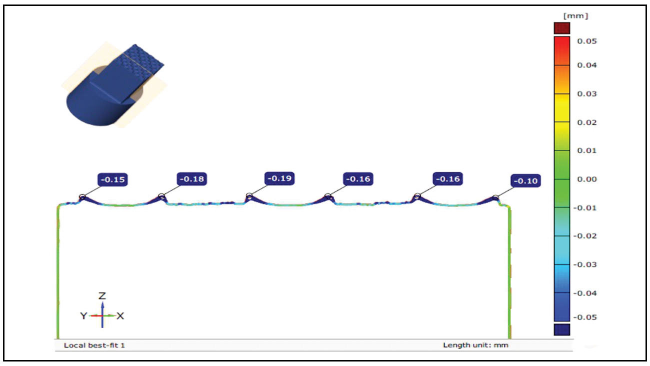

Fig. 7. The cross section profile of the electrode. Visible electrode wear. The mass loss of the electrode is 7 g

Summary

Use of laser ablation for texturing causes creation of the uneven, detrimental white layer with a thickness of 20 to 100 µm.

Texture created on the EDM machine has a much thinner and more uniform thickness of 2 to 3 µm.

Laser texturing is carried out with much greater speed and shape precision than EDM texturing, which also consumes the electrode.

It is not possible to use laser technology and EDM technology to create texture on one detail without any visible differences.

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