Konference studentské tvůrčí činnosti

Fakulta strojní ČVUT v Praze

LASER SURFACE TREATMENT

Ing. Radka Jindrová

Laser surface treatment

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1. Introduction

The laser beam has found several possibilities of use in technological process recently. Except established technologies such laser welding, cutting, drilling, engraving and marking there are new possibilities of laser beam usage for laser polishing, texturing and cleaning of surface. A lot of experiments of laser beam polishing and texturing were realized in Research Center of Manufacturing Technology. Now we can use some results of experiments in industry.

2. Laser polishing

Because surface roughness after laser engraving is deficient for some technical application there was a need to improve the surface roughness by laser beam polishing. Finding optimal laser parameters and working condition for achieving better surface roughness were aims of research of laser beam polishing. Effect of individual laser parameter (such us output power, frequency, speed, focus, number of repeat, angel of incidence, hatching method and track pitch) on surface roughness was investigated.

2.1 Technical devices for experiments, measurement and evaluation

Experiments were realized on machining centre MCVL 1000 LASER, that is combination of standard MCVL 1000 and a diode excited Nd:YAG laser (wavelength 1 064 nm) of a nominal output of 50W. Material of specimens was steel, copper, brass and dural. In the first part of experiments initial surface was ground. In the second part of experiments optimal laser parameters were applied on the laser engraved (micromilled) surface. Techniques of laser micromilling and laser polishing were suggested and tested with the aim of achieving lower value of surface roughness.

Fig.1 Machining centre MCVL 1000 LASER

Surtronic 3+ Taylor/Hobson with stylus Standard Pick-up was used for surface roughness measurement. Surface roughness was measured in longitudinal direction and across compared with laser beam travel. Microhardness was measured through the use of SCHIMADZU HMV-2 and picture of surface was taken with magnification 1:100. Distribution of residual stress in surface layer was measured by anodic etching method on the best laser treated surface.

2.2 Laser beam polishing of ground surface

Samples of dependence of surface roughness on particular laser parameter are displayed in the following graphs. These results were obtained in the first part of experiments.

a) **Dependence of surface roughness on frequency**
Laser parameters and working conditions: output power 50 W, speed 80 mm.s^{1}, focus on 14 mm under surface, repeat 1, marks in a parallel way, track pitch 0,07 mm, laser beam perpendicular

b) **Dependence of surface roughness on repeat**
Laser parameters and working conditions: output power 50 W, speed 80 mm.s^{1}, focus on 14 mm under surface, marks in a parallel way, track pitch 0,07 mm, laser beam perpendicular

c) **Dependence of surface on track pitch**
Laser parameters and working conditions: output power 50 W, speed 80 mm.s^{1}, focus on surface, marks in a parallel way, repeat 1, laser beam perpendicular

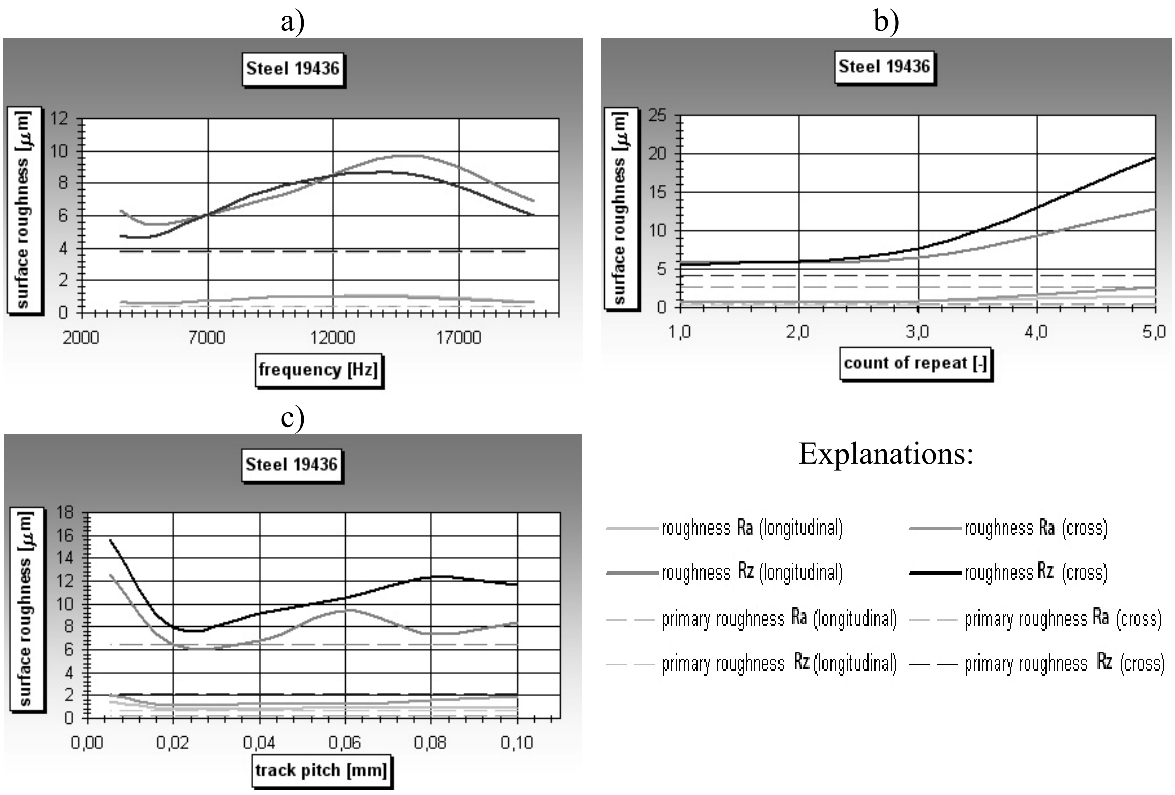

Fig.2 Surface roughness dependences on laser parameters

The best values of roughness after laser beam treatment were approximately following: $Ra_{longitudinal}$ = 0.50 μm, $Rz_{longitudinal}$ = 5.00 μm, Ra_{cross} = 0.50 μm and Rz_{cross} = 5.00 μm. In some cases roughness of treated surface was worse then roughness of beginning ground surface.

2.3 Laser polishing after laser micromilling

Two ways of laser polishing technique were investigated. The first way of laser polishing was based on laser micromilling with laser parameters for maximum stock removal setting and than different methods of laser polishing were applied on surface. More then 50 % improve of surface roughness was achieved in almost all experiments. Lowest values of surface roughness ($Ra_{longitudinal}$ = 0.24 µm, $Rz_{longitudinal}$ = 1.67 µm, Ra_{cross} = 0.37 µm and Rz_{cross} = 2.90 µm) were achieved in laser polishing technique MLE6A-5030 and surface roughness improve was from 70 to 83 % in consideration of value of laser micromilled surface roughness.

The second way of laser polishing was based on modification of laser micromilling for achieving lower values of surface roughness and than different methods of laser polishing were applied on surface. More then 50 % improve of surface roughness was achieved in almost all experiments too. Lowest values of surface roughness ($Ra_{longitudinal}$ = 0.27 µm, $Rz_{longitudinal}$ = 1.87 µm, Ra_{cross} = 0.39 µm and Rz_{cross} = 2.53 µm) were achieved in laser polishing technique LSVR7-7A531 and surface roughness improve was from 70 to 83 % in consideration of value of laser micromilled surface roughness.

Main principle of both ways of laser polishing was based on remelting of thin surface layer which caused asperity removing and surface smoothing. In following figure best surfaces after laser micromilling and laser polishing are illustrated. Size of treatment surface is 20 x 20 mm.

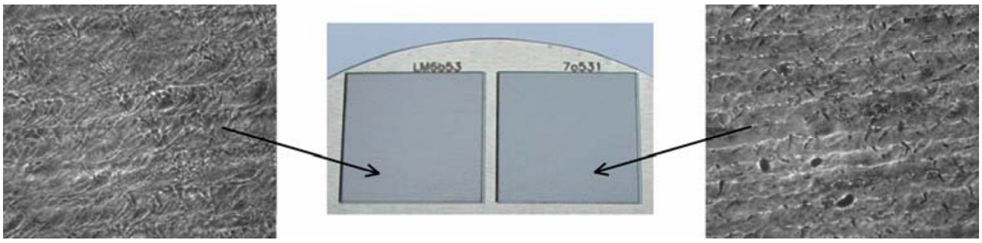

Fig.3 Best laser polished surfaces (real size, zoom 100x)

2.4 Effect of laser polishing on microhardness in surface layer

Microhardness was measured on the best polished surface. Value of microhardness of laser polished surface was higher then microhardness of ground surface. There was increase of hardness from value 27 HRC of ground surface to approximately 47 HRC in thin surface layer (depth 0.05 mm) for almost all laser polished surfaces. In following figure is an example of dependence of microhardness on depth for sample MLE8V50.

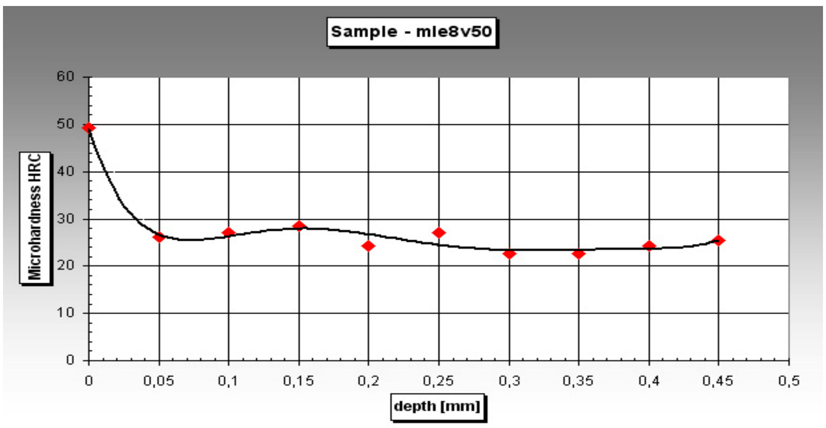

Fig.4 Microhardness (steel 19436)

2.5 Effect of laser polishing on residual stress in surface layer

Effect of different laser polishing methods on residual stress behaviour in surface layer was investigated on the best polished surface. Residual stress behaviour was measured by anodic etching method. Appearance of tensile stress in thin surface layer was found in almost all of laser polished surfaces. In following figure is example of dependences of residual stress on depth for ground surface, laser micromilled surface and some laser polished surface.

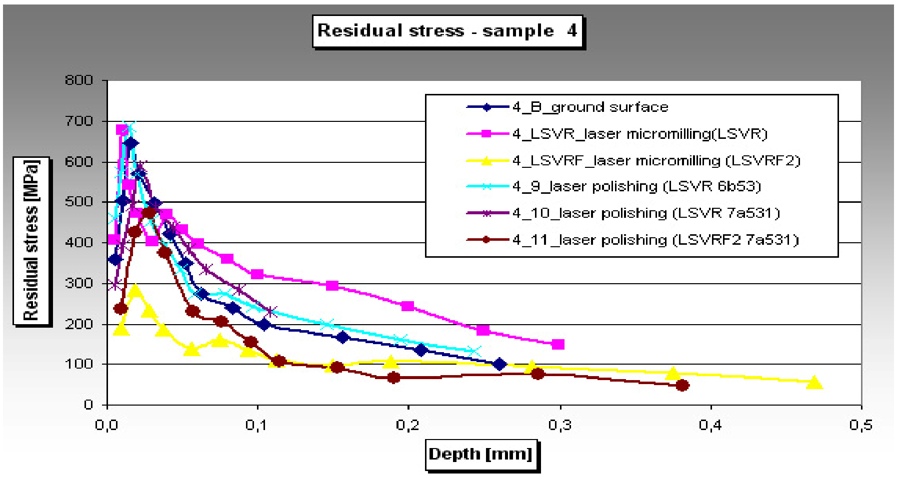

Fig.5 Residual stress (steel 19 436)

2.6 Effect of incidence angle on surface roughness during laser polishing

Effect of incidence angle on surface roughness during laser polishing was investigated. Incidence angle of laser beam was changed within the range from 10° to 90°. Laser parameters for polishing were used in the first part of experiments. Treated surface was remelted by laser beam. Laser parameters for laser engraving were used in the second part of experiments. Excess material of asperity was removed from treated surface. In following figure is graph of dependence of surface roughness on incidence angle for first part of experiments.

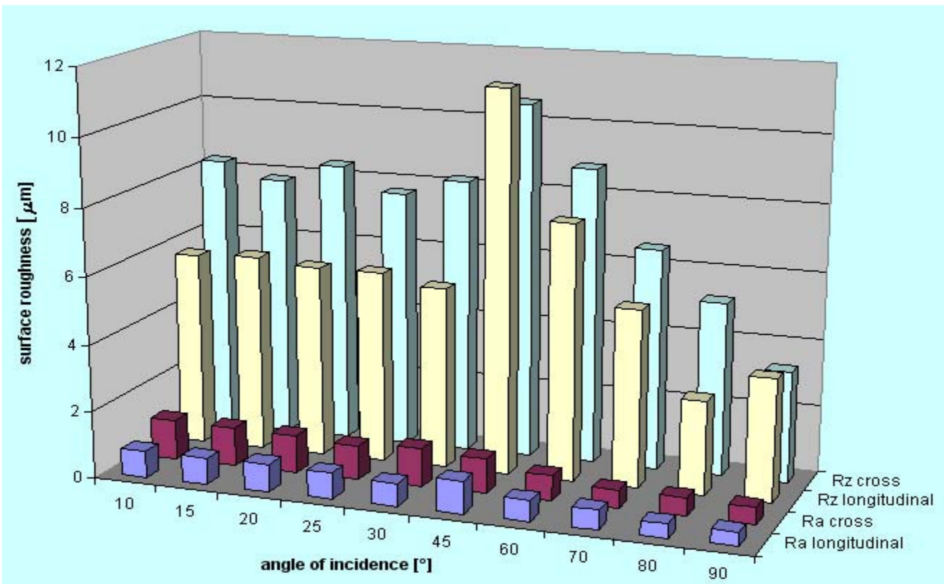

Fig.6 Surface roughness dependence on incidence angle
(steel 19 436, 1st part of experiments)

In following figure is graph of dependence of surface roughness on incidence angle for second part of experiments.

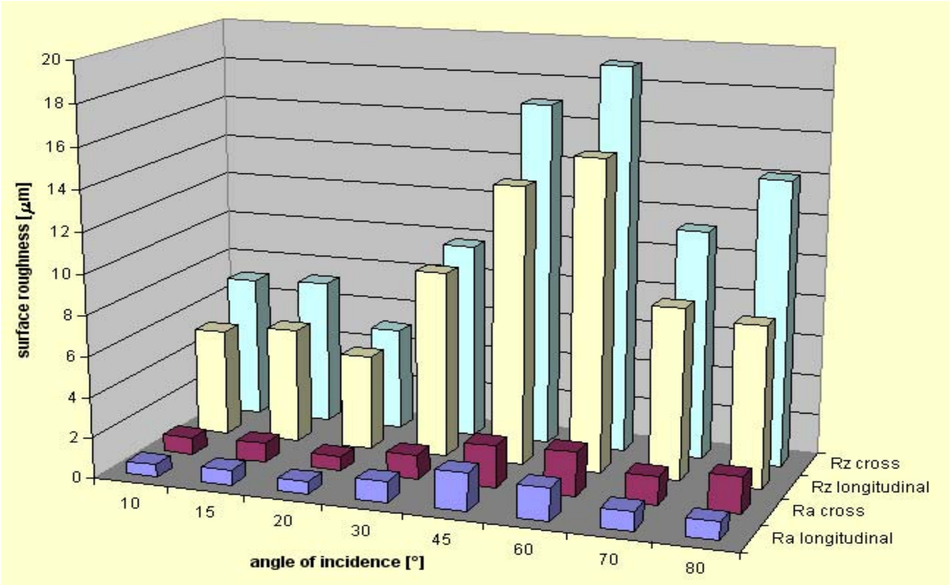

Fig.7 Surface roughness dependence on incidence angle
(steel 19 436, 2nd part of experiments)

In the fist part of experiment (laser parameters with remelting effect were used) best results were achieved with incidence angle from 70° to 90°. It could be caused by lower laser beam absorption and greater reflectance at less incidence angle which preclude required remelting of surface layer. Conversely in the second part of experiments (laser parameters for engraving was used) best results were achieved with incidence angle from 10° to 20°. It was caused by different geometry of laser beam spot.

2.7 Comparison of laser polishing results with piece of knowledge in technical literature

There are two ways of laser polishing. Remelting of material in thin surface layer by laser beam is basis of the first way. Smooth surface is caused by surface stress in melted material. Principle of second way of laser polishing is based on the actual surface determining before processing by a contour-measuring device and processing parameters are calculated from the desired surface and surface actually measured. Processing is carried out subsequently as appropriate.

It known from technical literature that best roughness values in range Ra = 0.24 ÷ 0.26 μm are achieved by laser polishing. Treated surface is shiny. It was achieved roughness value in range Ra = 0.27 ÷ 0.39 μm during experiments in RCMT and treated surface was black. Further property of treated surface is not adduced in literature. For example effect of laser polishing on microhardness and residual stress. Twice higher value of microhardness was measured on laser polished surfaces in RCMT.

3 Laser texturing

Different methods for creating of surface texturing were investigated. We can decide these methods into two groups:

- textures created by direct laser beam interaction with material that changes quality of surface
- textures created by graphic method – based on trajectory of laser beam
- textures created by laser engraving

3.1 Texturing created by surface melting

These textures are created by melting and consolidation without evaporation of material in thin surface layer caused by laser beam interaction. Laser parameters for creating these textures are dependent on size of treated surface. There are achieved greater values of surface roughness.

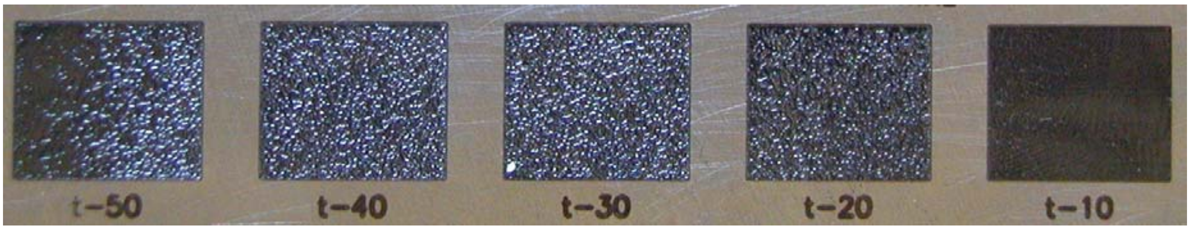

Fig.8 Textures created by surface melting (steel 19 436)

3.2 Texturing by incidence of separate laser pulses

These textures are created by incidence of separate laser pulses in the course of setting of low pulse frequency and high speed. These textures created only optical effect. Roughness of treated surface is almost changeless.

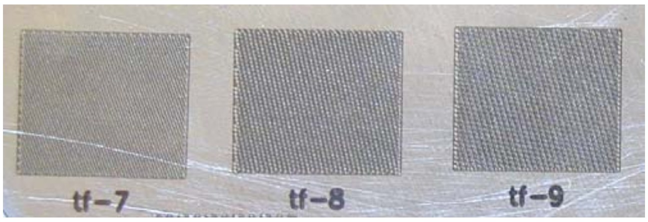

Fig.9 Texturing by incidence of separate laser pulses (steel 19436)

3.3 Deep texturing

Texture is created by surfaces with different depth and shape. Separate surfaces are created by different count of repeat. This method is similar to 3D laser engraving. Samples of deep texturing are in the following figure.

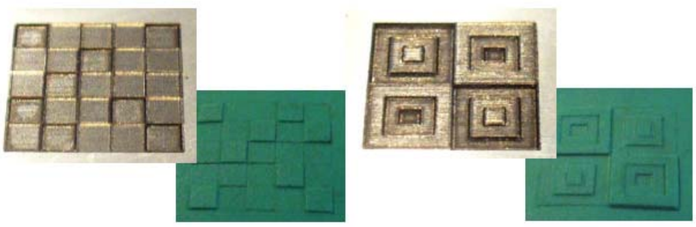

Fig.10 Deep texturing (steel 19436)

3.4 Soft texturing

These textures are created by combination of surfaces with different value of roughness. Laser parameters for achieving different value of surface roughness result from laser polishing experiments. Sample of soft texturing (combinations of smooth and rough surface) is in the following figure.

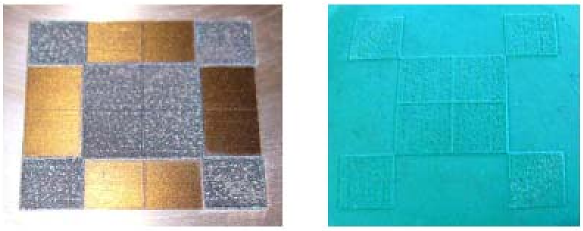

Fig.11 Soft texturing (steel 19436)

3.5 Graphic method of texturing

It is flexible method of texturing based on laser engraving of pattern that is created by laser beam trajectory. Patterns and their textured surfaces are illustrated in following figure. Size of pattern is 2 x 2 mm and size of textured surface is 10 x 10 mm.

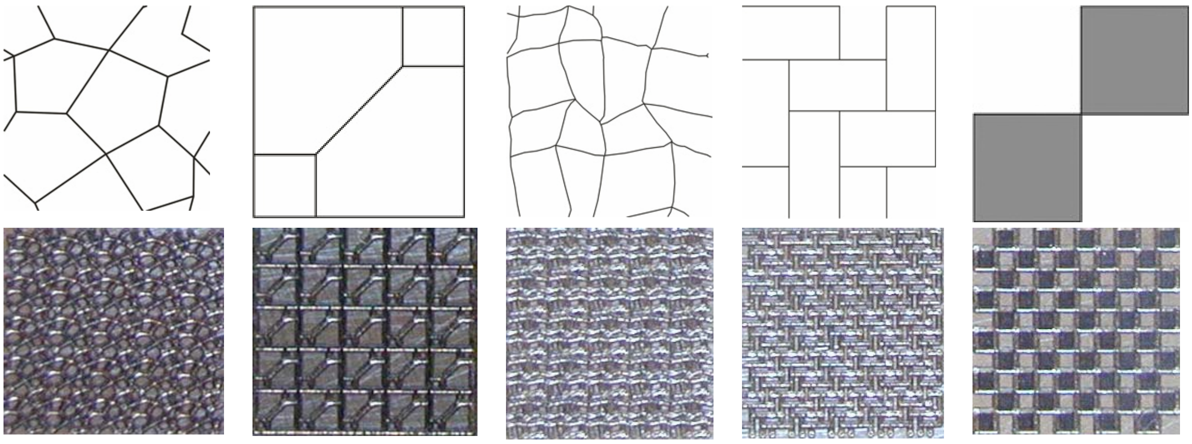

Fig.12 Patterns and graphic textures (steel 19 436)

It is possible to achieve different alternates of texture by changing of pattern size and engraving depth. Sample of pattern size changing is in following figure.

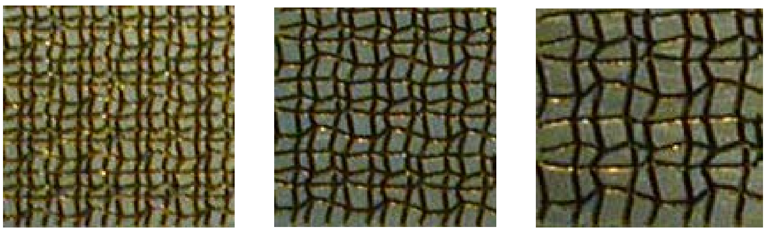

Fig.13 Alternates of texture by changing of pattern size

3.6 Comparison of laser texturing results with piece of knowledge in technical literature

These methods are known for creating of surface texturing:

- Laser engraving – method is suitable for treatment of former and mould surface.

- Method based on the actual surface determining before processing by a contour-measuring device and processing parameters are calculated from the desired surface and surface actually measured. Processing is carried out subsequently as appropriate.
- Texturing based on laser irradiation through mask

4. Industry applications of laser polishing and texturing

4.1 Surface treatment of carbon composites for implants into human body

Technology of laser texturing was applied on surface treatment of carbon fibre-reinforced carbon composites. There are expected to improve the cohesion of the carbon matrix, adhesion, growth and differentiation of osteogenic cells.

Fig.14 Textured carbon composites

4.2 Texturing of moulds

Technology of laser texturing was applied on surface treatment of moulds. Textures were created on incurvate surface. In the following picture is sample of laser textured mould.

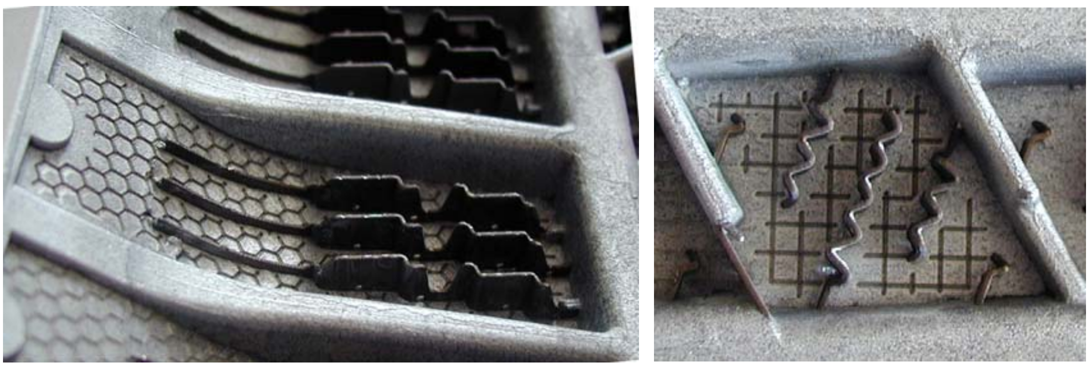

Fig.15 Textured mould surfaces

5. Conclusion

There are presented research results of laser polishing and texturing. Optimal laser parameters for laser polishing were obtained. These research results can be used in industry for production of small moulds, stamping and forming tools.

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