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► **To cite this version:**

Christophe Vincent, Guy Monteil, Thierry Barrière, Jean-Claude Gélín. Control of the quality of laser surface texturing. *Microsystem Technologies*, 2008, 14 (9-11), pp.1553-1557. 10.1007/s00542-008-0573-8 . hal-04382623

HAL Id: hal-04382623

<https://hal.science/hal-04382623>

Submitted on 4 Jun 2024

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Control of the quality of laser surface texturing

Christophe Vincent · Guy Monteil ·
Thierry Barriere · Jean Claude Gelin

Abstract Since the conception of the first lasers in the 60's, the knowledge and consequently the applications of laser have been widely increased. Laser surface texturing is a specific field among the various applications of the laser. This technique is employed in the aim of improving tribological performances for instance. This paper presents the laser surface texturing of a heterogeneous material. This material is lamellar cast iron. It has been chosen for its good friction properties. The textured surface is composed of grooves or dimples. The dimensions are micrometric. For the grooves, different cross sections have been engraved: semicircular, rectangular, trapezoidal and triangular. The dimples are cylindrical. All these laser textured surfaces are engraved with the laser manufacturing machine: DML 40 SI of Gildemeister (Germany). This machine is equipped with a galvanometric scanner, which allows tilted surfaces to be engraved. Various machining strategies and the following results are discussed in function of the different desired laser surface texturing results. In addition, to increase the aspect of the engraved surfaces, laser polishing is employed. Thanks to a defocalisation of the laser beam on the surface, the material is not ablated but melted. To be able to compare the different laser machining process, several techniques of control have been used: roughness profilometry, scanning electron microscopy and non contacting optical measurement. The rules of use of these methods must be defined bearing in mind their inherent limitations.

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1 Introduction

In the field of the high aspect ratio of micro engineering of surfaces, the laser exhibits a growing interest (Mutapic et al. 2005; Smolka et al. 2004; Yongjun Lai et al. 2006). A specific application is the laser surface texturing. The textured surfaces can have many applications but the most important is the improvement of the tribological performances of friction pairs (Erdemir 2005; Haefke et al. 2006; Kovalchenko et al. 2005; Pettersson 2005; Wang et al. 2001).

Different laser surface texturing has been studied with in mind the difficulty to characterize them. The textured surfaces are either grooves or dimples. The specificity of the present laser machining is the engraved material. It is a heterogeneous material: lamellar cast iron. The purpose of this laser texturing is to enhance the tribological performances.

2 Laser surface texturing

2.1 Process

The process of the laser surface texturing is the same whatever the manufacturing machine is excepted for the driving software of course.

The laser manufacturing machine is a DML 40 SI with a Nd:YAG laser. The mean power is 100 W. The laser spot diameter is 40 μm and the machine is equipped with a galvanometric scanner (Fig. 1), which allows the laser beam to be tilted (Vincent et al. 2006). This functionality is used to engrave tilted surfaces with a large depth.

The laser process is composed of five main steps:

- CAD: computational drawing of the textured surfaces.

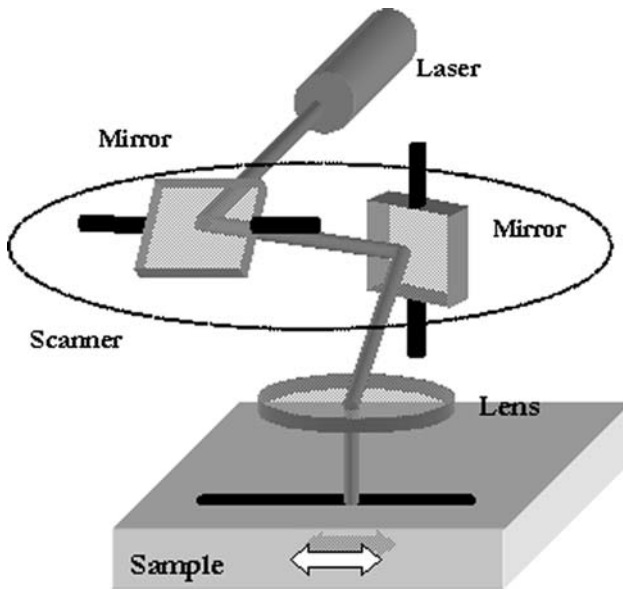


Fig. 1 Driving of the laser beam thanks to the galvanometric scanner

- CAM: after choosing the machining strategy i.e. the use of the galvanometric scanner or not, adjustment of the various parameters of the scan of the laser beam and the number of cuts for the border of the surface.
- Setting up the specimen to be machined on the work table thanks to a CCD camera for the lateral placement and a mechanical sensor to confuse the sample surface and the focus plan of the laser beam.
- Selection of the ablation parameters of the machined material in the library of the driving software to set up the values of the laser parameters or checking the right ones. If the engraved material is not referred after their determination is realized by means of the measurement of the engraved depth for the right adjustment of the operating parameters i.e. intensity of the current of the lamp.
- Laser machining: during the machining, an aspiration system collects the particles of the pulverized material. In spite of this system, some particles cool at the edge of the textured surfaces; so to eliminate the burr, a fine grinding must be made.

2.2 Textured surfaces

The textured surfaces are composed of grooves and dimples. The grooves can have different cross sections: semi circular, rectangular, trapezoidal and triangular. The dimples are cylindrical. All these texturations are engraved in lamellar cast iron. It is a heterogeneous material with good properties in tribological applications. The dimensions of the textured surfaces are micrometric so their characterizations lead to some technological problems.

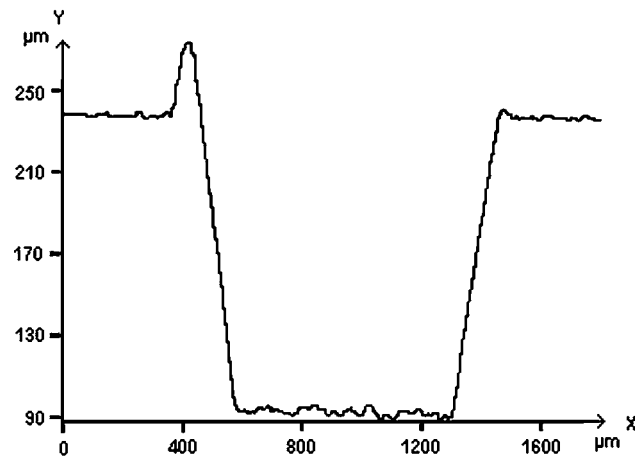


Fig. 2 Profile of a rectangular groove (width 1 mm, depth 100 μm) by a tactile roughness profilometer where the slope of the flanks corresponds to the one of the sensor

3 Characterizations of the textured surfaces

Different techniques have been employed to characterize the textured surfaces: the roughness profilometry, which uses a diamond sensor in contact with the specimen and two non-contacting techniques.

3.1 Roughness profilometry

The used sensor is ended by a conical diamond with a tip cone angle of 45° . Several profiles and thanks to specific software, either a 3D image can be built or a single profile can be traced (Fig. 2).

3.2 Scanning electron microscopy

The scanning electron microscopy (SEM) is a common method of observation of laser textured surfaces. This optical technique is very accurate but the preparation is very time consuming. In addition, the SEM only allows the textured surfaces to be characterized qualitatively.

To overcome this problem, a silicone mould of the grooves is realized. This one is then cut and metallized. Thanks to this method, the profiles of the grooves can be assessed (Fig. 3).

3.3 Non contacting optical measurements

At least to be able to characterize quantitatively the textured surfaces, a non contacting optical measurement has been used. It is composed of a microscope and a camera. Its operating principle combines the small focussing depth of

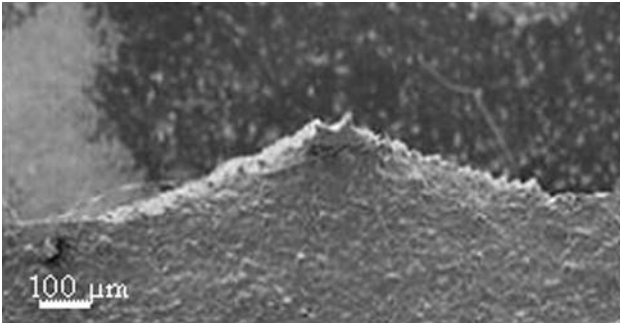


Fig. 3 SEM photograph of the profile of a silicone mould of the triangular groove (width 1 mm, depth 100 μm)

an optical system with a vertical scanning, generating 2D maps of focussed points for a preselected number of focussed plans. Then, an algorithm reconstructs this into a single 3D data set with a great accuracy (Figs. 4, 5).

4 Discussion

The first widely used method for the characterization of laser textured surfaces is the well known tactile roughness profilometry. If the only depth of a groove has to be measured this method can be employed. But as far as the profile of the groove has to be checked this method fails. As an example, Fig. 2 illustrates the two main artefacts of this technique. The flanks of the grooves are not vertical but exhibit the angle of the tip cone on the edge of the groove. In addition, it overestimates the height of the burr coming from the convolution of the profiles of the rectangular groove and the conical diamond.

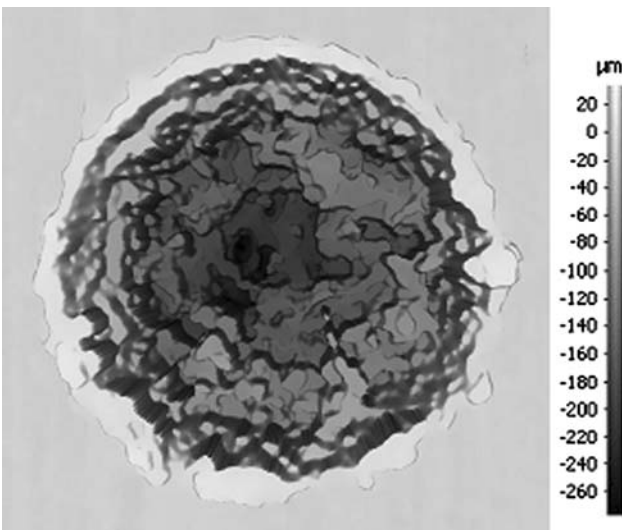


Fig. 4 Topographic image of a correct dimple (\varnothing 1 mm, depth 500 μm)

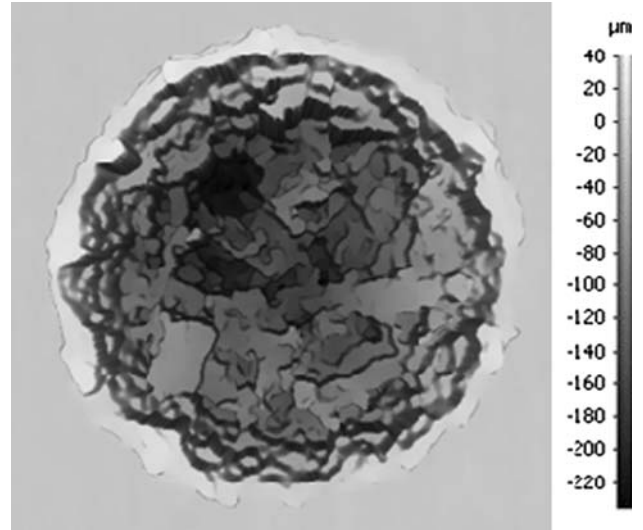


Fig. 5 Topographic image of an improper dimple (\varnothing 1 mm, depth 500 μm)

Then, to avoid a contact between the surface and a sensor, other methods have been used. The first one was the SEM but it is only a qualitative control. The silicone replica is the only way to obtain a quantification of the groove profile but could be questionable about its accuracy.

Finally, the only method which does not suffer these limitations is the optical confocal microscopy. By means of dedicated 3D software quantitative images of the grooves can be built up.

So the rules of use of these apparatus are closely linked to their inherent limitations (Vincent et al. 2006).

The purpose of such a laser texturation process is to enhance the performance of the sample surfaces. In order to measure precisely the efficiency of a type of texturation it is needed to ensure that the realized one is sufficiently close to the desired one. Particularly such parameters as the depth, the profile and the spacing of the patterns must be well known. In addition the roughness of the ideal plane areas must be as low as possible. Concerning the depth as the engraved material is lamellar cast iron, which is a heterogeneous material, the ablation speed is not yet known. The adjustment of the intensity of the laser has been realized setting for the first test this parameter between the one of graphite and steel (26 and 45%) and finally adjusted by comparing the depth of a square ablated area ($5 \times 5 \mu\text{m}^2$) to the desired one.

Concerning the depth, the machined one is more important than the desired one. The difficulty is the adjustment of the current of the lamp to obtain a mean depth, which is correct. As a matter of fact, the material is composed of two phases, graphite and ferrite, which need different laser adjustments so the only way to achieve the desired depth is this calibration method.

For the adequation of the profile of the grooves, the use of the galvanometric scanner and consequently the tilted laser beam is beneficial for the machining of large depths. For instance, the machining of the triangular groove with a perpendicular machining strategy induces the apparition of stairs on the flanks of the groove. If the tilted machining strategy is employed, the appearance of the flank of the groove is smoother (Fig. 6).

At least concerning the profile of the dimples following the machining strategy used for a given profile the material can be not completely expelled. In order to refine the geometry of the groove the laser may be tilted and also combined with the optimisation of the pulsation time of the laser. The final result can be illustrated on Fig. 7.

This example shows that it is absolutely necessary to have very accurate methods to measure precisely the dimensions of the grooves if the functional results have to be correlated with the desired dimensions of the laser textured surfaces. The last step is to check the surface roughness of the geometrical patterns created with the laser processing.

5 Laser polishing

After the engraving of the surface, a laser polishing can be used to lower the roughness of the textured surfaces. During the traditional laser machining, the material is pulverized and melted and so some scories appear (Fig. 8). Thanks to the offset between the sample surface and the focal plane of the laser beam, the energy is lower (Dobrev et al. 2006). Consequently, the material is not sublimated but melted. By this method the remaining roughness at the bottom or on the flanks can be reduced dramatically (Fig. 9). In addition, this laser polishing can be applied to the plateaus between the grooves to soften their roughness.

The values of the offset can be adjusted from -3 up to $+3$ mm per step of 1 mm. The qualifying orughness

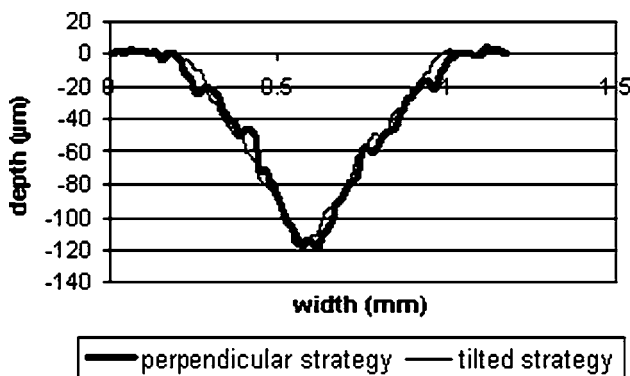


Fig. 6 Comparison between two machining strategies for a triangular groove (width 1 mm, depth 100 μm)

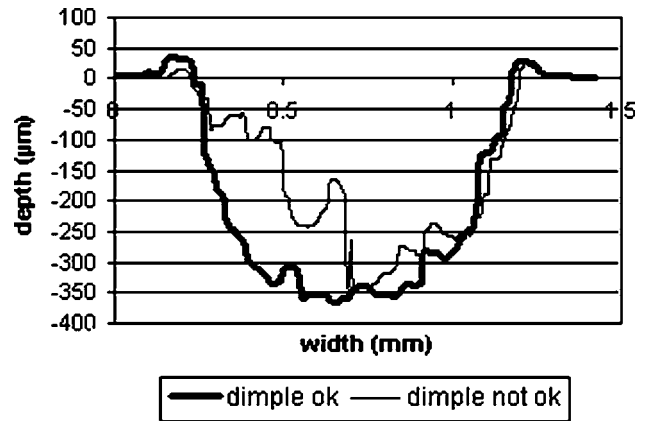


Fig. 7 Profile of two dimples (\varnothing 1 mm, depth: 500 μm) with the non contacting optical measurements

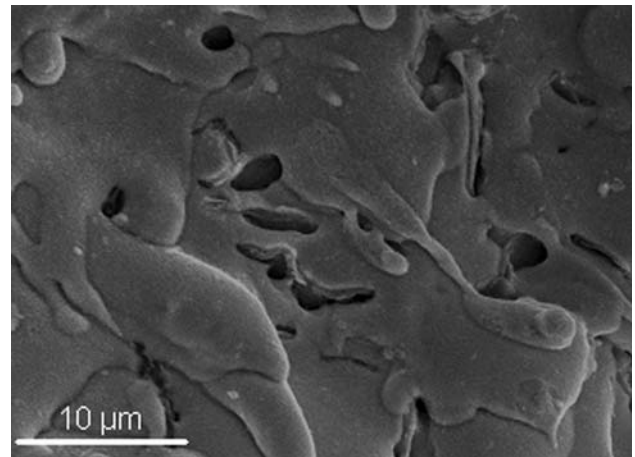


Fig. 8 SEM photograph of the bottom of a rectangular groove without laser polishing

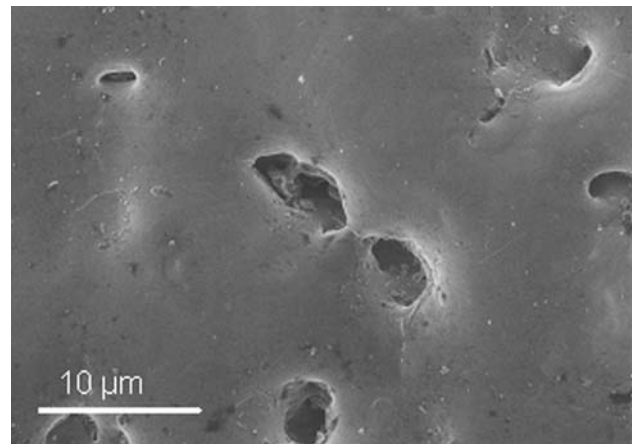


Fig. 9 SEM photograph of the bottom of a rectangular groove with laser polishing (offset = +2 mm)

parameter of the smoothed area is the mean arithmetical roughness R_a measured by means of a tactile profilometer. The results are described in Table 1. It can be seen easily

Table 1 Roughness of the laser textured surface after laser polishing

Offset (mm)	-3	-2	-1	0	+1	+2	+3
Ra (μm)	2.96	2.77	2.68	2.81	2.76	2.75	3.14

that with an adequate offset of the laser beam, the roughness can be lowered by about 5%.

6 Conclusions

Laser surface texturing has been shown to be a powerful tool for improving tribological performances. For such purpose dimples or grooves are engraved with micrometric dimensions. When surfaces are textured, there is a need to control precisely their shape and dimensions. Various techniques have been used to overcome the difficulty to measure such narrow sharp edge grooves. With the help of these techniques the laser machining strategies and the laser parameters can be adjusted in order to engrave the desired surfaces. In addition, the quality of the laser machining can be improved thanks to the laser machining in order to obtain the closest groove shape compared to the desired one and a smoother surface.

Acknowledgments The authors gracefully thank the support for the partners: ENSMM (Ecole Nationale Supérieure de Mécanique et des Microtechniques), Ecole des Mines de Paris/ARMINES, Total, Mecachrome, PSA (Peugeot-Citroën), Renault and ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie).

References

- Dobrev T, Pham DT, Dimov SS (2006) Laser polishing In: Menz W et al. (ed) Multi-material micro manufacture-2006, 4M 2006 proceedings, Grenoble, pp 273–276
- Erdemir A (2005) Review of engineered tribological interfaces for improved boundary lubrication. *Tribol Int* 38:249–256
- Haefke H, Gerbig Y, Dumitru D (2000) Microtexturing of functional surfaces for improving their tribological performance. In: Proceedings of the international tribology conference, Nagasaki, pp 217–221
- Kovalchenko A, Ajayi O, Erdemir A, Fenske G, Etsion I (2005) The effect of laser surface texturing on transitions in lubrication regimes during unidirectional sliding contact. *Tribol Int* 38:219–225
- Lai Y, Bordatchev EV, Nikumb SK (2006) Metallic micro displacement capacitive sensor fabricated by laser micromachining technology. *Microsyst Technol* 12:778–785
- Mutapcic E, Iovenitti P, Hayes JP (2005) A 3D-CAM system for quick prototyping and microfabrication using excimer laser micromachining. *Microsyst Technol* 12:128–136
- Pettersson U (2005) Surfaces designed for high and low friction. Ph.D. Thesis, Uppsala University
- Smolka G, Gillner A, Bosse L, Lützel R (2004) Micro electron beam welding and laser machining—potentials of beam welding methods in the micro-system technology. *Microsyst Technol* 10:187–192
- Vincent C, Monteil G, Barrière T, Gelin JC (2006) Laser surface texturing of lamellar cast iron. In: Juster N, Rosochowski A (eds) 9th international conference on material forming ESAFORM 2006, Glasgow, pp 567–570
- Vincent C, Monteil G, Barrière T, Gelin JC (2006) Comparison of the characterization of laser striation on lamellar cast iron with various techniques. In: Menz W et al. (ed) multi-material micro manufacture-2006, 4M 2006 proceedings, Grenoble, pp 153–156
- Wang X, Takars J, Krallics G, Szilagy A, Markovits T (2001) Experimental research on laser material interaction. *Tribol Int* 34:703–711