Latin America Optics and Photonics (LAOP) Conference 2022 © Optica Publishing Group 2022

Ultrashort laser pulse microtexturing on cutting tools

Wagner de Rossi[1], Antonio Arleques Gomes[1], Ricardo Elgul Samad[1], Álisson Rocha Machado[2,3], Pedro Augusto Bompeixe Cheliga[2]

1 – A Center for Lasers and Applications (CLA), Nuclear and Energy Research Institute (IPEN), Av. Prof. Lineu Prestes, 2242, Cidade Universitária, 05508-000, São Paulo – SP, Brazil
2 - Graduate Program in Mechanical Engineering, Pontifícia Universidade Católica do Paraná – PUC-PR, R. Imaculada Conceição, 1155, Bairro Prado Velho, CEP 80215-901, Curitiba/PR, Brazil. vitor.baldin@pucpr.edu.br; *alisson.rocha@pucpr.br*

3 – Federal University of Uberlandia, School of Mechanical Engineering, Av. João Naves de Ávila, 2121, Bloco 1M, 38400-902, Uberlândia, MG, Brazil. leonardo.rrs@gmail.com; alisson.machado@ufu.br, https://orcid.org/0000-0002-5388-2954

Abstract: Femtosecond laser pulses were used for texturing cutting tools in order to obtain better results in the traditional metal turning process. Some significant examples are presented in this work.

1 – **Introduction**

Surface texturing has been used for several purposes, the main ones being to improve the tribological aspects between two sliding surfaces[1] and in medical implants for better adhesion and cell growth. In particular, the laser texturing process has the advantages of being very precise, clean, reproducible, controlled by CNC systems, and with low environmental impact. Even so, traditional lasers, such as Q switched Nd:YAG lasers, produce thermal effects that lead to the formation of a layer of resolidified liquid material in the processed regions. This limits the dimension of the texture structure, produces very resistant burrs and can alter the physical and metallurgical properties of the surface in the affected region. These changes can compromise the intended results with texturing as a physical / metallurgical change and completely modify the interaction properties of this surface in a tribological pair, as in the case of cutting tools, or in biochemical processes in medical implants.

The use of ultra-short laser pulses, under certain conditions, can minimize or completely eliminate these drawbacks [2], since the temporal width of the pulses, on the order of 10^{-14} – 10^{-13} s, is significantly shorter than the electron-phonon interaction time, and the energy deposited in the lattice electrons is removed along with the ablated material before being transferred to the bulk of the material.

Experimental procedure.

In this work we present results of turning of low carbon steel ABNT 1020, machined with a carbide tool, P30 grade, laser textured with different types of structures [3]. Textures such as “straight channels” and “V”-chevrons were produced, both in parallel, perpendicular, and at 45° directions from the cutting edge; all with a depth of 30 µm at a distance of 50 µm from the cutting edge, spacing of 50 µm, and with a textured area of 4mmx4mm. In this region, friction occurs between the chip and the cutting tool (Fig. 1-a), and, therefore, the surface morphology can greatly alter the effects of this interaction. Thus, the objective is to find a texture for which there are improvements in the main effects of the turning process, such as the cutting temperature, machining force, and surface roughness of the processed part.

The texturing was perfomed with the “Femtopower Double 10 kHz” Ti:sapphire laser system, from Femtolasers, which emits pulses with a wavelength of 800 nm, 10 fs of temporal width, a repetition rate of 10 kHz, and maximum energy of 200 µJ per pulse. The beam is focused by a lens of focal length f = 20 mm, generating a focal point of 3.6 µm. The sample is moved by a translator stage with three-axis interpolation and controlled by ISO G-code programming.

The laser machining parameters were: energy of 4.0 µJ per pulse; laser beam travel speed of 1.5 mm/s and a pulse repetition rate of 10 kHz. With these conditions, parallel lines are drawn forming an ablated plane with a depth of ΔZ = 10µm. The total projected depth is obtained by repeating this process, with an automatic displacement of the focal point by ΔZ in the depth, as many times as necessary.

Disclaimer: Preliminary paper, subject to publisher revision

These conditions were found after an optimization work that took into account the maximization of process speed and material extraction without severe damage to the bulk of the affected region, as this can occur for fluences (energy/area) and/or rates of very high pulse overlap.

Figures 2, show the decrease in machining temperature and cutting force as a function of texture geometry.

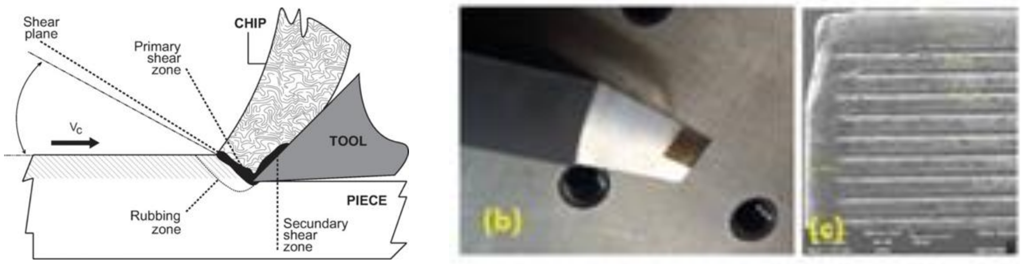

Figure 1. (a) Shear zones in chip formation. Source: Oliveira et al. (2021) [4]. (b) textured region in the machining tool; (c) enlarged view of parallel texture after turning process.

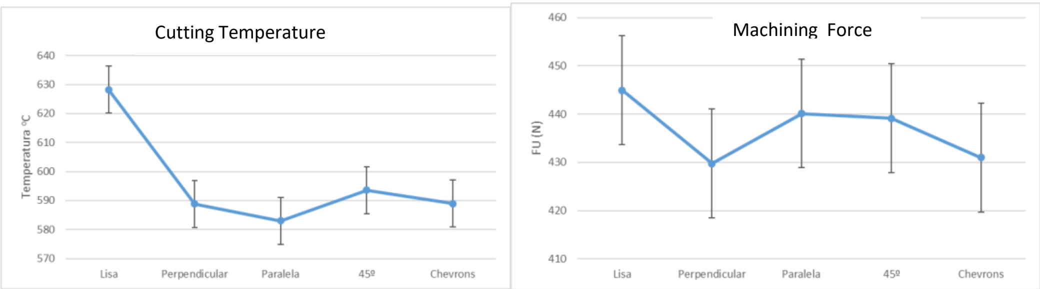

Figure 2 – Influence of textures on chip-tool interface temperature in tests with cutting speed variation (left); Machining force with feed rate variation (right).

Conclusions

Microtextures can be used to reduce the temperature at the chip-tool interface. In these experiments, the greatest reductions were for tools with microtextures of orientation Parallel to the cutting edge.

The machining force, with feed variation, was higher for untextured tools as compared to textured tools. The lower machining force was presented by tool with textures perpendicular to the cutting edge.

Regarding the surface integrity of the tools, it was found that after the tests, the tools with microtexture parallel to the main cutting edge had, in general, less workpiece material adhered to the rake surface and fewer microtextured channel breaks than the others tools.

References

1 Machado, Á. R.; Silva, L. R. R.; Souza, F. C. R.; Davis, R.; Pereira, L. C.; Sales, W. F.; De Rossi, W.; Ezugwu, E. O.;State of the art of tool texturing in machining. JOURNAL OF MATERIALS PROCESSING TECHNOLOGY., v.293, p.1 - 23, 202

2 Gamaly, E. G. (2011). "The physics of ultra-short laser interaction with solids at non-relativistic intensities." Physics Reports 508(4-5): 91-243.

3 Chéliga, P., A., B.; "O efeito da microtexturização a laser em ferramentas de corte de metal duro, classe P30, durante o processo de usinagem do aço ABNT 1020", Masters dissertation, Pontifícia Universidade Católica do Paraná, 2019.

4 Oliveira, G.C., Ribeiro, S.S. & Guimarães, G. An inverse procedure to estimate the heat flux at coated tool-chip interface: a 3D transient thermal model. *Int J Adv Manuf Technol* **112,** 3327–3341 (2021). https://doi.org/10.1007/s00170-020-06498-x