DEVELOPMENT OF AN AUTOMATIC PROCEDURE TO TEXTURE CUTTING TOOLS WITH A COMPLEX GEOMETRY

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ABSTRACT

Introduction

Nowadays, process sustainability is receiving more and more interest. The reduction of the amount of lubricant, and, consequentially, the possibility to work under Minimum Quantity Lubrication (MQL) conditions, are just some aspects taken into account in sustainable production. In order to achieve these needs, found that the development of new coatings is getting harder [1], a solution can be represented by the morphological modification of the surface at micro- and nano-dimensional level obtained by laser texturing. Several studies have emphasized the benefits reached during machining through this method [2]. These are also reflected to anti-adhesion properties [3], heat reduction [4], anti-friction [5]. Moreover, the fields of application are different, not only referred to the significant impact on tribological performance of cutting tools but also related to bearings [6] and engine cylinders [7].

In this work, an effective kinematic and methodological procedure to create regular dimples by texturing the entire development of the helix of tapping tools is developed. Rectangular dimples were selected as the texture pattern to ensure the evaluation of the depths reached. An ultrashort picosecond laser operating at the IR wavelength was used to structure the tapping tools. Finally, to ensure the effectiveness of the developed process, investigations have been carried out via SEM analysis.

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Materials and Methods

A commercial tapped tool distributed by Seco Tools under the MF-M10x1.50-ISO-6HX-XC-V055 codification has been considered. That's a TiN coated tapping tool used for steels and hardened steel with <62 HRC. Its complex geometry involves two different zones: a conical inlet aimed to facilitate the entry of the various threads into the pre-hole and a subsequent cylindrical zone that fully complies with the DIN 2174 standard of M10x1.5. The conical inlet involves the first three threads and is characterized by an inclination of β = 7.5° with respect to the longitudinal axis. The development is shown in **Figure *1***.

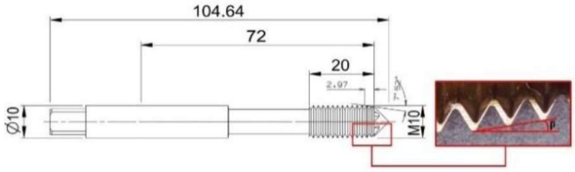

Figure 1 SECO tapping tool datasheet (left); magnification of the conical inlet zone (right). (All dimensions are in mm).

Picosecond laser technology operating at the IR wavelength of 1064 nm was used to texture the thread. The focused beam diameter was d ~ 10 µm evaluated at $1/e^2$ intensity. All the tests were performed with a fixed repetition rate of 400 kHz and an average output power over the tool of 0.82 W equivalent to a pulse energy of 4.1 µJ.

The system is composed by a Raylase Superscan IV galvanometric scanner coupled with an 80 mm F-theta lens which allows a working area of 39 x 39 mm^2 through automatic handling (in X and Y directions) of two mirrors mounted inside the scanner. The scan strategy consisted of two consecutive passes of overlapping scanlines performed with 1000 mm/s and 5 µm as marking speed and line spacing, respectively. These guarantee a correct distribution of the pulses along and between the scanlines, a homogeneous distribution of energy on the treated area, a precise regular dimples formation and a gradual increase in depth up to 10 µm (as maximum) of the dimples thus preventing the formation of recast material.

The remaining movements, outside the scan area, are permitted by an X-Y table on which a rotator is also installed. The tapping tool is gripped by the mandrel installed in the rotator. Finally, Z displacements are managed by the translation of the scan head. Laser source, roto-translator system for workpiece and head manipulation, optical scanning system, beam shaping and sensor for process control are totally integrated via C# libraries and LabVIEW to allow movements in the three translation directions and rotations thus following the helical path of the thread. The entire experimental setup is showed in Figure 2.

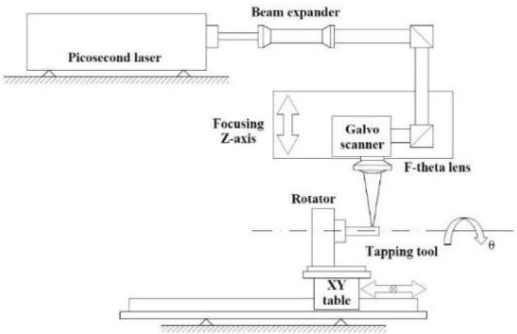

Figure 2 Laser system used for the experiments.

The entire area to be textured, which follows the complex geometry generated by the helix of the thread and it is involved during contact between the tool and the workpiece, affects 15% of the total area generated by the envelope of the helix itself. Three different typologies of dimples were selected: flat bottom, positive- and negative-inclination in relation to the cutting speed v_c. These geometries share the same shape, rectangular, with a maximum dimension with respect to the surface normal of 30 x 60 μm and 10 μm as the expected maximum depth. In order to reach the present depth, a machining strategy has been implemented, which consists in overlapping seven rectangles with a common height of 30 μm but with different widths, which progressively decrease from 60 to 20 μm. Every single rectangle was filled with an equally spaced horizontal hatch 5 μm in step to generate the above depth.

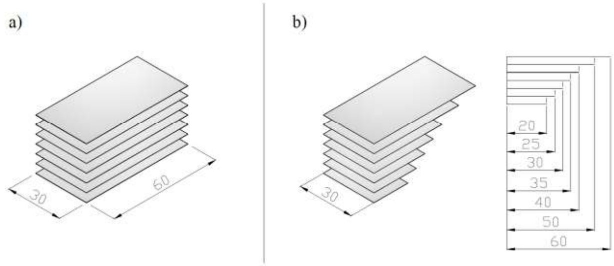

Figure 3 Dimples generation criteria. a) flat bottom; b) wedge dimples. Decreasing in width proceeds from top to bottom (All dimensions are in μm).

During laser processing, the laser beam must follow the entire thread of the tapped tool according to the winding direction of the helix and to operate at the correct focal height.

System integration allows to set up an automatic procedure to texture the tool. This consist of two stages. First, laser beam performs the progressive creation of the dimples by using a multi-quote Z approach for a fixed value of rotation θ. Thus, the laser initially focuses on the crest and creates textures on it. After completing this task, the system, through a movement of the Z axis, moves progressively to the next lower level until it reaches the thread root. This allows to calculate a single set of {X,Z} position of the laser vectors. The system can texture only one angular position in their entire height, from the crest to the root of the thread. The heights involved in the process were z* = 0, -0.06, -0.19, -0.38, -0.57, -0.76, -0.89, -0.99, -1.17 mm with the origin for the $z*$ dimensions located at the outer radius of the tread. Then, by automatically rotating the tool with an angular step of 4.5° and shifting the X position to follow the helical path, the process restarts as mentioned above.

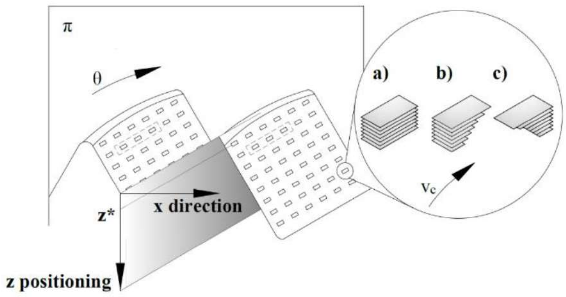

Figure 4 Textures on a circular sector of the tapped tool. In the enlarged figure: projected views of: a) flat bottom dimples; b) - c) positively (and negatively) inclined dimples wrt cutting speed v_c

Conclusions

Textured tapping tools were cleaned in an ultrasonic bath and then analysed via a Scanning Electron Microscope. The images obtained confirm the chosen laser parameters and the possibility to get precise regular dimples with specific dimensions on the thread of the tool through the picosecond laser technology. The maximum depths of the dimples settle around 10 µm, as expected. These values are interesting for future developments in which cutting tests will be performed to investigate forces and torques during tapping using textured and conventional SECO tapped tool under MQL conditions.

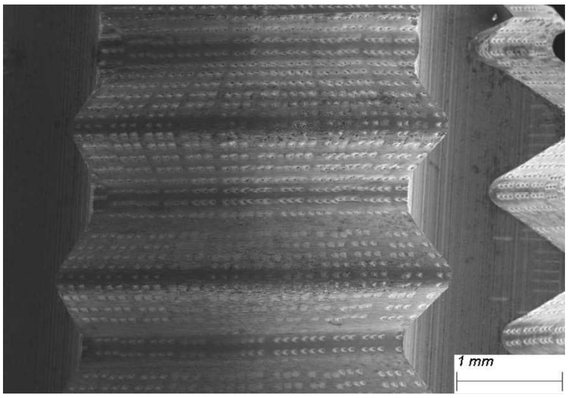

Figure 5 SEM image of the treated inlet conical zone.

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