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Characterization of multifunctional surfaces during fabrication

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Abstract

The multifunctional surfaces herein studied are intended for carrying high loads as well as providing lubrication. They are produced by hard turning, creating a periodic pattern that will constitute the lubricant channels, followed by accurate Robot Assisted Polishing to smooth the tops of the cusps to obtain a well defined bearing area. It is studied how the surface topography varies with the number of polishing passes. Hard-turned specimens with different feed rates are polished changing stone, spindle speed and pulse frequency. The profiles are filtered with the robust Gaussian regression filters according to ISO 16610-31 and analyzed according to ISO 13565. It is depicted how existing standards are not sufficient to fully characterize this kind of surfaces.

1 Introduction

During the years, it has become more and more common to exploit the surface microstructure by modifying its texture in order to achieve a particular functionality, e.g. to increase the tool life. A typical example is represented by plateau-honed surfaces for internal combustion cylinder bores. It is a two-step process to produce first a coarse texture establishing the valleys for lubricant retention and a second finer process to remove the upper portion of that texture [1]. Similarly to plateau-honed surfaces, the multifunctional surfaces (i.e. surfaces that can achieve more than one function) studied here are produced through a two-step process: hard-turning and Robot Assisted Polishing (RAP). The texture obtained is thought to improve load carrying capacity and lubrication. By means of ISO 13565 [1] and ISO 16610-31 [2], it is analyzed how changing the fabrication process parameters affect the surface texture.

2 Investigation of RAP process

The RAP machine has been developed by Strecon A/S [3] and can polish axisymmetrical tools fixed in a rotating spindle. A robot arm controls the polishing stone approaching the surface and moves back and forth in the axial direction, while pulsing with a pre-set frequency. In this study, cylindrical specimens with diameter Ø38 mm made in Vanadis 4E were hard-turned, with a low and high feed rate of 0.2 mm and 0.4 mm respectively. For each feed rate 4 specimens were polished with different RAP parameters. The RAP parameters varied are the polishing stone (H800 and H600), spindle speed (300 rpm and 500 rpm) and pulse frequency (3000 pulses/min and 5000 pulses/min). The development of the surface topography is studied as a function of the number of passes the robot performs. The assessment is made through 5 measurements taken with a 2-D skid profilometer. Every obtained profile is filtered by means of a robust Gaussian regression (RGR) filter of the 2nd order. The RGR filter, standardized in [2], has been demonstrated by [4] to be more effective than the double-step Gaussian filtering explained in [1] because it is not affected by end effects distorting the filtered profile. Moreover, the robustness ideally removes the outlier data from the profile and the mean line will therefore follow the plateau roughness created by the RAP process.

3 Results and discussion

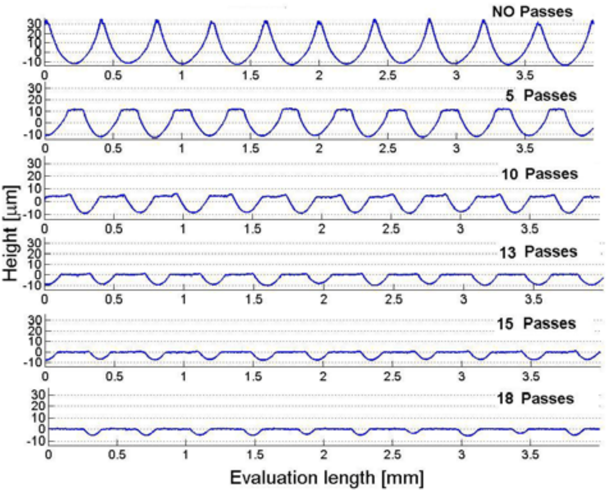

Figure 1: Development of surface topography as a function of the number of passes.

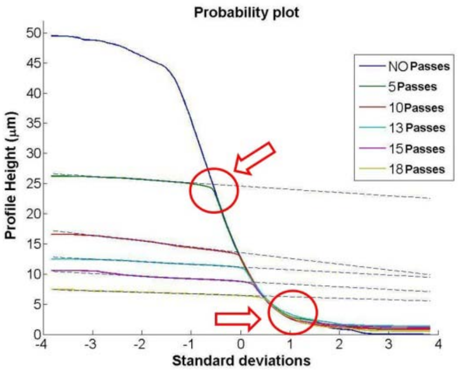

Figure 2: Probability plot evolution as a function of the number of passes.

Figures 1 and 2 illustrate an instance of the development of the multifunctional surface and the related surface probability plot (ISO 13565 – part 3) as a function of the number of polishing passages. As it can be seen from figure 1, the RGR filtering does not distort the profiles at the ends and, as the plateau bearing area increases, the zero line is shifted towards the plateaus. The probability plot of figure 2 shows that each profile has two sudden changing in slope (indicated by the arrows), one after the plateau region and one in the valley region. This is due to the fact that the coarse texturing is not a Gaussian process, but it creates a well-defined pattern. Parameters as Rvq can not therefore be calculated properly. To evaluate the different polishing parameters, Rt and the bearing area of the plateaus Ba are plotted against the number of polishing passes (figure 3). Ba is the intersection point between a line fitted through the plateau region and the first profile, which is aligned to the others. For the specimens with lower feed rate, the parameter that has most influence in the polishing is the spindle speed, which can achieve the same Rt value and a higher Ba of the plateaus (approximately 70%) with less than half of the passes of the other parameter settings. Concerning the higher feed rate, the spindle speed is still a very important factor, but not as decisive as before. Instead, the choice of a coarser polishing stone has more influence than with low feed rates in achieving a high bearing area of the plateaus.

4 Conclusions

A new typology of multifunctional surfaces obtained throug a two-step process (hard-turning for regular patterning and RAP for producing the plateaus) is studied. RGR filtering of the second order is applied, but the zero line can follow the plateaus only for high initial bearing areas. Moreover, due to the not-stochastic nature of the turning process, parameters of ISO 13565-3 are not suitable for these surfaces. Concerning the RAP process, the spindle speed is found to be a decisive factor to rapidly produce high initial bearing areas for low and high feed rates, while the polishing stone has only significant influence for high feed rates. The pulse frequency does not seem to influence the removal rate.

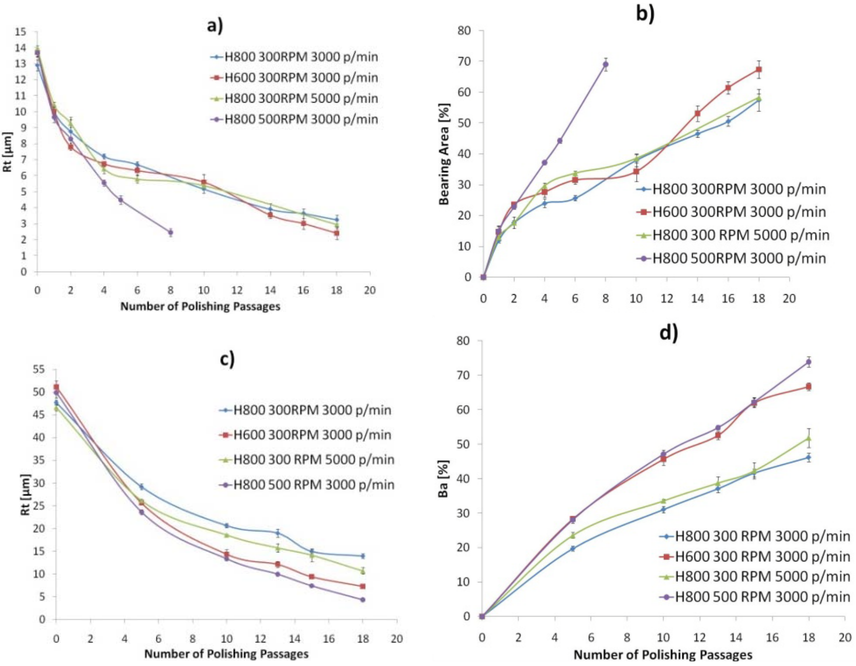

Figure 3: a) Evolution of Rt for specimens with feed rate 0.2 mm; b) Evolution of Ba for specimens with feed rate 0.2 mm; c) Evolution of Rt for specimens with feed rate 0.4 mm; d) Evolution of Ba for specimens with feed rate 0.4 mm.

References:

[1] ISO 13565 parts 1-3 (1996), Geometrical Product Specifications (GPS) – Surface Texture: Profile Method; Surfaces having stratified functional properties.

[2] ISO/TS 16610-31 (2010), Geometrical Product Specifications (GPS) – Filtering – Robust Filters: Gaussian Regression Filters.

[3] Strecon A/S, http://www.strecon.com/, visited 28th January 2011.

[4] Jiang, X. (2010), Robust solution for the evaluation of stratified functional surfaces, *CIRP Annals, Manufacturing Technology*, **59**, 573-576.