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Surface integrity functional analysis in hard turning AISI 8620 case hardened steel through 3D topographical measurement

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ABSTRACT

Purpose: This work aims investigate the resulting machined surface condition from hard turning process of mechanical components manufactured from case hardened steel.

Design/methodology/approach: The surface was examined by parameters obtained from the three-dimensional surface topography obtained with an interferometric laser instrument.

Findings: The selected roughness parameters analysis intends to have a functional characterization such as bearing capacity, fluid and lubricants retention ability and contact wear resistance.

Research limitations/implications: The obtained results were validated against similar ones, showing that the employed measuring techniques and analyses were correctly conducted.

Practical implications: The functional bearing area curve analysis parameters indicates that the resulting surface has a good area contact, good bearing capacity and reasonable ability to fluid retention as the reduced valley depth parameter Svk not produced higher values for all conditions tested.

Originality/value: The obtained results in the surface roughness measurement shows consistency with other authors results, and it shows that the technique of hardened material turning is capable of producing surfaces with functionality and quality.

Keywords: Machining; Hard turning; 3D topography; Roughness; Case hardening; AISI 8620; Surface integrity

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MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

In a machining process event, some expected characteristics are to be present at the final resulting surface. Surfaces generation engineering is not limited to a numeric value allocation to parts surface conditions. Identify and assign functional values that will influence performance when the part is at work condition is the main goal of surface engineering.

Surface performance has become an important criterion and has different meanings depending on the context but is mostly linked to fatigue, corrosion, wear and strength. It is usually assumed that performance is directly related to surface texture [1].

Stout et al [2] described the analysis of surface based on three-dimensional (3-D) measurements as more realistic and effective approach to understanding surface phenomena. A two dimensional (2-D) profilometric measurement presents the surface roughness on a single plan, it is effective where the surface is uniform and its patterns are perpendicular to the measurement plane. This assumption often creates doubts, due to the fact that in real machining process there are many parameters that can cause distortions at the surface's final condition.

The 2-D profilometric measurement is useful, as a method of acquiring data in a faster way [3], in this case the surface behaviour have to be already known, and the error by the profile generalization for all the rest of the surface does not affect the component performance.

Waikar and Guo [4] performed a detailed study about surfaces characterization of machined parts by the hard turning process, which highlighted the limitations of using the 2-D profilometer measurement.

The aim of this work is to present the roughness parameters obtained by measuring the 3-D topography resulting from the hard turning of mechanical components made of AISI 8620 steel, case hardened with 700 HV (58-62 HRC) and 1.0 mm case depth.

2. Experimental details

2.1. Roughness parameters

The functional characterization obtained, such as loading capacity and fluid retaining ability were analyzed using parameters based on the Abbot-Firestone Bearing Area Curve [3], obtained by the surface 3-D mapping with a Laser Interferometric equipment. Basic parameters used by many researchers [2] were also raised, which are the Arithmetic Mean Roughness (Sa) parameter and the Root-Mean-Square Roughness (Sq), both have strong correlation [4], but despite their lack of functional significance they have a general use, showing only statistical significance.

In addition to these parameters, were raised the topography skewness roughness (Ssk) value, defined as the deviations asymmetry from the average surface on the plan and the topography kurtosis roughness (Sku) which measure thinning or flattening degree of the peak heights distribution.

Table 1 presents the parameters descriptions and its reference values, when available, adopted in this work.

Table 1.
Parameter functional reference [3]

	Parameter Description	Functional Reference
Sa [μm]	Arithmetic mean roughness	-
Sq [μm]	Root-mean-square roughness	-
Ssk	Topography skewness roughness	Value < 0
Sku	Topography kurtosis roughness	Value > 3
Spk [μm]	Reduced peak height roughness	Lower values
Sk [μm]	Core roughness depth	Lower values
Svk [μm]	Reduced valley height roughness	Higher values

Several researchers [1-7], among others, discussed surface functional performance, Table 2 shows functions that are attributed to the roughness parameters and can be related to the component's surface performance.

Table 2.
Functional characterization [2]

	Ssk, Sku	Spk, Sk, Svk
Characteristic →	Distribution form	Functional
Function ↓	●	●
Bearings	●	●
Sealing	●	●
Friction	●	●
Joint stiffness	●	●
Slideways	●	●
Wear	●	●
Bonding	●	●
Painting	◗	●
Forming and drawing	◗	●
Fatigue	◗	●
Stress and Fracture	○	●
Reflectivity	○	●
Hygiene	◗	●
Key	● : Much evidence	
	◗: Some evidence	
	○ : Less evidence	

2.2. Tools and procedures

Investigations on 36 specimens made of case hardened steel DIN 21 NiCrMo 2 (AISI 8620) were conducted, with hardness 700HV (58-62HRC) and 1.0 mm average case depth.

The cBN insert was a TNGX110308S-WZ, 50% cBN content, tip radius 0.8 mm, wiper geometry. Insert tool holding: CTJNL2525M11 with tool angles: position angle = 93º, cutting edge inclination angle = - 6 º, rake angle = - 6 º.

The machine was a universal CNC Turning INDEX MC400, 20 kW, all the tests were conducted without cutting fluids.

Table 3 presents the cutting conditions for Cutting Speed Vc in m/min, Feed rate f in mm/rev and Constant depth of cut in millimeters.

Table 3.
Cutting conditions

	Vc [m/min]	f [mm/rev]	depth of cut [mm]
Condition 1	180	0.05	0.18
Condition 2	180	0.08	0.18
Condition 3	180	0.12	0.18
Condition 4	200	0.05	0.18
Condition 5	200	0.08	0.18
Condition 6	200	0.12	0.18

For each change in the pair Vc and f, the insert cutting edge was exchanged, so the tool wear was neglected for all tests.

For 3-D surface topography data acquisition an interferometric laser Microfocus Expert IV of UBM Corporation was used, the topographies data were treated and analyzed with the software Mountains Map Universal (version 3) from Digital Surf Company.

3. Experimental results

3.1. Surface topography characterization

The mapped 3-D topographies tests conditions are shown in Figures 1 and 2. The 3-D area mapping shows a common anisotropic surface from turning process, due to the single cutting edge feature of turning process, the surface is composed of well-defined peaks and valleys.

Figure 1 presents samples topographies machined with cutting speed Vc=180 m/min, all the samples machined with this condition presented similar results.

Figure 2 presents samples topographies machined with cutting speed Vc=200 m/min, all the samples machined with this condition presented similar results.

3.2. Surface roughness

Table 4 presents the average measured values for each roughness parameter selected to be analyzed and discussed in this work. It is important to observe that some roughness parameters showed higher deviations from the mean (Ssk can be taken as an example), demanding some attention to be taken in the final functional analysis.

Intending to have a better visualization of each cutting parameter influence on the roughness results, the results were plotted as response surfaces. The interpolation method applied was the Akima's method [7]. Also, along at each plotted surface, was indicated as black dots each average value and standard deviation used.

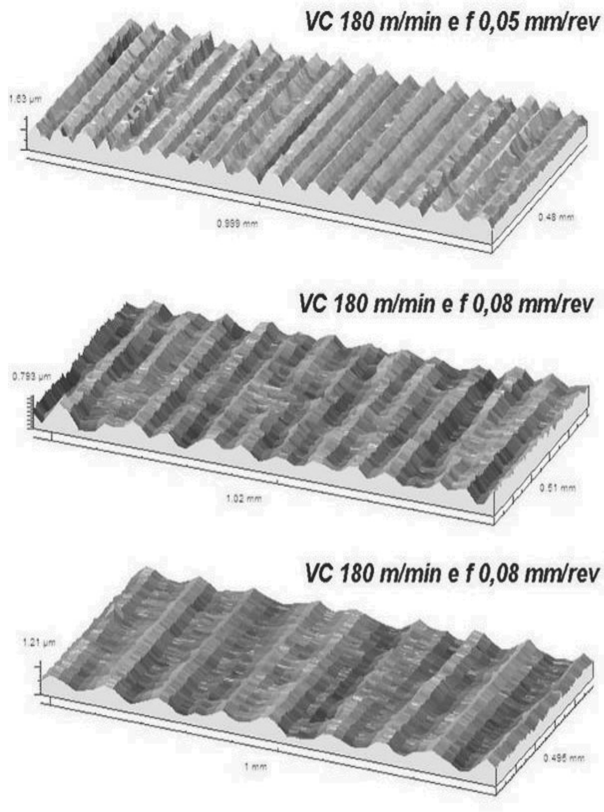

Fig. 1. Machined surface topographies with Vc=180 m/min

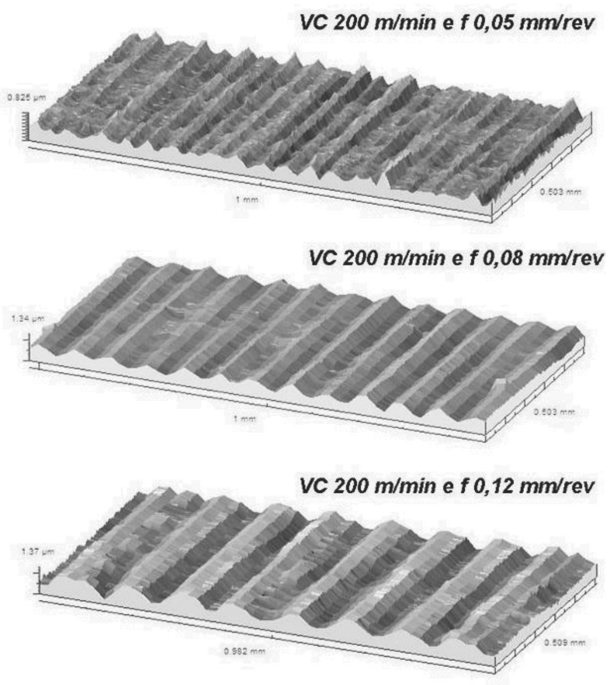

Fig. 2. Machined topographies with Vc=200 m/min

Table 4.
Average roughness values

		Vc 180 [m/min]	
	f 0.05 [mm/rev]	f 0.08 [mm/rev]	f 0.12 [mm/rev]
Sa [μm]	0.088	0.198	0.158
Sq [μm]	0.110	0.243	0.193
Ssk	-0.097	-0.133	0.131
Sku	3.057	3.013	2.652
Spk [μm]	0.094	0.179	0.151
Sk [μm]	0.286	0.655	0.523
Svk [μm]	0.109	0.216	0.148
		Vc 200 [m/min]	
	f 0.05 [mm/rev]	f 0.08 [mm/rev]	f 0.12 [mm/rev]
Sa [μm]	0.095	0.193	0.219
Sq [μm]	0.121	0.225	0.268
Ssk	0.151	-0.070	0.026
Sku	3.635	2.373	2.853
Spk [μm]	0.138	0.128	0.242
Sk [μm]	0.300	0.662	0.748
Svk [μm]	0.116	0.157	0.206

Figure 3 and Figure 4 shows the arithmetic mean (Sa) and root-mean-square (Sq) roughness values, obtained from each pair Vc and f used in the experiment.

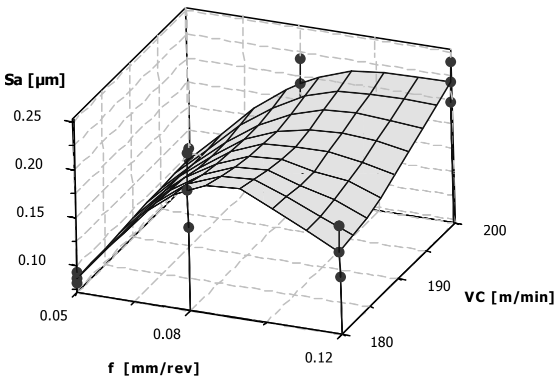

Fig. 3. Arithmetic mean roughness

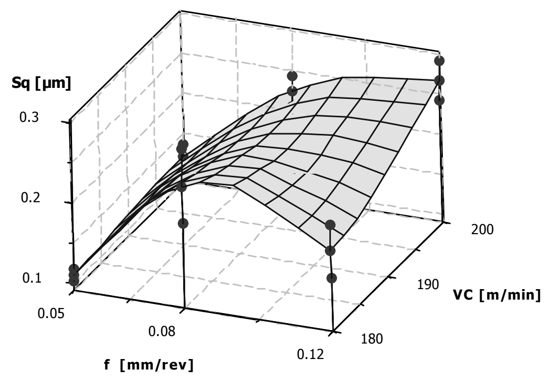

Fig. 4. Root-mean-square roughness

Figures 5 and 6 presents the topographies kurtosis roughness (Sku) and topographies skewness roughness (Ssk) obtained from each pair Vc and f employed in the experiments.

Figure 7 presents the bearing area curve parameter Reduced peak height roughness (Spk), obtained from each pair Vc and f employed in the experiment.

Figures 8 and 9 presents the bearing area curve parameters Core roughness depth (Sk) and Reduced valley height roughness (Svk), obtained from each pair Vc and f employed in the experiment.

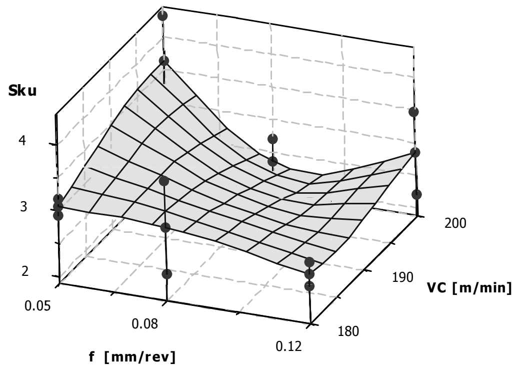

Fig. 5. Topography kurtosis roughness

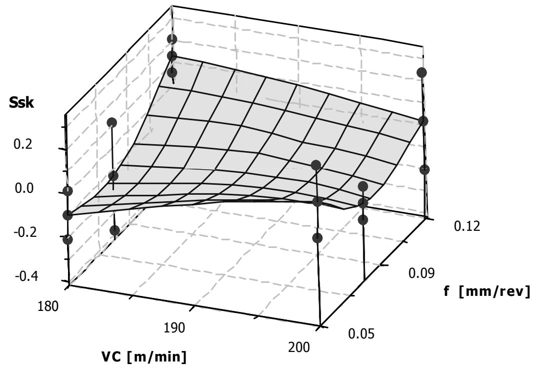

Fig. 6. Topography skewness roughness

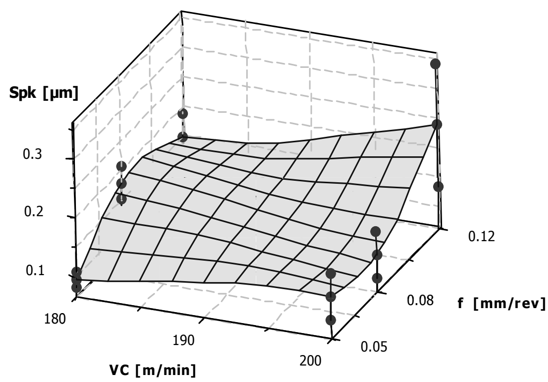

Fig. 7. Reduced peak height roughness

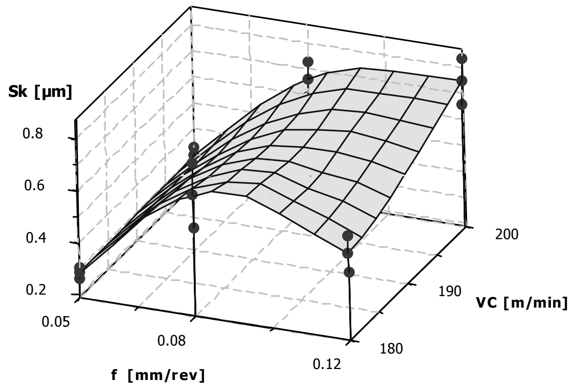

Fig. 8. Core roughness depth

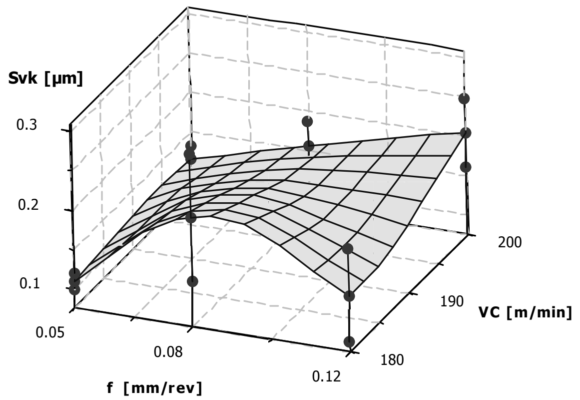

Fig. 9. Reduced valley height roughness

4. Discussion

Observing the response surface graphics it is noted that, for this research, the cutting parameter Feed rate (f in mm/rev) had the major influence on the roughness parameters. In order to validate the results, were compared the found roughness values to others authors similar conditions results (including Ground [4] and Super-Finish [6] process conditions). Tables 5 and 6 present comparisons considering the average between the two cutting speeds conditions (Vc in m/min) tested.

Table 5.
Results comparisons adapted from Waikar and Guo [4]

	Waikar e Guo [4]		This work		
Parameter	Hard Tuning	Ground	f=0.05 mm/rev	f=0.08 mm/rev	f=0.12 mm/rev
Sa [µm]	0.229	0.158	0.090	0.190	0.190
Sq [µm]	0.280	0.196	0.120	0.230	0.230
Ssk	0.530	-0.127	0	-0.100	0.090
Sku	2.880	2.790	3.400	2.700	2.800

Table 6.
Results comparisons adapted from Grzesik et al [6]

	Grzesik et al [6]		This work		
Parameter	Hard Turning	Hard Turn + Super Finishing	f=0.05 mm/rev	f=0.08 mm/rev	f=0.12 mm/rev
Spk [µm]	0.78	0.25	0.12	0.16	0.24
Sk [µm]	0.60	0.29	0.29	0.66	0.65
Svk [µm]	0.19	0.26	0.12	0.19	0.18

5. Conclusions

The surface integrity of mechanical case hardened material components, machined with hard turning process was analyzed and the main conclusions were listed below:

- The surface roughness measurement obtained results shows that, the hard turning technique is capable of producing surfaces with functionality and quality.
- The functional bearing area curve analysis parameters indicates that the resulting surface has a good area contact, good bearing capacity and reasonable ability to fluid retention as the reduced valley depth parameter Svk not produced higher values for all conditions tested.
- The topography skewness roughness did not presents negative values for all the conditions tested; therefore its functional characteristics can't be assigned to the surfaces.
- Due to the single cutting edge feature of turning process, the surface is composed of well-defined peaks and valleys; one can also observe in Figures 1 and 2 the feed influence on peaks/valleys numbers for the same mapped area.
- It is important to observe that some parameters presented wider standard deviation values (Skewness Ssk, Reduced peak height Spk and Reduced valley height Svk), therefore their functional values application must be carefully considered. Many parameters are more sensitive to surface conditions change, and as a result, a large dispersion in results is verified often causing ambiguity [8] in functional correlation results.
- The interaction of each cutting parameter influence on the roughness results is better viewed by plotting the response surfaces, along its averages and standard deviation values used.
- The obtained results were validated against similar ones, showing that the employed measuring techniques and analyses were correctly conducted.

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