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MULTI SCALE STUDY OF ABRASION SIGNATURE BY 2D WAVELET DECOMPOSITION

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Abstract
The high performance of industrial applications, requires increasingly technical functional surfaces, particulary from the point of view of topography and microtexture. To study the effect of abrasive finishing in a wide range of wavelengths of surface topography, we developed a multi-scale approach, based on the decomposition of surface topography by 2D continuous wavelet transform. This new approach made it possible to determine the multi-scale transfer function of machining by abrasion for each stage of finishing. The methodology can be extended to characterize abrasive wear in a wide range of scales.

Introduction

The use of hard turning as a finishing process is often limited by surface quality requirements in the case of component surfaces designed to support high stress. Low roughness can be achieved only at low feed rates. Moreover, tool wear leads to a deterioration in the surface after the tool has been in use for some time. A subsequent finishing operation can both increase the range of permissible feed rates towards higher values and prolong the life of the tool's cutting edge. One finishing operation whose working principle suits especially well for combination with hard turning is the belt grinding. This abrasive operation makes it possible to create surfaces of high quality, with specific functions like mechanical bearing pressure, sealing of metal joints, friction and noise of friction. Abrasive finishing modifies the surface topography in a wide range of scales of roughness and waviness, and consequently modifies the functionality of the surface in terms of bearing area, local plasticity and durability. This paper introduces a new approach based on a multi-scale decomposition of the surface topography before and after finishing by using a 2D continuous wavelet decomposition. This approach makes it possible to follow the effect of the various stages of finishing on a wide range of wavelengths, and makes it possible to determine the transfer function of the combination of hard turning and belt grinding.

Experimental procedure

The original steel surface was prepared by a hard turning operation, with a roughness parameter Ra of 0.9 µm. The belt grinding was carried out by calibrated silicon carbides abrasive grains whose size varied between 9 and 30 µm. The belt is applied to the rotating workpiece with a defined pressure and axial oscillation. During the abrasive tape motion, the abrasive grains undergo an oscillation of a frequency of 12 Hz in the direction perpendicular to that of the abrasive tape motion. The hard turned steel surface was finished with a double belt grinding, using a grain size of 30 µm for the first finishing and 9 µm for the second finishing. The surface topography at different stages of finishing was measured by a three dimensional white light interferometer.
The continuous wavelet transform can be interpreted as a multi-channel filter system. The surface topography components passe through a filter bank which is a set of the contracting wavelets. The number of wavelets corresponds to the number of iterations, because the wavelet is a function of contracting coefficient "a". The various scales of the decomposition can be presented in a cube like a stacking of images treated on a hierarchical basis of scales. This approach makes it possible to follow the effect of the various stages of finishing on a wide range of wavelengths, and makes it possible to determine the transfer function of the combination of hard turning and belt grinding.

In order to quantify the manufacturing effect on all the full range of wavelengths, from roughness to waviness, without any low pass filtering, we adopted the decomposition by continuous wavelet transform, to analyze the quality of surface finishing in a wide range of scales [1]. The methodology consists of the extraction of each scale by inverse wavelet transform, and then quantifying the arithmetic mean values for each scale : Ma.

The objective is to determine the spectrum of arithmetic mean values from the scales of waviness to roughness:

$$Ma(a) = \sum_{x=1}^{M}\sum_{y=1}^{N}\frac{\left|W_a^{*f}(x,y)\right|}{MN}$$

The example of figure 1 shows a multi scale decomposition of hard turned surface and the determination of the Ma(a) spectrum.

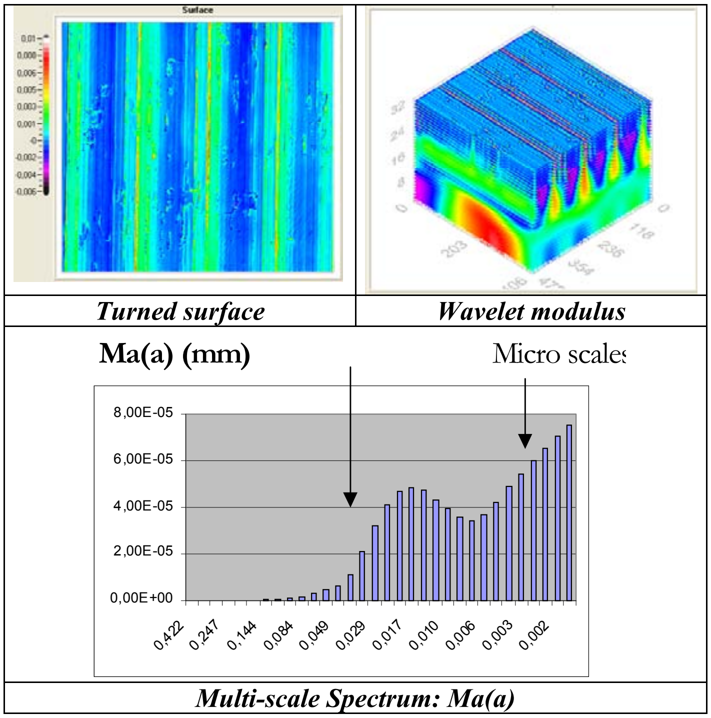
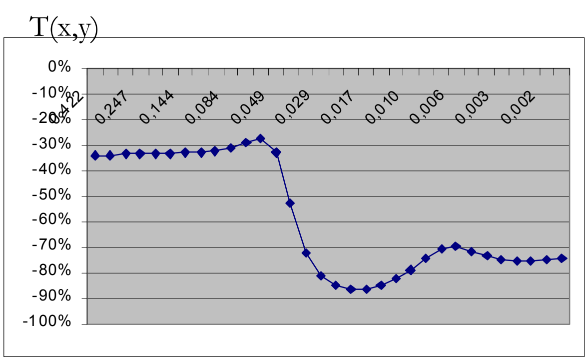
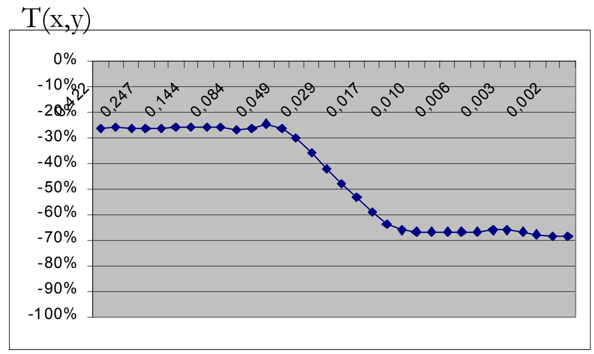


Fig.1. Wavelet modulus and Ma spectrum of hard turning

The use of the multi scale decomposition by wavelet transform allows the determination of the transfer function T(x,y) at each scale, by determining the ratio of Ma(a) spectrum between the belt grinding surface and the initial surface. As presented in figure 2, this computed transfer function makes it possible to identify the effect of machining at any scale, and permits quantification of the quality of the surface finishing from waviness to roughness scales [2,3].



First melt grinding (grains diameter: 30 µm)



Double melt grinding

Fig.2 . Transfer function of belt grinding

Conclusions

To study the effect of abrasive finishing in a wide range of wavelengths of surface topography, we developed a multi-scale approach, based on the decomposition of surface topography by 2D continuous wavelet transform. This new approach made it possible to determine the multi-scale transfer function of machining by abrasion for each stage of finishing. The abrasive finishing modifies the surface topography in a wide range of scales of roughness and waviness, and consequently modifies the functionality of the surface in term of bearing area, local plasticity and durability. The methodology can be extended to characterize worn surfaces in a wide range of scales.

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