

# The impact of different measurement data filters on the characterization of porous surfaces

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Surfaces of components can hold many different functional characteristics, which are strongly influenced by the surface micro-structure. When characterizing the microstructure the data is separated according to scale. In this paper the influence of two different data filters, the Gaussian filter and the wavelet transformation, on the characterization of the surfaces porosity is investigated.

## 1 Introduction

The surface of components can hold many different functional characteristics. These are strongly influenced by the surface texture, especially by the microstructure. That is to say, specifically functional micro-structuring can minimize e.g. friction or wear and, therefore, can increase the endurance of components [1]. In order to meet certain functional requests and thus the design of certain surface microstructures, an exact knowledge of the surface topography is required. In this work the porosity of thermally sprayed porous aluminum oxide surfaces is analyzed.

## 2 Background

The topography of a surface can be represented by a superposition of structures with different scales. It is distinguished between form, form deviation, waviness, roughness and noise [2]. To characterize the surface microstructure, the surface data firstly needs to be separated by size to obtain the so called scale limited surfaces. According to the international standard DIN ISO 25178 this is done by a F-operator, S-filter and optionally by a L-filter. The F-operator removes the nominal form, the S-filter removes small deviations and the L-filter removes large scale elements. The conventional approach is using the total least square (TLS) fit and the Gaussian filtering [1, 3]. However, these methods can hold some drawbacks why in this work the use of the wavelet transformation is compared to the conventional approach to decompose the surface data. To be investigated is the impact of the two different filtering methods on the characterization of the porosity.

## 3 Methods

The applied methods are subdivided into methods for the F-operator and methods for the S- and L-filter. The TLS fit is used to remove the form, the Gaussian filter as an S- and L-filter. On the contrary the wavelet transformation can be applied for any of

the operations. Further information on these methods and how they are used in surface metrology can be found in [1].

When filtering, appropriate filter parameters need to be chosen. This is done according to the lateral resolution of the surface data and the size of the to be characterized microstructures [2]. To be comparable the Gaussian filter size is further adjusted to the pseudo-frequency of the chosen decomposition level of the wavelet transform according to the following equation [4]:

$$F_a = \frac{F_c}{2^J \cdot \Delta_{x,y}},$$

with  $F_a$  being the pseudo-frequency,  $F_c$  the center-frequency of the mother wavelet waveform,  $J$  the decomposition level and  $\Delta_{x,y}$  the lateral resolution of the measurement system. The here chosen filter sizes can be found in Tab. 1.

	Wavelet	Gaussian
S-Filter	level 1	$\lambda_s = 0,72 \mu\text{m}$
L-Filter	level 10	$\lambda_l = 371,78 \mu\text{m}$

**Tab. 1** Decomposition level of the wavelet transformation and equivalent cutoff frequency of the Gaussian filter

## 4 Measurement Data

The porous surfaces under investigation are  $Al_2O_3$  surfaces manufactured by a thermally spraying process and subsequently polished. Evaluated is the porosity based on the surface height information obtained by a confocal laser scanning microscope Keyence VK-X210 with a 50x magnifying objective and a NA of 0,95. The obtained lateral resolution is  $0,277 \mu\text{m}$  and the vertical resolution is  $0,1 \text{ nm}$ . For simulation purposes artificial surfaces with defined size, height and distribution of pores are generated.

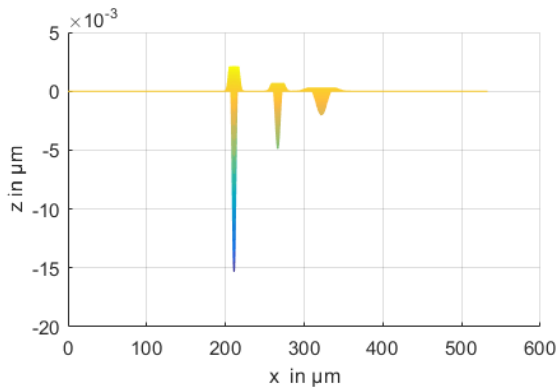
## 5 Results

The different filtering techniques are separately compared based on the simulation data and the

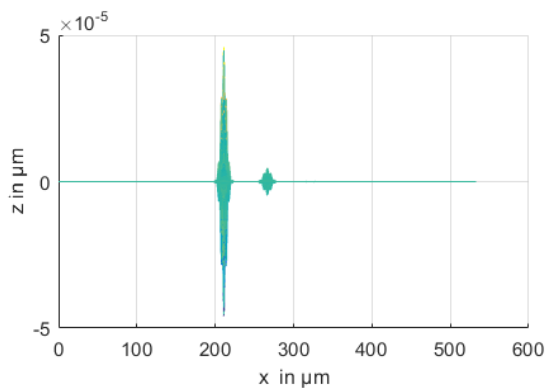
measured  $Al_2O_3$  surfaces.

### 5.1 Simulation

The results of the filtered simulation data show that the Gaussian filter has a higher influence on the microstructures than the wavelet decomposition. For the S-filter (low-pass filter) the Gaussian filter smooths the edges, which results in an enlargement of the size and a reduction of the depth of the pores, see Fig. 1. The deviation of the original surface image and the wavelet filtered image is much smaller compared to the Gaussian filtered image, see Fig. 2.



**Fig. 1** Lateral view of the difference image of the original and the Gaussian S-filtered image



**Fig. 2** Lateral view of the difference image of the original and the wavelet S-filtered image

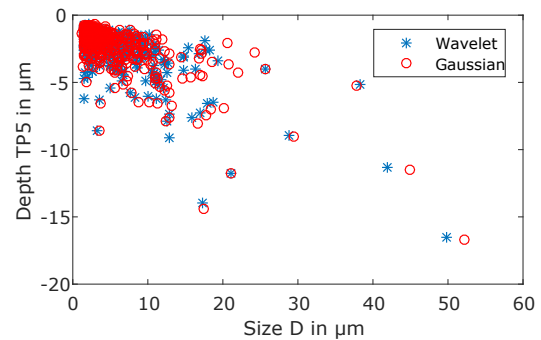
For the L-filter (high-pass filter) the effect is inverted and due to a bigger filter size stronger. Results of the evaluated pore parameters, the Heywood diameter (D) and the 5 % depth ( $T_{P5}$ ) of the scale limited surface gained by S- and L-filtering with both approaches can be seen in Tab. 2.

	Original	Wavelet	Gaussian
D	50,70 $\mu\text{m}$	88,06 %	93,35 %
$T_{P5}$	7,32 $\mu\text{m}$	103,00 %	102,00 %

**Tab. 2** Evaluated Heywood diameter and 5% depth after S- and L-filtering by Gaussian and wavelet filtering

### 5.2 Aluminum Oxide Surface

Due to the data size of the measured  $Al_2O_3$  surfaces only the impact of the S-filter is investigated. It is to be seen, that the deviation of the pores' depth and size differ with the two different approaches. For small pores the difference is hard to tell, however, for larger pores the evaluated size is larger for the Gaussian filtered surfaces than for the wavelet filtered surfaces, see Fig. 3.



**Fig. 3** Size and depth distribution of the pores after the Gaussian and wavelet filtering

## 6 Conclusion

The wavelet transformation holds various advantages compared to the Gaussian filter and the TLS fit. Not only is it faster and has a smaller impact on the microstructures, but for the form removal, here not further discussed, the form does not need to be known compared to the TLS fitting prior.

## 7 Acknowledgment

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