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DESIGNING THE NEW LOCAL DEFECT DIGITAL FILTER FOR THE SURFACE ROUGHNESS MEASUREMENT SYSTEMS

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Paper describes the new adaptive digital filtration algorithm for removing the local defects on the measured surface roughness profiles. The benefits of the proposed filtration algorithm in comparison with traditional Gaussian filter are shown.

1. Introduction

Surface geometry analysis is widely used in modern mechanical engineering and design for the assessment of the operational characteristics of the machine components and structures such as wear resistance, contact stiffness, corrosion resistance, impermeability etc. When analyzing the surface layer processes, which is comparative to initial surface roughness, it is strictly necessary to understand the processes of asperity forming, strengthening, and interacting taking into account all the complex surface geometry.

One of the major problems that arise during the surface geometry analysis is the separation of roughness, waviness and form from the measured surface profile [1]. The urgent need of reliable separation procedure is caused by the overlapped ranges of modern surface geometry measuring devices. For example, typical stylus profilometer is capable of measuring surface roughness, waviness and form, modern roundness machines are capable of measuring both surface form and waviness.

The Gaussian digital filter is the most common and recommended by international and many national surface geometry standards include ISO 11562:1996. High-pass Gaussian filter is used for the separation of surface roughness. Low pass Gaussian filter is used for the separation of surface waviness. But it has several well-known disadvantages.

First of all Gaussian filter produces significant surface distortion near the surface profile begin and end (boundary effects). For the boundary effect compensation the significant portions of the surface profile (about half of surface roughness base length) should be eliminated from analysis after the Gaussian filtration.

The second well known disadvantage of Gaussian filter is inability to filter relatively large surface form effects (for example surface cylindricity). That is why the additional form filters should be used in combination with Gaussian filter.

The third well known disadvantage is the poor efficiency dealing with local defects on the surface profile. For example the single surface scratch does not reflect the common surface characteristics. But it's significant relic still remains in the surface profile after Gaussian filtering.

The Gaussian regression filter allows to minimize first two disadvantages [2]. Well known double filtration method [3] do not remove local defect and only corrects the mean line position. Morphological filters [4] can deal with local anomalies on the measured

surface profile. But they are very complicated and slow and can hardly be used in built-in electronic modules.

Present article introduces the new digital filtration algorithm for removing the local defects on the measured surface profiles. The benefits of the proposed filtration algorithm in comparison with traditional Gaussian filter are shown. The proposed digital filter can be easily combined with Gaussian filter for removing both local defects and surface waviness.

2. Filtration algorithm

The proposed new algorithm for filtration of the local defects on the measured surface profile has two adjustable parameters shown in Figure 1. First adjustable parameter is the filter sensitivity *Ara* to the *Ra* surface roughness parameter (arithmetically average profile roughness height within the base length). Filter recognizes the local defect if it produces the local *Ra* deviation exceeding the *Ara* value. The valid *Ara* values are 1.5 and more. Second adjustable parameter is the filter sensitivity *Asm* to the *Rsm* surface roughness parameter (arithmetically average horizontal profile roughness step within the base length). According to *Asm* value the critical local defect width is specified. The valid *Asm* values are 0.5 and less.

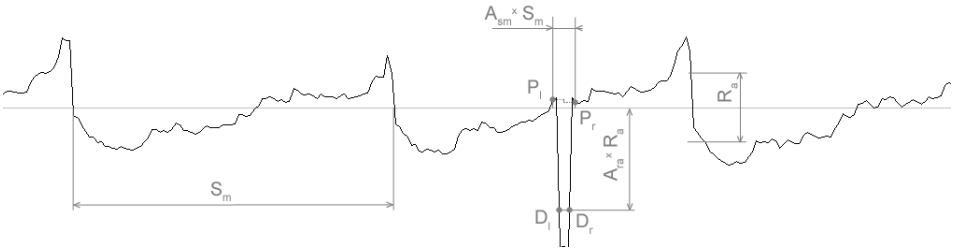


Figure 1: Profile parameters involved in the local defect filtering algorithm

Filtration algorithm includes four main steps. The first step of algorithm is the local defect detection. The line for detecting the local defects is constructed according to local *Ra* parameter value and *Ara* value specified. The Y_i profile nodes are marked belonging to the local defect if:

$$|Y_i| \geq A_{ra} \cdot R_a . \tag{1}$$

The second step of algorithm is the local defect boundary definition. The boundary nodes of local defect D_l and D_r are determined on this algorithm step. The third step of the algorithm is the profile smoothing zone definition. At this step the boundary nodes of the profile smoothing zone are determined according to following procedure:

$$P_l = D_l - N_{ld}\,, \quad P_r = D_r + N_{ld}\,, \quad N_{ld} = \frac{1}{2}\left(A_{sm} \cdot S_m - \left(D_r - D_l\right)\right). \tag{2}$$

The last fourth step of algorithm is the profile smoothing. At this step the measured profile values in the determined profile smoothing zone $(P_l ; P_r)$ are substituted by the

smooth linear distribution values. The smooth line is drawing from the left boundary node Y_{P_l} to the right boundary node Y_{P_r} of the removed local defect.

3. Analysis of the filter capabilities

Two different surface roughness profiles were used to investigate the main advantages of the proposed local defect filter. The first is profile is a simulated surface roughness profile which is combined of 5equal size half-ellipsoid roughness elements (Figure 2). The second profile is the real technological surface roughness profile for the surface after polishing (Figure 3).

The single local scratch of significant height and very small width was added to the source surface roughness profiles as shown in Figure 2. b), Figure 3. b). This local defect significantly changes the resulting values of the roughness parameters as shown in Table 1 and Table 2. For example the Ra parameter value was changed by 2.6% for smooth simulated profile and by 12.7% for polished profile. An extremal surface roughness parameter Rmax was changed even more significantly. It's value was changed by 74% for simulated surface profile and 103% for polished surface profile.

Table 1

Comparison of Gaussian filter and Local defect filter for ellipsoid profile

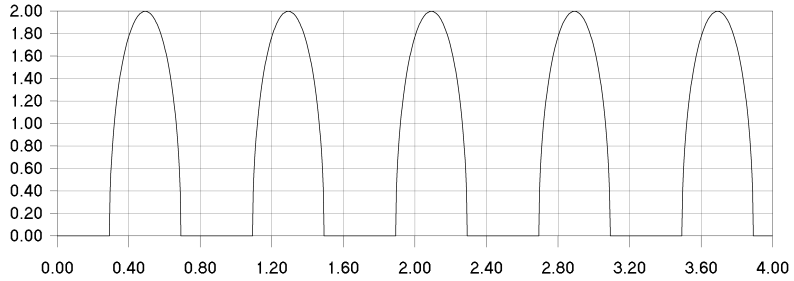
Roughness parameter	**Parameter value**				
	Source profile	**Local defect added**	**Difference from source profile**	**Local defect-filtered**	**Difference from source profile**
	Without gauss filtering				
Ra (um)	0.8057	0.8263	2.56%	0.8057	0
Rmax (um)	2.0000	3.4876	74.4%	2.0000	0
	Combined with gauss filtering				
Ra (um)	0.8018	0.8222	2.54%	0.8017	0,01%
Rmax (um)	1.996	2.6332	31.92%	1.996	0

Table 2

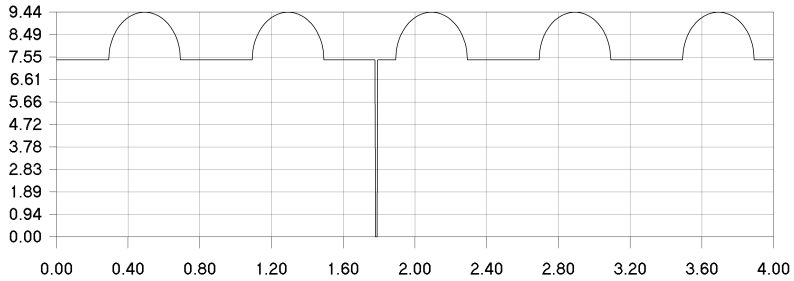
Comparison of Gaussian filter and Local defect filter for polished profile

Roughness parameter	**Parameter value**				
	Source profile	**Local defect added**	**Difference from source profile**	**Local defect-filtered**	**Difference from source profile**
	Without gauss filtering				
Ra (um)	0.1288	0.1452	12.73%	0.1285	0.23%
Rmax (um)	0.9187	1.8640	102.9%	0.9187	0
	Combined with gauss filtering				
Ra (um)	0.1242	0.1352	8,86%	0.1239	0.24%
Rmax (um)	0.9040	1.8030	99,45%	0.9040	0

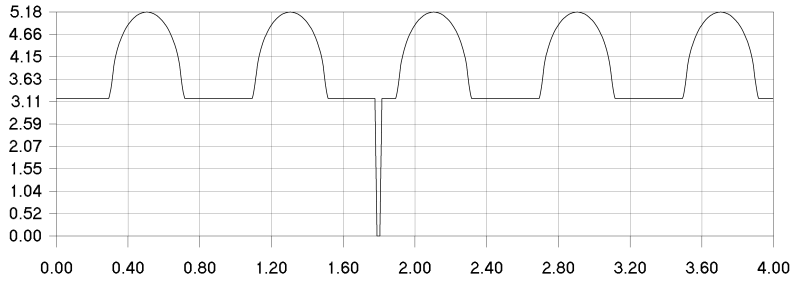
Only part of local defect was removed after implying the traditional Gaussian filter and the significant trail of the scratch remained as shown in Figure 2. c) and Figure 3. c). Roughness parameter Ra still changed by 2.5% and 8.9% respectively. Roughness parameter Rmax changed by 31.9% and 99.5% respectively. Local defect was almost fully removed by implying the proposed local defect filter as shown in Figure 2. d) and Figure 3. d).



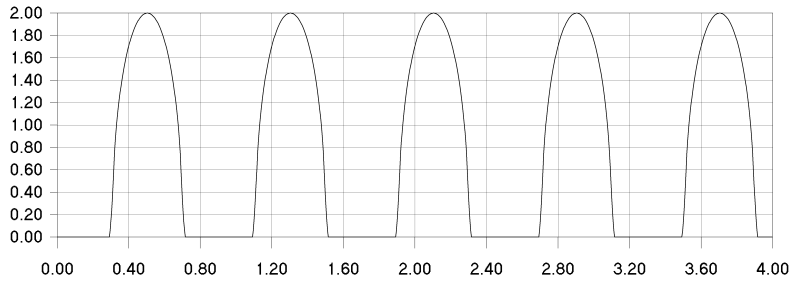
a) source profile



b) single scratch on source profile

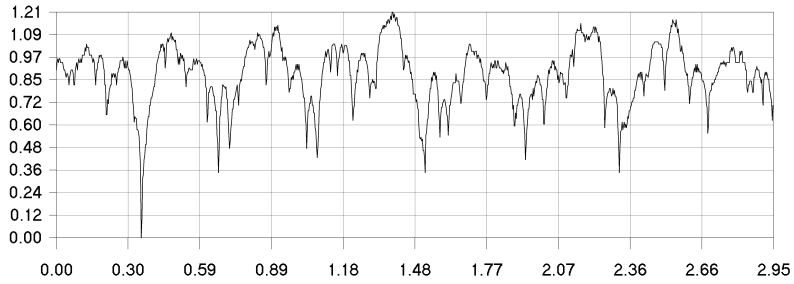


c) local defect remnants after Gaussian filtering

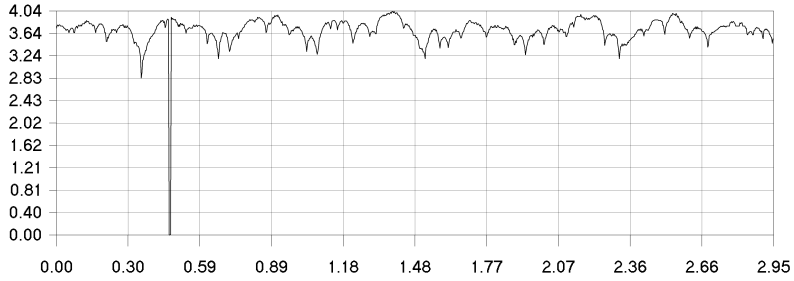


d) local defect removed by proposed filter

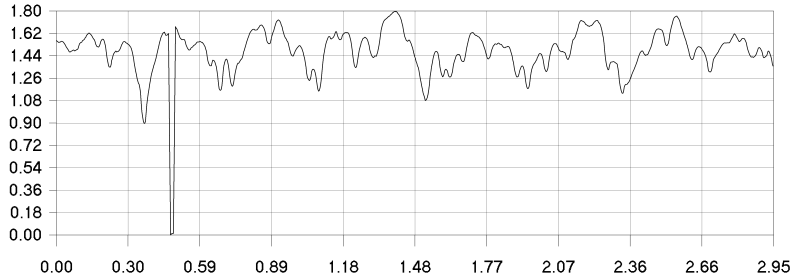
Figure 2: Filtration of single scratch on ellipsoid surface



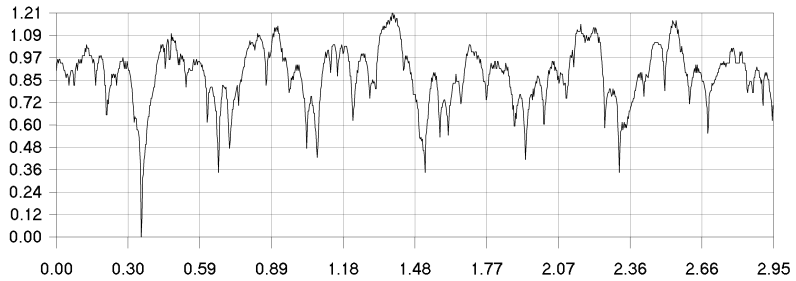
a) source profile



b) single scratch on source profile



c) local defect remnants after Gaussian filtering



d) local defect removed by proposed filter

Figure 3: Filtration of single scratch on polished surface

4. Conclusion

Proposed digital filter has the advantage over the traditional digital Gaussian filter in processing surface profiles having local defects that does not characterize the surface roughness geometry. But the implementation of local defect filter does not discard the necessity of using Gaussian filter. The Gaussian filter is still needed for removing some surface slope and nano-roughness effects. The proposed filter should be used in combination with traditional Gaussian filter. Combination of the proposed digital filter with Gaussian filter can ensure the adequacy of the resulting surface roughness parameters.

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