14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

FUNCTION ON GAUSSIAN AND 2RC FILTERS TO DETERMINE THE ROUGHNESS PROFILE IN REAL NON-PERIODIC AND PERIODIC SURFACES

Mite Tomov, Mikolaj Kuzinovski
"Ss. Cyril and Methodius" University in Skopje,
Faculty of Mechanical Engineering, Karpoš II. bb,
P.BOX 464, 1000 Skopje, Macedonia

Neven Trajčevski
Military Academy - Skopje,
Macedonia

ABSTRACT
Represented and simulated the function of Gaussian and 2RC filter in determining the roughness profile of the primary profile obtained by measuring the real non-periodic and periodic surfaces. The metrological characteristics are noticed on both filters. To indicate differences between roughness profiles obtained using the Gaussian filter and roughness profiles obtained using the 2RC filter. Imperfection and limitations of Gaussian filter and possible influences to determine of roughness profile for non-periodic and periodic surfaces are analyzed. Emphasized is the phase distortion of filter mean line obtained using 2RC filter and its possible influences to determine of roughness profile for measured surfaces.
Keywords: Gaussian filter, 2RC filter, Filtration, Periodic surface, Non-periodic surface.

1. INTRODUCTION
Surface review on macro plan provides determination of deviations from desired form and dimensions. Surface waviness can be gained by review of surface on medium plan, while as roughness on micro plan. Review of geometric structure of surface of a surface layer as deviation from form, waviness and roughness is widely accepted and standardized [1,2,3,4,5]. Separation of roughness, waviness and form from measured total profile is provided by means of a filtration process. Two filtration methods are developed, known as E filtration system and M filtration system [2]. Implemented and defined are three types of profile filters λ_s, λ_c and λ_f. Procedure for obtaining roughness and waviness profiles and sequence of application of profile filters is standardized in ISO 4287:1997[5]. It should be underlined that the American national standard ASME B46.1 -2002 [3] does not define filter λ_f, i.e. it is considered that length at which roughness profile is determined is small in order to determine its form, as well.

2. METROLOGY CHARACTERISTICS OF GAUSSIAN AND 2RC FILTERS

2.1. 2RC filter
Basic metrology characteristics of digital high-pass 2RC profile filter are weighting function and transfer characteristic, standardized in ASME B46.1 -2002 [3]. In [3] are given graphic interpretations of weighting function and transfer characteristic. Nowadays, 2RC profile filter is discarded from International ISO standards. Weighting function of 2RC filter is given with [3]:

$$S(x) = \frac{A}{\lambda_c}\left(2 - A\frac{|x|}{\lambda_c}\right)\exp\left(-A\frac{|x|}{\lambda_c}\right) \qquad \ldots(1)$$

where A=3,64 for 75 % transmission at λ_c, x is the position in millimeters from the origin of the weighting function $(-\infty < x < 0)$, and λ_c is the long wavelength roughness cut-off. Roughness profile could be gained by subtracted of filter mean line from primary profile. 2RC filter mean line is gained by convolving the primary profile with weighing function given in equation (1). Weighting function is generated in interval $-2\lambda_c \leq x \leq 0$, since a nonsymmetrical filter is in question in terms of the start of profile filter. Then, filter mean line of primary profile determined by using 2RC filter does not represent the waviness profile [1,2]. Its non-linear phase as a result of which a phase distortion of filter mean line in terms of primary profile occurs is the most mentioned disadvantage of 2RC filter. Sensitivity of 2RC filter on deep valleys of primary profile causes pulled down of filter mean line from mean portion of profile towards the valley. Distortions of filter mean line towards ends of primary profile are also characteristics that could be considered as 2RC filter disadvantage. Due to this occurrence shortening of part of primary profile is practiced in length of $2\lambda_c$ from its start [1,2], which contributes to inapplicability of 2RC filter when measuring very short profiles.

2.2. Gaussian filter

Incomparably, nowadays most commonly used profile filter in surface metrology is the phase-correct Gaussian filter with metrology characteristics standardized in ISO 11562:1996 [6] and ASME B46.1 -2002 [3]. In [3,6] are given graphic interpretations of weighting function and transfer characteristic. Weighting function of Gaussian filter is given with [3,6]:

$$S(x) = \frac{1}{\alpha\lambda_c}\exp\left[-\pi\left(\frac{x}{\alpha\lambda_c}\right)^2\right] \qquad \ldots(2)$$

where $\alpha = \sqrt{\ln 2/\pi} = 0.4697$, x is the position from the origin of the weighting function and λ_c is the long-wavelength roughness cut-off. Roughness profile is gained as a difference between primary profile and filter mean line determined with Gaussian profile filter. Against ASME B46.1 -2002 [3] filter mean line, determined with Gaussian profile filter, presents the waviness profile. Gaussian filter has a linear phase and does not cause phase distortion of filter mean line in terms of primary profile and therefore is mostly called phase-correct profile filter. Filter mean line determined with Gaussian filter has distortion on profile ends as a result of the openness of primary profile which is not the case when it is applied on closed profiles. The effect of this deviation of Gaussian filter mean line is removed by shortening roughness profile in terms of primary profile for one length of λ_c, i.e. per one half of λ_c on both profile ends. Shortening parts of roughness profile in value of one λ_c makes Gaussian filter inapplicable when measuring very short profiles, which could be considered as its disadvantage. Sensitivity to deep valleys on primary profile results into pulled down of filter mean line from mean portion of primary profile towards the valley, and later on by creating a fictitious characteristic of roughness profile in valley proximity again another negative characteristic of Gaussian filter. For overcoming this disadvantage ISO 13565-1:1996 [7] foresees special filtration mode for primary profiles with deep valleys. It is significant to mention that standard ISO 13565-1:1996 [7] provides much freedom in application of this filtration mode.

3. DETERMINATION OF FILTER MEAN LINES AND ROUGHNESS PROFILES ON REAL ETALON SURFACES BY APPLICATION OF MATLAB (R2009B)

Usage of contact (stylus) profilometers, which have pick-up with skid provide obtaining primary profiles on which skid has already did mechanical filtration, wherein waviness and form profiles are removed from measured profile [8]. There of need is imposed for determining effects of disadvantage and limitations of Gaussian and 2RC filter on primary profiles gained by measuring real surfaces where waviness and form are not expressed. For the purpose real non-periodic and periodic etalon surfaces representatives of machining with grinding and turning are measured. Stylus profilometer Surtronic 3+ with pick-up TYPE 112-2672 (DCN 001) with stylus radius of 2 μm and skid radius of 8.7 mm is used for measurements on real surfaces. Coordinates of points on primary profiles are gained by means of software TalyProfile, Version 3.1.4. In these researches, software package Matlab (R2009b) is used for simulating filtration process by means of Gaussian and 2RC profile filters and obtaining profile mean lines and roughness profile. Weighting functions of Gaussian and 2RC filter provided with equations (1) and (2) are used for obtaining filter mean lines. Primary profiles, filter mean lines and roughness profiles gained from non-periodic and periodic real etalon surfaces are presented on Fig. 1,2,3 and 4.

4. ANALYSIS OF INFLUENCE OF PROFILE FILTER CHARACTERISTICS UPON GAINED ROUGHNESS PROFILES

These studies included non-periodic profiles (representatives of machining with grinding) and periodical profiles (representatives of machining with turning).Non-periodic primary profiles gained by measuring real etalon surfaces-representatives of machining with grinding with various values of Ra are presented on Fig. 1 and 2.

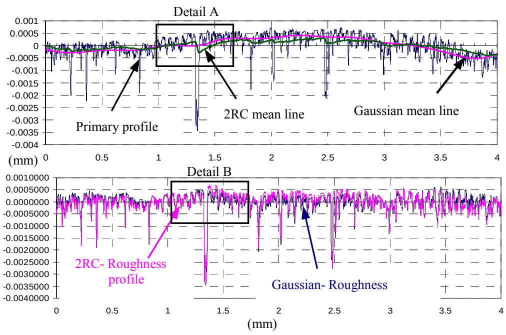

Fig. 1. Primary profile, filter mean lines and roughness profiles gained from non-periodic real surface-machining with grinding, with Ra=0.2 μm.

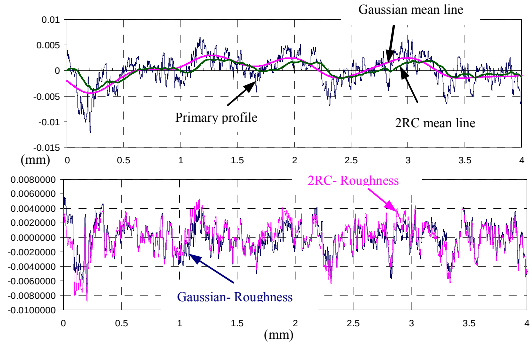

Fig. 1. Primary profile, filter mean lines and roughness profiles gained from non-periodic real surface-machining with grinding, with Ra=1.6 μm.

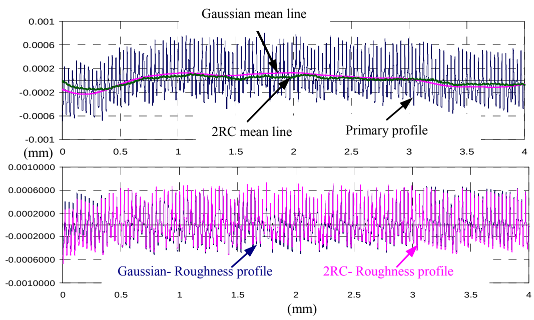

Fig. 2. Primary profile, filter mean lines and roughness profiles gained from periodic surface- machining with turning, with Ra=0.2 μm.

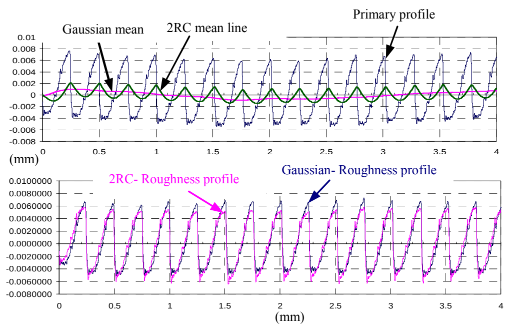

Fig. 2. Primary profile, filter mean lines and roughness profiles gained from periodic surface- machining with turning, with Ra=3.2 μm.

The fact that the form of these profiles is non-periodic against whole profile length permits to see and conclude that disadvantage of Gaussian and 2RC profile filters shall be differently expressed against profile length. Primary profile on Fig. 1 characterizes with small presence of waviness and expressed individual valleys. Due to waviness absence and the position at start and end of primary profile around zero value per z-axis, distortions of mean filter lines on profile ends shall not have much effect therefore shortening of roughness profile in terms of primary profile is not of significant importance. Here, the high sensitivity of 2RC profile filter on individual valleys of primary profile, detail A, Fig. 1, has to be underlined, which results in pulled down of filter mean line from mean portion of primary profile towards the valley. This pulled down of mean line later on cause's distortion of roughness profile in valley proximity and creation of fictitious characteristic of roughness profile, detail B Figure 1. Comparison of roughness profiles gained by Gaussian and 2RC profile filters indicates that there are segments of profiles wherein they overlap and segments wherein they differ. Expressed waviness per whole length of primary profile is present on profile presented on Fig. 2. In such case the effect of disadvantage of Gaussian and 2RC profile filters is obvious. Distortion at start of 2RC filter mean line is extremely expressed. Still, crucial role for discrepancy of roughness profiles against their whole length has the phase distortion of 2RC filter mean line. On Fig. 3 and 4 are presented primary profiles, filter mean lines determined with Gaussian and 2RC profile filter and roughness profiles for periodic surfaces, representatives of machining with turning with various values of Ra. From the form of gained filter mean lines could be seen that filter mean line gained with 2RC filter is more sensitive on valleys and peaks than the mean line gained with Gaussian profile filter. This is more expressed by increase of Ra value i.e. reduction of number of valleys and peaks within same profile length. Same conclusion could be reached for phase distortion of filter mean line determined with the 2RC profile filter. It could be clearly seen on Fig. 4 that mean line determined with 2RC profile filter has phase distortion in terms of primary profile. From Fig. 3 and 4 can be concluded that the distortion of profile ends highly expressed in case when waviness participates in primary profile, Fig. 4. On profiles on Fig. 4 profile ends distortion does not occur, so in such cases profile shortening in terms of primary profile is not necessary. The comparison of roughness profiles gained by usage of Gaussian and 2RC profile filters clearly indicates that large coinciding of profile forms exists. Largest deviation is noticed on Fig. 4 where the effect of phase distortion of 2RC profile filter starts to be prominent. This phase distortion is continuous against whole profile length since a periodic profile is in question. On same figure can be also seen a height distortion of one in terms of other roughness profile. The reason for such occurrence is higher sensitivity of 2RC profile filter on valleys and peaks in comparison with Gaussian profile filter. Such condition of height distortion can mostly affect the position of mean profile line out of which roughness parameters are expressed, while as largest changes on parameters can be expected on Rp, Rv and RSm.

5. CONCLUSION

Through analyzed real non-periodic and periodic surfaces the belief that filtration process has main and crucial role in determining of roughness profile form was verified. The parallel determination of Gaussian and 2RC filter mean line for one same primary profile and their mutual comparison provided following conclusions to be reached.

- It was indicated that if primary profile characterizes with deep valleys then distortion of filter mean line from profile core occurs when using both filters. Additional deviation and obtaining fictitious characteristic of gained roughness profile shall cause phase distortion of 2RC filter mean line.
- This analysis provides conclusion that the advantage in application of Gaussian filter in terms of 2RC filter when obtaining roughness profile from non-periodic surface is justified.
- When waviness is not present, phase distortion of filter mean line generated by means of 2RC profile filter can affect only when periodic profile characterizes with a smaller number of valleys or peaks or when roughness profile has higher values for RSm.
- Sensitivity of filter mean lines gained by application of Gaussian and 2RC profile filter on deep valleys and peaks does not affect periodic surfaces. Only by increasing value for RSm, and using 2RC profile filter, can expect certain vertical distortions of roughness profile.
- Analysis of periodic real etalon surfaces demonstrated that there isn’t significant difference between roughness profiles gained by application of Gaussian and 2RC profile filter, which justifies the usage of both filters.
- The effect of cut-off size change i.e. filter size is not included in the analysis. It is taken against recommendations provided in International and American standards.

6. REFERENCES

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"Trends in the Development of Machinery and Associated Technology" **TMT 2010**
Mediterranean Cruise, 11-18 September 2010

EDITORS: Dr. Sabahudin Ekinović, Dr. Yildirim Uctug, Dr. Joan Vivancos Calvet

Proceedings

ISSN 1840-4944