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SURFACE TEXTURE FILTRATION –INTERNATIONAL STANDARDS AND FILTRATIONS TECHNIQUE OVERVIEW

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Abstract: *Filtration is required at several reasons in the process of surface texture analysis. The main reason for using a filter is to separate long-scale components from short-scale components. Filtration techniques are used in surface metrology to separate the roughness component from the waviness component and the form component to calculate parameters according to international standards. Paper described problems roughness and wavering of profiles and surface area with a comprehensive reference to the relevant international standards.*

Keywords: *Filtration, Surface texture, Roughness, Waviness.*

1. INTRODUCTION

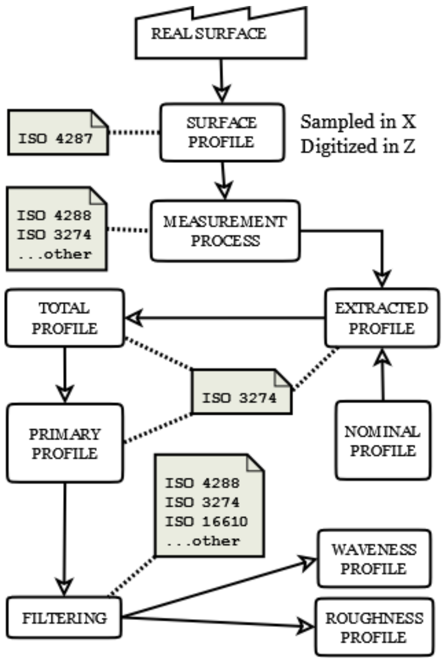
An important application of metrology in industry arises while inspecting geometrical attributes of manufactured objects to verify whether they satisfy tolerances specified during the product development phase.

Intuitively, a real surface is the set of infinite number of points that separate a work-piece from its surrounding. Given any physical work-piece, it is, of course, impossible to come up with a computable mathematical representation of this set; we need some additional information about the resolution at which the real surface is perceived. Theoretically, a mathematical model that approximates the real surface can be obtained within any measure of closeness by choosing the nesting parameter very close to zero [4].

A real surface corresponding to a specified nesting parameter is then partitioned into real integral features. These features still contain infinite number of points. During actual inspection, however, we sample only a finite number of points on these features. These are called extracted integral features. It turns out that sampling alone is insufficient to extract a feature; it should be accompanied by some smoothing to remove noise and unwanted details from the measured data. Therefore, techniques for extracting information on real integral features involve both sampling and some filtration [5].

Filtration is required at several reasons in the process of surface texture analysis. The main reason for using a filter is to separate long-scale components from short-scale components. We want to separate waviness from roughness. Filtration techniques are used in surface metrology to separate the roughness component from the waviness component and the form component to calculate parameters according to international standards. Characterization surface parameters can be derived with an aim to control the manufacturing process.

ISO 3274 defines a measurement scheme shown on picture 1. The profile measured by profile-meters is called the extracted profile. It is sampled and digitized, and represents an abstraction of the real surface [2].



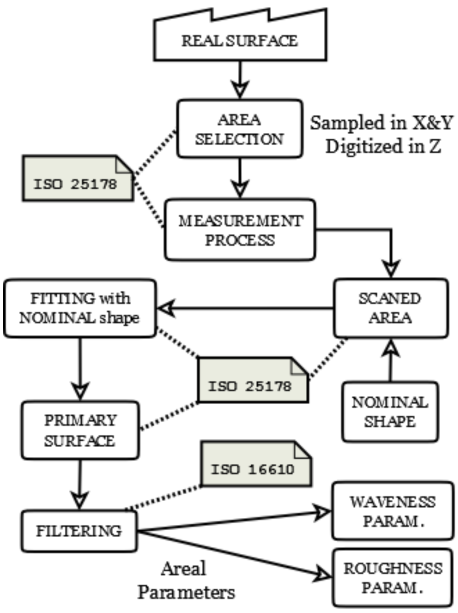
Picture 1. Procedure for obtaining Primary profile, Roughness and Waviness (ISO 3274)

Before the measurement process is started, the section of the surface that will be measured should be determined. The reference system is placed so that the *x*-axis runs perpendicular to the process traces. Several filtering effects are introduced by the probe and the bandwidth of the instrument). The real surface is modelled by a mechanical surface (boundary) when measured with a stylus, or by an electromagnetic surface which represents the surface envelope sensed by an optical probe [ISO 14406].

For profiles, we have **Pa** (Mean line/curve for Primary profile), **Ra** (Roughness parameters) and **Wa** (Waviness parameters).

In contrast with naming rules used with profile parameters, prefixes of the areal parameters do not reflect the nature of the surface, distinguishing between roughness and waviness. In the ISO 25178 standard, all areal parameters start with the upper case letter S or the upper case letter V.

For surfaces, we only have **Sa**, which can therefore be a parameter of roughness, or waviness, or calculated on the primary surface, depending upon the pre-filtering that is carried out before the parameter is calculated. This decision is based upon the multiplicity of processing and filtering methods that are available to metrology engineer for extracting information from a surface [1]. Processing methods do not necessarily separate the surface texture into two components that are roughness and waviness but in certain cases alter the surface in a subtler manner [5].



Picture 2. Procedure for obtaining Primary surface, areal waviness and roughness (ISO 25178)

Procedures, shown on pictures 1&2 are quite similar [2]. The vocabulary introduced in ISO 25178**.** The S-filter removes short-scale components. The L-filter removes long-scale components. The F-operator is the form removal operation. Scale-limited surfaces – SF surface or SL surface – are obtained after the respective filters or form removal operations have been applied. Areal parameters are then calculated on one of these surfaces, but contrary to profile parameters, they do not reflect the previous filter operation in their name [5].

2. SURFACE TEXTURE INTERNATIONAL STANDARDS

Engineers working in the field of surface texture should know following GPS (Geometrical Product Specification) ISO standards; Profile Surface Texture Standards:

- ISO 1302 (GPS) - Indication of surface texture in technical product documentation
- ISO 3274 (GPS) - Surface texture: Profile method - Nominal characteristics of contact (stylus) instruments
- ISO 4287 (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters
- ISO 4288 (GPS) - Surface texture: Profile method - Rules and procedures for the assessment of surface texture
- ISO 5436-1 (GPS) - Surface texture: Profile method - Measurement standards - Part 1: Material measures
- ISO 5436-2 (GPS) - Surface texture: Profile method - Measurement standards - Part 2: Software measurement standards
- ISO 12085 (GPS) - Surface texture: Profile method - Motif parameters
- ISO 12179 (GPS) - Surface texture: Profile method - Calibration of contact (stylus) instruments
- ISO 13565-1 (GPS) - Surface texture: Profile method - Surfaces having stratified functional properties - Part 1: Filtering and general measurement conditions
- ISO 13565-2 (GPS) - Surface texture: Profile method - Surfaces having stratified functional properties - Part 2: Height characterization using the linear material ratio curve
- ISO 13565-2 (GPS) - Surface texture: Profile method - Surfaces having stratified functional properties - Part 3: Height characterization using the material probability curve
- ISO 16610-1 (GPS) - Filtration - Part 1: Overview and basic concepts.

Areal surface texture standards ISO 25178 consist of the following parts:

- Part 1: surface texture indications; specifies the rules for indication of areal surface texture in technical product documentation (e.g. drawings, specifications, contracts, reports) by means of graphical symbols.
- Part 2: terms, definitions and surface texture parameters
- Part 3: specification operators
- Part 6: classification of methods for measuring surface texture
- Part 70: material measures for the calibration of

instruments

- Part 71: soft gauges - SDF file format
- Part 72: soft gauges - X3P file format
- Part 600: nominal characteristics of surface texture measuring instruments
- Part 601: nominal characteristics of contact (stylus) instruments
- Part 602: nominal characteristics of non-contact (confocal chromatic probe) instruments
- Part 603: nominal characteristics of non-contact (wave front interferometric microscope) instruments
- Part 604: nominal characteristics of non-contact (coherence scanning interferometry) instruments
- Part 605: nominal characteristics of non-contact (point autofocus profiling) instruments
- Part 606: nominal characteristics of non-contact (focus variation) instruments
- Part 607: nominal characteristics of non-contact (confocal) instruments
- Part 700: calibration of surface texture measuring instruments
- Part 701: calibration and measurement standards for contact (stylus) instruments

Other useful international standards for surface texture:

- ISO 1 (GPS) - Standard reference temperature for geometrical product specification and verification
- ISO 1101 (GPS) - Geometrical tolerancing - Tolerances of form, orientation, location and run-out
- ISO 8785 (GPS) - Surface imperfections - Terms, definitions and parameters
- ISO 14406 (GPS) - Extraction
- ISO 14253 (GPS) - Inspection by measurement of workpieces and measuring equipment - Part 1: Decision rules for proving conformance or non-conformance with specifications
- ISO 14638 (GPS) - Masterplan
- ISO/IEC Guide 98-1:2009 Uncertainty of measurement - Part 1: Introduction of the expression of uncertainty in measurement
- ISO/IEC Guide 98-3:2008 Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (= GUM)
- ISO/IEC Guide 99:2007 International vocabulary of metrology - Basic and general concepts and associated terms (= VIM)

3. FILTRATION TECHNIQUE

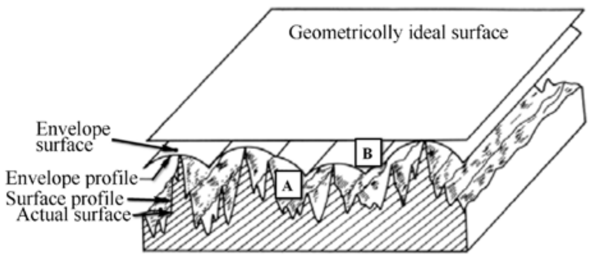
Filtration is one of the core elements of analysis tools in geometrical metrology. It is the means by which the information of interest is extracted from the measured data for further analysis. Noises are removed by filters before fitting routines are applied to generate the geometry of the measurand [2].

The first filters were implemented as physical high-pass filters using resistors and capacitors soldered behind a selector. The initial aim was to avoid large signal variations in order to draw the profile correctly on a thermal band of paper, or to display a roughness average indication on a dial indicator. These RC filters were used for almost 30 years on all types of stylus profile-meters.

These filters could date back to two traditional filtration systems emerged in 1950s [4], the mean-line based system (M-system, picture 3.) and the envelope based system (E-system, picture 4.).

Picture 3. The mean-line system

The M-system generates a reference line passing through the measured profile from which the roughness is assessed. Reference line, shown on picture 3. represent reference line [4]. This line is called the mean line due to the fact that the profile portions above and below the reference line are equal in the sum of their areas.



Picture 4. The envelope system; A-Roughness; B-Waviness [4]

The E-system was acting totally differently; the E-system appeared as a large disk rolling across over the profile from above, and the covering envelope formed by the rolling disk [4]. As shown in picture 4, the E-system gains its basis from the simulation of the contact phenomenon of two mating surfaces, whereby peak features of the surface play a dominant role in the interaction operation.

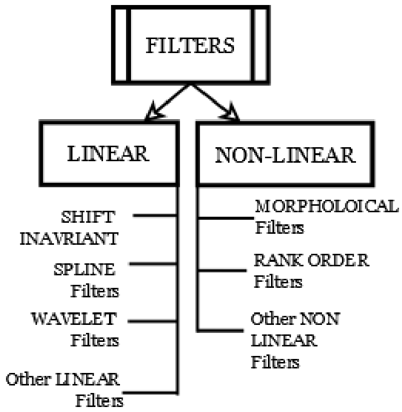
The fact is that the M-system and the E-system are complement to each other, rather than compete against each other and none of them can fulfill all the practical demands by themselves alone.

The M-system was greatly enriched by incorporating advanced mathematical theories. The Gaussian regression filter overcame the problem of end distortion and poor performance of the Gaussian filter in the presence of significant form component.

The E-system also experienced significant improvements. Introducing mathematical morphology, morphological filters emerged as the superset of the early envelope filter, but offering more tools and capabilities.

Filters can be classified in a certain hierarchy, picture 5. Most of the filters used today in dimensional metrology belong to the class of linear filters [3]. Especially the following filters are used:

- Electrical RC filters, implemented by hardware
- Phase correct 2RC filters, implemented by software
- Gaussian filter, implemented by software
- Spline filter, implemented by software
- Robust Spline filter, implemented by software



Picture 5. Filters Classification

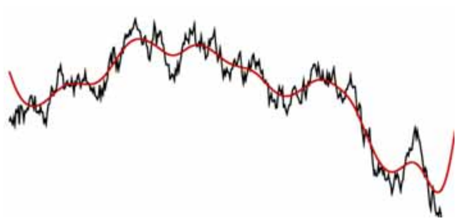
4. FILTRATION ACCORDING ISO 16610

The following profile filters are published in the ISO 16610 series [1]:

- Gaussian filters (ISO 16610-21)
- Spline filters (ISO 16610-22)
- Spline wavelets (ISO 16610-29)
- Robust Gaussian regression filters (ISO 16610-31)
- Robust Spline filters (ISO 16610-32)
- Morphological filter (ISO 16610-41)

4.1. Gaussian filter

The Gaussian filter, picture 6, belongs to the class of linear shift invariant filters. The implementation is possible by software only, because the filter is non-causal. It is a phase correct filter with a symmetrical weighting function [1]. The Gaussian filter has replaced the phase correct 2RC filter.



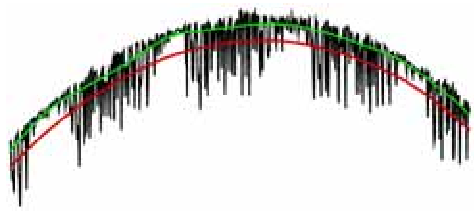
Picture 6. The Gaussian filter (ISO 16610-21) [6]

The Gaussian filter has the following disadvantages [4]:

- The filter is a continuous filter, i.e. the implementation is arbitrary (no unique algorithm).
- The filter has end-effects, i.e. data at both ends of the filtered signal must be discarded.
- The filter has problems with signals, which have a large curvature.
- An adjustment of the signal before filtering is necessary.
- Finite periodic signals cannot be filtered, because of the end-effects.
- The filter is not robust, i.e. sensitive to outliers.

4.2. Spline filter

The spline filter has been developed to overcome the disadvantages of the linear shift invariant filters like the Gaussian filter, picture 7. Spline filters are still linear phase correct filters, but are not shift invariant filters. They are implemented by software only, using a very fast matrix algorithm. There exits a robust version of the spline filter, which is insensitive to outliers [5].

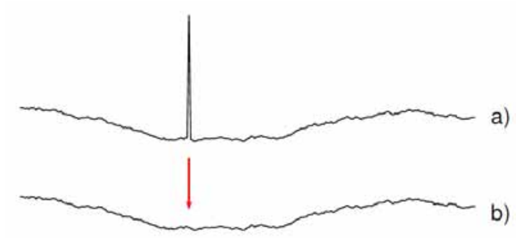


Picture 7. Spline filter (green) vs. Gaussian filter (red) [6]

4.3. Wavelet filters

Wavelet filters are linear filters and can be used to remove noise or outliers [1], picture 8.

Contrary to the Fourier transformation, the wavelet decomposition allows not only to determine the wavelength content of a measured profile, but also to localize where a particular wavelength occurs.

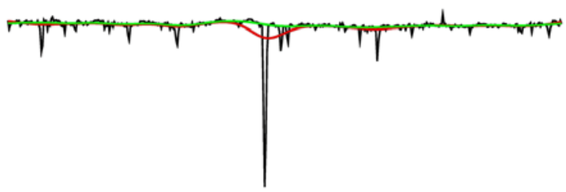


Picture 8. (a) original profile with outlier; (b) outlier removed by a wavelet filter [6]

The smooth part of a wavelength decomposition of a profile corresponds to a low pass filter, while the detail part corresponds to a high pass filter. The wavelength decomposition, like the Fourier transformation, can be reversed and allows thus the construction of wavelet filters [5].

4.4. Robust Spline filter

The robust Spline filter is applied as a profile filter in roughness or form measurements, picture 9. The filtered signal shows no unwanted deviation caused by deep holes or scratches in the surface (green line on picture 9.), as the Gaussian filter does (red line on picture 9.). The robust Spline filter is also insensitive to outliers.



Picture 9. The robust Spline filter (ISO 16610-32) [6]

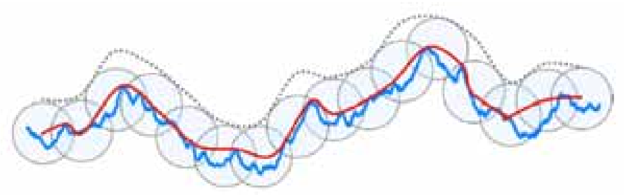
4.5. Morphological filters

Morphological filters can be interpreted as a simulation of the track of a reference point of a rigid solid body, as for example the center of a ball, which is moving along the surface of a workpiece being continuously in contact with the surface to be filtered [4].

One of the main application of morphological operations is the morphological reconstruction of a tactile measured profile. Morphological filters are non-linear filters.

Picture 10. Morphological closing filter (upper red curve) obtained by rolling a disk over the profile [5]

Two morphological operation called *dilatation & erosion* are used to define a mechanical surface. If the disk is rolled over the surface, it is called *dilatation*. The path of its center is recorded (red line, picture 10). Note how this fills "valleys" while preserving the "peaks" [4]. If the disk is rolled below the surface, it is called *erosion* (gray dotted line, picture 11). The path of disk envelope is recorded. Note how this knocks out the "peaks" and preserves the "valleys".



Picture 11. Morphological opening filter (upper red curve) obtained by rolling a disk over the profile [5]

Dilation and erosion are not filters; they are just morphological operations [5]. When dilation is followed by erosion, it is called a morphological closing filter. If the sequence is reversed, i.e. erosion followed by dilation, it is called a morphological opening filter.

When applied in alternating sequence, these two filters can be used to selectively eliminate features of any given "size" from the input data [3]. Closing and opening filters can also be cascaded to create alternating symmetrical filters.

5. CONCLUSION

This paper provides a brief overview of the standards and technique that are relevant to the texture of the surface. Paper described problems roughness and wavering of profiles and surface area with a comprehensive reference to the relevant international standards. Paper offers to metrology engineers a guideline to choose the appropriate filter for various applications.

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