UDC 62-408.8:620.179.118:621.317.39 May 1990

Phase correct filters for use in electrical stylus instruments

DIN 4777

Oberflächenmeßtechnik; Profilfilter zur Anwendung in elektrischen Tastschnittgeräten; phasenkorrekte Filter

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

See Explanatory notes for connection with draft International Standard ISO/DIS 11562 published by the International Organization for Standardization (ISO).

1 Scope and field of application

This standard specifies the characteristics of phase correct filters for the measurement of surface roughness and waviness by means of electrical stylus instruments.

Such filters are suitable for the measurement of all parameters of surface roughness and waviness using the same cut-off wavelengths.

2 Concepts

2.1 Profile filter

A profile filter is a filter that separates the roughness profile from the long-wave profile components and the waviness profile from the roughness.

2.1.1 Phase correct profile filter

A phase correct profile filter is a profile filter that does not cause phase shifts during the transmission of the profile which would lead to asymmetrical profile distortions. Phase correct profile filters separate the roughness profile from the complementary long-wave components of the traced profile.

2.2 Phase correct profile filter mean line ('the mean line')

The mean line of phase correct profile filters applies to the waviness and any other long-wave profile components that are not associated with the surface roughness. The mean line is determined for any point of the traced profile by a weighted mean value symmetrical to it over a defined length.

2.3 Roughness profile

The roughness profile represents the deviations of the traced profile from the mean line. It is determined by subtraction of the mean line from the traced profile.

2.4 Waviness profile

The waviness profile results from the mean line of the phase correct filter after separation from the form profile components.

2.5 Transmission characteristic of a filter

The transmission characteristic of a filter ('filter characteristic', for short) indicates the amount by which the amplitude of a sinusoidal profile is attenuated as a function of its wavelength.

2.6 Weighting function

The weighting function for calculating the mean line indicates, for each point of the profile, the weight attached (weighting factor) to neighbouring points of the profile used in establishing the associated point of the mean line (weighted averaging).

2.7 Cut-off wavelength

The cut-off wavelength, λ_c, of a phase correct filter is the wavelength of a sinusoidal profile 50 % of the amplitude of which are transmitted by the profile filter. Phase correct profile filters are identified by their cut-off wavelength value.

The cut-off wavelength is graded as follows (cf. DIN 4768): 0,08, 0,25, 0,8, 2,5, and 8,0 mm.

3 Characteristics of phase correct profile filters

3.1 Weighting function

The weighting function of phase correct profile filters, $s(x)$, has a Gaussian profile, as shown in figure 1. It is expressed by equation (1) as follows:

$$s(x) = \frac{1}{\alpha \cdot \lambda_c} \cdot e^{-\pi\left(\frac{x}{\alpha \cdot \lambda_c}\right)^2} \qquad (1)$$

where

x is the position from the centre of the weighting function;

λ_c is the cut-off wavelength of the profile filter,

$$\alpha = \sqrt{\frac{\ln 2}{\pi}} = 0,4697 \qquad (2).$$

Continued on pages 4.

3.2 Filter characteristic

Phase correct profile filters permit the surface roughness and waviness to be plotted simultaneously. Depending on the method of measurement selected, the filter characteristic of such filters can have the form of either

- the characteristic of the waviness profile (mean line)

or

- the characteristic of the roughness profile.

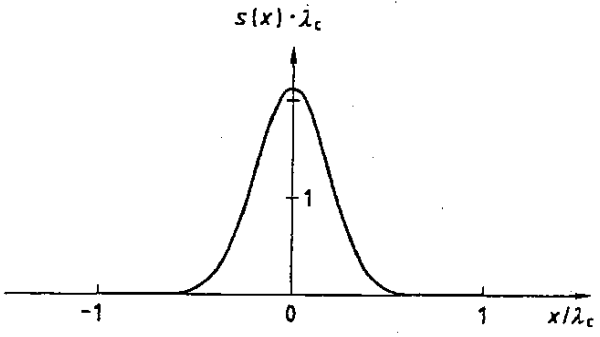

Figure 1: Weighting function of phase correct profile filters (Gaussian filter)

3.2.1 Filter characteristic of waviness profile

The filter characteristic of the waviness profile (i.e. of the mean line) is determined from the weighting function by means of the Fourier transformation. It is expressed by the following equation:

$$\frac{a_1}{a_0} = e^{-\pi\left(\frac{\alpha \cdot \lambda_c}{\lambda}\right)^2} \qquad (3)$$

where

a_0 is the amplitude of the sine profile before filtering;

a_1 is the amplitude of the sine profile in the mean line;

λ_c is the cut-off wavelength of the profile filter;

λ is the wavelength of the sine profile.

This characteristic corresponds to that of a low-pass filter which transmits low-frequency or long-wave signals and attenuates higher-frequency or short-wave signals depending on its characteristic (see figure 2). The mean line corresponds to the waviness profile, superimposed by a component of the deviation of form or the alignment error.

NOTE: This filter characteristic relates to the transmission of the long-wave profile components that are not associated with the surface roughness.

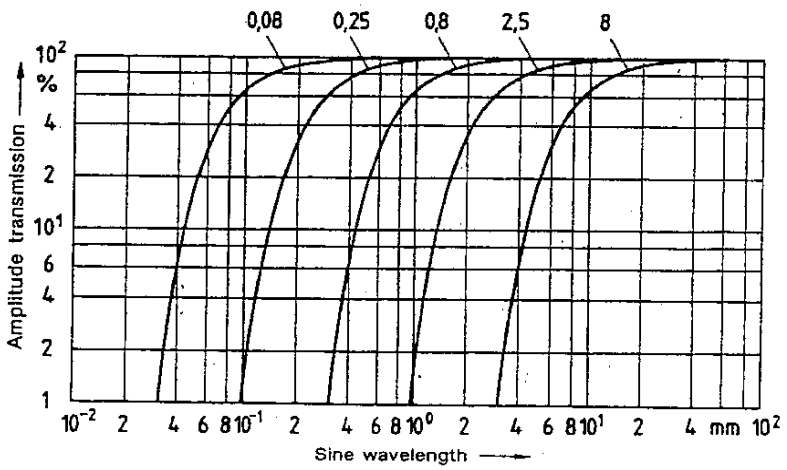

Figure 2: Filter characteristic of the waviness profile with cut-off wavelengths λ_c of 0,08, 0,25, 0,8, 2,5, and 8,0 mm (low-pass filter)

3.2.2 Filter characteristic of roughness profile

The filter characteristic of the roughness profile is complementary to that of the waviness profile, i.e. of the mean line, because the roughness profile is the difference between the actual profile and that line. It is expressed by the following equations:

$$\frac{a_2}{a_0} = 1 - \frac{a_1}{a_0} \tag{4}$$

$$\frac{a_2}{a_0} = 1 - e^{-\pi\left(\frac{\alpha \cdot \lambda_c}{\lambda}\right)^2} \tag{5}$$

where a_2 is the amplitude of the sine profile in the roughness profile.

The filter characteristic of the roughness profile corresponds to that of a high-pass filter which attenuates low-frequency or long-wave signals, depending on its characteristic, and transmits higher-frequency or short-wave signals.

4 Limits of error

For phase correct filters no tolerances are given here. Instead, the instrument manufacturer shall provide a graphical representation of the deviations of the realized phase correct filter from the Gaussian filter as percentage over a range of 0,01 λ_c to 100 λ_c. The curve obtained (deviation curve) is relevant both for calibration of the measuring instrument and for instrument users. An example of such a curve is given in figure 4.

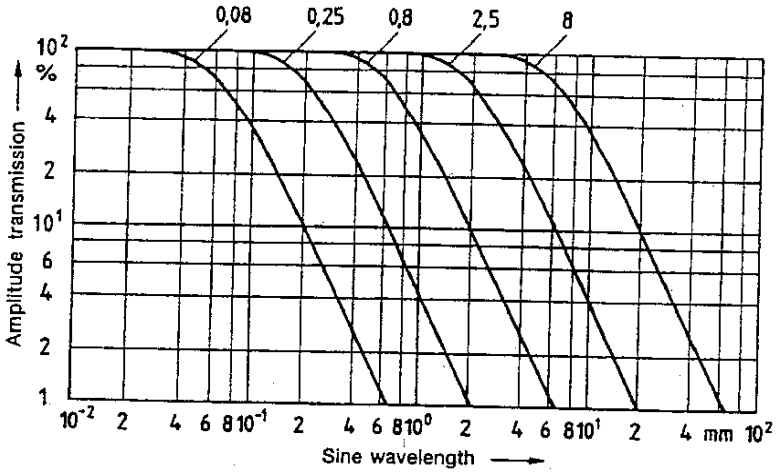

Figure 3: Filter characteristic of the roughness profile with cut-off wavelengths, λ_c, of 0,08, 0,25, 2,5, and 8,0 mm (high-pass filter)

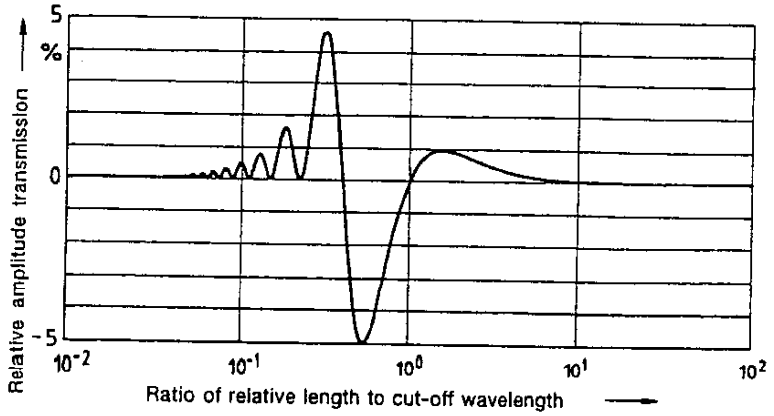

Figure 4: Example of a deviation curve (realized phase correct filter/Gaussian filter)

Standards referred to

DIN 4768 Determination of surface roughness parameters R_a, R_z, and R_{max} using electrical stylus instruments; concepts and measuring conditions

ISO/DIS 11562 Metrological characterization of phase corrected filters and transmission bands for use in contact (stylus) instruments

Other relevant standards

DIN 4772 Electrical stylus instruments for surface roughness measurement

DIN 4774 Measurement of the depth of waviness by means of electrical stylus instruments

DIN 4776 Measurement of surface roughness parameters R_K, R_{PK}, R_{VK}, M_{r1}, and M_{r2} for the description of the material portion (profile bearing length ratio) in the roughness profile; measuring conditions and evaluation procedures

Explanatory notes

For a number of years, electrical stylus instruments with phase correct digital filters that are incompatible with standardized 2-step RC-filters but produce comparable results have been available worldwide. It may therefore be assumed that the difference in measured values for R_a, R_z and R_{max}, obtained when using one or the other type of filter, is smaller than the actual inhomogeneity of the tested surfaces. For surfaces produced by metal cutting, such differences are usually of only a few percent and may be disregarded.

The considerable phase shift in the case of 2-step RC-filters that occurred when determining waviness parameters as well as all further roughness parameters, led to asymmetrical profile distortions and subsequently to inaccurate measurements. Such disadvantages have been overcome by the use of phase correct filters.

The following criteria have been taken into consideration in the preparation of this standard.

a) Since there is a complementary relationship between the filter characteristics of the roughness and waviness profiles, both characteristics shall be phase correct. It is thus expedient to define as the cut-off wavelength the sine wave 50 % of the amplitude of which are transmitted into the roughness profile and 50 % into the waviness profile.

b) For digital stylus instruments, use of a Gaussian filter has proved to be practical.

c) If tolerances are given, these shall be both suitable from the point of view of calibrating the measuring instrument and meaningful from the point of view of its users. For this reason, no tolerances have been specified. Instead, deviation curves (realized filter/Gaussian filter) shall be supplied with each instrument.

d) New phase correct filters shall be compatible with existing 2-step RC-filters defined in national and international standards (ISO/DIS 11562) in so far as they achieve reproducible results (within the natural scatter of measured values).

International Patent Classification

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