Surface Texture Analysis Using Dektak Stylus Profilers

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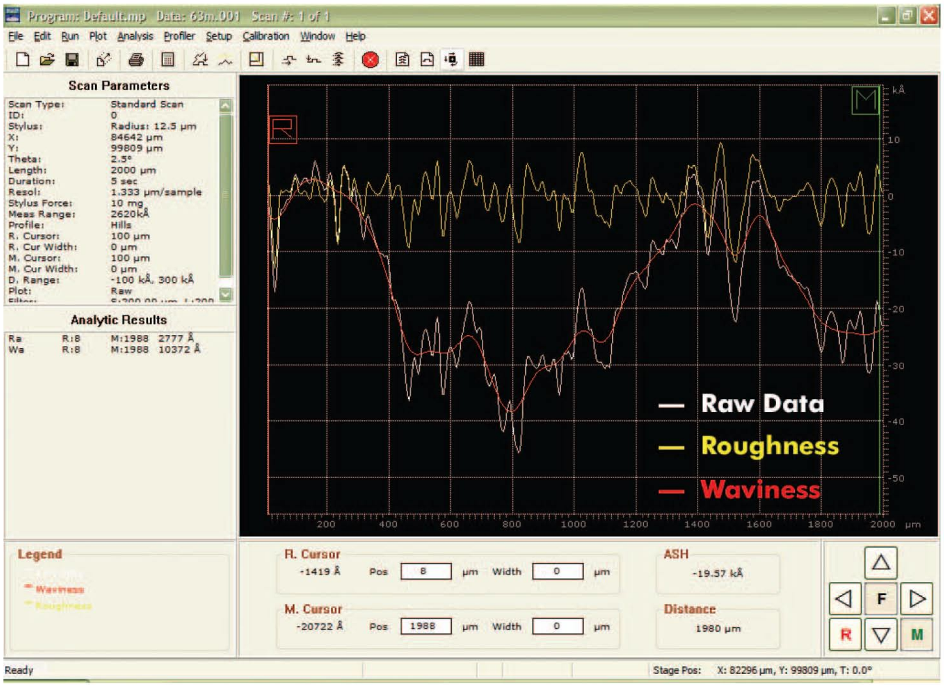


Figure 1. Dektak stylus profilers are equipped with extensive analysis software for calculating a wide range of roughness and waviness parameters. User programmable cut-off filters enable waviness, roughness and unfiltered data to be displayed simultaneously.

Introduction

"Surface texture" refers to the local deviations of a surface from its "ideal" shape. Accurate characterization of surface texture is critical for controlling the function and reliability of precision components and the processes used to manufacture them. This application note discusses the basic characteristics of surface texture and illustrates how stylus profiling can be used to measure, analyze and control surface texture.

Surface Characterization

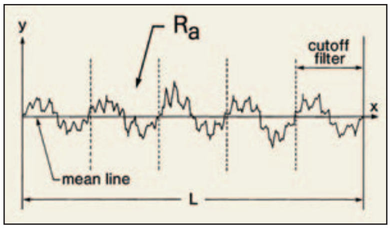
Effective surface characterization requires accurate acquisition of data, coupled with appropriate analysis. Traditional measurement methods have reported only surface roughness, providing an incomplete picture of the surface texture, which comprises a matrix of complex, interrelated characteristics.

Early surface parameters were developed based upon the use of averaging-type, stylus-based instruments[1]. Such instruments could detect divergence from the anticipated shape but provided little insight into the root causes of the deviation. More recently, high-resolution, digital profilers with computerized analysis techniques have encouraged the development of more sophisticated, real-world parameters that can help determine the cause of process changes as well as the results.

Roughness and Waviness

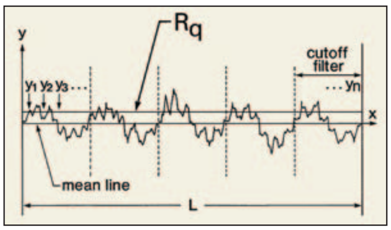
The American National Standards Institute's B46.1 specification[1] defines surface texture as the repetitive or random deviation from the normal surface that forms the three dimensional topography of a surface.

Consider a theoretically smooth, flat surface. If a small hollow appears at the center of this surface, the surface



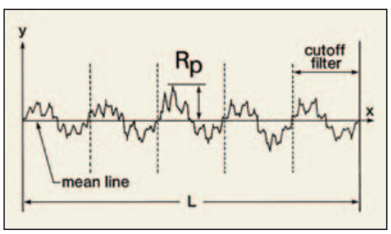
R_a is the arithmetic average deviation from the mean line within the assessment length (L).

$$R_a = \frac{1}{L}\int_{x=0}^{x=L} |y| dx$$

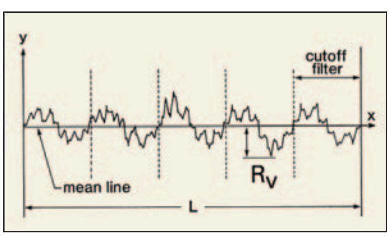


R_q is the RMS value of roughness.

$$R_q = \sqrt{\frac{1}{L}\int_0^L y^2(x) dx}$$



R_p is the maximum height of the highest point of roughness above the mean line.



R_v is the maximum depth or the lowest point of roughness below the mean line.

will be smooth but curved. Two or more equidistant hollows produce a wavy surface. As the frequency of these waves increases, (i.e., as the space between them decreases), the resulting surface would be considered flat but rough. In fact, surfaces having the same height of irregularities are regarded as curved, wavy, or rough, according to the spacing of these irregularities.

Roughness and waviness can originate during manufacturing, and each process may tend to produce one texture or the other. Waviness, the more widely spaced repetitive deviations, can usually be attributed to individual machining processes or to external environmental factors. Factors such as vibration, chatter, heat treatment, or warping strains can induce waviness. Roughness, the finer, random irregularities of surface texture, more frequently results from chemical or mechanical polishing, grinding or finishing processes.

In addition to roughness and waviness, surface texture may exhibit directionality. The predominant direction of surface irregularities is referred to as lay. Lathe turning, milling, drilling, and grinding typically produce surfaces with pronounced lay.

Defects are also considered a component of surface texture and may range from pitting and marring to scratches, warping, etc.

The surface of a manufactured component typically exhibits roughness superimposed over waviness and may also include lay and/or defects as well.

Characterizing Surface Texture

Surface texture is not a measurable quantity; it is not possible to assign a unique "texture" value to every different surface. However, it is possible to measure some of the intrinsic characteristics, or parameters, of surface texture.

Surface parameters are generally defined using profile data developed using stylus-based measurement systems. Stylus profilers, such as the Dektak® Series profilers from Veeco Instruments Inc., use a variety of diamond-tipped styli to detect minute surface variations in surface topography. In a profiler, the stylus is mechanically coupled to the core of an LVDT (Linear Variable Differential Transformer). A precision stage moves the sample surface across an optically flat reference surface beneath the stylus. As the stage moves the sample, the stylus rides over the surface, detecting roughness variations as small as ten angstroms in height. The LVDT produces an analog signal corresponding to the vertical stylus movement. This signal is amplified, conditioned, digitized and stored for manipulation, analysis and display.

High and Low Pass Filters

Dektak stylus profilers include a wide range of analyses for measuring particular surface parameters. They may refer to roughness (designated as R parameters) or waviness (designated as W parameters). As mentioned earlier, a typical surface exhibits roughness superimposed over waviness.

To accurately measure surface roughness, the more widely-spaced waviness deviations must be factored out of the calculations. Dektak profilers employ a user-selectable waviness (high pass) filter, in accordance with the ANSI B46.1 specification, to delineate roughness from waviness. High frequency signals above the selected cutoff value are passed to the roughness algorithms. In this manner, analytical functions such as R_a (average roughness) are calculated using only high frequency roughness data. Similarly, a low pass filter removes roughness components from the waviness calculations.

The rule of thumb for selecting the high pass filter value is 1/100 the length of the scan. It is recommended that the scan length be five to ten times longer than the low pass cutoff wavelength. Once the desired filters have been programmed, they are automatically applied whenever a roughness or waviness analysis is performed. The scan data is conditioned by the cutoff filters and stored. The original, unfiltered profile remains unaffected and can be displayed simultaneously with the filtered roughness and waviness profiles (as in Figure 1).

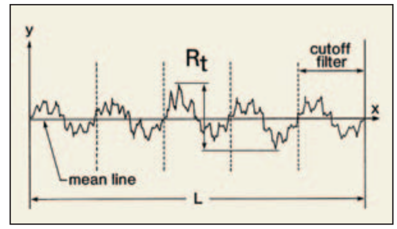
Average Roughness

The one parameter that is standardized all over the world and is specified and measured far more frequently than any other is the arithmetic average roughness height, or Roughness Average. Universally called R_a, it was formerly known as AA (Arithmetic Average) in the United States, and CLA (Center Line Average) in the United Kingdom. It is defined as the arithmetic mean of the departures of the profile from the mean line. An approximation of average roughness (R_a) is obtained by adding the Y values without regard to sign and dividing the sum by the number of samples taken.

R_a is used to detect general variations in overall profile height. A change in R_a typically signifies a new variation in the process. It could be a change in the tool, the coolant, the material, or any other machine related factor. However, R_a cannot detect differences in spacing and its distribution, or the presence or absence of infrequently occurring high peaks and deep valleys.

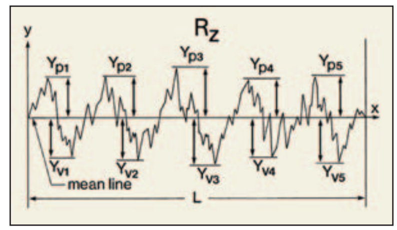
R_q (or also known as RMS) is the root-mean-square average of the departures of the roughness profile from the mean line. R_q has statistical significance because it represents the standard deviation of the profile heights and it is used in the more complex computation of skewness, the measure of the symmetry of a profile about the mean line.

Dektak profilers include both the R_a and R_q standard analytical functions, as well as other widely used parameters for analyzing roughness and waviness. The accompanying figures provide descriptions of several of these parameters. Note that in each of the figures showing roughness parameters the scans are divided into five consecutive and equal portions representing the waviness filter cutoff length.



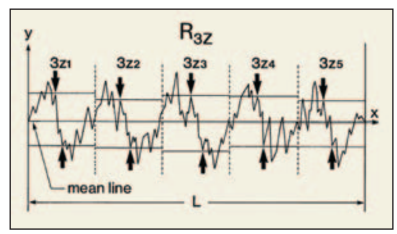
R_t is the sum total of the maximum valley and maximum peak of roughness.

$$R_a = |R_p| + |R_v|$$



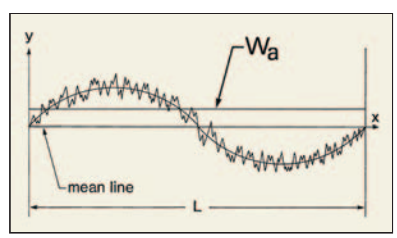
R_z is the average height difference between the five highest peaks and the five lowest valleys of roughness.

$$R_{z(ISO)} = \frac{1}{5}\left(\sum_{i=1}^{5} Y_{pi} + \sum_{i=1}^{5} Y_{vi}\right)$$

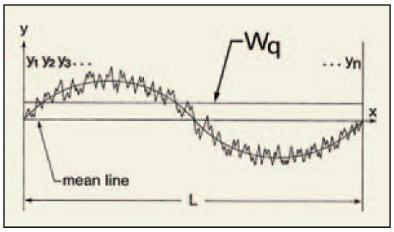


R_{3z} is the distance between the third highest peak and the third lowest valley of roughness within a sampling length, usually averaged over several sampling lengths.

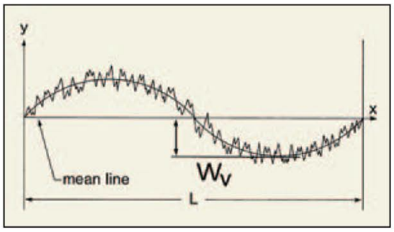
$$R_{3z} = (3_{z1} + 3_{z2} + 3_{z3} + 3_{z4} + 3_{z5})$$



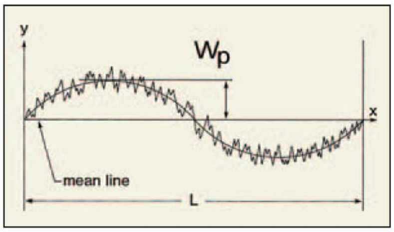
W_a is the arithmetic average deviation of waviness from the mean line.



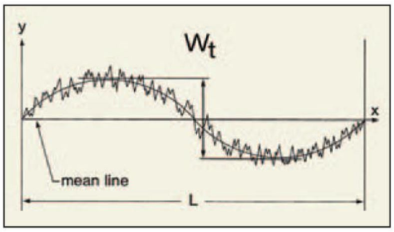
W_q is the corresponding parameter to W_a it is the RMS value of waviness.



W_v is the maximum depth or the lowest point of waviness below the mean line.



W_p is the maximum height or the highest point of waviness above the mean line.



W_t is the sum total of the maximum valley and maximum peak of waviness.

$$W_t = W_v + W_p$$

Conclusion

Understanding surface texture requires both accurate assessment of the surface profile and the proper analytical functions to characterize the surface. Dektak stylus profilers provide both, with low-force, high precision scanning and a comprehensive set of analytical functions and filters to make the most of scan data. For more on surface texture analysis, please review the excellent sources shown below.

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References

1. ANSI B46.1 "Surface Texture (Surface Roughness Waviness and Lay)" 2002, published by the American Society of Mechanical Engineers.
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3. ISO/DIS 4287/1 "Surface Roughness-Terminology-Part 1: Surface and its Parameters." First edition 1984, published by the International Organization for Standardization.
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