Form deviation plus roughness
Characterization of surface information in manufacturing metrology

By conventional machining processes, three main components of surface topography are generated and they are classified according to their causes, reasons for their formations.

The first component is “the roughness and irregularities” which are inherent in the production process, left by machining (e.g. cutting tool, spark), as a result of the built of edge formation and tool tip irregularities are described with it. Second component is the waviness which results from factors such as deflections (machine or work), vibrations, unbalanced grinding wheel, irregularities in tool feed, chatter or extraneous influences. The third component of the surface, which is left after elimination of roughness and waviness, is defined as its form.

In Figure 1, an overview of those surface components with respect to lateral and vertical dimensions is given. Roughness measurement shown in the bottom left region of this graph, where detailed information in lateral and vertical dimensions is needed. And today the most common method to measure surface roughness is still the application of stylus contact based surface measurement instruments.

Although stylus type instruments are suitable for many applications and well accepted throughout industry, challenges can arise due to the mechanical contact with the sample, as surface or instrument damage may occur. Thus for applications, where tactile techniques have shortcomings e.g. risk of contamination, recessed surfaces or complex structures, then non-contact optical instruments continue to evolve to better meet these ever increasing measurement requirements. And due to emerging possibilities of optical surface metrology tools, there has been a trend to measure as many parameters as possible with a single measurement system. A common way of measuring roughness together with flatness is the utilization of multiple objectives together with a xy stage (for stitching).

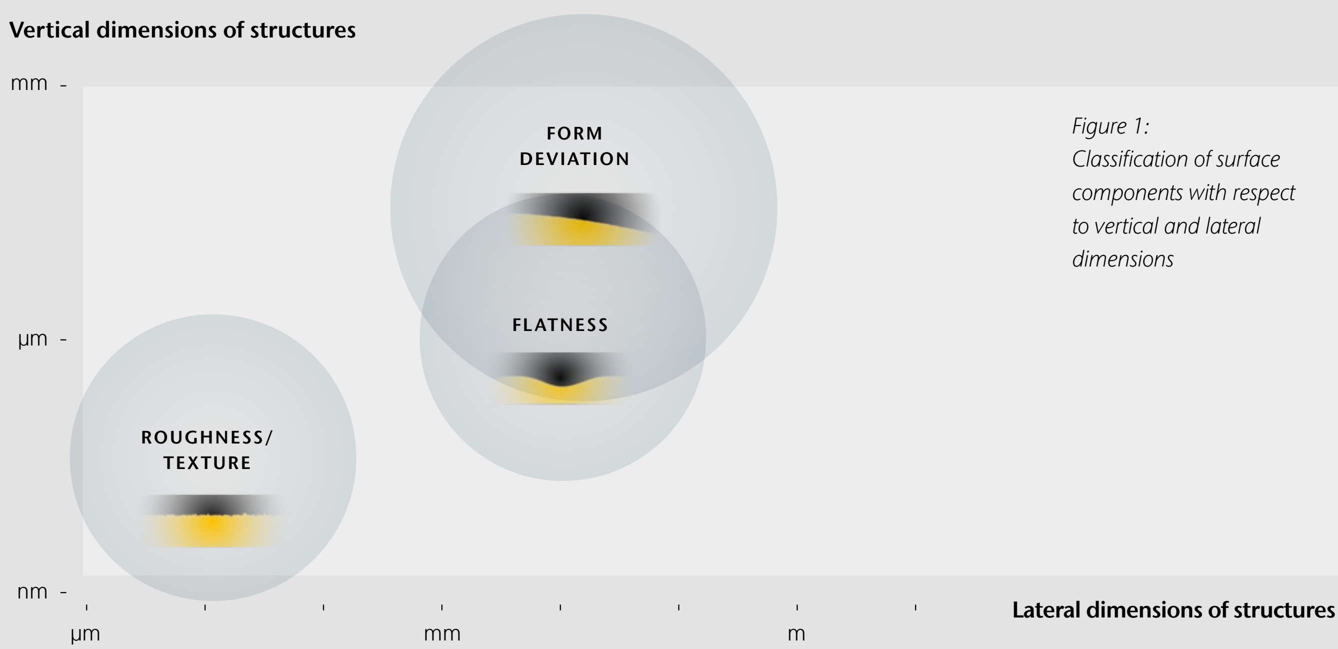
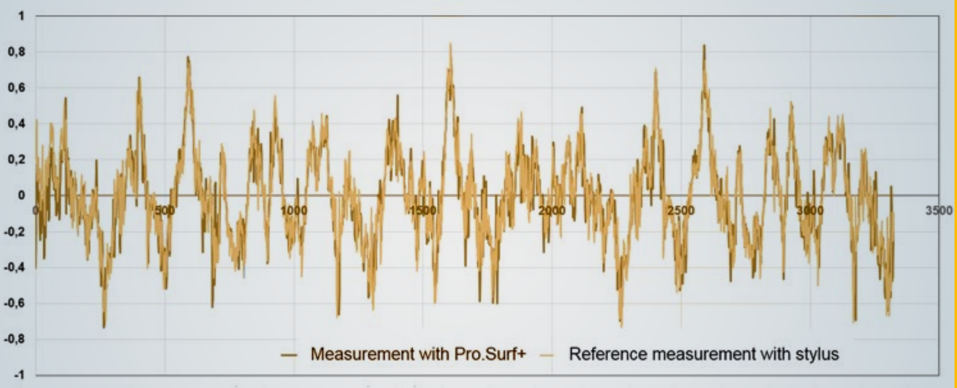


Figure 1: Classification of surface components with respect to vertical and lateral dimensions

In order to overcome such limitations and provide additional benefits, the Polytec TopMap family has been extended by a multi-sensor system which can be easily used to measure form deviation plus roughness parameters all within a single measurement instrument setup.

*Figure 2:
Combining the advantages of both worlds, large areal measurements and roughness measurements*



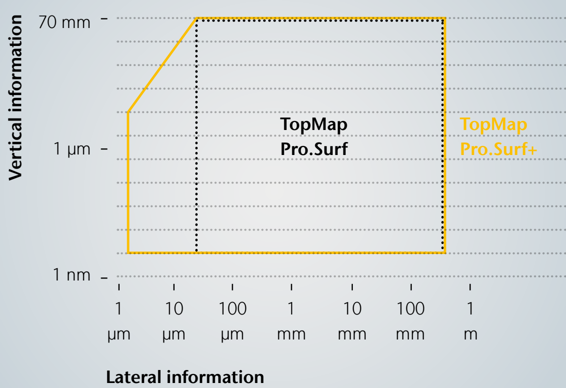


Figure 3:
Measured profile with Pro.Surf+ versus reference profile (tactile calibration measurement)

Figure 4:
Modular concept of TopMap Pro.Surf+

But this approach may be time consuming and limited to the properties of chosen objectives (working distance, crash with a sample, limited field of view). Moreover, most of the technical drawings require a profile based 2D parameter set, for which areal information from a high magnified objective is not completely required. Another aspect is the specified profile length within a technical drawing: In some cases, when using an optical instrument the field of view of an objective is smaller than the necessary profile length required to conform to international standards. Zick-zag profiles can be drawn across the surface but due to either the directionality of the surface or the nature of the roughness, this is not always allowed according international standards due to directional surface structures or higher levels of surface roughness.

Multi-sensor concept of Polytec

The TopMap large FoV white light interferometers from Polytec are mainly designed for big and heavy samples. As an example a single measurement volume (without stitching) of 30 x 40 x 70 mm^3 (X x Y x Z) can be acquired with nanometer vertical resolution. One of the strengths of white-light interferometry, is the very high vertical resolution of the measurement system, which does not depend on the magnification of the objective and this makes it possible to resolve even large surfaces with very high resolutions in a very short time, where the other techniques (like confocal or focus variation) need to apply objectives with high magnification and combine many regions to cover the surface. It is also worth mentioning that white light interferometers are very good at measuring highly polished, lapped and smooth surfaces, unlike the focus variation or fringe projection techniques which require a surface to contain higher levels of image contrast. Thus for the applications in which high lateral resolution is required, the multi-sensor concept integrated with chromatic confocal probing was developed.

As a method, chromatic confocal probing is an optical point based sensor most similar to the stylus profilers in terms of spot size and resolutions. Surface data is acquired by scanning the point sensor with help of a laterally translated stage just as with tactile methods. Such a configuration allows for tracing complex shapes. Even when used in conjuction with time sensitive areal measurements, it does not require any vertical scanning unit, which makes chromatic confocal technology static and without any moving parts in the optical head.
For applications where multiple measurement parameters are asked, the form deviation on the whole surface can be characterized with the white-light interferometer, then additional measurements with the chromatic confocal technology can be performed to evaluate roughness. Similar to stylus measurements, the position, length and the shape of the profile can be easily chosen by the operator.

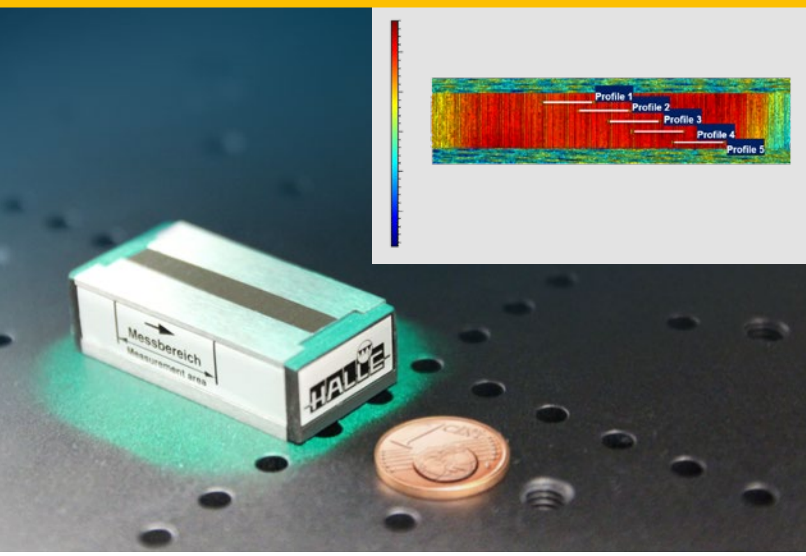


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Figure 5:
Overview of roughness standard used for the comparison measurements

Measurements with TopMap Pro.Surf+

Even new optical methods provide new opportunities, there is still a discussion on the comparison of results acquired by optical verses stylus instruments. Each data acquisition method has its own advantages and disadvantages based on the optical, mechanical or electro-magnetic properties of the workpiece. Since the optical properties of the surfaces are not necessarily identical to that of the mechanical properties, comparison of different contact and non-contact measurements can prove helpful in understanding how such differences can influence the end numerical results.

In order to compare the results of Pro.Surf+ with the results acquired by tactile methods, a roughness standard (Halle Standard, KNT 4058/01 class A) was measured for comparison purposes. As shown in Figure 5, the roughness standard made of hardened stainless steel of dimensions 40 mm x 20 mm x 11.3 mm was measured by Pro.Surf+. As measured by contact stylus instrument, 5 individual profiles are analyzed.

The comparison of the results is shown in Figure 3: The measurement results on the calibration protocol are: Ra 0.197 µm Rz: 1.46 µm. Measurement results by Pro. Surf+: Ra 0.197 µm Rz: 1.43 µm. The measurement data of Pro.Surf+ is in good agreement with the reference profile of the stylus instrument. Although Ra values are identical, there is a slight difference between Rz values. This can be explained with definition of parameters: Ra depends on the average properties of surfaces, whereas Rz is calculated with maximum and minimum characteristics. As discussed above the measured heights of optical and tactile instruments can be different which can result in slightly different measured height values in the peaks and valleys of the structured surface.

Exploring new possibilities

Thanks to the modular concept of the TopMap family, it is possible to upgrade the standard Pro.Surf to a Pro.Surf+ and new capabilities with the roughness module of Pro.Surf+ can be easily seen in the Figure 4.

Summary

Due to the latest developments in manufacturing technologies, there is a huge demand to understand surface characteristics of products within industry in a fast time but with a high degree of surface information and high levels of accuracy. And it is not easy to identify a measurement technique which fulfills all the requirements fully in a single measurement system. Depending on the application, regardless of optical or tactile technique, every methods has its own advantages and disadvantages. However, thanks to new concepts like “multi-sensor” approaches, tools in optical surface metrology are improved to solve most of the requirements simultaneously. Especially for applications when form and roughness need to be measured within a single measurement cycle, this is now possible with this novel combination, i.e. of large area white light interferometry and combination chromatic confocal measurement technologies.