TopMap

Success stories

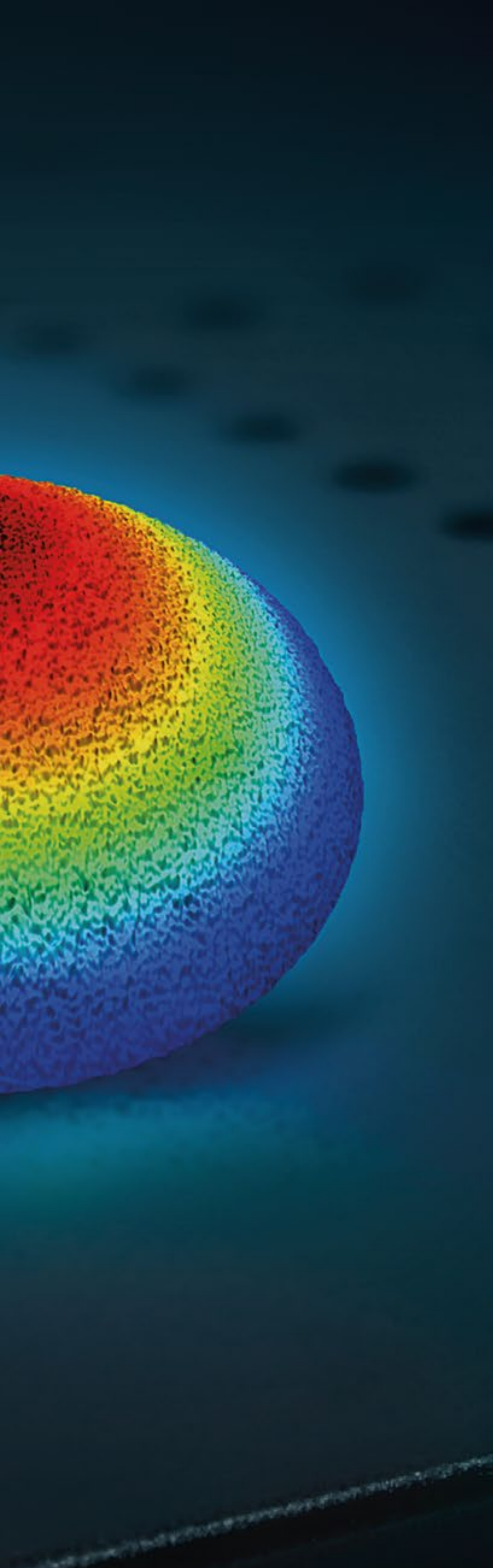
Applications of 3D surface metrology

Content

Images courtesy: Images courtesy of the authors unless otherwise specified. Pages 1: ©Scruggelgreen/shutterstock.com, ©whitehoune/shutterstock.com, ©stockphoto-graf/fotolia.de, © Pages 1, 3 , 4, 52, 53: peshkov/fotolia.de, ©bitter/fotolia.de, ©yorphasin/shutterstock.com, ©ChristianNasca/iStock.com, ©46design/shutterstock.com, ©Mirage_studio/shutterstock.com; Pages 8, 12, 50: ©4th Life Photography/fotolia.de, ©shapecharge/iStock; Pages 18, 21: ©Gorodenkoff/fotolia.de, ©ssguy/shutterstock.com, Pages 2, 24, 35: ©Andrey_Kuzmin/shutterstock.com, ©Voyagerix/iStock.com; Pages 14, 15: ©D-Keine/iStock.com; Pages 26, 27: ©humphery/shutterstock.com; Pages 29: ©Evannovostro/fshutterstock.com, Page 30: ©Alex Yeung/shutterstock.com; Page 54, 55: ©pixel/fotolia.de, ©Es sarawuth/fotolia.de

34

Non-contact inspection of coated surfaces



“Surfaces in the right light.”

Dr. Gnass about market trends and need for optical surface inspections

Dear readers,

our development team never stands still; market requirements and needs are always changing, with research and production environments constantly evolving. Take for example microsystem applications, with components becoming smaller every day and having tighter tolerances than ever before.

The same can be said about topography of precision parts, they become more complex and therefore more problematic to characterize, especially when the measurement needs to be directly integrated in the production process. Reducing the measuring time has become a critical factor for an efficient production throughput. The market trend shows that in the next years optical measurement technologies will become even more significant, because optical solutions are faster and able to measure different parameters simultaneously in many applications

With more than 50 years of experience in optical technologies, Polytec has a deep understanding not only in measurement techniques, but also in the daily challenges, needs and expectations of users around the world.
In the highly complex field of topography metrology, we want to share our knowledge and our experiences with you. We hope to inform and inspire you with this publication “Surfaces in the right light”. From applications in different branches and technology background to sectorial trends. If you have questions or need more in depth information, please do not hesitate to contact us!
For now enjoy the reading.

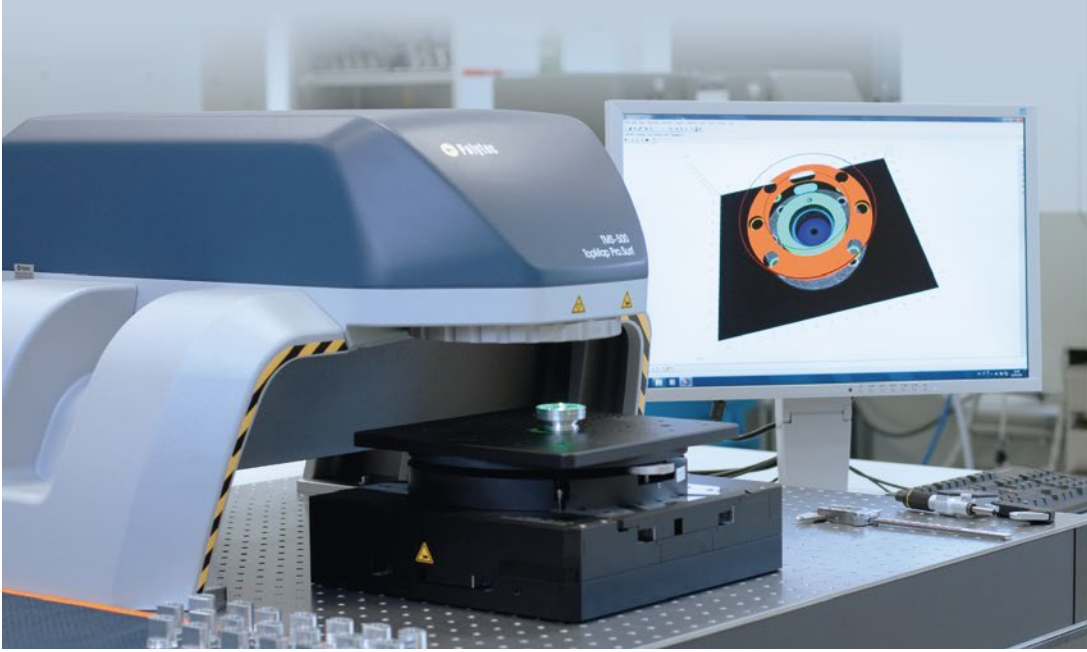
Best regards

Dr. Dietmar Gnass
CEO

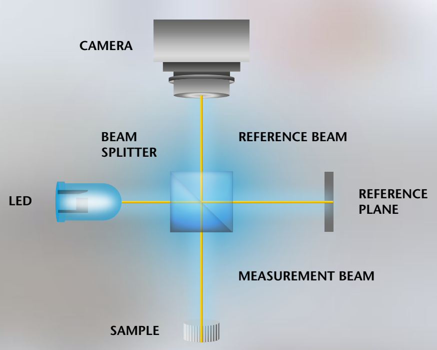
Dr. Dietmar Gnass
CEO Polytec GmbH

Areal surface measurement with white-light interferometry

Structured functional surfaces with tight tolerances require high-precision measurement systems that quickly scan the topography of a workpiece. Well-established white-light interferometry achieves a resolution at the nanometer scale.



Principle of scanning white-light interferometry



Why measure with light?

!

- Non-contact, non-destructive and repeatable surface characterization
- Full areal information in 3D to capture all surface details
- On almost any surface
- Excellent lateral resolution
- Check manufacturing tolerances in a short time

Why measure with TopMap white-light interferometers?

!

- Large field of view even without stitching
- Objective-free design avoids risk of collision
- Smart Surface Scanning Technology measures on almost any surface independent from reflectivity
- High precision and repeatability
- Easy to automate
- Excellent vertical resolution independent of objective magnification

Characterize form parameters with a large field of view

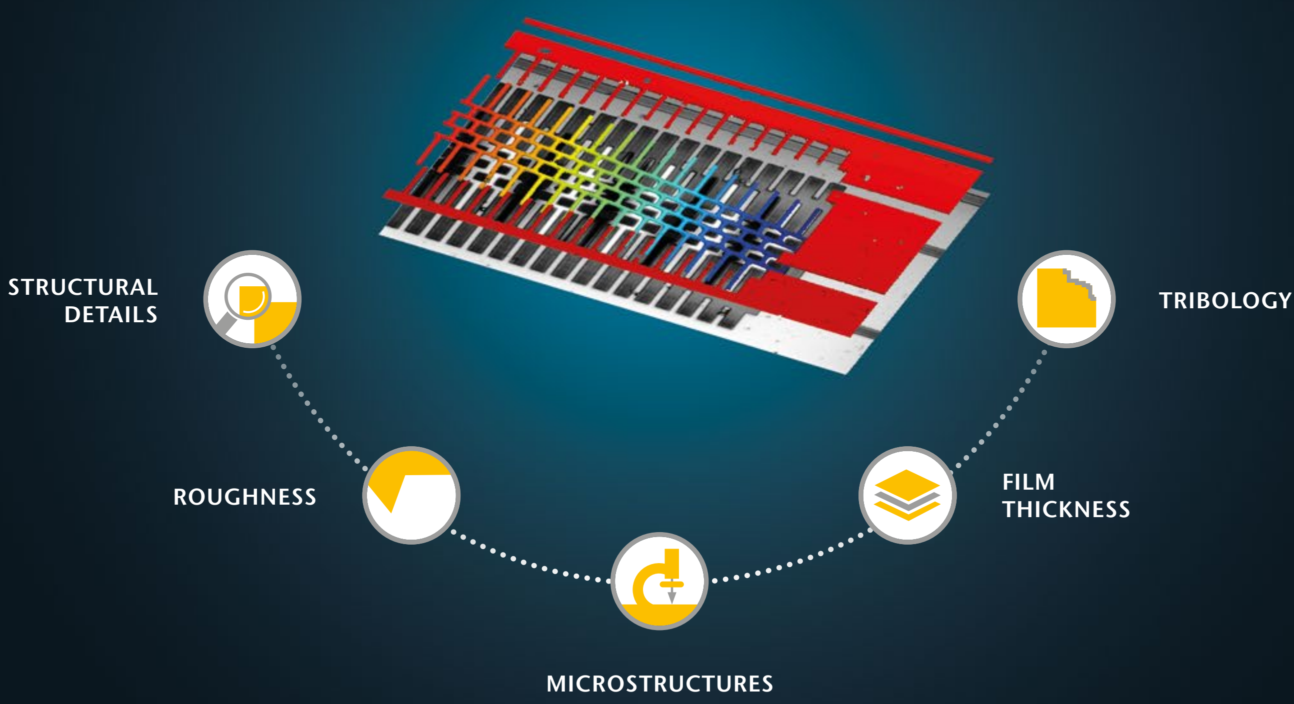
Measure flatness, waviness and more

Regarding functional surfaces, flatness is often decisively important. Examples are parts with sealing surfaces for pressure and vacuum technology, and also transparent foils for displays, semiconductor components, metal and ceramics surfaces. TopMap systems allow an areal measurement of large surfaces up to a volume of 230 x 220 x 70 mm³ and therefor provide a fast, reliable and complete characterization of your workpiece.

Analyze multiple surfaces

Determining parallelism, height differences or angles between several surfaces often require a large vertical measurement range. TopMap large FoV systems offer vertical range up to 70 mm which allows you to measure surfaces separated by high steps or located at the base of drilled holes. The telecentric optical design avoids shadowing effects.

Characterize structures with high resolution



Characterize microstructures

Functional surfaces often require certain structures. For example, it can be important to characterize the type and distribution of pores used to hold lubricant between frictional surfaces in tribology. Besides, microstructres show a key role for improving the adhesion of coatings in the steel industry. Unwanted structures may increase frictional forces or cause disturbing vibrations.

Evaluate roughness

Characterization of roughness is a must-do, particularly when wear properties, lubrication or the bearing load of product surfaces need to be subsequently optimized. Information with micrometer and nanometer resolution is crucial for characterizing texture and for improving evaluation methods.

We talked with Prof. Dr.-Ing. Prof. h.c. mult. Dr.-Ing. E.h. Dr. h.c. mult. Albert Weckenmann, former professor at the University of Erlangen-Nuremberg, Germany, about the limitations of tactile surface measurement technology and the opportunities of non-contact methods.

“Optical surface metrology complements tactile measurement techniques”

Polytec is headquartered in Waldbronn and you were also born in Waldbronn. Can we say that Waldbronn is famous for its experts in metrology?

That’s a nice question for an introduction. Well, we are both working on making Waldbronn known as a nucleus for metrology. Waldbronn became known as the cradle of high-quality metrology with the establishment of Polytec. When I made my decision to dedicate myself intensively to metrology, I still had to "emigrate" in order to meet like-minded people and to find the right technical-scientific environment.Today, Polytec is a kind of incubator for young professionals as well as a flourishing company. This shows our young researchers how successful you can be with metrology, and at the same time, how interesting optical measurement technology is. So it can surely be said that Waldbronn's atmosphere offers a globally successful climate that at least favors metrology and offers great perspectives to interested people. Today it is no longer necessary to "emigrate" in order to make a fortune in metrology.

Why do you think manufacturing metrology is still dominated by tactile methods and what should be done to get a higher acceptance of optical methods?

There are historical reasons. Surface parameters were defined for the first time in the middle of the last century when the expert community put its faith in tactile methods. Other methods were simply not available. At that time there were neither optoelectronics nor computers. Only tactile measurement parameters could be defined for specifying workpiece surfaces, established in standards and noted on technical drawings along with which measurement instruments were available at that time. Technologies have since advanced in terms of surface requirements, manufacturing procedures and measurement techniques. When well defined, established and standardized parameters are changed, the entire chain – from standardization via design, manufacturing, quality assurance up to the measurement techniques and the interpretation of the results must keep pace with – the development. Almost all of the people involved in specifying, manufacturing and quality assurance, such as operators, technicians and engineers, must be retrained, and the question arises whether the "old" technical drawings are still valid. So there are some very good reasons why people involved with production measurement technology have very conservative attitudes. Optical methods are therefore being introduced very tentatively into surface measurement technology. The acceptance can be accelerated only moderately through measures that are aimed at conviction and acceptance. This in turn means investment in trade fairs, printed material, measurement examples, discussions, training courses and so on.

As an expert in the field of metrology, which advantages of optical surface measurement techniques provide the most benefits to the end-users?

The benefits range from the fast, two-dimensional application to the capture of a three-dimensional topography with an extremely high density of points. Also, the evaluation procedure should be appropriate to product functionality. Unfortunately this is missing in most cases. Today, industry has the most experience with tactile techniques and if a new approach like optical is introduced, users always want to compare the results. It is however not always possible to compare them directly. What can you say about the conditions required to compare results from two different measurement techniques? It is better not try to compare results with one another. The comparison is misleading in all aspects. By the way, what can be done with the measurement result? If you want to determine the expected functionality, then many of the standardized parameters such as Ra, Rq, Rz and others are hardly of any use for it. Nobody can and should aim

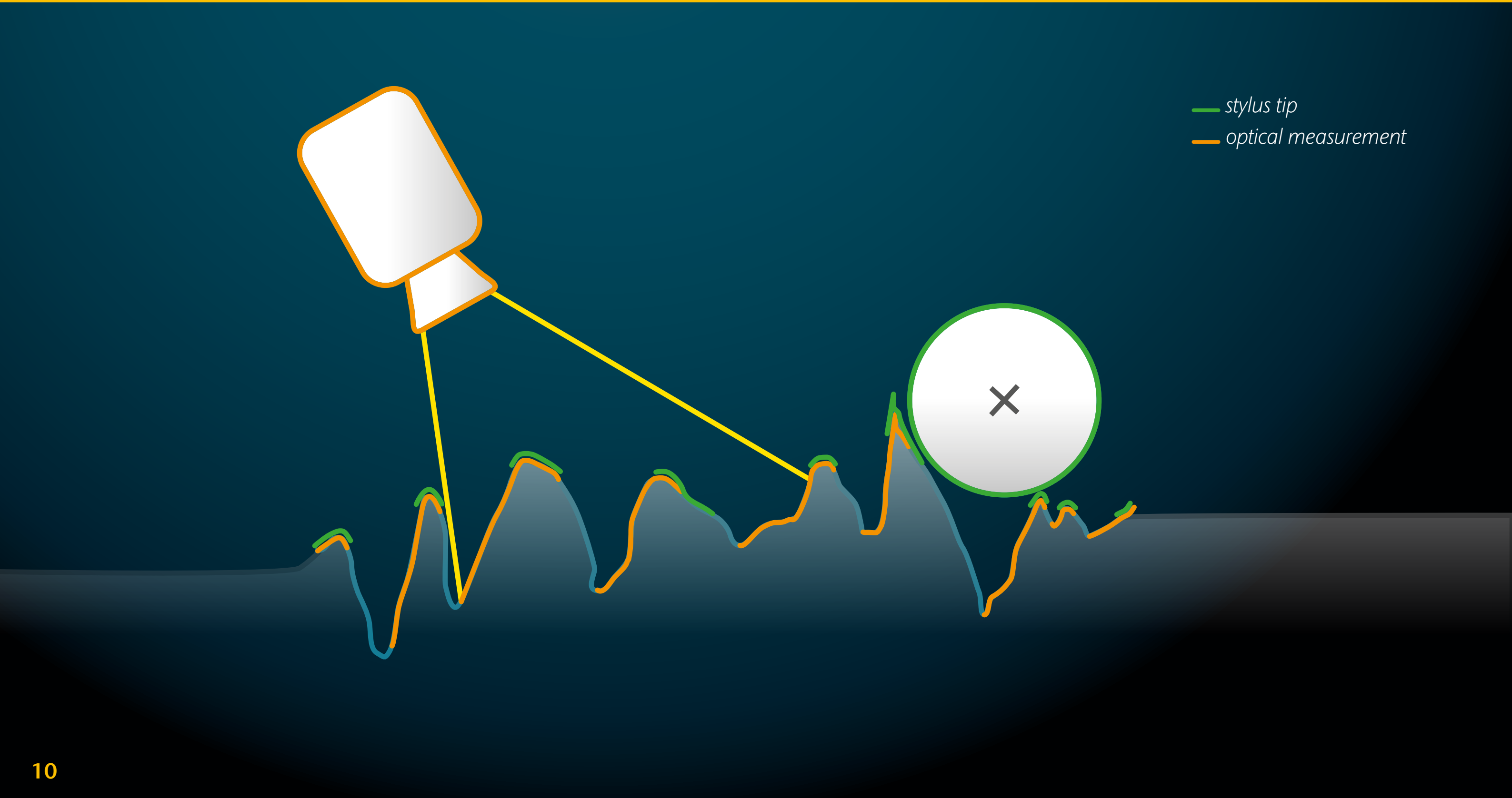
Characterization of precision parts with different surface parameters to replace tactile measurement technology. In areas where this technology is established, it will continue to be applied. It makes more sense to use the many fold advantages of the optical data acquisition for new applications and to extend the computerized evaluation in such a way that the degree of the expected functionality can be predicted. There are different optical methods for characterizing surfaces. Each one has its advantages and limitations. The end-user wants to see results, or in other words his or her aim is to characterize the product or process based on the measurement results. From this point of view, how would you define a measurement result that satisfies the end-user? Surface measurements are carried out with two main goals. One is to predict the functionality, in other words: how well it fulfills the functional requirement; the other is to correct the production process. When the measurement provides the expected and required information with the necessary precision, under the prevailing ambient conditions and within the time frame which is necessary for the process management, then the end-user is satisfied. Polytec's optical surface measurement instruments work according to the principle of white light interferometry. However, different from other manufacturers, large measurement fields (up to 30 x 40 mm) can be acquired with fine vertical resolution. This high level of information is available very quickly, especially for applications where function-oriented surface characterization is required.

As a pioneer in the field of function-oriented characterization of technical surfaces, which other aspects are also beneficial for the end-user?

> "The user has to choose the most suitable method for his measurement task."

Many parameters have to be taken into account: What area of the workpiece should be measured and what is the material, the function of the surface, the manufacturing process, the parameters of the manufacturing process, the envisioned topography, ambient conditions, integration into networks, connection with Industry 4.0 structures and many more. In every case, the user should consider before the measurement, whether there is any need to measure at all and how the measuring

See more details



effort can be minimized. There is only a need to measure what will be processed further, required for documentation or necessary in the event that there are complaints or liability claims. Costs can be saved if nothing will be done with the measurement results! Although the level of available information about products in micro- and nanometer dimensions is increasing (thanks to optical methods), industry is still trying to solve problems with macro-dimensional methods.

You are an expert for GPS (geometrical product specifications) so what can you say about the future of GPS for this new field?

The GPS tolerancing system will definitely be required in the future; after all, we do not only have micro-nano parts! For micro- and nanotechnology (e.g. structured surfaces with a resolution in the nanometer range), constructive, creative solutions have to be invented - in particular a specification system compatible with GPS or a new tolerancing system. A simple reduction or miniaturization of the processes and parameters would not be enough – considering the laws of the physics – because the aspects of physical principles require other measures.

Rotational movements, for example, which are mainly used in the macro area are no longer applicable in the nano area. Elastic torsional and bending movements are being increasingly used; this forces us to develop new ways of thinking for the realization of functional requirements and the design of components.

How would you characterize the future of optical surface measurement instruments?

The application of optical surface measurement instruments will increase steadily but slowly.

> “Optical measurement technology will not displace tactile surface measurement technology, but complement it.“

Measurement principles and the measurement techniques based on them have been developed to become efficient measurement instruments which comply with requirements and constitute a solid basis for further developments and adaptions to the respective purposes. Optical measurement technology will be used at an increasing rate for micro and nano technologies among other things. After the development of instruments, which have already achieved a high level, now the focus must be evaluation. After a function-oriented specification of the parameters, something new must be created for verifying the manufactured components in order to evaluate them.

In future, nobody will be interested in contemplating „data graveyards“. Existing knowledge about product functionality should be used in a way that the degree of product reliability can be inferred from the measurement result.

And last but not least: The metrology must also be suitable for Industry 4.0 and AMP 2 (Advanced Manufacturing Partnership). This is a challenge for all companies, but especially for those branches that are oriented towards quality assurance.

I wish Polytec the best of luck and always the right ideas to meet these challenges. The surroundings of Waldbronn with the KIT in Karlsruhe and the University of Stuttgart a little bit further afield, with their committed and ambitious institutions as well as numerous manufacturing companies in the region, are an excellent environment to meet the challenges of the future.

Prof. Dr. Weckenmann, we thank you for this interview and wish you the very best for your future.

Contact

Prof. Dr.-Ing. Prof. h.c. mult. Dr.-Ing. E.h.
Dr. h.c. mult. Albert Weckenmann

Formerly Chair QFM – Quality
Management and Manufacturing Metrology
University of Erlangen-Nuremberg, Germany

albert.weckenmann@albert-weckenmann.de

Polytec had the chance to interview Prof. Dr.-Ing. Jörg Seewig, Chair of Metrology and Sensor Technology at the TU Kaiserslautern, about optical in-process measurement technology in the automobile industry.

The advantage of cost-efficiency

Professor Seewig, what are the main points of focus for you as Chair of Metrology and Sensor Technology?

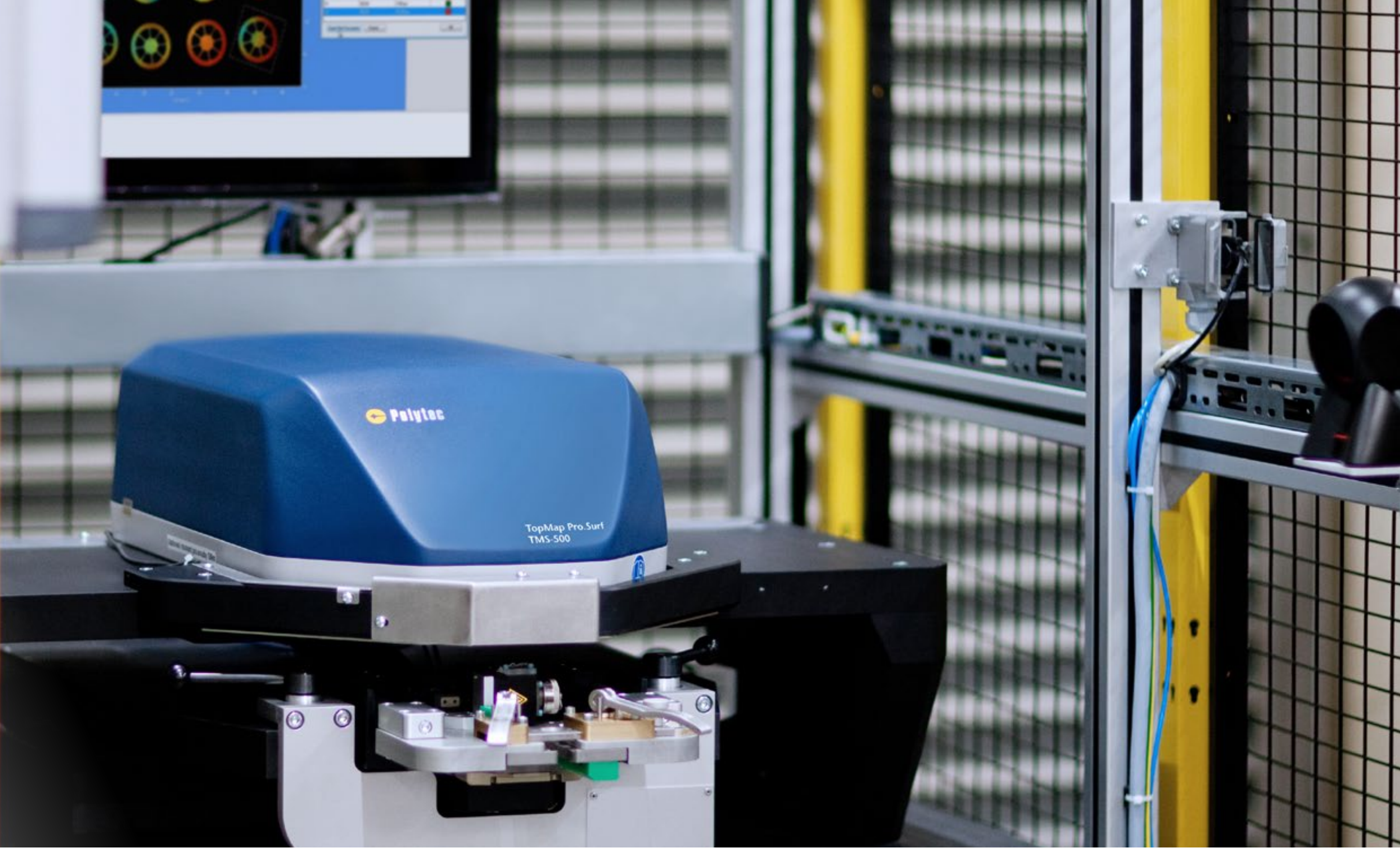
We are working on the basic principles and applications of optical metrology in manufacturing processes. We are still working out what our focal points will be as we are still in intensive discussions with our expert colleagues, for example from mechanics, manufacturing technology, material sciences and tribology. One main theme in these discussions is optical inprocess measurement technology, where a combination of surface measurements and material characterization is particularly appealing. This, in particular, affects composite materials. Apart from that, we are working on questions of parameter identification and the analysis of measurement uncertainty. Here we find it very exciting how we can include the knowhow from the other areas, for example, from manufacturing technology, the a-priori knowledge of manufacturing tolerances or from mechanics, modeling of material properties.

To what extent have the optical measurement techniques – that are new for many users – already found their way into use in the automobile industry and what is your opinion on their future importance?

In this industry, surfaces are still predominantly measured in the classic way, for example using tactile processes. There is a historical reason for this – the scale drawings all refer to the standards that have been prevalent so far. But the industry is increasingly using optical processes as well. There is a high level of interest in optical measurements in manufacturing where many different types of functional surfaces need to be tested that cannot be characterized by a simple profile section, for example particle surfaces or structured surfaces. In particular, the possibility of being able to measure surfaces directly on the production line is very exciting to larger car manufacturers; however, there is still no industrial standard that describes the measurement procedure in detail.

As a specialist directly involved in this field, what is the status of the forthcoming industrial standard for optical procedures?

The ISO 25178 standard which defines "Specification and measurement of 3D surface texture", also covers optical 3D surface measurements, and while it is quite extensive, it does not necessarily help in practice. This is why, independent of the ISO standard, industry users are being asked to define standardized measure-



ment procedures with good reproducibility that are applicable to 3D optical surface measurements. After all, reproducibility of measurement values for measurements made at different times and in different locations is more decisive in the quality management chain than the requirement for traceability to a calibration standard. Instrument manufacturers such as Polytec provide excellent support in the development of stable measurement systems and standardized measurement processes that are optimized for their respective application.

What do you consider to be the most important advantages of optical surface measurement techniques?

In comparison to the tactile measurement techniques, optical procedures are fast, particularly with functional surfaces, as they acquire the entire surface in one pass. The high precision of the measurement is an important advantage because tooling machines are becoming increasingly precise and shape tolerances of the workpieces are becoming ever tighter. After all, according to the golden rule of metrology, the measurement uncertainty should be a factor of 10 below the tolerance specification. In addition to that, optical procedures offer the possibility of automatically optimizing the instrument setup thus generating an optimal set of parameters. In this context, cooperation between specialists from the instrument manufacturers and users on workpiece-specific evaluation of a stable measurement and evaluation process is of great importance.
The combination of short measurement times and using new optical measurement techniques in an early stage of the process chain also results in high overall cost-efficiency – an advantage that is currently very important to all manufacturers.

Contact

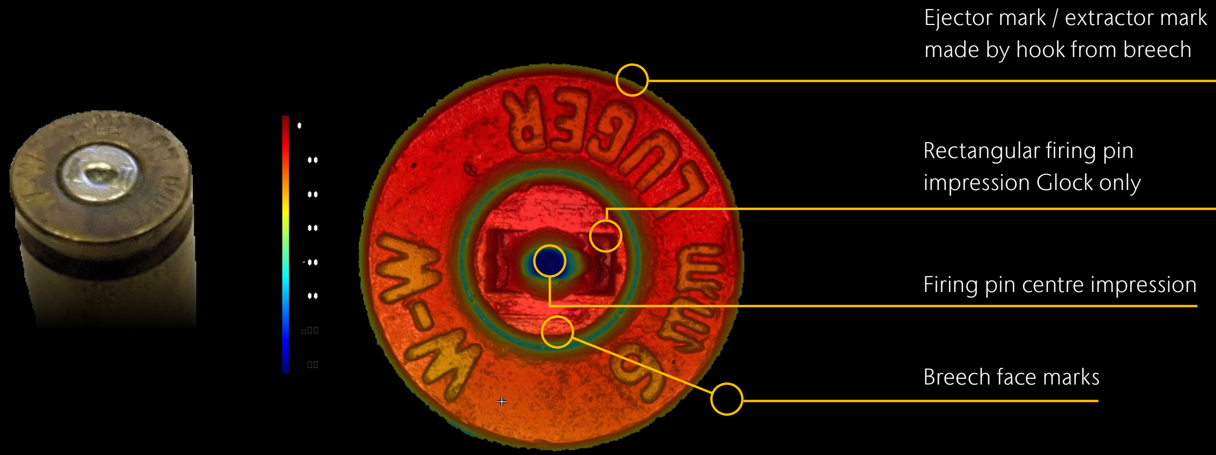
Prof. Dr.-Ing. Jörg Seewig,
Chair of Metrology and Sensor Technology
at the TU Kaiserslautern

The smoking gun

Forensic science plays a vital role in the criminal justice system by providing scientifically based information through the analysis of physical evidence. During an investigation, evidence is collected at a crime scene or from a person, analyzed in a crime laboratory and then the results are presented in court. Surface metrology (the science of measurement) can be used to study surfaces for the finest of physical details. This finest of information can be used to show how a surface was generated.


5
5

Macro scale Glock cartridge
9 mm



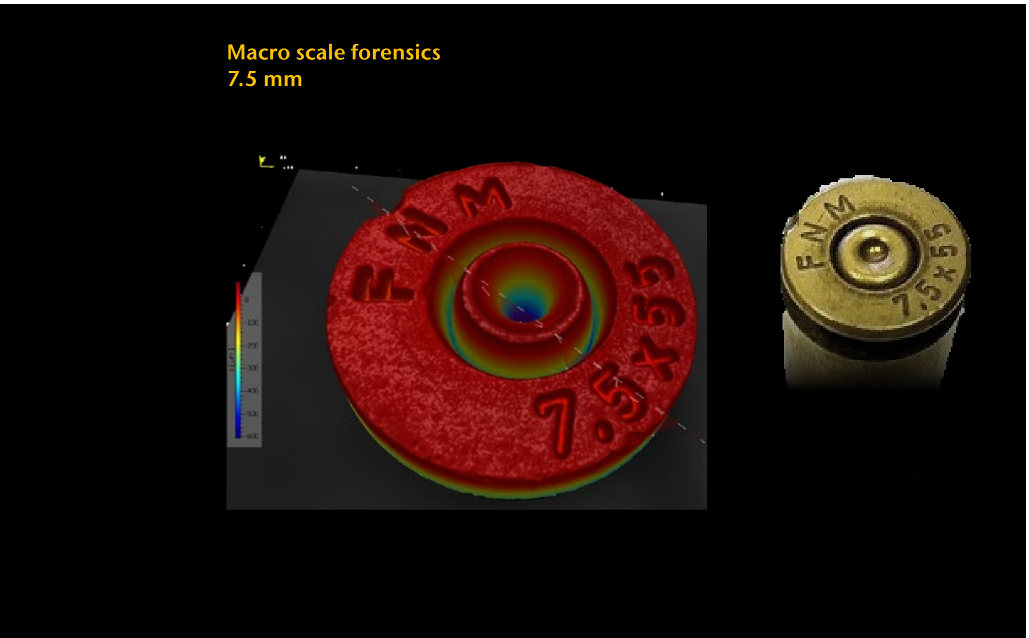
The various spatial scales of information contained within each impression relate to groups of information regarding the firearm it was fired from. Larger scale information relates to the machining processes used on the firearm, and can therefore be used to determine the manufacturer of the firearm. Smaller-scale spatial information may be individual to the one particular firearm, and originate from handling/storage.

Macro Scale Ballistic Tool Mark Identification

When a cartridge is fired from a gun, tell-tale markings are transferred from the inner surface of the firearm resulting in plastic deformation of the cartridge. The firing pin hits the primer cap of the cartridge, igniting the primer which in turn causes deflagration of the main propellant. This main propellant forces the slightly oversized bullet through the barrel of the gun, in which it is shaped by the rifling marks of the inner surface. Simultaneously, the cartridge case will be forced into the breech face of the barrel, thus imparting machining marks onto the cartridge base. Finally, the cartridge case is extracted from the breech of the firearm, leaving another impression on the cartridge.

Current ballistic tool mark identification techniques rely on the imaging of these tool marks using grey-scale microscopy, which is arguably a subjective and unrepeatable methodology. Using areal acquisition, height information of the tool mark can be accurately and objectively gained. Therefore, a shift to the areal acquisition would be a benefit in criminal proceedings, where the accuracy of the information could not be cast into doubt.

Here the surface topography information was captured using the TopMap Pro.Surf from Polytec. The TopMap Pro.Surf is a macro lens coherent scanning interferometer. This instrument offers a large field of view allowing the whole object to be measured within a single data collection routine, which greatly speeds the measurement process when you need non-contact 3D areal base surface topography. The Z-resolution is to the nanometer level providing high resolution to the finest of detail. The technology of data collection can cope with polished, rough, dark and light surface types. All these surface effects are present on the end of the cartridge. Through the lifetime of the cartdridge its end surface undergoes many changes and a final physical transformation at the point of firing. It gets polished, pushed, pulled, coated in carbon and ends up becoming a multi-faceted surface with different reflectivities and surface texture types.



Firearm examination is a forensic tool used to help the court determine whether two bullets were fired from the same gun barrel. During the firing process, rifling, manufacturing defects, and impurities in the barrel create striation marks on the bullet. Identifying these striation markings in an attempt to match two bullets is one of the primary goals of firearm examination.

Conclusion

Appropriate, high accuracy surface metrology practices and equipment are critical for the advancement of forensic science. Evidence that can be proved to be quantifiable could not be cast into doubt and could prove critical for any legal court proceedings.

Non-contact 3D areal surface topography from Polytec has been proven to be fast, stable and repeatable. The TopMap Pro.Surf although traditionally designed for the industrial manufacturing market, with it’s innovative optical measurement technology has shown itself to be suitable for challenging forensic measurements.

Contact

Dr. Katie Addinall
The Future Metrology Hub
University of Huddersfield
k.addinall@hud.ac.uk

Joe Armstrong
Sales International
Business Unit Optical Measurement Systems
Polytec GmbH, Germany

How fair are specifications in optical surface metrology?

“Fair Datasheet” as a guideline for comparing specifications of different optical surface measurement systems

In manufacturing metrology, measurement results are the necessary feedback for monitoring and regulating the production. While surface metrology checks sample tolerances, the evaluation of the entire topography of work pieces provides valuable hints for the production process itself.

With the right evaluation procedure on measurement data, manufacturing benefits from additional information like the presence of environmental vibration, unbalanced machining conditions, wear or changing material properties. In the end, the selection of the right measurement technique regarding surface inspections is key for quality, functionality and durability of produced parts. So what details should we look for in the selection process? Datasheets provide general technical specification and are crucial for the decision. But are datasheets standardized enough, so technicians and purchase departments can compare them easily? The specifications comprise general information about the metrological performance of a particular optical instrument, like vertical or lateral resolution, but the measurement of specific samples remains a quite individual task.

First of all, there are many more factors like environmental conditions, individual characteristics or the sample material itself, which should be considered. And the determination of the measurement uncertainty, when considering many influencing factors (operator, sample, environment, ...) is the right way to understand the "measurement" itself. The measurement uncertainty is a strong method which can be estimated by declared and accepted procedures, described in the *ISO Guide to the Expression of Uncertainty in Measurement* or GUM, published in 1993. Though the measurement uncertainty is specific to a measurement and not a characteristic for the instrument, on the other hand any information in datasheets regarding measurement uncertainty is helpful.

Secondly, there are different approaches in the datasheets of optical surface metrology on what to specify and how to specify. This shows differences among available datasheets, as the conditions under which they are specified are not always clear and practice-oriented, which makes datasheets not comparable and the customers are left alone.

Looking at elementary specifications like the lateral and vertical resolution for optical surface measurement instruments, we can even see different approaches from manufacturers from Europe, Asia and North America.

Varying definition of the lateral resolution

Originated from microscopy (not optical surface metrology), two peaks are accepted to be resolved if the image complies with the Rayleigh's criterion. To get the shortest distinguishable distance between two points, Lord Rayleigh said, that two points are resolved if the distance between them is larger than the distance between the main maximum and minimum of the diffraction pattern. Thus, the resolution is a function of the wavelength (λ) and the numerical aperture (NA) of the objective:

$$\text{Lateral resolution} = \frac{1.22 \cdot \lambda}{2 \cdot NA} = 0.61 \frac{\lambda}{NA}$$

The achieved minimum separation between resolved asperities determines the best lateral resolution of the system. The Sparrow criterion, however, calculates the resolution with a factor appr. 20% smaller than the Rayleigh factor. This means, Sparrow is not as strict as Rayleigh and the calculated resolution is specified smaller. Regarding the lateral resolution, some manufacturers specify according to the Rayleigh criteria, some follow the Sparrow criteria and others even use their own definitions.

Comparing approaches for lateral resolution	
Manufacturer A	*"Lateral Resolution = Sparrow criterion"*
Manufacturer B	*"Spatial sampling = Pixel size on the surface. Optical resolution = Half of the diffraction limit according to the Rayleigh criterion. Values for white LED. Spatial sampling could limit the optical resolution."*
Manufacturer C no direct information in the data sheet	*"Width measurement accuracy: Value obtained using manufacturers` specified standard gauge with measurement in manufacturers` specified measurement mode."*

Different approaches for vertical resolution

From a practical point of view, the term "vertical resolution" basically tries to specify the smallest step-height measurable before the measurement data disappears in noise. An approach for reducing noise is repeating the measurement and taking the average, which in a real production environment is hardly possible.

Comparing approaches for vertical resolution	
Manufacturer A no direct definition but related information in the foot notes	Footnote 1) *"Repeatability of the RMS surface roughness parameter Sq, under the same conditions as for (2). Note that the repeatability of the Sq is sometimes referred to informally as vertical resolution."* Footnote 2): *"Surface topography repeatability for SmartPSI mode, 1-sec acquisition, full FOV with 3x3 median filter, in a lab environment"*
Manufacturer B	Vertical resolution: *"System noise measured as the difference between two consecutive measures on a calibration mirror placed perpendicular to the optical axis.* *For interferometric objectives, PSI, 10 phase averages with vibration isolation activated. The 0.01 nm are achieved with Piezo stage scanner and temperature controlled room."*
Manufacturer C	A value for vertical resolution is provided, but no information about how to calculate / measure.

The rising need for comparison

- Identical definitions are lacking, which allows manufacturers to define their own attractive values.
- Datasheets are not comparable and can easily confuse non-expert users, possibly resulting in sub-optimal investment decisions.
- Values can be obtained under ideal conditions or with some averaging techniques. But those are not practice-oriented and in most cases, it is not the information that a customer looks for.

The fair datasheet

An association consisting of optical surface instrument manufacturers (e.g. Polytec, Alicona and Nanofocus), key users of such equipment (e.g. Audi, Bosch and Daimler) and scientific supervisors (Technical University of Kaiserslautern, PTB Physikalisch Technische Bundesanstalt and industrial institutions like ZVEI and VDI) have developed the “Fair Data Sheet”. The results of the working group not only cover the definition of metrologcial features but also recommend a general structure for datasheets in optical surface metrology. The full version of all documents, issued by the Fair Data Sheet Initiative can be downloaded on
http://optassyst.de/fairesdatenblatt/

The approach of the Fair Data Sheet allows the comparison of different instruments and technologies with each other, and it also helps manufacturers in purchase processes by providing understandable and reproducible specifications.

3D measurement on shock absorber pistons

When manufacturing pistons for automobile shock absorbers, very tight tolerances must be adhered to regarding shape and surface parameters, and this despite high throughput. It is difficult for tactile measurement systems to attain the necessary reproducibility because of the discontinuous shape of the workpiece and the low position of the surface to be measured. White-light interferometry as an optical measurement technology in contrast provides an areal 3D data acquisition of the entire surface and all faces within seconds with a high level of repeatability.

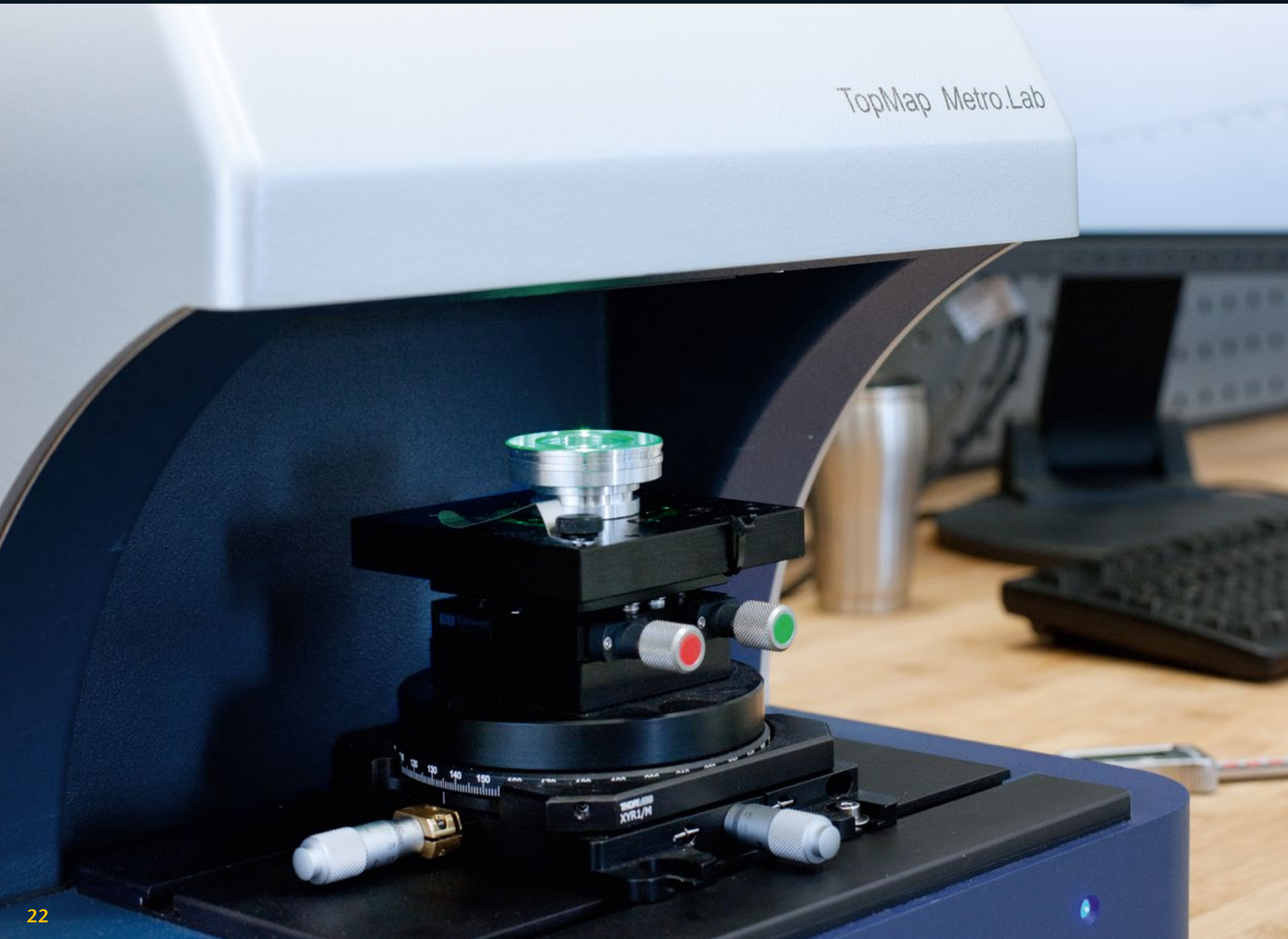


Figure 2: 3D optical surface metrology measures and visualizes step height, parallelism and further form parameters in a single measurement

Requirements of shock absorber pistons

Shock absorbers absorb vibrations or dampen movement. Their widespread use in industry and in the automobile sector have given rise to numerous technical solutions for various problems. In a motor vehicle for example, shock absorbers are safetyrelevant components and are also important for comfort.

Conventional car shock absorbers convert the kinetic energy into heat. This is done through resistance that a working piston has to overcome in a tube filled with oil. Shape and parameters of the piston are optimized for the special damping properties of the respective task. The working piston has orifices to allow flow through.

The shape of particular surfaces impacts on the flow characteristics. The workpiece may also have to be manufactured to fit additional components precisely, such as valves. This means that tight tolerances need to be complied with, even when producing larger numbers of pieces. White-light interferometry over large surface areas is very appropriate for quality control of such components. So far, surface measurements have predominantly been carried out using tactile methods. With this method however, measurements on flatness and waviness parameters and determining height differences, flatness or parallelisms is difficult and time-consuming. For tactile measurement systems, the uninterrupted shape of the workpiece and the deep position represent a great challenge when trying to achieve the necessary reproducibility.

3D characterization of the piston

White-light interferometry as an optical measurement technology provides the topography of all the surfaces within seconds, with a high level of repeatability. In Figure 2 you can see a 3D profile of the faces in the piston interior and in Figure 3 the topography of the lateral face

Figure 3: Topography of the lateral face and of two inner faces.

and two deeper interior faces. Polytec TMS software enables hiding certain regions by setting masks to analyse individual sections with more details. Figure 4 shows the upper face with its lacerated inside edge and the profile of deeper inside ring faces.

The geometric parameters, such as angles, slopes or height differences can easily be determined. Determining circular line profiles is also possible. For rotationally symmetric surfaces, this is the center of the circle which can also be ascertained automatically with the aid of software. Starting which such an „anchor point“, it is possible for example to evaluate a circular line profile with a constant position on the workpiece. As whitelight interferometry over large surface areas covers entire surfaces in one measurement, you can determine the values for parallelism and flatness very quickly.

White-light Interferometry in manufacturing

Even though this method can be used to determine deviations in the complete topography in manufacturing often only a few parameters are relevant for quality control. In the above example, these were the height difference between the two ring surfaces and their flatness. Such measurements can be made automatically.

Thanks to the concept of measurement recipes, all acquisition and evaluation settings of a measurement can be saved and the operator performes the measurement with just one click.The program can issue the measurement values with additional information, such as parts number, date and time, etc. Depending on the measurement task, the measurement may only take a few seconds.

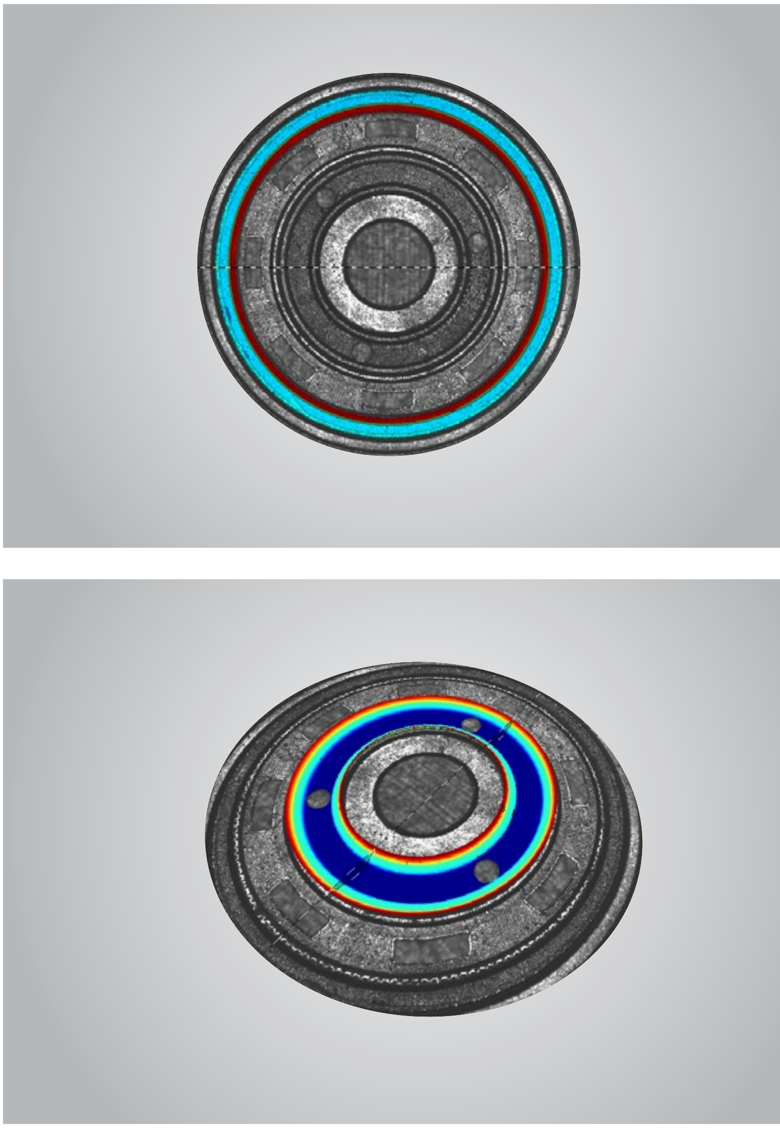
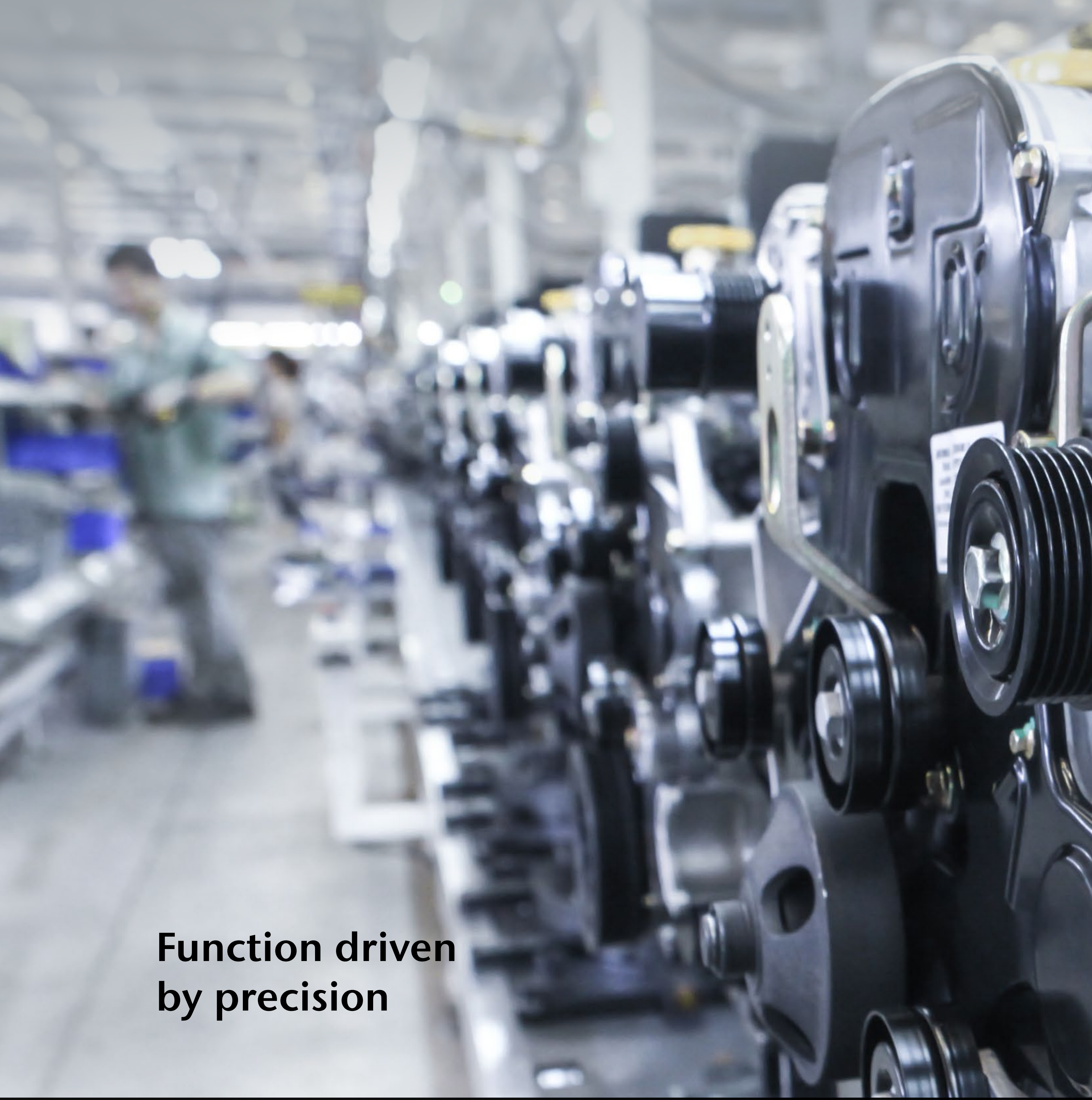
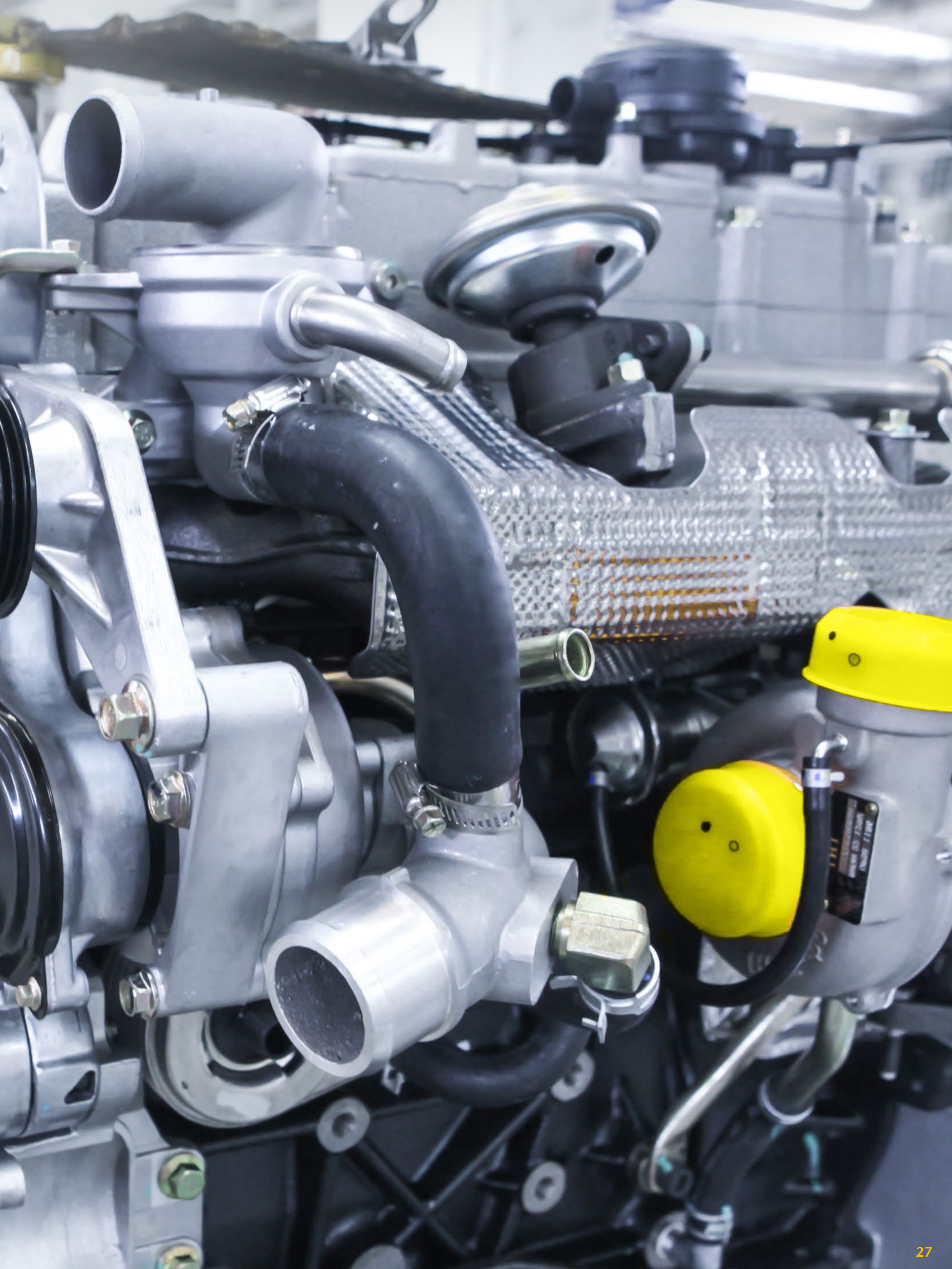


Figure 4: 3D and line profile of olnly the upper face (above); 3D profile of the deeper ring face (below)



Function driven by precision

Implementing and standardizing optical measurement methods for a better surface characterization in the industry. Combustion engines should offer fuel efficiency and emit hardly any pollutants, while offering ample performance and a high level of driving comfort. This requires the optimum interaction of all components. In turn, this demands compliance with precision shape tolerances for the individual functional components. For the manufacturer, this means that compliance with these tight tolerances must be guaranteed during quality checks in manufacturing to preclude customer complaints or even recalls.



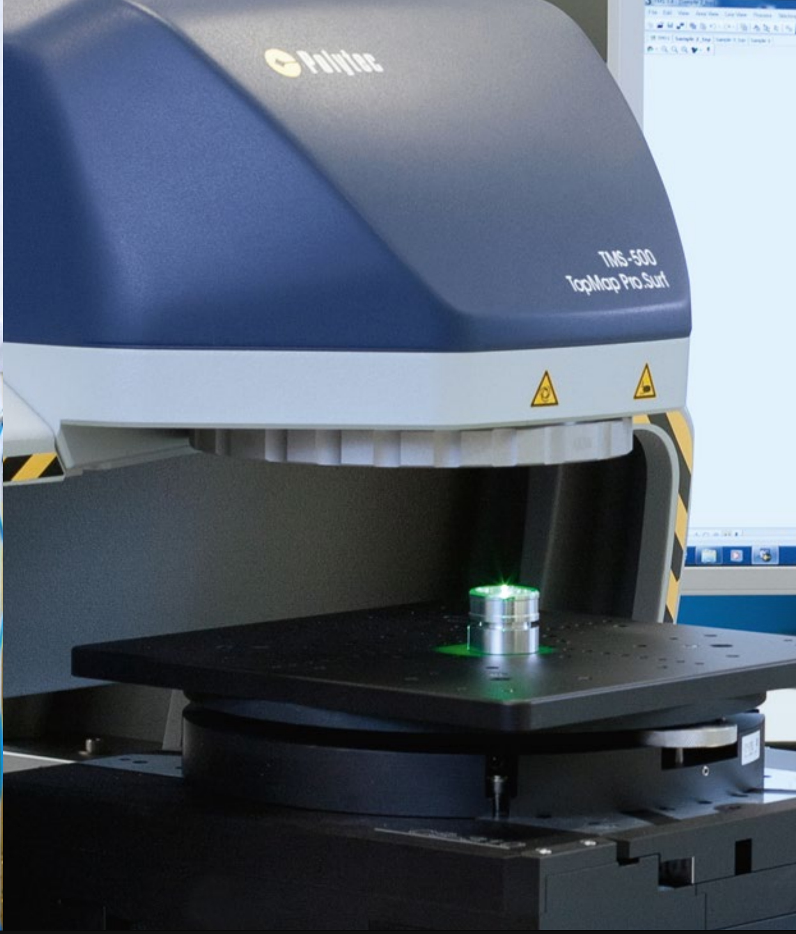


Figure 2: TopMap Pro.Surf sensor integrated into a production line

Figure 3: Measure in hard-to-reach areas like holes with a special optical design and a 70 mm vertical scan range

High vertical precision with a large lateral field-of-view

In many cases, flatness measurements are critical for the functionality of a surface and this may be related to several individual surfaces, Stylus (contact) profiler methods have been used to characterize surfaces for a long time. With these methods, the tolerances are inspected using individual measurement points or through linear scans. Line-only profiles are often inadequate, especially when the entire surface must be analyzed to determine flatness or parallelism. To determine the surface topography using stylus methods, many parallel line profiles are recorded and combined into a single surface. These measurements are very time-consuming and are not acceptable in production quality control situations where throughput is critical. Because fast measurements over large surface areas are easily accomplished using optical measuring methods, these techniques are increasingly in use for production applications.

In many cases, flatness measurements are critical for the functionality of a sample and this may be related to several individual surfaces, such as the relation of the surface at the bottom of a blind hole and the surface at the top of the hole. For such applications white-light-interferometry is a great solution, since the vertical resolution is independent of the lateral field-of-view. This enables the measurement of large surfaces with high vertical resolution. Polytec developed the TopMap white-light interferometers for mastering these measurement tasks. This product line offers an excellent price/performance ratio and can, for example, quickly and reliably measures flatness, roughness parallelism and step height. As in the example shwon in Figure 2, TopMap Pro.Surf was designed to be integrated into production lines.

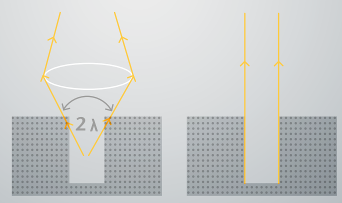


Figure 4: High aspect ratios can be easily characterized with telecentric optics used in Polytec large FoV systems

Figure 5: Protection housing for harsh production environments

Measuring flatness, roughness, and parallelism in quality control

Top and bottom workpiece surfaces displayed in Figure 3 are to be inspected for flatness, roughness and parallelism, where one surface is 60 mm deeper than the other. The TopMap white-light interferometers with its vertical scan range of up to 70 mm and a telecentric optical path is the ideal solution for completing such measuring tasks. The light beam virutally runs parallel to the object (Figure 4) and, unlike microscopes with their cone-shaped beam patterns, the telecentric optics of TopMap large field-of-view (FoV) white-light interferometers do not show shadows and even reach deeply recessed surfaces.

The surface of the workpiece to be measured can be smooth or rough, dark or light, with a specular or a light-scattering surface. A special measurement and analysis algorithm Smart Surface Scanning technology ensures excellent results, even if the surface has spatially varying optical properties. The measurement duration depends on the task at hand and usually takes only a few seconds. The concept of „measurement recipes“ also allows you to easily automate routine measurements and ensures that the necessary data is acquired for a pass/fail analysis or for external quality assurance software.
If the measurement is to be taken on the production floor, Polytec offers a dust-free and vibration-insulated protection housing (Figure 5). With very fast measuring speed, the TopMap systems can easily hold up with the required cycle times in production.

Quality around the clock

The surface quality of watch and clock parts depends on white-light-interferometry. Optical metrology is gaining importance for quality assurance of precision micro-parts. Fast, high resolution measurements using a non-contact, non-reactive (zero mass loading) optical technique are particularly appealing for micro-parts. This story takes a closer look over the watchmaker's shoulder to see, how white-light interferometry can support their precision engineering.

Figure 1: Close-up of the pure date disc of a clock (diameter: 21 mm)

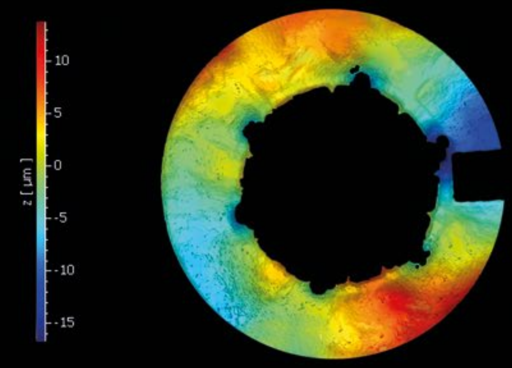


Figure 2: Respective flatness evaluation of the date disc, using a TopMap In.Line surface profiler

Flatness of a date disc

In contrast to several other optical surface metrology methods, such as fringe projection or focus variation, white-light interferometry can be used for measurements on both rough and optically smooth surfaces. Whereas the well drive and the bottom plate are rough metal surfaces, the date disc (Figure 1) is an optically smooth and reflective plastic surface with an external diameter of 22 mm. The flatness has to stay within 50 µm as this is crucial for its functionality. Figure 2 shows the measurement result performed with a TopMap In.Line surface profiler.

Surface roughness of a minute wheel

Figure 3: Minute wheel drive

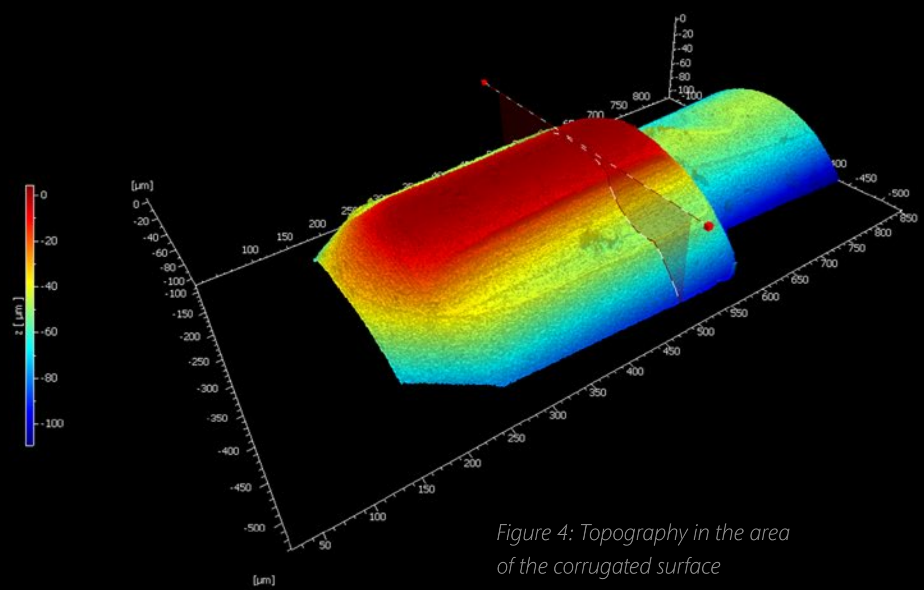


Figure 4: Topography in the area of the corrugated surface

A minute wheel drive from a watch is shown in Figure 3. To verify manufactured quality, the surface roughness on the inclined area, which is about 100 x 300 µm² must be measured. Making the measurement using a tactile instrument is a problem due to the geometry of the measurement area on the other hand optical techniques such as white-light interferometry allow the topography to be captured within a matter of seconds. In Figure 4, the results of such a measurement using a Polytec TopMap µ.Lab microscope-based white-light interferometer is shown. To measure the surface roughness, the corrugated surface is isolated by TMS software (a process that can be automated at any time) and the Ra value on a profile section is determined (Figure 5). To be sure that the correct values are determined, the filter characteristics for separating shape, roughness and ripple can be infinitely adjusted to suit the scale of the test sample.

In the above example, a cutoff wavelength of λ = 80 µm and a sampling length of L = 240 µm were used. The arithmetic mean roughness index was determined here at Ra = 161.2 nm.

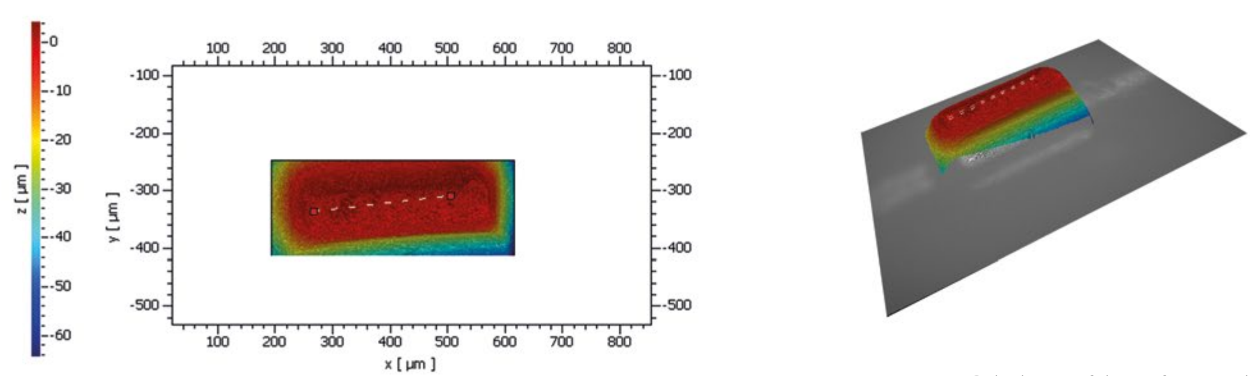
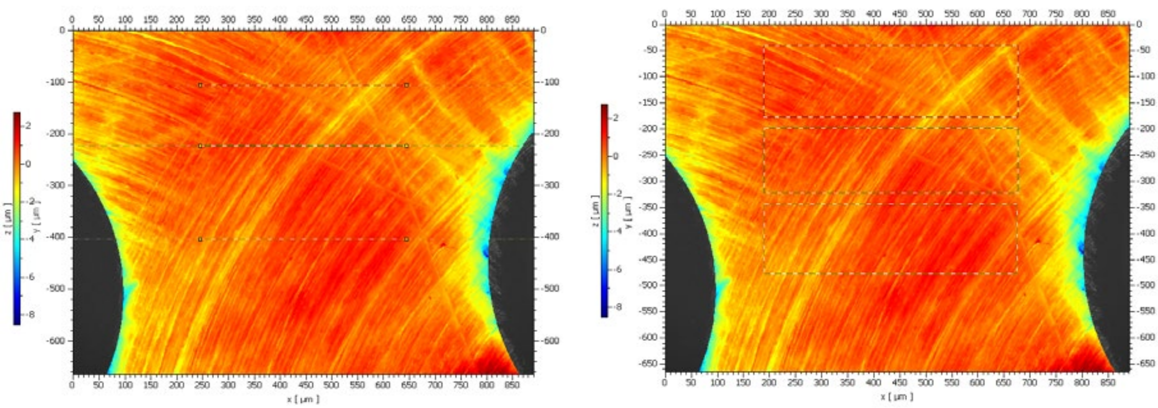
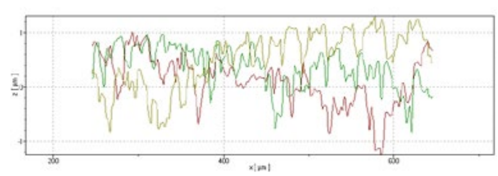


Figure 5: Calculation of the surface roughness (Ra = 161.2 nm) in the area of the corrugated surface (c = 80 µm, L = 240 µm)





Characteristic: All Characteristics — 8 / 8

Evaluation	Region / Profile	Nominal Value	Value
Ra	[Horizontal] - Profile 1	0.0 nm	184.3 nm
Ra	[Horizontal] - Profile 2	0.0 nm	186.8 nm
Ra	[Horizontal] - Profile 3	0.00 nm	194.77 nm
Ra (Average)	[Horizontal] - Profile 1, 2, 3	0.00 nm	188.63 nm
Sa	Mask 1	0.0 nm	193.7 nm
Sa	Mask 2	0.0 nm	184.2 nm
Sa	Mask 3	0.0 nm	188.6 nm
Sa (Average)	Mask 1, 2, 3	0.0 nm	188.8 nm

Figure 8: Calculation of the arithmetic mean roughness based on profile (Ra) and based on areal (Sa) information

The flatness of the bottom plate (Figure 6) is another test criterion. The challenge is flatness measurement on a comparatively large area of about 15.5 x 8.5 mm². In contrast to other optical measurement techniques, such as confocal microscopy, the vertical resolution of white-light interferometers is independent from the objective magnification, thereby resolving even large surfaces in a very short time. With the aid of the Polytec TopMap white-light interferometer, larger surfaces can be captured with nanometer resolution in the z-direction at one single measurement. In Figure 7, the results of such a flatness measurement are shown, between holes on the bottom plate are places and the results are in contrast to a one dimensional tactile profile measurement, the optical acquisition of the topography across the surface offers the possibility to characterize the roughness in two dimensions.

Similar to the standard roughness parameters defined for one dimensional profiles, roughness parameters can also be applied to two dimensional data (areal) and with the larger number of measurement points, can provide correspondingly more reliable data than individual profiles made up of only a few data points. Please see Figure 8 for a comparison of areal and profile based evaluation.

Figure 6: Bottom plate

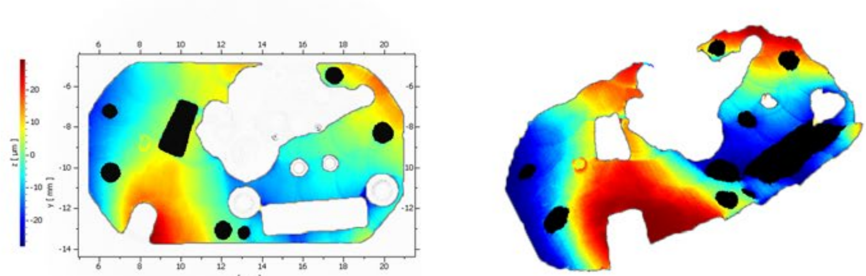
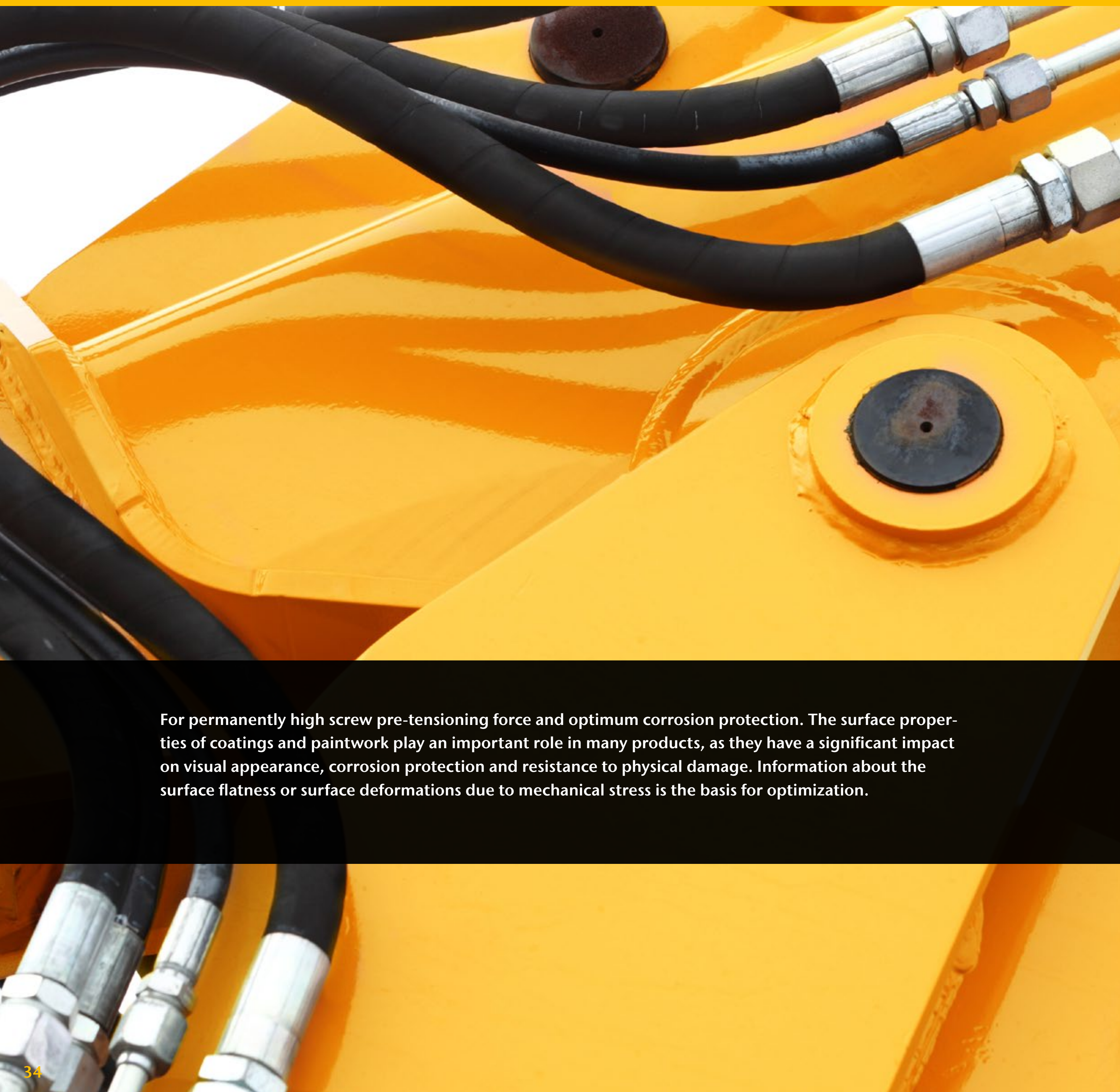


Figure 7: Determining the overall flatness of the bottom plate and the measurement point for the surface roughness

Non-contact inspection of coated surfaces by white-light interferometry



For permanently high screw pre-tensioning force and optimum corrosion protection. The surface properties of coatings and paintwork play an important role in many products, as they have a significant impact on visual appearance, corrosion protection and resistance to physical damage. Information about the surface flatness or surface deformations due to mechanical stress is the basis for optimization.

This information can be used to better control friction, minimize wear, increase resistance against external influences, improve conductivity, determine quality parameters for future paint finishes or examine the limits of certain coating procedures for screw connections. Optical measuring methods are used here as non-contact and non-destructive analysis and testing methods on almost all materials – especially for sensitive surfaces.

Prof. Dipl.-Ing. Alfred Isele and his team at the Faculty of Mechanical and Process Engineering at the University of Applied Sciences Offenburg, Germany are investigating the impact of organic corrosion protection systems and other coatings on screw connections. The motivation for this is the longevity of the tested components and their connections. These should subsequently function reliably over the entire service life, usually twenty years or longer under harsh environmental conditions, installed in machines, automobiles, heavy duty machinery or e.g. wind turbines. The screw connection of components must therefore be permanently tight but must also not damage the surface coating or paintwork on contact surfaces, in order to obtain the requisite corrosion protection.

Corrosion protection coatings effect screw connections

“Connections between uncoated components behave differently than those between painted components,” says Professor Isele pointing out the fundamental difference. Metallic surfaces are in direct contact without an intermediate layer, and the screw connection compresses the intermediate layer in painted components. This results in small deformations in the µm range, which nevertheless have a vital impact on the connection. This impairs the quality of the connection, i.e. the holding force of the screw, over many years of use and corrosion protection.

The University of Applied Sciences Offenburg, Germany is investigating the behavior of the surface at these connection points, as well as the changes in pre-tensioning force and deformations that occur under certain conditions (Figure 1), in order to determine limit values such as temperature or load level.

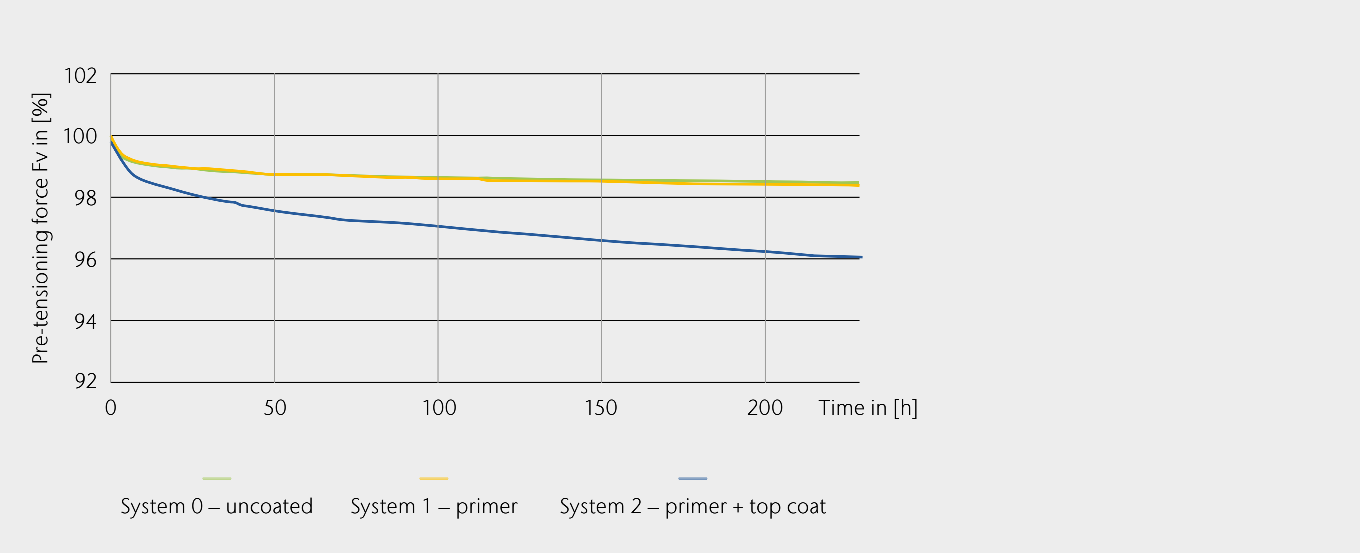


Figure 1: The loss of pre-tensioning force decreases depending on the surface coating.

Non-contact surface metrology is the key

The commonly used profile method is a tactile surface measurement method with diamond probe elements. “Unfortunately, this method has two disadvantages for our testing”, says Prof. Isele regretfully. “The point-by-point tactile measurement is quite slow and we only get one sectional image per measurement. However, since a corrosion protection coating is subject to application-related layer thickness fluctuations, a single cross-sectional image is not sufficient for quantitative evaluation. We therefore need a measurement procedure that allows surfaces to be measured completely. In addition, the tactile profiling method has the disadvantage that the geometry of the probe and the sample surface are always subject to a certain amount of wear.”

On the other hand, optical methods such as white-light interferometry perform large-area surface inspections without contact and wear, enabling short measurement times and high reproducibility.

TopMap measuring systems from Polytec also offer a very high vertical resolution, independent of the field of view. Additionally, Polytec TopMap solutions with telecentric optics allow to acquire large areas

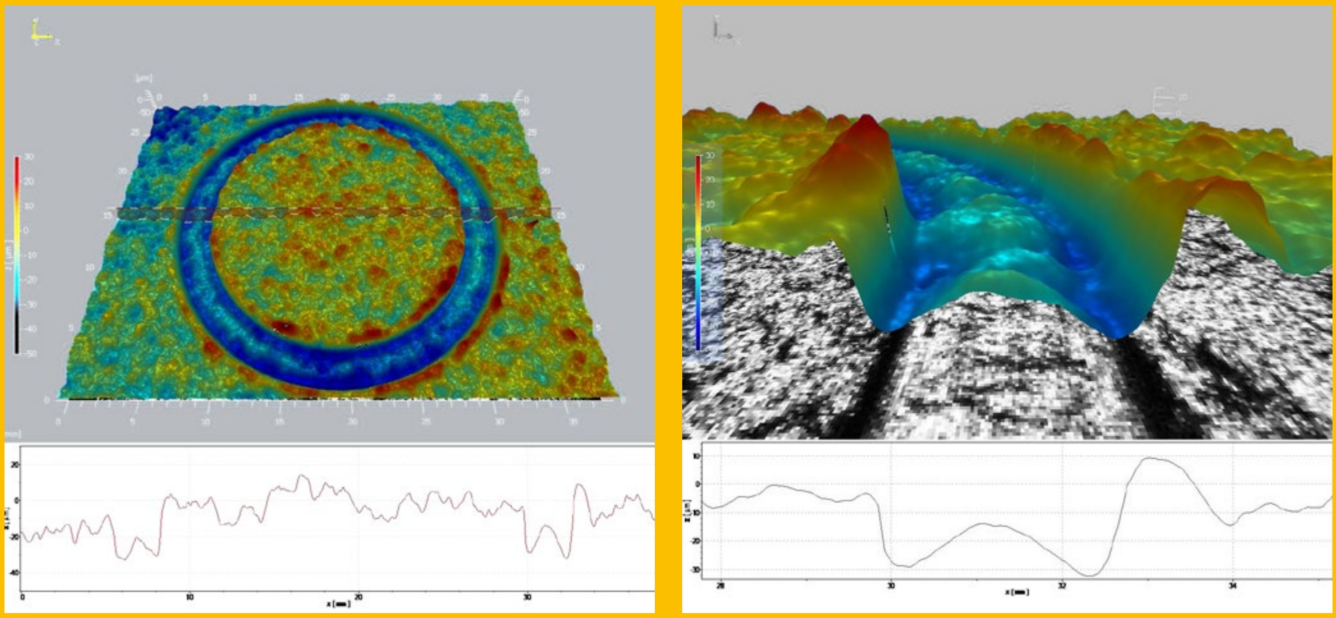


Figure 2: Non-contact recording of roughness profiles as a quality indicator for paint quality and appearance, on large areals on the left and as cross sections on the right (copyright: University of Applied Sciences Offenburg)

and thus more details with a single view without stitching (merging of measurement areas) (Figure 2).

Everything in view thanks to white-light interferometry

The white-light interferometers of the TopMap series offer a large vertical travel range and nm resolution in the non-contact measurement of flatness, step heights and parallelism. The telecentric optics can even measure steep steps, such as those found in drill holes. “We were also impressed by the ease of operation and the user-friendly evaluation options”, adds Prof. Isele. The open software architecture also makes it possible to program routine tasks or set up your own user interface.

However, the measurement system is not only suitable for laboratory areas, but can also be used in production. This measurement technology is integrated in a dust-proof and vibration-damped test station and is operated directly in machine shops e.g. along the sheet metal production chain in the automotive industry: The high-quality appearance of a vehicle depends largely on the paint quality. TopMap can supply characteristics for checking the appearance along the entire painting process and before the final inspection. Here, the surface roughness determined over a large area serves as a quality parameter for the paint quality and the subsequent appearance.

Prof. Dipl.-Ing. Alfred Isele

Contact

Prof. Dipl.-Ing. Alfred Isele
University of Applied Sciences
Offenburg, Germany

alfred.isele@hs-offenburg.de

Editor

Ellen-Christine Reiff,
M.A. Redaktionsbüro Stutensee, Germany

www.polytec.com/us/surface-metrology

Comparing different technologies
Overview of optical methods for surface metrology

For applications where tactile surface measurement techniques have shortcomings, non-contact optical instruments have been developed to overcome these shortcomings. Especially with the development of computing capability, these methods provide surface information quickly and with high resolution.

Surface measurement techniques like chromatic confocal probing, white-light interferometry, focus-variation or confocal methods are the most common examples. Every technique has its pros and cons.

Chromatic confocal probing

As an optical method, chromatic confocal probing is most similar to stylus profilers. Surface data is acquired by scanning a point sensor with the help of a laterally translated stage and, as with tactile methods, the length of the scanned profile is only limited by the displacement of the stage. Such a configuration allows for tracing complex shapes and even circular profiles can be measured. It is limited for time sensitive areal measurements though, but it comes without any vertical scanning unit, which makes this technology completely static.

Confocal microscopy

Surface information by confocal microscopy is generated by acquisition of sequential confocal images through the depth of focus of the objectives. Even the numerical aperture of those objectives show advantages in some cases, the vertical resolution depends on the selected objectives. In other words metrological performance changes with the magnification/field of view of the objective. Objectives with higher numerical aperture can reduce the noise, but due to their small measurement fields, in most cases, a combination of multiple fields (stitching) is required, which takes additional time. On the other hand objectives with lower magnification have comparably larger measurement area but suffer from poorer vertical resolution and reduced slope acceptance which means surfaces with localized steepness will prove difficult to measure.

Focus variation

Focus variation uses the small focus depth of the optics to gather information from a surface, illuminating the area with modulated white-light and detecting the reflected light from the probe. While the distance between probe and objective constantly changes, the data is acquired. Depending on the sample topography, different sections of the probe are displayed on a digital sensor. For each position of the object, the focus is calculated anew.

The focus variation technique provides images with color but the vertical resolution is limited in comparison to the confocal and white-light interferometry. And similar to confocal techniques, the vertical metrological performance depends on the chosen objective. In some cases, there is also a need to enhance textures on the workpiece to provide enough light for a robust measurements.

Thanks to the telecentric optical design and the 70 mm large vertical scan range, the Polytec TopMap systems can even measure in hard-to-reach areas such as holes.

White-light-interferometry

Although the numerical aperture of the objectives is limited, white-light interferometry provides high vertical resolving power. Moreover vertical resolution is independent of measurement field (field of view). Therefore even larger surfaces can be measured with nanometer vertical resolution. Similar to the other optical techniques, the lateral resolution is determined by the objective magnification.

In summary, it can be stated that every technique has its own limitations and strengths. However, in some applications, the user cannot compromise and needs some special solutions. This is where Polytec's modular and multi-sensor concept for surface metrology shows its full potential.

Multi-sensor applications

In several applications, it is required to characterize surfaces with measurements like distance, width, height, form, surface texture, roughness, volume or film thickness. And the information about the quality of large surfaces (in the sense of micro- and nano metrology), which demands large measurement ranges (mm^2 to cm^2), can only be assessed by combining measurements on nano- and micrometer scales.
For such applications, measurement tools with multi-sensor capability provide more flexibility.
Especially for the characterization of sealing surfaces, concepts with different measurement capabilities are required. Typically those applications require the measurement of form deviation on larger surfaces in mm range and at the same time evaluation of roughness

with nanometer resolution. If the form deviation is out of tolerance, the required contact for sealing between different surfaces cannot be achieved. Even with a perfect surface finish, there would be leakages due to the empty volume in contact regions. If the form deviation is within tolerance, roughness of the contact surfaces is the second important factor to achieve the required sealing performance. In terms of surface metrology, a system which enables the measurement of form deviation on large surfaces and the characterization of roughness on long profiles will be the right solution.

White-light Interferometry combined with chromatic confocal probing

The vertical resolution of white-light interferometers is independent from the objective magnification, thereby resolving even large surfaces in a very short time. Polytec's TopMap Pro.Surf is a white-light interferometer specially designed for large area measurement. The measurement volume (without stitching) of 30 x 40 x 70 mm^3 (X x Y x Z) can be acquired with a vertical resolution in nanometer range and at the same time an appropriate lateral resolution.

For the applications in which high lateral resolution is required, the multi-sensor concept integrated with chromatic confocal probing is available. As an example, after having characterized the form deviation on the whole surface with the white-light interferometer, additional measurements with the chromatic confocal sensor can be performed to evaluate roughness. Similar to stylus measurements, the position, length and the shape of the profile can be chosen by the user. TopMap Pro.Surf+, the newest member of Polytec's surface metrology family, makes it possible to measure the whole area of 228 x 221 mm^2 for the application where form deviation and roughness is required simultaneously. As manufacturing technologies continue to develop, there is a pressing demand to understand surfaces in more detail, both in the lab and on the production floor. Identifying a single superior measurement technique to fulfill all requirements may not be possible. Depending on the interaction with the surface, regardless of optical or tactile method, every technique has its own advantages and disadvantages. Therefore, new multi-sensor concepts combining different techniques are the best answer to cope with the wide range of surface metrology applications.

Areal measurements with Polytec white-light interferometers capture surface data of large structures without stitching.

Contact

Dr.-Ing. Özgür Tan
Strategic Product Marketing
Polytec GmbH

info@polytec.de
www.polytec.com

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).

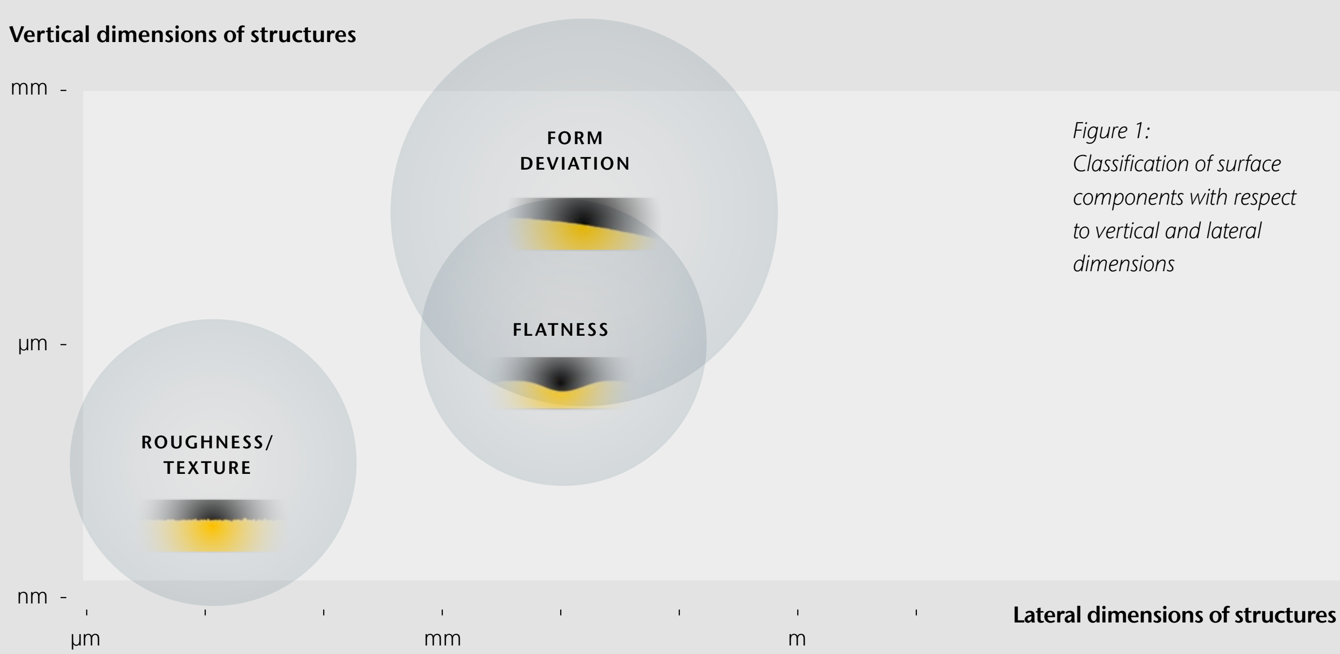
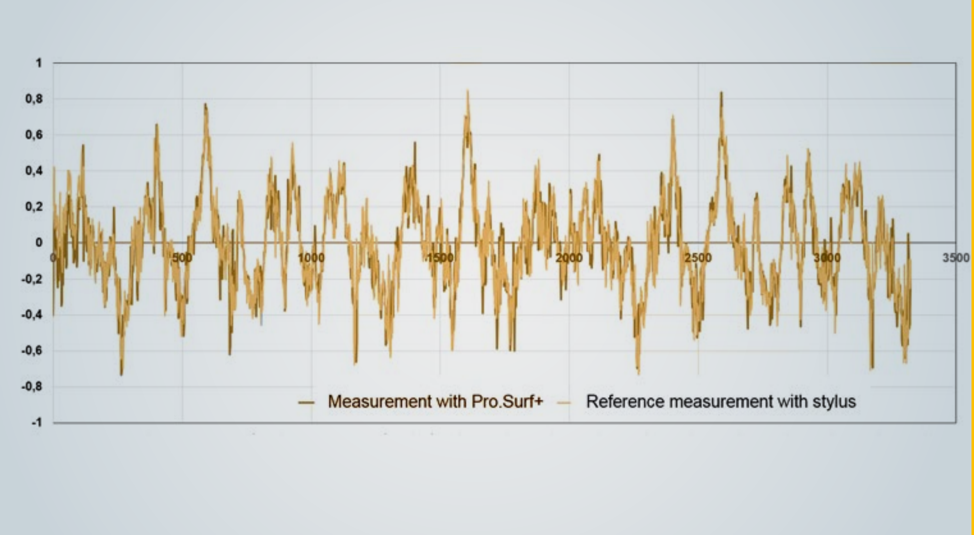


Figure 1: Classification of surface components with respect to vertical and lateral dimensions

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*



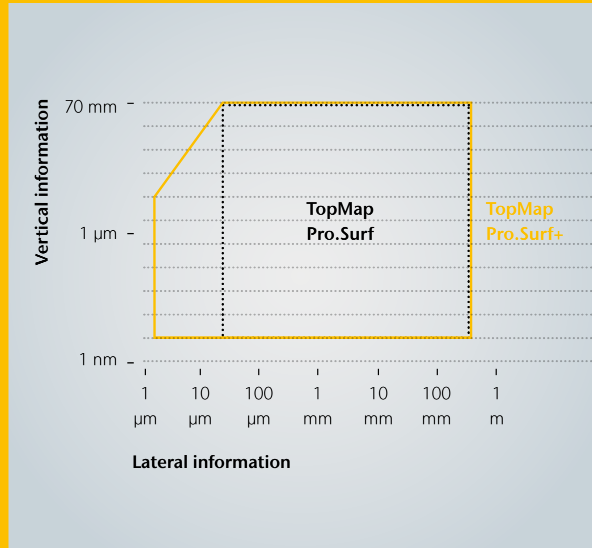


Figure 3:
Measured profile with Pro.Surf+ versus reference profile (tactile calibration measurement)

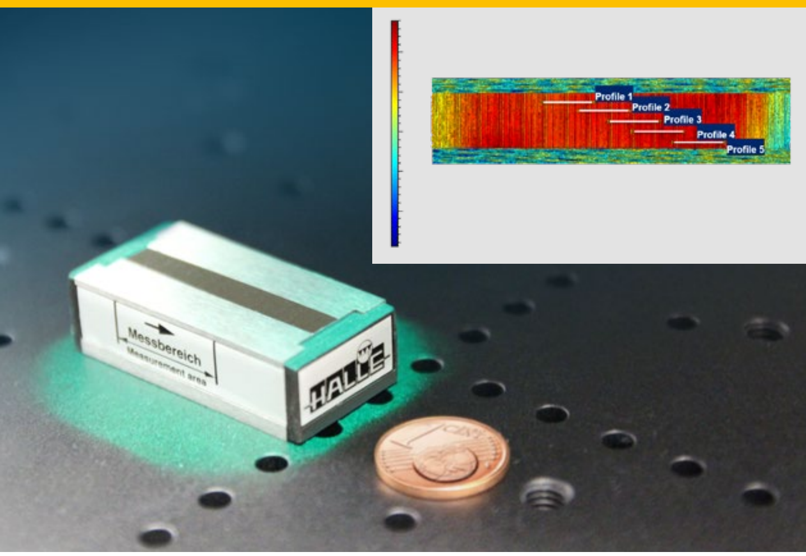
Figure 4:
Modular concept of TopMap Pro.Surf+

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.



Contact

Dr.-Ing. Özgür Tan
Strategic Product Marketing
Polytec GmbH

info@polytec.de
www.polytec.com

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.

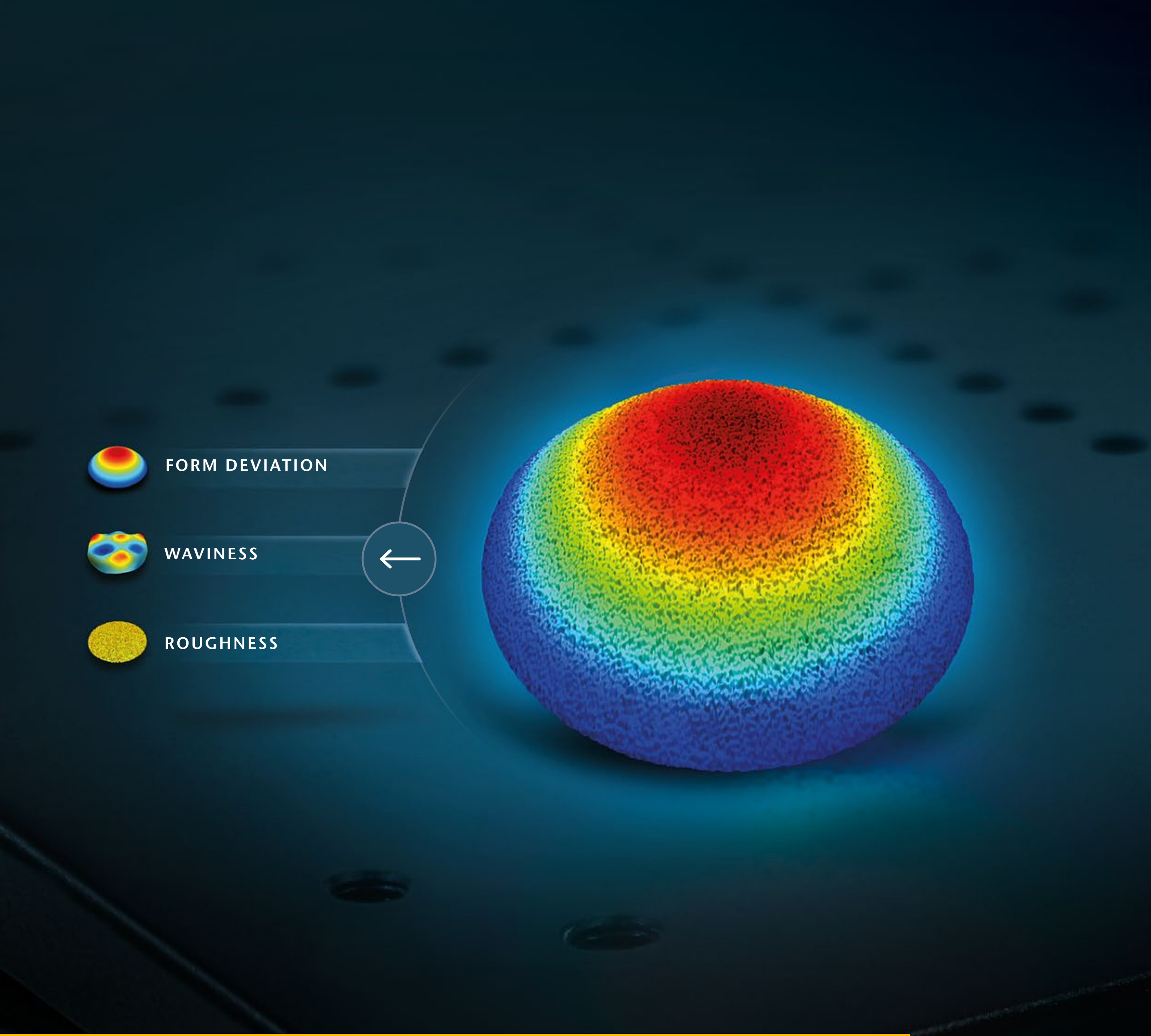
The comparison of the results is shown in Figure 3: The measurement results on the calibration protocol are: Ra 0.197 µm Rz: 1.46 µm. Measurement results by Pro. Surf+: Ra 0.197 µm Rz: 1.43 µm. The measurement data of Pro.Surf+ is in good agreement with the reference profile of the stylus instrument. 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.



Surface metrology tailored to your needs

Consistently producing high-quality precision parts is better achieved when the supporting metrology is tightly integrated with the manufacturing process. By combining Polytec's TopMap optical metrology with special adaptations, companies can realize the advantage of closed-loop manufacturing on the production floor that is rapid, effective and ergonomic, meeting their need for high quality-assurance standards.

QC Package – tailored to manufacturing needs

Typical applications of surface metrology for quality control (QC) can be classified according to the locations where the instruments are installed, see Figure 1. A typical location is the testing laboratory, where the environmental conditions are quite stable and the users are knowledgeable about the capability of the measurement systems.

In contrast, surface metrology at locations near to production lines must provide instruments that can perform automated measurements in harsh and complex conditions with substantially more turnover in staff. These near-to-production installations should be equipped with additional safety measures to avoid common mistakes as a precaution against inexperienced or new operators.

Finally, for critical in-line applications, metrology systems must be able to be integrated with the production flow, must accommodate process modifications (design, specification and material changes) and must be designed for global serviceability (easy repairs) and supportability (availability of replacement parts) to limit potential downtime issues and costs. When unanticipated but necessary production line changes occur, manufacturing companies expect a rapid response from a production line partner and a fast accommodation of their installed equipment. Depending on the requirements of manufacturing, Polytec's metrology systems are adjustable and were designed to adapt quickly, avoiding poor measurement that result in poor product quality. In many cases, the software alone can adjust the workflow allowing new measurement tasks to be easily established. By using intelligent and simplified user interfaces, even operators that lack expert knowledge can perform accurate measurements and complex analysis.

Polytec TopMap metrology – your flexible partner

To fulfill these requirements, Polytec developed the concept of a "recipe" – a software program that can store acquisition parameters (e.g. measurement position, light settings, camera parameters...) together with evaluation parameters (post-processing steps, visualization options, export possibilities...) for a specific measurement task (Figure 2).

Once the required settings for a specific measurement task are determined, those parameters can be saved within a recipe. The operator can then perform a measurement with a simple mouse click. Since the recipe documents all of the steps regarding "how to measure" and "how to evaluate", any changes can be easily monitored.

Figure 1: Different environments for surface inspections with different needs

Managing different samples

Multiple recipes are an excellent solution for close-to-manufacturing applications where tests and sample types can be sequentially very different. Polytec's QC Operator Interface is a software designed simplify the management of several samples with individual recipes or one sample with different recipes. After developing a recipe, the QC Operator Interface makes it accessible through the user interface drop-down menus. In this way, all selected recipes are easily available to the operator, see Figure 3. The analytical outputs from the recipes such as numerical values, 2D/3D views, and pass/fail decisions can be shown quickly and easily exported

Simply put, the QC package provides:

- Handling of different sample types by recipes
- Increased flexibility through easy changes of measurement settings
- Tracking of measurement settings for traceability
- Clear pass/fail analysis for quick decisions
- Advanced reporting capabilities for results sharing

Figure 2: Polytec recipes allow loading and saving of measurement and evaluation parameters

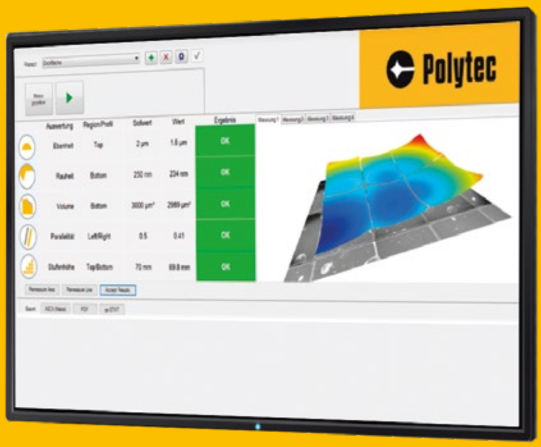


Figure 3: The QC Operator Interface software manages predefined recipes for efficient surface quality control

Summary

Simply installing a metrology system into the production process doesn’t, by itself, assure the quality of manufactured parts. In addition to the data requirements of quality control departments (e.g. precision, repeatability, reproducibility, linearity, stability), quality depends on the support capabilities of the instrument supplier to fulfill the broader QC needs of manufacturing.

Polytec’s TopMap family and global support team offer flexible tools and build formats which are tailored to the broad needs of manufacturing environments. Polytec white-light interferometers are well-established quality inspection tools designed for the metrology lab, near-to-production or in-line and close-loop production applications.

Contact

Dr.-Ing. Özgür Tan
Strategic Product Marketing
Polytec GmbH

info@polytec.de
www.polytec.com/topmap

Interview with Dr. rer. nat. Wilfried Bauer
Senior expert for standardization and
Polytec representative for ISO 25178

Polytec ISO activities

As an expert, you're close to customers, ongoing standardization activities and intimately familiar with current industrial trends. What do you believe are the most important current developments in the field of surface metrology?

For many workpieces the match of small tolerances are required. This leads to higher demands on measuring instruments. At the same time, the number of characteristics to be checked for functionality purposes is growing too. In some cases, critical components have to be checked in production-related applications or even directly in-line without any time delays. This means that the measuring instruments have to perform measurement tasks automatically where possible with short throughput times, and provide the data to boot. This is also important for digitalization in the production process.

The optical measuring techniques provide suitable methods for overcoming these challenges. Polytec white-light interferometers are optimized for quality assurance measurements and are already viable for these tasks today.

Key conventions and standards must be complied with in industrial production. What hurdles still have to be overcome with respect to standardizing optical surface metrology, and what obstacles have already been successfully overcome?

Optical measuring technology is now considered in new international standards that, in days gone by, were mainly written for tactile systems. The ISO 25178 series of standards takes highly optical methods into account and defines the likes of white-light interferometers (ISO 25178-604) or confocal microscopy (ISO 25178-607). I, myself, am a project manager for ISO 25178-700 ("Calibration, adjustment and verification of areal topography measuring instruments"), which deals with calibrating area-measuring instruments for the first time. Such instruments are mainly optical, and are increasingly being given special consideration in this standard. It must be noted that the standard can be applied, with reasonable effort, to routine calibrations in measuring laboratories too.

Many users are not aware about the advantages of using optical methods. In principle, it's worth mentioning that the standards in development give users more freedoms. But users need to know in detail how to harness them. If you're browsing the working program for new standards, there are still many open questions regarding the evaluations. While we're staying on the ball, everything will still take some time.

The second edition of the day-long, user-focused "TopMap Day" workshop is taking place in the fall, and this time it's being held right on Polytec's premises in Waldbronn. What are the program highlights? The agenda features a section on monitoring tools for quality control ("QC"). What's this abbreviation and this tool all about?

I believe that precisely the solutions to the challenges we mentioned before will be a highlight of the TopMap Day. Quality monitoring solutions will be on show under the name "QC Tools" (with "QC" standing for "quality control"). They're superb for routine measurements on different workpieces.

TopMap family
Non-contact surface characterization
in a new dimension

TopMap
Pro.Surf

High-end surface scanning
with large field of view.

TopMap
Pro.Surf+

Measurement of both form parameters
plus roughness details.

The TopMap white-light interferometers evaluate surface parameters on entire areas without contact just within seconds - for precise and reliable quality inspections**. Get more details about TopMap on www.polytec.com/topmap**

TopMap
Micro.View®+

Modular high-end optical surface profiler.

TopMap
Micro.View®

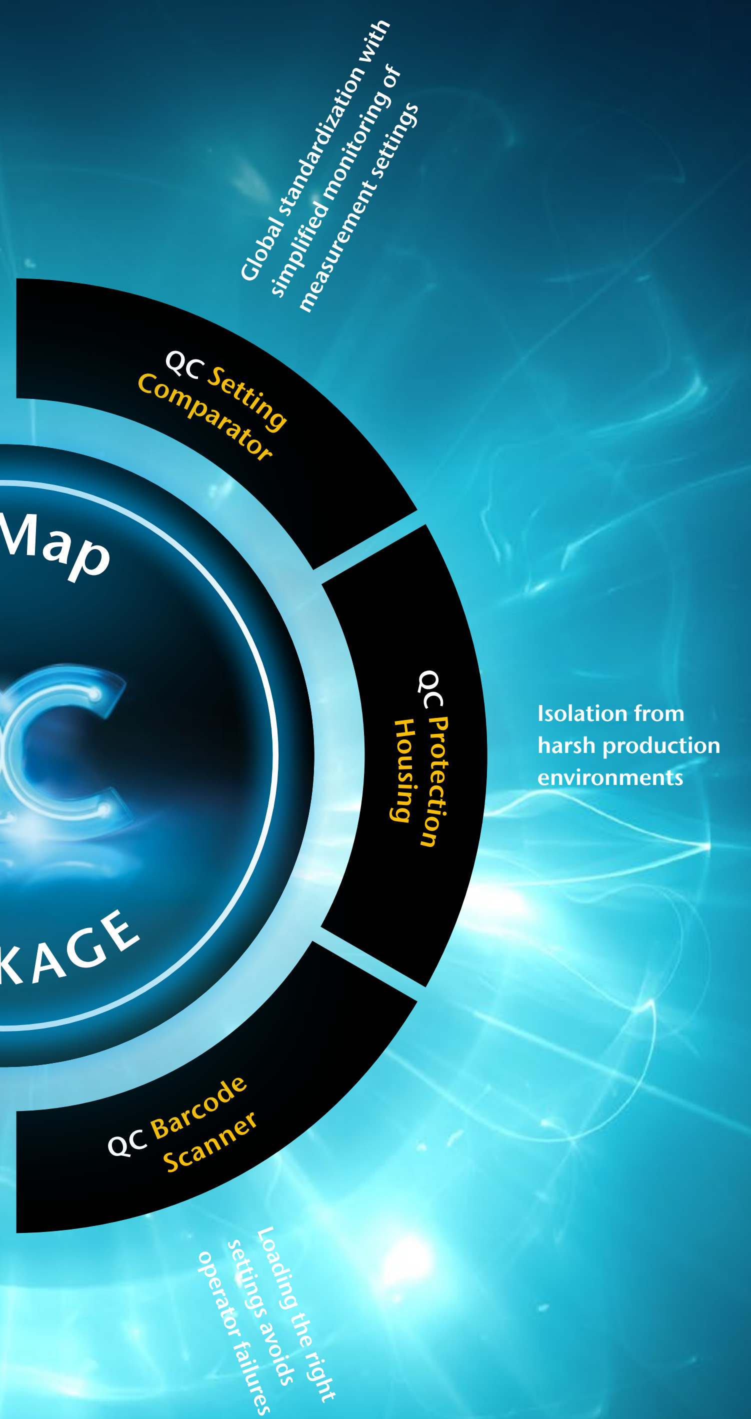
Table-top optical surface profiler.

TopMap
Metro.Lab

Compact 3D surface metrology workstation.

Quality control in challenging production environments

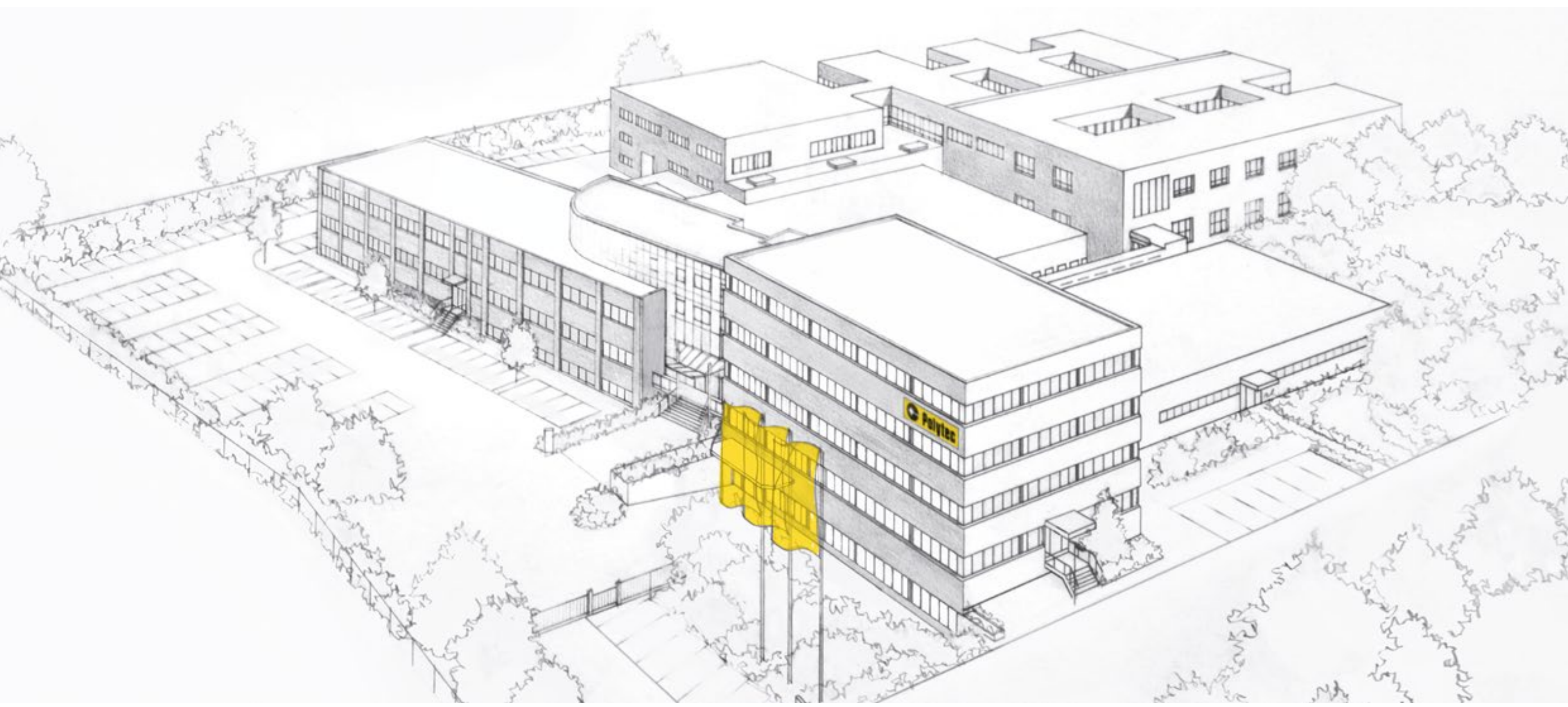
The inspection of surface quality in clean and appropriate quality labs is no true challenge. But what exactly is ideal in real life production environments? How can you measure precision mechanics reliably in challenging production environments



Typical influences in manufacturing halls can affect the measurement reliability. Noise and vibration from the surrounding machines are disturbing and uncontrolled influences, when measuring right in the middle of the machine shop. Real production environment is not only loud and busy, it also influences surface inspections and precision measurements. In a test setup we measured a sample with a classic sealing surface, like it is common in the automotive or precision engineering. External influences in the machine shop came from machines running in the same hall, like milling, drilling, cutting etc. Here, the objective-free design and large areal measurement avoid stitching and successfully acquired 3D surface data in a steady and reproducible way just within seconds. Thanks to the innovative Polytec ECT Environmental Compensation Technology the TopMap surface metrology system performs reliably even when it gets rougher.

Watch the video:

Polytec



Shaping the future since 1967

High tech for research and industry.
Pioneers. Innovators. Perfectionists.

Find your Polytec representative:
www.polytec.com/contact

Polytec GmbH · Germany
Polytec-Platz 1-7 · 76337 Waldbronn

OM_BR_TMS_Surfaces_E_52054
2020/06 – Technical specifications are subject to change without notice.

www.polytec.com