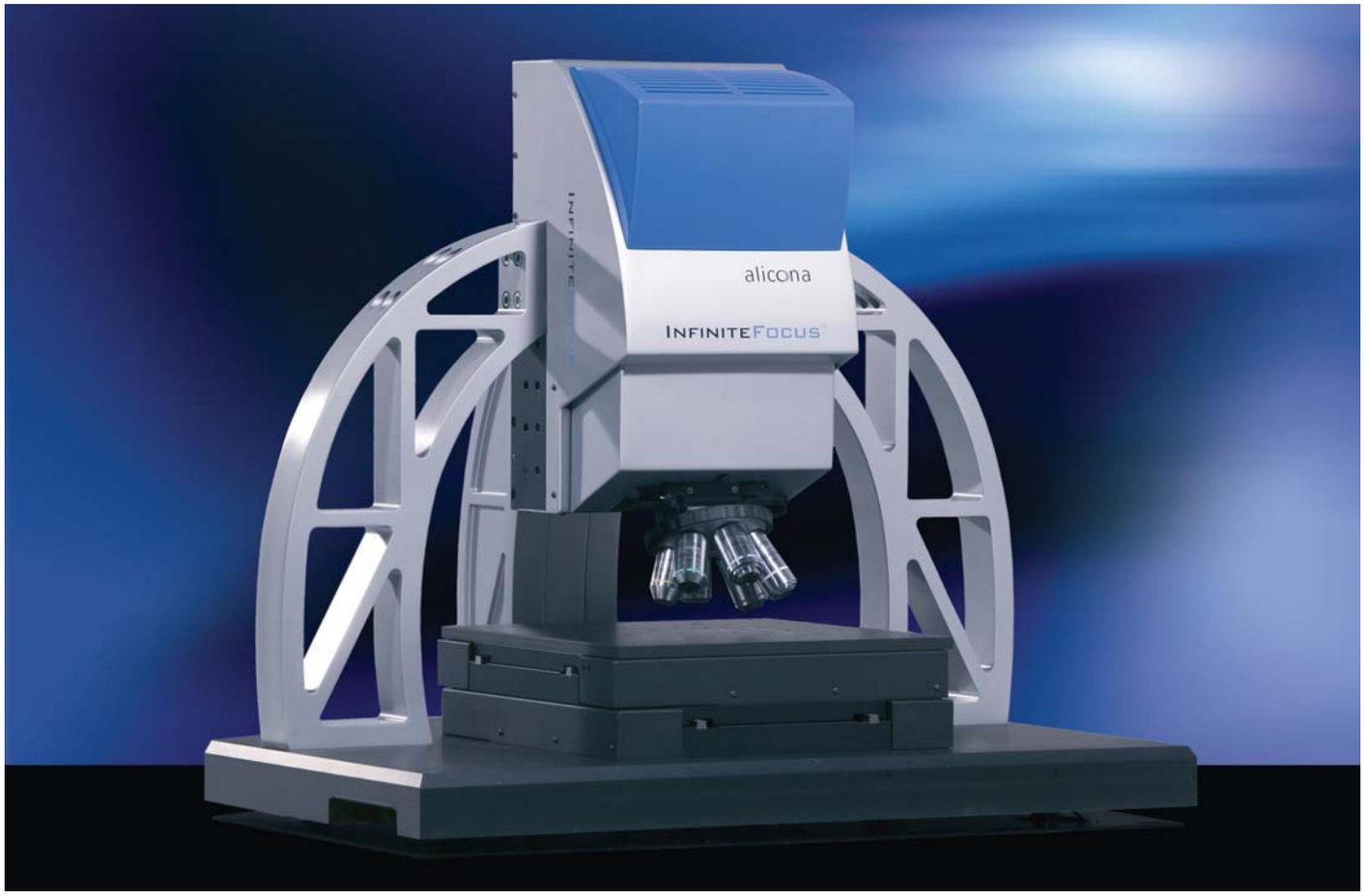
FOCUS VARIATION — NEW ADVANCE IN OPTICAL 3D METROLOGY FOR MICRO MACHINING APPLICATIONS



Brian Kyte and Mark Raleigh

The measurement of micro-machined components has produced significant challenges for measurement and inspection. The components to be measured generally have steep slopes, complex geometries, multiple forms, and varying reflective properties (see Figure 1). In addition, they generally have stringent surface finish requirements.

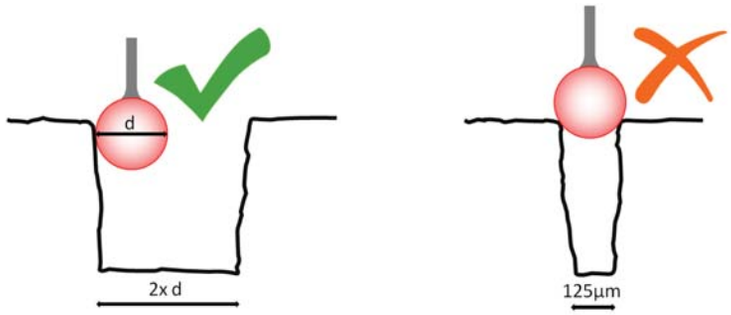
Products of this nature at this size can be impossible to measure with tactile systems, such as touch probe micro CMMs and stylus type surface finish systems. This is particularly true on items with steep slopes, narrow grooves, form and small edge radius measurements in the 5–10 μm range.

With a typical micro CMM probe size of 125 μm, some mechanical interference restrictions immediately become obvious on the measurement of these complex shapes. The first is that the smallest bore size that can be measured is about 250 μm and that any radii less than 125 μm cannot be measured at all. The micro CMM systems are very good for the measurement of external forms over small and larger areas, but are not optimised for complex micro machined components.

Optical techniques that have been typically used in this area, such as White Light Interferometry, confocal microscopy and Atomic Force Microscopy, are very good for measuring smooth surfaces, but have restrictions in terms of complex geometry measurement, large Z heights, high slope angles and high aspect ratio measurements. (See Figure 2)

Figure 1. A 3D Copper Impregnated Micro HeX Plate model, measuring 700 μm x 550 μm x 150 μm high

Figure 2. Measurement Problems With Tactile Instruments in Micro Machining



Consequently, industry requires new and effective measurement systems, providing traceable, repeatable and high-resolution results. Focus-Variation, a new optical technology, can meet these demanding requirements. (See Figure 3)

Using this technology enables measurements from a vertical resolution of up to 10 nm on complex topographies and across large measurement fields up to 100 mm x 100 mm, with full colour information, are possible. This readily obtainable data makes this technology ideally suited for use with micro machined components.

Here, we describe this new technique, developed by Alicona Imaging and used as the operation method in our product InfiniteFocus. This technique overcomes these issues, allowing optical metrology to be used in many different micro engineering areas with improved results. (See Figure 4)

The results described later are based on an InfiniteFocus user based in the USA, who has used the technology to enhance their capabilities in providing measured data with components.

FOCUS-VARIATION

The operating principle of Focus-Variation moves the small depth of focus of an optical system, combined with modulated light, over the object, with continuous vertical scanning, producing a topographic 3D data model of the surface. As the distance between the object and objective is varied, the variation of sharpness is used for measuring 3D depth information, and a dense 3D point cloud is obtained.

In contrast with other optical scanning methods, the full vertical scan range is used to measure depth data. Each 3D point has an x, y and z position, with an associated representative colour, plus an estimated measurement uncertainty. From this, a surface representation of the object is obtained, with the colour registered to the 3D data. This 3D data can also be exported for reverse engineering or CAD comparison.

> “Since we have acquired the InfiniteFocus, our abilities have dramatically changed. Now, we can provide solutions, as well as components. Reverse engineering has grown into an integral service, as well as a shared resource, for all levels of manufacturing”

It is on this dense 3D surface representation surface model that measurements are made producing areal data, enabling comprehensive dimensional and form measurement, plus surface characterisation. This also allows measurement of functions such as roughness (Ra) on the form, enabling, in many instances, complete dimensional and surface characterisation of the object being studied.

The technique produces complex areal data, allowing comprehensive characterisation not typically available with tactile systems.

Focus-Variation has been added to the latest ISO standard for classifying surface texture methods. The new ISO standard 25178 for the first time includes standardised parameters to classify optically areal-based measurements.

The advantages of Focus Variation can be summarised as:

- Most data is presented in the true surface colour of the object, with the colour fully registered to the 3D data
- Steep slopes >800 can be imaged and measured
- Varying surface finishes can be imaged and measured at the same time
- High “Z” ranges from 10 nm to 22 mm can be captured
- Full form measurement of cylinders, spheres and cones are possible
- Measurement profiles can be placed in the precise position required
- Full 3D surface characterisation on forms is possible

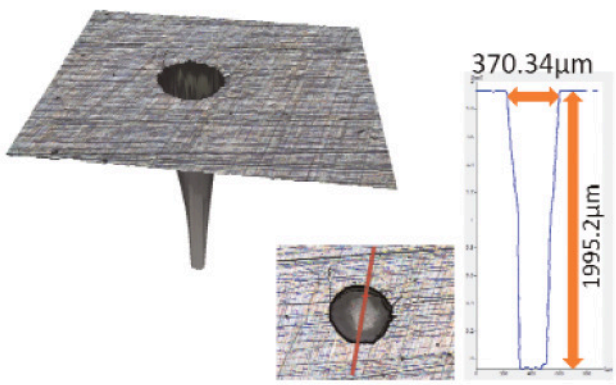


Figure 3. High Aspect Ratio With Focus Variation

- Roughness, wear, form, and contour measurements are possible.

As an areal-based technique, FocusVariation also enables 3D area surface characterisation of the surface to be measured providing in depth information.

APPLICATIONS

The InfiniteFocus method was chosen by The EDM Department, Bartlett IL, to measure the components that it manufactures.

The EDM Department specialises in micro-machining, using EDM and laser-based technology, and is considered to be a leader in its field. The company has a commitment to quality and has always believed that it produces micro machined components according to customer specifications. Using the InfiniteFocus system, it is now able to prove the results.

The company has strived to maintain itself at the peak of the technology and now boasts the ability to produce features at sub 10 micron size. It has been and continues to be innovative in developing new methods and technologies to achieve improved results. As demand increases for smaller and smaller micro components, it has moved from a physical to a visual measurement technology for conformation of results.

Mark Raleigh, CEO of The EDM Department, when explaining the reasons why

the FocusVariation technology was chosen, said: "Due to the increasing trend of miniaturisation and increased functionality, our customers are faced with the challenge of manufacturing products with very complex features and topography. It is the role of our company to not only meet these requirements, but also provide the means to confirm control. Today, the solution must address metrology, as well as manufacturability.

"Since we have acquired the InfiniteFocus, our abilities have dramatically changed. Now, we can provide solutions, as well as components. Reverse engineering has grown into an integral service, as well as a shared resource, for all levels of manufacturing. This sponsors process improvements. Small, independent steps forward; offering our customers what the next generation of product development will demand.

"With refined statistical programmes, we have appreciated 6-7% improvements in process performances. Surface finishes have improved over 7% under identical resource requirements. All of this is because we can now see and measure what we produce.

"Under the current economic challenge, we have all learned how to wear more than one hat. The same standard should be held for all resources. The system is serving a quality inspection role, a sales role and an R&D role.

"The way InfiniteFocus visualises manufactured components in 3D is a true selling argument for us. Recently, six out of seven new customers came from

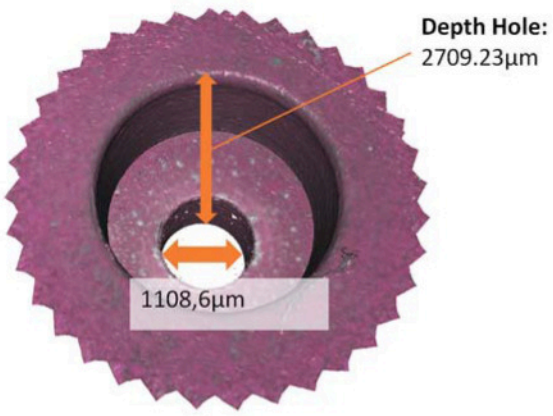


Figure 4. Large Field of View With High 'Z' Range

Figure 7

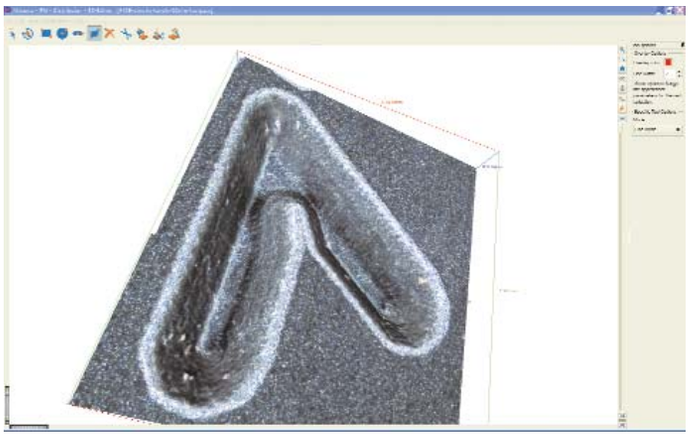
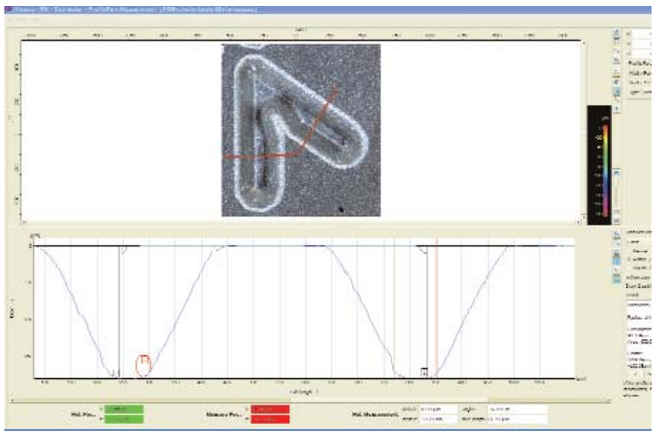


Figure 8



the presentation of visualisation and measurement results. It simply proves our manufacturing quality."

"We have also seen some considerable advantages in areas that we had not considered when deciding to buy the system. The data produced includes a 3D point cloud of up to 100 Mio., even over large areas. This has enabled us to compare CAD data with the manufactured component, looking for variation that is easily quantified using the software available. The latest version of the IFM software also has form-fitting functionality for cones, cylinders and spheres, improving versatility and capability even further.

"The areal-based measurement tools have also enabled us to look at surface characteristics that directly affect the component's performance; this is a new area to us that we are now exploiting to our advantage.

"As we move forward, we see the FocusVariation technology being a major contributor to the growth of our company.

"Many of our customers are involved in medical devices, which have their own particular measurement requirements, and we had looked at many different conventional measurement techniques for this area and the others that we work in."

The following are typical examples of what The EDM Department. is now able to achieve:

TYPICAL APPLICATIONS

The example shown previously in Figure 1 is a Micro-Hex Pattern.

When we view this in a profile-measuring module, it can be seen that the width of the spaces between the posts is 41 μm and the height of the pillar is 142 μm, providing an aspect ratio of nearly 5:1. It can also be seen that it is possible to measure the radius on the top of the pillar at 17.3 μm. (See Figure 5)

> "The operating principle of Focus-Variation moves the small depth of focus of an optical system, combined with modulated light, over the object, with continuous vertical scanning, producing a topographic 3D data model of the surface."

Using projection in 2D, it is also possible to measure the width of each of the hexagon pillars (nominally 50 μm). (See Figure 6)

Figure 7 shows a pre-Formed Shape in PCD Diamond. When measured the width at the bottom of the groove is 72 μm, the depth is 180 μm and the radius in the groove base is 14.41 μm and the inclusive angle is 700. This is a typical example of where there would be mechanical interference with a micro CMM, making the width at the bottom and the radius un-measurable. (Figure 8)

Figure 9 shows a Micro-Element Cone in S90-V Stainless Steel. When used in the Form Measurement module recently introduced into the InfiniteFocus measurement tools, we can readily fit a cone and measure it, even on a part of the image. (See Figure 10)

Referring to this latter example Mark continued, "We have shown here how the Focus Variation technology used in InfiniteFocus can enhance the capabilities when measuring micro machined components. The technology can also be used in macro and sub-micron applications and for in-depth surface texture analysis.

"The measurement of surface texture plays a crucial part in checking and controlling the properties of technical surfaces. Also, the measurement of surface texture can be used to characterise and optimise surfaces with respect to their functional behaviour.

"Traditionally, surface texture measurements have been performed by tactile devices with the use of profile roughness parameters. Optical measurement techniques,

such as focus variation, have become increasingly popular in this area, as they have several important advantages over contact stylus instruments. As an example, they do not damage the surface and are able to measure whole areas, with complex geometries, at one time and not only surface profiles. This enables them to measure larger areas in shorter periods of time and to characterise surfaces by areal surface texture parameters.

Mark concluded: "This area will become increasingly important in the Micro Engineering sector as technology and demands increase. The focus variation technology described here will allow these functional characteristics to be measured, allowing micro engineering to play a larger part in mainstream activities."

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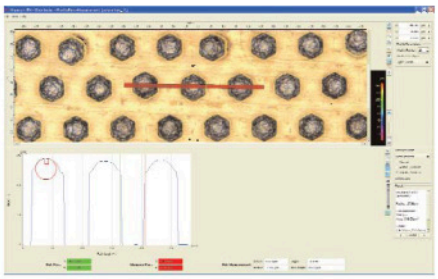
Brian Kyte is the Director of Alicona UK Ltd., a subsidiary of Alicona GmbH in Austria where the InfiniteFocus is manufactured. He has worked at Alicona UK since it was formed five years ago and has been instrumental in achieving a high profile, and influential collaborations for Alicona, along with high sales volumes. His background is in imaging and measurement, both with optical and electron microscopy systems, and he has been working with Alicona products almost since the parent company was formed in 2001. Email: brian.kyte@alicona.com Web: www.alicona.com



LEFT:
Figure 5

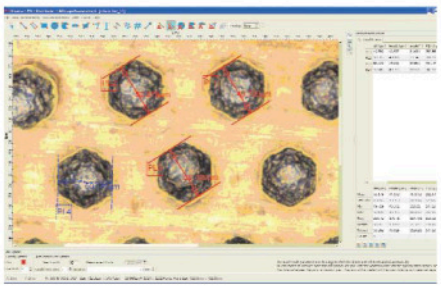


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Figure 6