

Current Problems in the Field of Surface Texture Measurement

Richard Leach

Centre for Basic, Thermal & Length Metrology, National Physical Laboratory, Queens Road,
Teddington, Middlesex TW11 0LW, UK.

1 Abstract

This paper discusses some of the problems that plague surface metrology. Whereas the most popular instruments on the shop floor are 2D or profiling systems, there is a clear industrial push towards 3D measurements. The paper discusses the ill-defined route to traceability for 3D surface texture measurements and suggests areas that need further research. It is asserted that the lack of specification standards and methods for performance verifying 3D instruments is the main cause of the large spread in the results seen in recent comparisons.

2 Introduction

There are many industries that have to control, and therefore, measure surface topography in some form or other. Profiling instruments have traditionally been used in the metal-working, automotive, ceramic and aerospace industries, whereas 3D instruments are starting to be used in areas as diverse as fabrics and papers, micro-optics and into research for nanotechnology. It is asserted that what is now needed is a broad-based research programme into methods for calibrating and performance verifying 3D instruments. Without such methods, industrial users of 3D instruments have an ill-defined route to traceability and will not be able to assure product quality and value for money. This paper is primarily concerned with the measurement of surface texture, but many of the arguments also apply to the measurement of form.

Surface texture measuring instruments can be either contacting or non-contacting. The main contacting method employs a conical diamond-tipped stylus that traverses across the surface (ISO 3287: 1996). An inductive transducer usually measures the vertical displacement of the stylus. There are a variety of non-contacting probes that optically interact with the surface. Typical examples are interferometers (De Groot and Deck 1994), triangulation, scattering (Bennett and Mattson 1999) and auto-focussing systems (Stout and Blunt 2000), and, less commonly, speckle correlation (Vorburger and Teague 1981) and ellipsometric systems (See *et al* 1996). On rare occasions pneumatic systems are employed (Thomas *et al* 1998). A whole range of scanning probe microscopes is also available, but such instruments are not discussed here.

3 Metrology issues

Despite the importance of surface texture measurement to many industrial sectors, it is still uncommon to see instruments that are calibrated in all the axes that they operate (Leach 2000a). Usually it is only the vertical displacement that is traceably calibrated and the horizontal axis is presumed to be true. This shortcoming is especially pronounced for 3D instruments. To allow for traceability of 2D profile measurements NPL has developed a contact stylus instrument with traceable metrology in the vertical and horizontal axes (Leach 2000b). This instrument, known as NanoSurf IV, is used to provide traceable calibration of artefacts that can in turn be used to calibrate other instruments (see figure 1 for a photograph of NanoSurf IV). International standards ISO 5436 (2001) and ISO 12179 (2001) discuss calibration artefacts and methods for profile instruments. It is also rare to see uncertainties quoted with surface texture measurements – this effectively makes a measurement result not traceable.

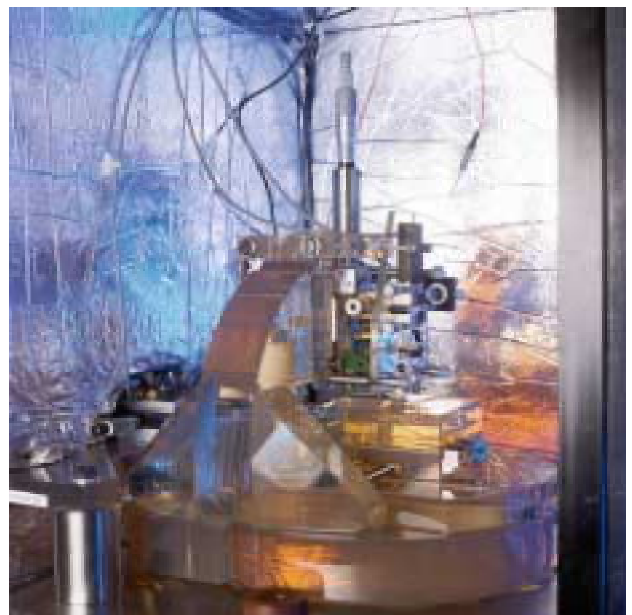


Figure 1 NanoSurf IV

4 3D or not 3D?

3D measurements have the following advantages over 2D (Leach *et al* 2001):

- The 3D techniques comes closer to describing the “real” surface and the parameters derived possess greater functional significance;
- The 3D techniques allow parameters to be derived relating to area for the first time, e.g. texture “strength” and direction, material void volume, etc.
- Since the 3D techniques take data from an area rather than a profile, the parameters have a greater statistical significance and better repeatability;
- 3D measurements are visually more effective as a characterisation tool.

However, 3D measurements can take much longer than 2D measurements, the instruments are more expensive and they are not supported by a specification standards infrastructure. Draft specification standards have been written following an EC-funded project (SURFSTAND) but further research is needed to allow calibration and performance verification of 3D optical instruments.

5 Parameter rash

In 1972 Prof David Whitehouse coined the term “parameter rash” to describe the proliferation of surface texture parameters (Whitehouse 1972). There are currently sixteen 2D surface texture parameters that can be used to assign a number to a surface (ISO 4287: 1997). The draft standards suggested by the SURFSTAND project name seventeen 3D parameters (Blunt 2001). On top of these, there are a number of specialised parameters that are used in specific industrial sectors. Problems arise due to modern parameters and out-of-date parameters having the same name, but different definitions (e.g. the *Rz* parameter). Also, many parameter descriptions are mathematically ambiguous (e.g. *Rsm*, Leach and Harris 2001) and further research is required in this area to avoid different software engineers from producing different algorithms to calculate the same parameter.

6 A recent comparison

It is widely recognised in the literature that different results are obtained from different measurement systems measuring the same features of the surface (Franks 1991) - this fact is often overlooked in practice. There is no reason to suppose, for example, that optical radiation associated with a non-contacting sensor penetrates to *exactly* the same depth below a surface as a contacting stylus will penetrate elastically. Optical and stylus probes happen to agree well on many types of surfaces, but extra care must be taken when interpreting the measurement data towards the extremes of the operational range of an instrument. Optical probes, for example, do not perform well when large local surface slopes are present that are well within the tracking capability of most styli. A recent comparison (Leach 2001a) of profiling measurements has shown a wide variation in results for laboratories with different, and in some cases identical, measuring systems. In one example, an artefact of sinusoidal profile, with an 8 μm period and 0.15 μm *Ra*, measurements of *Ra* varied from 20 nm to 2455 nm! The comparison included stylus instruments, interferometers and a triangulation system. Figure 2 shows the results of the comparison.

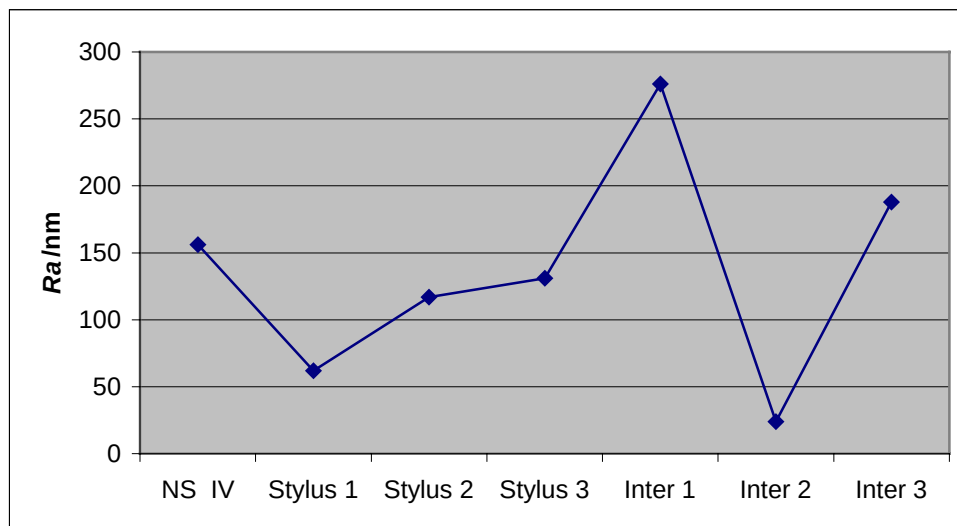


Figure 1 Results with an 8 μm nickel sinusoid (the 2455 nm value discussed in the text is off the scale of this graph)

7 Complicated standards

There are currently fourteen specification standards relating in some way to 2D surface texture measurement. Many of these standards are difficult to interpret. NPL has now produced a good practice guide that covers the use of stylus instruments in 2D, i.e. the guide is designed to give practical advice as well as help with interpreting the standards (Leach 2001b, www.npl.co.uk/e-store/).

8 Conclusion

Results such as those described in section 6 highlight the potentially disastrous route that is being adopted by some industrial sectors, i.e. making 3D measurements with instruments that are not fully calibrated in all the axes in which they need to measure. Commercial instruments have appeared on the market prior to the adoption of specification standards – this will always be the case but the user rarely knows precisely what the instrument is measuring. More research is required in this field in order to produce methodologies for calibration and performance verification of all instrument types on all surface types. Specification standards and best practice guides will be required and instrument users must make traceable measurements with instruments that are fully calibrated in all the axes in which they need to measure.

9 Acknowledgements

The author wishes to thank members of the Dimensional Metrology Awareness Club (www.npl.co.uk/npl/clubs/dmac) for airing many of the issues discussed in this paper. The paper was funded by the National Measurement System Programme for Length 1999-2002 Project 7.

10 References

- ISO 3274: 1996, Geometrical product specifications (GPS) – surface texture: Profile method – nominal characteristics of contact (stylus) instruments, International Organisation for Standardization, Geneva.
- ISO 4287: 1997, Geometrical product specifications (GPS) – surface texture: Profile method – terms, definitions and parameters, International Organisation for Standardization, Geneva.
- ISO 5436: 2001 (Parts 1 and 2), Geometrical product specifications (GPS) – surface texture: Profile method – measurement standards, International Organisation for Standardization, Geneva.
- ISO 12179: 2001 Geometrical product specifications (GPS) – surface texture: Profile method – calibration of contact (stylus) instruments, International Organisation for Standardization, Geneva.
- Bennett J. M and Mattson L, Introduction to surface roughness and scattering, Optical Society of America, 1999, 130 p.

Blunt L., Proc. NMC 2001, Harrogate, UK (2001)

Deck L. and De Groot P., Appl. Opt., v.33, p. 7334-7338 (1994).

Franks A., Nanotechnology, v.2, p. 11-18 (1991),

Leach R. K., Materials World, Feb., p. 18-19 (2000a).

Leach R. K., Meas. Sci. Technol., v.11, p. 1162-1172 (2000b).

Leach R. K. and Harris P. M., Meas. Sci. Technol. submitted (2001a).

Leach R. K., Proc. IMEKO, NIS, Cairo, Egypt, (2001a).

Leach R. K., Measurement Good Practice Guide No 37. Measurement of Surface Texture Using Stylus Instruments, National Physical Laboratory, 2001b, 84 p.

Leach R. K., Blunt L., Chetwynd D. G. and Yacoot A., Proc. ISMTII, NIS, Cairo, Egypt (2001).

See C. W., Somekh M. G. and Holmes R. D., Appl. Opt., v.35, p. 6663-6668 (1997).

Stout K. J. and Blunt L., Three Dimensional Surface Topography, Penton Press, London, 2000, 285p.

Thomas T., Hamaker C., Martyniuk J. and Mirro G., Precision Engineering, v.22, p. 233-242 (1998).

Vorburger T. V. and Teague E. C. Precision Engineering, v.3, p. 61-83 (1981).

Whitehouse D. J., Wear, v.83, p. 75-78 (1972).