Microscopy & Microtechniques Focus

THE USE OF ADVANCED 3D SURFACE METROLOGY FOR THE CHARACTERISATION OF MICRO AND NANO SURFACE STRUCTURES

J Armstrong, L Blunt and R Blunt

Over recent years the discipline of surface metrology has advanced greatly both in terms of instrumentation and in terms of techniques for surface characterisation. Recent developments in White Light Interferometer (WLI) instrumentation and in measurement software (particularly the so-called coherence correlation algorithm) for this technique has increased the vertical (i.e. height) resolution of these instruments to give a capability of 0.01 nm (i.e. 0.1 Angstrom), which makes it a practical tool for assessing the quality of micro and nanoscale surfaces. Whilst both WLI and AFM techniques have allowed visualisation of the 3D surface texture of surfaces at the micro and nanometer scale, a clear advantage of interferometry is that it is contactless, fast and can cover large areas, whereas the AFM technique, although it has a better measurement resolution tends not to suit the measurement of large areas and low spatial frequency components. A common flaw in the use of both of these instrument types is that despite the "richness" of the data collected it is usually only the Ra, Rq or Rt values of the surface texture that are quoted. True surface areal texture information cannot be described by such parameters Consequently these simple amplitude based roughness parameters are inadequate for describing anything more than very simple surface-structures and as a result differing textures can often yield similar roughness values. This paper outlines the recent advances in 3D surface characterisation and the use of white light interferometry.

Author Details:

J Armstrong, Taylor Hobson Ltd,
L Blunt, University of Huddersfield,
R Blunt, IQE (Europe)

ROUGHNESS AND TRIBOLOGY

In the sheet steel manufacturing industry, surfaces and their properties are as important as the bulk properties of the material. Many sheet surfaces are in fact designed to have very specific surface topographies. The surface topography has an effect on a wide range of application properties, such as formability, friction, wear, visual appearance, bonding behavior of paints and coatings, corrosion resistance, fatigue behavior, sealing capacity, electrical and thermal contact resistance, etc.

It is due of these properties that specific "patterns" are produced on the steel sheet to enhance specific properties. The patterns are introduced via production of a mirror image topography on the sheet steel rollers. The rollers subsequently imprint the pattern onto the steel sheet. When these patterns are produced on the sheet surfaces the end product is known as "textured steel". The textured steel will have surface properties designed to improve its functional performance.

SURFACE TEXTURE IS COMPLEX

Surface characteristics can be complex and is present at different scales, roughness, waviness and form can and do exist in combination. In addition to the finish produced by the manufacturing process, there is an inherent structure in the material especially at the sub micron and nano-scale. In metals, grain boundaries produce surface irregularities that are extremely fine compared with the texture from the manufacturing process however in some case these irregularities can give a macro scale appearance such as that *used in architectural stainless steel.*

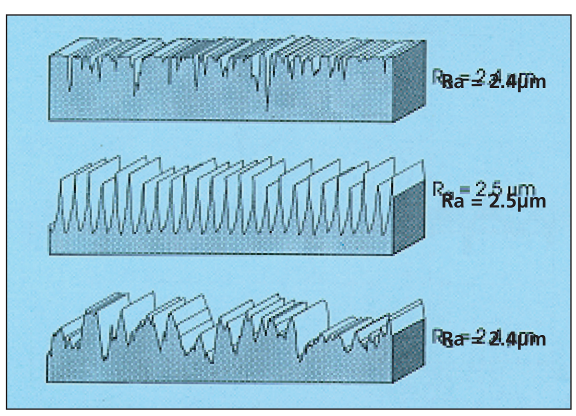


Figure 1. The misleading nature of the Ra parameter.

The driving force behind the development of a plethora of roughness parameters is due to the limited nature of the classic roughness parameters and the complex nature of surface texture. Care must be taken when selecting a parameter; i.e. amplitude parameters such as Ra can be applied to both a sinusoidal and stepped shaped surface but still offer a similar Ra value, Ra is typically very limited and fails to give clues as to the functional performance of surfaces, *Figure 1.*

However, if parameters are correctly applied they can prove useful in describing differences between many surface types. Parameters can be used to relate surface appearance (optical), surface energy (cleanliness, hygiene), surface resistance /conductivity (shielding), heat transfer (heat flux control), barrier (corrosion performance, permeation control), adhesion, surface topography (friction, forming behavior, touch), compatibility with additional organic coating layers (paints, glues…) and others.

The latest generation of areal (3D) roughness pamameters fall into three four classifications and attempt to describe amplitude, spatial, hybrid and volumetric properties of the surface. *Table 1*[1,2]

Table 1. Classification of Areal Parameters

	Amplitude Parameters
Sq	Root-mean square deviation of the surface (μm)
Sz	Ten point height of the surface (μm)
Ssk	Skewness of the surface
Sku	Kurtosis of the surface
	Spatial Parameters
Sds	Density of summits of the surface (mm^{-2})
Str	Texture aspect ratio of the surface
Sal	Fastest decay autocorrelation length (mm)
Std	Texture Direction of the surface (deg)
	Hybrid Parameters
SΔq	Root-mean square slope of the surface (μm/μm)
Ssc	Arithmetic mean summit curvature ($μm^{-1}$)
Sdr	Developed surface area ratio (%)
	Volume Parameters
Vmp	Material Volume in Peak zone ($μm^3/mm^2$)
Vmc	Material Volume in Core Zone ($μm^3/mm^2$)
Vvc	Void Volume in Core Zone ($μm^3/mm^2$)
Vvv	Deep Valley void Volume ($μm/mm^2$)

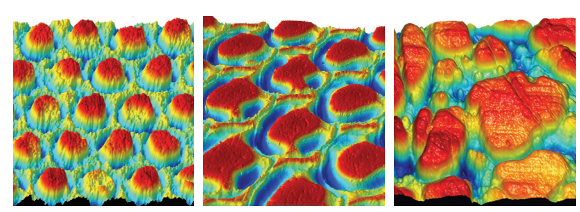


Figure 2. Examples of sheet Steel products

SURFACE PATTERN ANALYSIS

The information in all surface geometrical patterns is contained in the attributes of the individual pattern features and the structural relationships between these features.

To extract this information the individual pattern features need first to be identified before characterisation. Care is needed in extracting these features since the measurement process can produce many insignificant artificial features that swamp the subsequent pattern analysis.

The stable extraction of significant surface features form what is termed a structured surface has been discussed in detail by Scott [3]. Techniques to characterise structured surfaces are still being researched with some very promising novel ideas being developed [4-7].

It is envisioned that pattern analysis, through feature parameters, will become a critical tool for the future in the surface texture toolbox and this will be an essential requirement of precision and nanoscale metrology of high aspect ratio features and heavily patterned surfaces.

The difficulty with this type of surface metrology lies around the ability to automatically separate pattern features. This issue is very similar to image segmentation in the field of image processing. Data captured from the measurement of an heavily patterned/structured surface can be displayed and visually analysed as a surface metrology problem or it can be considered as an image analysis problem.

Thus if the data is considered as image analysis information then in order to partition an image into a number of separated areas, various approaches to segmentation can be applied and *Figure 3* shows the effect of segmenting the surface of a steel sheet to separate critical significant surface peaks pits and saddle points as well as defining the surface pattern based on closed contours.

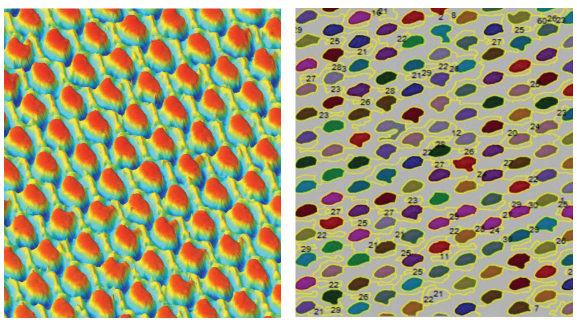


Figure 3. Pattern analysis of steel sheet structured surface

CONCLUSIONS

Structured surfaces are becoming increasingly common place within the sheet metal industry for the enhancement of surface performance. It should be noted that simple surface parameters on there own are often insufficient for describing these complex structured surfaces. With the introduction of newly developed 'S' parameters attempts to characterise all aspects of a complex surface topography are being developed to allow full structural characterization.

When the surface structure becomes very complex in nature it is of great benefit to describe and view the surface 3-dimensionally.

The Talysurf CCI which offers non-contact "Areal" measurement capability was found to be a tool ideally suited to this task, with the high-density measurements offering an excellent representation of surfaces as well as a significantly wide field of view [8,9]. Areal measurements by this instrument are produced using coherence correlation interferometry, a microscope based technique providing high vertical resolution (0.01nm Z resolution) and high surface sensitivity. Thus allowing data capture on previously difficult to measure surfaces to be measured accurately and repeatable. It is suitable for the measurement of both highly reflective and low reflective surface types such as metal, glass, ceramics, coatings, polymers and inks can all be measured.

REFERENCES

1. Jiang X, Scott P., Whitehouse D., Blunt L., Paradigm Shifts in Surface Metrology Part I: Historical Philosophy (RSPA20071874), y Proc R. Soc. Lond A., 463, 2049-2070 (2007).

2. Blunt L, .Stout K.J, EC Project final report "Development of a Basis For 3D Surface Roughness Standards" SMT4-CT98-2209 (DG12). (2001)

3. Scott P.J. in "Advanced Techniques for Assessment of Surface Topography" Ed

4. Blunt L.and Jiang X, Kogan Page Science London (2003)

5. Barré, F. & Lopez, J. Watershed lines and catchment basins: a new 3D-motif method, Int J. Mech. Tools Manufact., vol 40, (2000) pp1171-1184.

6. Mezaghani S. Zouhani H., "Characterisation of 3D waviness and roughness motifs" Proc Int Conf 9th Met and Prop of Surfaces Halmstad Sweden Sept (2003)

7. Lezoray O.and Cardot H., Histogram and watershed based segmentation of color images, Technical Report, University of Caen, France, (2000)

8. A Bankhead, UK Patent Application 0206023.4

9. D Mansfield, 'The TalySurf CCI 3000 - A Metrology Solution for Micro-Systems', DMAC April 2003

RMS - Learning for Life

MICROSCIENCE 2008
www.microscience2008.org.uk
RMS

The Royal Microscopical Society wholeheartedly endorses the ethos of lifelong learning and is a keen advocate of education and professional development. "As a professional body we see that one of our core rolls is to provide educational resources, not only to our members but to the community as a whole, in order to develop careers and support a wider understanding of science and microscopy at all levels", explains Rob Flavin, Executive Director of the RMS.

Professional development

To sustain learning and development, the RMS publishes The Journal of Microscopy and a series of microscopy books, as well as helping young scientists through bursaries. The Society further demonstrates its commitment to professional development by offering qualifications in microscopy, and organising annual 5 day training courses in light, electron and confocal microscopy, flow cytometry and cell imaging. In addition, it stages its own scientific meetings that address topics at the cutting-edge of microscopy.

Forthcoming RMS events:

Date	Event Title	Location
17 -18 December 2007	Aberration Corrected & Quantitative (S)TEM & Advances in Tomography II	Manchester
10 January 2008	Cytotoxicity and Characterisation of Nanoparticles/tubes and Wires	Cambridge
31 March - 01 April 2008	Electron Backscatter Diffraction Conference	Sheffield
07 - 11 April 2008	The Microscopic Ice Age - A Course in Cryo Techniques for Electron Microscopy Rothamsted Research,	Harpenden
14 - 18 April 2008	Spring School in Electron Microscopy	University of Oxford
23 - 26 June 2008	MICROSCIENCE 2008 - International Conference and Exhibition on the science of microscopy and imaging	ExCeL, London
07 - 09 July 2008	Light Microscopy Summer School	University of York
10 - 11 July 2008	Getting the most from your Confocal	University of York

Financial support

In order to support their continuing education, RMS members are entitled to a substantial discount on all course and meetings fees. Offering further assistance to young scientists who are members, the RMS encourages them to attend conferences in both the UK and abroad through a generous bursary scheme.

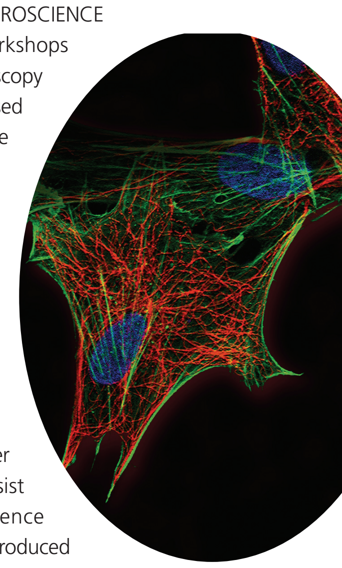
"Having a good grasp of the basic theories and practices of microscopy is a vitally important step to carrying out meaningful research, and we are especially keen to support researchers in the early stages of their careers," explains Debbie Stokes, RMS Honorary Secretary Science (Physical).

RMS

Training for free at MICROSCIENCE 2008

Providing a free 'taster' to RMS courses, at MICROSCIENCE 2008, the RMS will be running a Learning Zone that is designed to provide an introduction to microscopy and the latest technology for the newer user. Sharing the main exhibition hall with the MICROSCIENCE 2008 exhibition and equipped with its own lecture theatre, the venue will offer a programme of free seminars. It will also host equipment loaned by exhibiting companies to allow visitors to get hands on experience, guided by renowned experts drawn from the international ranks of the RMS.

In addition to free access to the latest technology and volunteer experts who will generously pass on their knowledge within the RMS learning Zone, MICROSCIENCE 2008 will also offer free workshops from leading imaging and microscopy companies. All of which is encompassed within the world's largest free exhibition dedicated to imaging and microscopy.



"Due to the many free training opportunities available at MICROSCIENCE 2008, researchers and technicians should be able to access local training budgets from within their respective organisations to facilitate attendance," explained Rob Flavin. "There are also further RMS bursaries available to assist both exhibition and conference attendance, including the newly introduced MICROSCIENCE Early Stage Researcher Bursaries specifically for the future generation of microscopists. This all presents such a valuable learning opportunity, that we hope to see many academic and industrial researchers from Europe and around the world."