University of HUDDERSFIELD

University of Huddersfield Repository

Brown, L. and Blunt, Liam

Surface Metrology for the Automotive Industry

Original Citation

Brown, L. and Blunt, Liam (2008) Surface Metrology for the Automotive Industry. In: Inaugural Automotive Researchers' Conference, 8-9 January 2008, University of Huddersfield.

Surface Metrology for the Automotive Industry

Leigh T Brown, Liam A Blunt
Centre for Precision Technologies, The University of Huddersfield, Queensgate, Huddersfield.

Abstract

The automotive industry has often been at the forefront in the use and development of metrology techniques for both research and quality control. With the development of improved measurement technology, in terms of both accuracy and range of measurement there is scope for further utilising surface metrology and associated characterisation techniques to improve and predict the performance of functional surfaces in a variety of applications.
The development of surface metrology techniques includes the ability to measure areal surfaces rather than the traditional profile characterisation techniques such as the widely used Ra (average roughness).
This paper will discuss the limitations of profile measurement and how these limitations can be overcome with the use of areal surface characterisation techniques to give a better understanding of the functional surface. The paper will then go on to discuss a case study, where areal measurement has been instrumental in the improvement of process and function.

Introduction

<u>The Limitations of Profile measurement</u>

The standard method for characterisation of surfaces in most industries for quality purposes is the use of basic 2D profile measurement and is often depicted as an average roughness value (Ra). Ra is not the only parameter used to describe profile measurements of a surface; in fact there are in excess of two hundred 2D parameters which can be used to describe various attributes of a surface measurement. Though if we examine three different surface profiles with a similar value of Ra we can see how the parameter does not give a full description of the surface.

Honed

Turned

Ground

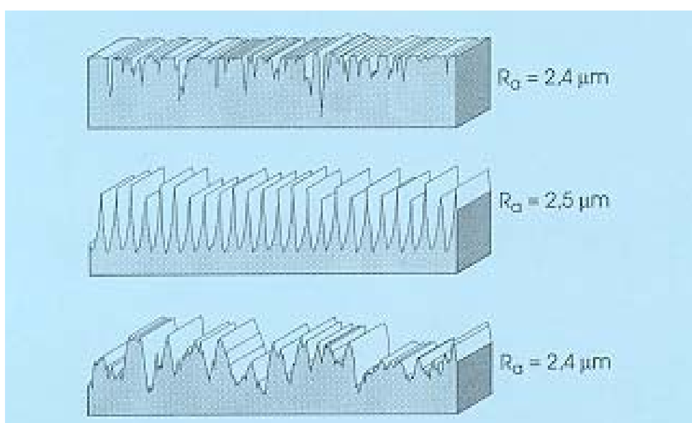


Figure 1 – The limitations of Ra as a Surface Descriptor

As can be seen from figure 1, the three surface profiles are from surfaces manufactured with inherently different properties, yet the three values of Ra are very similar, as although for example the honed surface is dominated by valleys and plateaux's in contrast to the turned surface which is dominated by peaks with a high aspect ration, they share an Ra in the region of 2.5 microns. This highlights the limitations of profile measurement and characterisation as although the Ra value might be well within specified tolerances it can quite clearly be seen that the function of the two surfaces would differ considerably.

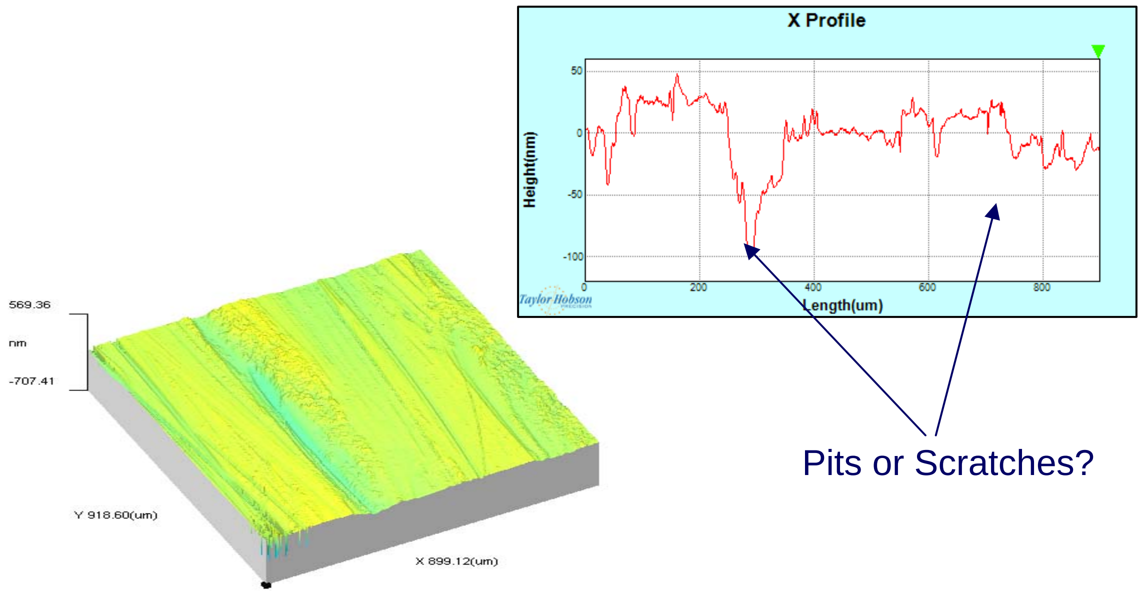


Figure 2 – The benefits of areal characterisation (L Brown 2006)

Figure 2 shows how some problems with profile characterisation can be overcome, as can be seen, if a random profile is taken from the areal surface measurement, features can be seen that could be either discrete pits or scratches, it is easily determined from the areal measurement that the features are in fact scratches. Depending upon the application of the surface, this could have significant consequences for function.

Traditionally the restriction of areal surface measurement was the range of surface metrology instrumentation available, from figure 3, it can be seen that there are area measurement tools which span a wide range and resolution. This indicates that there is generally a measurement solution for a wide variety of applications, including most that might be encountered in the automotive industries and allied technologies.

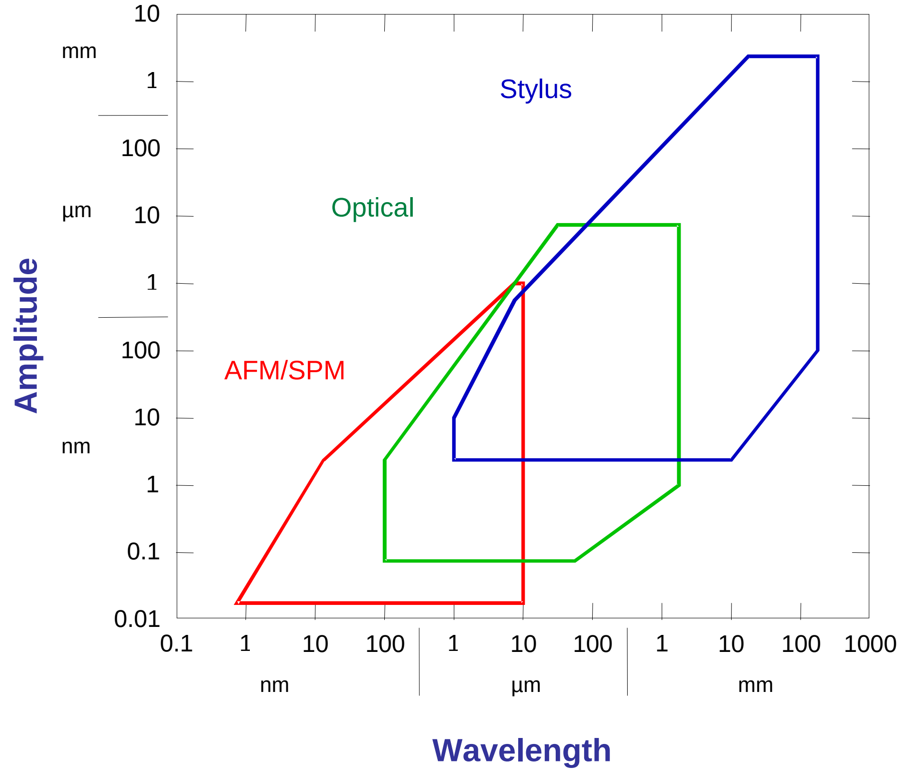


Figure 3 - Steadman Diagram showing the range and resolution of available measurement techniques

Areal Measurement and Characterisation

Following the advances in areal surface measurement instrumentation a need was realised for developments in characterising surfaces whilst trying to avoid the ambiguity which was noted in profile characterisation. A suite of areal surface texture parameters were developed which aim to give a holistic set of functional descriptors capable of characterising surfaces fully. The areal parameters can be seen in figure 4.

It can be seen from the figure that the parameters are arranged into groups or families which concentrate on the characterisation of various aspects of the surface such as amplitude (roughness), spacing (spatial aspect such as texture strength), and hybrid (topography features such as slope of the surface). The curve related parameters are a set of descriptors which have been specifically developed with some tribological automotive applications in mind, and are particularly useful in the characterisation of bearing surfaces.

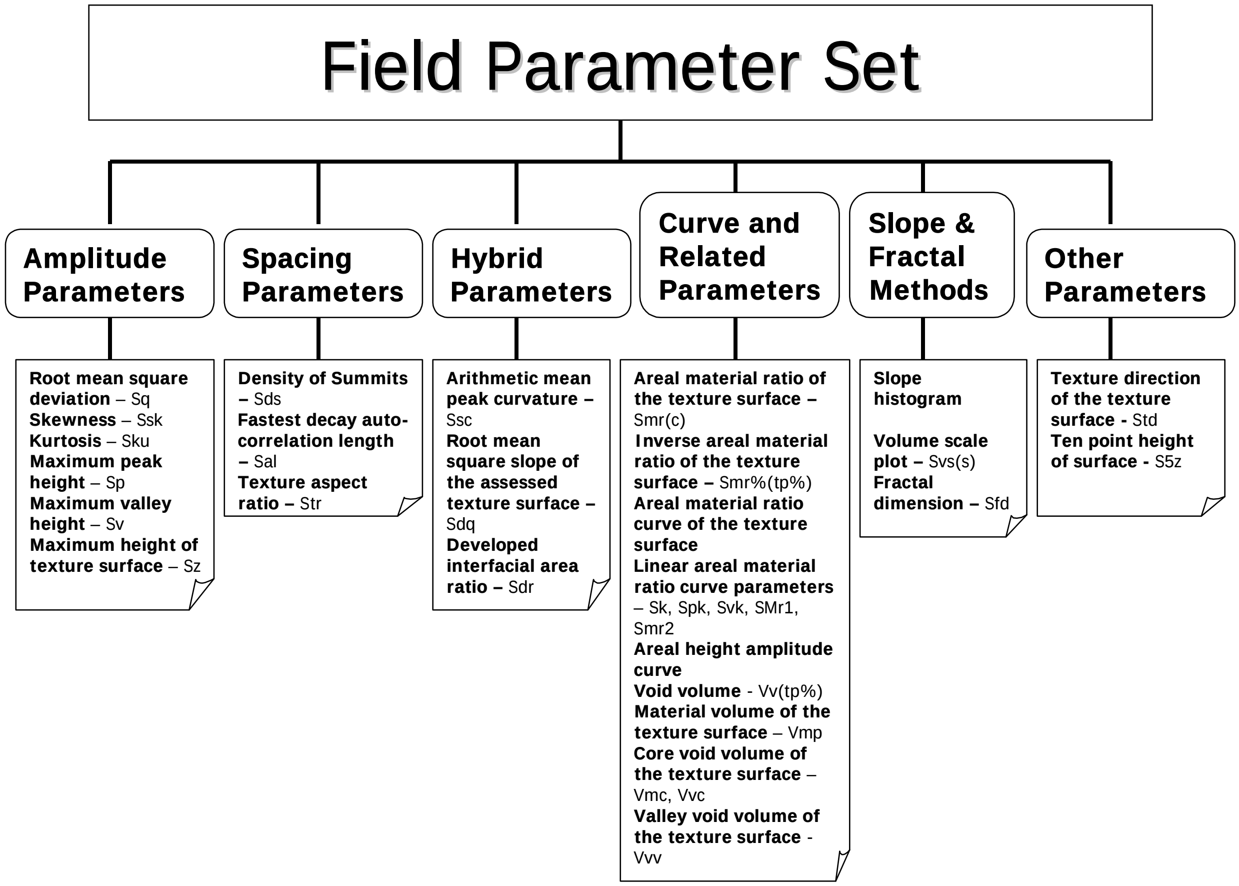


Figure 4 – Areal surface texture parameters

Another enhancement in the surface characterisation toolbox is the development and standardisation of advance filtering techniques. With filtering techniques it is possible to extract aspect of the surface such as form waviness and roughness in order to better understand the functionality of a surface.

The following case study utilises a variety of techniques in order to offer an explanation for a particular manufacturing problem.

Applications of areal characterisation – Case study

Machining Assessment of Journal Bearings on Transmission Pumps Using Wavelet Analysis

A series of transmission oil pumps were manufactured by a company for use in heavy earth moving vehicles. The journal bearings in the pumps were finished using a grinding process. Unfortunately increasing performance demands on the pumps had led to a number of early service failures. The problem of the surfaces of the journal bearing was highlighted as the only possible reason for failure. The journal bearings on the transmission pumps were manufactured and finished on a production grinder to a company specification of $R_a = 1.6\mu m$, the usual roughness achieved from the shop floor being $R_a = 0.8\mu m$. The initial failures of journal bearings appeared on the pump drive shafts and the pumps failed due to total wear out of the bronze bush counter faces.

The manufactures reduced the surface roughness of the bearings by machining their pump journals on a tool room grinder. This led to improved service performance and no further failures were reported. The tool room grinder however, is not well suited for mass manufacture and so the production grinder was operated in such a way as to achieve the same or similar levels of roughness as the tool room grinder and roughness levels of $R_a = 0.6\mu m$ were achieved.

Machining at this level of roughness appeared to be initially successful until further pump failures were again reported. Alarmed by this situation, manufactures went on produce pumps having targeted roughness levels of $R_a = 0.3\mu m$ on the tool room grinder. Recently, a new computer numerical control (CNC) grinding machine has been introduced into the production line and an improvement in service life has been reported.

The following case study seeks to examine the differences between the ground surfaces and make some assumptions regarding the service performance.

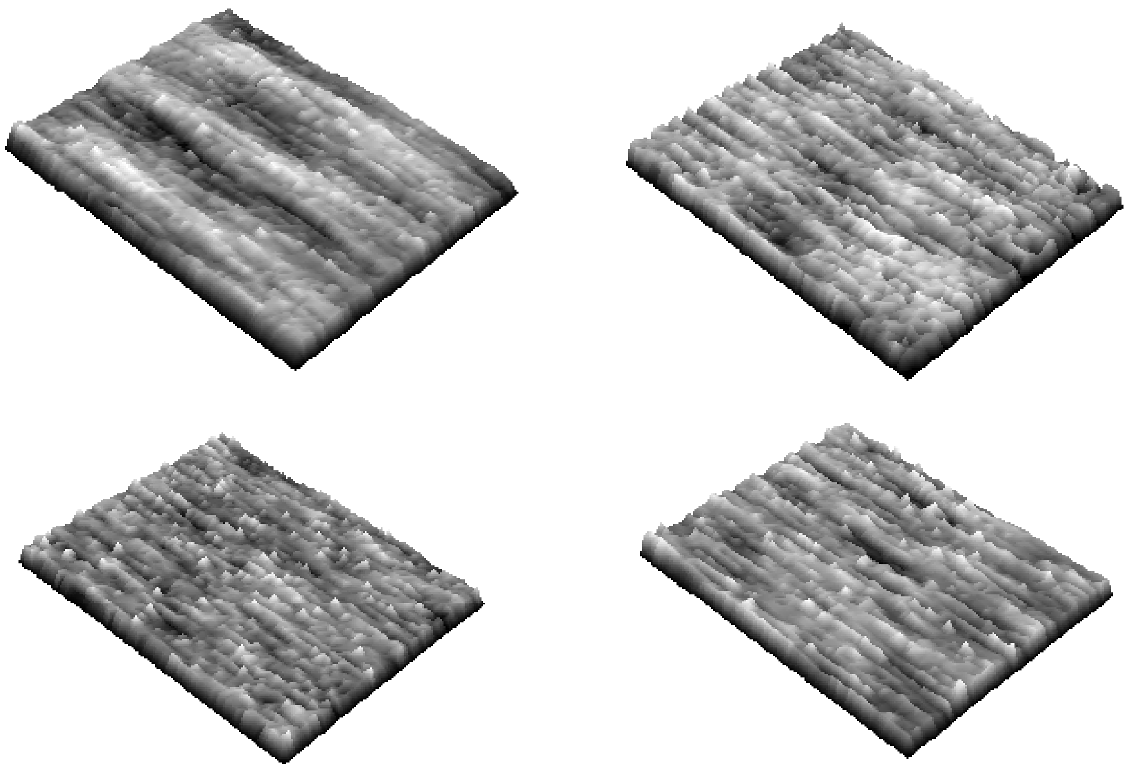
9.5.2 The Study

The 3D surface measurement and characterisation was employed to analyse the manufacturing processes. Four set of journals were measured. Each journal was measured three times at 120 degree steps around the circumference using a WYKO NT2000 interferometer in vertical scanning mode. All of the specimens provided in the four groups were measured over an area of $0.9 \times 1.2mm^2$. The set of measured journals are outlined below:

- *Production from 1999 shafts*
- *Failed 1999 shafts*
- *Tool room production shafts*
- *CNC production from 2000 shafts*

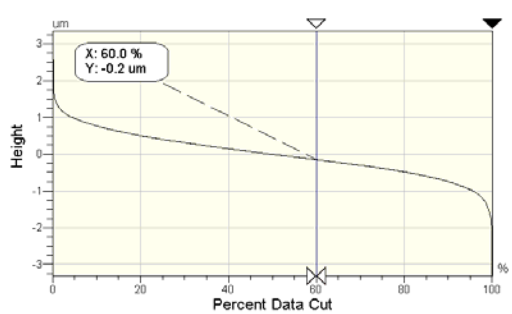
After initial form removal, the axonometric projections of the measured surfaces of journal pumps are shown in Figure 5. It can be seen that there is evidence of waviness in the surface texture of the components ground on the production grinder and also on failed specimen (in Figure 5*a*-*b*). The waviness is significant across the lay of the surfaces. When considering the bearing area ratio curve, it is clear that the tool room and CNC surface have flatter bearing ratio curves, at roughness levels of 0.2um height below the mean plane (company specification of the manufacturer) the bearing ratio are 78% ~ 85.5% as shown in figure 6.

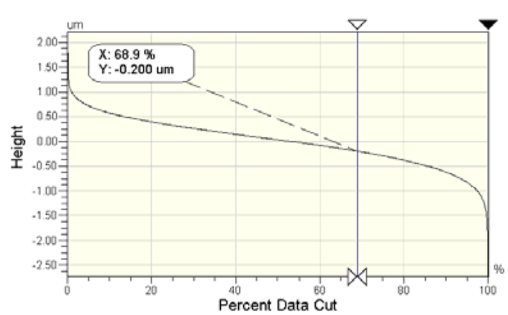
(a) Production ground specimen b) Failed specimen after test.



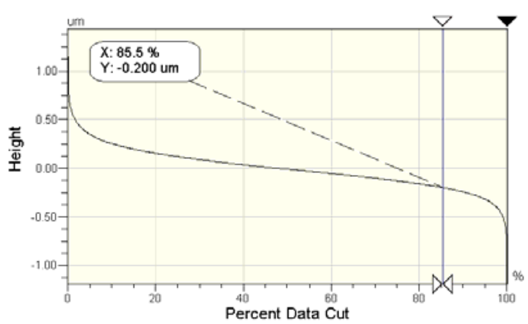
(c) Tool room ground specimen (d) CNC ground specimen

Figure 5- The surface textures of the four groups of journal bearings

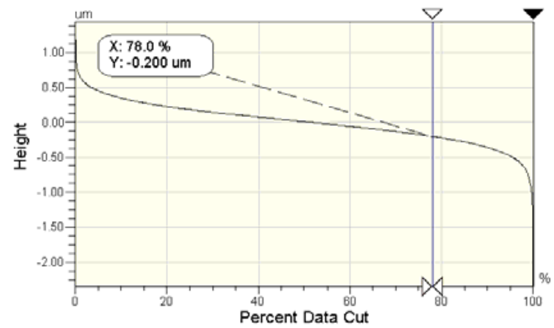




(a) Production ground specimen



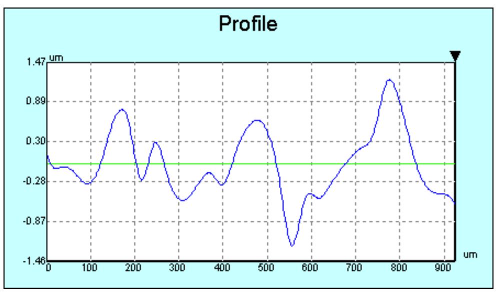
(b) Failed specimen after test



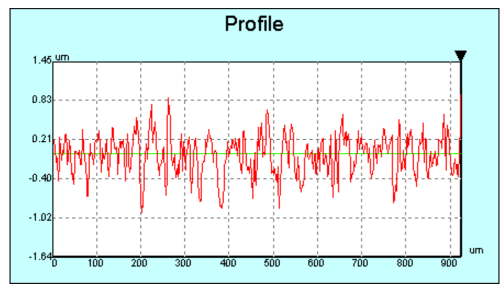
(c) Tool room ground specimen

(d) CNC ground specimen

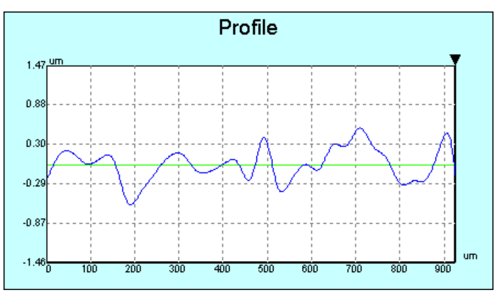
Figure 6- Bearing ratio curves for the four groups of journal bearings



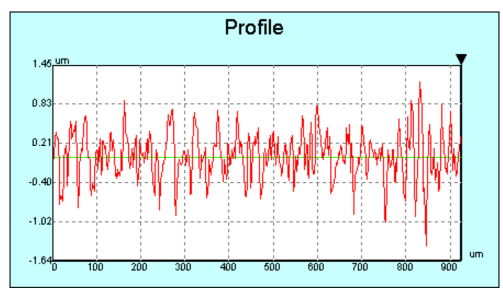
(a) Waviness profile of the production ground specimen



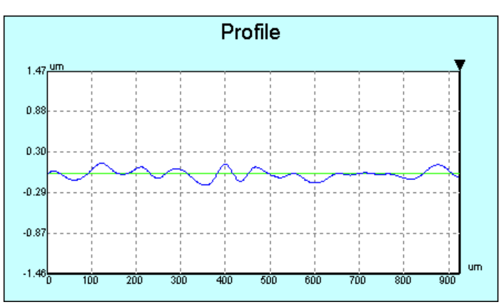
(b) Profile of roughness of the production ground specimen



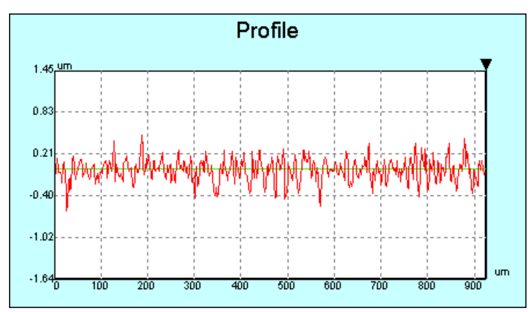
(c) Waviness profile of the failure specimen



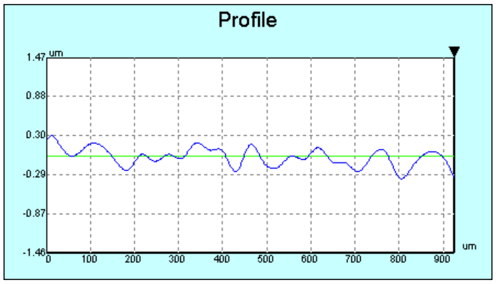
(d) Profile of roughness of the failed specimen



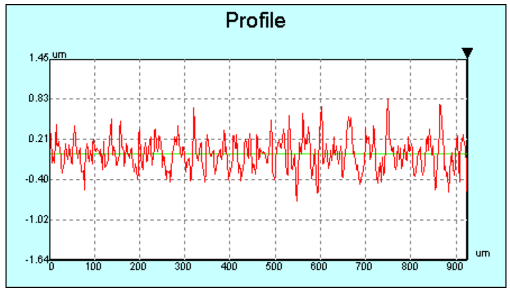
(e) Profile of waviness of the tool room ground specimen



(f) Profile of roughness of the tool room ground specimen



(g) Profile of waviness of the CNC ground specimen



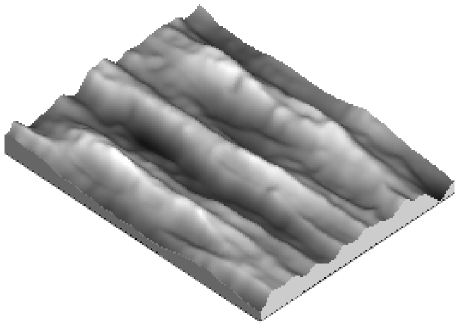
(h) Profile of roughness of the CNC ground specimen

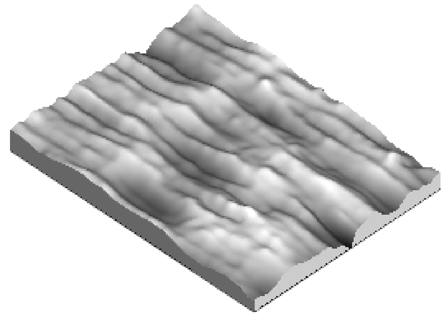
Figure 7 The profiles derived from decomposed rough and wavy surfaces of the four groups of journal bearings

Wavelet Analysis

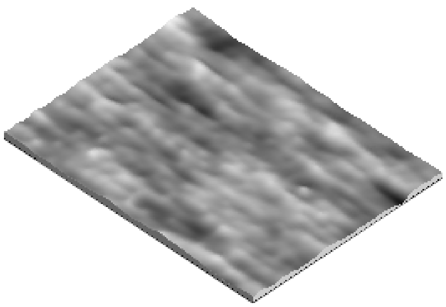
In this study, a wavelet filter based on the second generation bi-orthogonal lifting scheme is employed to separate and extract the roughness and waviness elements of journal surface of the pumps. Using Wavelet filtering, the benefit is that filtered surfaces will record the nature of real waveform, shape and amplitude within a permitted cut-off wavelength, and there will be no distortion of the filtered surface within this cut-off wavelength. Consequently, the real waveforms have not suffered any attenuation for wavelengths up to the cut-off wavelength as would be the case using conventional filter cut off techniques.

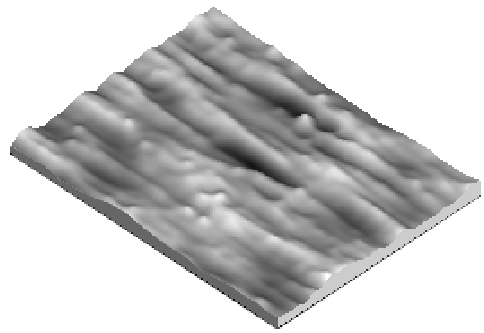
Identification of roughness and waviness in above surface textures can be accomplished by suitable choice of cut-off wavelengths. Figure 7 shows low frequency and high frequency profiles derived from the decomposed roughness and wavy surfaces that have been filtered using $\lambda_c = 0.08mm$ for the roughness and $\lambda_f = 1.2mm$ for waviness. It is considered that roughness levels are below $R_a = 0.3\mu m$ and waviness below $W_a = 0.2\mu m$. All ground surfaces have a similar roughness structure with only slight differences in amplitude. Significantly there are different levels of waviness among the four groups. The axonometric projections of the wavy surfaces are shown in Figure 8. The production surface does appear to contain more waviness components. The CNC surface has a similar wavy structure to the tool room ground surface with the amplitude of the waviness greatly reduced when compared to the production ground surfaces.





(a) Standard production ground specimen b) Failed specimen after service





(c) Tool room ground specimen (d) CNC ground specimen

Figure 8 - The wavy surface of the four group journal bearings

Discussion

Overall the study showed significant differences between the tool room ground surfaces and the production ground surfaces. These were centered around the presence of waviness within the surface texture of the production ground surfaces. CNC ground surface shows a significant improvement comparing with the production ground surfaces.

By using wavelet analysis, it is clear that the particular grinding practices produced considerable waviness in the surface texture. The waviness was a result of grinding chatter, which adversely affect the work piece surface finish and performance. Chatter was associated with vibrations in the grinding process. Vibrations during grinding were probably caused by bearings, spindles and the unbalance of grinding wheels as well as external sources. Such waviness is thought to be evident on the surfaces measured in the present study and particularly evident on the work pieces machined on the production grinder. After analysis of the production grinder the waviness was attributed to grinding wheel unbalance. The waviness on the journal surfaces led to high spot contact during service causing local high contact stress zones above failure limits at the more stringent service conditions. Elimination of the waviness has led to no more reported pump failures.