Structured Geometry Surfaces Features for Optimised Function

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Abstract

With the deepening understanding of the importance of the surface and its properties on the function of engineering components there has been an increasing focus on "designing" the surface topography to optimise functionality. Increasingly this "design" aspect of surfaces has taken the form of giving the surface a clearly defined topographical structure or surface micro geometry. The aim of the surface structure is to ensure specific surface properties which enhance or even define the surface functionality. Such structures are not necessarily new and plateau honing of automotive cylinder liners is a clear example of a traditional process where bearing and lubrication transport and retention properties are enhanced. The latest developments in the applications of structured surfaces cover functionality as wide as enhanced tribological properties, tailored optical properties and optimised bio cellular attachment. The features on the functional surfaces are usually defined geometrical structures such as craters with specific volume and spacing or protuberances having fixed geometries heights and spacing. The concept of structured surfaces is introduced in this review paper along with examples of the application of surface structures in the fields of injection moulded optics, bio implant attachment and enhanced tribological properties. The surface structures are discussed in terms of the improved properties and the challenging aspects of modelling function and their measurement and characterisation.

1 The evolution of structured surfaces

The process of creating a surface leaves a "finger print" on the surface of a part that is unique to the creation process. Conventional manufacturing processes produce "non engineered" surfaces resulting from the need to achieve a nominal geometry of a part. However surfaces are increasingly "engineered" or "structured", where the final processing imparts functional properties. With the increasing application of micro and nano-scale components the surfaces are the critical factor which dominates the component function. In a bid to optimise the component functionality there has been a huge focus on the component surfaces and designing the surface structure to optimise a particular surface related function. This had led to a reclassification of surface types as shown in figure 1[1].

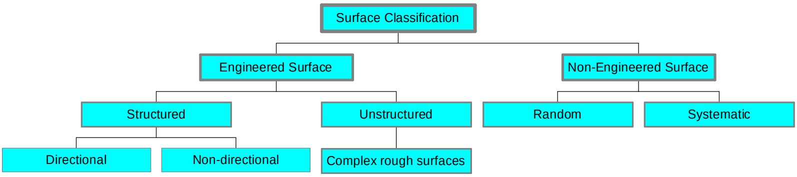


Figure 1: Classification of Surfaces

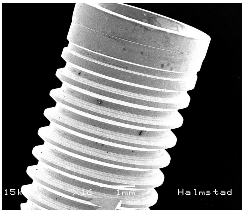
Structured surfaces whilst new to the engineering field have been widely observed in nature, from the self cleaning abilities of the lotus flower to the optimised fluid flow over shark skin. A particularly remarkable recent study has investigated the structured nature of snake skin where layered nano-scale fibrals on the snake membrane structures are thought to aid motion and sub-microscale pits are present at the membrane interfaces these are considered to aid the bearing properties [2].

2 Scales of structures

The scale of surface structures can vary from the nano-scale to the millimetre scale. What is critical is that the scale operates at the scale of the unit event of the function that the structure is trying to influence[3]. For example, where osseointegration is the desired function, manufactured structures optimised to cellular scale have been produced on Ti dental implants. The surface is produced by controlled electrochemistry using a calcium based electrolyte. This gives a surface structure of sub micro sized pores in a complex TiO/Ca oxide layer. These surface have then been function tested using pull out test in rat tibia, Figure 2 [4].

3 Design

To utilize structured surfaces successfully requires a deep understanding of the function. This is not a trivial undertaking and normally requires the development of a mathematical model relating the function to the surface structure geometry. Additionally extensive experimental data is needed especially where models are lacking. Even if both requirements appear to be satisfied there may still be difficulties. In the case of laser texturing used to reduce friction/wear in sliding contact, leading researchers still fail to agree on the validity of the Reynold's equation when trying to explain the lift phenomena associated with the surface structure [5]. Dobrica et al [6] however contend that the Reynolds equation can be applied in textured sliders, as long as dimple aspect ratio is sufficiently large, and Re (Reynolds number) sufficiently small.



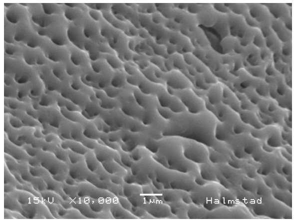


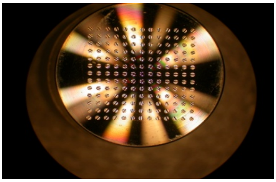
Figure 2: a) Ti dental screw implant b) Sub micron structured surface.

4 Manufacture, Specification and Measurement

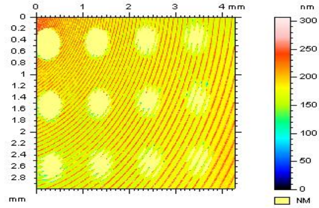
The use surface geometrical structures in the field of optics is a more mature technology and is becoming ever more important in the production of roll to roll optical polymer films. The quality of the optical performance is very closely related to the precision of the geometry of the structure. Assessment of the structure geometry however is not straightforward and requires a philosophical change in the approach to characterising the surface. The new approach characterises the geometrical primitives i.e. identifies the dominant geometry and its deviation from specification. The characterisation requires a combination of conventional surface metrology and co-ordinate metrology methodologies, this takes the form of data filtering, pattern analysis, edge detection, datum establishment, surface fitting and application of areal roughness parameters [7].

Figure 3 shows an example of a diamond turned mould insert used to produce optical depixelators for mobile telephone screens, the structure consists of an array of hemispherical depression produced by a rapid tool servo technique. The quality of the image on the phone screen is dependent on the precision of the roundness of the hemispherical impressions. For assessment of this structure the surface is measured using an optical interferometer, Figure 3b. The surface data is then analysed using an edge detection technique based on a Laplace of Gaussian filter. The technique detects the depression edges a single continuous contour Figure 3c. Further analysis of the edge contour removes the basic circular form using a least squares technique.

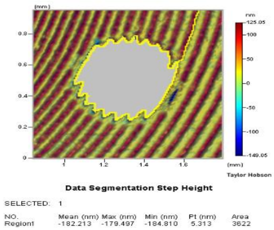
Following this, the edge contour is analysed to quantify the peak to valley deviation this information is then used to optimise the manufacturing process.



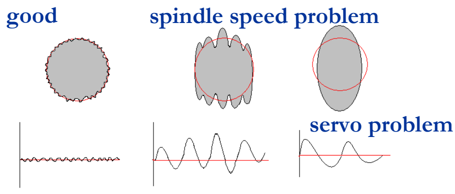
a) Machined insert



b) Measured surface



c) Continuous contour capture by edge detection



d) Schematic roundness trace of continuous contour

Figure 3: Mould insert

5 Conclusions

- Structured surfaces are becoming increasingly technologically important
- The developed structures are highly function specific
- Application needs deep knowledge of part surface function.
- Metrology requires combining surface metrology with CMM techniques. These methods have shown success for new techniques, BUT more study and case studies are needed to validate the basic approach.

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