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MANUFACTURING THE FUTURE CONFERENCE 2013

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Abstract: Freeform surfaces are replacing traditional surfaces and have significantly reduced volume and weight and highly improved performance in modern complex optic systems, bio-systems and other disciplines [1]. These high-precision freeform components are enabled by state-of-the-art micro-machining technologies, compromising mechanical methods (diamond turning and polishing etc.), physical methods (laser beam and ion beam machining), and chemical methods (lithography, electro-chemical machining etc.). However, a fundamental pre-requisite to achieve the potential growth to these high-added value freeform components is to measure and characterize these components with the required accuracy such that their manufacturing quality can be controlled. The surface topography is a fingerprint of all process stages of the manufacturing process. Thus identifying and evaluating these topographical features on freeform surfaces left by production techniques are critically important in that they could present an indication of the manufacturing quality and offer feedback to the process control.

Morphological methods, a useful tool in surface metrology, are employed here to extract these machining marks in the surface topography so that they can be subsequently characterized. Morphological methods are built on the basis of mathematical morphology and widely used in image processing. The central ideal of morphological methods is to examine the geometrical structure of a surface by probing it with structuring elements (usually circular, e.g. disks for profiles and balls for surfaces). The morphological closing operation suppresses valleys on surface, while the opening operation removes peaks. The combination effect of closing and opening thus suppresses both peaks and valleys. Nonetheless the conventional implementation is limited to planar surfaces (images) and therefore unsuitable for freeform surfaces because they are continuous surfaces depending on global complex geometry and having no translational and rotational symmetry. This limitation is broken up by using a novel morphological method, which was recently developed based on alpha shape theory [2]. The proposed morphological method is applicable to freeform surfaces and enables arbitrary size of ball (disk) radius. Case studies are presented to demonstrate the usability of the proposed method. A tooth implant surface and an F-theta lens surface are studied. Micro-machining marks on surfaces are successfully extracted and characterized.

Significance Statement: the significance of this work is the use of a novel morphological method to identify and characterize micro-machining signatures on freeform surfaces as a feedback for manufacturing process controlling.

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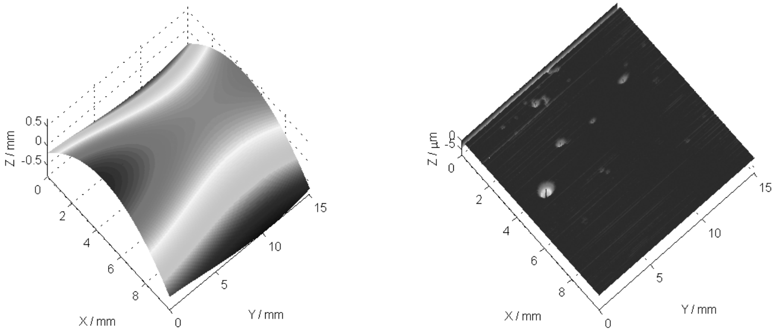
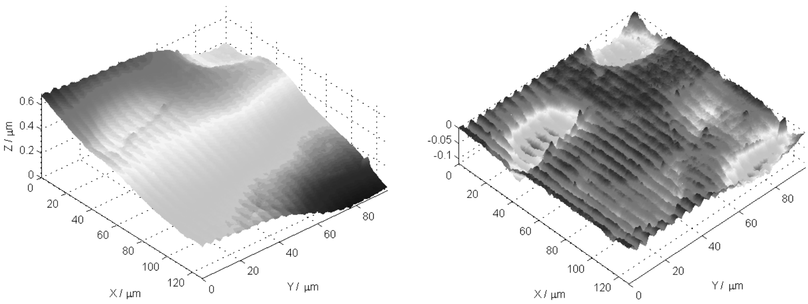


(a) *(b)*

Figure 1. The measured F-theta surface (a) and the residual surface (b) generated by the morphological closing operation with ball radius 3 mm, which clearly presents machining marks.



(a) *(b)*

Figure 2. The measured tooth implant surface (a) and the residual surface (b) generated by the morphological closing operation with ball radius 10 mm, which evidently presents sand-blasting marks.

References

[1] Jiang X., Scott, P. J. and Whitehouse, D. 2007 Freeform surface characterisation – a fresh strategy, CIRP Annals, 56(1): 278-282.

[2] Jiang X., Lou, S. and Scott, P. J. 2012 Morphological Method for Surface Metrology and Dimensional Metrology Based on the Alpha Shape, Measurement science and technology, 23(1): 015003.