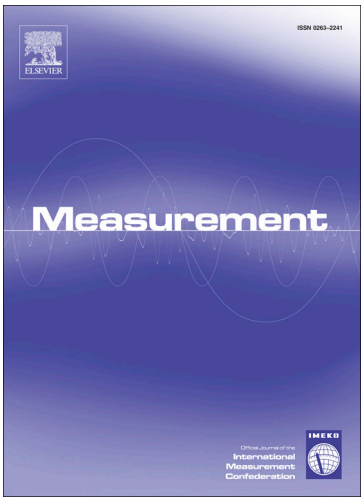

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A Hybrid Measurement Sampling Method for Accurate Inspection of Geometric Errors on Freeform Surfaces

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Abstract

For economic inspection of geometric errors on freeform surfaces, only a finite sample of points could be measured across the surface. Sampling strategy defines the number and distribution of this finite sample of measurement points. Only a well-selected sample of measurement points can accurately represent geometry of manufactured surface. Thus optimization methods could be employed to improve sampling strategies. In present work, a new hybrid sampling strategy is developed using Particle Swarm Optimization (PSO) method. The developed sampling strategy was compared with two existing strategies: (1) basic sampling strategy with uniform distribution in Cartesian space, and, (2) advanced adaptive sampling strategy developed by Yu et al. (2013). Accuracy and effectiveness of the developed method were verified through simulations. Case studies for several sample sizes showed that, the deviation of measured surface and its reconstructed model can be significantly reduced using the developed sampling method compared to the two aforementioned methods.

Keywords

Freeform surface inspection, Coordinate measuring machine, Measurement sampling strategy, Optimization

1- Introduction

Products with freeform surfaces have applications in various industries including aerospace, automotive, molding, biomedical, optics, etc. Geometric accuracy of freeform surfaces can significantly influence proper function of the product. Therefore, it is critical to inspect the geometry of the manufactured freeform surfaces and ensure that the accuracy requirements have been met. Geometric inspection on freeform surfaces is either done by contact or non-contact measurement methods [1]. Despite improvements of non-contact measurement methods, contact methods are still popular especially when higher inspection accuracy is required [2]. Coordinate measuring machine (CMM) equipped with contact probe is one of the most common contact measurement instruments that acquires coordinates of points across the manufactured freeform surface either point-by-point or through scanning. Then these discrete measured points can be used to reconstruct a continuous substitute geometry of the manufactured freeform surface in CAD environment. When the surface reconstruction process is accurate enough, reconstructed surface using the measured points on the manufactured surface is an accurate representation of the physical manufactured surface. Therefore the substitute geometry could be compared with the desired CAD model to accurately estimate the existing manufacturing errors on the produced freeform surface [3]. The freeform surface inspection process using coordinate measuring machine is demonstrated in Figure 1.

If numerous accurate points could be measured on a freeform surface, the geometric inspection would be conducted very accurately. However, it is not economic to measure excessive number of points on the surface using CMM [4]. Therefore one of the active research areas in contact-based inspection of freeform surfaces is measurement sampling strategy (i.e. sample planning) through which reasonable number of measurement points are strategically allocated across the freeform surface to ensure the manufactured surface is being reconstructed according to accuracy requirement and with minimum possible time or cost [5].