Optimizing Slow Tool Servo Machining of Microlens Arrays Through Data-Driven Tracking Error Prediction and Trajectory Replanning

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The application of microlens arrays based on slow tool servo machining is increasingly prevalent in the field of complex surfa ce optics. However, current slow tool servo technique poses a significant challenge in balancing machining efficiency with sur face profile accuracy, primarily due to the rapid variations in the spatial frequency of the microlens. To handle this dilemma, this study proposes a data driven tracking error prediction method and trajectory replanning approach. The specific method i nvolves establishing a functional model that relates axis tracking error to the velocity and acceleration of the motion trajector y in slow tool servo machining. To further improve the predictive accuracy of this model, multiple calibration experiments we re conducted, and a set of predictive model parameters was obtained based on least squares method. Furthermore, the origin al machining trajectory's velocity and acceleration were replanned, and combined with the predictive model results, to minimi ze the tracking error, thus optimizing the surface quality of microlenses in slow tool servo machining. To validate the effective ness of the proposed method, diamond turning experiments were conducted on a three axis ultra precision machine tool. The experimental results showed that this method not only significantly improved the surface accurac y of the microlens arrays but also slightly increased the machining speed, resolving the predicament of slow tool servo machi ning of microlens arrays.

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