Parallel tool servo turning of microstructured surfaces using complementary filters

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***Abstract**: Tool servo diamond turning is a promising technology for machining microstructured surfaces. Since the tool trajectory of complex microstructured surfaces contains a mix of low-frequency and high-frequency components, traditional slow slide servo technology faces challenges in processing quality and machining efficiency, because of the constrained control bandwidth of the large-mass slow slide. Although the current ultra-precision machine tool is equipped with a fast stage to compensate for the tool servo tracking error of the slow slide, the high-frequency spectral components in the trajectory can still cause nonlinear motion errors of the slow slide. Such motion errors are orthogonal to the motion direction of the slow slide and thus cannot be compensated for by the fast stage. To address these issues, this paper proposes the concept of a parallel tool servo (PTS) by integrating a tool decomposition method into the dual-stage machine tool to obtain the high-precision manufacturing of microstructured surfaces. Utilizing the complementary filters, this method decomposes the original tool trajectory into a low-frequency trajectory for the long-stroke slow slide and a high-frequency trajectory for the high-bandwidth fast stage. This tool path decomposition method fully utilizes the dynamic features of the slow slide and fast stage, thus enabling the cooperative operation of the dual-stage machine tool. Compared to the conventional geometry-based trajectory decomposition method, the proposed frequency-based PTS method significantly reduces the form errors of the machined composite microlens arrays, thereby demonstrating the effectiveness and superiority of the proposed PTS approach in producing microstructured surfaces.*