A Method for In-Process Cutting Force and Temperature Monitoring Using Cutting Tool Itself in Ultra-Precision Machining

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In-process monitoring of cutting force and temperature in micro-nano scale cutting zones of ultra-precision machining play an important role in evaluating machined surface quality and optimizing machining process. However, the traditional sensors for measuring cutting temperature and cutting force are discrete from the tool, making it challenging to meet the requirements of ultra-precision machining attributing to the low measurement accuracy, slow response time, and low spatial resolution. In this work, a high-spatial resolution, high-sensitivity smart tool setup was developed, containing a cutting force measurement module for three-axis cutting force measurements and a boron-doped diamond tool functional of temperature sensing, thereby realizing the integration of ultra-precision machining and in-process monitoring. A solution for multi-channel measurement of pico-coulomb weak charge and microvolt weak voltage signals was proposed, to shorten the signal transmission chain and enable high-precision monitoring of cutting force and temperature. Subsequently, in-process monitoring of cutting force and temperature experiments were conducted during ultra-precision machining of acrylic glass, copper, and single-crystal silicon under various process parameters, in which the advancements of the smart tool setup was validated, compared with those of traditional cutting force and cutting temperature sensors. It is of significant importance for achieving high-consistency machining of large-scale and micro-structure functional surfaces.