Molecular dynamics simulation of tool wear in el liptical vibration cutting of 3C-SiC

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KEYWORDS: Molecular dynamics simulation, Elliptical vibration cutting, Silicon carbide, Tool wear

Cubic silicon carbide (3C-SiC) has been widely used in the fields of photoelectric, field emission and micro-electromechanical systems because of the outstanding performance including high electron mobility, great breakdown field strength, and high thermal conductivity. However, the intrinsic hard brittle characteristics of 3C-SiC introduce great difficulties in ultra-precision cutting without obvious cutting tool wear. For the last few decades, elliptical vibration cutting (EVC) has been successfully applied in machining of many difficult-to-cut materials. As the cutting tool is fed at a nominal cutting speed, the tool tip is controlled to vibrate elliptically in the plane determined by the nominal cutting direction and the chip flow direction. The transient undeformed chip thickness is much smaller than the nominal depth of cut, leading to smaller cutting forces than ordinary cutting. Besides, the contact surfaces between the cutting tool and workpiece are exposed to the cutting fluid or gas in each vibration cycle, which suppresses the thermo-chemical wear of diamond tool. However, the high hardness of 3C-SiC could cause severe abrasive wear on the diamond tool in the cutting process. During EVC, the cutting tool usually vibrates in a high frequency and the transient material removal thickness ranges from a sub-nanometer level to a few nanometers. The interaction mechanism between cutting tool and workpiece is more complicated than ordinary cutting and an in-deep understanding of the tool wear mechanism during EVC is required. In this research, MD simulation is conducted to investigate the tool wear mechanism during EVC of monocrystalline 3C-SiC. Based on the modified MD model, the tool vibration amplitude and nominal depth of cut in the simulation model is remarkably increased to describe the transient material removal feature in a single vibration cycle. The results indicates that during EVC, a part of the wear atoms can be detached from the cutting tool and left on the machined surface while other wear atoms are adhered on the flanks face near the cutting tool edge. Besides, it is observed that wear in the bottom of the tool edge mainly occurs in the initial stage of the vibration cycle while wear near the tool rake face can be observed in the extrusion-shear stage. According to the stress analysis, the tool rake face experiences obvious tensile stress in the extrusion-shear stage. Furthermore, the shape of the cutting tool is changed and compression of the internal material is observed with the propagation of crack, which can be identified as microchipping of the cutting tool. Besides, the diamond-to-graphite transformation (graphitization) is observed during the crack propagation, which indicates that the graphitization can be caused by shear-induced deformation. The results in this research could open a potential to improve the understanding in diamond tool wear mechanism during EVC on brittle and hard materials.

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Word count: Not more than 500 words

Acknowledgements

This work was funded by the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No.: PolyU 15221322),