Fabrication of groove-with-protrusion structures by ultrasonic vibration-assisted burnishing using a laser-grooved tool

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Micro-textured surfaces, such as groove and protrusion structures, are attracting considerable interests due to their anchor effect in direct bonding of metals and polymers, where the interfacial texture enhances the bonding strength of dissimilar materials. Especially the protrusion shape allows the metal to puncture the polymer side of the interface, thereby providing higher bonding strength against external shear forces. However, for the processing of such microstructures, powder additive manufacturing has difficulty in local processing and the protrusions may delaminate due to external forces, while material removal processing also has many restrictions on the shapes of texture available for machining and has relatively low machining efficiency. Therefore, an alternative technique for producing micro-protrusion textures in a local area with high efficiency is required.

In this study, an ultrasonic vibration-assisted burnishing method with a tool that has pre-formed micro-grooves at the tip was established to fabricate groove-with-protrusion structures on metal surface by plastic deformation. Before the burnishing experiment, the tip of ball-shaped polycrystalline diamond (PCD) burnishing tool was irradiated with a femtosecond pulsed laser to generate multiple trapezoid grooves which were approximately 42 μm in depth. Then the burnishing with and without ultrasonic vibration was conducted on a copper surface to investigate the characteristics and mechanism of plastic flow process.

The results showed that the protrusions and grooves were successfully produced along the tool path on the material surface, which were several tens of micrometers in height and depth. Cross-sectional observation also revealed that dislocation movement at the top surface was increasingly activated as the burnishing depth increased, causing significant grain elongation and refinement. This indicates that shear stress applied by burnishing produced refined grains, which flowed and formed the protrusion shape. Furthermore, ultrasonic vibration-assisted burnishing enhanced the plastic flow of refined grains, which was more concentrated on the topmost surface, leading to an increase in the height of the protrusions. This research demonstrates the feasibility of a highly efficient method for simultaneous generation of groove-with-protrusion structures.

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