Numerical and experimental investigation on the influence of tool rake angle on fused silica in in-situ laser assisted diamond cutting

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Fused silica has been widely applied in various fields such as optical devices, precision instruments, and laser fusion because of its excellent properties. However, it is difficult to achieve high-quality machining of fused silica through conventional diamond cutting owing to severe diamond tool wear caused by the high hardness, brittleness and low fracture toughness of fused silica. In-situ laser assisted diamond cutting (LADC) improves ductile machinability by a focused laser beam passed through a transparent tool, which is considered a viable manufacturing technology to enhance the machinability of fused silica. Besides, large hydrostatic pressure generated during diamond cutting using a tool with a negative rake angle decreases the initiation of brittle fracture, which contributes to the high-quality machining of fused silica. Therefore, laser assistance and using a diamond tool with a negative rake angle are promising methods for machining hard and brittle materials. In this study, a model using smoothed particle hydrodynamics (SPH) method was constructed to simulate the diamond cutting process of fused silica. The distribution of stress and hydrostatic pressure are successively investigated to reveal the influence of tool rake angle and laser assistance on the crack propagation, surface generation, and chip formation during diamond cutting of fused silica. Grooving and end face turning experiments were performed to demonstrate the critical depth of cut (DOC) for ductile-brittle transition (DBT) and surface roughness during in-situ LADC using tools with different rake angles. Results show that the shear zone area and the maximum hydrostatic compressive stress increase with the rise of negative rake angle from 0° to -65° during in-situ LADC, resulting in the increase of the critical cutting depth. With laser assistance, the fracture chips disappear and the continuous chip increase gradually, resulting in a smoother machined surface. The use of a diamond with a large negative rake angle is a practical approach to improve the machined surface quality. The relationship of the surface roughness and the cutting distance is obtained, providing theoretical basis for high-quality machining of fused silica. Thus, our findings play a role in improving the surface finish of fused silica processed by ultra-precision machining, facilitating the application of fused silica in precision instruments.