

Ductile Regime Single Point Diamond Turning of Quartz

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Quartz (fused silica) is one of the advanced engineered ceramic materials designed to operate in extreme environments. Glasses such as quartz exhibit excellent optical and mechanical properties (good thermal resistance, excellent corrosive resistance, high hardness, etc.) which are needed for advanced technology applications. However, severe challenges arise when attempting to machine these extremely brittle materials to obtain a mirror like surface finish for optical devices. The combination of hardness ($\approx 9.8\text{GPa}$) and brittleness (low fracture toughness $\sim 4\text{MPa}\cdot\text{m}^{0.5}$) plays an important factor in limiting glass materials from being easily machined using simple conventional machining techniques (i.e. grinding, polishing, lapping etc) without causing any brittle. Single Point Diamond Turning (SPDT) is one of the fabrication techniques that meet the demand of today's precision engineering requirements, which requires both fast production rate and better surface quality for optical devices. The mechanics of material removal in glass (Quartz) can be classified in two categories; brittle fracture and ductile plastic deformation. Good optical quality surfaces can be achieved by removing the material in a ductile manner. The strength, hardness and fracture toughness of the work piece material are the governing factors that control the extent of brittle fracture. The high demand for superior surface quality in the optical and electronic industry has been consistently pushing/breaking the barriers in various nanotechnology and nanomanufacturing areas such as SPDT. In fact, it was just in the 1960's where precision engineering involved a maximum precision of about $10\mu\text{m}$. Mirror finishing of brittle materials such as glass is a fairly new matter for SPDT due to the many challenges, such as tooling, machining accuracy, brittle material properties, etc. that had to be overcome in the precision manufacturing industry. Attempts have been made in the past to machine glass in a similar manner to ductile metals by using SPDT. SPDT has shown positive effects when performed on materials which are often used as aspherical shapes in optical products. Such advances are essential in order to economically produce high quality ceramic and glass parts. The main goal of the subject research is to improve the surface quality of Quartz to be used as an optic device (mirrors and windows) via single point diamond turning (SPDT). Surface roughness (Ra) values of less than 50nm without sub surface damage were obtained.