Abstract

Because of their thermo-mechanical characteristics, brittle materials like glass and zirconia are said to be difficult to machine by the precision manufacturing sectors. Therefore, machining hard and brittle materials is an undertowing challenge for researchers. The appropriate machinability aspects of such materials are achieved with ductile regime machining (DRM) which is achieved with a controlled depth of cut, feed, and high cutting velocity. Such carping issues can be suppressed through a bit increase in the softness of the brittle materials. Therefore, heating of such material can raise the bar for the softness in such materials so as to increase their machinability. But the localized heating leads to a higher temperature gradient between heated and non-heated regions of the work material so the thermal stresses in it result in micro as well as macro cracks. Such deplorable issues can be solved through bulk heating of the work materials. Apparently, the comparisons of their softness can be examined through the scratch tests performed at different temperatures. Also, acoustic emission (AE) sensors are being used for in-line monitoring to identify the ductile-brittle transitions during the machining process. In the presented work, efforts are made to develop a sophisticated lab-made portable multipurpose heating setup for achieving various operations such as machining, elevated temperature scratch and indentation tests, grinding, etc. on hard and brittle materials by softening the material with preheating of the samples. This setup has been evaluated at different temperatures of the sample surface up to 426 °C. Furthermore, this setup is modified to work up to 1000 °C. This setup is capable of holding as well as heating the samples.

After the successful development of the portable heating setup, 45S5 bioglass samples have been used for micro scratch tests as well as the portable heating setup is used to heat those samples. The temperature values are kept between room temperature (27 °C) and

420 °C during the performed tests. Subsequently, traction force, coefficient of friction during the scratch tests, and scratch images are compared as the elucidated outcome softness of the material. It is found that there is a significant reduction in traction forces and coefficient of frictions during tests with a rise in the sample temperature.

Subsequently, more scratch tests are performed to determine the ductile-brittle transition load and the corresponding depth of cut. To achieve this objective, 45S5 bioglass samples are scratched at the fixed scratch speed, ramp load, and different sample temperatures varying from 27 °C to 700 °C. As a consequence, the effect of high temperature during the scratch on traction forces, hardness, critical load, and critical depth of cut has been analyzed. It is observed that a higher temperature helps to lower the traction force and increase the depth of cut at a particular normal scratch load and speed. Based on the results, the modified bifano model for the determination of the critical depth of cut is proposed to be used during the machining of 45S5 bioglass.

Furthermore, the elevated temperature scratch tests have been performed at different scratch speeds and sample temperatures varying from 27 °C to 420 °C. Apparently, 5 level haar wavelet analysis of AE signals were found to be a great tool to predict the appropriate depth of cut and traction forces for better machinability. It is observed from the traction force plots, SEM images, and contour plots of scratches that a higher temperature leads to lower traction force and higher depth of cut. Thereafter, the future scope of the present research work is discussed.