Hybrid Laser-Mechanical Machining of Advanced Materials

Joseph Nix[1], Chris Ellis[1], Priyanka Ghosh[1], Sam Smith[1], Sundar Marimuthu[1]*

1-The Manufacturing Technology Centre, Ansty Business Park, Coventry, UK

Sundar.Marimuthu@the-mtc.org

Ceramic Matrix Composites (CMCs), particularly alumina-based Oxide-Oxide (Ox-Ox) CMCs, are increasingly important due to their exceptional thermomechanical properties, making them suitable for high-temperature applications from aero-engines to gas turbines to nuclear reactors. However, their machinability remains a significant challenge, with conventional mechanical machining and laser processing proving inefficient due to either high tool wear or delamination or low productivity or high thermal damage. This study investigates the potential of Hybrid Laser-Mechanical Machining (HLMM) for cutting and edge trimming of 6 mm thick Ox-Ox CMC, comparing its performance with standalone laser cutting and mechanical machining. Experimental trials were conducted on a ROMI D800 3-axis CNC machine incorporated with both mechanical spindle and a IPG QCW laser-based drilling nozzle. HLMM involves sequential processing—initial bulk removal using a laser followed by mechanical finishing.

Surface characteristics, such as surface roughness, thermal damage, and cutting forces, were evaluated using an optical microscope, a Sensofar S-Neox scanner, and a Kistler dynamometer. Results showed that standalone laser cutting, while fast, resulted in high surface roughness (Sa ~38 µm) and significant dross formation. Mechanical machining offered better surface quality (Sa ~7 µm) but at a slower rate (2-13 mm/min). HLMM achieved a balanced outcome with an overall cutting speed of 560 mm/min, surface roughness below 10 µm, and minimal thermal damage. HLMM significantly reduced peak cutting forces by 82%, compared to standalone mechanical machining, and extended tool life by 160%, demonstrating its capability to produce high-quality cuts with reduced mechanical stress. These findings suggest HLMM as a promising solution for machining advanced materials like Ox-Ox CMCs, providing a techno-economically viable alternative for high-precision and high-productivity applications in advanced manufacturing sectors.