Finite element analysis of material removal in AWJM using different material models and spatial distributions for garnet abrasives

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Abstract: Garnet, the most widely used abrasive material in abrasive waterjet machining (AWJM), presents challenges in modelling its behaviour. Therefore, a finite element (FE) model was proposed to analyse the effect of using different material models and spatial distributions for garnet on the erosion behaviour of Al 7075-T6. Three popular material models were considered for garnet, including rigid, linear elastic, and tensile failure models, in addition to the Johnson-Holmquist (JH2) model. These four models were tested and compared for single and multiple particle impact under different waterjet pressures, abrasive mesh sizes, and impact angles. Furthermore, the effect of particle spatial distribution within the jet pass was examined. The model results demonstrated that using different material models for garnet significantly controls the erosion behaviour in AWJM. In addition, the radial distribution of the abrasive particles critically affected the erosion process and kerf geometry, while the axial distribution insignificantly influenced the erosion rate.

Keywords: abrasive waterjet; finite element simulation; garnet material model; spatial distribution of abrasive particles; material removal.

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1 Introduction

Abrasive waterjet machining (AWJM) is based on an advanced technology that allows the production of high-quality and low-cost components free of heat-affected zones or excessive stresses (Thakur and Raut, 2023). The material removal in AWJM mainly relies on rapid erosion (Yuvaraj and Kumar, 2018). This phenomenon occurs when the workpiece material absorbs the kinetic energy of the solid abrasive particles upon impact. These particles reach extreme impact velocities due to being accelerated by the ultra-high velocity waterjet (up to 1,000 m/s) (Alberdi et al., 2010). Most analytical theories categorise the removal mechanism according to the workpiece material into two types: ductile erosion and brittle erosion (Hutchings and Shipway, 2017). Each type comprises different modes, i.e., the ductile removal mechanism involves cutting and deformation wear, while the brittle one involves the formation of microcracks. Under the continuous impact action of abrasive particles, the material deteriorates, and hence microchips are removed from the workpiece. The effectiveness of the erosion process counts on several factors, including impact velocity, mass flow rate, incident angle, hardness, shape, size, distribution, and orientation of the abrasive particles. The stochastic interaction among these factors complicates the full description of underlying mechanics using experimental or analytical methods. In addition, the erosion phenomenon includes short-duration dynamic responses such as stress waves, high strain rates, deformations, and propagation of cracks (Mieszala et al., 2017).