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A user-friendly finite element model for radial mode abrasive waterjet turning

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Abstract
This paper aims to develop a finite element (FE) model precisely simulating the multi-particle impact in the radial mode abrasive waterjet turning (AWJT). An explicit dynamic analysis was carried out to predict the crater profile resulting from the impact of the abrasive particles along a limited segment of the jet pass over the workpiece surface. The effect of both momentum transfer loss and abrasive load ratio was taken into consideration while calculating the impact velocity of the abrasive particles. To build a user-friendly model, the scripting feature of ABAQUS was involved to automatically perform all the repetitive modeling procedures. The presented FE model considers four variable turning parameters tested at five levels each, including impact velocity, abrasive mass flow rate, traverse rate, and workpiece speed. The obtained crater profile from the simulation process was utilized to calculate the depth of cut (DOC) at different parameter combinations. A comparison between the numerical and experimental results shows a good agreement with an average absolute relative error of 9.74%.

Keywords
Abrasive waterjet turning, radial-mode, finite element method, user-friendly model, python scripting, depth of cut

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Introduction

Abrasive waterjet (AWJ) is an advanced machining technology that employs a waterjet to accelerate the abrasive particles towards the workpiece. The waterjet is usually pressurized up to 620 MPa so that the abrasive particles can strike the target surface at a velocity between 300 m/s and 1000 m/s. Almost all the earlier theories and practices confirmed that the material removal in AWJ occurs based on the erosion principle.[1] AWJ machining is featured by high versatility, negligible cutting forces in the range 40–80 N, no heat-affected zone due to low temperatures in the range 10–40°C, simplicity of workpiece fixturing, and little burr formation. Therefore, it can machine difficult to cut, heat-sensitive and fragile materials, most notably ceramics, composites, Inconel, titanium alloys, and glass.[2] AWJ was initially utilized for linear cutting of plates, but it has kept evolving to performing controlled depth processes such as milling and turning.[3] Hashish[4] reported that abrasive waterjet turning (AWJT) can efficiently turn carbide-metal composites, glass, and ceramics. This process exploits the eroding action of AWJ to produce axisymmetric workpieces using the same principles of centre lathe turning where the AWJ replaces the traditional tool insert. According to the positioning mechanism of the AWJ nozzle with respect to the workpiece, AWJT is subdivided into radial or offset mode, as shown in Figure 1. Li et al.[5] pointed out that the radial mode is more efficient based on the rate of material removal since it allows the maximum utilization of the AWJ energy. Liu et al.[6] were able to achieve a higher material removal rate (MRR) up to 28% using the radial mode turning of alumina ceramics at the same turning conditions. On the other hand, the offset mode can provide better surface quality and easier control of the cutting depth.

Several experimental studies have investigated the effect of the process parameters on the performance of AWJT. Hlaváček et al.[7] demonstrated the superiority

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