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Present status and some critical issues of abrasive jet materials processing: a review

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Abstract

Abrasive jet bombarding is one of the versatile materials processing techniques and is applied in abrasive jet machining, deburring, shot-peening, erosion testing, fast cleaning, surface preparation and polishing. Some special types of operations like micro-machining, polishing of micro-channels are the current issues in research and development. Various critical issues of abrasive jet material processing are reviewed and presented in this paper.

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Keywords: *Abrasive jet machining, erosion testing, shot-peening, surface cleaning,deburring, surface preparation, grit blasting*

1. Introduction

First study on particle impact by the mixture of smoke and dust was carried out in Germany in 1931[1]. An intense stream of air or gas suspended abrasive particles can be used for machining, shot-peening, cleaning, debarring, surface preparation, erosion resistant testing, micro-machining, polishing, etc. processes by means of erosion. The kinetic energy of abrasive particles (solid erodent velocities reaching 300 m/s [2]) is used to strike the work surface and the work material is removed by means of micro-fracturing[3]. AJM is advantageous due to its high degree of

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flexibility where the abrasive media can be carried by a flexible hose to reach internal, difficult-to-reach regions. The AJM grows localized force and less heat generation than traditional machining processes[4]. The abrasive jet system is used for machining glass, ceramics, ferrous materials and polymers[5] also. Different types of operations like cutting[6], drilling[7], grooving[8], engraving[9]are accomplished. Conventional cutting tools leave bars behind machining operations. Sometimes, bar removal[10] and edge rounding of sharp machined edges become essential and can be effectively smoothened using abrasive jet.

Service life prediction against combined erosion and corrosion are essential for safety reason of turbine blades, propellers, etc. like power plant and aerospace components. Abrasive jet system provides a suitable means for testing erosion resistance[1,11] of those engineering components. Abrasive jet system is used for surface preparation[12] of substrates to hold thermal spray coatings and clad layers. By means of grit blasting, substrate surface is cleaned and made rough to increase surface area for good adherence to the coating materials. Abrasive jet cleaning[13] of rust and oily surface before welding is faster and advantageous than any other surface cleaning like grinding, filing, etching, etc. Shot-peening [14,15] is commonly practiced process for hardening of machined surface like machine bed, gear teeth etc. Relatively, less velocity large particles are used for plastic deformation of work surface for building compressive residual stresses. Shot-peening is also applied for adherence performance analysis[16] of thermal spray coating. Research and development works are ongoing in various R&D laboratories on abrasive jet micro-machining[17], micro-grooving[8], polishing of micro-channels[18], etc. It is becoming an attractive and promising technology for processing ceramics and semiconductors for fabricating micro-channels, micro-holes and multi-level planar areas for the fabrication of micro-fluidic devices, micro-electro-mechanical systems (MEMS), and optoelectronic components where damage-free, micro-part features are required[19,20].

In this present work, a comprehensive review has been made to find out various critical issues of abrasive jet material processing for end users information.

2. Status and some critical issues of abrasive jet material processing

2.1. On the abrasive jet machining(AJM)

Search and review show that some experimental investigations were conducted on AJM of difficult-to-machine materials. The researchers did experiments on abrasive jet cutting, drilling, grooving, and engraving of various materials. The studies on the influencing process parameters were performed. Some referred critical investigations on AJM and their findings are enlisted in the table 1. The ductile and brittle both the materials are prone to erosion. The erosion rate is maximum when impingement angle is 20-30º for ductile material, but in case of brittle material erosion rate is maximum when impingement angle is 90^o[21]. The erosion resistance of material increases with increasing hardness and also erosion rate decreases with increasing temperature. The material removal rate increases with increase in pressure and nozzle diameter up to a specific level.

The erosion phenomenon carries the risk of cracks remaining in the surface, possibly leading to premature failure of the component, which produces a serious problem when applied to micro-machining of brittle materials. But the use of fine abrasives as a projectile is one of the appropriate solutions because smaller particles tend to make the material removal behaviour more ductile[22]. A well-established erosion models for brittle materials, the ideal crack system illustrated[23] is frequently used to model solid particle impact. When a brittle material is loaded by a sharp indenter, a plastic zone is formed beneath the indent, and a radial crack may propagate downwards from the base of the zone at a threshold load. This crack does not contribute to the material removal but degrades the strength and on unloading, a lateral crack propagates at the base of the plastic zone. The lateral cracks are strongly relates to the material removal phenomenon. Balasubramaniam et al.[24]reported some influencing effects on AJM performance. The increasing particle size increases MRR and penetration rates. Increasing SOD increased entry side diameter, edge radius and MRR. The increasing centreline velocity increased penetration depth and MRR. Increasing peripheral velocity increased MRR and edge radius. Aluminium oxides, silicon carbides, boron carbides, crushed glass, sodium bicarbonate, dolomite are various abrasive particles used for abrasive jet processing[25]. The abrasive jet micromachining having technical and economic advantages over existing micromachining technologies and attracts much attention as a powerful method for dimpling of hard and brittle materials[26]. Micro holes machined through micro-AJM are tapered, and reduction in the taper angle is possible. In conventional micro-AJM, as the machining progresses, changes of stand-off distance affecting the shape of the machined hole.