Research Review on Multi-Objective Optimization of Surface Roughness and Kerf Taper Angle in Abrasive Water Jet Machining of Steel Bold

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Abstract - Abrasive Water jet machining (AWJM) may be a non-conventional producing method, wherever material is far away from the work piece by impact erosion of pressurized high speed water stream mixed with There are numerous method parameters that have an effect on the standard of machined surface cut by AWJM. But, the traverse speed, hydraulic pressure, stand-off distance, abrasive rate and kind of abrasive are vital.

This paper reviews the analysis work applied from the beginning to the event of AWJM inside past few years. It reports on the AWJM analysis regarding performance measures improvement, watching and method management, method variables improvement. A large vary of AWJM industrial applications for sort of materials are reportable with variations.

The paper conjointly discusses the longer term trend of analysis add the world of AWJM. Also, because of complicated nature of abrasive water jet machining method, it's terribly tough to manage all 3 quality factors i.e. kerf taper, kerf width, stri-ation marks at the same time to attain desired quality. This work so deals with multi-objective improvement considering 3 objectives as: reduction of kerf dimension, reduction of kerf taper, and maximization of depth of striation free surface in abrasive However, the vital performance measures in AWJM are Material Removal Rate (MRR), Surface Roughness (SR), Kerf width, Depth of cut.

Key Words: Material Removal Rate (MRR), Surface Roughness (SR), Kerf angle, Depth of cut traverse speed, hydraulic pressure, stand-off distance.

1. INTRODUCTION

Manufacturing industry is becoming more time conscious and quality oriented with the advancement in global economy. This becomes necessary to use non conventional machining processes such as Chemical Machining, Laser Machining, Electric Discharge Machining, Abrasive Water Jet Machining, etc. Abrasive water jet machining (AWJM) is a non-conventional machining process that employs high-pressure water for producing high velocity stream, entrained with abrasive particles for a wide variety of materials ranging from soft to hard. AWJM is a versatile machining process primarily used to machine materials ranging from soft to hard like titanium, inconel, etc. hard and difficult to machine materials [1]. Abrasive water jet machining makes use of the principles of both abrasive jet machining and water jet machining. The first industrial application manufactured by McCartney Manufacturing Company and installed in Alto Boxboard in year 1972. The invention of the abrasive water jet in 1980 and in 1983 the first commercial system with abrasive entrainment in the jet became available. This technique is mainly suitable for softer, brittle and fibrous materials. This process operates without heat generation so machined surface is free from heat affected zone (HAZ) and residual stresses. AWJM has higher machining versatility and better flexibility. The major drawback of this process is, it generate loud noise and a messy working environment. AWJM have certain advantageous characteristics, which turns to achieve significant penetration into manufacturing industries. Faster set-up and programming• Less sensitive to material properties as it does not cause• chatter Very little fixturing for most parts• Machine virtually any 2D shape on any material• No heat affected zone (HAZ) on part• Machine thick plates• AWJM is normally used for applications like Paint removal, Cutting frozen meat, Surgery, Cutting, Pocket Milling, Turning, Drilling, Textile, Leather industry. Materials which are cut by AWJM are Steels, Non-ferrous alloys, Super alloys, Exotic materials, Ti alloys, Ni- alloys, Polymers, Metal Matrix Composite, Ceramic Matrix Composite ,high tech ceramics, Concrete, Wood, Plastics, Metal Polymer Laminates, etc.

2. Literature Review

A literature review of the recently printed analysis work on AWJM is distributed to grasp the analysis problems concerned and is bestowed here,

Wang And Jun (1999) witnessed an opposite trend in of kerf taper angle with relation to the water pressure once cutting chemical compound matrix composite as a result of the outer rim of the diverged jet still had decent energy to cut this comparatively soft material. Literature reveals that kerf taper Angle increase with an increase the nozzle crosswise speed

Shunmugam et al., 2009, Wang and Wong, 1999]. Wang and Jun (1999) found that kerf taper angle decreases with increase in the nozzle crosswise speed, this could be due to the completely different varieties of materials processed, the completely different pressure and speed ranges elect, as well as completely different ratios of jet energy used to the energy needed to cut the materials. Constant quantity influence of AWJM on a wide selection of materials. Literature according that the kerf taper angle decrease with increase within the water pressure

Shanmugam et al., 2009; Khan et al., 2007]. AN increase in standoff distance (distance of the nozzle tip from the work surface) leads to AN increase in kerf taper angle [Shunmugam et al., 2009; Khan et al.,

It has been according from the experimental investigation on ceramic material, that abrasive mass flow rate will not have vital result on the kerf taper angle. This is as a result of the truth that abrasive mass flow rate

Guru Sewak Kesharwani [1] investigated on victimization Non spherical (Triangular & Trapezoidal) Sharp edge form ceramics abrasive particle as abrasive for cutting surface material sculptural may be a atomic number 22 primarily based super alloy (Ti–6Al– 4V) extensively utilized in the region trade. it's determined that traverse speed is a vital parameter within the case of controlled depth edge (CDM) for AWJM. By experiment they found that with the changed setup of abrasive feed system, a discount of roughly two hundredth time for edge the Ti-6Al-4V sample is achieved. It's conjointly confirmed that surface waviness will be reduced as traverse speed is exaggerated by victimization changed abrasive feeding system.

[2] Has distributed study on the influence of method parameters on the irregularities of corundum ceramics surfaces generated by abrasive water jet. Taguchi's style of experiments was distributed so as to gather surface roughness values. Experiments were conducted in varied water pressure, nozzle traverse speed, abrasive mass rate and standoff distance for cutting corundum ceramics victimization abrasive water jet cutting method.

[3] Distributed work to optimize the metal removal rate (MRR) of stainless-steel 403 in abrasive water jet machining victimization analysis of variance and Taguchi technique. The MRR is optimize by victimization 3 parameters water pressure, abrasive rate and stand-off distance and L9 orthogonal array of Taguchi technique accustomed analyze the result. They ended that the water pressure (WP) was the foremost influencing issue for stainless-steel 403 work material followed by stand-off distance and abrasive rate.

[4] Investigated on diminution of kerf taper angle and kerf dimension victimization Taguchi's technique in abrasive water jet machining of marble. Water pressure, nozzle crosswise speed and abrasive rate.

Experiments were conducted per Taguchi's style of experiments. It absolutely was ended that the nozzle crosswise speed was the foremost vital issue poignant the highest kerf dimension, the kerf taper angle.

Casting method. The experiments were conducted using L9 Taguchi technique. It was observed that the contribution of water pressure on surface roughness found to be more significant than traverse speed and standoff distance. It was confirmed that obtained mathematical modeling can be successfully employed to predict the surface roughness of composites.

[6] Studied optimization of the {method} parameters on abrasive water jet machining (AWJM) victimisation Taguchi method for alloy 800H material. The approach used is predicated on the analysis of variance (ANOVA) and signal to noise quantitative relation (SN Ratio) to optimize the AWJM method parameters for effective Material Removal They confirmed that determined best combination of AWJM method parameters satisfy the important would like for machining of alloy 800H in actual apply.

[7] Investigated the result of method parameters, viz water pressure, Traverse speed and Standoff distance, of Abrasive Water Jet Machine (AWJM) for soft-cast steel (MS) on surface roughness (SR). Taguchi's technique, analysis of variance (ANOVA), F-test and signal to noise quantitative relation (SN Ratio) area unit wont to optimize the thought-about parameters of Abrasive Water Jet Machining. In Taguchi's style of experimentation, L9 orthogonal array is developed and ended that water pressure and thwart wise speed area unit the foremost vital parameters and standoff distance is sub

[8] Disbursed experiments on cutting of salt glass by AWJM. Depth of cut is measured with totally different machine parameter settings as water pressure, abrasive rate, traverse speed and standoff distance. Optimum condition of management parameter setting is additionally searched through particle swarm optimization (PSO).Also, scanning microscopy (SEM) image reveals to some extent, and therefore the nature of cut surface

Dev Anand [9] investigated work on optimization of Machining Parameters in abrasive water jet machining (AWJM) method for Copper Iron Alloy victimisation RSM and multivariate analysis. The method parameters thought-about was water pressure, abrasive rate, opening diameter, focusing nozzle diameter and standoff distance. They studied the result of 5 method parameters on metal removal rate (MRR) and surface roughness (SR) of the Copper Iron alloy victimisation multivariate analysis.

[10] Studied the results of fabric thickness, traverse speed and abrasive mass rate throughout abrasive water jet cutting of Al on surface roughness. They analyzed that traverse speed has nice result on the surface roughness at

the lowest of the cut and therefore the correlation between the surface roughness and different abrasive

Srikar [11] investigated work on optimization of abrasive water jet machining method parameters victimisation Taguchi gray relative analysis (TGRA). The method parameters area unit chosen as abrasive rate, pressure, and standoff distance. From ANOVA it's found that water jet pressure has a lot of vital result on kerf breadth and MRR instead of abrasive rate and standoff distance.

They analyzed that foreseen S/N quantitative relation is nearest to the conformation check S/N ratio; this conclude that the TGRA method adopted for optimization of parameters is correct.

Observed that, in single pass machining, for the same increase in standoff distance, the top kerf width increases (≈18%) whereas the bottom kerf width

Affects the top and bottom kerf width in a similar scale or magnitude [Chen et al., 1996].

Similarly Shunmugam et al. (2009) observed that with an increase in the abrasive mass flow rate the kerf taper angle seems to decrease insignificantly. Generally standoff distance, transverse speed and a water pressure have the more effect on the kerf taper angle than the abrasive flow rate. A combination of high water pressure, low transverse speed and a small standoff distance generate more parallel kerf. It is found that the top kerf width (wt in figure1) slightly increase with increase the water pressure

Shanmugam et al., 2009; Wang and Jun, 1999; Wang and Wong, 1999; Chen et al., 1996]. These investigations reveal that a higher water pressure produce a wider slot as a jet with greater kinetic energy impinges onto the target material. While Kantha and Krishnaiah (2006) did not find any relationship between water pressure and top kerf width. It has been reported that the top kerf width is inversely proportional to the nozzle transverse speed because a slower pass allows more abrasive particle to impact on the target and open a wider slot [Wang and Jun, 1999; Wang and Wong, 1999]. This is also supported by Hascalik et al. (2007). However Chen et al. (1996) found that nozzle transverse speed has little effect on the top kerf width on the cutting of brittle material. Thus, literature review reveals that AWJM is applied to a wide variety of materials and the potential of AWJM in cutting of marble is still remain unexplored. Moreover, conflicting results are obtained for parametric influence of AWJM on kerf characteristics for wide variety of materials owing to their different compositions and material properties. It becomes imperative to study the effect of process parameters in AWJM of most commonly used Makrana marble. Present work attempts to do this by investigating the effect of AWJM process parameters on top kerf width and kerf taper angle. Further, optimization of process parameters is also performed for minimum values of top kerf width and kerf taper angle

Influence of process parameters AJM process is affected by the number of settings. Some factors may contribute differently depending on the combination of other factors and materials properties. Although, several dominating tendencies can be underlined. The independent process parameters involved in AAJM were classified by Hashish [164] into two general groups and later into three groups by the Nouraei et al. [13], which are discussed below.

Hydraulic parameters

Nozzle pressure

Pressure directly affects flow velocity and, as an aftermath, the kinetic energy of the in-flow particles. Thus, an increase in pressure leads to the growth of MRR and surface roughness. In AAJM, working pressure may vary from 0.2 to 1 MPa that usually corresponds to 100 . . . 300 m /s of particle velocity. During precoating machining for improvement of coated layer bonding to zirconium substrate, a working pressure less than 0.2 MPa was recommended [165]. For post-coating treatment of TiAlN, the optimal nozzle pressure in terms of roughness and MRR was given between 0.2 MPa and 0.4 MPa [13]. The highest hydrophobic properties of were observed after blasting with 0.6 MPa [166]. For surface smoothening, relatively low-pressure conditions are generally concluded (Fig.12). Low pressure is also reported to produce steeper kerf slope [14].

Jet velocity

Due to boundary conditions between air jet and stable surroundings, abrasive jet velocity are non-uniform in both radial and axial direction. Li et al. [15] conditionally divided air flow into three velocity regions.

Rajaratnam et al. [168] informed that the length of initial region is around 6.2 times of nozzle diameter for air jet and near to 100 times for water jet. The last one — impact or diffused droplet region is the area of abrupt flow decelerations and turning into parallel to work piece surface direction. Inside potential core, air velocity is higher than that of the particle, thus the particle preserves its acceleration until it becomes faster than air. Maximum particle velocity is achieved near to the beginning of main region [98,169]. Further, the centre line particle velocity decreases almost linearly as the distance from the nozzle exit increases [170].

Machining parameters

Traverse speed

Traverse speed is a speed of the reciprocal motion of the blasting nozzle relative to the machined surface. The speed selection is based on requirements of feature geometry. In precise etching by micro-blasting, the speed may fall down to 0.25 mm/s [71,107]. The slower speed provides deeper erosion spot. Particle distribution in a flow cross section has normal character [104], consequently, the abrasive jet produces Gaussian shape footprint with a bottom at the distribution centre [114]. However, at some conditions, the machined profile can turn to the flat or even convex pattern, as was reported recently [14].

Feed step

Feed step is a length of nozzle axis shift for each path alongside the previous one. Correct sequential groves overlapping with a small erosion depth may be considered as polishing. With an eye to provide a small pick to valley value of machined surface, the feed step should be small enough to conjugate the flat regions of two bottoms, otherwise, sinusoidal surface profile occurs (Fig. 14).

Stand-off-distance

Stand-off-distance is the distance between the nozzle exit and machined surface. Moving from conventional sand-blasting to powder-blasting, SOD was shortened from a few meters to several hundreds of micrometers.

4. IV. SCOPE FOR FUTURE WORK

The discussions within the previous sections show the key analysis areas in AWJM. Researchers have contributed in different directions however thanks to complicated nature of the method, loads of labor continues to be needed to be done. The work given here is an overview of recent developments of AWJM. From on top of the long run analysis studies could also be done as mentioned below: Apart from cutting, AWJM is additionally appropriate for numerous precise machining processes. The AWJM method has wanted the advantages of mixing with alternative material removal strategies to more expand its applications. In most of the analysis work, mainly traverse speed, water jet pressure, standoff distance, abrasive grit size and abrasive rate of flow are taken under consideration. Very little work has been rumored on impact of nozzle size and passageway diameter. Most of the analysis on improvement has been carried out on method parameters for improvement of one quality characteristic like depth of cut, surface roughness, material removal rate, kerf pure mathematics. No a lot of analysis was given on nozzle wear. Analysis could also be carried on the optimization for the ability consumption, dimension accuracy and multi-objective improvement of AWJM method

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