A Comprehensive Review in the Field of Abrasive Water-Jet Machining

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Abstract— The progress in research and development in the field of making composites and advanced ceramic formulated in high performance material, but on others it also offers various challenges when shaping (cutting) them in desired shape and size. It has believed that these materials cannot be effectively been machined by conventional machining techniques. Excluding economics, the selection of process of machining mainly depends upon the machined surface integrity. The water jet with multiphase i.e. water + abrasive + air, makes this cutting process one viable option as compared to other conventional processing. In this paper an extensive review has been presented in the field of abrasive water jet machining which includes various research work undertaken by the researchers, computational as well as experimentally, who investigates the influence of various process parameters during cutting operations.

Keywords— AWJM, CFD, Abrasive, Erosion rate

I. INTRODUCTION

Abrasive water-jet machining (AWJM) is considered to be an mechanical, non-conventional machining technique where abrasive particles for instance Silica sand, Garnet, Aluminum oxide, Silicon carbide etc are entrained in high speed waterjet to wear down the materials from the surface of material. About 90% of machining is done by using garnet as abrasive particle. In AWJM material removal take place by erosion induced by the impact of solid particles. Material removal occurs by cutting wear and deformation wear, cutting wear defines erosion at smaller impact angle. Deformation wear occur by repeated bombardment of abrasive at larger impact angle. Abrasive waterjet machined surface are grouped into three sections they are a) Initial damage region (IDR), b) Smooth cutting region (SCR) and c) Rough cutting region (RCR). [1]

II. LITERATURE

Shukla and Singh 2017 experimentally examined the parameters of the abrasive water jet machine and applied a optimization technique i.e. Taguchi and evolutionary approach. Their paper illustrates the application of applied optimization approach. Optimal process parameters of AWJM has been given and for experimentation AA6351 Al alloy has been used where effect of kerf top width and tape angle has been parametrical investigated. The obtained result has been compared with seven different optimization algorithms and the results are showing good validation.
Sookhak Lari et al. 2017 use a novel rotating Elastomeric mask system for forming 3 dimensional characteristic by means of abrasive jet micro machining. Their work explains the new technique to instant machining through AJM. The validation of experimentation has been done by W-shaped symmetric and asymmetric, trapezoidal and wedge shaped footprints. Moreover, they also explain the benefits of the novel rotating mask system.

Kowsari et al. 2017 using CFD the erosive footprint of flat and curved glass through AJ micro machining has been examined. Both computational and experimental model has been developed to judge the erosive footprint due to micro particle impact. The obtained footprint mainly depends upon the target curvature as it widen in lateral particle return varied.
Fig. 3. Impingement of AJM jets on curved targets at a standoff of 20 mm. Air velocity magnitude contours and particle trajectories for rod diameters of: (a) 5 mm, and (b) 3 mm. [3]

Nouraei et al. 2017 calibrated the computational erosion model of Abrasive slurry jet micro machining for cutting ductile material to developing micro channel. Using CFD a novel empirical model has been developed to predict the cutting profile of ductile material. The model includes the impact angle and velocities of jet micro particles; the size of particle is around $10 \mu m$. The results have been compared with previous experimental work and shows good accuracy rate of less than 5%.

Fig. 4. CFD predictions of Model 2 for $10 \mu m$ nominal diameter particle trajectories at oblique jet impingement. Particles P1 and P2 illustrate variation in local impact angle across footprint. [4]

Žarko et al. 2016 applied extreme learning machine approach to develop a model to examine the roughness of machined surface by abrasive water jet machining. The result predicted by ELM model has been compared with genetic algorithm of ANN model. It has been found that the results of ELM model has high degree of accuracy and can be utilized for further work.

Fig. 5. Surface roughness at the bottom [5]
Dewan Hasan et al. 2016 perform numerical investigation to examine the impact characteristics of particle on the cutting surface of the AWJM. The effect of different radius of curvature on cutting profile has been observed. The result shows that for large radius of curvature particle has trends to slide and stay and have very small impact angle. The study also predicts the particle distribution factor for cutting and deformation wear.

Patel and tendon 2015 conducts an experiment to investigate the thermal enhance AWJM. In the experimentation external heat is given by gas welding setup which heats up the work specimen i.e. Titanium, mild steel and metal Inconel. The influence of heat treatment of surface morphology has also been analyzed and it has been found that using thermal enhance machining increases the material removal rate and also requires less power for operating machine.
Naser et al. 2015 examined the impact of entrained air in the abrasive water jet micro machining. The existing model of high-pressure slurry has been updated and using this, the particle velocity can be predicted which can be verified by using double disc approach. On comparing centerline waviness of micro channel, conventional AWJM has 3.4 times higher than high pressure slurry one. While, the roughness of centerline both machining have same approximation. Moreover, on comparing the widths of micro-channels at a given depth high pressure slurry has 26% narrower than AWJM.

Fig. 9. Experimental setup of double disc apparatus (DDA) used for measuring particle velocity in HASJM and AWJM. Nozzle moved along the radial direction of the discs. Not to scale.[8]
Vishal et al. 2014 use Taguchi approach to minimize the kerf taper angle and width of AWJM for cutting marble. In study three different process parameters has been taken in consideration i.e. pressure of water, transverse speed of nozzle and mass flow rate of abrasive particle. They revealed that transverse speed of the nozzle is the most significant factor which affects the top kerf width and taper angle.

John et al. 2017 present a short communication in which influence of drilling and AWJ on damage on the performance of carbon fabric/epoxy plates with holes. It has been found that the surface roughness holes formed from the AWJ has higher as compared to conventional drilled holes. Conventional drilling has greater stiffness degradation as compared to AWJ during short-duration cyclic tests.
III. CONCLUSIONS

On the basis of literature review various conclusion has been drawn which has been enlisted below.

- It has been found that AWJM is significantly been gaining attention in the area of material cutting and machining particularly in machining advanced material such as ceramic and composites. Since it offer various unique benefits over other conventional and non-conventional techniques which make it a most promising choice in the machining industry.

- Excluding cutting, AWJM is also appropriate for accurate machining processes such as drilling, polishing, milling and turning. The AWJM process has sought the benefits of combining with other material removal methods to further expand its applications.

- Insufficient literature available so far revels the standoff distance at the optimal value during the AWJ cutting process by monitoring and control. This kind of work has not been reported for any other parameters. So, more work is required to be done in this area.

- In most of research work, mainly traverse speed, waterjet pressure, standoff distance, abrasive grit size and abrasive flow rate have been taken into account. Very little work has been reported on effect of nozzle size and orifice diameter.

- Most of the research on optimization work has been carried out on process parameters for improvement of a single quality characteristic such as depth of cut, surface roughness, material removal rate, kerf geometry and nozzle wear. There is no any research paper found based on the optimization for the power consumption, dimension accuracy and multi-objective optimization of AWJM process. So, this area is still open for future research work.

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