Effect of material Properties on Abrasive Water Jet cutting of Ti-6Al-4V

Archit Patil[1], Ankita Bais[2], Kalpesh Dhawale[3], Avinash Bobade[4], Paramjit Thakur[5]

[1]Student, Saraswati College of Engineering, India, patil.architap@gmail.com
[2]Student, Saraswati College of Engineering, India, ankitabais07@gmail.com
[3]Student, Saraswati College of Engineering, India, kalpeshdhavale41@gmail.com
[4]Student, Saraswati College of Engineering, India, aabobade25@gmail.com
[5]Professor, Saraswati College of Engineering, India, paramjit3010@gmail.com

Abstract: Water jet machining is one of the adaptive unconventional type of machining with significant advantages over the conventional type machining. While working with Ti-6Al-4V under waterjet. It is critical to measure the depth of cut of a material while working on the water-jet machine. Although having more benefits of unconventional water jet machine this may be one of the drawback which may increase machining time. This paper gives review of different research papers on machining of various alloys under water jet machining, effect of material properties and optimization techniques used.

Keywords: Abrasive water jet machining; Machining of Ti alloy; Matlab; Parameters optimization.

INTRODUCTION

Abrasive water jet (AWJ) is an unconventional method used in machining of difficult-to-machine materials like titanium, tool steels, super-alloys, hardened steels, glass, composites, metal matrix composites, laminates and advanced ceramics by high pressure, high velocity water jet. This list of materials expands daily as people apply the unique properties of fluid jets to industrial problems. This machining process is now a day's replacing the conventional machining processes due to their significant advantages in present industrial scenario. AWJM is a process in which a very high velocity stream of water is used to accelerate particles of an abrasive material, which in turn cuts the workpiece material by erosion principle. It is critical to measure the depth of cut of a material while working on the water-jet machine. Although having more benefits of unconventional water jet machine this may be one of the drawback which may increase machining time. In this project, we are going to predict the depth of cut of Titanium alloy while working under water jet machine using signal processing and then Artificial Intelligence and its hybrid techniques.

The various modern machining processes getting widely used in the industries are: electric discharge machining (EDM), abrasive jet machining (AJM), ultrasonic machining (USM), electrochemical machining (ECM) and laser beam machining (LBM) including various modified versions of these processes. These processes work on a particular principle by making use of certain properties of materials which make them most suitable for some applications and at the same time put some limitations on their use. These processes involve large number of respective process variables (also called as process parameters) and selection of exact parameters setting is very crucial for these highly advanced machining processes which may affect the performance of any process considerably. Due to involvement of large number of process parameters, random selection of these process parameters within the range will not serve the purpose. The situation becomes more severe in case if more number of objectives are involved in the process. Such situations can be tackled conveniently by making use of optimization techniques for the parameter optimization of these processes

From last few decades, many researchers are working on the process monitoring and optimizing the process parameters in AWJ machining with different materials. Many different Artificial Intelligence(AI) techniques like Artificial Neural Networks (ANN), Fuzzy logic and Adaptive Neurofuzzy Inference System (ANFIS) are being used in predicting and optimizing the process parameters. AWJM processes these AI techniques giving the details of formulation of optimization models, solution methodology used and optimization results. Use of these techniques are enhancing the AI revolution and automation. However, these approaches require a large amount of data for training them so as to achieve a reasonable accuracy in the prediction of process parameters. By using time domain, frequency domain and wavelet domain, process parameters can be predicted in online process monitoring. For online process monitoring acoustic emission, cutting force dynamics, sound detection, infrared thermography and vibration sensing techniques can be used. These techniques are used for investigating different phenomena associated with manufacturing process such as tool wear, tool breakage, non-destructive evaluation and surface roughness. Titanium alloys are among the hardest materials which can sustain maximum temperatures at cutting zone. **Ti-6Al-4V** (UNS Designation **R56400**) is an alpha-beta titanium alloy featuring high strength, low weight ratio and excellent corrosion resistant. It is one of the most commonly used titanium alloys and is applied in a wide range of applications where low density and excellent corrosion resistance is necessary such as e.g. aerospace industry and biomechanical applications (implants and prostheses). As it is hard to machine this material with conventional we can machine it with AWJM.

LITERATURE SURVEY OF MACHINING PROCESSES

The AWJM process considered for the work on effect of material properties which is difficult to cut in following subsection as cutting of various metals and alloys, material properties on responses of AWJM, on optimization techniques.

LITERATURE SURVEY ON CUTTING VARIOUS METALS AND ALLOYS

Vundavilli et al [1] experimentally analyzed the depth of cut of 6063-T6 aluminium alloy using fuzzy logic combined with GA. It was suggested that improvement in results was found by replacing the membership function distributions. Jain et al [2] did experiment on material removal rate on AJM of Glass, Al6061-T6 through GA analysis. Mass flow rate of abrasive particles, mean radius of abrasive particles and velocity of abrasive particles were used as the important input factors. Objectives for brittle and ductile materials were attempted separately. Jegaraj and Babu [3] analysed on AWJM the depth of cut, kerf width and surface roughness of 6063-T6 aluminium alloy by using Neurogenetic technique. They suggested the minimum experiments for developing the model while water jet pressure, abrasive flow rate, traverse rate and orifice size were the input variables. Srinivasu and Babu [4] proposed depth of cut of 6063-T6 aluminium alloy on AWJM by Neurogenetic approach. Water pressure, abrasive flow rate, jet traverse rate were the input parameters used in experiment. Remark by them is given that optimised depth of cut was confirmed almost nearer to the desired value. Tsai et al [5] experimentally analysed surface finish of SKD61mold steel. Taguchi method was used on abrasive jet polishing. It improved the surface finish approximately by 87% if additive types, abrasive particle material and orifice diameter were the input parameters. Parikh and Lam [6] studied abrasive mass flow rate, focus diameter, traverse rate and pump pressure on AWJM by ANN technique. The result of neural network was shown as better than other techniques. Orifice diameter, depth of cut and work piece-abrasive material were the factors varied. Rao et al [7] performed the experiment on AJM on glass, Al-6061-T6 through SA algorithm. The input parameter mass flow rate of abrasive particles, mean radius of abrasive particles and velocity of the abrasive particles were used. It was give the remark that, surface roughness was considered as a process constraint and objective for brittle and ductile material was attempted separately. M. A. Azmir and AK Ahsan [8] found that material removal rate was smaller at smaller nozzle tip distance and better kerf was observed at high pressure of glass in AWJ drilling using Taguchi method. They use nozzle tip distance, abrasive flow rate, stand of distance, water pressure as work variables. Jagdish et al [9] optimized AWJM of green composites by varying water pressure, stand of distance, nozzle speed in RSM. The proposed design can be used in environmentally conscious manufacturing process.

LITERATURE SURVEY ON MATERIAL PROPERTIES ON RESPONSES OF AWJM

Caydas and Hascalik [10] analysed the surface roughness in AWJM of AA7075 aluminium alloy by varying traverse speed, water jet pressure, stand of distance, abrasive grit size and abrasive flow rate. The values of variables were obtained from Taguchi ANN method. Water jet pressure was shown as the dominant variable affecting the surface roughness to greater extent. Rao and Kalyankar [11] explained the surface roughness was considered as a process constraint. It used TLBO algorithm on glass, Al6061-T6 on AJM by varying mass flow rate of abrasive particles, velocity of abrasive particles and mean radius of abrasive particles. Zain et al [12] objected surface roughness of AA 7075 aluminium alloy by varying traverse speed, water jet pressure, and stand-off distance and abrasive grit size. It integrated approaches of ANN and SA. Same model was attempted by GA and SA algorithms. Number of interactions taken by their approach was comparatively more than the other advanced optimization techniques. Kok et al [13] performed experiment on AWJM on 7075 aluminium alloy composites using GEP techniques while depth of cut, particle size and particle weight fraction was initial variables used. Results obtained by using GEP were compared with the experimental results. Ke et al [14] used Taguchi method for surface roughness on AJM on silicon wafers. The optimum variable setting was produced to reduce the roughness to 0.118 micron. They use Mesh size, impact angle, stand-off-distance, jet pressure, traverse speed were the primary variables.

Iqbal et al [15] found surface roughness, % proportional of striation of striation free area, width of cut, production rate using ANOVA and DerringerSuich multi-criteria decision modelling approach on AWJM on AISI 4340 and aluminium 2219. In this experiment cutting feed and thickness were shown as the highly influential parameters. Kechagias et al [16] did experimental analysed on AWJM on material transformation induced plasticity sheet steels through Taguchi method. It objected kerf geometry and surface roughness while sheet thickness, nozzle diameter, traverse speed and standoff-distance were the input variables. This work was focused more on the software based approach.

LITERATURE SURVEY OF OPTIMIZATION TECHNIQUES

Chang and Kuo [17] analysed the surface roughness and material removal rate of aluminium oxide in laser assisted turning using Taguchi method. They varied the rotation speed, feed, depth of cut and pulse frequency during experimentation identified that the rotational speed was the most significant parameter affecting both the surface roughness material removal rate. R.Rinaldo et al [18] analysed the natural variables of drilling tools in Finite element analysis and studied spindle speed frequency. They conclude that cutting mechanisms can be achieved by initiation propagation. ANOVA GRA (GRT relational analysis) analysis of Si3Ni4-TiN conductive ceramic composite in EDM was done by C. Sathiya

Narayanan et al [19] material removal rate, taper angle, circularity, run out, surface roughness was observed by varying current pulse on time, pulse off time, dielectric pressure and spark gap voltage. Increase in spark eroding process was experimentally observed. Saha et al. [20] using ANN for WEDM of tungsten carbide-cobalt composite found that peak current and capacitance significantly increases cutting speed and surface roughness. Pulse-on time, pulse-off time, peak current and capacitance were varied during experimentation. Somashekhar et al. [21] analysed the material removal rate of aluminium in micro-EDM by varying gap voltage, capacitance and feed rate. They concluded that more variation in MRR was observed due to capacitance compared to others. They used ANN and SA as optimization techniques. Amini et al [22] used combination of Taguchi method, ANN and GA methods to optimize the material removal rate and surface roughness of TiB2nano-composite ceramic in WEDM by varying power, time off, voltage, servo and wire feed rate. Shown that the achieved optimization result were in good agreement with the experimental result. Shrivastava and Dubey [23] optimized the material removal rate by 76% and wheel wear rate by 31% in electric discharge diamond grinding of copper-irongraphite MMC by using ANN, GA and grey relational analysis as optimization techniques. Singh and Gill [24,27,28] used adaptive Neuro-fuzzy inference system to calculate MRR by varying depth of penetration, time of penetration and penetration rate in porcelain ceramic, Alumina ceramic and sillimanite ceramic Fuzzy logic-based models were designed to simulate MRR. Rao and Kalyankar [25] used TLBO for cutting speed of WEDM of oil hardened and nitride steel. Surface roughness was considered as constraint. Pawar and Rao [26] studies TLBO application for Titanium in AWJM. Power generation was considered as constraint.

CONCLUSION

The change in various process parameters leads to change in material properties. The optimization of process parameters can be done by using various techniques like fuzzy logic, TLBO, Taguchi Method and online process monitoring by using different artificial intelligence techniques.

FUTURE SCOPE

There is no work found on the prediction of depth of cut while working under AWJM by using a mathematical model to find the optimum process parameter.

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