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Improving surface roughness of abrasive waterjet cutting process by using statistical modeling

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ABSTRACT

Abrasive waterjet (AWJ) cutting is considered one of the optimum machining processes for cutting a reflective, conductive, or heat sensitive materials like aluminum alloys. The aim of this work is to understand the effect of abrasive waterjet cutting parameters (traverse speed, water pressure and standoff distance) on surface roughness quality of the cutting process. The material under study is aluminum alloy 7075 which is used widely in space applications. Design of experiments and statistical modelling techniques are employed to establish a relationship between the control factors and output responses. Response Surface Method (RSM) is used for surface roughness modeling. The results showed that an improvement of the surface roughness can be achieved by increasing the water pressure at low traverse speed or decreasing the pressure at high traverse speed, or decreasing the standoff distance at low traverse speed and low pressure in the investigating range.

Introduction

In 1968 Norman Franz, USA [1] succeeded in using high pressure steam of water to cut laminated paper tubes. In 1979, Hashish and Du Plessis added the abrasives to the water to increase the ability of cutting hard materials such as steel, marble, concrete, titanium and hardened alloys [2]. Abrasive waterjet (AWJ) cutting is one of the recent non-traditional manufacturing processes.it can be used in satellite structure manufacturing such as aluminum alloys [3]. AWJ cutting for metallic materials does not leave Heat Affected Zone (HAZ) and has no thermal distortion. It enables penetration of thick cross sections with respect to other techniques, and has a minimum stresses and small cutting forces on the product [4–6].

Understanding the influence of the control factors (traverse speed, water pressure and standoff distance, i.e. the distance between the nozzle and the surface of the sample) on the behavior of the AWJ process is considered essential point for enhancement the cutting performance of the process [7].

Despite the influence of process parameters on the surface roughness was investigated previously, deep understanding and modeling for the influence of these parameters and their interactions on the cutting quality have not been reported previously [8–13]. The influence of the cutting parameters and specially water pressure on surface roughness has not robust results.

Wang and Wong discovered that the surface roughness initially decreases with increasing of water pressure. With a more increase in pressure, the surface roughness value increases greatly [14].

Ramulu et al. found that the erosion of the surface during cutting increases when applying low water pressure with high traverse speed [15]. Most of the researchers concluded the increasing of water pressure increase the surface roughness quality [8,12,13,16,17].

Detail behavior of the process parameters and specially the interactive influence of these parameters is still considered a point of weakness for the process due to contradiction between the results of the previous researches.

The objective of this study is to develop a statistical model to investigate significant control parameters and their interactions for the abrasive waterjet cutting process of aluminum alloy 7075 by using Response Surface Methodology (RSM) [18]. A mathematical model was implemented for the output response (surface roughness) which can predict the surface roughness at different cutting conditions. The experiment was designed by using Central Composite Design (CCD). The result of model revealed a robust correlation between input factors and output parameters.

The input cutting parameters are: traverse speed (A [mm/min]), water pressure (B [MPa]), and standoff distance (C [mm]) and the output response is surface roughness (R_a [μm]).

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Experimental work

Equipment

The abrasive waterjet machine model (CL510-waterjet-Italy) was used for this study is shown in Fig. 1. It depends on intensifier (SL VI50) with maximum pressure 420 MPa. It can penetrate and cut approximately most of material types without causing toxic fumes, dust and thermal alternations on the edges.

A cutting head is of self-aligning type as shown in Fig. 2. It is moving on cantilever structure and controlled by Lantek CAD–CAM software. It includes a mixing chamber where the water stream is mixed with abrasive. The output stream of water and abrasive mixture allow to cut any shape and most of materials up to thickness of 150 mm. The calibrated output orifice diameter is 0.3 mm.

Test specimens and preparation

According to previous investigations for the recommended control parameters ranges for AWJ cutting process [9,12,13,15–17,19]. Screening experiments were done for estimating and ensuring the previous recommended ranges, which are relevant to the working alloy and working thickness. The preliminary working windows for the control parameters are as following; traverse speed from 30 to 150 m/min, generating pressures from 100 to 300 MPa, and 1–3 mm standoff distance. Experiments were designed to cover most of available ranges of the cutting parameters in the control system of the AWJ cutting machine, and in the same time to be as relevant as possible to previous working ranges of the parameters.

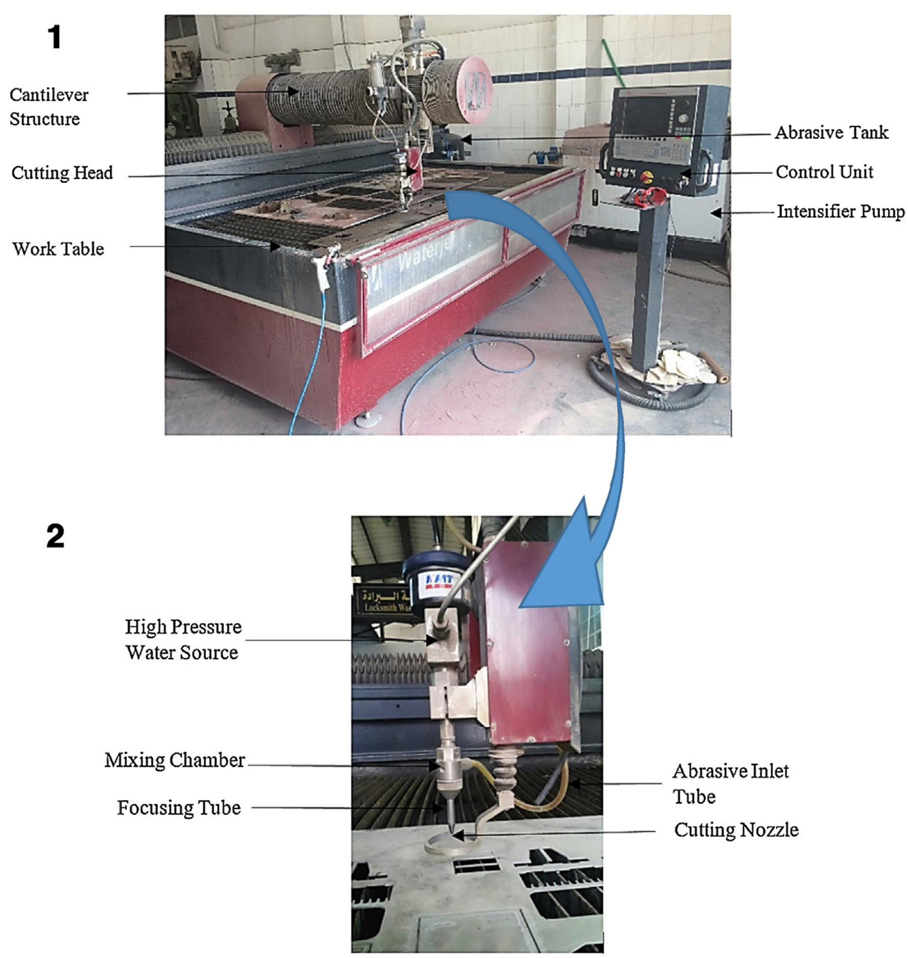
30 specimens used of aluminum alloy 7075 with thickness 7 mm. Experiments were carried out to evaluate the effect of these three factors on the surface roughness.

Table 1
Input process parameters setting.

Symbol	Process parameter	Setting range
A	Traverse speed	30–150 mm/min
B	Water pressure	100–300 MPa
C	SOD	1–3 mm

Table 2
Garnet chemical composition.

Minerals	Chemical composition	Proportion by weight
Almandine garnet	$Fe_3Al(SiO_4)_3$	>98%
Ilmenite	$FeTiO_3$	<1.5%
Shell	$CaCO_3$	<0.2%
Quartz	SiO_2	<0.5%
Zircon	$ZrSiO_4$	<0.2%



Figs. 1 and 2. Abrasive waterjet machine. Cutting head.

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