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An Experimental Study of Abrasive Waterjet for Deburring

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Abstract. Deburring is a major bottleneck in manufacturing organizations. Burrs on the milled surface need to be removed and the surface quality must be maintained. Abrasive waterjet (AWJ) has been used in various operation for a wide range of materials. But no detailed investigations are known to be carried out on AWJ deburring. An orthogonal experiment is designed to investigate the effects of the AWJ parameters on burr removal and on surface quality. The results show that AWJ can remove the burrs from the stainless-steel specimens effectively under the condition of proper parameters, and the parameters such as abrasive grit size and stand-off distance are important not only for burr removal but also for surface quality, and slurry concentration is another important factor for surface quality.

Introduction

Waterjet added with solid particles (e.g. garnet and quartz particles), which is named as abrasive waterjet (AWJ), is a powerful tool in processing various materials. It is minimal force, no heat damage and environmentally friendly. So the AWJ machining has numerous potential applications including stripping, cutting, drilling, milling, peeninig, cleaning, forming and coating removal[1].

The AWJ cutting is the earliest process applied widely in industry. The AWJ technology is divided into premixed abrasive waterjet and postmixed abrasive waterjet according to the different ways of entering the abrasive[2]. The first commercial abrasive waterjet system for cutting automotive glass adopted the postmixed abrasive waterjet due to little damages to the high pressure equipment. In the postmixed abrasive waterjet machining process, abrasive particles or abrasive slurry is entrained into the water stream and then accelerated through a nozzle, then the mixture come out with a very high velocity. When the jet is directed on to the target surface, the target surface is struck by abrasive particles and impacted by waterjet and sheared by lateral flow of waterjet.

In recent years, a great deal of research has been done to improve the cutting capacity and cutting quality, including studies of the mechanisms of the AWJ cutting process[3~5]. With the development of the pump technology and nozzle manufacture, the AWJ cutting has gradually become mature and steady. In the mean time, the AWJ drilling[6] for small diameter holes and the AWJ milling[7] for difficult-to-machine materials have been researched and proved to be a potential processing method. However, a few investigations on removing burrs from workpiece by the AWJ had been reported.

Burrs are generated in most machining process. Even with the advancement of technology, problems of burr removal are still encountered by manufactures and researchers[8]. The proper control of burrs in manufacture and the selection of suitable deburring1techniques can improve the products quality and reduce manufacturing costs. There are three classes about deburring methods. The first is manual deburring, the second is mechanical deburring and the other is non-conventional methods. There are many non-conventional deburring methods such as thermal deburring, ultrasonic deburring, magnetic abrasive deburring, laser deburring and abrasive jet etc..

Abrasive jet deburring has been investigated for the influence of abrasive jet deburring process parameters[9,10]. Different from abrasive jet, AWJ adopted abrasive slurry not abrasive powder. Because adding liquid, the mechanisms of burr removal are different. But the investigation of the application of AWJ in deburring is reported rarely. In order to make better use of AWJ technology and improve deburring status, A Taguchi orthogonal experimental design and analysis was used to systematically determine the main factors. Results of deburring experiments indicate that the AWJ has a great potential to be used as a burr removal machining technology.

Experimental design and procedure

Specimens. The material of specimens is stainless steel sheets, and the shape of specimens is 16 mm square with 4mm thick. The burrs on the surface were generated by a face milling operation. Eight specimens were prepared for 8-run experiments.

Selection of the process parameters and experimental design. Fig.1 shows the parameters associated with the AWJ deburring process. The effects of stand-off distance and impingement angle on the material removal rate and the penetration rate have been analyzed by various investigators. Waterjet pressure and abrasive flow rate have also been studied in some papers. In this paper, an air pump is used as the power plant of AWJ not is a water-pump, and abrasive slurry is substituted for abrasive powder.

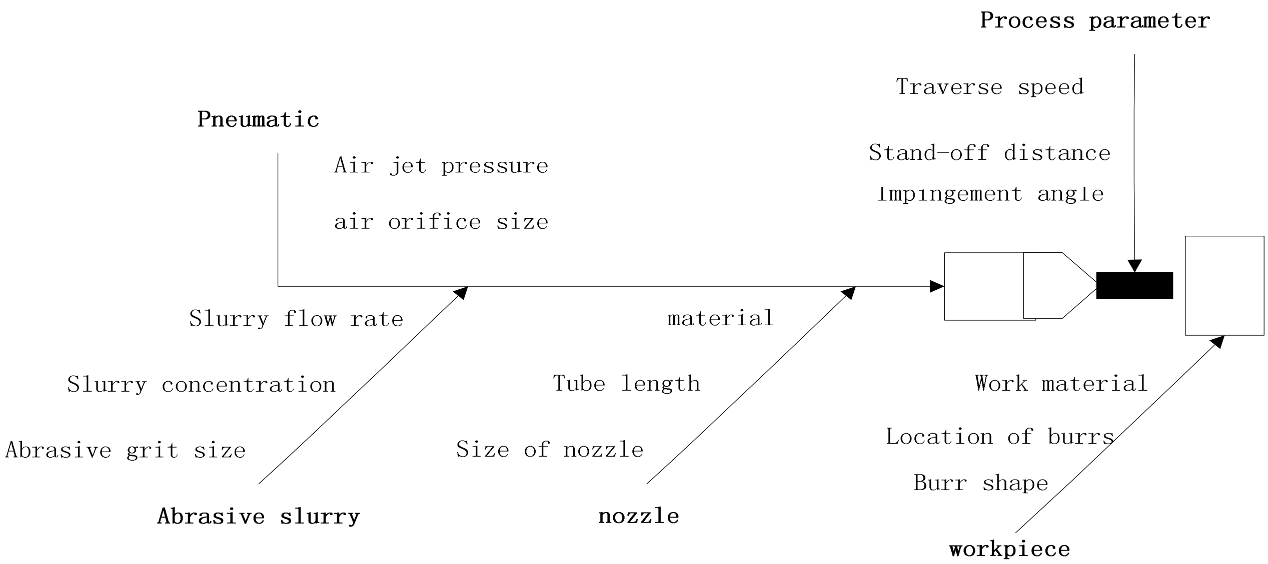

Fig.1 Parameters associated with the AWJ process

The purpose of the paper is to distinguish the influence of these parameters on the burr removal and the surface quality achieved. Due to limited test conditions, these parameters investigated include air pressure, slurry concentration (the ratio of the weight of the abrasive to the weight of the abrasive and adding fluid), abrasive grit size, stand-off distance, size of nozzle and impingement angle. In order to acquire more information in the short time, Taguchi orthogonal experimental design and analysis was used to systematically determine the influence of these parameters on the quality of deburred stainless steel specimens. Burrs removal and the surface quality were designed as the criterion for assessing the quality of the deburred specimens. Table 1 shows the level of each variable used in the experiment.

Table 1 Level of each variable used in the experiment

variable	Level 1	Level 2
Air pressure	3[MPa]	6[MPa]
Slurry concentration	0.25	0.5
Abrasive grit size	50[um]	150[um]
Stand-off distance	5[mm]	15[mm]
Size of nozzle	0.5[mm]	1[mm]
Impingement angle	0[°]	30[°]

The orthogonal design for the two levels of seven factors has been done and 8-run experiments has been performed to study the main effects. The output was designed as "0", "0.5" or "1" during assessing the burr removal. The value "1" represents that burrs were completely removed, and "0" represents that burrs were completely retained. The value "0.5" represents the status was in between. During assessing the surface quality, the output was designed as the surface roughness. According to analysis of variance table, the percentage effect of each variable was calculated by the ratio of the individual parametric sum of squares to the total sum of squares of all parameters.

Experimental procedure. All the experiments were performed on a test rig built by precession machining institute in Xi'an technological university. The specimens with burrs are held in a simple fixture which is mounted on an X/Y table. A height gauge was used to establish the necessary stand-off distance. An optical profile projector was used to measure the quality of deburred specimens and a surface roughometer was used to measure the surface quality.

Results and discussion

Table 2 The percentage effect of each parameters on burr removal

factors	F value
Air pressure	22.56
Slurry concentration	8.84
Abrasive grit size	56.78
Stand-off distance	89.37
Size of nozzle	17.50
Impingement angle	13.44

Table 3 the percentage effect of each parameters on surface quality

factors	F value
Air pressure	17.66
Slurry concentration	40.09
Abrasive grit size	78.26
Stand-off distance	57.74
Size of nozzle	15.58
Impingement angle	28.19

Through the 2-level, 7 factors, 8-run experiments, the effect of each parameters on the burr removal and on the surface quality was achieved. The details were depicted in Table 2 and Table 3. According to the orthogonal experimental analysis, setting the significance level $\alpha = 0.10$, $F_\alpha(1,1) = 39.86$ can be gained from the F distribution table on the side of the quantile. To observe the data in Table 2 and in Table 3, the F value of each parameter was compared with the F distribution. The parameter whose F value is greater than F distribution impacts on the process output significantly. For the effect of burr removal, the stand-off distance is the most important factor, followed by the abrasive grit size. For surface quality, the most important factor is the abrasive grit size, followed by the stand-off distance, finally is the slurry concentration.

Conclusions

In order to make better use of AWJ deburring technology, A Taguchi orthogonal experimental design and analysis was used to systematically determine the main factors. The results obtained in this experimental research support the following conclusions.

(i) The burrs can be removed effectively from the samples of stainless steal by the abrasive waterjet via the proper process parameters.

(ii) Based on the orthogonal experiments, the parameters, viz. the abrasive grit size and stand-off distance, are important factors for burr removal and surface quality. Additionally, the slurry concentration also affects surface quality significantly.

Due to space limitation, This paper only reported the investigation of main factors which affect burr removal and surface quality. The influence rules of these parameters on burr removal will be reported in follow-up study.

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