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A Comparative Studies and Reports on Abrasive Water Jet Roughness with Laminated Glass Cut

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Abstract: *Abrasive waterjet (AWJ) is a non-conventional machining process utilized for cutting bendable, weak and hard materials. AWJ cuts practically all materials, nonappearance of warm bending, high adaptability, littler cutting powers, no warmth influenced zone and being ecologically inviting. In the current examination an endeavor has been made to consider Depth of Cut (DOC) and Surface Roughness of overlaid glass cut by AWJ. Stream Pressure (p), Speed of Traverse (u) and Flow pace of rough (ṁ) are fluctuated at three unique levels. An aggregate of 27 analyses considering various degrees of parameters have been completed on a trapezoidal formed overlaid glass of 38 mm thickness. DOC is estimated with stature estimating check. The impact of parameters on surface harshness and DOC is gotten through fundamental impact plot. Surface Roughness (Ra) values are estimated at the wear area along cut bearing. Dimensional examination displaying for Ra is completed to anticipate the model condition for Ra by Buckingham's π–technique. Correlation of model normal Ra and exploratory normal Ra is completed to anticipate the appropriateness of the model.*
Keywords: *Abrasive Waterjet (AWJ), Statistical Modelling, Mathematical modeling.*

I. Introduction

Abrasive Water Jet (AWJ) cutting is one of the un conventional machining processes employed in industry. In this process, high velocity of water and abrasive particles are employed to for material removal. A stream of abrasive particles are introduced into the stream of water and is made to impinge on to the work material with a high velocity. AWJ is mainly used to cut materials such as ceramics, metals, wood, marbles, and layered composites [1][3] [4]. Surface roughness is an important parameter that ensures the quality of machined part. Quality of product has a direct relation with the surface roughness. Many literatures highlights the machining performance in AWJM for materials like tiles, marbles, glass, aluminum, etc. Cutting of laminated glass by traditional machining is difficult due to reasons such as delamination, surface damage and poor finish. It may also require secondary operations like trimming and drilling. It is found an unsafe practice in cutting both sides separately. During conventional cutting it is difficult to cut this laminated glass because it results in delamination or breakage. Also surface finish is not so good, sharp edges are formed at the cutting surface. Hence AWJ cutting of laminated glass is studied in the present work.

Ushasta Aich et al. [1] has carried out an investigation on borosilicate glass cut by AWJ machining. In this investigation depth of cut [DOC] is measured for varying cutting parameters such as standoff distance, traverse speed, abrasive flow rate, and water pressure. The results so obtained are in-line with experimental results. Kumar Abhishek et al. [2] employed grey relational analysis for optimizing the process parameters to machine holes on soda lime glass and the result of confirmation test was found to be better. UshastaAich et al. has conducted experiment on cutting of borosilicate glass by AWJ machining. Material removal rate (MRR) and DOC are measured with different settings of parameters-water pressure, abrasive flow rate, traverse speed and standoff distance. Regression model of DOC has been developed and the validation result of the estimated model favors the practical use of the model in the chosen range. Dr. M. Chithirai Pon Selvan [4] carried out an investigation on surface roughness which is an important cutting performance measure in AWJ cutting of borosilicate glass. Taguchi's design of experiments was carried out in order to collect surface roughness values. Experiments were conducted by varying the traverse speed, abrasive flow rate, standoff distance and water pressure for cutting borosilicate glass using abrasive water jet cutting process. This experimental study has resulted in increased surface smoothness with reduced standoff distance. Deepak Doreswamy et. al. [5] has reported the effect of AWJ machining parameters on kerf width, on graphite filled glass fiber reinforced epoxy composite. Experiments were conducted based on Taguchi's L27 orthogonal arrays. The regression models were developed to predict kerf width. Scanning electron microscope is used to study the Surface morphology. Optimized Process parameters ensures small kerf width. R.Prabhu, V.Thirunavukkarasu [8] has worked on the influence of various process parameters in abrasive water jet machining while machining the Bullet proof glass. Surface roughness is measured with different process parameter. Waterjet pressure, abrasive flow rate, standoff distance and traverse speed are improved together by using Taguchi Grey Relational Analysis. M. Chithirai Pon Selvan and Dr. N. Mohana Sundara Raju [9] reported the influence of process parameters on surface roughness

(Ra) of cast iron. Taguchi's design of experiments was used and experiments were carried out by varying waterjet pressure, traverse speed, abrasive mass flow rate and standoff distance. It was found that surface roughness reduces as standoff distance decreases. Derzija Begic-Hajdarevic et al. [10] studied the surface roughness in AWJ cutting of Aluminium workpiece. Surface roughness was measured by using Mitutoyo stylus instrument across the depth of cut. There was a marginal change in the surface roughness upon increasing the abrasive mass flow rate. R.Horváth et.al. [11] carried out research on examination of average surface roughness in waterjet cutting and factorial design of experiments were used for further optimization. The surface roughness value is measured at different places. It was found thickness of the material is very important factor that affects the surface roughness. The Empirical model has been constructed to calculate average surface roughness (Ra) and was found to be in good relation with the experimental results. Vlatko Marušić et.al [12] studied the effects of machining parameters on jet lagging in AWJ cutting. [3]

II. Experimentation

2.1. Material

In the present investigation laminated glass of size 300 x 300 x 38mm (as show in figure 1) is used as specimen. The laminated glass is cut to trapezoidal shape at an angle of 45°. The AWJ machine is used for cutting of laminated glass is as shown in Figure 2. The machine is equipped to operate in the range between the pressure values of 1000 bar and 4500 Bar and maximum traverse speed of 8000 mm/min with drive motor power of 45 KW.

In the present investigation waterjet pressure (MPa), abrasive flow rate (kg/min) and traverse speed (mm/min) are considered as control parameters. Garnet of #80 mesh size is used for AWJ cutting. Depth of cut (DOC) and surface roughness (R_a) are measured.

Figure 1: Laminated glass specimen

Figure 2: Abrasive Water Jet Machine

Initially cutting parameters were determined by literature review and then preliminary experiments are done, and finally cutting parameters are adjusted in an attempt to get the desired response. Water pressure p (Mpa), Traverse speed u (m/min) & Mass flow rate ṁ (g/min) were selected as input parameters in the present study and three-level design is employed for modelling. By the preliminary experiment conducted using the above parameters glass was found to exhibit abrupt behavior of breaking in 300 MPa water pressure, traverse speed of 700 mm/min. and hence water pressure was limited to 200 MPa. In order to meet the above criteria L27 orthogonal array has been chosen and three levels are selected based on Taguchi method DoE. The different levels of parameters are mention in the Table 1 given below.

Table 1: Levels of parameters used in experiment

SL NO	Parameters	Level 1	Level 2	Level 3
1	Water pressure p (Mpa)	100	150	200
2	Traverse speed u (m/min)	300	400	500
3	Mass flow rate ṁ (g/min)	199	309	425

The cutting experiment is carried out on the laminated glass with the above stated parameter values from preliminary experimentation. The experimentation is conducted for the 27 combinations of the selected input parameters. Depth of cut (DoC) and surface roughness is measured for each trial.

2.3. Measurement of DOC

The depth of cut (DOC) is measured using height measuring gauge as shown in figure 3.

Figure 3: Height measuring gauge

2.4. Measurement of Surface Roughness

The R_a is measured using Mitutoyo surface tester and it is measured for all the 27 experiments at cutting wear region along the DOC. The stylus material is a diamond tip of radius 5μm with sensor moving along the surface of the sample.

Figure 4. Mitutoyo surface roughness test instrument

III. Result And Discussions

The results for DOC and Ra is shown in the below table

Table 2. Experimental results of DOC and Ra

EXP.NO	p[MPa]	ṁ[kg/min]	u[mm/min]	DOC[mm]	Average Ra (µm)
1	100	0.199	300	13	3.565
2	100	0.199	400	11.5	3.685
3	100	0.199	500	10	3.67
4	100	0.309	300	15	3.65
5	100	0.309	400	11	3.43
6	100	0.309	500	9	3.61
7	100	0.425	300	13.5	3.635
8	100	0.425	400	12	3.65
9	100	0.425	500	11	3.87
10	150	0.199	300	22.5	4.10
11	150	0.199	400	18	3.816
12	150	0.199	500	17	4.06
13	150	0.309	300	21	4.19
14	150	0.309	400	18	4.08

EXP.NO	p[MPa]	ṁ[kg/min]	u[mm/min]	DOC[mm]	Average Ra (µm)
15	150	0.309	500	15	3.62
16	150	0.425	300	19	4.036
17	150	0.425	400	18	3.656
18	150	0.425	500	16.5	3.823
19	200	0.199	300	24.5	3.856
20	200	0.199	400	23.5	4.204
21	200	0.199	500	22	4.21
22	200	0.309	300	28	3.596
23	200	0.309	400	24.5	3.903
24	200	0.309	500	23	4.023
25	200	0.425	300	28.5	4.25
26	200	0.425	400	24	3.996
27	200	0.425	500	22.5	4.218

The maximum DOC is obtained for highest water pressure of 200 MPa and highest abrasive mass flow rate of 0.425 kg/min with lowest traverse speed of 300 mm/min cutting condition. At higher water pressure, more amount of kinetic energy is available with the water. This high pressure water coupled with high abrasive flow rate will provide more water jet energy and more number of cutting edges of abrasive particles for cutting of glass. In addition, lesser traverse speed of water jet will assist this high pressure water with more number of abrasive particles to cut at a point for more duration of time when compared to lesser traverse speed jet. The above reasons will help in achieving higher DOC.

Similarly, minimum DOC is achieved for lower water jet pressure of 100 MPa with abrasive mass flow rate of 0.199 kg/min and higher traverse speed of 500 mm/min cutting condition. At lower water jet pressure less amount of energy is available for cutting of glass. This low pressure of water is coupled with low abrasive flow rate thus providing less water jet energy followed by reduction in number of cutting edges of abrasive particles for cutting of glass. In addition, higher traverse speed of water jet will assist low pressure water with less abrasive particles to cut at a point for less duration of time. Hence this is the reason for lower DOC.

Surface roughness is measured along the DOC for all 27 experimental specimens on the cutting wear zone only due to the limitations on use of Mitutoyo surface tester. The measurements are conducted from the top surface to one-third the distance from top surface of the cut. This region is considered to be cutting wear region. Table 2 shows the average Ra for all 27 experimental conditions.

3.1. Main effect plots for Depth of cut

The main effect plot is used to find the influence of the process parameters. Figure 6 shows the influence of process parameters on DOC of laminated glass cut by AWJ cutting process using Minitab software package. The best combination of input parameters to optimize DOC can be easily found from this plot. From Figure 5, it has seen that the water pressure and traverse speed slope is more, hence these two parameters has greater influence on the DOC.

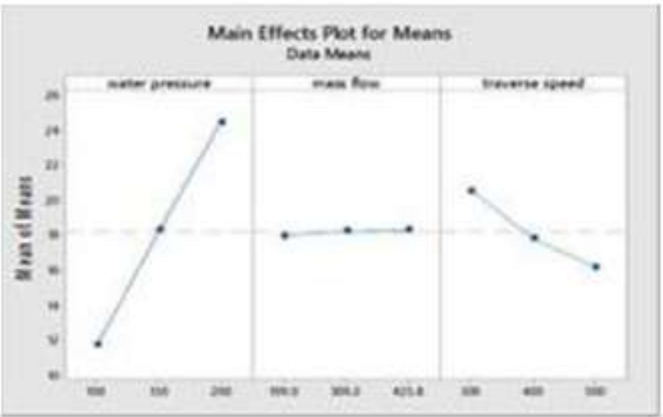

Figure 5. Main effect plot of process parameters on DOC

3.2. Mathematical Modeling of R_a

In the present study Buckingham's π –method is used to determine the relationship between R_a and Water pressure (p), abrasive mass flow rate (ṁ) & Traverse speed (u):

Where a & b are constants to be evaluated from experimental data On solving,

a= -0.13 & b=6.05

Finally, the model equation for R_a is

So this is the model equation to find average R_a on cutting wear region.

The graph below shows the experimental surface roughness and the surface roughness values obtained using mathematical modeling:

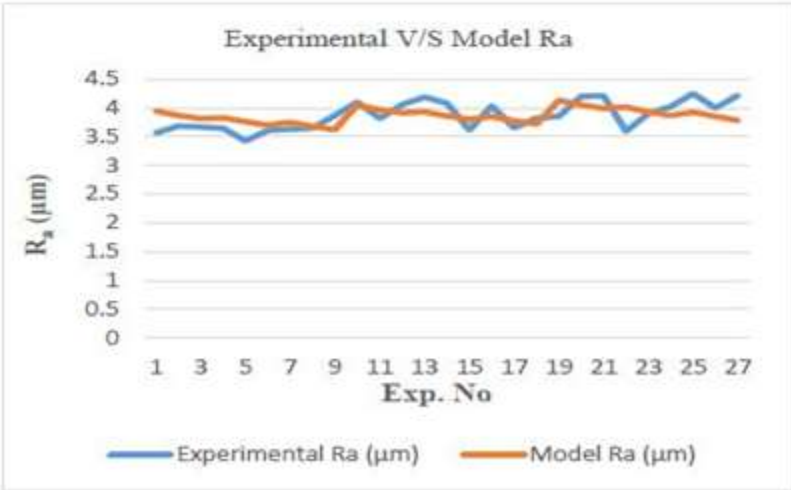

Figure 6

The minimum model R_a valve is 3.62 µm obtained for cutting condition 100 MPa waterjet pressure, 0.425 kg/min of abrasive flow rate and 500 mm/min of traverse speed. The maximum R_a valve is 4.133 µm obtained for the cutting conditions of 200 MPa waterjet pressure, 0.199 kg/min abrasive flow rate and 300 mm/min traverse speed. The R_a valves obtained from modelling are compared with average experimental R_a and the error in terms of percentage is calculated. Then comparison of model R_a and average experimental R_a were made, the proposed model predicted almost ±10% R_a value than the experimental values.

IV. Conclusion

In the present work, analysis of DOC and model equation for surface roughness R_a for laminated glass cut by AWJ is developed. The experiments were done on the 38mm thickness of trapezoidal shaped laminated glass. Water pressure is the main reason for higher DOC compared to abrasive flow rate and traverse speed. The lowest average R_a value for the cutting wear region is 3.43 (µm) is obtained for cutting condition of Waterjet pressure p 100 MPa, abrasive flow rate ṁ 0.309 kg/min & traverse speed u 400 mm/min. For better R_a values higher waterjet pressure (p), higher Mass flow rate ṁ and lower traverse speeds are recommended. Similarly for Waterjet pressure p of 200MPa, abrasive flow rate ṁ of 0.425kg/min & traverse speed u of 500mm/min has the highest average R_a value for the cutting wear region is 4.218 (µm).

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