Parametric Optimization Of Input Parameters On Surface Roughness And Cylindricity During Ultrasonic Drilling Of Alumina Ceramic

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Abstract: As one of the cost effective machining method for alumina ceramic, Ultrasonic drilling has attracted much more attention and there exist a numerous publication on the process. However little investigation on surface roughness and cylindricity in the Ultrasonic Drilling has been reported. This paper presents an experimental observation on surface roughness and cylindricity using three different slurry like Silicon carbide, Boron carbide and Alumina and keep frequency and thickness as input parameter and tool diameter as constant parameter. L9 orthogonal array is made for experimental design with the help of Taguchi method. Using TOPSIS Optimization methods conclude that when the frequency was increased and the thickness was decrease getting the optimum result for all slurry.

Index terms: Ultrasonic drilling, Alumina ceramic, Frequency, slurry, Surface roughness, cylindricity.

I. INTRODUCTION

Ultrasonic Machining (USM) is the process of removal of material by the abrading action of grit-loaded liquid slurry circulating between the workpiece and a tool vibrating perpendicular to the workface at a frequency above the audible range. [1]

Ultrasonic Drilling is a hybrid machining process that combines the material removal mechanisms of diamond grinding and ultrasonic machining (USM). It is also known as rotary ultrasonic machining (RUM). In RUM, a rotary core drill with metal-bonded diamond abrasives is ultrasonically vibrated and fed toward the workpiece at a constant federate or a constant force (pressure). Coolant pumped through the core of the drill washes away the swarf, prevents jamming of the drill, and keeps it cool. [3]

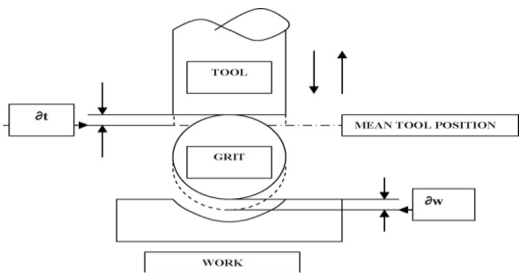

Fig.1 Schematic diagram of ultrasonic drilling
∂t = penetration in to tool, ∂w= penetration in to work piece.

The main advantages of the Ultrasonic Drilling for Industrial applications are machines precise features in hard, brittle materials such as Glass, engineered ceramics, CVD SiC- Chemical Vapor Deposition Silicon Carbide, Quartz, single crystal materials, PCD - Polycrystalline diamond etc.

Also limitless number of feature shapes including round, square and odd-shaped thru-holes and cavities of varying depths can be machined with high quality and consistency with good aspect ratios as high as 25 to 1 are possible, depending on the material type and feature size.

USM machined surfaces exhibit a good surface integrity and the compressive stress induced in the top layer enhances the fatigue strength of the workpiece. Unlike other non-traditional processes such as laser beam, and electrical discharge machining, etc., ultrasonic machining does not thermally damage the workpiece or appear to introduce significant levels of residual stress, which is important for the survival of brittle materials in service. [2]

II. LITERATURE SURVEY

Singh R and Khamba J S (2008) studied the comparison of effect of three different slurry silicon carbide, boron carbide, and alumina on machining characteristics of titanium in ultrasonic drilling. And they observed that the combination of boron carbide slurry and stainless steel tool give best material removal rate. [3]

Zenga W M et al. (2005) observed the tool wear in rotary ultrasonic machining (RUM) of advanced ceramics of silicon carbide (Sic). They observed some wear mechanisms for grinding wheels due to cutting forces in produces with increases in number of. The maximum cutting force increases with the number of holes drilled during the first tool wear stage, and starts decreasing during the second tool wear stage. [2]

Azarhoushang B and Akbari J (2007) done ultrasonically assisted drilling of Inconel 738-LC with the help of ultrasonically vibrated tool holder and checked their circularity cylindricity, surface roughness and hole oversize They observed that the application of ultrasonic vibration can improve the hole quality considerably [4].

Wiercigrocha M.,et al.(2005) studied the extensively adynamics of ultrasonic percussive drilling of hard rockssuch as sandstone, limestone, granite and basalt with diamond-coated tools in very specific laboratory conditions , in order to investigate the applicability of this technique to down hole drilling. It has been found out that the material removal rate (MRR) as a function of static load has at least one maximum. [5]

Pujana J. et al. (2009) analysis the ultrasonic-assisted drilling of Ti6Al4V material in which the ultrasonic vibration was applied on the Ti6Al4V workpiece samples. Several parameters of ultrasonic-assisted drilling were monitored, including feed force, chip formation by means of high-speed imaging, and temperature measurement on the drill tip by means of infrared radiation thermometry. They observed that the ultrasonic assistance offered lower feed force and higher process temperatures as compared to conventional drilling. It has also shown higher force reductions and higher temperature increments when vibration amplitude was increased [6].

Liao Y.S. et al. (2007) check the feasibility study of the ultrasonic vibration assisted drilling of Inconel superalloy and they found from the literature that the tool holder of a machining center is retrofitted so that axial resonant vibration can be provided to the sample and tool. Also they noted that the chip size is reduced, and the variation of torque in drilling becomes smaller when we applied the axial resonant vibration. Furthermore it is noted that there is little improvement in drilling performance when the frequency of the ultrasonic vibration is varied [7].

Simon S.F et al. (2005) designed a vibrated work piece holder' to study a burr size reduction in metal removal process of drilling by ultrasonic assistance They studied two stages experimental investigation of ultrasonic assisted drilling on A1100-0 aluminium and having 175 holes with uncoated and TIN coated drillbit. They found that that the high frequency with controlled amplitude reduced chip size and burr size. TiN-coated HSS drill offers resistance to the wear caused by fatigue in UA drilling. [8]

Phadnis V A. et al. (2013), 'A finite element model of ultrasonically assisted drilling in carbon / epoxy composites' Procedia CIRP 8 pp. 141 – 146. This paper present finite element model of UAD in carbon/epoxy composites. This model accounting the volumetric and thermal softening phenomena in the workpiece material under the influence of localized vibro-impacts and parametric study like (feed rate, spindle sped, amplitude and frequency) and examined the effect of variation in intensity of ultrasonic energy on the extent of softening in the carbon/epoxy composite for UAD. The result shows that good co-relation of Fe model with the experimental results. And a constitutive material model suitable to model both volumetric and thermal softening in CFRP laminate under ultrasonic vibrations. [9]

Aziz M and Ohnishi O (2012) developed the micro long flat drill with nominal diameter and flute length of 20 µm and 200 µm deep drillbit for drilling of duralumin and stainless steel workpiece. They have used ultrasonic vibration and step feeding method for drilling and showed 10 µm web thickness has largest tool life in both materials. And also good balance between the chip removal capability and the tool rigidity. They also show that USV micro drilling proposed good method to improving drilling capability of long flat drill. And step feeding micro deep drilling may increase the interference between the drill tip and the hole entrance resulting in shorter tool life. [10]

III. Experiments

1.1 Experimental setup

Ultrasonic Drilling experiments were performed on ultrasonic Drilling machine (Rajasthan Tools & Spares, Jaipur, and Rajasthan, India). This experimental setup is showed in Fig.2.

Fig.2 Ultrasonic drilling Machine set-up

The experimental set-up maonly consists of:

- The power supply converts 50 Hz electrical supply to high frequency (20 kHz) AC output. This is fed to the piezoelectric transducer located in the ultrasonic spindle. The ultrasonic transducer converts electrical input into mechanical vibrations.
- Standard High Speed Steel drill beat of 10 mm diameter. And grit size of 150 for all slurry.
- Max. drilling thickness is 10mm.
- The work piece material was Alumina ceramic.

1.2 Design of experiments (Taguchi method)

Taguchi method of designing experiments has been used widely by engineers and industries in order to obtain information about the effects of different factors on a given process. This technique is based on orthogonal arrays to reduce number of experiment to be executed. Here we have two factoer and three level for three different slurry. An L9 orthogonal array is chossen to conduct the ultrasonic test.

Table.1 Design factor and their level for AL_2O_3, B_4C, SIC slurry

Level	Factors	
	Frequency (KHz)	Thickness (mm)
1	20	4
2	22	6
3	24	8

Table 2. Taguchi orthogonal array for ultrasonic drilling experiments for AL_2O_3, B_4C, SIC slurry

Test no.	Frequency	Thickness
1	20	4
2	20	6
3	20	8
4	22	4
5	22	6
6	22	8
7	24	4
8	24	6
9	24	8

For the ultrasonic test L9 array should be full factor test. Table.1 shows that factor with that level in ultrasonic test and L9 Array is shown in Table.2. There are three categories of quality properties in the analysis of SN ratio. These categories are: smaller is better, higher is better and nominal is best. In the present study it is desired to minimize the Surface roughness and Cylindricity. Therefore, the smaller is better
Category is used with the Eq. 1 [11]:

$$S/N = -10 \log \left[\frac{1}{n}\sum y^2\right]$$

1.3 TOPSIS Optimization

TOPSIS (for the Technique for Order Preference by Similarly to Ideal Solution) was developed by Hwang and Yoon in 1980 as an alternative to the ELECTRE method and can be considered as one of its most widely accepted variants. The basic concept of this method is that the selected alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution in some geometrical sense.

The TOPSIS method assumes that each criterion has a tendency of monotonically increasing or decreasing utility. Therefore, it is easy to define the ideal and negative-ideal solutions. The Euclidean distance approach was proposed to evaluate the relative closeness of the alternatives to the ideal solution. Thus, the preference order of the alternatives can be derived by a series of comparisons of these relative distances.
The steps of topsis optimization are given below:
Step.1 Construct normalized decision matrix.
Normalize scores or data as follows:

$$r_{ij} = \left(x / \left(\sum_{i=1}^{m} x_{ij}^2 \right)^{\frac{1}{2}} \right)$$

for i = 1… m; j = 1… n

Step.2 Construct the weighted normalized decision matrix.
Assume we have a set of weights for each criteria wj for j = 1…n.
An element of the new matrix is:

$v_{ij} = w_j r_{ij}$

Step.3 Determine the ideal and negative ideal solutions.
Ideal solution.

$A^* = \{ v1^* , \ldots, vn^*\}$, where $vj^* = \{ \max_i (v_{ij})$ if $j \in J$; $\min_i (v_{ij})$ if $j \in J' \}$

Negative ideal solution.

$A' = \{v1', \ldots, vn'\}$, where $v' = \{ \min_i (v_{ij})$ if $j \in J$; $\max_i (v_{ij})$ if $j \in J' \}$

Step.4- Calculate the separation measures for each alternative.
The separation from the ideal alternative is:

$$S_i^* = [\Sigma_j (v_{ij} - v_j^*)^{2]\ ½} \qquad i = 1\ldots m$$

Similarly, the separation from the negative ideal alternative is:

$$S_i' = [\Sigma j (v_{ij} - vj')^2]\ ½ \qquad i = 1\ldots m$$

Step.5- Calculate the relative closeness to the ideal solution Ci*

$Ci^* = S_i' / (Si^* + S_i')$, $\quad 0 < Ci^* < 1$

Select the Alternative with Ci* closest to 1.

Table.3 Optimization of response parameter of SIC slurry

SR no.	r_{ij}		w_{ij}			Ra	Cylindricity
					A*	0.074278	1.00514538
					A'	0.028568	0.00548623
	Ra	Cylindricity	Ra	Cylindricity	S_i^*	S_i'	Ci*
L1	0.062332	1.005145	0.062332	1.005145	0.0119469	1.0002292	0.01180315
L2	0.057137	0.682063	0.057137	0.682063	0.3235368	0.6771796	0.32330521
L3	0.028569	0.670097	0.028569	0.670097	0.3381521	0.6646107	0.33722044
L4	0.07272	0.9154	0.07272	0.9154	0.0897587	0.9109846	0.08969199
L5	0.074278	0.717961	0.074278	0.717961	0.2871844	0.7217931	0.28462914
L6	0.033243	0.783774	0.033243	0.783774	0.2251424	0.7783019	0.22436963
L7	0.062359	0.005486	0.062359	0.005486	0.9997302	0.0337904	0.96730553
L8	0.05454	0.664114	0.05454	0.664114	0.3416022	0.6591396	0.34134900
L9	0.029348	0.849587	0.029348	0.849587	0.1619170	0.8441013	0.16094837

Table.4 Optimization of response parameter of B_4C slurry

SR no.	r_{ij}	w_{ij}		Ra	Cylindricity
			A*	0.094241	0.9265259
			A'	0.026926	0.0040209

	Ra	Cylindricity	Ra	Cylindricity	S_i^*	S_i'	Ci*
L1	0.094242	0.653388	0.094242	0.653388	0.273138	0.6528470	0.29496999
L2	0.067315	0.819413	0.067315	0.819413	0.110445	0.8163919	0.11916369
L3	0.026926	0.851547	0.026926	0.851547	0.100763	0.8475260	0.10625779
L4	0.084144	0.439163	0.084144	0.439163	0.487468	0.4388874	0.52622134
L5	0.075393	0.867614	0.075393	0.867614	0.061854	0.8708835	0.06631424
L6	0.032985	0.706945	0.032985	0.706945	0.227966	0.7029498	0.24488334
L7	0.050773	0.004021	0.050773	0.004021	0.923529	0.0238470	0.97482831
L8	0.044428	0.910459	0.044428	0.910459	0.052340	0.9066070	0.05458109
L9	0.034331	0.926526	0.034331	0.926526	0.059911	0.9225347	0.06098117

Table.5 Optimization of response parameter of AL_2O_3 slurry

SR no.	r_{ij}		w_{ij}			Ra	Cylindricity
					A*	0.071559	1.0548879
					A'	0.025417	0.0044980
	Ra	Cylindricity	Ra	Cylindricity	S_i^*	S_i'	Ci*
L1	0.056282	0.919646	0.056282	0.919646	0.1361022	0.915668	0.1294029
L2	0.047204	0.791166	0.047204	0.791166	0.2648443	0.786969	0.2517976
L3	0.025418	0.824977	0.025418	0.824977	0.2344960	0.820478	0.2222764
L4	0.052651	1.054888	0.052651	1.054888	0.0189088	1.050742	0.0176775
L5	0.054466	0.67621	0.054466	0.67621	0.3790633	0.678400	0.3584646
L6	0.039942	0.926408	0.039942	0.926408	0.1323132	0.922024	0.1254941
L7	0.07156	0.004498	0.07156	0.004498	1.0503900	0.046141	0.9579201
L8	0.050835	0.689734	0.050835	0.689734	0.3657412	0.685707	0.3478449
L9	0.027233	0.953456	0.027233	0.953456	0.1106941	0.948960	0.1044624

IV. RESULT AND DISCUSSION

For optimization in topsis method we need the separation value should be higher. So that we minimize the surface roughness and cylindricity. Table no.3 showed the Result and optimization value for silicon Carbide slurry.

For optimum Surface roughness and cylindricity level no 7 give Optimum value. It means 24 KHz frequency and 4mm thickness give best result.

Same as Table no.4 showed the Result and optimization value for Boron Carbide slurry. For Optimum Surface roughness and cylindricity level no 7 give optimum value. It means 24 KHz frequency and 4mm thickness give best result.

And Table no.5 showed the Result and optimization value for silicon Carbide slurry. For optimum Surface roughness and cylindricity level no 7 give optimum value. It means 24 KHz frequency and 4mm thickness give best result.

V. CONCLUSION

From the experiment we conclude that for surface roughness slurry is affect the values and boron carbide give minimum surface roughness and for cylindricity alumina is minimum cylindricity. And we can also conclude that maximum frequency and minimum thickness gives better surface roughness and cylindricity in AL_2O_3, B_4C, SIC

REFERANCES

[1] Pandey P.C., H.S.Shan (2012) “Modern Machining Process” (Tata McGraw Hill Education Private Limited, pages 7-38.

[2] Zenga W.M. et al. (2005), ‘Experimental observations of tool wear in rotary ultrasonic machining of advanced ceramics’, International Journal of Machine Tools & Manufacture 45 pp. 1468–1473.

[3] Singh R., Khamba J.S. (2008), ‘Comparison of slurry effect on machining characteristics of titanium in ultrasonic drilling’, journal of materials processing technology 1 9 7 pp. 200–205.B.

[4] Azarhoushang, Akbari J. (2007), ‘Ultrasonic-assisted drilling of Incone738-LC’, International Journal of Machine Tools & Manufacture 47 pp. 1027–1033.

[5] Wiercigrocha M., Wojewoda J., Krivtsov A.M. (2005), ‘Dynamics of ultrasonic percussive drilling of hard rocks’ Journal of Sound and Vibration 280 pp. 739–757.

[6] Pujana J. et al. (2009), ‘Analysis of ultrasonic-assisted drilling of Ti6Al4V’ International Journal of Machine Tools & Manufacture 49 pp. 500–508.

[7] Liao Y.S., Chen Y.C., Lin H.M. (2007), ‘Feasibility study of the ultrasonic vibration assisted drilling of Inconel superalloy’ International Journal of Machine Tools & Manufacture 47 pp. 1988–1996.

[8] Chang S S.F., Gary M. Bone (2005),’ Burr size reduction in drilling by ultrasonic assistance’ Robotics and Computer-Integrated Manufacturing 21 pp. 442–450.

[9] Phadnis V a et al. (2013), ‘A finite element model of ultrasonically assisted drilling in carbon/epoxy composites’ Procedia CIRP 8 pp. 141 – 146.

[10] Aziz M, Ohnishi O (2012), ‘Novel micro deep drilling using micro long flat drill with ultrasonic vibration’ Hiromichi Onikura Precision Engineering 36 168– 174.

