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Developmental and Experimental Study of Rotary Ultrasonic drilling process

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Abstract: The proper selection of machining conditions and machining parameter is an important aspect, before going to machine a brittle material by rotary ultrasonic drilling process Because these conditions will determine such important characteristics as; Material removal rate (MRR) and Surface roughness (SR). The purpose of this work is to determine the optimal values of machining parameters of rotary ultrasonic drilling process. The work has been based on the effect of three design factors: Tool feed rate, vibration frequency and grain size of abrasive particle on such characteristic like material removal rate (MRR). This work has been done by means of the technique of design of experiment (DOE), which provides us to perform the above-mentioned analysis with small number of experiments. In this work, a L_9 orthogonal array is used to design the experiment. The adequate selection of machining parameters is very important in manufacturing system, because these parameters determine the surface quality and dimensional accuracy of the manufactured part. The optimal setting of the parameters are determined through experiments planned, conducted and analyzed using the Taguchi method.

Keywords: RUSM, Material removal rate, Drilling, Taguchi method

I. INTRODUCTION

Ultrasonic machining is a unconventional machining process. The removal of material from the surface of a part takes place through high frequency, low amplitude vibrations of a tool against the material surface in the presence of abrasive particles. The tool vibrates vertically or orthogonal to the surface of the part at amplitudes of 0.05 to 0.125 mm (0.002 to 0.005 in.). The fine abrasive grains are mixed with water to form a slurry that is distributed across the part and the tip of the tool. Ultrasonic machining is used for brittle materials as well as materials with a high hardness due to the micro cracking mechanics.

II. LITERATURE SURVEY

1) *T. B. Thoe , D. K. Aspinwall and M. L. H. Wise (1998)* stated about the fundamental principles of ultrasonic machining, the material removal mechanisms involved and the effect of operating parameters on material removal rate, tool wear rate and workpiece accuracy are reviewed, with particular emphasis on the machining of engineering ceramics. The problems of producing complex 3-D shapes in ceramics are outlined.
2) *M. Wiercigrocha, J. Wojewodab and A.M. Krivtsov (2003)* studied ultrasonic percussive drilling with diamond-coated tools under laboratory conditions on rocks such as sandstone, limestone, granite and basalt, in order to investigate the applicability of this technique to down hole drilling. An experimental set-up, a program of work and example results are presented. The studies showed that an introduction of high-frequency axial vibration significantly enhances drilling rates compared to the traditional rotary type method. It has been found out that the material removal rate (MRR) as a function of static load has at least one maximum.
3) *V. Baghlania, P. Mehbudia, J. Akbarib and M. Sohrabi (2013)* explained in his study about the effect of ultrasonic vibration amplitude, spindle speed and number of steps to drill each hole on machining force and surface roughness were investigated. Optimized conditions and results predicted by Taguchi method showed close agreement with the results obtained by experiment.
4) *Z. Yaoa, Z.N. Guoa, Y.J. Zhanga, Y. Denga and W.T. Zhang (2013)* suggested that according to the characteristics of rotary ultrasonic machining, the paper designs rotary ultrasonic power matching circuits. The experimental results verify the proposed compound frequency tracking method is feasible and effective which eliminates temperature, load changed on the effect of the transducer.

5) *Vaibhav A. Phadnis, Anish Roy and Vadim V. Silberschmidt (2013)* explained the ultrasonically assisted drilling (UAD) is a novel machining technique suitable for drilling difficult-to-machine materials such as carbon/epoxy composites, where ultrasonic vibrations are superimposed on the tip of the revolving drill bit. A parametric study was also carried out to examine the effect of variation in intensity of ultrasonic energy on the extent of softening in the carbon/epoxy composite for UAD.
6) *S.Das, B. Doloi and B. Bhattacharyya (2014)* presented the study on the influences of ultrasonic machining process parameters such as abrasive grain size, power rating and tool feed rate on generated stepped hole profile. The experimental investigations carried out for determining the influence of USM process parameters will provide effective guideline to select parametric settings for achieving maximum material removal rate and desired job profile accuracy on stepped hole drilling operation on alumina.
7) *Li Li, Andrew Mathieson and Margaret Lucas (2015)* presented a study of a miniature ultrasonic surgical drill designed for bone biopsy, based on an ultrasonic/sonic drill. In this study it is incorporated in a miniature ultrasonic surgical drill and the effective impulse delivered to the bone is used to evaluate the drilling performance. To develop a miniature surgical device based on maximizing the effective impulse, optimization of the ultrasonic horn and free-mass is first demonstrated.
8) *Takuya Asami and Hikaru Miura (2015)* explained the ultrasonic machining is a processing method using both the ultrasonic vibration of the tool horn and abrasive slurry. They studied a new ultrasonic machining method using ultrasonic complex vibration caused by the longitudinal and torsional vibration.
9) *Vakili Azghandia, M.A. Kadivarb and M.R. Razfar (2016)* explained the effect of imposing ultrasonic vibration on conventional drilling. The cutting force was compared between conventional drilling (CD) and ultrasonic assisted drilling (UAD). With numerical calculations and analytical software (Ansys), the test structure and the horn were designed and also the vibratory behavior of the parts was predicted to have vibrations with longitudinal mode and in the direction of the tool feed, reaching to the peak at the tip of the tool. The results show a considerable improvement in drilling process due to transformation of cutting process and chip removal mechanism: In ultrasonic assisted drilling the average of the drilling thrust force along the axis of the tool decreased noticeably.
10) *Milan Nad, Lenka Cicmancova and Stefan Hajdu (2016)* explained the rotary ultrasonic machining (RUM) is a hybrid process that combines diamond grinding with ultrasonic machining. It is most suitable to machine hard brittle materials such as ceramics and composites. Due to its excellent machining performance, RUM is very often applied for drilling of hard machinable materials.

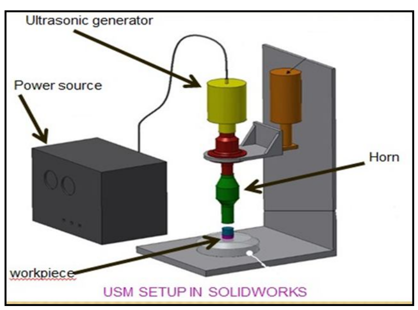

Fig. 1. Schematic diagram of experimental setup

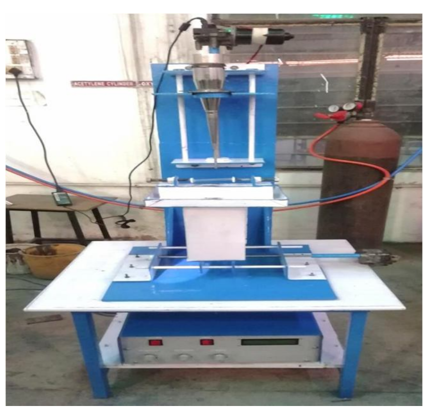

Fig.3. Developed rotary USM Experimental Setup

III. PROCESS PARAMETER DESIGN

The selection and design of parameter is also an important task for the completion of experimental work and study the effect of input parameters on the output responses. The range of parameters for rotary ultrasonic process is shown in Table 2.

The selected process parameters for the experiments are as follows:

A. *Input Parameters*

1) Frequency
2) Grain size
3) Feed rate

B. *Output Parameters*

1) Material Removal Rate

Table2. Process parameters with their range

S.No.	Process parameters	Unit	Symbol	Levels		
				1	2	3
1	Tool Feed Rate	MM/MIN	TFR	0.27	0.29	0.31
2	Vibration Frequency	KHz	F	15.5	21.5	27.5
3	Abrasive Grain size	Mesh	G	200	250	300

IV. EXPERIMENTAL METHOD

Experiments are per formed on a self-developed experimental setup of rotary ultrasonic machine. Total nine experiments with three repitions were performed to study the effect of input on output parameters. For determining the experimental results experiments has been designed by Taguchi Method. In this all the three input parameters are varied accordingly and their effect on the output parameters have been noted. Nine experiments have been performed with varying values of input parameters.

A. *Calculation Of Feed Rate*

The feed rate is calculated as:
N - Number of revolutions of the lead screw in one machining operation
P - Pith of the lead screw
TFR - Tool feed rate
TFR = (N*P) / Machining time

B. *Calculation Of Material Removal Rate*

MRR = (Initial Weight - Final Weight) / Machining Time

After performing each experiment, the material removal rate is calculated by the difference between the initial weight of glass and the weight of glass after performing the experiment. The machining time and the feed rate is also noted for each experiment.

Table.3. Shows experimental results

S.No.	Parameters			MRR (g/min.)
	TFR	F	G	
1	0.27	15.5	200	0.0104
2	0.27	21.5	250	0.0115
3	0.27	27.5	300	0.0133
4	0.29	15.5	250	0.0125
5	0.29	21.5	300	0.0127
6	0.29	27.5	200	0.0147
7	0.31	15.5	300	0.0133
8	0.31	21.5	200	0.0127
9	0.31	27.5	250	0.0134

V. RESULTS AND DISCUSSION

A. Effect of Input Parameters on MRR

The value of MRR increase with the increase in tool feed rate because due to less gap between the tool and workpiece the hammering action increases and hence the material removal rate increases. Vibration frequency affects the MRR significantly. The increase in Vibration frequency, increases the MRR. The size of abrasive particle is affected MRR by first decreasing and then in decreasing order.

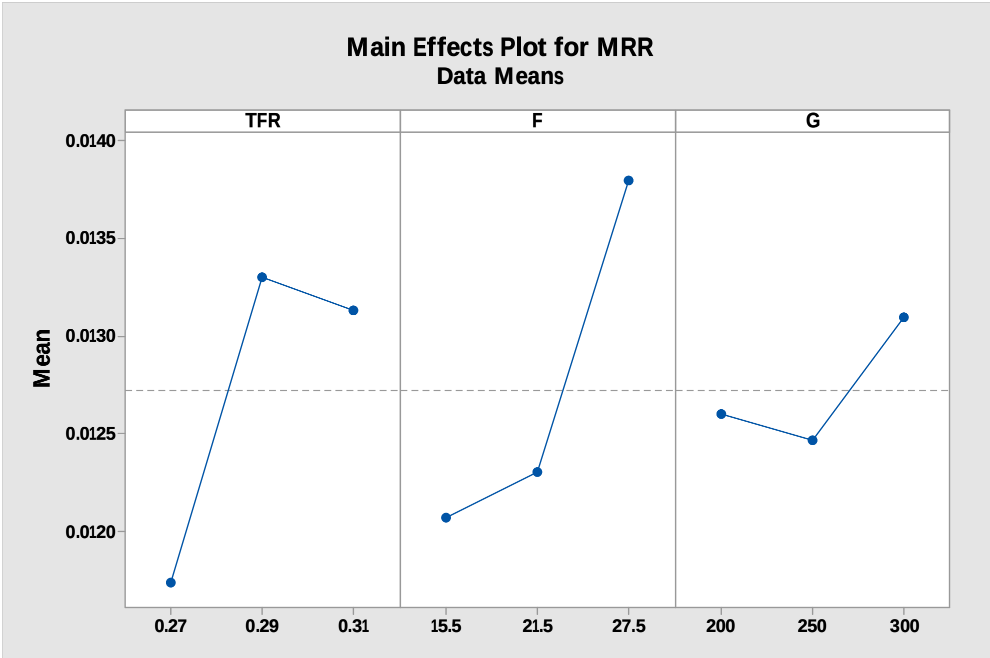

Fig.4: Shows main effect plot

VI. CONCLUSIONS

The major objective of the research is to find the effect of input parameters on output responses like material removal rate (MRR), in rotary ultrasonic drilling process. The conclusions based on the experimental results are summarized as follows:

A. MRR is increasing with tool feed rate and then decreases.
B. MRR is increased with increase in vibration frequency.
C. The size of abrasive particle is affected MRR by first decreasing and then in decreasing order.

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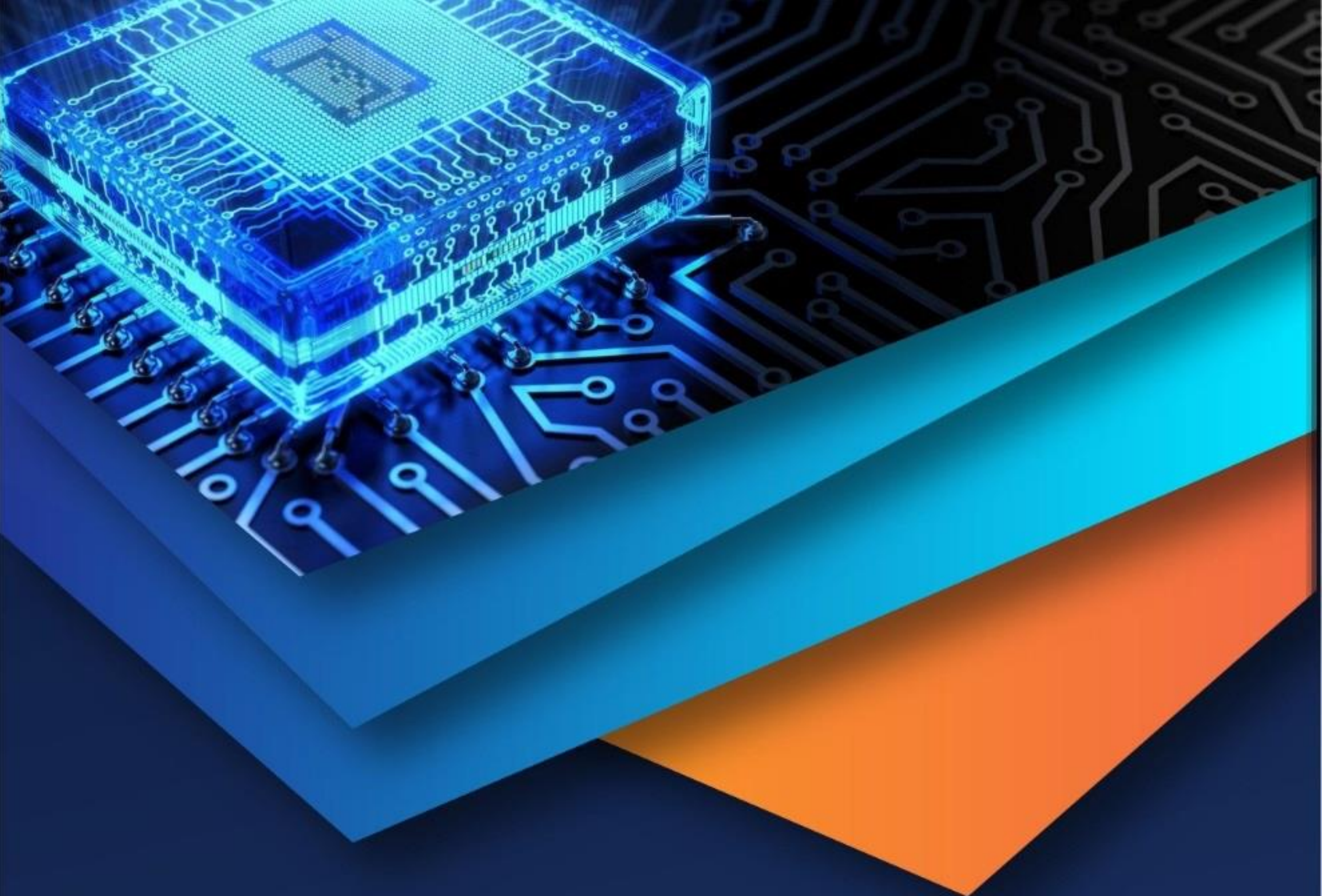

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