International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

# EXPERIMENTAL INVESTIGATION OF VARIOUS PARAMETERS OF ROTARY TYPE ULTRASONIC MACHINING

**Srinivas S. Kasaraneni [1], Dr. A.B. Borade [2]**

[1] *Acharya Shrimannayaran Polytechnic, Wardha: 442001*
[2]*Jawaharlal Darda Institute of Engineering & Technology Yeotmal*

---***---

**Abstract -** *Rotary type ultrasonic machining processes is advancement of ultrasonic machining process in which rotational motion is provided to tool along with ultrasonic vibration and tool feed. Rotating tool is fed into workpiece with ultrasonic frequency of vibration. In this paper, mathematical model is formed between various process parameters of rotary type ultrasonic machining and surface roughness and material removal rate.*

***Key Words***: rotary ultrasonic machining, material removal rate, surface roughness

## 1. INTRODUCTION

Non-traditional machining is a type of machining process that is used to remove excess material by using various types of energy i.e. mechanical, thermal, electrical, or chemical energy (or combinations of these energies). Ultrasonic machining is a non-traditional machining process. It is grouped under mechanical group of non-traditional machining process. It is based on impact erosion. Ultrasonic machining process is an abrasive process and material removal is purely mechanical. Rotary type ultrasonic machining is one of the cost-effective machining processes available for drilling holes in advanced ceramics. Rotary type ultrasonic machining is a hybrid machining process that combines the material removal mechanisms of diamond grinding and ultrasonic machining, resulting in higher material removal rate (MRR) than that obtained by either diamond grinding or Ultrasonic machining. Rotary type ultrasonic machining also gives superior surface finish, improves hole accuracy, capability to drill deep holes and low tool pressure. Silicon carbide which is having wide applications in the field of abrasive and cutting tools, automobile parts, foundry crucibles, electric systems, power electronic devices is used for experimentation.

## 2. DESIGN OF EXPERIMENTATION

The process parameters selected to examine rotary type ultrasonic machining are surface roughness and material removal rate. Hence it is important to involve various parameters which influence rotary type ultrasonic machining. Following are various input and output parameters which are considered for experimentation.

**Table -1:** List of Variable

| *Name of parameter* | *Symbol* | *Nature* |
|---|---|---|
| Frequency of vibration | F | Input & varying |
| Amplitude of vibration | A | Input & varying |
| Tool speed | N | Input & varying |
| Tool feed | f | Input & varying |
| Abrasive grit size | G | Input & varying |
| Diameter of tool | D | Input & constant |
| Density of workpiece | ρ | Input & constant |
| Coolant flow | C | Input & constant |
| Surface roughness | Ra | Response |
| Material removal rate | MRR | Response |

Plan of experimentation is the combination of various input parameters for which output parameters will be measured. Proper plan of experimentation is required because all aspect of the rotary type ultrasonic machining process needs to be covered. Hence full factorial method with three level and five input parameter is considered for experimentation. Hence for three level and five variables total 243 readings are obtained according to factorial plan. Following is the level of each parameter obtained after pilot experimentation.

**Table -2:** Level of Variables

| Level | F | A | N | f | G |
|---|---|---|---|---|---|
| Lower | 20 | 10 | 1000 | 0.5 | 50 |
| Middle | 30 | 30 | 1500 | 1.5 | 100 |
| Higher | 40 | 50 | 2000 | 2.5 | 150 |

## 3. MODEL FORMULATION

Mathematical model is a description of a system using mathematical concepts. The process of developing a mathematical model is termed mathematical modelling. A model may help to explain a system and to study the effects of different components, and to make predictions about behavior of system components under various working conditions. To maintain the dimensional homogeneity, Buckingham's Pi theorem is used. Hence according to Buckingham's Pi theorem, following pi terms are formed.

$$\pi_1 = f \times \frac{D^3}{C} \qquad \pi_2 = \frac{a}{D} \qquad \pi_3 = N \times \frac{D^3}{C}$$

$$\pi_4 = F \times \frac{D^2}{C} \qquad \pi_5 = \frac{G}{D}$$

$$\pi_{01} = \frac{R_a}{D} \qquad \pi_{02} = MRR\ \frac{1}{\rho \times C}$$

These five independent pi terms and two dependent pi terms will be used to form mathematical model. Each dependent pi term will is assumed to be the function of all independent pi terms.

$$\pi_{01} = f(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5)$$

$$\pi_{02} = f(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5)$$

Graphs obtained from pilot experimentation hints that dependent and independent parameters have exponential relationship. Hence

$$\pi_{01} = k_1 \times {\pi_1}^{a_1} \times {\pi_2}^{b_1} \times {\pi_3}^{c_1} \times {\pi_4}^{d_1} \times {\pi_5}^{e_1}$$

$$\pi_{02} = k_2 \times {\pi_1}^{a_2} \times {\pi_2}^{b_2} \times {\pi_3}^{c_2} \times {\pi_4}^{d_2} \times {\pi_5}^{e_2}$$

Now forming the mathematical model means to find the value of unknowns in the above equation.

Taking log of the both the sides of above equation gives

$$\log \pi_{01} = \log k_1 + \log {\pi_1}^{a_1} + \log {\pi_2}^{b_1} + \log {\pi_3}^{c_1} + \log {\pi_4}^{d_1} + \log {\pi_5}^{e_1}$$

$$\log \pi_{01} = \log k_1 + a_1 \log \pi_1 + b_1 \log \pi_2 + c_1 \log \pi_3 + d_1 \log \pi_4 + e_1 \log \pi_5$$

Above equation is valid for all the readings collected during experimentation. Hence putting summation on both the sides

$$\sum_{i=1}^{i=n} \log \pi_{01} = \sum_{i=1}^{i=n} (\log k_1 + a_1 \log \pi_{1_i} + b_1 \log \pi_{2_i} + c_1 \log \pi_{3_i} + d_1 \log \pi_{4_i} + e_1 \log \pi_{5_i})$$

Where n is number of readings

All these mathematical equations are solved in software package MATLAB and following result is obtained.

$$\pi_{01} = 5.28652 \times {\pi_1}^{0.0258} \times {\pi_2}^{1.7589} \times {\pi_3}^{-2.1369} \times {\pi_4}^{2.6987} \times {\pi_5}^{2.1580}$$

$$\pi_{02} = 1.69842 \times {\pi_1}^{1.2385} \times {\pi_2}^{2.2541} \times {\pi_3}^{1.1800} \times {\pi_4}^{1.3214} \times {\pi_5}^{2.8280}$$

All above equations are in form of dimensionless pi terms. It is required to express them in terms of variable for the purpose of analysis of the process

$$R_a = 5.28652 \times f^{0.0258} \times a^{1.7589} \times N^{-2.1369} \times F^{2.6987} \times G^{2.1580} \times C^{-0.5876} \times D^{-3.8528}$$

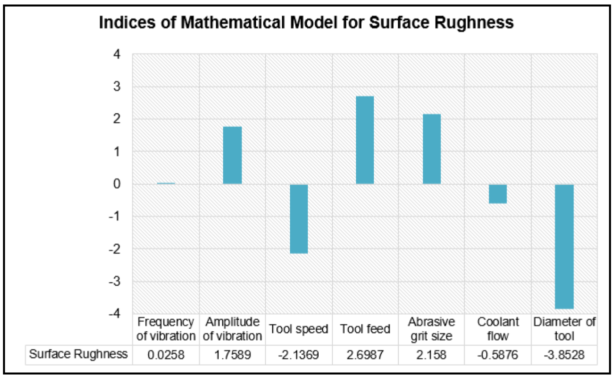
$$MRR = 1.69842 \times f^{1.2385} \times a^{2.2541} \times N^{1.1800} \times F^{1.3214} \times G^{2.8280} \times C^{-2.7399} \times D^{4.8162} \times \rho^{1}$$

## 4. RESULT & DISCUSSION

Mathematical model expresses relationship between input and output parameters. It is important to check the impact of each input parameter on each output parameter. Positive index shows direct relationship while negative index expresses inverse relationship.

Relationship between surface roughness and various input parameters is

$$R_a = 5.28652 \times f^{0.0258} \times a^{1.7589} \times N^{-2.1369} \times F^{2.6987} \times G^{2.1580} \times C^{-0.5876} \times D^{-3.8528}$$




**Graph 1:** Effect of input parameters on surface roughness

In case of surface roughness; frequency of vibration, amplitude of vibration, tool feed, and abrasive grit size have positive impact on surface roughness. While Tool speed, coolant flow rate and Diameter of tool are inversely proportional to surface roughness.

It means when frequency of vibration, amplitude of vibration, tool feed, abrasive grit size increases, surface roughness increases i.e. poor surface finish is obtained. And when Tool speed, coolant flow rate and Diameter of tool decreases, superior surface finish is obtained. Indices of the mathematical model show that surface roughness is highly influenced by Tool diameter, abrasive grit size and tool feed.

Diameter of tool directly comes in contact with the workpiece and hence as the tool diameter changes actual area of contact between tool and workpiece changes. Increase in area divides the total force applied by the tool which ultimately results in less material removal and hence surface roughness decreases which improves surface finish.

In case of abrasive grit size, increase in grit size results in increase in roughness because abrasive grit having higher dimension penetrates more in the workpiece which increases the size of crest and valley on the workpiece. As the tool feed increases, interaction time between tool and workpiece decreases which results in reduction in time taken by the tool to remove the material. Hence surface roughness increases i.e. surface finish decreases.

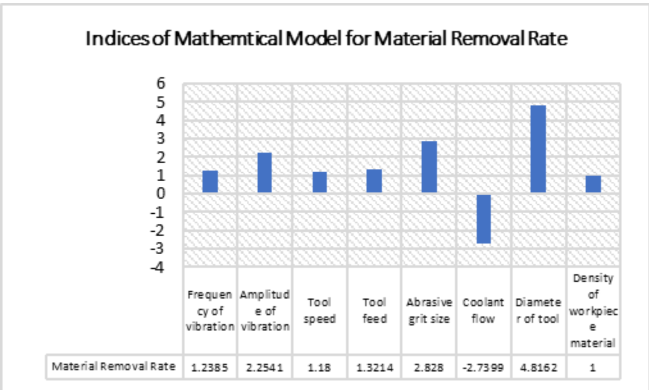
As the tool speed increases, surface roughness decreases because more tool speed confirms more interaction of tool and workpiece which allows increases in surface finish. It is observed in case of amplitude of vibration that increase in amplitude of vibration increases surface roughness because more amplitude of vibration means more penetration of tool in workpiece and hence surface roughness increases. Coolant flow rate affects surface roughness inversely. Increase in coolant flow rate lowers the temperature of workzone which results in improvement of surface finish.

Relationship between material removal rate and various input parameters is

$$MRR = 1.69842 \times f^{1.2385} \times a^{2.2541} \times N^{1.1800} \times F^{1.3214} \times G^{2.8280} \times C^{-2.7399} \times D^{4.8162} \times \rho^{1}$$

In case of material removal rate; frequency of vibration, amplitude of vibration, tool speed, tool feed, abrasive grit size, diameter of tool and density of workpiece have positive impact on material removal rate.

It means that, as frequency of vibration, amplitude of vibration, tool speed, tool feed, abrasive grit size, diameter of tool and density of workpiece increases, material removal rate increases and as coolant flow rate decreases material removal rate decreases. From indices of mathematical model it is observed that, material removal rate is highly influenced by, diameter of tool, coolant flow, frequency of vibration and tool speed.




**Graph 2:** Effect of input parameters on material removal rate

As the diameter of tool increases, area of contact between tool and workpiece increases and hence material removal rate increases. As frequency of vibration increases to and fro movement per unit time of tool also increases and hence more and more material removal takes place. More tool speed confirms more interaction of tool and workpiece which allows more removal of material from workpiece and hence increase in material removal rate.

In case of coolant flow rate, as coolant flow rate increases material removal rate decreases. This happens because coolant flow lowers temperature of machining zone. Rise in temperature increases material removal rate and hence as coolant flow rate increases, material removal rate decreases.

## 5. CONCLUSION

1. It is concluded that when frequency of vibration, amplitude of vibration, tool feed, abrasive grit size increases; surface roughness increases i.e. poor surface finish is obtained. And when Tool speed, coolant flow rate and Diameter of tool decreases, superior surface finish is obtained.
2. A predictive mathematical model is developed for estimating the surface roughness. The experimental and theoretical results seemed to correlate fairly well.
3. It is observed that the mathematical model follows the physical phenomena of rotary type ultrasonic machining process accurately. Hence it is concluded that the proposed models help the simulation of the rotary type ultrasonic machining in real life scenario.
4. It is concluded that as frequency of vibration, amplitude of vibration, tool speed, tool feed, abrasive grit size, diameter of tool and density of workpiece increases, material removal rate increases and as coolant flow rate decreases material removal rate decreases.
5. A predictive mathematical model is developed for estimating the material removal rate. The experimental and theoretical results seemed to correlate fairly well.
6. It is observed that the mathematical model follows the physical phenomena of rotary type ultrasonic machining process accurately. Hence it is concluded that the proposed models help the simulation of the rotary type ultrasonic machining in real life scenario.

## 6. REFERENCES

[1] Z. Yu, X. Hu and K. P. Rajurkar, "Influence of Debris Accumulation on Material Removal and Surface Roughness in Micro Ultrasonic Machining of Silicon," CIRP Annals- Manufacturing Technology, vol. 55, no. 1, pp. 201-204, 2006.

[2] E. Kai, T. Tomoya, T. Hachiro and M. Makoto, "Microultrasonic Machining Using Multitools," in Proceedings of The 7th International Conference on Progress of Machining Technology, Japan, 2004.

[3] Z. Yu, C. Ma, J. Li and D. Guo, " Prediction of tool wear in micro USM," CIRP Annals - Manufacturing Technology, vol. 61, no. 1, p. 227–230, 2012.

[4] W. M. Zeng, Z. C. Li, Z. J. Pei and C. Treadwell, "Experimental observation of tool wear in rotary ultrasonic machining of advanced ceramics," International Journal of Machine Tools & Manufacture, vol. 45, no. 12-13, p. 1468–1473, 2005.

[5] H. Zarepour and S. H. Yeo, "Predictive modeling of material removal modes in micro ultrasonic machining," International Journal of Machine Tools & Manufacture, vol. 62, p. 13–23, 2012.

[6] H. Zarepour, S. H. Yeo, P. C. Tan and E. Aligiri, "A new approach for force measurement and workpiece clamping in micro-ultrasonic machining," International Journal of Advanced Manufacturing Technology, vol. 53, no. 5-8, p. 517–522, 2011.

[7] Z. C. Li, L. W. Cai, Z. J. Pei and C. Treadwell, "Edge-chipping reduction in rotary ultrasonic machining of ceramics:Finite element analysis and experimental verification," International Journal of Machine Tools & Manufacture, vol. 46, no. 12-13, pp. 1469-1477, 2006.

[8] X. H. Shen, J. H. Zhang, H. Li, J. J. Wang and X. C. Wang, "Ultrasonic vibration-assisted milling of aluminum alloy," The International Journal of Advanced Manufacturing Technology, vol. 63, no. 1-4, pp. 43-49, 2012.

[9] Y. Peng, Z. Liang, Y. Wu, Y. Guo and C. Wang, "Characteristics of chip generation by vertical elliptic ultrasonic vibration-assisted grinding of Page | 118 brittle materials," The International Journal of Advanced Manufacturing Technology, vol. 62, no. 5-8, pp. 563-568, 2012.

[10] D. Liu, W. L. Cong, Z. J. Pei and Y. Tang, "A cutting force model for rotary ultrasonic machining of brittle materials," International Journal of Machine Tools & Manufacture, vol. 52, no. 1, pp. 77-84, 2012.

[11] J. C. Aurich, I. G. Reichenbach and G. M. Schuler, "Manufacture and application of ultra-small micro end mills," CIRP Annals - Manufacturing Technology, vol. 61, no. 1, pp. 83-86, 2012.

[12] J. Guo, S. Y. Morita, M. Hara, Y. Yamagata and T. Higuchi, "Ultraprecision finishing of micro-aspheric mold using a magnetostrictive vibrating polisher," CIRP Annals - Manufacturing Technology, vol. 61, no. 1, pp. 371-374, 2012.