

Experimental Study of Process Parameters On Material Removal Mechanism in Hybrid Abrasive Flow Machining Process (AFM)



Engineering

KEYWORDS : Abrasive flow machining, Centrifugal force, Material removal, taguchi method

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ABSTRACT

Abrasive flow machining (AFM) is a non-traditional machining process for the production of high quality surface of inner profiles that are difficult to access & is used to deburr, remove recast layer & radius surfaces.

In this process material was removed by a grinding medium. The grinding medium consists of a semi-solid fluid made up of polymer, gel and abrasives and Non Newtonian polymer. In this investigation the key parameters abrasive mesh size, abrasive concentration, rotational speed of tooling rod and diameter of rod were varied to see their effects on material removal. Hybrid machining process has been developed to enhance the rate of material removal. In this process, centrifugal force has been provided to grinding media by rotating tool rod inside the workpiece causes effective MR. For this a set up has been developed. For experimental design L9 orthogonal array based on taguchi method was used.

1 INTRODUCTION

The performance of any machining process is measured in terms of material removal & surface quality produced. Conventional process such as grinding, honing, lapping, buffing & super finishing have been in used in many years for material removal and finishing. However the uses of all these processes are limited to a restricted shape & geometry of work piece. Abrasive flow machining (AFM) is a widely used non-conventional machining process to achieve high material removal & good surface quality (13). The ability of abrasive media used in AFM to reach inaccessible areas to finish inner surfaces makes this more effective than other advanced machining processes. This process has found application in many areas like aerospace, automobile, medical instruments, finishing of industrial valves, mould and die making and semiconductor equipments etc. The AFM used setup carried two vertically opposite cylinders & in between these cylinders a fixture is placed. The abrasive media moves back and forth through the restricted passage in the fixture. The abrasive particles in the media consist of cutting edge with different orientations, which helps in material removal. Different types of abrasive grains like silicon carbide, aluminum oxide, boron carbide and diamond powder are used. To increase the interaction between abrasive and work piece, a mechanism was provided by attaching a D.C geared motor which provides rotational motion to the tooling rod inside the work piece (11). When the media was extruded, this media was acted upon a centrifugal force which throws the abrasive particles on inner surfaces of work piece with high velocity & more material removes from the work piece (12). The dominant process parameter is found to be abrasive concentration followed by rotational speed of rod, abrasive grit size and diameter of tool rod.

2. LITERATURE SURVEY

A number of cycles are required to achieve the material removal. It has been reported in a number of studies Jain et al.(1999); Shan H.S. et al.(1997); William R.E and Rajurkar (1992); Przyklenk(1986) that abrasion was more pronounced in some initial cycles. A linear dependence between material removal and surface roughness versus number of cycles was indicated within 1 to 8 cycles (1-4). Williams and Rajurkar and Williams et. al. have investigated that viscosity of the media is one of the significant parameters of the AFM process. Keeping all other parameter constant, an increase in viscosity improves material removal rate (5-6). Siwert noted that abrasive particle to base material ratio (by weight) should vary from 4:1 to 1:4 with 1:1 as the most appropriate ratio. As the concentration of abrasive in the media increase, MR increases (7).

As the abrasive mesh size increases, the material removal value decreases (8). To increase the performance of AFM, magnetic field has been applied to the AFM process. The magnetic field increase the no. of active abrasive grits taking parts in abrasion (9-10). Taguchi methods used by many researchers for engineering analysis. This method employs design of orthogonal array to compute the effect of process parameters on material removal (11). Different shapes of CFG rods also used to see their effect on ΔRa . The speed of rotation of CFG rod has a major effect on material removal (12-13). It was noted that that very little research work was carried out for the basic mechanism of material deformation involved in the AFM process under widely varied machining conditions. It requires more research work towards hybrid machining process by considering the advantages of different machining process. This present paper was intended to cover this need in area of advanced machining process. Hence to study the effect of different process parameters on material removal of brass, a setup has been designed & experiments were carried out to test the significant effect.

3. EXPERIMENTAL SET-UP

Figure 1 shows the schematic diagram of hybrid abrasive flow machining process. The abrasive media consist of three parts: silicon based polymer, hydrocarbon gel, and abrasive particles and non Newtonian liquid polymer. All these constituents were mixed in equal proportion to form the medium. The abrasive used in this study was aluminum oxide (Al₂O₃). The fixture used in this research was made up of three parts as shown in fig 2. The CFG rod attached with gears puts up between two idle gears. This gear train was rotated by a mechanism provided by a dc geared motor, bevel gear and shaft. The rotational speed of CFG rod can be increase or decrease with the help of a controller. The cylindrical workpiece and the CFG rod puts up in between these parts. The media was extruded from one cylinder to other cylinder through restricted passage provided by fixture and CFG rod. The process was made hybrid by providing a mechanism for produce centrifugal force (12). The cylindrical work piece as shown in fig 3 was fitted between this CFG rod. This $\varnothing 12 \times 16$ -mm long cylindrical workpiece initially drilled followed by boring to 8.00 ± 0.05 mm as shown in fig 3. Initially the weight of workpiece was measured & after experiment final weight was measured. Before any measurement the workpiece was cleaned by acetone properly. The difference was calculated and analyzed. For experimental design L₉ (3⁴) orthogonal array based on taguchi method was adopted & total 27 experiments are carried out.



Figure 1 Hybrid AFM Set-up



Figure 2 CFAAFM fixture parts

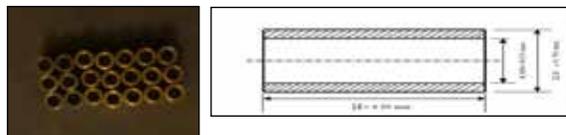


Figure 3 Workpiece Geometry

4. EXPERIMENTATION-WORK

For experimental analysis, L9 (3*4) orthogonal array based on Taguchi methodology was adopted. Each parameter was studied at three levels. As MR is higher the better type quality characteristics. So S/N ratio was calculated for this type as:

$$\left(\frac{S}{N}\right)_{HB} = -10 \log (MSD_{HB})$$

Where $MSD_{HB} = \frac{1}{R} \sum_{j=1}^R (1/y_j^2)$

R = Number of repetitions, y = response value Analysis of variance (ANOVA), F-Test is performed. These test values indicated the significant AFM parameters which affect MR.

4.1 PROCESS PARAMETERS:

The selected process parameters & their range is specified in table 1 & other constant parameters are shown in table 2.

Symbol	Parameter	Unit	Level1	Level2	Level3
G	Abrasive Grit size	No. (micron)	60(250)	100(150)	200(75)
C	Abrasive to media ratio	% by wt.	1:1	1.15:1	1.3:1
R	Rotational speed of CFG rod	RPM	0	40	80
D	Diameter of CFG rod	mm	3.2	4.2	5.2

Table 1 . Process parameters value at different level

Sr.no.	Process Parameters	Range	Unit
1	No. of cycle	6	No.
2	Extrusion pressure	4	N/mm2
3	Shape of CFG rod	Triangular 3.2-5.2	-----
4	Initial surface Ra	1.8-2.3	µm
5	Media flow volume	290	cm³
6	Fixture material	Teflon	-----
7	Polymer-Gel ratio	1:1	% by weight
8	Temp. of media	32 ± 2	°C
9	Reduction Ratio	0.95	-----
10	Work piece Material	Brass	-----

Table 2. Constant process parameters and their value

4.2 EXPERIMENTAL DESIGN The scheme of experiments for the setting of various parameters is as given in the Table3. R1, R2, R3 represents response value for three repetitions of each trial.

Sr no.	G	C	R	D	R1	R2	R3	S/N ratio
1	60	1	0	3.2	2.12	1.8	2.09	5.96
2	60	1.15	40	4.2	3.32	3.41	3.82	10.88
3	60	1.30	80	5.2	6.01	5.82	5.31	15.10
4	100	1	40	5.2	2.48	2.43	2.41	7.75
5	100	1.15	80	3.2	3.5	3.72	3.82	11.30
6	100	1.30	0	4.2	3.21	3.09	3.22	10.03
7	200	1	80	4.2	2.01	2.5	2.31	7.03
8	200	1.15	0	5.2	1.95	1.99	1.89	5.77
9	200	1.30	40	3.2	2.82	2.95	3.02	9.33

TABLE 3: Orthogonal array L9 With experimental results of various Response characteristics

The Material removal for s/n ratio & average value of raw data at three levels L1, L2, L3 for each parameter shown in table 4.

LEVEL	G		C		R		D	
	S/N data	Raw data						
L1	10.65	3.74	6.91	2.24	7.25	2.37	8.86	2.87
L2	9.69	3.10	9.31	3.05	9.32	2.96	9.31	2.99
L3	7.37	2.38	11.48	3.94	11.14	3.89	9.54	3.37
L2-L1	-0.96	-.65	2.40	0.81	2.06	0.59	0.45	0.12
L3-L2	-2.32	-.72	2.17	0.89	1.83	0.93	0.23	0.38
DIFF.	1.36	-.07	-.23	0.08	-.24	0.34	-0.22	0.26

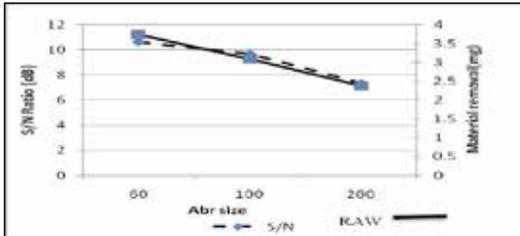
TABLE 4. Main Effect (S/n & Raw data)

Where L1,L2 and L3 denotes the value of S/n & raw data at levels 1,2 & 3 of parameters.L2-L1 is the main effect when the corresponding parameter changes from level 1 to level 2. L3-L2 is the main effect when the corresponding parameter changes from level 2 to level 3.

4.3 DISCUSSION

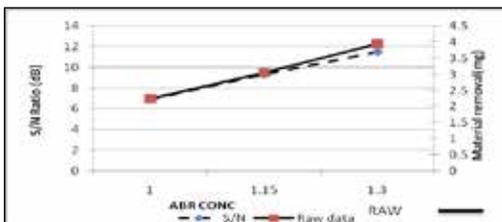
4.3.1 ABRASIVE MESH SIZE

From the fig (a) it was deduced that as the mesh size increases, material removal decreases. Because as mesh size increases, size of particle decreases which equals finer materials and more no. of finer grains removes lesser material. Because with increase in mesh size (decrease in grain size) the depth of penetration as well as width of penetration decrease. Hence removes less material.



a) Effect of abrasive size on S/N data & RAW data
4.3.2 ABRASIVE TO MEDIA RATIO

As the concentration of abrasive particles in the media increases, viscosity of media increases. Now more no. of grains available for machining. Only these grains are responsible for material removal. When more no. of grains comes in contact with workpiece, results in more MR.

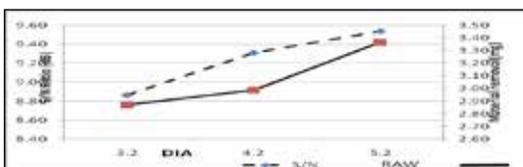


(b) Effect of abrasive conc. on S/N data & RAW data
4.3.3 RPM

As the RPM of CFG rod was given, the MR increase because when there was no movement of rod, the abrasive particles move only due to extrusion pressure. But when RPM was given, the rod rotates. It produces a centrifugal force on abrasive in all directions which enhance the workpiece & abrasive interactions & MR increases. As the speed of CFG rod increases, the velocity of abrasive particles increases. Then they strike on the workpiece surface with higher force & as a result more amount of material removal takes place.

(c) Effect of rotational speed on S/N data & RAW data
4.3.4 DIAMETER OF ROD

As the diameter of CFG rod increases, the gap between the workpiece and rod decreases. Then cross-sectional area through which medium was flowing decreases & resistance to flow of medium increases. It enhances the magnitude of normal force acting on abrasive, which results in high depth of indentation. Hence more MR occurs



(d) Effect of diameter of rod on S/N data & RAW data.

5. ANALYSIS

To study the significance of the parameters, ANOVA was performed. It was noted that % contribution of Abrasive to media ratio was highest (38.55) followed by RPM (31.12), abrasive

mesh size (24.75) & dia of CFG rod (3.56). Also it was noted that MR for raw data was highest at third level of abrasive concentration (C3), first level of abrasive size (G1), third level of RPM (R3) & third level of dia of CFG rod (D3).

Table 5 Pooled Anova (RAW data)

Source	SS	df	V	F ratio	P%
Abr size	8.36	2	4.8	110.45*	24.75
Abr conc.	13.02	2	6.51	172.01*	38.55
RPM	10.51	2	5.25	138.86*	31.12
Rod Dia	1.20	2	0.6	15.89*	3.56
Error	0.68	18	0.4		2.02
Total	33.76	26			100

SS- Sum of square, df-degree of freedom, V-variance, SS'- pure sum of square. *Significant at 95% confidence level, Fcritical = 3.4928.

5.1 CALCULATION OF OPTIMUM RESPONSE CHARACTERISTICS:

The mean at the optimal MR was calculated as: $MR = G^*1 + C^*3 + R^*3 + D^*3 - 2T^*$

T* = Overall mean of MR for raw data = 3.08 mg
G* = Mean value at 1st level of Abrasive size = 3.74 mg
C* = Mean value at 3rd level of Abrasive conc. = 3.94 mg
R* = Mean value at 3rd level of RPM = 3.89 mg
D* = Mean value at 3rd level of diameter = 3.37 mg

After calculation, we get MR = 8.78 mg

The confidence interval of confirmation experiments (CI_{CE}) and of population (CI_{POP}) was calculated by using the following equations

$$CI_{CE} = \sqrt{F_{\alpha}(1, f_c) V_e \left[\frac{1}{n_{eff}} + \frac{1}{R} \right]} \quad CI_{POP} = \sqrt{\frac{F_{\alpha}(1, f_c) V_e}{n_{eff}}}$$

F_α(1, f_c) = The F-ratio at the confidence level of (1-α) against DOF 1 and error degree of freedom f_c = 4.414 (Tabulated F value)
N = Total number of result = 27

V_e = Error variance = 0.4 (Table 5)

R = Sample size for confirmation experiments = 3

f_c = error DOF = 18 (Table 5)

$$n_{eff} = \frac{N}{1 + [\text{DOF associated in the estimate of mean response}]}$$

n_{eff} = 3

So, CI_{CE} = ± 1.085

And CI_{POP} = ± 0.767

The 95% confirmation interval of predicted optimal range (for confirmation run of three experiments) is:

$$7.70 < MR > 9.87$$

The 95% confirmation interval of the predicted mean is:

$$8.01 < MR > 9.55$$

5.1 CONFIRMATION EXPERIMENTS

In order to confirm the results obtained, confirmation experiments have been conducted for response characteristic of MR. For the maximum MR, the optimal levels of the process parameters are G₁C₃R₃D₃. It was noted that overall mean of observed value lies within 95% of CI_{CE} of optimal range.

5.2 CONCLUSION

The following conclusion can be notice from the results:

- a. The abrasive concentration has highest contribution (38.49%) towards MR.
- b. The contribution of speed of CFG rod is 31.12%. As speed increases, MR increases.
- c. Abrasive size has (24.75%) contribution for improvement rate of MR.
- d. Dia of CFG rod is also significant and shows (3.56 %) contribution MR.

REFERENCE

- [1] Jain R.K., Jain V.K. and Dixit P.M. "Modelling of material removal and surface roughness in abrasive flow machining process", Int. J. of Machine Tool and Manufacture (1999), Vol. 39, pp. 1903-1923 | [2] Shan H.S., and Dubey A.K. "Micro machining by flow of abrasives", Proceedings 17th AIMTDR Conference, Warangal, India (1997), pp. 269-275 | [3] William R.E., and Rajurkar K.P."Stochastic modelling and analysis of abrasive flow machining", Trans. ASME, J Engg. For Ind. (1992), Vol. 114, pp. 74-81 | [4] Przyklenk K. "Abrasive flow machining- A process for surface finishing and deburring of work pieces with a complicated shape by means of abrasive laden media", Advances in Non-Traditional Machining, PED, ASME (1986), Vol. 22 , pp. 101-110 | [5] William R.E., and Rajurkar K.P, Rhoades L.J. "Performance Characteristics of abrasive flow machining", SME Technical paper No. FC 89-806 (1989). | [6] Williams R.E., and Rajurkar K.P. "Stochastic modelling and analysis of abrasive flow machining" Trans. ASME, J. Engg. For Ind. (1992), Vol. 114, pp. 74-81 | [7] Siwert D.E. "Tooling for the extrude hone process", Proc. SME International Engineering Conference (1974), pp. 302-305. | [8] V.K.Jain, S.G Adsul, Experimental investigation intoabrasive flow machining.International journal of machine tools & manufactures40 (2000), 1003-1021. | [9] Sehjapal Singh, H S Shan, Wear behaviours of materials in magnetically assisted AFM. Journals of materials processing technology 128(2002) 155-161. | [10] Singh S, Shan H S, Development of magneto abrasive flow machining process. Int J machine tools manuf. 42 (2002) 953-959. | [11] Brar B.S,Walia R S, Singh V.P. National conference on advancements and futuristic trends in mechanical & materials engineering, (2011) ,7-8. | [12] Ramandeep Singh,R. S Walia, Study the effect of centrifugal force on abrasive flow machining process. International journal of research in mechanica engineering & technology vol 2,issue April 2012. | [13] Walia R S , Shan H S ,Kumar P, Abrasive flow machining with additionally centrifugal force applied to media.Mini Science technology 10(2006) :341-354 |