

Research Article

Experimental Investigation of Machining Parameters for AFM using Round Shaped of AISI D2

Sandeep Chouhan^{Å*} and Sushil Mittal^Å^Å Mechanical Engg. Deptt. HCTM Kaithal, India

Accepted 07 June 2014, Available online 20 June 2014, Vol.4, No.3 (June 2014)

Abstract

The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and particularly in processes related to Abrasive Flow Machining (AFM). D2 steel (Tool steel) is one of the most widely used materials due to its unique high strength that is maintained at the elevated temperature and its exceptional wear resistance. D2 steel possessing high strength and toughness is usually known to create major challenges during its machining. The study was aimed to investigate the machining characteristics of D2 steel under different process conditions. Parts of the experiment were conducted with the L9 orthogonal array based on the Taguchi method. The results showed that the response variables were strongly influenced by the control factors (input parameters).

Keywords: Abrasive Flow Machining (AFM), Material removal rate, Surface roughness, Optimization, Taguchi Method

1. Introduction

Abrasive flow machining (AFM) is a purely mechanical process. A chemically inactive and non-corrosive media, similar to a soft clay, is used to improve surface finish and edge conditions. AFM process consist of two cylinder stocks, one from the lower cylinder pumping an abrasive laden medium throughout and one from the upper cylinder makes up one process (figure 1.1). The polymer abrasive medium which is used in this process possesses trouble-free flow ability, better nature deformability and excellent abrading capacity. This media is also known as an abrasive laden medium, not-so-silly putty (Rhoades L.J. *et al*, 1987), or a liquid file (Jain V.K. *et al*, 2002) reported that initial surface roughness and hardness of the workpiece affects material removal during AFM process.

It has been reported in a number of studies that abrasion is more pronounced in some initial cycles after which improvement in the surface finish stabilize or reduce in some cases (Jain R.K. *et al*, 1999; Shan H.S. *et al*, 1997). (W.B. Perry *et al*, 1989) reported that abrasion is high where medium velocity is high. (Siwert D.E. *et al*, 1974), suggested 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. (Davies P.J. *et al*, 1995) reported a relationship between the number of cycles, temperature and pressure drop across the die for the given type of polymer and abrasive concentration. The basic mechanism of abrasion has been the subject of many investigators. (M.M. Khrushchov *et al*, 1960; D. Graham *et*

al, 1972). M.C. Shaw *et al*, 1971) proposed a theory of microchip formation for fine finish grinding assuming spherical abrasive grain. An increase in pressure and medium viscosity increases material removal rate while surface finish value (Ra) decreases R.E. Wiliams *et al*, 1989; T.R. Loveless *et al*, 1994).

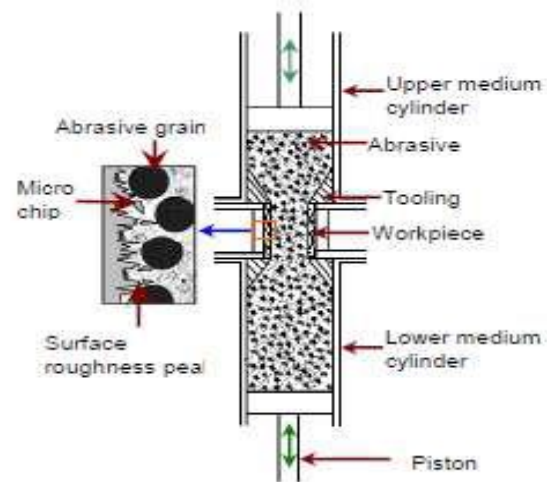


Figure 1.1 Schematic diagram of two-way AFM process (Rajendra K. Jain *et al*, 2001)

2. Experimental Design

2.1. Experimental Materials

In the present investigation, Die steel D2 (carbon: 1.5%, Cr 12%, Si 0.3%, Mn 0.3%) as work-piece material. The internal cavity to be machined in the test specimen was

*Corresponding author **Sandeep Chouhan** is a Research Scholar and **Sushil Mittal** is working as Asst. Prof.

Table 3.1 Workpiece material AISI D2 steel

S.No	No. of cycles	Mesh no.	Concentration	Specimen Weight in Grams (Before Exp.)	Specimen Weight in Grams (After Exp.)	Time Taken In Sec	MRR % Grams/sec	Change in Surface roughness (µm)	SNRAI (db)
1	50	100	40	20.348	20.343	0.15	3.33	3.37	10.1568
2	50	150	50	20.987	20.984	0.13	2.3	3.4	7.5816
3	50	200	60	20.568	20.564	0.14	2.85	3.39	8.8894
4	100	100	50	19.788	19.775	0.2	6.5	3.34	16.1275
5	100	150	60	20.84	20.826	0.22	6.36	3.35	15.9499
6	100	200	40	21.188	21.179	0.21	4.28	3.36	12.6889
7	150	100	60	20.283	20.256	0.28	9.64	3.33	19.1687
8	150	150	40	21.676	21.651	0.3	8.33	3.32	17.9332
9	150	200	50	20.771	20.745	0.32	8.12	3.35	17.7692

Table 3.2 ANOVA results for MRR of die steel D2 (raw data)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Contribution
No. of cycle	2	89.664	89.664	44.832	244.41	0.000	90.38
Mesh no	2	5.104	5.104	2.552	13.91	0.001	5.13
Concentration	2	2.531	2.531	1.266	6.90	0.011	2.54
Error	11	2.018	2.018	0.183			
Total	17	99.317					

S = 0.428282 R-Sq = 97.97% R-Sq(adj) = 96.86%

prepared by drilling operation followed by boring to the required size.

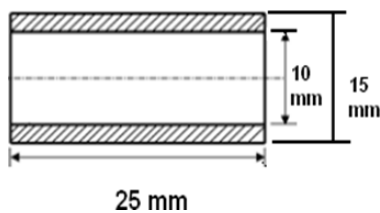


Figure.1.2 AISI D2 Steel **Figure.1.3** Dimensions of the workpiece

2.2. Procedure

In this investigation, a developed AFM setup has been used. This setup has been designed for the maximum extrusion pressure of 1000 N/mm². It employs two hydraulic actuators for the extrusion of media from one media cylinder to the other, through the work-piece during the forward stroke.

2.3 Process parameters

The machining parameters, such as Concentration (C), Mesh number (M) and Number of cycles (N) were varied to determine their effects on the machining characteristics material removal (MR) and %age improvement in surface finish. (Singh Mandeep et al, 2010). The experiments were

designed to study the effect of these on response characteristics of AFM process.

Response parameters

The average of R_a value was calculated and the percentage improvement in roughness was estimated as:

$$\Delta Ra = \frac{(\text{Initial roughness} - \text{Roughness after machining}) \times 100}{\text{Initial roughness}}$$

Material Removal in mg (MR): The material removal signifies the amount of material that has been removed from a specimen in a specified number of process cycles. It was estimated by calculating the difference between initial weight of the specimen and final weight of the specimen after processing at a specified set of conditions by AFM.

2.3.3. Experimental design based on Taguchi Method

A Taguchi design or an orthogonal array the method is designing the experimental procedure using different types of design like, two, three, four, five, and mixed level. In the study, a three factor mixed level setup is chosen with a total of eight numbers of experiments to be conducted and hence the OA L9 was chosen. This design would enable the two factor interactions to be evaluated. As a few more factors are to be added for further study with the same type of material, it was decided to utilize the L9 setup, which in

Table 3.3 ANOVA results for surface roughness of die steel D2 (raw data)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Contribution
No. of cycle	2	0.0070778	0.0070778	0.0035389	20.02	0.000	70.93
Mesh no	2	0.0007444	0.0007444	0.0003722	2.11	0.168	7.46
Concentration	2	0.0002111	0.0002111	0.0001056	0.60	0.567	2.11
Error	11	0.0019444	0.0019444	0.0001768			
Total	17	0.0099778					

S = 0.0132954 R-Sq = 80.51% R-Sq(adj) = 69.88%

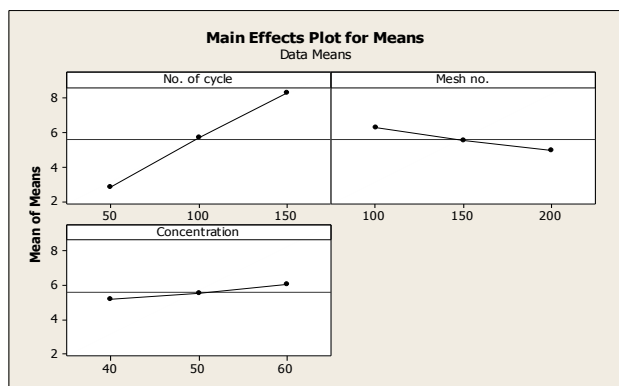
turn would reduce the number of experiments at the later stage. In addition, the comparison of the results would be simpler. The levels of experiment parameters are number of cycles, mesh number, concentration are shown in Table 3.1

3. Analysis and Discussions

3.1. Analysis by Taguchi Method

The experiments were planned by using the parametric approach of the Taguchi's Method. The response characteristic data is provided in Table 3.1 and 3.2. Both the response parameters viz. material removal and %age improvement in surface finish, are of higher the better type of machining quality characteristics, hence the S/N ratio for these types of responses is given below.

3.2. Experimentation



Optimal combination: $A_3B_1C_3$

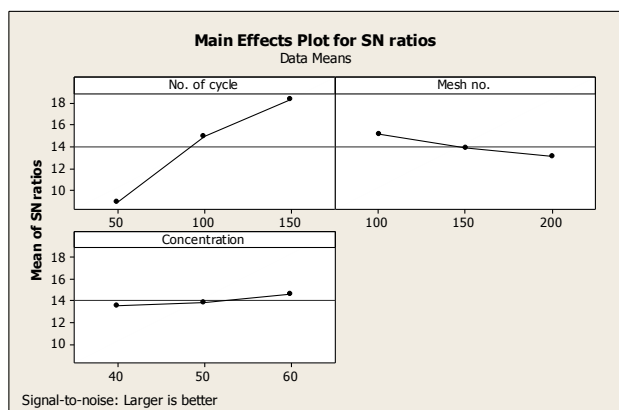
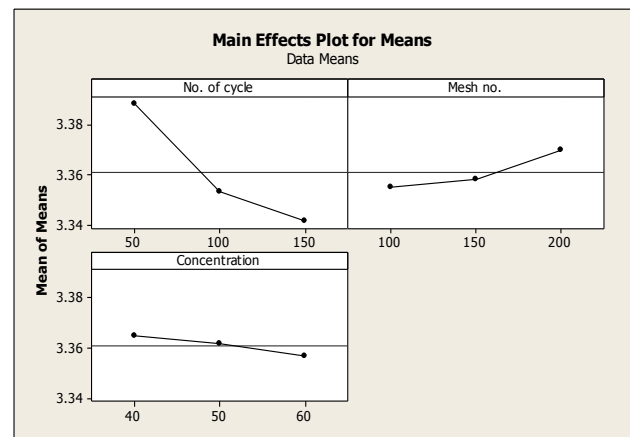


Figure 3.2 Effects of process parameters of D2 on MRR-raw data and S/N ratio



Optimal combination: $A_3B_1C_3$

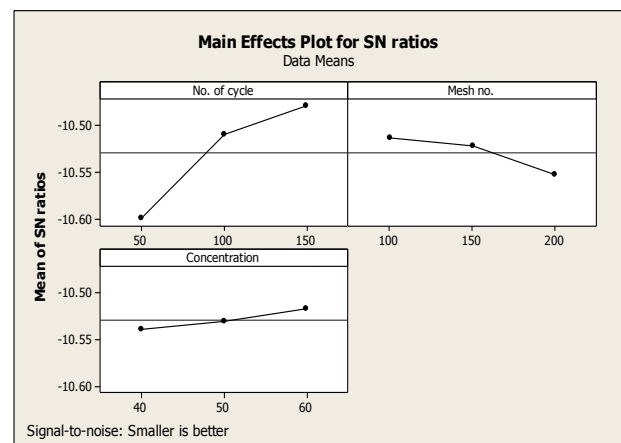


Figure 3.3 Effects of process parameters on surface roughness of D2 –raw data and S/N ratio

4. Prediction of the mean

The average value of performance characteristics obtained through the confirmation experiments must be within the 95% confidence interval ($\alpha = 0.05$), CI_{CE} (fixed number of confirmation experiments)

For material removal rate the overall population of the mean is $:\mu = 5.578$

Optimal combination for the material removal rate : $A_3B_1C_3$

For material removal rate (D2 die steel)

$$\mu_{MRR} = (\mu A_3 + \mu B_1 + \mu C_3) - (2\mu) = 103.634$$

Table 3.4 Prediction and experimental results

Response	Units	Predicted value	Experimental value	CI _{CE}
MRR(D2)	Gm/sec	103.634	90.10	102.75<103.634<104.513
Surface roughness(D2)	μm	27.02	25.12	26.99<27.02<27.047

For surface roughness the overall population of the mean is : $\mu = 3.36$

Similarly for surface roughness

$$\mu_{SR} = (\mu A_3 + \mu B_1 + \mu C_3) - (2\mu) = 27.02$$

For calculation of CI_{CE}, the following equation has been used:

$$CI_{CE} = \sqrt{Fa(1, fe)Ve\left\{\frac{1}{n_{eff}} + \frac{1}{R}\right\}}$$

Fa(1,fe) = the F-ratio at a confidence level of (1-a) against the DOF 1 and error degree of freedom fe (for MRR fe=44, so Fa=4.84)

V_e = error variance for material removal rate

V_e = 0.183 (from table)

$$N_{eff} = \frac{N}{1 + \text{Total DF involved in estimation of mean}}$$

N = Total number of experiments

$$N_{eff} = 18/1+6 = 18/7 = 2.5715$$

$$1/n_{eff} = 0.388$$

R = sample size for confirmatory experiments = 2

Hence putting all the values in equation (4.1)

$$CI_{CE(MRR)} = \pm 0.8796$$

The 95% confidence level for μ_{cs} is,

$$CI_{CE(MRR)} = 102.75 < 103.634 < 104.513$$

Similarly, for surface roughness (D2 die steel)

$$V_e = 0.0001768 \text{ (from table)}$$

$$N_{eff} = 18/1+6 = 18/7 = 2.5714$$

$$1/n_{eff} = 0.388$$

$$R = 2$$

$$Fa = 4.84$$

Putting the values in equation 4.1 yields;

$$CI_{CE(S,R)} = \pm 0.0275$$

The 95% confidence level for $\mu_{S,R}$ is,

$$CI_{CE(S,R)} = 26.99 < 27.02 < 27.047$$

The predicted optimum values and the confidence intervals have been tabulated in table.

Range of applicability

In the present study the input parameter setting in the die steel D2 steel on the abrasive flow machining such as number of cycles, mesh number, concentration have been optimized for two machining characteristics viz material removal rate (MRR) and surface roughness.

Conclusions

Based on the experiments following conclusions have been drawn:

1. In the case of Surface roughness the most important factor is number of cycle then mesh number and after that concentration.
2. Input parameters setting of number of cycle at 150 cycle, mesh number at 100, concentration 60% have given the optimum result for MRR, when D2 steel was machined with abrasive flow machine. The percent contribution of number of cycle is 90.38% and mesh number is 5.13%. the percent contribution of concentration is 2.54%.
3. Number of cycle used significantly affect surface roughness (R_a) in AISI D2 die steel on abrasive flow machine.
4. D2 steel exhibits good machine ability

References

- Rhoades L.J. (1987). Abrasive flow machining with not-so-silly putty, Met Finish, July 27–29.
- Jain V.K., Adsl S.G (2002), Experimental investigations into abrasive flow machining, International Journal of Machine tool and Manufacturer, 40, pp.1003-1021.
- Jain R.K., Jain V.K. and Dixit P.M. (1999), Modelling of material removal and surface roughness in abrasive flow machining process, Int. J. of Machine Tool and Manufacture Vol. 39, pp. 1903-1923.
- Shan H.S., and Dubey A.K. (1997), Micro machining by flow of abrasives, Proceedings 17th AIMTDR Conference, Warangal, India pp. 269-275.
- W.B. Perry (1989), Abrasive flow machining—Principles and Practices, in: Nontraditional Conference Proceedings, pp. 121–127
- Siwert D.E. (1974), Tooling for the extrude hone process, Proc. SME International Engineering Conference, pp. 302-305.
- Davies P.J., Fletcher A.J (1995), The assessment of the rheological characteristics of various polyborosilixane/grit mixtures as utilized in the abrasive flow machining, Proceedings of Instn. Mech. Engrs. 209, 409-418.
- M.M. Khrushchov, M.A. Bavichev, Research on wear of metals, Ch. 8, NEL Translation No. 893, National Engineering Laboratory, East Kilbride, 1960.
- D. Graham, R.M. Baul (1972), An investigation into the mode of material removal in the grinding process, Wear 301–314.
- M.C. Shaw (1971), A new theory of grinding, in: Proceedings Of Institutions Conference on Production Science in Industry, Melbourne, pp. 73–78.
- R.E. Wiliams, K.P. Rajurkar (1989), Metal removal and surface finish characteristics in abrasive flow machining, PED, 38ASME, New York, pp. 93–106.
- T.R. Loveless, R.E. Willams, K.P. Rajurkar (1994), A study of the effects of abrasive flow finishing on various machined surfaces, Journal of Material Processing Technology 47, 133–151.
- R.E. Williams, K.P. Rajurkar (1992), Stochastic modeling and analysis of abrasive flow machining, Transactions of the ASME, Journal of Engineering for Industry 114, 74–81.
- Rajendra K. Jain, V.K. Jain (2001). Specific energy and temperature determination in abrasive flow machining process International Journal of Machine Tools & Manufacture 41, 1689–1704.
- Singh Mandeep (2010), M.Tech. Thesis: Design and Development of Abrasive Flow Machining Setup, PEC Univ. of Tech., Chandigarh.