International Journal of Scientific & Engineering Research Volume 8, Issue 7, July-2017
ISSN 2229-5518

An investigation on Effects of End Milling process on Noise during Machining of Copper

P.V.Suresh Babu[1], Anil Kumar[2], Suha K. Shihab[3], Arshad Noor Siddiquee[4]

Abstract - This paper presents an investigation of noise level during fillet end milling operation on commercially pure copper using CNC vertical milling machine. The most critical process parameters such as semi finish spindle speed (rpm), semi finish feed (mm/min.), finish depth of cut (mm) and finish feed (mm/min.) are taken into consideration to reduce the noise level during machining. The Taguchi method was used to perform systematic experimentation through L9 orthogonal array. According to the study, the noise level (in dB) is considered as lower-the-better. The signal to noise ratio (S/N ratio) and analysis of variance (ANOVA) were employed to analyse the effect of milling parameters on noise level in milling process. The contributions of each process parameters to obtain the required output characteristics were studied. Results revealed that the depth of cut of finish is the dominant factor affecting noise level.

Index Terms - ANOVA, depth of cut, Milling, Noise, optimization, orthogonal array, process parameter, Taguchi design.

1. INTRODUCTION

Milling is a cutting process which uses a multi-point milling cutter to remove material from the surface of a work piece to produce simple as well as complex shapes. In end milling process the axis of rotation of the cutting tool is kept perpendicular to the direction of feed i.e. either parallel or perpendicular to the machined surface. Milling is usually an intermittent cutting operation as the teeth of the milling cutter enters and exit the work piece during each revolution. Through this interrupted cutting action the teeth is subjected to a cycle of impact force and thermal shock on every rotation creating high levels of noise. A specific form of computer numerical controlled (CNC) machining is used for CNC milling.

In milling process, the two major classes are: (i) face milling and (ii) peripheral milling. Face milling is used to cut flat surfaces (faces) into the workpiece, or to cut flat-bottomed cavities and the cutting action occurs primarily at the end corners of the milling cutter. In peripheral milling, the cutting action occurs primarily along the circumference of the cutter, so that the cross section of the milled surface receives the shape of the cutter. In this case the blades of the cutter can be seen as scooping out material from the work piece.

It is reported that with the increase in performance of machining operations, noise levels have become an occupational health and safety problems. Identification of the main sources of noise emission when milling an aluminium component was analysed. A typical study by J.Rech et al. [1] mentions that the cutting speed, feed and axial depth of cut tend to increase sound pressure level by increasing the impact energy. Titanium (Ti) and its alloys are excellent contenders while selecting materials in aviation industry. Titanium alloys are

1. P V Suresh Babu is working as Assistant Director (Mechanical) with the Ministry of Micro, Small & Medium Enterprises, Govt. of India, New Delhi and currently pursuing M-Tech (Manufacturing Technology & Automation) from Al-Falah University, Faridabad, India. Email: kelanvava@gmail.com
2. Anil Kumar is working as Investigator (Mechanical) in the Ministry of Micro, Small & Medium Enterprises, Govt. of India, New Delhi and currently pursuing M Tech (Manufacturing Technology & Automation) from Al-Falah University, Faridabad, India.
3. Suha K. Shihab, Department of Mechanical Engineering, Engineering College, Diyala University, Diyala, Iraq.
4. Arshad Noor Siddiquee, Professor, Department of Mechanical Engineering, Jamia Millia Islamia, New Delhi, India. Email: arshadnsiddiqui@yahoo.com

very difficult to machine due to poor thermal conductivity causing excessive heat at the tool-workpiece junction, springiness, and material build up along the cutting edge of tool. Nowadays, high speed machining (HSM) is becoming popular due to high material removal rate (MRR) and greater productivity. A series of experiments have been performed using response surface methodology (RSM) to develop a relationship with roughness (Ra) and machining parameters, i.e., cutting speed, feed, and depth of cut (input variables). It was observed by Khalid H. Hashmi et al. [2] that surface roughness was primarily influenced by depth of cut. Ch. Ratnam et al. [3] optimized Process Parameters for Surface Roughness (Ra) and Surface Hardness (H). Single cut machining was performed with CNC Vertical Milling machine by using HSS end mill cutters. Process parameters like cutter (tool) speed, feed rate and depth of cut with constant rotation of workpiece were chosen while machining Brass material under dry condition. Taguchi's Orthogonal Array (OA) was adopted for experimentation and Signal-to-Noise ratio (SN ratio) of the responses was used for finding optimality of process parameters. The influence and contribution of the process parameters on the responses was studied with the help of Analysis of Variance (ANOVA).The problem of undesired self-excited chatter vibrations in milling was found to be very common. G. Totis et al. [4] has done research work with the new model of tooling system dynamics and explained the regenerative effect in milling. In their study they concluded that geometrical features of the tooling system were significant and affect the stability borders of about +25%. Nurezayana Zainal et al. [5] studied the cutting parameters of end milling for machining performance, measurement and minimum surface roughness. Taguchi method was used for experimental design. The analysis of variance was applied to investigate the effects of cutting speed, feed rate and depth of cut on the surface roughness. Glowworm swarm optimization has improved the machining process performance by estimating a much lower value of minimum surface roughness as compared to the results of experimental and particle swarm optimization. Eyup Bagci and Seref Aykut [6] have investigated through Taguchi optimization method, the effect of parameters on the surface roughness value in terms of cutting parameters when face milling of the cobalt-based alloy (stellite 6) material was used. It was found that the Taguchi method was very suitable to solve the surface quality problem occurring in the face milling of stellite 6 material. V. M. Prajapati et al. [7] have investigated the effect of machining parameters on product quality and productivity of the process. An orthogonal array of L9 was used and ANOVA was performed to find out the significance of each of the input parameters on the material removal rate and surface roughness. Khairi Yusuf et al. [8] optimized the parameters that could produce significant good surface roughness by using the Taguchi design method in the Computer Numerical Control (CNC) end mills. The experiment results showed that the most significant factors affecting the surface roughness of Titanium alloy during end milling process was primarily the spindle speed of machine, secondly, the type of end mills tool used, third, the feed rate adopted and lastly, the depth of cut chosen.

Bala Murugan Gopalsamy et al. [9] applied the Taguchi method to find out the optimum process parameters for end milling while having hard machining of hardened steel. Zhang et al. [10] investigated the Taguchi's design application to optimize the surface quality in a CNC face milling operation. An orthogonal array of L9 was used and the ANOVA analysis was adopted for identifying the significant factors affecting surface roughness. The experiment results indicated that the effects of spindle speed and feed rate were significant than depth of cut. Joshi et al. [11] investigated the SR response on CNC milling using the Taguchi technique based on analysis of variance. The experiment was done using 5 blocks of (100mm x 34mm x 20mm) of aluminium cast heat-treatable alloy material. The output characteristic of surface finish was analysed by software Minitab 15 and the ANOVA was formed, which gave the percentage contribution of each influencing factor on surface roughness. Bajic et al. [12] investigated the optimized process parameters for SR in face milling. Test sample made of carbon steel St 52-3 having dimensions of 230mmx100mmx100mm was used for the experiments. The results revealed that the feed and cutting speed were the significant parameters affecting the surface roughness.

From the survey of literature, it is evident that there are published works on the effect of process parameters on noise based on Taguchi method of design of experiments. However, there is limited literature available on the study of the effect of milling process parameters on noise using pure copper. Moreover, in the sustainable

International Journal of Scientific & Engineering Research Volume 8, Issue 7, July-2017
ISSN 2229-5518

manufacturing environment, the importance of noise is only going to increase. It may be important to highlight that the noise can be readily measured inline during machining. Further, if its relationship with input parameters is established other machining responses can also be predicted through noise indirectly. Due to the wide range of applications of pure copper, an attempt has been made in this study to optimize the fillet milling parameters such as semi finish spindle speed, semi finish feed, finish depth of cut and finish feed for minimum value of noise level. In this study, the experiments were conducted on the CNC vertical milling machine to determine the optimised values of machining parameters. Taguchi method is used to obtain the optimal combination of the milling process parameter and ANOVA is used to investigate which milling parameter significantly affected the performance characteristics.

2. EXPERIMENTS AND METHOD

2.1 Machining process and experiment plan

In this study, the optimization of process parameters of fillet milling operation on pure copper material was studied. For this purpose the noise level was measured in dB. Experiments were carried out according to Taguchi's L9 Orthogonal Array (OA) on a CNC vertical milling machine.

2.2 Work piece Material Used

Commercially pure copper block of size 75 mm x 75 mm x 75 mm used for machining operation. Pure Copper is a soft, malleable, and ductile metal having very high thermal and electrical conductivity. But, due to its high strength and high ductility its machinability is considered to be poor.

2.2.1 Mechanical Properties

Mechanical properties of the work material (commercially pure Copper) used in the investigation is given in Table – 1.

Table1: Mechanical properties

Mechanical Properties	Values in metric
Vickers Hardness	50
Ultimate Tensile Strength	210 MPa
Yield Tensile Strength	33.3 MPa
Elongation at Break	60 %
Modulus of Elasticity	110 GPa
Bulk Modulus	140 GPa
Poissons Ratio	0.343
Modulus of Shear	46.0 GPa

2.3 Cutting Tool Used

The fillet milling operation was done using Tungsten Carbide ball type end mill cutter (3 mm). Tungsten carbide has a very high thermal conductivity of 90 $W\cdot m^{-1}\cdot K^{-1}$, and a coefficient of thermal expansion of 5.5 $\mu m\cdot m^{-1}\cdot K^{-1}$. Tungsten carbide is a very hard material, ranking about 9 on Mohs scale, having a Vickers number of 2600.

2.4 Machine Tool

The CNC Vertical milling machine of 7.5 kW spindle power was used to conduct the end milling operation with ball milling cutter Of 3 mm radius. The noise level values were measured by using a sound level meter, make: Lutron, model: SL-4001, range: 30 – 130 dB, Least count: 0.1dB.

3. EXPERIMENTAL PROCEDURE

The experimental studies were performed on a CNC vertical milling machine. This machine was programmed to machine the work-piece in accordance with the predetermined locus. The experimental set-up is shown in Figure-1.

Figure-1 Experimental set-up

Table-2. Experimental factors and their levels

Factor	Symbol	Unit	Level-1	Level-2	Level-3
Semi finish Spindle speed	A	rpm	4500	5000	5500
Semi finish feed rate	B	mm/min	600	700	800
Finish depth of cut	C	mm	0.05	0.075	0.10
Finish feed rate	D	mm/min	400	500	600

The experiments were conducted using four controllable process parameters such as semi finish spindle speed (rpm), semi finish feed(mm/min), finish depth of cut(mm) and finish feed(mm/min) at 3 different levels as shown in the Table - 2.

International Journal of Scientific & Engineering Research Volume 8, Issue 7, July-2017
ISSN 2229-5518

Nine experimental runs based on L9 orthogonal array were performed as per the plan shown in Table - 3. Ball mill cutter of radius 3 mm was used to machine the fillet of work piece. The noise level during the process was measured using a sound level meter.

Table - 3. Experimental plan

Exp. No.	A Semi finish Spindle speed rpm	B Semi finish FEED mm/min.	C Finish Depth of Cut mm	D Finish FEED mm/min.
1	4500	600	0.05	400
2	4500	700	0.075	500
3	4500	800	0.100	600
4	5000	600	0.075	600
5	5000	700	0.100	400
6	5000	800	0.050	500
7	5500	600	0.100	500
8	5500	700	0.050	600
9	5500	800	0.075	400

Other set of parameters which were not varied and were kept constant are as given below:

Rough spindle speed - 4500 rpm
Rough Depth of Cut - 0.20 mm
Rough Feed - 1100 mm/min
Fillet Radius - 3.0 mm
Semi-finish Depth of Cut - 0.10 mm
Finish spindle Speed - 6000 rpm

3.1 Experimental Parameters and Design

The Taguchi method which is a powerful tool for parameter design of performance characteristics was used to determine optimal machining parameters for minimum noise level in machining. Taguchi methods are statistical methods, or sometimes called robust design methods, to improve the quality of manufactured goods, and are recently applied to engineering, biotechnology, marketing and advertising. This method uses a special design of orthogonal arrays to study the entire parameter space using small number of experiments.

Taguchi methods are used to improve product quality at the design stage by integrating quality control into the product design process prior to large-scale manufacturing. Genichi Taguchi, a Japanese engineer, proposed several approaches to experimental designs which are referred to as "Taguchi Methods."

3.2 Signal to Noise (S/N) Ratio

The S/N ratio is a performance measure to obtain chosen control levels that best cope up with noise. The S/N ratio takes both the mean and the variability into account. In simple terms, the S/N ratio is the ratio of mean (signal) to the standard deviation (noise). The S/N equation depends on the criterion of the quality characteristic to be optimized. While there are many different possible S/N ratios, three of them are considered standard and are generally applicable in the situation below:

- Biggest - best quality characteristic (strength, yield),
- Smallest - best quality characteristic (contamination).
- Nominal - best quality characteristic (dimension).

1. Smaller – the –Better.
   S/N = -10 *log (mean square of the response)
   $$\eta = 10\ln_{10}\frac{1}{n}\sum_{i=1}^{n} y_{i2}$$
2. Larger – the – Better.
   S/N = -10*log (mean square of the inverse of the response)
   $$\eta = 10\ln_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}$$
   Where n= number of measurements in trial/row, in this case n=1, 2…, 9 and Yi is the ith measured value in a run/row. i =1, 2………
3. Nominal – the – Better.
   S/N = 10 * log (the square of the mean divided by the variance)
   $$\eta = 10\ln_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{\mu^2}{\sigma^2}$$

The SN ratios are derived from the quadratic loss function and are expressed in a decibel scale. After the SN ratio has been computed for each run of an experiment, Taguchi method uses a graphical approach to analyse the data. In the graphical approach, the SN ratios are plotted for each factor against each of its levels and finally, confirmation tests are run for the "optimal" product setting to verify that the predicted performance is actually realized.

In the present study, the Taguchi design of experiments was used to investigate the effect of the machining parameters on noise level (dB) generated during fillet machining on vertical milling machine. The lower-the-better criterion was chosen to calculate the S/N ratio, since low value of noise level is required for obtaining better performance. The S/N ratio was calculated by using equation-

$$S/N = -10\log\left[1/n \sum_{i=1}^{n} y_i^2\right]$$

4. RESULTS AND DISCUSSION

In the following sections, we describe the results of the present study and also present a discussion on the results in light of available literature. Effect of fillet machining parameters on noise level in pure copper material was successfully investigated. Measured values of noise and corresponding signal-to-noise (S/N) ratio as per the Taguchi's L9 orthogonal array are shown in Table-4.

Table-4. Orthogonal array L9 of experiments and results

Ex. No.	A	B	C	D	dB	SN ratio
1	1	1	1	1	81.5	-38.2232
2	1	2	2	2	84.0	-38.4856
3	1	3	3	3	80.0	-38.0618
4	2	1	2	3	83.5	-38.4337
5	2	2	3	1	78.0	-37.8419
6	2	3	1	2	84.0	-38.4856
7	3	1	3	2	82.0	-38.2763
8	3	2	1	3	81.0	-38.1697
9	3	3	2	1	85.0	-38.5884

4.1 Analysis of Mean (ANOM)

The analysis of mean is performed to obtain an optimum level of machining parameters for multi performance characteristics. The ANOM results are shown in Table-5. It can be seen from Table-5 that the factors- finish depth of cut, semi finish feed and finish feed have the higher values of ranges of 0.44, 0.21 and 0.20 respectively. Greater value of difference in S/N ratio shows greater effect or more significance.

Table-5. Response Table for Signal to Noise Ratios

S No.	Symbol	Level 1	Level 2	Level 3	Max – Min (range)	Rank
1	A	-38.26	-38.25	-38.34	0.09	4
2	B	-38.31	-38.17	-38.38	0.21	2
3	C	-38.29	-38.50	-38.06	0.44	1
4	D	-38.22	-38.42	-38.22	0.20	3

4.2 Analysis of Variance (ANOVA)

The analysis of variance was conducted to study the significance of machining parameters on noise level based on their % contribution. The ANOVA results are shown in Table-6. It can be seen from the Table-6 that the % contribution of process parameter finish depth of cut, C, is maximum i.e. 64.21% followed by finish feed rate, D (16.79%), semi finish feed, B (15.50%) and semi finish spindle speed, A (3.50%). Therefore the finish depth of cut parameter (C) is the most important parameter that affects noise during machining.

Table-6. Analysis of Variance for S/N ratios

Source	DF	Seq SS	Adj SS	Adj MS	% contribution
A	2	0.016033	0.016033	0.008017	3.50
B	2	0.070991	0.070991	0.035496	15.50
C	2	0.294075	0.294075	0.147038	64.21
D	2	0.076887	0.076887	0.038444	16.79
Error	0	-	-	-	-
Total	8	0.457986			100

4.3 Optimization for Noise Level

4.3.1 Plots

Initially the experiment results were used to obtain S/N ratios for the performance characteristics to find a desirable result with the best performance and smallest variance. Figure-2 shows the normal probability plot of the residuals for the noise levels and it reveals that the residuals either fall on a straight line or are very close to the line implying that the errors are distributed normally.

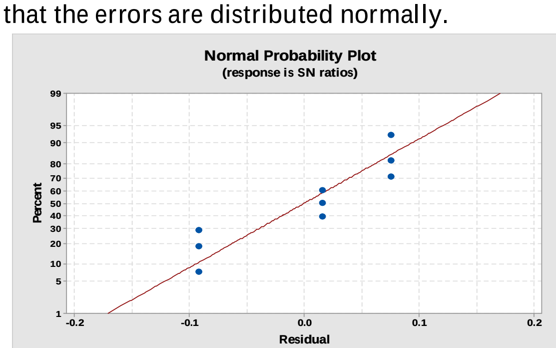

Figure-2. Normal probability plot

Figure-3 depicts the main effect plot for S/N ratio. It can be seen from the results shown in Table-5 and Figure-3, that within the range of investigated input parameters, the optimal combination of the machining parameters for noise level is A2B2C3D1, i.e., semi finish spindle speed (A) at 5000 rpm, semi finish feed rate (B) at 700 mm / min., finish depth of cut (C) at 0.10 mm and finish feed (D) at 400 mm / min.

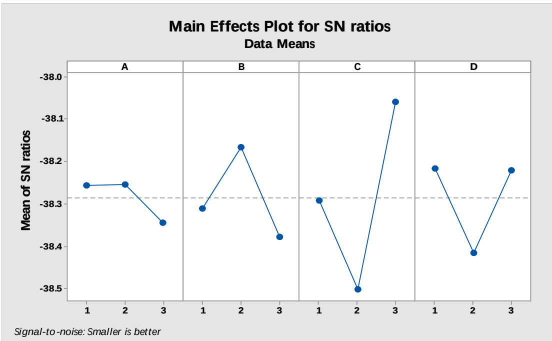

Figure-3. Main effect plot for SN ratios

5. CONCLUSION

In this experimental study, effect of process parameters (semi finish spindle speed, semi finish feed rate, finish depth of cut and finish feed) on noise level during CNC fillet machining of pure copper was investigated. The machining parameters were optimized using Taguchi method for obtaining minimum noise level. On the basis of the results of the present study, following conclusions are made:

- Within the investigated range of input parameters, the optimal combination of the machining parameters that yields minimum noise level is A2B2C3D1 i.e. semi finish spindle speed (A) at 5000 rpm, semi finish feed rate (B) at 700 mm / min., finish depth of cut (C) at 0.10 mm and finish feed (D) at 400 mm / min.

- The percentage contribution of finish depth of cut (64.21%) is maximum followed by finish feed rate (16.79%), semi finish feed (15.50%) and semi finish spindle speed (3.50%). Therefore the finish depth of cut parameter (C) is the most important process parameter that affects noise most significantly.

REFERENCES

[1] J. Rech, F.Dumont, A. Le Bot, P. J. Arrazola, "Reduction of noise during milling operations", CIRP Journal of Manufacturing Science and Technology, 9 / 2016

[2] Khalid H. Hashmi, Ghulam Zakria, Muhammad Baqar Raza, Shahid Khalil, "Optimization of process parameters for high speed machining of Ti-6Al-4V using response surface methodology", The International Journal of Advanced Manufacturing Technology, July 2016, Volume 85, Issue 5, pp 1847–1856.

[3] Ch. Ratnam, K. Arun Vikram, B. S. Ben, B. S. N. Murthy, "Process monitoring and effects of process parameters on responses in turn-milling operations based on SN ratio and ANOVA", Measurement, Volume 94, December 2016, Pages 221–232.

[4] G. Totis, P. Albertelli, M. Torta, M. Sortino, M. Monno, "Upgraded stability analysis of milling operations by means of advanced modeling of tooling system bending", International Journal of Machine Tools and Manufacture, Volume 113, February 2017, Pages 19–34

[5] Nurezayana Zainal, Azlan Mohd Zain, Nor Haizan Mohamed Radzi, Muhamad Razib Othman, "Glowworm swarm optimization (GSO) for optimization of machining parameters", Springer Science + Business Media New York, April 2014.

[6] Eyup Bagci and Seref Aykut, "A study of Taguchi optimization method for identifying optimum surface roughness in CNC face milling of cobalt-based alloy(stellite6)", International Journal of Advanced Manufacturing Technology, 2006, 29:940-947. ALLOY-

[7] Prof. V. M. Prajapati, Prof. K. H. Thakkar, Prof. S. A. Thakkar, Prof. H. B. Parikh, "Study and investigate effects of cutting parameters in CNC milling process for aluminium 8011h14 through taguchi design method", International Journal of Innovative Research in Science, Engineering and Technology , Vol. 2, Issue 7, July 2013.

[8] Khairi Yusuf, Y. Nukman, T. M. Yusof, S. Z. Dawal, H. Qin Yang, T. M. I. Mahlia and K. F. Tamrin, "Effect of cutting parameters on the surface roughness of titanium alloys using end milling process", Scientific Research and Essays, Vol. 5(11), pp. 1284-1293, 4 June, 2010

[9] Bala Murugan Gopalsamy, Biswanath Mondal and Sukamal Ghosh, "Taguchi and ANOVA: An approach for process parameters optimization of hard machining while machining hardened steel", Journal of Scientific and Industrial Research, Vol.68, August 2009, PP.686-695.

[10] Zhang, Julie Z., Chen, Joseph C. and Kirby, E. Daniel," Surface roughness optimization in an end-milling operation using the Taguchi design method."Journal of Materials Processing Technology Vol.184, pp. 233–239, 2007.

[11] Joshi, Amit and Kothiyal, Pradeep," Investigating effect of machining parameters of cnc milling on surface finish by taguchi method" International Journal on Theoretical and Applied Research in Mechanical Engineering, Volume-2, Issue-2, pp. 113-119, 2013.

[12] Bajic, D., Lele,B. and Zivkovic, D.,"Modeling of machined surface roughness and optimization of cutting parameters in face milling." Vol.47, pp.331-334, 2008.