Materials Today: Proceedings 21 (2020) 189–193

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Prediction of surface roughness and tool wear in milling process on brass (C26130) alloy by Taguchi technique

S.V. Alagarsamy [a], M. Ravichandran [b,*], M. Meignanamoorthy [c], S. Sakthivelu [d], S. Dineshkumar [e]

[a] Department of Mechanical Engineering, Mahath Amma Institute of Engineering and Technology, Pudukkottai, India
[b] Department of Mechanical Engineering, K. Ramakrishnan College of Engineering, Tiruchirappalli, India
[c] Department of Mechanical Engineering, Mother Terasa College of Engineering and Technology, Pudukkottai, India
[d] Department of Mechanical Engineering, Mountzion College of Engineering and Technology, Pudukkottai, India
[e] Department of Mechanical Engineering, Chendhuran College of Engineering and Technology, Pudukkottai, India

ARTICLE INFO

Article history:
Received 15 April 2019
Accepted 30 April 2019
Available online 4 July 2019

Keywords:
Brass (C26130) alloy
End milling
Surface roughness
Tool wear
Taguchi technique
ANOVA

ABSTRACT

The machining parameters is optimized during CNC end milling process of brass C26130 alloy using Taguchi technique. The experimental results shows that the combination of 750 rpm spindle speed, 20 mm/rev feed rate and 1 mm depth of cut was identified as the optimum level for minimum surface roughness (SR) and the combination of 750 rpm spindle speed, 60 mm/rev feed rate and 0.75 mm depth of cut was identified as the optimum level for minimum tool wear (TW). ANOVA results revealed that the spindle speed and feed rate was identified as the highest influencing parameters on SR and TW.

Peer-review under responsibility of the scientific committee of the International Conference on Recent Trends in Nanomaterials for Energy, Environmental and Engineering Applications.

1. Introduction

Now days, the use of brass and its alloys play a vital role in many industrial applications because of its favourable properties such as high specific strength, hardness, high elastic modulus and good wear and corrosion resistance [1]. Metal cutting process is one of the most essential and frequent operations used for every manufacturing of industries because of its ability to remove materials faster with better surface finish [2]. Among the conventional machining process, Milling and end milling are the most important machining processes. End milling process is the widely used machining operation for metal removal in every production industries including the transportation, marine, defence, aircraft and aviation industries when the quality is an considered factor in the production of complex or intricate shapes and slots with high tolerance accuracy [3–5]. In recent decades, modern manufacturing industries are attracted to use of CNC milling machine which is very useful for its flexibility, accuracy and versatility that permits production of components in short time, and low cost with high quality surface finish [6]. Some researchers reported that the effect of parameters during end milling process. Sakthivelu et al. investigated the machining characteristics of aluminium alloy 7075 with various milling process parameters on material removal rate (MRR) and SR using Taguchi method. They revealed that feed rate was the most influencing factor on SR and depth of cut was the most dominant factor for MRR [7]. Subramanian et al. studied the surface roughness of AL7075-T6 during end milling process and reported that SR increases with increase the feed rate, whereas SR decreases with increase the cutting speed [8]. Rajeswari et al. investigated that the effect of geometrical and machining parameters on SR and tool wear rate (TWR) during end milling of Al356-SiC metal matrix composite using HSS end mill cutter. They concluded that cutting speed has most significant parameter on SR and TWR followed by helix angle and rake angle [9]. Ibrahem Maher et al. optimized the process parameter such as spindle speed, feed rate and depth of cut on SR during end milling of brass (60/40) alloy and concluded that high spindle speed would result in lower the surface roughness [10]. Cetin Ozay et al. analyzed the influence of various cutting process parameters on SR during tangential turn milling process of MS58 brass material. They observed that the better surface quality obtained at lower cutting tool speed with lower work piece speed [11]. Anis Nair et al. optimized the end milling parameters on SR of brass UNS C34000 by using Taguchi method.

* Corresponding author.
E-mail address: smravichandran@hotmail.com (M. Ravichandran).

https://doi.org/10.1016/j.matpr.2019.04.219
2214-7853/
Peer-review under responsibility of the scientific committee of the International Conference on Recent Trends in Nanomaterials for Energy, Environmental and Engineering Applications.

They revealed that the speed was the most significant factor on SR [12].

The aim of the present study is to analyze the effect of end milling process parameters namely spindle speed (rpm), feed rate (mm/rev) and depth of cut (mm) on surface roughness (SR) and tool wear (TW) during machining of brass C26130 alloy. Signal to noise ratio (S/N) and analysis of variance (ANOVA) was used to identify the optimal parameters on SR and TW.

2. Experimental details

2.1. Materials used

In the present experimental work, Brass C26130 alloy having dimensions of 150 mm × 50 mm × 10 mm were used as a work material. The reason for selecting this material is that, the brass C26130 alloy gains more importance in automotive, nuclear and aerospace industries because of its unique combination of properties, it is stronger and harder than copper. The chemical composition and properties of the work piece material are given in Tables 1 and 2.

2.2. Design of experiments

In present study, three process parameters namely, spindle speed (rpm), feed rate (mm/rev) and depth of cut (mm) was considered as the predominant parameters based on the output performance characteristics on end milling process of any materials with an objective to minimize the surface roughness and minimize the tool wear [13]. According to Taguchi method, an L9 orthogonal array was selected for the experiments. The milling process parameters and their levels are presented in Table 3. The experiments were carried out as per L9 orthogonal array and the experimental layout is provided in Table 4.

2.3. Machining process

The machining operation was performed by using CNC vertical milling machine (CNC MILL). The diameter of 12 mm HSS end mill cutter was used as a cutting tool. The uniform length, breadth and depth of machining were maintained at all the experiments. The experimental setup is shown in Fig. 1(a). The surface roughness was measured at three different locations by using surface roughness tester (Mitutoya Talysurf SJ-210) and the average surface roughness (SR) value is considered. The surface roughness test is shown in Fig. 1(b). The tool wear was calculated based on the weight difference of the tool before and after the machining process under a period of machining time. The weight of the tool was measured by using electronic weighing balance machine with accuracy of 0.0001 g. The calculated and measured output responses are provided in Table 4.

2.4. Taguchi technique

Taguchi method is a standard statistical technique for optimizing the process parameters in any process and also can reduce the number of experiments [14]. In present work, the experimental results were analyzed through Taguchi based S/N ratio analysis. In the Taguchi method, the output response values are converted into a signal-to-noise (S/N) ratio η values. The term "signal"

Table 1
Chemical composition of brass (C26130) alloy.

Elements	Copper	Lead	Iron	Zinc	Arsenic
Weight (%)	71.2	0.05	0.05	28.64	0.06

Table 2
Properties of brass (C26130) alloy.

Density(g/cm^3)	Hardness (HV)	Tensile Strength (MPa)	Elongation (%)	Modulus of Elasticity (GPa)	Melting Point (°C)	Poisson Ratio
8.55	80–130	280–350	35–40	110	965	0.33

Table 3
Machining parameters and their levels.

Symbol	Process Parameter	Units	Level		
			1	2	3
A	Spindle speed	rpm	500	750	1000
B	Feed rate	mm/rev	20	40	60
C	Depth of cut	mm	0.5	0.75	1.0

Table 4
Taguchi L9 array and output responses.

Ex. No	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	SR (μm)	S/N ratio (dB)	TW (g/min)	S/N ratio (dB)
1	500	20	0.5	1.165	−1.3265	0.00649	43.7551
2	500	40	0.75	1.188	−1.4963	0.00666	43.5305
3	500	60	1.0	1.087	−0.7246	0.00038	68.4043
4	750	20	0.75	0.594	4.5243	0.01375	37.2339
5	750	40	1.0	0.945	0.4914	0.00517	45.7302
6	750	60	0.5	0.872	1.1897	0.00015	76.4782
7	1000	20	1.0	0.978	0.1932	0.0305	30.3140
8	1000	40	0.5	0.913	0.7906	0.06909	23.2117
9	1000	60	0.75	0.837	1.5455	0.00157	56.0820

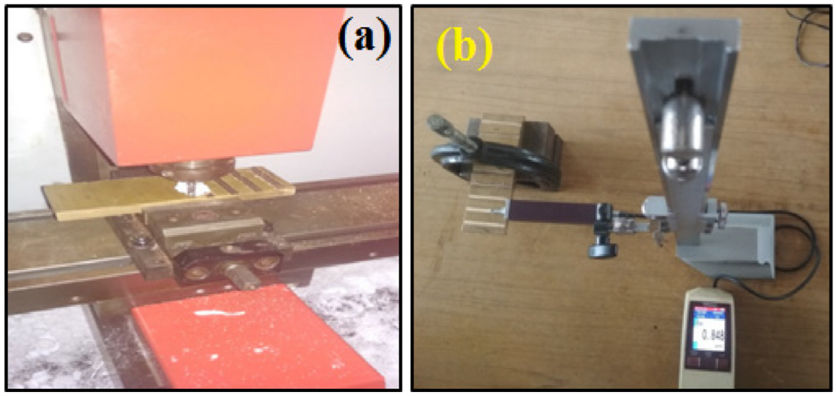

Fig. 1. (a) End milling process setup and (b) Surface roughness testing.

represents the desirable mean value and the "noise" represents the undesirable value for the output performance characteristics. There are three types of quality characteristics are possible to evaluate the S/N ratio such as smaller-the-better (SB), nominal-the-better (NB) and higher-the-better (HB) [15]. Since, we require minimum surface roughness (SR) and minimum tool wear for this study [16,17]. Hence, the smaller-the-better S/N ratio characteristic was selected for SR and TW by using given equation.

$$\text{S/N ratio} = -10\log_{10}(1/n)\sum_{k=1}^{n} Y_{ij}^{2} \quad (1)$$

where n – number of replications, Y_{ij} – observed responses value where i = 1, 2, 3.....n; j = 1, 2, 3.......k. The evaluated output response and their corresponding S/N ratio are depicted in Table 4.

3. Result and discussions

3.1. Effect of parameters on surface roughness

Fig. 2 illustrates the main effect of process parameters, such as spindle speed, feed rate and depth of cut on surface roughness. It is clearly noticed that, middle level of spindle speed, low level of feed rate and middle level of depth of cut decreases the surface roughness. The mean S/N ratio for surface roughness is given in Table 5. From the Table, spindle speed and feed rate is most influencing parameters for surface roughness followed by depth of cut. The minimum surface roughness is obtained for the optimal combination of parameters (A2B1C2).

ANOVA is a standard statistical tool, which is used to determine the individual effect from all of the input process parameters. In this analysis, the percentage of contribution of each parameter is employed to measure its corresponding effects on output responses [16]. In present study, ANOVA was applied to analyze the influence of the end milling parameters, namely, spindle speed, feed rate and depth of cut that extensively affects the surface roughness (SR) and tool wear (TW). Table 6 shows the ANOVA results of surface roughness. From the table, it is observed that the spindle speed has greater influence on controlling the surface roughness of the brass C26130 alloy (P = 68.74%), followed by the depth of cut (P = 10.97%) and feed rate (P = 6.67%).

3.2. Effect of parameters on tool wear

Fig. 3 shows the main effect plot of process parameters, such as spindle speed, feed rate and depth of cut on tool wear. It is clearly

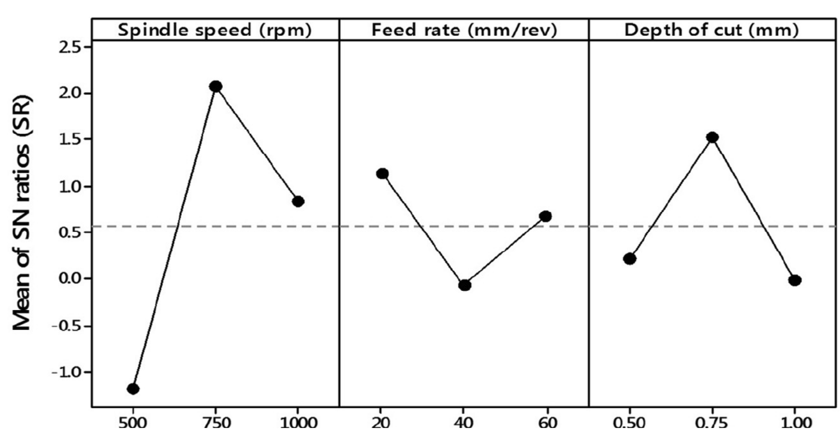

Fig. 2. main effect plot for surface roughness.

Table 5
S/N ratio table for surface roughness.

Level	1	2	3	Delta	Rank
Spindle speed (A)	−1.18248	2.06844	0.84310	3.25091	1
Feed rate (B)	1.13033	−0.07146	0.67019	1.20179	3
Depth of cut (C)	0.21791	1.52448	−0.013331	1.53781	2

Table 6
ANOVA table for surface roughness.

Source	DoF	Seq.SS	Adj.SS	Adj.MS	F	P	Con (%)
Spindle speed (A)	2	0.18514	0.18514	0.09257	5.05	0.165	68.74
Feed rate (B)	2	0.01794	0.01794	0.00897	0.49	0.671	6.66
Depth of cut (C)	2	0.02956	0.02956	0.01478	0.81	0.554	10.97
Error	2	0.03667	0.03667	0.01833			
Total	8	0.26931					

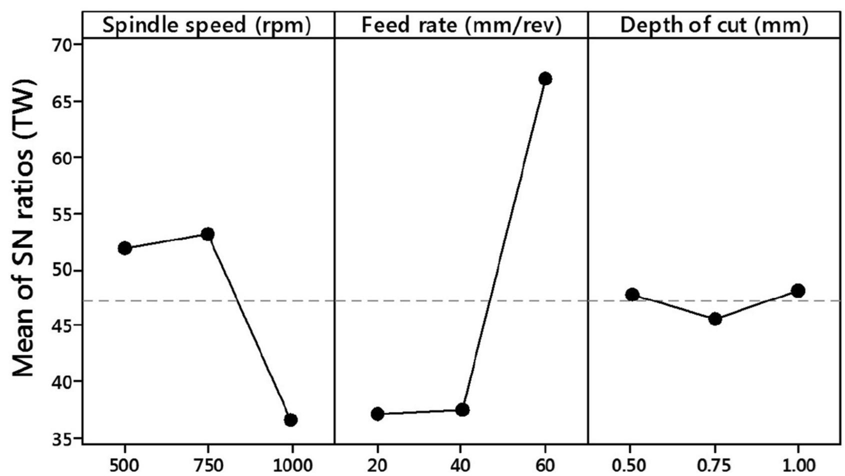

Fig. 3. main effect plot for tool wear.

understood that, middle level of spindle speed and high level of feed rate and depth of cut decreases the tool wear. The depth of cut increases, the high contact between the tool edges and work piece causing increased in tool wear rate. The mean S/N ratio for tool wear is presented in Table 7. From the Table, it can be clearly noticed that, feed rate is the most significant factor affect the tool wear followed by spindle speed and depth of cut. The minimum tool wear is achieved for the optimal combination of process parameters (A2B3C3).

Table 8 shows the results of ANOVA and contribution of each individual parameter on tool wear. It is also confirmed that spindle speed is most influencing parameters with contribution of 39.92% and followed by feed rate 26.22% and depth of cut 12.88%. Increase in spindle speed and feed rate increases the surface roughness and thus the tool wear is also increased due to the more erode of materials.

4. Conclusions

1. The present investigation was made to find the optimal machining parameters for END milling process of Brass (C26130) alloy by using Taguchi methodology.
2. The optimum parameters obtained for minimum surface roughness: spindle speed 750 rpm, feed rate 20 mm/rev and depth of cut 0.75 mm.
3. The optimum parameters achieved for minimum tool wear: spindle speed 750 rpm, feed rate 60 mm/rev and depth of cut 1 mm.
4. From ANOVA results, it is found that spindle speed was the most significant factor affecting surface roughness followed by depth of cut which contributes 68.74% and 10.97%.
5. The spindle speed was most dominant factor affecting the tool wear followed by feed rate which contributes 39.92% and 26.22% respectively.

Table 7
S/N ratio table for tool wear.

Level	1	2	3	Delta	Rank
Spindle speed (A)	51.90	53.15	36.54	16.61	2
Feed rate (B)	37.10	37.49	66.99	29.89	1
Depth of cut (C)	47.81	45.62	48.15	2.53	3

Table 8
ANOVA table for tool wear.

Source	DoF	Seq.SS	Adj.SS	Adj.MS	F	P	Con (%)
Spindle speed (A)	2	0.0016054	0.0016054	0.0008027	1.90	0.344	39.92
Feed rate (B)	2	0.0010544	0.0010544	0.0005272	1.25	0.444	26.22
Depth of cut (C)	2	0.0005179	0.0005179	0.0002590	0.61	0.619	12.88
Error	2	0.0008429	0.0008429	0.0004215			
Total	8	0.0040206					

References

[1] S. Marichamy, M. Ravichandran, B. Stalin, B. Sridhar Babu, FME Trans. 47 (2019) 116–121.
[2] Thakur Paramjit Mahesh, R. Rajesh, Procedia Mater. Sci. 5 (2014) 2493–2502.
[3] M. Nurhaniza, K.A.M. Ariffin, F. Mustapha, J. Int. Manuf. Eng. 4680380 (2016) 1–9.
[4] S. Jeyakumar, K. Marimuthu, T. Ramachandran, Indian. J. Eng. Mater. S. 22 (2015) 29–37.
[5] S.V. Alagarsamy, M. Ravichandran, P. Raveendran, K. Karthikeyan, H. Saravanan, Int. J. TechnoChem. Res. 4 (2) (2018) 117–124.
[6] M. Lohithaksha, Maiyar, R. Ramanujam, K. Venkatesan, J. Jerald, Procedia Eng. 64 (2013) 1276–1282.
[7] S. Sakthivelu, T. Anandaraj, M. Selwin, Mech. Mech. Eng. 21 (2017) 95–103.
[8] M. Subramanian, M. Sakthivel, R. Sudhakaran, Arab. J. Sci. Eng. (2014) 1-15, https://doi.org/10.1007/s13369-014-1219-z.
[9] S. Rajeswari, P.S. Sivasakthivel, Multidiscipline Model. Mater. Struct. 1573–6105 (2017) 1–23.
[10] M.E.H. Ibrahem Maher, Ahmed A.D. Eltaib, R.M. Sarhan, El-Zahry, Int. J. Adv. Manuf. Technol. 74 (2014) 531–537.
[11] Cetin Ozay, Vedat Savas, Adv. Nat. Appl. Sci. 6 (6) (2012) 866–874.
[12] Anish Nair, P. Govindan, Int. J. Mech. Produc. Eng. Res. Dev. 3 (2013) 227–240.
[13] C.C. Tsao, Int. J. Adv. Manuf. Technol 40 (2009) 41–48.
[14] S. Marichamy, M. Saravanan, M. Ravichandran, G. Veerappan, Russ. J. Non-Ferr. Met. 57 (6) (2016) 586–598.
[15] S. Dinesh Kumar, M. Ravichandran, Mater. Test. 60 (2018) 877–884.
[16] H. Ramakrishnan, R. Balasundaram, N. Ganesh, N. Karthikeyan, J. Brazilian Soc. Mech.l Sci. Eng. 40 (2017) 1–15.
[17] C. Vinoth Kumar, B. Santhosh Kumar, N. Ganesh, M. Udaya Kumar, Int. J. Mech. Eng. Robot. Res. 3 (2014) 75–86.