Power Consumption and Surface Quality Optimization of Cutting Condition for S50C Material in Turning Process using Means Utility Concept and Taguchi Method

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Abstract

This paper aims to study the effects of cutting condition to the power consumption and surface quality in tuning process on mild steel S50C. The machine was used in this study is CNC turning and carbide cutting tool. The optimize process parameters by means utility concept and Taguchi technique applied to identify the machinability and energy efficiency. The three types of process parameters with five different levels including, cutting speed, feed rate, and depth of cut have been used in this work. The selection of these parameters was based on literature review, and tool manufacturing recommendations. The Taguchi orthogonal array $L_{25}(5^3)$ have been used for conducting the experiments. The results shown that most significant factor for power consumption is depth of cut (60.58%) followed by feed rate (30.27%) and cutting speed (4.36%). For surface roughness, the most significant factor is feed rate (98.49%) followed by depth of cut (0.99%), and cutting speed (0.02%). Nevertheless, the minimum power consumption of machine condition is in contrast to the surface roughness quality. Therefore, this technique can be applied for production planning to control the product quality and machining cost.

Keywords: Power consumption, cutting condition, Turning process, S50C, Taguchi method, Surface roughness

I. INTRODUCTION

Manufactured products require machining at some stage of their production sequence. Machining process is the removal of unwanted materials (machining allowance) from the workpiece so as to obtain a finished product of the desired size, shape, and surface quality [1]. The energy consumption in machining contributes a significant part of manufacturing cost and produces a great environmental impact. The turning CNC machine working principle is similar to general machinery, but different in the control systems of the driven mechanism its use computer numerical control the motors instead of the manual command [2]. The characteristic of product is depending on cutting parameters i.e. cutting speed, feed, depth of cut. The carbon steel JIS S50C is widely used in machinery manufacturing, good mechanical properties. Generally, S50C use to make mechanical parts, like spring, gear, tension bar, the roller, the axis, the load spindle etc. Design of experiment is the method, which is used to study the experimentations of industrial processes for finding statistical significance, relationships and optimize machining processes parameters [3].

Therefore, the objectives of this experiment aim to demonstrate the difference in the values of the cutting parameters for characterize power consumption in machining process. In addition, the relationship between cutting parameters, energy consumption and surface roughness were analyzed.

II. LITERATURE REVIEW

In machining process studies investigations, statistical design of experiments is used quite extensively.

Aman et al. [4] have studied the power consumption on CNC machine using response surface methodology and Taguchi's technique. The most significant factor in minimizing power consumption is cutting speed following by depth of cut.

Carmita et al. [5] research machining condition on material AISI 6061 T6, the result showed that feed rate is the most significant factor for minimizing energy consumption and surface roughness.

Salem et al. [6] using multi-objective optimization technique on dry machining of SUS 316. The most significant factor onto surface roughness was feed rate followed by cutting speed.

Jagannatha et al. [7] used the utility concept identify the factor for multi-response optimization problems. It found that is good agreement between the predicted values and experimental values of optimization.

III.RESEARCH METHODOLOGY

The machine was use in this study is CNC turning Mori Seiki Dura Turn 2030 with the Sandvik cutting tool model CNMG 120408 QM 4325 [8]. The material is plain carbon steel S50C in JIS standard. The experiment condition use CNMG 120408 QM 4325 Idemitsu coolant fluid during the cutting process. All the experiments were repeated five times and average values of all experimental. We use Taguchi Method, orthogonal array L25 and S/N ratio analysis in order to find out the optimal values of cutting parameters that minimize the response variable. The design of experiment is 25 sample with 3 factors and 5 levels The process parameters and design methodology to 3 factor 5 level including cutting speed; 258 m/min, 315 m/min, 345 m/min, 375 m/min, 405 m/min feed rate; 0.2 mm/rev, 0.275 mm/rev, 0.35 mm/rev, 0.425 mm/rev ,0.5 mm/rev and dept of cut; 1 mm, 2.25 mm, 3.5 mm, 4.75 mm, 6 mm. manufacturing recommendations as shown in Table 1 and Table 2.

Table 1 Parameters level

Level	Velocity (m/min)	Feed (mm/rev)	Depth of Cut (mm)
1	285	0.2	1
2	315	0.275	2.25
3	345	0.35	3.5
4	375	0.425	4.75
5	405	0.5	6

Table 2 Experiment Details

No. of Experiement	Velocity (m/min)	Feed (mm/rev)	Depth of Cut (mm)
1	285	0.2	1
2	285	0.275	2.25
3	285	0.35	3.5
4	285	0.425	4.75
5	285	0.5	6
6	315	0.2	2.25
7	315	0.275	3.5
8	315	0.35	4.75
9	315	0.425	6
10	315	0.5	1
11	345	0.2	3.5
12	345	0.275	4.75
13	345	0.35	6
14	345	0.425	1
15	345	0.5	2.25
16	375	0.2	4.75
17	375	0.275	6
18	375	0.35	1
19	375	0.425	2.25
20	375	0.5	3.5
21	405	0.2	6
22	405	0.275	1
23	405	0.35	2.25
24	405	0.425	3.5
25	405	0.5	4.75

The specimen size diameter 48 mm x 72 mm in length, running experiment following all condition on Table 2. The power meter Fluke 438-II were use in this study for correct the power consumed of each batch and analysis with software Power log 430-II. The surface quality was use Mitutoyo surface testing machine model SV-3100 to finding arithmetical mean roughness value (R_a) and average maximum peak (R_z) as shown in Figure 1.

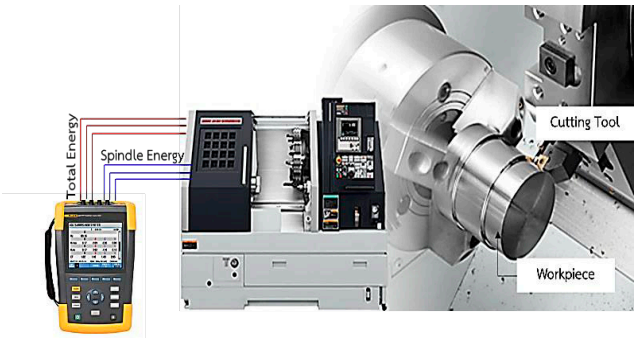

Figure 1 Experimental setup of power measurement

IV. RESULTS AND DISCUSSION

Influence of power consumption

The experimental results of power consumption all motors of machine in the average from 5 times experiment are presented in Table 3.

Table 3 Average power consumption

No.	Power Usage (kW)
1	3.54
2	8.34
3	11.34
4	14.7
5	17.28
6	7.86
7	10.2
8	12.06
9	15.48
10	6.6
11	8.04
12	9.78
13	13.14
14	7.38
15	10.38

Table 3 Average power consumption (Cont.)

No.	Power Usage (kW)
16	7.44
17	10.68
18	5.22
19	8.46
20	12.78
21	8.88
22	3.96
23	7.38
24	11.4
25	15.9

Surface roughness

The experimental results of surface roughness in R_a and R_z are presented in Table 4.

Table 4 Average surface roughness

No. of Experiment	Ra (um)	Rz (um)
1	1.505	6.018
2	2.565	10.809
3	3.323	13.581
4	4.63	18.003
5	6.056	24.793
6	1.456	6.837
7	2.283	9.96
8	3.389	13.904
9	5.199	22.813
10	5.702	21.678
11	1.459	6.526
12	2.263	9.487
13	3.761	15.099
14	4.464	17.196
15	6.086	23.628
16	1.489	6.894
17	2.626	11.118
18	3.28	13.051
19	4.832	18.94
20	5.674	22.372
21	1.599	6.771
22	2.252	9.156

Table 4 Average surface roughness (Cont.)

No. of Experiment	Ra (um)	Rz (um)
23	3.661	14.269
24	4.456	17.899
25	6.245	24.565

ANOVA Analysis Result

The Main effects which influence the 5 cutting conditions that affect power consumption are presented in Figure 2

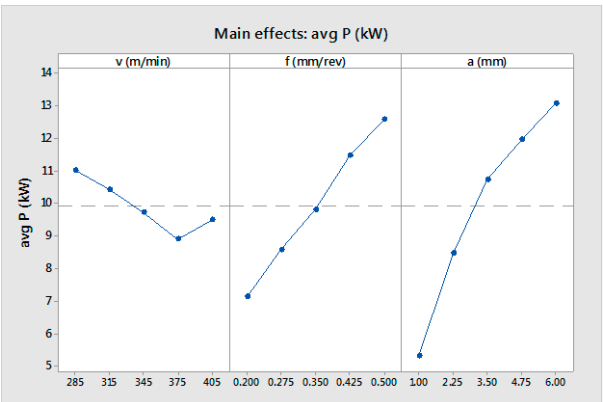

Figure 2 The main effects of the average power consumption (avg P, kW).

The Main effects which influence the 5 cutting conditions that affect surface smoothness are presented in Figure 3.

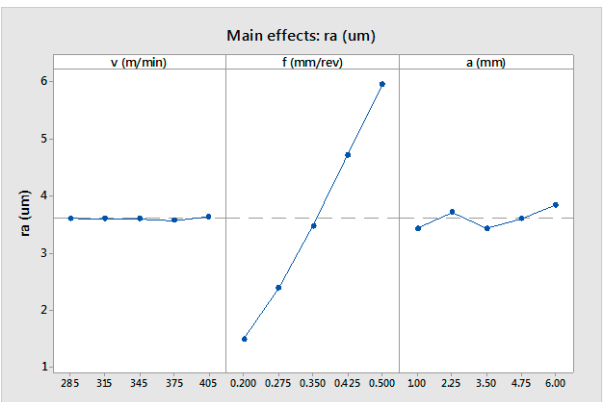

Figure 3 The main effects of surface smoothness (ra, um).

V. CONCLUSION

The results of turning process for S50C confirmed with mean utility concept and Taguchi's technique shown that, for minimizing of total energy consumed, dept of cut is the most significant factor (60.58%) followed by feed rate (30.27%) and cutting speed (4.36%). The minimize of power consumption is 3.54 kW at the cutting parameters as V=285 m/mm, f=0.2 mm/rev and a=1 mm. The most optimal parameter effective to surface roughness is feed rate (98.49%), The height quality of surface roughness Ra=1.456 at the condition as V=315 m/mm, f=0.2 mm/rev and a=2.25 mm at the increasing of feed rate the surface quality will be significantly reduced.

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