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Research Article

ANALYSIS OF SURFACE ROUGHNESS, SOUND LEVEL, VIBRATION AND CURRENT WHEN MACHINING AISI 1040 STEEL

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ABSTRACT

AISI 1040 steel is widely used for production of various parts. This material has been studied by many researchers. In this work, turning tests were carried out on AISI 1040 steel workpieces at five different depth of cuts, four different feed rates and 4 different cutting speeds without coolant. The influence of the cutting parameters on turned part surface roughness, vibration, sound level and machine tool motor current were examined. A full factorial experimental design method was used. The Response Surface Methodology (RSM) and Analysis of Variance (ANOVA) were used to determine the effects of input parameters on the resultant surface roughness, vibration, sound level, current. The experimental results showed that increasing feed rate increased the surface roughness, vibration, sound level and current values. The most effective cutting parameter on all the output parameters was found to be the feed rate. Furthermore as feed rate and depth of cut increased, the current value and sound level also increased.
Keywords: AISI 1040, surface roughness, sound level, vibration, current, ANOVA.

1. INTRODUCTION

AISI 1040 steel is among the most widely used materials in manufacturing industry. Its hardenss can reach up to 55 HRC by heat treatment. It is used for making various parts such as die & mould parts, crankshafts, camshafts, studs, nuts and bolts. Numerous studies have been carried out on the machining of this material [1-6].

Surface quality is highly effective in the manufctured parts' performances. Surface quality also influences the parts' service life especially at higher operating speeds. A surface with high roughness values increases the friction when they are in contact with the other parts. Increasing friction results in higher temperature and this, in turn, increases corrosion, oxidation and wear rate. This shortens the service life of the manufactured products. In addition, the temperature caused by friction prevents the parts from working properley. One of the main factors determining surface roughness is the cutting parameters employed during machining [7]. Therefore, much work has been carried out on surface roughness in machining. The most important cutting parameter for the surface roughness is generally the feed rate [8]. It has been reported that the

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surface roughness value increases as the feed rate increases [9-13]. They examined the influences of cutting parameters on surface roughness. Their experimental results showed that the surface roughness value increased as the feed rate increased.

The vibrations occuring during machining cause many negative situations, especially the degradation of surface quality [14], reduced tool life [15], loss of machine rigidity, shorter machine m aintenance times, noise and chronic diseases for the operator [15-16]. Determination of appropriate cutting parameters reduces the amount of vibration. Therefore, vibration is one of the important research topics in terms of machinability. There are many studies on this subject [17-19].

Energy consumption in machining is of great importance in many respects. Increasing competition has led to the necessity of being economical. Therefore, many studies have been conducted on energy consumption [20-22]. The relationship between cutting parameters and energy consumption was investigated for an economic manufacturing [23-24]. As the feed rate, depth of cut and cutting speed increase, the amount of energy consumption increases. In their research, Zhou et al. have established a mathematical model of effective energy use [23].

On the other hand, fossil fuels are used primarily for energy production. The use of these fuels causes carbon emissions. This causes the ecological and climatic balance to deteriorate. Therefore, the production of a large number of parts with little energy consumption is of great importance in terms of social and environmental problems.

Several statistical analyses were performed to determine the optimal cutting parameters in the complex machining processes [25]. In these studies, the RSM method was used in several studies and the effect rates of the cutting parameters were determined [26-28]. Regression equations were developed for special machining operations. The regression equations express the function between the variables [29].

Although surface roughness, tool wear and cutting forces in machining of AISI 1040 steel have been widely studied, little or no work is seen on vibration, sound level and motor current values in machining of this material [26,27]. This study aims at examining the influnces of the cutting parameters on the surface roughness, sound level, vibration motor current when turning AISI 1040 steel through ANOVA and RSM.

2. MATERIALS AND METHOD

2.1. Workpiece Material

The turning tests were carried out on hot rolled AISI 1040 steel cylindrical workpiece. Table 1 gives the chemical composition AISI 1040 steel. The workpiece part was 50 mm in dimension and 100 mm in length.

Table 1. Chemical composition of AISI 1040 steel (wt. %)

Fe	Mn	P	C	S
98.6-99	0.6-0.9	≤ 0.04	0.37-0.44	≤ 0.05

2.2. Test Procedure, Test Parameters and Tooling

The machining tests were performed dry by single point continuous turning on a TAKSAN TTC 630 turning centre, with a variable spindle speed of up to 4000 rpm and power rating of 37 kW. The cutting tools used were commercial grade TiCN-Al_2O_3-TiN coated carbide with the geometry of WNMG 080408 MT and manufactured by TaequTec. These cutting tools had TT5100 TaeguTec designation conforming to ISO P20-35. A MWLNR 2525 M08 tool holder was used to rigidly mount the cutting tools. The workpiece parts were clamped using a three-jaw precison chuck. The length of the workpiece parts overhanging from the chuck was 70 mm. As the length of the workpiece was quite short, the tailstock was not used to support the workpiece. In order to avoid excessive vibration, the overhang of the tool holder was held as short as possible. The test parameters and their levels are given in Table 2 and they were selected based on the cutting tool manufacturer's recommendation, previous studies and industrial practice.

Table 2. Test parameters and their levels

Factor	S.	Units	Level				
			1	2	3	4	5
Cutting speed	*v*	m/min	50	75	100	125	
Feed rate	*f*	mm/rev	0.1	0.2	0.3	0.4	
Depth of cut	*a*	mm	1	1.5	2	2.5	3

The vibration measurements were performed using a Pro Vibro PVM 303 unit. This unit was mounted behind the chuck. The measurements were obtained in mm/s during the machining operations. In order to measure the sound level, a Lutron SL-401 (The measurement was taken when the device is in position A weighting Character and function of SL) model sound level meter was used. This device was located to a position 1 m away from the chuck and was set to slow mode for eliminating the possible momentary fluctuations in the sound level. The current measurements were conducted using a UNI-T UT201 digital clamp multimeter. The current value passing through a phase was measured and multiplied by three to find the total current value. The pictures of the used devices are given in Figure 1. Output parameters of the vibration, sound level and motor current values were indicated during the machining tests as shown in Figure 1. These indicated values were recorded using a video camera throughout the machining tests. Their average values were calculated.

a) b) c)

Figure 1. The used devices for measurement of a) vibration, b) sound and c) motor current

On the turned surfaces, surface roughness (Ra) measurements were performed using a Mitutoyo SJ 201 with a cut-off length of 0.8 and sampling length of 5 mm. Three measurements were made on each turned surface. The whole test setup is given schematically in Figure 2. For the statistical analysis, Minitab 16 version was used.

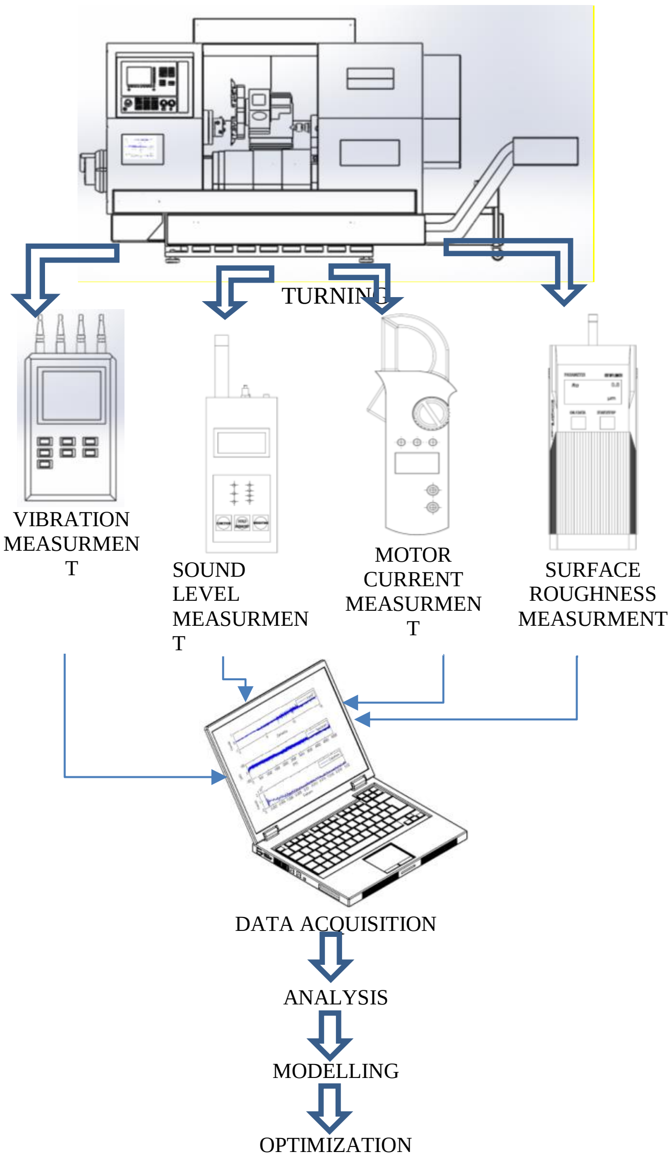

Figure 2. Schematic view of the experimental set-up.

3. RESULTS AND DISCUSSION

Table 4 gives the experimental results of average surface roughness (Ra), sound level (SL), vibration (Vib) and motor current values for all the 80 turning tests.

Table 4. Experimental results of surface roughness, sound level, vibration and motor current

Run	a (mm)	V (m/min)	f (mm/rev)	Vib. (mm/s)	Sound L. dB)	Current (A)	Ra (µm)
1	1	50	0.1	0.1	72.5	8.13	0.69
2	1	50	0.2	0.2	73.4	8.73	1.05
3	1	50	0.3	0.3	74.2	12.8	2.56
4	1	50	0.4	0.5	75.4	14.7	3.81
5	1	75	0.1	0.2	73.4	8.6	0.66
6	1	75	0.2	0.3	74.6	9.9	1.62
7	1	75	0.3	0.4	75.3	15.3	2.69
8	1	75	0.4	0.4	76.6	17.2	3.95
9	1	100	0.1	0.2	74.2	9.21	0.90
10	1	100	0.2	0.3	74.5	12.63	1.44
11	1	100	0.3	0.4	77.4	16.1	2.63
12	1	100	0.4	0.5	79.3	19.2	4.11
13	1	125	0.1	0.3	73.4	9	0.53
14	1	125	0.2	0.3	74.9	15	1.54
15	1	125	0.3	0.6	79.8	18.4	2.74
16	1	125	0.4	0.6	82.3	23.1	3.81
17	1,5	50	0.1	0.2	73.3	6.87	0.77
18	1,5	50	0.2	0.4	73.6	7.98	1.14
19	1,5	50	0.3	0.4	75	10.7	2.55
20	1,5	50	0.4	0.7	76.8	13.3	3.57
21	1,5	75	0.1	0.2	73	8.52	0.72
22	1,5	75	0.2	0.3	74	9.9	1.63
23	1,5	75	0.3	0.5	75	13.2	2.86
24	1,5	75	0.4	0.8	77	15.8	4.75
25	1,5	100	0.1	0.1	74	9.9	0.66
26	1,5	100	0.2	0.3	74	11.7	1.51
27	1,5	100	0.3	0.5	78	15.6	2.62
28	1,5	100	0.4	0.9	81	18.9	4.62
29	1,5	125	0.1	0.2	75	9.6	0.79
30	1,5	125	0.2	0.3	75.7	13.14	1.88
31	1,5	125	0.3	0.6	79.3	17.7	3.13
32	1,5	125	0.4	1	81	21.1	4.20
33	2	50	0.1	0.3	74	7.8	1.48
34	2	50	0.2	0.4	75	9.6	1.92
35	2	50	0.3	0.7	75.8	11.04	3.04
36	2	50	0.4	1.2	77.2	12.03	4.38
37	2	75	0.1	0.3	73	9.84	0.97
38	2	75	0.2	0.4	75	11.4	1.79
39	2	75	0.3	0.7	76	13.17	2.92
40	2	75	0.4	1	78	16.8	4.52

Run	a (mm)	V (m/min)	f (mm/rev)	Vib. (mm/s)	Sound L. dB)	Current (A)	Ra (µm)
41	2	100	0.1	0.2	74.5	11.67	1.05
42	2	100	0.2	0.4	74	13.8	1.68
43	2	100	0.3	0.8	78	16.2	3.36
44	2	100	0.4	1.1	79	18.3	4.37
45	2	125	0.1	0.1	73	11.34	1.08
46	2	125	0.2	0.3	75	14.16	1.54
47	2	125	0.3	0.8	78	17.34	3.06
48	2	125	0.4	1.2	82.6	20.7	4.48
49	2,5	50	0.1	0.4	75.1	9.9	1.48
50	2,5	50	0.2	0.6	73.2	10.92	2.33
51	2,5	50	0.3	0.9	75.6	12.93	3.30
52	2,5	50	0.4	1.3	76.5	14.4	4.54
53	2,5	75	0.1	0.2	72.8	10.68	0.84
54	2,5	75	0.2	0.5	75.1	13.74	1.92
55	2,5	75	0.3	0.7	75.3	16.08	3.04
56	2,5	75	0.4	1.2	77	18.45	4.30
57	2,5	100	0.1	0.2	74	11.7	0.67
58	2,5	100	0.2	0.3	74	14.25	1.93
59	2,5	100	0.3	0.6	76	18	2.94
60	2,5	100	0.4	1.3	78	21.39	4.60
61	2,5	125	0.1	0.2	73	12	0.74
62	2,5	125	0.2	0.4	76	15.39	1.74
63	2,5	125	0.3	0.8	78	19.8	2.87
64	2,5	125	0.4	1.3	81	24.06	4.30
65	3	50	0.1	0.2	72.7	10.2	0.74
66	3	50	0.2	0.7	74.4	11.73	2.38
67	3	50	0.3	1	75	13.5	3.26
68	3	50	0.4	1.4	76	16.5	4.49
69	3	75	0.1	0.3	71.6	10.98	0.74
70	3	75	0.2	0.3	71.6	13.62	1.83
81	3	75	0.3	0.7	73	16.5	3.05
72	3	75	0.4	1.2	75	11.7	3.85
73	3	100	0.1	0.2	72	9	0.97
74	3	100	0.2	0.3	73	10.32	1.15
75	3	100	0.3	0.7	74	11.4	2.43
76	3	100	0.4	1.2	76	13.2	3.80
77	3	125	0.1	0.2	73	9.24	0.79
78	3	125	0.2	0.4	75	10.8	1.24
79	3	125	0.3	0.8	76	12.54	2.43
80	3	125	0.4	1.4	79	14.16	3.83

3.1. Surface Roughness

Main effect plots are given in Fig. 3 for the surface roughness values. As can be seen from Fig. 3, the most effective cutting parameter on surface roughness is the feed rate. With increasing the feed rate, the surface roughness increases. That is because; increasing feed rate leaves larger feed marks on the turned workpiece when turning with a cutting tool having a defined nose radius. Similar findings were also reported in the published studies [13,17,29]. Contrary to the feed rate, increasing the cutting speed decreases the surface roughness. However, this decrease is quite low. In machining operations, increasing cutting speed usually results in decreases in surface roughness. This is obviously seen when machining workpieces of high ductility. This decrease I surface roughness can be attributed to the decreased built-up edge (BUE) tendency. With increasing depth of cut, the surface roughness values increases until a maximum value is reached beyond which they decreased.

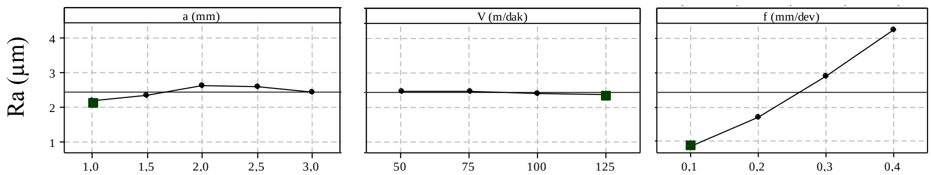

Figure 3. The effect of cutting parameters on means response characteristics for surface roughness.

Analysis of variance (ANOVA) was used to analyse the experimental surface roughness results. ANOVA determines the parameters having significant influence on surface roughness. The level of confidence for the analysis is 95 %. The ANOVA results are given in Table 5. A P-value lower than 0.05 indicates a statistically significant level of the source for the corresponding response. The last column of Table 5 indicates percent contribution of significant source. It is seen from Table 5 that the source f has significant influence on the surface roughness. The percentage contribution of f on the surface roughness is seen to be 94.05. It can be said that the surface roughness is not almost influenced by the depth of cut and cutting speed.

Table 5. ANOVA for surface roughness

Surface roughness							
Source	D	Seq SS	Adj SS	Adj MS	F	P Value	Contr.(%)
a	1	0.923	0.923	0.923	18.36	**0.000**	0.68
v	1	0.145	0.145	0.145	2.89	0.094	0.11
f	1	127.701	127.701	127.701	2541.71	**0.000**	94.05
a^2	1	1.052	1.052	1.052	20.94	**0.000**	0.77
V^2	1	0.006	0.006	0.006	0.11	0.739	0.00
f^2	1	1.370	1.370	1.370	27.27	**0.000**	1.01
a x V	1	1.034	1.034	1.034	20.58	**0.000**	0.76
a X f	1	0.003	0.003	0.003	0.05	0.816	0.00
V x f	1	0.026	0.026	0.026	0.51	0.477	0.02
Error	70	3.517	3.517	0.050			2.59
Total	79	135.776					100.00

Fig. 4 shows the response surface plots of the surface roughness against the cutting parameters. It is also seen from the response surface plots that increasing the feed rate significantly increases the surface roughness.

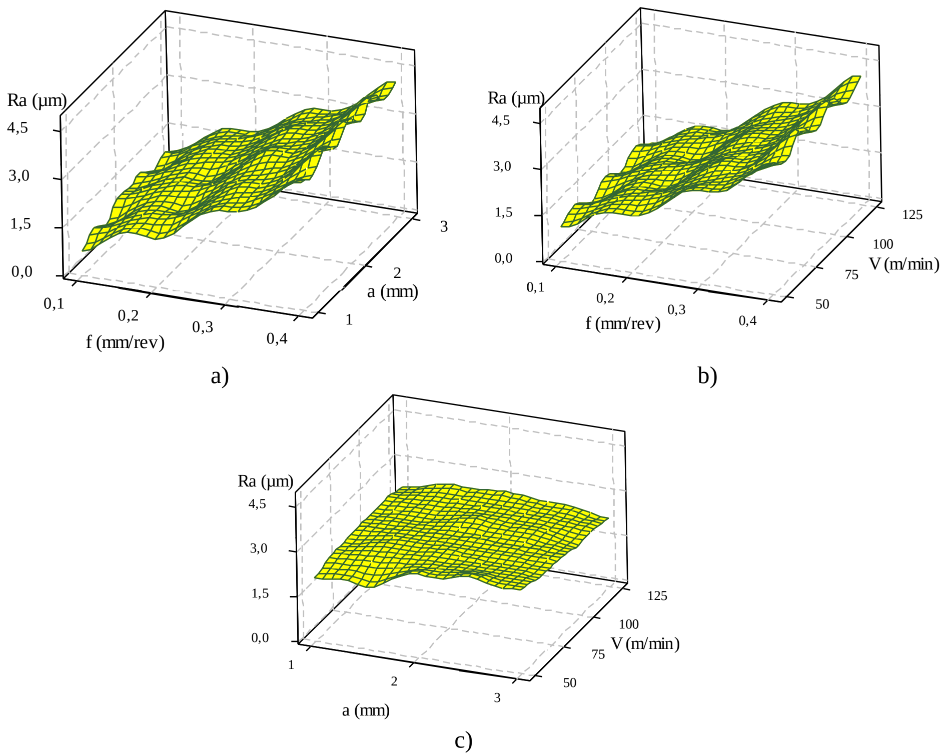

Figure 4. Surface roughness versus a) feed rate and depth of cut, b) feed rate and cutting speed and c) depth of cut and cutting speed.

3.2. Vibration

As shown in Fig. 5, the increase in the depth of cut and feed rate increase the vibration values. The increasing the depth of cut and feed rate increases the load acting on the cutting tool holder. This increase in the load is likely to result in more vibration. Unlike the depth of cut and feed rate, the cutting speed does not have a substantial influence on the vibration. Increasing the cutting speed decreases the vibration to some extent. Although the vibration in the machine tool spindle is expected to increase slightly due to the increase in the cutting speed, the increasing cutting speed decreases built-up edge (BUE) formation and this, in turn, helps decrease the vibration.

Low engine power causes the machine tool to be forced more and results in increased vibration value. The increase in vibration value results in an increase in tool wear and surface roughness values. Therefore, low feed and depth of cut should be preferred when machining materials. This reduces the amount of vibration. Reduction in the amount of vibration results in increased tool life, reduced surface roughness and increased rigidity.

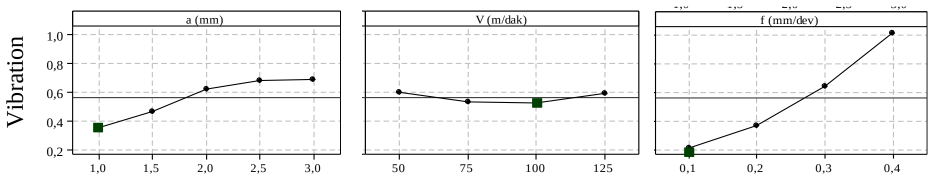

Figure 5. The effect of cutting parameters on means response characteristics for vibration.

The ANOVA results are given in Table 6. It is seen from Table 6 that the sources f and a have significant influence on the vibration. The percentage contributions of f and a on the vibraion are seen to be 68.88 and 12.44, respectively.

Table 6. ANOVA for vibration

Vibration Source	D	Seq SS	Adj SS	Adj MS	F	P Value	Contr.(%)
a	1	1.2781	1.27806	1.27806	169.97	**0.000**	12.44
v	1	0.0004	0.00040	0.00040	0.05	0.818	0.00
f	1	7.0756	7.07560	7.07560	941.00	**0.000**	68.88
a^2	1	0.1072	0.10719	0.10719	14.26	**0.000**	1.04
V^2	1	0.0845	0.08450	0.08450	11.24	**0.001**	0.82
f^2	1	0.2205	0.22050	0.22050	29.32	**0.000**	2.15
a x V	1	0.1378	0.13781	0.13781	18.33	**0.000**	1.34
a X f	1	0.7875	0.78751	0.78751	104.73	**0.000**	7.67
V x f	1	0.0541	0.05408	0.05408	7.19	0.009	0.53
Error	70	0.5263	0.52634	0.00752			5.12
Total	79	10.2720					100.00

As can also be seen from Fig. 6, the feed rate has the highest influence on the vibration. Therefore, increasing the surface roughness values with increasing the feed rate (Fig. 3 and Fig. 4) can also be attributed to the increasing vibration.

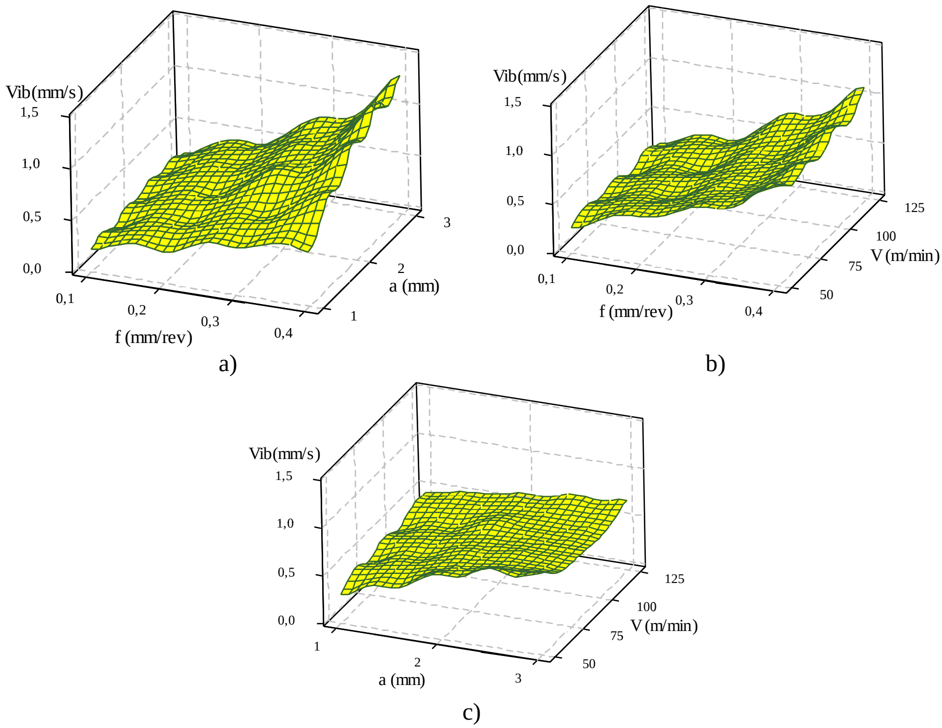

Figure 6. Vibration versus a) feed rate and depth of cut, b) feed rate and cutting speed and c) depth of cut and cutting speed.

3.3. Sound Level

Figure 7 shows that the sound level varies depending on the cutting parameters employed. The most influential cutting parameter on the sound level is seen to be the feed rate. This is followed by the cutting speed and depth of cut. Increasing the feed rate and cutting speed increases the sound level. However, with the increasing depth of cut, the sound level increases until a maximum value is reached beyond which they decreased. Increasing depth of cut was expected to increase the sound level similar to the influence of increasing feed rate. However, this did not happen. During the turning operation, the chip morphology was seen to change with the depth of cut. At the lower depth of cuts, continouous chips were formed while at the higher depth of cuts short chips were formed. This was thought to result in the irregularities in the sound level.

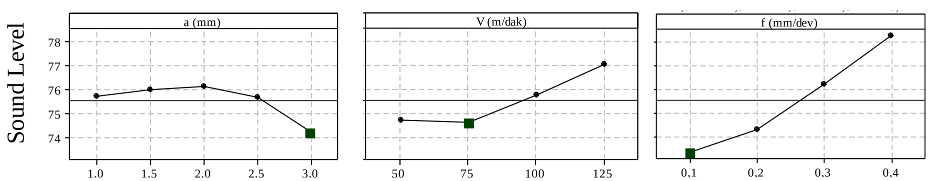

Figure 7. The effect of cutting parameters on means response characteristics for sound level.

The ANOVA results are given in Table 7. It is seen from Table 7 that the sources f and v have significant influences on the sound level. The percentage contributions of f and v on the sound level are seen to be 56.92 and 13.61, respectively. Fig. 8 shows the influences of cutting parameters on the sound level.

Table 7. ANOVA for sound level

Sound level							
Source	D	Seq SS	Adj SS	Adj MS	F	P Value	Contr.(%)
a	1	17.490	17.490	17.490	29.28	**0.000**	3.65
v	1	65.206	65.206	65.206	109.15	**0.000**	13.61
f	1	272.745	272.745	272.745	456.58	**0.000**	56.92
a^2	1	19.153	19.153	19.153	32.06	**0.000**	4.00
V^2	1	10.153	10.153	10.153	17.00	**0.000**	2.12
f^2	1	5.778	5.778	5.778	9.67	**0.003**	1.21
a x V	1	8.757	8.757	8.757	14.66	**0.000**	1.83
a X f	1	2.322	2.322	2.322	3.89	0.053	0.48
V x f	1	35.725	35.725	35.725	59.80	**0.000**	7.46
Error	70	41.816	41.816	0.597			8.73
Total	79	479.145					100.00

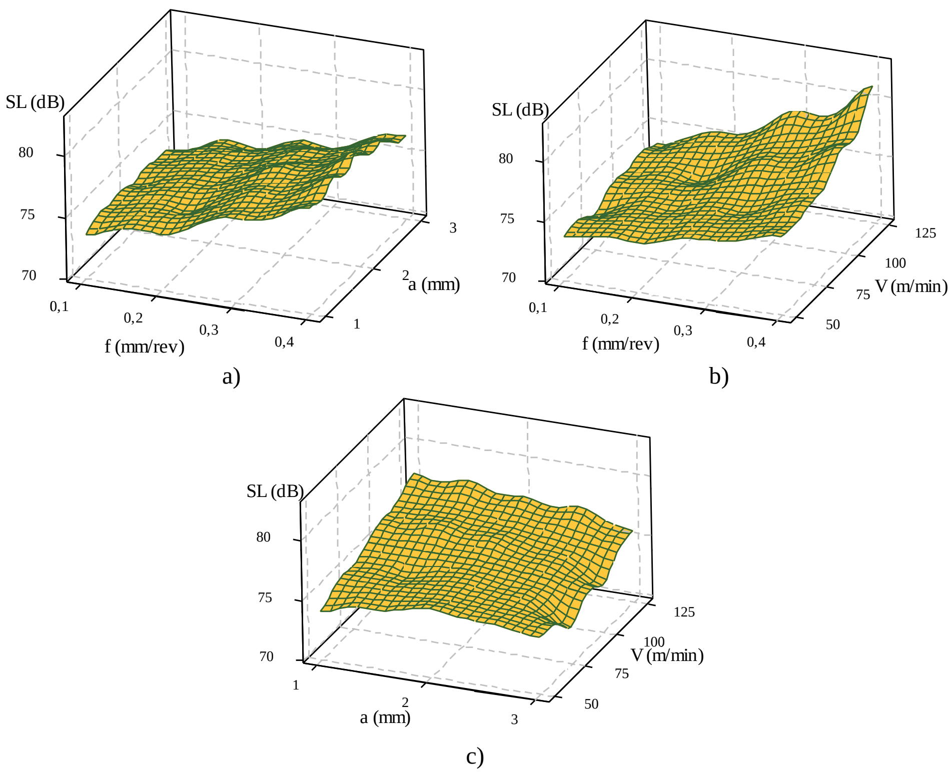

Figure 8. Sound level versus a) feed rate and depth of cut, b) feed rate and cutting speed and c) depth of cut and cutting speed.

3.4. Motor Current

Determination of the cutting forces in a machining operation is important. That is because, the cutting forces have a direct influence on the generation of heat, and thus on tool wear, quality of machined surface and accuracy of workpiece. They are also used in the design of machine tools, cutting tools and fixtures [30]. The cutting forces are generally measured using dynamometers which are expensive devices and not easy to use. There are some indirect methods to determine the cutting forces. These methods are generally practical and inexpensive. Motor current is such a way to determine the cutting forces.

Motor current values obtained in this study are given in Figure 9. As the feed rate, the depth of cut and the cutting speed increase, the motor current value generally increases. These increases in the motor current are the expected results as the increasing depth of cut, cutting speed and feed rate increases the power consumption. Fig. 10 shows the influences of cutting parameters on the motor current.

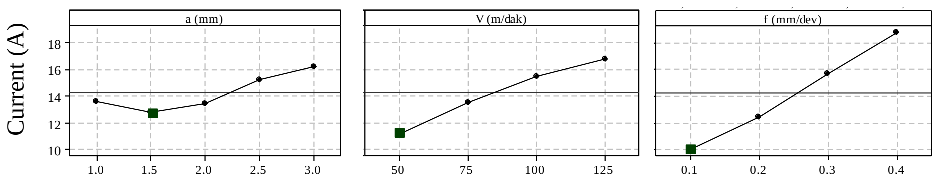

Figure 9. The effect of cutting parameters on means response characteristics for motor current.

The ANOVA results are given in Table 8. It is seen from Table 8 that the sources f, v and a have significant influences on the motor current. The percentage contributions of f, v and a on the sound level are seen to be 59.96, 24.322 and 6.506, respectively. Fig. 10 shows the influences of cutting parameters on the sound level.

Table 8. ANOVA for motor current

Current Source	D	Seq SS	Adj SS	Adj MS	F	P Value	Contr.(%)
a	1	94.10	94.10	94.096	142.65	**0.000**	6.506
v	1	351.77	351.77	351.769	533.30	**0.000**	24.322
f	1	867.21	867.21	867.214	1314.74	**0.000**	59.960
a^2	1	26.43	26.43	26.428	40.07	**0.000**	1.827
V^2	1	5.48	5.48	5.476	8.30	**0.005**	0.379
f^2	1	2.04	2.04	2.038	3.09	0.083	0.141
a x V	1	0.13	0.13	0.128	0.19	0.662	0.009
a X f	1	0.03	0.03	0.033	0.05	0.825	0.002
V x f	1	52.95	52.95	52.952	80.28	**0.000**	101.827
Error	70	46.17	46.17	0.660			3.192
Total	79	1446.31					100.000

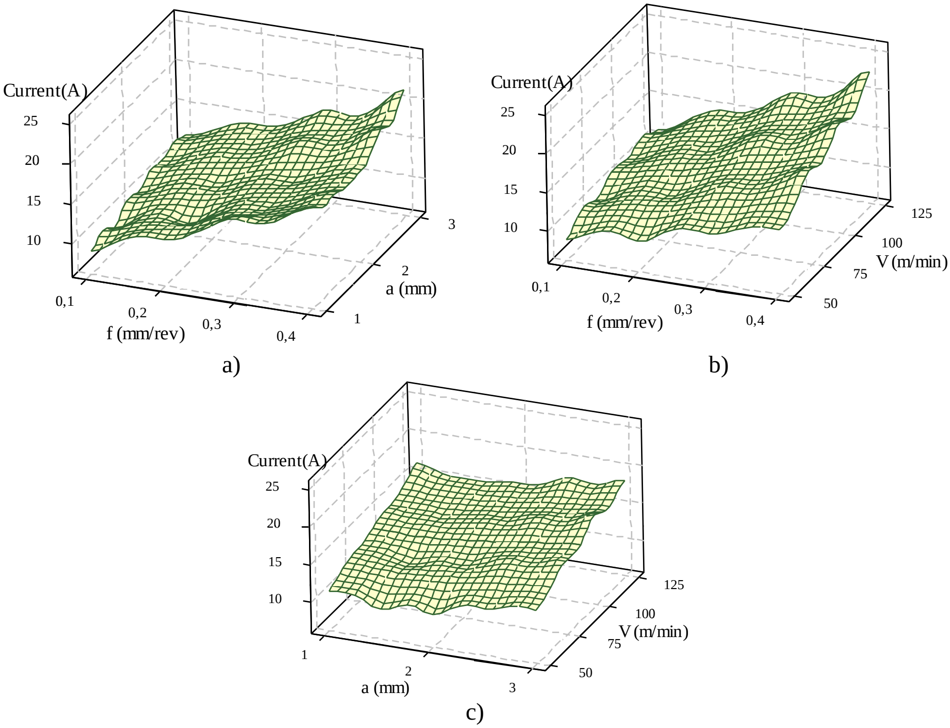

Figure 10. Motor current versus a) feed rate and depth of cut, b) feed rate and cutting speed and c) depth of cut and cutting speed.

3.5. Optimum Values of Cutting Parameters

In particular, it is difficult to determine the optimum cutting parameters in a machining operation as there are a lot of input factors. Table 9 shows the effects of optimum levels of the input factors on the output factors. The lowest values of the output factors were defined as the optimum levels and these are shown in boldface type.

Table 9. Optimum values of cutting parameters for surface roughness, vibration, sound level and motor current

S	Ra (µm)			Vib. (mm/s)			Sound Level (dB)			Current (A)		
	a	*v*	*f*	*a*	*v*	*f*	*a*	*v*	*f*	*a*	*v*	*f*
1	**2.1702**	2.4733	**0.8723**	**0.3500**	0.5950	**0.2150**	75.7000	74.7350	**73.3750**	13.6250	**11.1880**	**10.0475**
2	2.3369	2.4552	1.6960	0.4625	0.5300	0.3700	75.9813	74.6150	74.3000	**12.7444**	13.5475	12.4650
3	2.6031	2.4123	2.8930	0.6188	**0.5250**	0.6450	76.1313	75.7450	76.2350	13.4494	15.4820	15.7220
4	2.5967	**2.3607**	4.2402	0.6813	0.5900	1.0100	75.6625	**77.0500**	78.2350	15.2306	16.7950	18.7780
5	2.4200			0.6875			**74.2063**			16.2163		
D	1	4	1	1	3	1	5	4	1	2	1	1

3.6. Regression Equations

Regression equations were obtained for surface roughness, vibration, sound level and motor current using Minitab 16 software. These equations are given below.

Regression equation for surface roughness:

$$R^2 = 1 - \frac{SS_{residual}}{SS_{model} + SS_{residual}}$$

$$SS_{residual} = 3.517\ SS_{model} = 135.776 \text{ (Tablo3 den)}$$

$$R^2 = 1 - \frac{3.517}{135.776 + 3.517} = 0.974751 = 97.47\%$$

$$Ra = -1{,}88578 + 1{,}77020 * a + 0.0108943 * v + 4{,}40365 * f - 0.2741107 * a^2 - 0.0000134 * v^2 + 13{,}0875 * f^2 - 0.00575267 * a * v - 0.0741667 * a * f + 0.00573067 * v * f$$

R^2=97.47 % R^2(adj)=97.08%

Regression equation for vibration:

$$Vib = 0.30025 + 0.39875 * a - 0.00706 * v - 3{,}203 * f - 0.087 * a^2 + 0.000052 * v^2 + 5{,}25 * f^2 - 0.0021 * a * v + 1{,}255 * a * f + 0.00832 * v * f$$

R^2=94.88% . R^2(adj)=94.22%

Regression equation for sound level:

$$SL = 71.7433 + 6.02082 * a - 0.08743 * v - 11.3235 * f - 1.16964 * a^2 + 0.00057 * v^2 + 26.875 * f^2 - 0.01674 * a * v - 2.155 * a * f + 0.21384 * v * f$$

R^2(adj)=91.27%. R^2(adj)=90.15%

Regression equation for motor current:

$$Current = 5.9091 - 4.07496 * a + 0.079151 * v - 0.80285 * f + 1.37393 * a^2 - 0.0004186 * v^2 + 15.9625 * f^2 + 0.00202 * a * v - 0.255 * a * f * +0.260344 * v * f$$

R^2=96.81%. R^2(adj)=96.40%

4. CONCLUSIONS

1. Surface roughness, vibration, sound level and motor current values varied depending on the employed cutting speed, feed rate and depth cut in machining of AISI 1040 steel.
2. Based on the ANOVA analysis results, it was seen that the feed rate had the highest influence (90 %) on the surface roughness. The cutting speed and depth of were not found to have a significant influence on the surface roughness. The surface roughness was modelled with 97 % accuracy.
3. The feed rate was found to be the most influential cutting parameter on the vibration. Incrasing the feed rate and depth of cut increased the vibration. This was followed by the depth of cut. The vibration was modelled with 95 % accuracy.
4. The most influential parameter on the sound level was the feed rate. It is influence on the sound level was found to be 57 %. The feed rate was followed by the cutting speed. Incresing the feed rate and cutting speed increased the sound level. The sound level was modelled with 91 % accuracy.
5. The motor current values were influenced by feed rate, cutting speed and depth of cut by 60 %, 24 % and 7 %, respectively. Increase in all the three cutting parameters increased the motor crrent values. The motor current was modelled with 97 % accuracy.

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