INVESTIGATION OF THE EFFECTS OF THE CUTTING PARAMETERS AND COOLANT ON THE SURFACE ROUGHNESS VALUE IN THE MACHINING OF AISI 4340 WITH CBN TOOLS

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ABSTRACT
With the heat treatment applied to the workpiece, the material gains are abrasion resistance, friction resistance, thermal resistance and strength. However, hardening of the material makes to machining is difficult. Advances in machine tool and CBN insert technology have facilitated the machining of hard materials. Since CBN tools also prevent the increase of temperature, the use of coolant is not required. In addition, achieving a grinding quality surface makes it possible to use hard turning as an alternative to grinding. In this experimental study, AISI 4340 material with CBN tooling experiments which were increased to 63 HRC hardness by heat treatment were applied. Cutting is done under cooling and dry cutting conditions. Machining experiments were carried out at 3 different cutting speeds and 3 different feed rate at constant depth of cut. It was observed that surface roughness value increased with increasing feed rate. It was observed that dry cutting conditions decreased the surface roughness value in a small amount.

Keywords: AISI 4340, hard turning, CBN, surface roughness

Introduction

The increase in world population and economic levels has led to the use of more machines or devices. The use of more technological devices has led to more energy consumption. Processing of raw materials and production of these devices causes energy consumption. Not only the production phase, but much of the energy consumption occurs in the use of the devices. Therefore, the efficiency of machines and devices should be high and should be produced with minimum energy. In the efficiency of machines and devices, the surface quality of the machine parts is of great importance. At the same time, reducing machine weights reduces friction. Reducing the weight of the machine makes it both more efficient and lower raw material consumption. For all these reasons, the machinability of AISI 4340 material was investigated by a lot of researcher [1-4]. The material has been given high strength by heat treatment. It is aimed to make the machine part work efficiently by the attention to the good surface quality. The processing time is kept short in order to minimize costs. Cutting parameters have been examined to minimize energy consumption.

Energy consumption is one of the main factors in the manufacturing industry[5-8]. Because a significant part of the energy consumption belongs to the manufacturing industry. So the solution of many problems in energy consumption belongs to the manufacturing industry. The type of energy used in the manufacturing industry is electrical energy. Most of the electrical energy is obtained from fossil fuels (coal, oil and natural gas). As a result of combustion of fossil fuels, the emitted gases accumulate in the atmosphere. These gases accumulate in the atmosphere, creating a greenhouse gas effect. It causes the rays coming from the sun to cling and increase the temperature on our planet. This increase in temperature causes the glaciers to melt and increase the water level. In addition, an increase in temperature causes an increase in evaporation. Clouds formed by increasing evaporation cause heavy rainfall or hail. Causes of torrential rains, floods and disasters. Causes loss of life and property. It causes damage to agricultural land and decreases grain products. It also causes damage to fruits and vegetables. These conditions cause an adequate nutrition problem. Therefore, health problems due to malnutrition are likely to occur.

Energy efficiency can be achieved with higher quality products. It is very important for the quality of the products that the surface roughness value is low [9-11]. Because the lower roughness value results in lower friction force. Lower friction forces less heat generation and less energy consumption. Transportation, textile, food, mold, medicine, furniture, construction, agriculture, such as the use of all areas of life in the manufacture of machines that will provide a good surface quality energy saving is at a very high level.

Another concept that is as important as the surface quality of materials; high abrasion and friction resistance. It is possible to obtain these properties by heat treatment with very low cost. It is also possible to increase the strength of the material up to 3 times. Therefore, the material used is reduced by 3 times. Lower material weight also results in lower frictional forces. It is of great importance to examine the workability conditions of these materials, which have been widely used with the developing technology in recent years.

In this study; In order to produce high quality products in a short time with minimum energy consumption, a detailed examination is provided in this study. The effects of the parameters were analyzed by statistical methods. Mathematical models have been extracted.

Materials and Methods

The use of AISI 4340 materials is increasing day by day. Because high strength, heat treatment suitability, abrasion and friction resistance meet many expectations in the industry. In addition, the high surface quality achieved in hard turning of the material is also of great importance. Therefore, AISI 4340 material of 50 mm diameter and 250 mm length was selected. The center was drilled before the material was hardened. The workpiece material was allowed to stand at 950 C for 2 hours, then was suddenly cooled in oil. Tempering at 350 C was done to get the tension of the material. It was tested whether the desired properties were acquired or not. Hardness value of 50 HRC was reached. The material is connected between tailstock and mirror. Some material was removed from the surface and prepared for processing experiments.

These materials need to be processed on high-rigidity machines. Therefore, TTC 630 model CNC lathe of TAKSAN company was used in this experimental study. This machine has 20 KW power. The machine tool does not lose its precision at high cutting speeds.

Inserts with Sandvik Coromant DCGW11T304 geometry are used for the turning of hard materials. Coolant was used in the cutting process. The tool holder DDJNR 2525K was used. The tool holder is connected at a distance of 10 mm to reduce vibration. In determining the cutting parameters, data in the literature and tool catalog values were taken into consideration.

At the time of Machining, UNI-T UT 201 clamp multimeter was used to measure the current value. A phase value was measured. The voltage values are taken from the regulator. Total power consumption is calculated by multiplying the total time.

Immediately after the machining test, the surface roughness value was measured with the Mitutoyo SJ 201 roughness tester. Measurements were taken at 3 different points and the aricmetic mean was calculated. The sampling range was selected as 0.8.

Experiment results

Experimental results and predictive values obtained at 2 different cutting conditions such as dry cutting conditions (1) and the use of coolant at a constant depth of chip depth of 0.1 mm, 3 different cutting speeds, 3 different feed rate, are given in Figure 1.

Deney No	C.C.	V (m/min)	F (mm/rev)	Ra(µm) (Exp.)	Ra(µm) (Esti.)	Current(A) (Exp.)	Current(A) (Esti.)
1	1	140	0,04	0,28	0,290	2,46	2,453
2	1	140	0,06	0,59	0,607	2,51	2,528
3	1	140	0,08	1,91	1,923	2,6	2,603
4	1	160	0,04	0,32	0,283	2,54	2,549
5	1	160	0,06	0,55	0,618	2,65	2,624
6	1	160	0,08	2,01	1,953	2,71	2,699
7	1	180	0,04	0,4	0,281	2,65	2,646
8	1	180	0,06	0,59	0,635	2,71	2,721
9	1	180	0,08	1,99	1,989	2,79	2,796
10	2	140	0,04	0,31	0,290	2,44	2,422
11	2	140	0,06	0,69	0,607	2,48	2,495
12	2	140	0,08	1,9	1,923	2,55	2,568
13	2	160	0,04	0,24	0,283	2,47	2,470
14	2	160	0,06	0,65	0,618	2,58	2,543
15	2	160	0,08	1,98	1,953	2,61	2,617
16	2	180	0,04	0,2	0,281	2,49	2,518
17	2	180	0,06	0,69	0,635	2,59	2,592
18	2	180	0,08	1,98	1,989	2,68	2,665

Figure 1. Estimated results in experimental studies and mathematical models obtained

Surface roughness

As shown in Figure 1, the surface roughness value increases with increasing feed rate. The depth of the helical channels on the surface increases due to the increase in the feed rate. At lower feed rates, the difference between the high and low zones decreases. Therefore, the surface roughness value decreases.

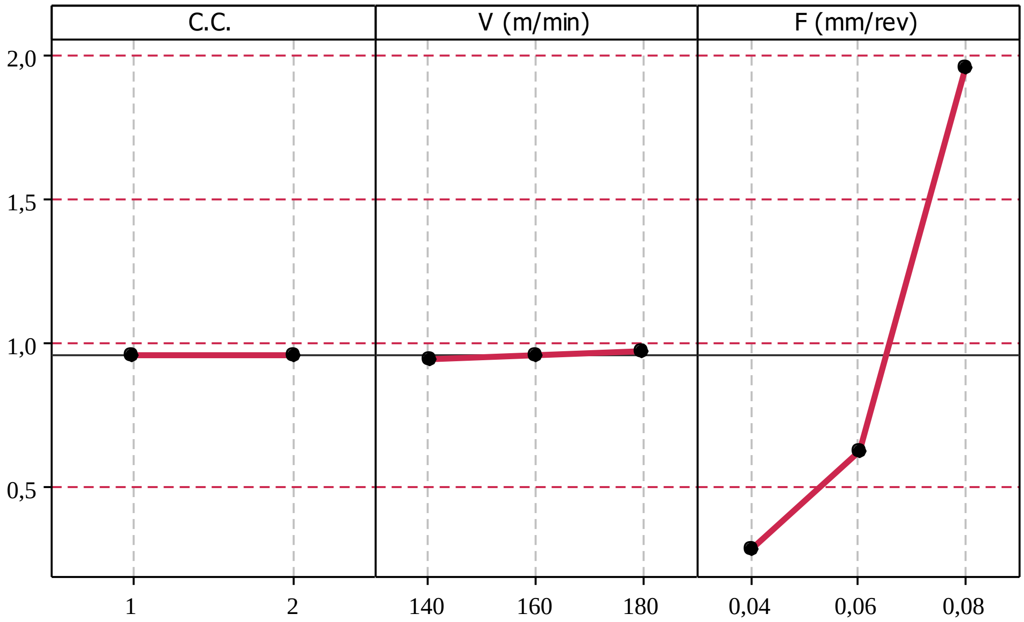

Figure 2. Effects of cooling method, cutting speed and feed rate on surface roughness value

As shown in Figure 2, the effect of the cutting parameter on the surface roughness value when remove material with CBN tools. Because of the manufacturing technology of CBN tools, high hardness materials (55-65 HRC) are processed without the use of coolant. The feed rate appears to have a significant impact. The increase in the feed rate causes deterioration of surface quality.

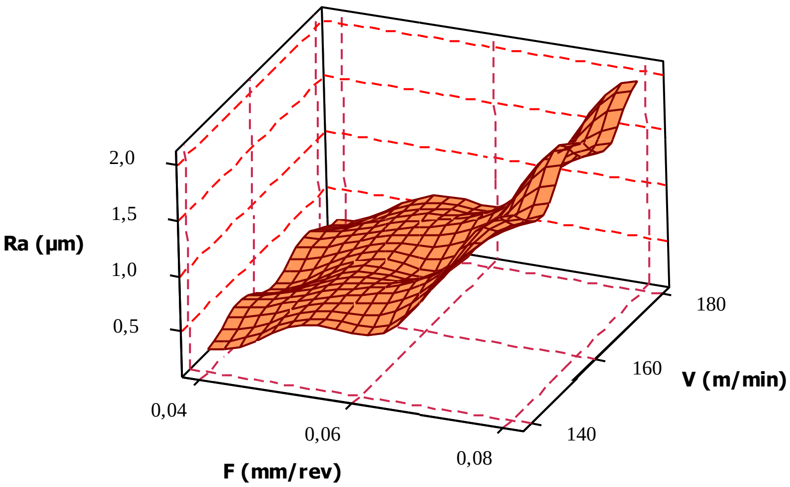

Figure 3. Relationship between surface roughness and cutting parameters

The ANOVA results of the surface roughness values are given in Figure 4.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Cont.
Regression	5	9,37195	9,37195	1,87439	486,28	0,000	99,5
Linear	2	8,36911	8,36911	4,18455	1085,62	0,000	88,9
V (m/min)	1	0,00241	0,00241	0,00241	0,62	0,445	0,0
F (mm/rev)	1	8,36670	8,36670	8,36670	2170,62	0,000	88,8
Square	2	1,00003	1,00003	0,50001	129,72	0,000	10,6
V (m/min)*V (m/min)	1	0,00003	0,00003	0,00003	0,01	0,937	0,0
F (mm/rev)*F (mm/rev)	1	1,00000	1,00000	1,00000	259,44	0,000	10,6
Interaction	1	0,00281	0,00281	0,00281	0,73	0,410	0,0
V (m/min)*F (mm/rev)	1	0,00281	0,00281	0,00281	0,73	0,410	0,0
Residual Error	12	0,04625	0,04625	0,00385			0,5
Lack-of-Fit	3	0,00705	0,00705	0,00235	0,54	0,667	0,1
Pure Error	9	0,03920	0,03920	0,00436			0,4
Total	17	9,41820					100,0

Figure 4. ANOVA for surface roughness

According to the variance analysis, the parameter which has the greatest effect on the surface roughness value is the feed rate. It has an effect of 99.5%. This effect is so high that the number of parameters is limited. If one of the input parameters is tool radisu, this effect rate may be slightly reduced.

$Ra= 3,11-0,00410417*V-115,750*f+0,00000625*V^2+1250*f^2+0,0468750*V*f$

R^2= 99,51% R^2(pred) = 98,85%

With the regression formula obtained at 95% confidence interval, highly accurate experimental results can be predicted.

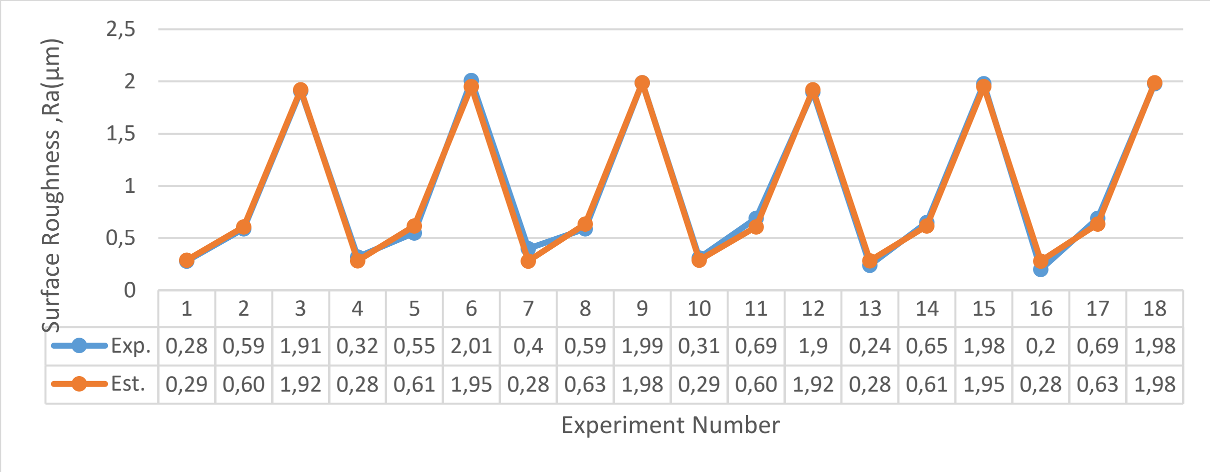

Figure 5. Comparison of experimental results and predictive results for surface roughness value.

Mathematical model was obtained depending on cutting speed and feed rate. A simple mathematical model and experimental results are very similar. Therefore, it is possible to predict the surface roughness value at the desired cutting speed and feed rate.

Current Current Rating

The ANOVA results of the instantaneous current values are given in Figure 6.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	0,165706	0,165706	0,033141	84,22	0,000
Linear	3	0,158689	0,158689	0,052896	134,42	0,000
C.C.	1	0,029606	0,029606	0,029606	75,23	0,000
V (m/min)	1	0,063075	0,063075	0,063075	160,28	0,000
F (mm/rev)	1	0,066008	0,066008	0,066008	167,74	0,000
Interaction	2	0,007017	0,007017	0,003508	8,92	0,004
C.C.*V (m/min)	1	0,007008	0,007008	0,007008	17,81	0,001
C.C.*F (mm/rev)	1	0,000008	0,000008	0,000008	0,02	0,887
Residual Error	12	0,004722	0,004722	0,000394		
Total	17	0,170428				

Figure 6. Analysis of Variance for Current (A)

The most effective parameter on the current value is the feed rate. This is followed by cutting speed and cooling method. All three parameters have a certain effect on the current value.

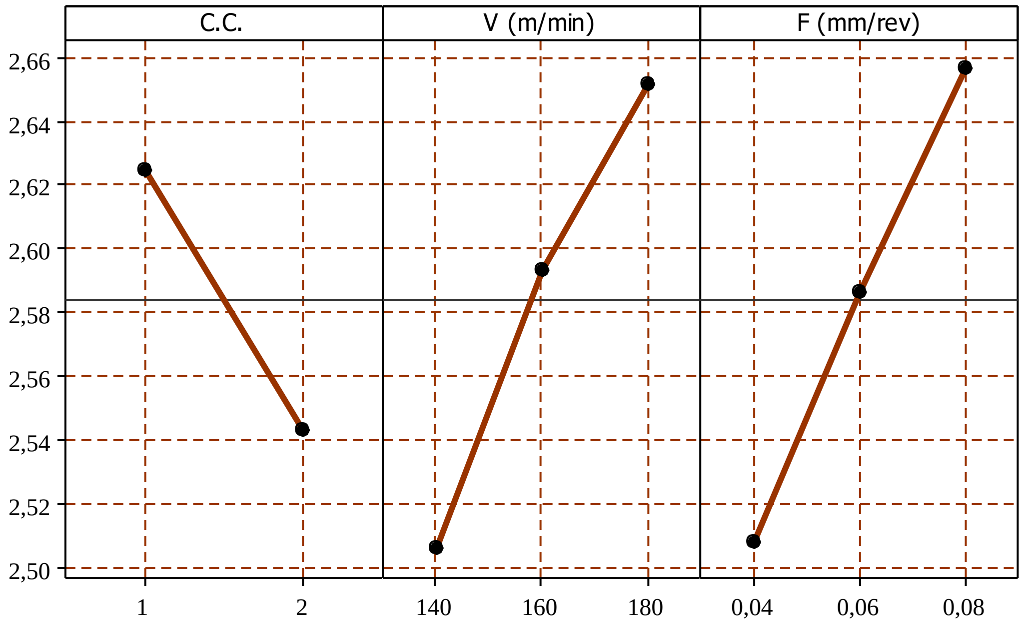

Figure 7. The effect of cutting conditions on the instantaneous current value

As shown in Figures 6 and 7, the instantaneous current value increases with increasing feed rate and cutting speed. Has a significant impact on the current value.

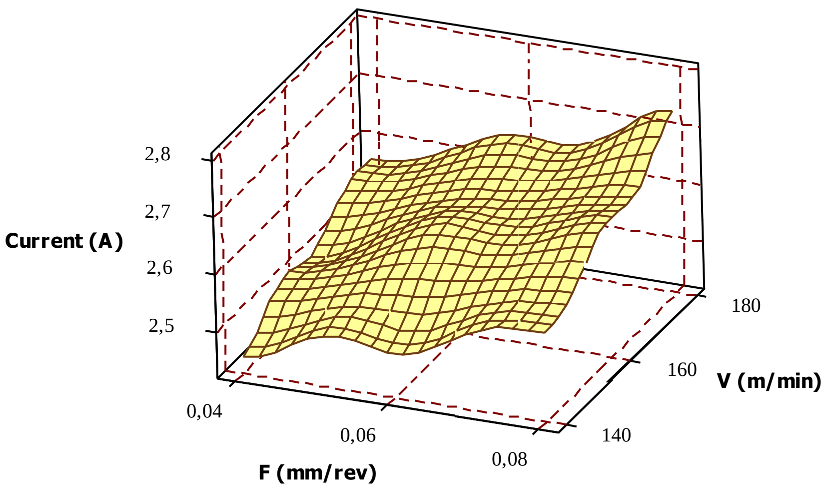

Figure 8. The relationship between current value and cutting parameters

The increase in feed rate reduces the machining time. One increases the amount of material removed in time. Therefore, the load amount per unit time increases and the instantaneous current value increases. However, as the machinig time is shortened, the total power consumption or energy consumption is reduced.

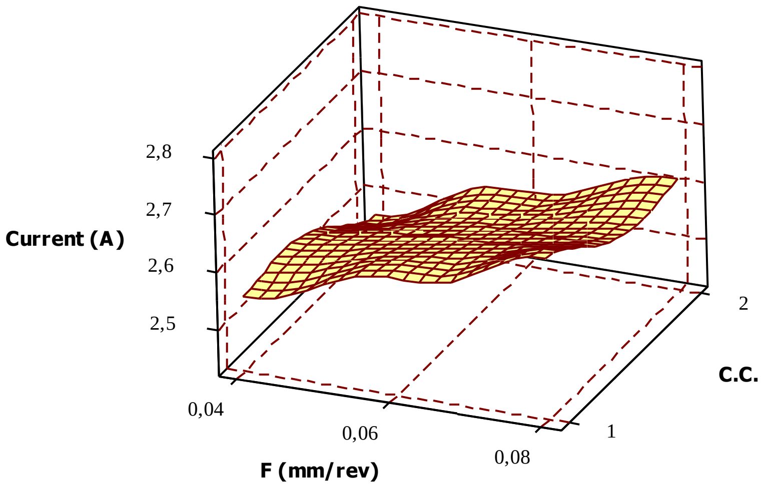

Figure 9. Effects of progress and cooling on current value

The feed rate, the change in current value at dry or coolant cut is shown in figure 8. The cooling condition No. 1 is dry cutting. The cutting condition 2 is the cutting condition with coolant. The coolant did cause some current to decrease. The basilica factor is the lubricant effect of the coolant. This facilitates chip flow. Chip flow is easier to reduce the amount of load on the machine and the instantaneous current value decreases.

Current(A) =1,31556+ 0,310556* C.C. +0,00725000*V +3,83333*f -0,00241667*C.C*v -0,0833333*C.C.*f

R^2 = 97,23% R^2(pred) = 94,04% R^2(adj) = 96,07%

A mathematical model of the current value based on cooling conditions, feed rate and cutting speed was established. Estimated results are obtained with a high value of 97.23% in the 95% confidence interval.

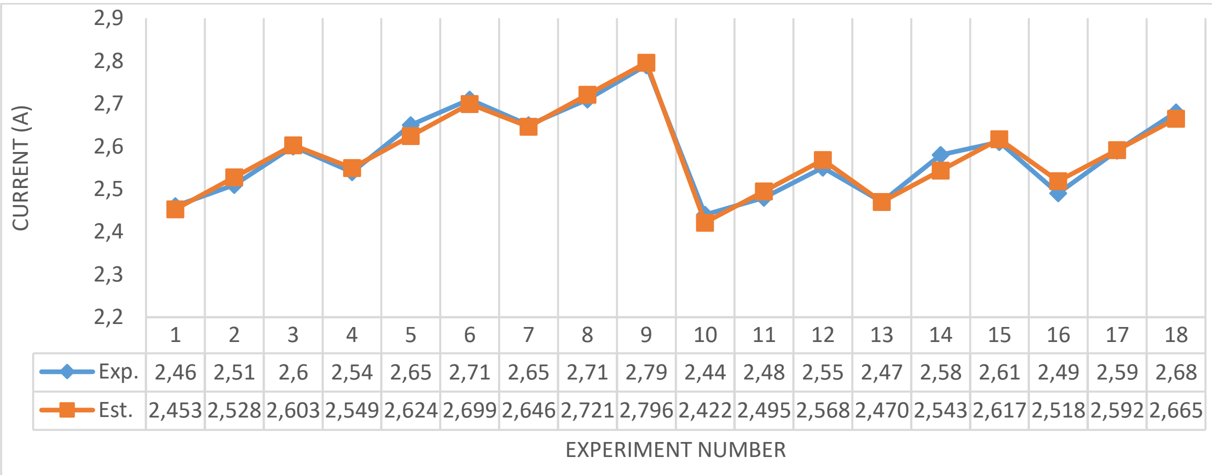

Figure 10. Comparison of experimental results and estimated values for current value

According to the obtained mathematical model, the estimated values and experimental results are very close to each other. A successful regression formula was obtained.

Results

According to the experimental results;

The most effective parameter on the surface roughness value is the feed rate. The increase in the feed rate caused the surface roughness value to increase. While the cutting speed had little effect on the surface roughness value, the cooling system was found to be ineffective.

Mathematical model of surface roughness value is obtained. It was seen that the experiments and estimated result values were very close to each other for surface roughness.

It was found that cooling, feed rate and cutting speed were effective on the instantaneous current value. With the increase in feed rate and cutting speed, instantaneous current value increases. Instantaneous current value decreases in cut using coolant.

Mathematical model of instantaneous current value is obtained. The results of the experiments showed that the estimated current values were very close to each other.

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