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RESEARCH ARTICLE

INVESTIGATION of the CORRELATION BETWEEN POWER CONSUMPTION and SURFACE ROUGHNESS in the TURNING of HARDENED DIN 1.2367 STEEL

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ABSTRACT

Increasing demands in the industrial sector have also increased costs. The share of electricity costs is quite high in these cost increases. Therefore, electricity expenses have become an important phenomenon in the manufacturing sector. On the other hand, brought efficiency to the fore increasing costs in the manufacturing sector. It is tried to give data that will contribute to productivity in manufacturing sectors with this research. The influences of cutting parameters that these are depth of cut, feed rate, and speed of cutting were examined on roughness of surface, power consumption and current of machine through turning of DIN 1.2367 steel using cutting tools are made of coated carbide under dry test case in this study. This study attempts to develop prediction and optimization models to analyze the effect of turning parameters on roughness of surface, power consumption, and ultimately roughness of surface and simultaneous consumption of power. The values of total power consumption were calculated by time of machining and instantaneous current values in the study.

The study results indicated that feed rate has the most important influence on output parameters. The value of surface roughness raised with increasing values of feed rate (56.86 % feed rate). It has been examined that grinding quality surface is obtained, especially at low feed values. The power consumption value increases with rising cutting speed and cut of depth (38.50 % cutting depth) values. Also, the rising in the depth of cut values is effective in the increase in power consumption values.

Keywords: *Hard turning, power consumption, energy, surface roughness.*

1. INTRODUCTION

With the advancement of technology, new equipment and machines are affecting human life. The parts of machine that make up these machines determine the performance of the machine. It is desirable to have a high strength of the machine parts. The high strength of machine parts is provided by heat treatment. Heat treatment increases the strength of the machine part, making it difficult to work. The turning of materials having a hardness above 45 HRC is named hard turning. As the hardness of the materials increases, the resistance to friction increases with the strength. Friction resistance increases the service life of the machine part [1-5].

Increasing the service life is a significant factor in choosing a machine and equipment. It is not desirable that the machines fail, or the service life is short. It is often a waste of raw material when the machine happens inefficient. The raw material, which is limited to raised production amount, should be used more effectually. Further, a shorter machine life reasons more energy sources to be consumed. Another factor in increasing machine life is the surface roughness and cutting parameters. Surface roughness is a sensitive quality criterion that indicates the quality of a product and is effective in the joint surface of two parts. In another saying, the surface roughness is a widely used product quality index in terms of different parameters like aesthetics, resistance of corrosion, considerations of tribological, improvement of the fatigue life, exact fit of crucial mating surfaces. However, achieving a predefined surface roughness and being under certain limits often rises consumption of power and reduces efficiency.

Many studies on the optimization of cutting parameters for roughness of surface, forces, wear of tool, etc. has been done in the last years. But a few studies have been done to optimize the energy productivity of machine tools. Metal cutting processes have been optimized based on economic and technological matters without environmental aspects, formerly [6]. Several studies [7-10] done for optimization of surface roughness and consumption of power for unlike materials indicate opposite results – a small number of researchers have investigated cutting speed is the most important impact by watched by cutting depth in reducing power consumption for CNC machine tools. Moreover, some researchers [11-12] examined that cut of depth is the important factor tracked by cutting speed to decrease the consumption of power. Also, feed rate is the important factor traced by depth of cut to decrease the power consumption was observed in some studies [13-14]. So, more studies are needed to observe the effect of turning parameters on performance features.

Recent review articles on machining indicate that the most mutual turning performances noted by investigators are the machining / manufacturing cost and material removal rate after roughness of surface [15]. Recently, researchers have begun analyzing and optimizing consumption of power in turning progress [16-17]. Savings of energy up to 6-40% can be get based on the best optimal selection of machine tools, parameters of cutting and the suitable optimum tool path design [18]. The impacts of cutting parameters (cutting depth, speed of cutting, and feed rate) on power consumption and roughness of surface were examined on Bhattacharya et al. [8] study. A workpiece considered AISI 1045 steel material was used and using the coated carbide as a cutting tool in their study. Their study results that cutting speed, one of cutting parameters, had a significant impact on surface roughness and power consumption, while other parameters did not significantly affect responses. In the light of the explanations above, the aim of this research is the relationship between inlet parameters like cutting speed, feed rate and cut of depth was decided on output parameters, viz surface roughness, and power consumption, during turning DIN 1.2367 steel using coated carbide insert. In brief, this study is to improve predictive and optimization models for analyzing the effect of turning parameters on roughness of surface, consumption of power, and eventually on surface roughness and power consumption at the same time. Also, in this study, I would like to put forward after I have reflected the result of the surface roughness and power consumption to the researcher studying in this field yet, then how improving surface roughness results in reduced machine power consumption.

2. MATERIALS and METHOD

Appropriate selection of parameter sets of the machining process is important in modelling with optimization and estimation calculation. This is achieved by making sense of the relationship between parameters affecting the machining process and optimizing the machining conditions. In this part of the study, experiments were carried out on a specific machine tool to understand the effect of different process parameters on the characteristics of performance, namely surface roughness and power consumption.

2.1. Workpiece Material

DIN 1.2367 steel (X38CrMoV5-3 named on EN standard) was utilized as the piece of work in this study. This steel is widely utilized (used in extrusion dies, injection moulds, die cores, punches, etc.). It is a steel resistant to high temperatures in terms of its mechanical properties. Appropriate for heat intervention, it has reach high hardness values, easily. It has peak toughness later the hardening process. It has a high resistance against corrosion and temperature. Therefore, in the mold industry, gear manufacturing, crank-connecting rod manufacturing, and bolt-nut manufacturing has widespread use, such as in manufacturing. DIN 1.2367 tool steel was used in the study. The chemical composition of this tool steel (Ø50.5x250 mm) is shown in Table 1. The high chromium content (5%) in DIN 1.2367 indicates that it is more resistant to abrasion at high temperatures. Hardness of use may be slightly more than estimate (1-2 Rc).

Table 1. Composition of Chemical for DIN 1.2367 Steel [19].

Ingredient	Content (%)					
	C	Si	Cr	Mo	Mn	V
DIN 1.2367	0.38	0.40	5	□3.00	0.40	0.50

2.2. Process and Parameters of Test and Tooling

In this study, hardening experiments were carried out in Kastamonu University Laboratory. The devices in the laboratory are those that are periodically calibrated. They are devices with high accuracy in experimental studies. It was determined whether there was a temperature drop in the heating furnace. After these stages, the work was started. First of all, the center hole is drilled before the hot work tool steel is heat treated. Vacuum method was used in the heat treatment stage in the study. The reason for using this method is to increase the homogeneity of the part to be used in experimental studies by heat treatment. The DIN 1.2367 steel was first heated (950 C, it was kept in the oven for 1 hour), then cooled (It was cooled in oil after being removed from the oven.) until its hardness value reached 60 HRC . To take away the brittleness of the material, it was cooled in air by standing at 350 ^{o}C for 1.5 h. 50 HRC gained after this process. Tempering process was applied to remove the brittle structure of the material. As the hardness of the material increases, corrosion resistance, wear resistance and yield strength increase. Also, because the material was cooled in oil, no martensite structure was formed. In addition, it is seen that no carbon precipitate occurs at the grain boundaries. Thus, the workpiece maintains both hardness and corrosion resistance at high temperatures. This is one of the reasons why the use of DIN 1.2367 steel is so common.

Treatment of heat that is a very process of economical has improved the DIN 1.2367 steel's properties of mechanical. After that, which raised the yield strength of the steel threefold, the 1 mm material was removed. The tests were carried out on peak precision apparatus. Results of test indicating the material features of DIN 1.2367, a hot tool steel, are given below as seen Figure 1 (Fig. 1) and Fig. 2.

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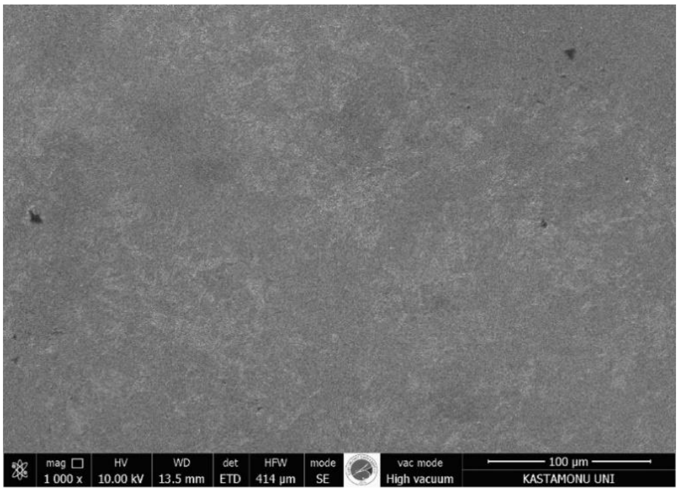


Figure 1. Steel images SEM.

When Fig.1 is examined, cementite grains scattered in martensite blocks are observed. The hardness of steels having martensite structure by giving water decreases while the toughness increases with the tempering process. Microstructures consist of needle-like martensite and plate artensite.

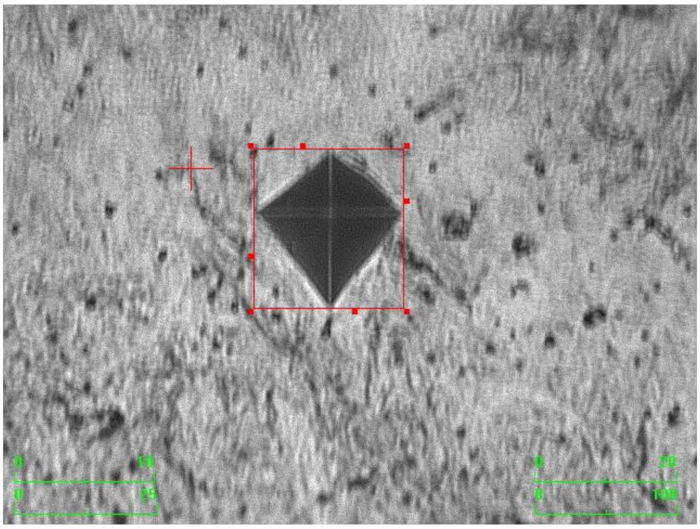


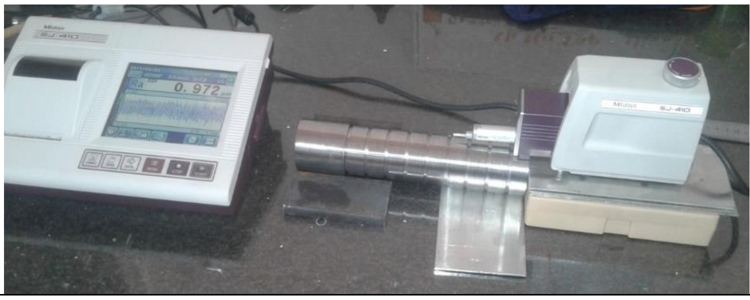
Figure 2. Hardness of the steel.

Micro hardness measurements of the pattern were obtained from 5 different values of hardness and the value of hardness was decided by averaging these data. There has been a high increase in the hardness of the steel and this situation can be seen in Fig. 2. The machining machine used in the study is a model called TTC-630 was used that it was produced by Tezmaksan Co. The high rigidity of this model machine allowed tests of measurement to be carried out in a secure environment. The technical data of lathe machine is seen in the following Table 2.

Table 2. The data of technical for TTC 630.

Special Feature	Value
Diameter of Maximum turning	250 (mm)
Prime power rating	20 (kW)
Max. Speed range	4000 (rpm)
Diameter of chuck	200 (mm)

In order to get efficient and accurate results from the study results, the connections of the equipment in the experimental setup must be made sensitively and securely. In the study, 1.2367 tool steel samples were connected between the chuck center and the cutting tool was connected precisely after the process. Measurement of values of surface roughness was done with Mitutoyo SJ-410 device shown in Figure 3a. Also, the devices shown in Figure 3b were used to measure instantaneous current values. In addition, the measurements of the instantaneous current value were made with the devices indicated in Figure 3b. Both devices were calibrated and verified before the experiment. The environment is isolated so that the devices are not affected by the environment. This situation prevented unnecessary noise from distorting the experimental data.

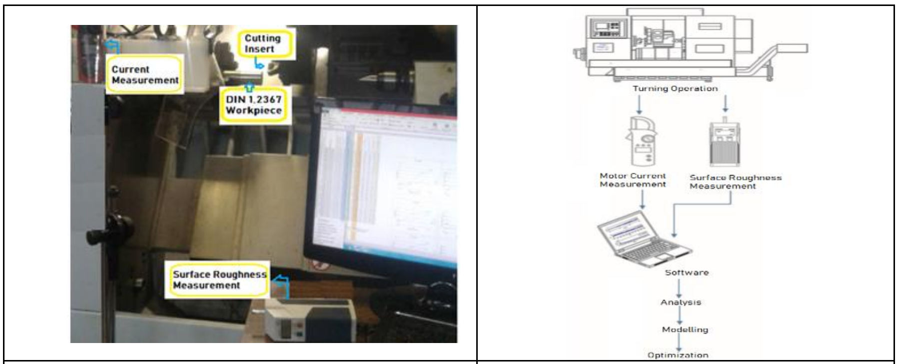


a)

b)

Figure 3. a) Measuring the surface roughness value, **b)** Measurement of instantaneous current value.

LC ISO-16610-21 standards were complied with for surface roughness measurements. Taequtec company's 11T308 model DCMT geometry cutting tools were used for chip. turning operations may vary for each workpiece. For this reason, efficiency can be achieved in the workpiece with the appropriate workpiece and optimum rotational progress. For this reason, the cutting tool has been selected in accordance with the workpiece. Experimental setup is given in Fig. 4a. Also, it is seen schematic diagram in Fig. 4b.



a b

Figure 4. a) Experimental setup, **b)** Schematic diagram in experimental setup.

Parameters of cutting needed to obtain a quality surface of grinding are favoured, while determining for parameters of cutting. Tool holders suited are utilized in the cutting tool. The parameters of cutting for the DIN 1.2367 steel are seen in Table 3. The units are given in the SI unit system.

Table 3. Cutting Parameters for DIN 1.2367.

Parameter Factors	SI Base Units	Factor Levels		
		1	2	3
f- Feedrate	mm/rev	0.06	0.12	0.18
v- Speed of Cutting	m/min	175	200	225
a- Cutting Depth	mm	0.10	0.15	0.20

To see the influences of the cutting parameters, the cutting values are selected over a wide range. By selecting very close values, the effect rate of that parameter was not reduced. By selecting far distant values, the effect rate of that parameter was not increased. The ranges of the cut-off parameters could not go beyond the catalog values [20]. Surface quality is very important in the turning process. A surface quality like grinding quality gives very good results in hard turning processes. Also, hard turning shortens machining times. Therefore, there is no need to grind the material surface. This situation reduces energy consumption. Another reason is that the depth of grinding in the machine has been raised to value of 0.005 while the time of machining has long time. The powder material released during the process shows the energy consumed during the processing time. Thanks to the desired quality of surface, the feed rate has not raised much.

The resulting data were analyzed using R (programming language) software and the Minitab 16 statistics program to run basic statistics including parametric regression and analysis of variance. The distribution curves were omitted. Formulas of regression were calculated. Variance analysis was carried out between the subject variables and unsubjects variables. Finest values for cutting were decided using methods of multiple optimizations for the minimal roughness of surface, consumption of power and time of processing. The best parameters of cutting were defined using the optimization method, weighted according to the importance of dependent variables.

2.3. Methodology of Response Surface

This method (The response surface methodology (RSM)) is utilized to decide a relationship between input and output parameters. It concerns defining parameters for input and output, plan of design in experimental, performing an analysis of regression, calculating variance analysis and examination results for response surface methodology [21].

The influences of cutting parameters on variables of response were examined in dry turning in the study. A complete factorial design that is orthogonal array was chosen for this study which containing three cutting parameters having depth of cut, cutting speeds and feed rate values. This situation is seen in Table 3. Information about the formulas used in the preparation of the test values is given below. The power consumption spent during the process is found according to formula (1).

$$P = \sqrt{3}\, x\, V\, x\, I\, x\, Cos\Phi = \sqrt{3}\, x 380 x\, I\, x\, 0{,}95 \quad (1)$$

Experimental feed rate values can be calculated with following formula (2).

$$V= \frac{\pi D n}{1000} \quad (2)$$

The amount of progress in one minute can be calculated following formula (3).

$$F= n\, x\, f \quad (3)$$

The processing time spent during the operation is found according to the formula (4).

$$t= L\, x\, 60 / F \quad (4)$$

The time spent throughout the process is found by formula (5).

$$T= \frac{\pi.D.60.L.a_{max}}{1000.V.f.a} \quad (5)$$

It has set cutting parameter (a, V, f) being experimental parameters. Values of current were measured by apparatus (trademark is UNI-T UT201) and given in Table 4. The time spent throughout the process is found from formula (5) and displayed in Table 4. Also, Power Consumption Values are found from formula (1) and surface roughness values were taken from the device by machining that they are shown in Table 4.

3. RESULTS and DISCUSSIONS

The obtained results in the light of the knowledge and tests given in Chapter 2 (Material and Method) are reflected as follows.

3.1. Experimental Results

It can be seen experimental results in Table 4.

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Table 4. Experimental Conditions and Results.

Numbers of Experiment	a (mm)	V (m/min)	f (mm/rev)	Time (s)	Current (Watt)	Total Power Consumption (Watt)	Ra (µm)
1	0.1	175	0.06	35.89	2.67	1669.47	0.3
2	0.1	175	0.12	17.94	2.81	1757.01	0.53
3	0.1	175	0.18	11.96	2.93	1832.04	1.23
4	0.1	200	0.06	31.40	2.72	1700.73	0.25
5	0.1	200	0.12	15.70	2.84	1775.77	0.54
6	0.1	200	0.18	10.47	2.99	1869.56	1.21
7	0.1	225	0.06	27.91	2.85	1782.02	0.22
8	0.1	225	0.12	13.96	3.04	1900.82	0.64
9	0.1	225	0.18	9.30	3.24	2025.87	1.54
10	0.15	175	0.06	23.92	2.82	1763.26	0.33
11	0.15	175	0.12	11.96	2.96	1850.80	0.66
12	0.15	175	0.18	7.97	3.20	2000.86	1.15
13	0.15	200	0.06	20.93	3.05	1907.07	0.28
14	0.15	200	0.12	10.47	3.24	2025.87	0.6
15	0.15	200	0.18	6.98	3.46	2163.43	0.9
16	0.15	225	0.06	18.61	3.10	1938.34	0.33
17	0.15	225	0.12	9.30	3.36	2100.91	0.36
18	0.15	225	0.18	6.20	3.37	2107.16	1.36
19	0.2	175	0.06	17.94	2.91	1819.54	0.34
20	0.2	175	0.12	8.97	3.12	1950.84	0.67
21	0.2	175	0.18	5.98	3.21	2007.12	1.37
22	0.2	200	0.06	15.70	3.15	1969.60	0.36
23	0.2	200	0.12	7.85	3.39	2119.67	1.02
24	0.2	200	0.18	5.23	3.85	2407.29	1.37
25	0.2	225	0.06	13.96	3.40	2125.92	1.1
26	0.2	225	0.12	6.98	4.26	2663.65	3.66
27	0.2	225	0.18	4.65	4.40	2751.19	4.42

Increasing cutting speed and increasing feed rate caused an excessive increase in surface roughness values. Because, the tool is not appropriate to get good machining with these parameters of cutting. However, with low cutting parameters, very good results were obtained in machining.

3.1.1. Values of surface roughness (Ra)

After each cutting experiment, values of surface roughness (Ra) were measured. The variance analysis values calculated for roughness of surface is seen in Table 5. Roughness of surface has a important impact on all cutting parameters. A p value less than 0.05 shows an important relationship at the 97.27% confidence interval. The value of surface roughness is influenced by the various cutting parameters (12.27 % depth of cut, 12.27 % cutting speed, and 56.86 % feed rate) as seen Table 5. Influences of parameters of cutting on roughness of surface are seen in Fig. 5 and Fig. 6. The slope of feed rate is large which indicates that has more impact on roughness of surface. The gradient of the cutting speed and depth of cut is no big which indicates that both no have more effect on roughness of surface. The most impact parameter of cutting on the roughness of surface is the feed rate. This reinforces the statement that the impacts of feed rate are more influential than speed of cutting on decreasing the forces and enhancing the surface machining [22]. The rising in cutting speed did not cause an important change in roughness either, because of the increased number of revolutions did not make an important vibration in the machine. So, there was not much deviation in the values of roughness. Thus, the machine does not lose its rigidity with the increasing number of revolutions (cutting speed) due to its rigidity. Also, increasing speed causes the pressure to drop in machining. The decrease in cutting pressure causes the cutting force to decrease. This provides a better cutting. Therefore, low depth of cut and high speed of cutting should be preferential in new machine tools.

As seen in Fig. 5, it is seen that the most efficient parameter on the average roughness value among the cutting parameters is the feed rate. It was observed that the increase of the cutting speed (V) from 175 m/min to 225 m/min and the increase of the cutting depth (a) from 0.10 mm to 0.20 mm did not have a serious effect on the surface roughness, compared to the feed rate. When the feed rate (f) increased from 0.06 mm/rev to 0.18 mm/rev, it was determined that the surface roughness (Ra) value increased 14 times (1400%) on average. The depth of the channels on the cylindrical surface increases with incrementing feed rate. Therefore, the values of surface roughness made parallel to the advancement axis also increase. It is aimed to obtain low surface roughness values in hard turning operations. For this reason, it is preferred that the values of the feed rates are low.

Table 5. Values of Variance Analysis for Roughness of Surface.

The source	The total degrees of freedom (DF)	SS of Seq	SS of Adj	MS of Adj	F	P	Contribution (%)
Defined regression	9	10.6187	10.6187	1.17986	67.42	0.000	97.27
Parameter’s Linear	3	8.8856	8.8856	2.96187	169.24	0.000	81.40
Value of a	**1**	**1.3393**	**1.3393**	**1.33934**	**76.53**	**0.000**	**12.27**
Value of V	**1**	**1.3393**	**1.3393**	**1.33934**	**76.53**	**0.000**	**12.27**
Value of f	**1**	**6.2069**	**6.2069**	**6.20694**	**354.66**	**0.000**	**56.86**
Square	3	0.5360	0.5360	0.17867	10.21	0.000	4.91
a *a	1	0.1723	0.1723	0.17227	9.84	0.006	1.58
V *V	1	0.2632	0.2632	0.26320	15.04	0.001	2.41
f *f	1	0.1005	0.1005	0.10054	5.74	0.028	0.92
Interaction	3	1.1971	1.1971	0.39904	22.80	0.000	10.97
a *V	1	0.8640	0.8640	0.86403	49.37	0.000	7.91
a *f	1	0.0631	0.0631	0.06307	3.60	0.075	0.58
V *f	1	0.2700	0.2700	0.27000	15.43	0.001	2.47
Error of residual	17	0.2975	0.2975	0.01750			2.73
Total	26	10.9163					100.00

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R^2: Accuracy Value	R^2 = 97.27 %	R^2 (MS of adj) = 95.83 %

While one of the most important indicators of surface quality is the surface roughness value, ovality and the formation of a white layered structure on the surface are undesirable. In addition, the ovality prevents the workpieces from working properly. White layer structure formation causes residual stresses on the surface. This causes the strength of the workpiece to decrease. Hence, it causes a decrease in wear resistance. Speed of cutting and depth of cut have a significant impact on both ovality and white layer formation. For surface quality, only a low surface roughness value will not be sufficient. In such cases, low depth of cut and high cutting speeds should be preferred to improve machinability characteristics.

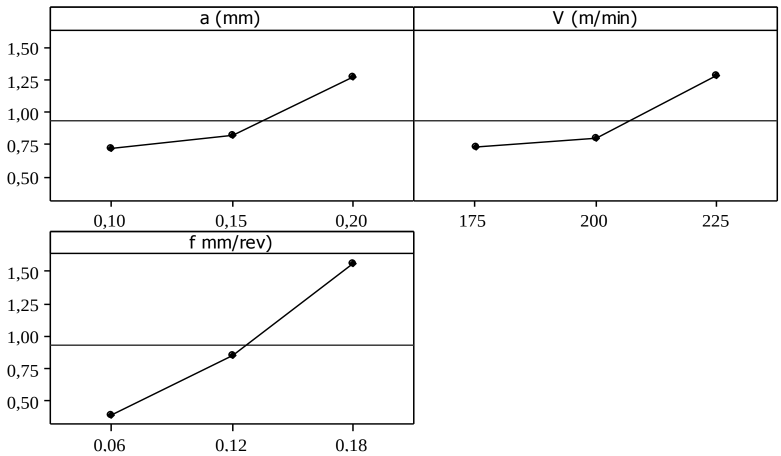
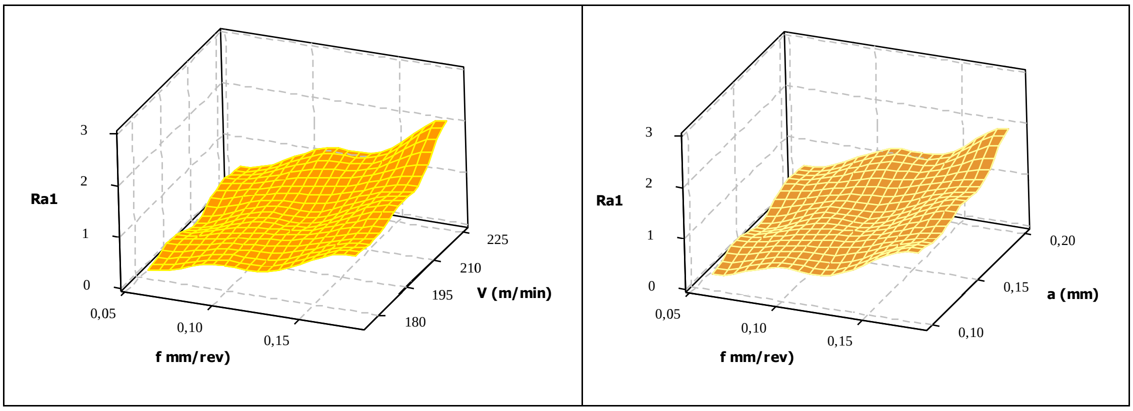


Figure 5. The influence of cutting parameters on means response features for surface roughness.



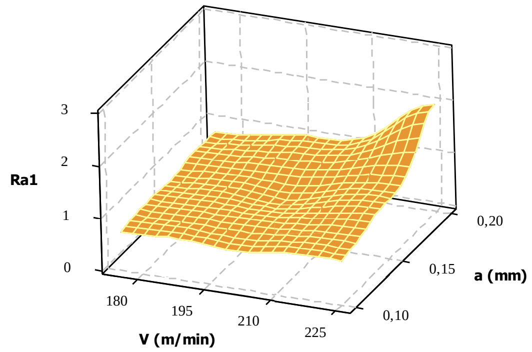


Fig. 6. 3-dimensional representation of the influences of cutting parameters on the surface roughness.

As the feed rate values rise, surface roughness values are also raised as shown in Fig. 5 and Fig. 6. As shown in Fig. 5, due to the mutual effect between the cutting depth and roughness of surface values, while roughness values of 0.75 µm were seen at 0.10 mm the cutting depth, there was no important rise in value of roughness at 0.15 mm. As it can be shown in Fig. 5, it has been tracked that the roughness value from 0.15 to 0.20 mm has suddenly increased. Likewise, while roughness values of 0.75 µm were seen at 175 m/min the cutting speed, there was no significant increase in roughness value at 200 m/min, with the interaction between the cutting speed and surface roughness values. There has been noticeable rise from 200 m/min to 225 m/min. Also, this tendency is reinforced by the percentage additive values in the ANOVA results.

Cakir, A.K. [23] investigated values of surface roughness, sound levels and current of machine in the turning hardened AISI S1 steel material. The most best surface roughness values were found by the most influential cutting factor that is the feed rate, in his study. Asiltürk and Akkuş [2] They used Taguchi method for optimizing turning parameters to down surface roughness. Results indicated that the feed rate was the most impressed factor effecting roughness of surface in their study. However, Cetin et al. [22] showed the influences of depth of cut and feed rate are more influence than cutting speed on decreasing the forces and develop the finish of surface, as mentioned above.

3.1.2. Motor current rating

The motor current values show the instantaneous load and power consumption of the machine, so they are important. In other words, as the amount of strain on the machine tool increases, the current value increases. Cutting parameters affect motor current values in machining processes. That's why it's good to know. The current, power consumption and surface roughness values obtained according to the cutting parameters are indicated in Table 4. Increasing of the feed rate amounts causes the instantaneous current value to increase. Similarly, the increment in the cutting depth caused an increment in the amount of load on the machine tool and an increase in the current value. The instantaneous current value is an indicator instead of the cutting forces, which are expensive and laborious to measure. Choosing a low depth of cut ensures a low load amount in study. Also, the increase in cutting speed provides a slight increase in the current value. Because the increase in the number of revolutions causes an increase in the current consumed by the motor. In addition, increasing cutting speed causes the cutting forces to decrease. Despite this, although the cutting forces decreased a little, the current value increased a little as the engine speed increased.

We can think of the total power consumption as a function of the value of instantaneous current and the time of processing. Even if the value of instantaneous current rises, the total power consumption is lower because the time of processing is very short. Available current values rise with increasing speed of cutting and depth of cut. Since the load per unit time rises, the motor current value increases as the feed rate increases. Also, it can be seen in the increment in the instant chip section. Choosing the depth of cut in the study provides low load amount. That's way, a small increment in the current value is viewed with rising feedrate.

3.1.3. Power consumption

Energy consumption in machines used in machine tools starts at the preparation stage. Throughout this time, the machine tool not only consumes electrical energy, but also requirements a certain amount of time to be ready for operational progress. While energy consumption directly contributes to power consumption, it affects the operational time during the machine operation. Therefore, the total process time is affected.

The total processing time and the instantaneous current value affect the power consumption, which causes serious costs. Since the electric current used in machining processes is gotten as outcome of burning fuels of fossil, it increases carbon emissions. This situation also harms the ecological balance. The world has limited reserves in underground resources. Therefore, efficient use of energy is important. Machine tool manufacturers, where energy consumption is high in the manufacturing industry, should also take this into account. For these reasons, it is necessary to determine the optimum cutting parameters in machine tools and to work with minimum power consumption. This will reduce energy costs. Linear regression model was used to estimate surface roughness and power consumption. Table 6 shows analysis of variance for power consumption. Confirmation experiments are shown in Table 4.

Table 6. Analysis of Variance for Power Consumption.

Source	DF	SS of Seq	SS of Adj	MS of Adj	Value of F	Value of P	Contribution (%)
Regression	9	1639347	1639347	182150	94.49	0.000	98.04
Linear	3	1470525	1470525	490175	254.28	0.000	87.94
a	**1**	**643746**	**643746**	**643746**	**333.94**	**0.000**	**38.50**
v	**1**	**399719**	**399719**	**399719**	**207.35**	**0.000**	**23.90**
f	**1**	**427060**	**427060**	**427060**	**221.54**	**0.000**	**25.54**
Square	3	2215	2215	738	0.38	0.767	0.13
a*a	1	139	139	139	0.07	0.791	0.01
v*v	1	1373	1373	1373	0.71	0.410	0.08
f*f	1	703	703	703	0.36	0.554	0.04
Interaction	3	166607	166607	55536	28.81	0.000	9.96
a*v	1	91789	91789	91789	47.62	0.000	5.49
a*f	1	47921	47921	47921	24.86	0.000	2.87
v*f	1	26897	26897	26897	13.95	0.002	1.61

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Residual Error	17	32771	32771	1928			1.96
Total	26	1672119					100.00
R^2 = 98.04%			R^2(predicted) = 94.52%			R^2 (adj) = 97.00%	

The power consumption has an important impact on all three parameters of cutting. Value of P less than 0.05 shows that there is an important correlation in the 94.52 % interval of confidence. Cutting depth (a) was based to be the most important fact on the power consumption which express 38.50% contribution of sum variation. The next additives on the power consumption come from the feed rate and the cutting speed having additive of 25.54% and 23.90% seriatim. The quadratic terms that they are v^2, f^2, a^2 don't have statistical importance on power consumption because of they have less level of additive and p value is also more than the assurance level. The interactions which are (v×f), (a×v) and (a×f) have 1.61%, 5.49% and 2.87% additives, seriatim. Also, residual error has only 1.96% additive. The R^2 is 0.9804 which shows that 98.04% of the sum variations are expressed by the model. The R^2 (Adj.) = 0.97 showing 97% of the sum variability is expressed by the model after regardful the importance facts. R^2 (Pred.) = 0.9452 which indicates that the model is hoped to express 94.52% of the variability in recent data. The increment in the cut-off parameters causes rising of the value of instantaneous current. Likewise, the increment in factors of cutting shortened the time of processing. The increase in the cut-off factors rises the instantaneous current value but decrease the consumption of power as it shortens the processing time. The most useful factor in power consumption is the time of processing. Operating only the machine tool causes a large part of the consumption of energy. In this instance, it is essential to rise the cutting factors to shorten the working time of the machine. However, it is not preferred to increase the feed rate in the cutting parameters as it increases the surface roughness value. So, to reduce energy consumption, shorten the processing time, and avoid to deteriorating the surface quality, while the speed of cutting and cutting depth can be increased, the feed rate must be reduced. This can be seen in Fig. 7 and Fig. 8.

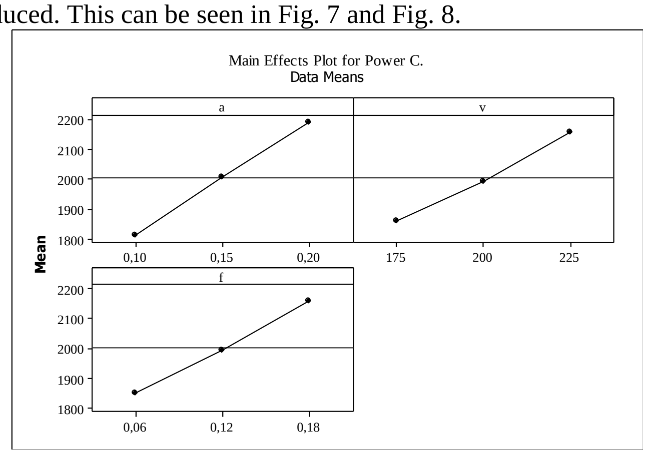

Figure 7. Main Effects Plot for Power Consumption.

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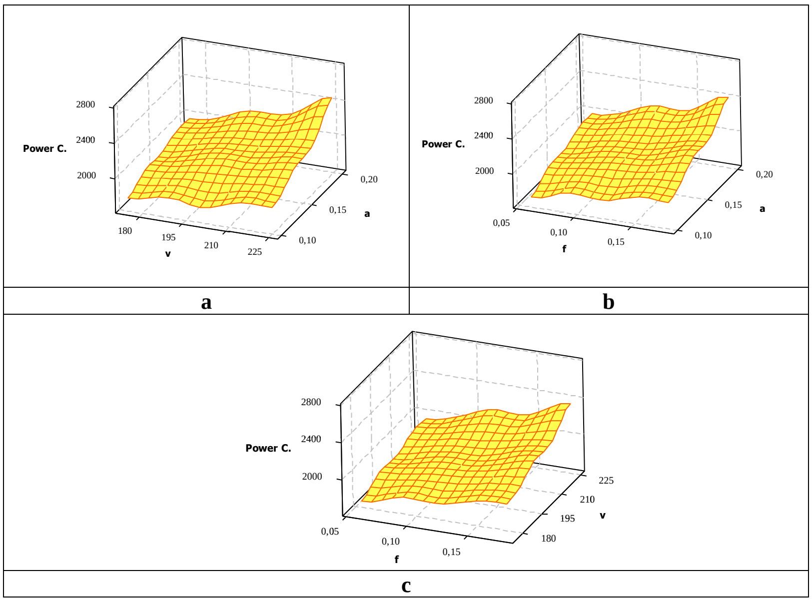

Figure 8. a) Power Consumption with v and a correlation, **b)** Power Consumption with f and a correlation, **c)** Power Consumption with f and v correlation.

The power consumption value rises with the speed of cutting and cutting depth. The increment in the values of depth of cut is more impact in the increment in power consumption value. This situation backings the discussion that the influences of the depth of cut are more efficacious than feed rate and cutting speed to get least consumption of power and best quality of surface in their study by Hanafi et. al. [12].

3.2. Correlation Between Cutting Speed, Feedrate and Power Consumption

Cutting speed and feedrate which have importance value on surface roughness how affect power consumption can be seen in Fig.9. Consumption of power is also low at low feedrate and low cutting speeds. This situation also ensured that the surface roughness was low. However, rising of these values, the generated power consumption values in the processing also increase. However, the rate of this increase decreases at optimum values. The value of surface roughness raised with rising feed rate values that it is 56.86 %. It has been examined that grinding quality surface is obtained, especially at low feed values. The power consumption value increases with rising cutting speed and cut of depth (38.50 % cut of depth) values.

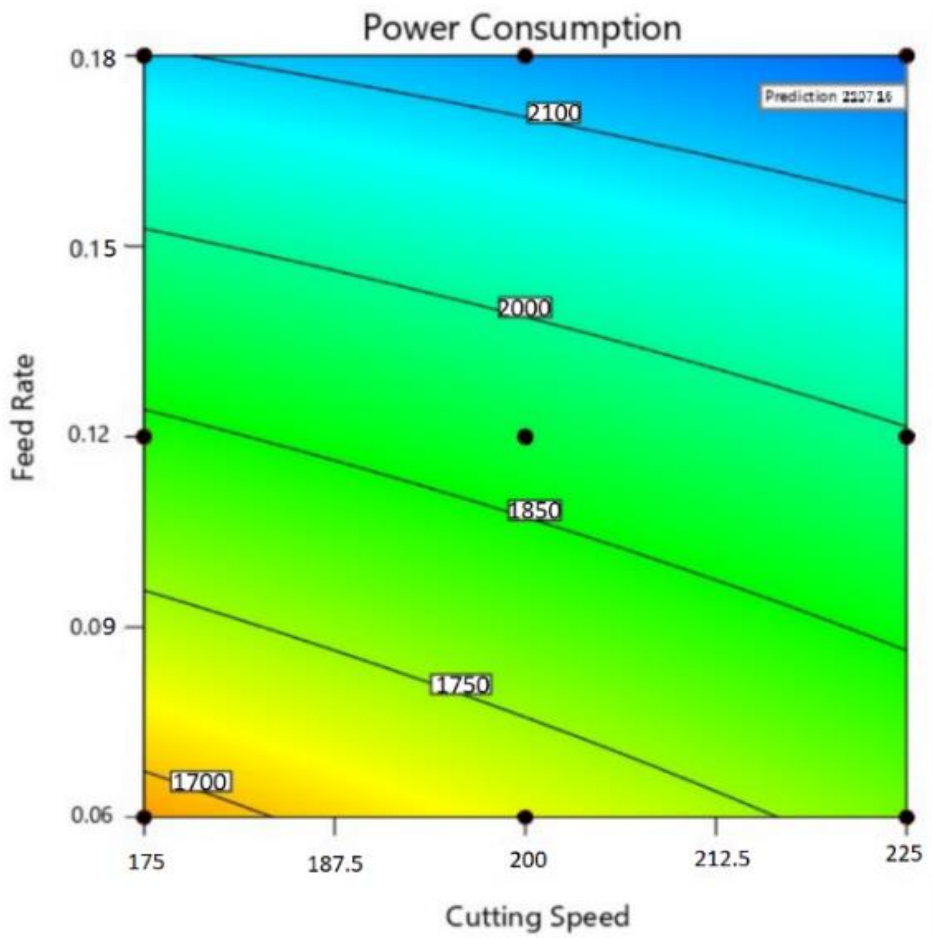

Figure 9. Correlation of between Cutting Speed, Feedrate and Power Consumption.

3.3. Correlation Between Surface Roughness, Power Consumption, and Instantaneous Current
The power consumption value rises with the speed of cutting and depth of cut in the turning process. The increase in depth of cut is more impressive in increasing the power consumption value. Fig. 10. shows the correlation between surface roughness, amount of instantaneous current, and total power consumption. According to Fig. 10, while the surface roughness value increased, the instantaneous current values also increased significantly. Even if the value of instantaneous current rises, the total power consumption reduces as the total time of operation decreases. This is reached by the preference of high cutting speed and high cut of depth. This can be seen in the graphical representation of the numerical data in Figure 10. The increase in current values increased the total power consumption, but with the decrease in the total cutting time, there is a significant decrease in power consumption. Towards the end of the experiment, the rapid increase in surface roughness increased the instantaneous current value and total power consumption rapidly. The final cutting parameter is due to

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the bad run-out of the tool combination. This is an acceptable situation. It did not have much of an effect because of considering the overall experimental results.

Experiment Number	Current (Watt)	Total Power Consumption (Watt)	Ra (µm)
1	2.67	1669.47	0.3
2	2.81	1757.01	0.53
3	2.93	1832.04	1.23
4	2.72	1700.73	0.25
5	2.84	1775.77	0.54
6	2.99	1869.56	1.21
7	2.85	1782.02	0.22
8	3.04	1900.82	0.64
9	3.24	2025.87	1.54
10	2.82	1763.26	0.33
11	2.96	1850.80	0.66
12	3.2	2000.86	1.15
13	3.05	1907.07	0.28
14	3.24	2025.87	0.6
15	3.46	2163.43	0.9
16	3.1	1938.34	0.33
17	3.36	2100.91	0.36
18	3.37	2107.16	1.36
19	2.91	1819.54	0.34
20	3.12	1950.84	0.67
21	3.21	2007.12	1.37
22	3.15	1969.60	0.36
23	3.39	2119.67	1.02
24	3.85	2407.29	1.37
25	3.4	2125.92	1.1
26	4.26	2663.65	3.66
27	4.4	2751.19	4.42

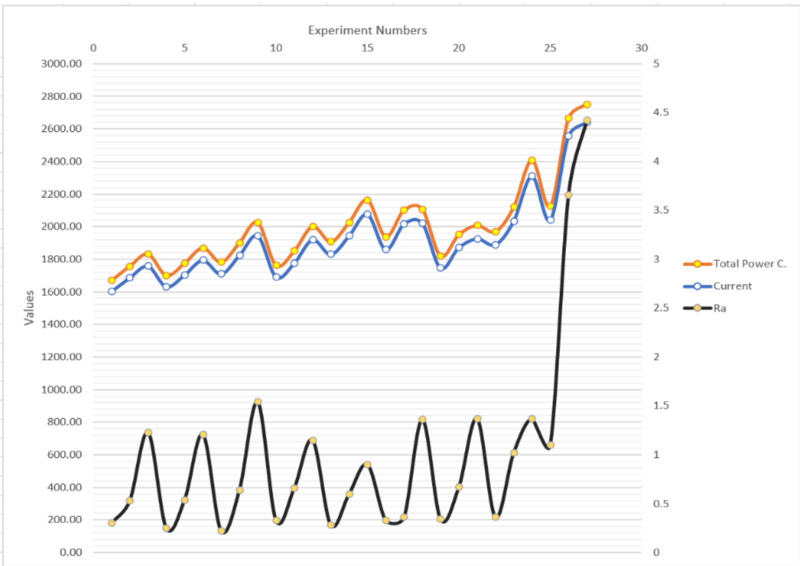

Figure 10. Correlation Between Surface Roughness, Power Consumption, and Instantaneous Current.

4. CONCLUSIONS

This study presents the corelation between cutting parameters such as cutting speed, feedrate, cut of depth and response parameters, namely surface roughness, and power consumption, during turning DIN 1.2367 steel.

Predictive model was statistically importance using an ANOVA. Analysis of variance shows influence of feedrate on the surface roughness is 56.86 %. Also, the value of surface roughness is modelled with 95.83 % accuracy. It is important using suitable cutting tool to get good surface quality in turning process. It has been traced that value of surface roughness increased with rising feed rate values. By contrast with depth of cut and cutting speed had no significant impact on the surface roughness value. The error of residual contribution is 2.73% for surface roughness. This situation indicates the results of experimental for values of surface roughness was dependable. The low current value range is due to the low depth of cut. However, there is a strong relationship between the current value and the cutting parameters. The value of instantaneous current rises because of rising cutting parameters. Although the instantaneous current value is increased, the total power consumption is also reduced as the total processing time is decreased. Also, the power consumption value increases with rising of cutting depth and cutting speed values (%38.50 cutting depth). The increment in the depth of cut is more impact in the increment in power consumption value. This study can be furthermore extended to analyze the impact of different cutting conditions and cutting tools on power consumption and surface roughness during machining. Response surface methodology and genetic algorithms using cutting parameters enable to develop optimization of surface roughness and power consumption. In the study, the most effective parameter on the roughness of surface is the feedrate, which provides good surface quality and extends the processing time. To compensate for this loss of time, high depths of cut and high cutting speeds can be preferred. In this way, many workpiece manufacturing is achieved with good surface quality, low current values, and low power consumption.

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NOMENCLATURE

P= Power consumption (W),
I= Current (A),
V=Voltage (380 V),
Cos Φ = 0.95
T= Total processing time (s)
F= The amount of progress in one minute (mmmin),
n= speed (rev/min),
f= The amount of progress per revolution (mmdev)
t= processing time(s), L= Total processing length (mm)

Ra (µm)	Surface roughness value
a (mm)	Depth of cut
V (m/min)	Cutting speed
f (mm/rev)	Feed rate
R2	Accuracy value
Pred. R2	Predicted R2
Adj. R2	Adjusted R2
Seq SS	Sequential sum of squares
Adj. SS	Adjusted sum of squares
Adj MS	Adjusted mean squares
DF	The total degrees of freedom
F	An F-value appears for each term in the analysis of variance table
P	The p-value is a probability