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Reducing the Roughness and Sound Intensity by Optimization of Cutting Parameters in Processing of AISI 2714 Steel Material on CNC Milling Machine

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Abstract: Within the scope of this study, optimization of cutting parameters (feed rate, cutting speed and depth of cut) was aimed in order to reduce the noise level that occurs during the processing of AISI 2714 steel on CNC milling machine without compromising the surface roughness. Experimental design was examined in three variables, three levels and two target functions. In order to investigate the contribution of these parameters to the target function, the experiments were carried out in accordance with the experiment plan determined by using the "Central Composite Design (CCD)" of the "Response Surface Method (RSM)". Mathematical models have been developed in order to predict sound intensity and surface roughness by applying regression analysis to the experimental results. As a result, it has been observed that the most effective parameter in reducing the surface roughness is the feed rate, followed by the depth of cut. While the depth of cut was the most effective parameter in reducing the sound intensity, it was determined that the next effective parameter was the feed rate.

Keywords: cutting parameters; milling machine; sound intensity; surface roughness; response surface method; worker health

1 INTRODUCTION

Noise is common in almost all workshops exposed to above limit values. Prolonged exposure to noise negatively affects the health of employees, especially sense of hearing [1]. For this reason, it is of great importance to reveal the negative effects of noise on the health and safety of employees on each machine tool and to develop protective measures [2, 3]. On the other hand, it should not be forgotten that it is a particularly important measure of success in terms of factors such as surface quality of products in machining, obtaining desired tolerance values, ease of use of the product, mechanical properties and fatigue life. It has been reported in the literature that surface roughness affects the corrosion resistance, amount of wear, fatigue resistance and lubrication properties of machined parts [4, 5]. In this respect, surface quality should not be reduced while noise prevention works are carried out. However, while improving the surface quality, the loom-induced sound intensity is generally not taken into account. This situation causes undesirable harmful effects in terms of employee health. Therefore, the cutting parameters must be optimized in such a way that the sound intensity remains within the limits in accordance with the legal legislation, without increasing the surface roughness values. Machining processes in machining can be improved using stepwise optimization procedures such as the Response Surface Method and Taguchi, which help manufacturers meet their desired needs [6, 7].

Surface roughness values and bench sound intensity are two important data when evaluated separately or together in determining cutting parameters. Recently, some studies have been done on these issues, but there are not enough studies to evaluate these parameters together and to establish the relationship between them. In the examinations made, it was seen that in most of the studies, the surface roughness values and noise were generally examined for the operations on the lathe. In spite of this, when the processes performed in the milling machine in the manufacturing sector are examined, it has been reported in the literature that the milling operations reach the highest sound pressure level in all machining processes [8].

Simunovic et al. [9] evaluated the surface roughness based on digital image properties. Digital image of the machined surface was provided for every test sample. Based on experimental design and obtained results of roughness measuring, a base has been created of input data (features) extracted from digital images of the samples' machined surfaces. This base was later used for generating the fuzzy inference system for prediction of the surface roughness using the adaptive neuro fuzzy inference system (ANFIS). Assessing error, i.e. comparison of the assessed value *Ra* provided by the system with real *Ra* values, is expressed with the normalized root mean square error (*NRMSE*) and it is 0.0698 (6.98%). Madhusudan et al. [10] The researchers have presented fault diagnosis studies of the face milling tool using SVM technique and DWT features with sound signals through machine learning approach. The different feature extraction methods (DWT, EMD and statistical), decision tree technique for feature selection and different classifiers (ANN, SVM and K-star models) were used and their performances on classification of the face milling tool were studied. The SVM classifier has provided a good classification accuracy of about 83% with the DWT features. Suresh Babu et al. [11] presented an investigation of noise level during fillet end milling operation on commercially pure copper using CNC vertical milling machine. The Taguchi method was used to perform systematic experimentation through L9 orthogonal array. The signal to noise ratio (S/N ratio) and analysis of variance (ANOVA) were employed to analyse the effect of milling parameters on noise level in milling process. The contributions of each process parameters to obtain the required output characteristics were studied. Results revealed that the depth of cut of finish is the dominant factor affecting noise level. Shiva et al. [12] described the advantages and limitations of trumpet edges over symmetrically honed edges in tool life and surface quality. The analysis carried out in milling of AISI 4140 steel with the trumpet edge of $K = 1.6$ produced a surface of stable *Ra* value around 0.2 μm with good quality. Khawaja et al. [13] objective was to achieve sustainable machining by simultaneously optimizing sustainable machining drivers during the HSM of 15CDV6 HSLA steel under MQL and flood lubrication. The comparative investigation exposed that significant improvement in *Ra* (1.1 - 16.6%) and *ST* (1.3 - 2.3%) of the material using MQL has been witnessed and gives a strong indication that MQL is a better substitute than the flood lubrication. Kumar ve Verma [14] developed a sturdy hybrid module for multi criteria optimization of conflicting machining performances during milling of GO doped Epoxy/CFRP composites. In the study, Taguchi L9 OA was used in the combined optimization approach of AHP and TOPSIS. The optimal results were verified through a confirmatory test, which showed good agreement with actual ones. The ANOVA inferred that *S* (79.55%) and *F* (4.80%) were the most important parameters for overall assessment value. Trung [15], presented the influences of cutting parameters (cutting speed, feed rate, and depth of cut) on the surface roughness during milling and used AISI 1045 steel. The analysis of experimental results found out the influence of the input parameters as well as their interaction on the surface roughness. In addition, the study proposed two models of surface roughness prediction, one of which is developed according to Response surface method (RSM) and the other is built on the basis of Johnson transformation. Research results showed that the Johnson-based is better than the model using RSM. Fountas et al. [16] dealt with comparing the fractional and full factorial design of experiments on evaluating surface roughness characteristics during slot milling of Al 7075 alloy. The selected input parameters were assigned to an L27 orthogonal array to determine the experiments. Several statistical tools have indicated that the fractional factorial approach is just as suitable as the full factorial design of experiments for analysing machining (milling) results of aluminium alloys.

After the literature review, the cutting parameters determined within the scope of this study are cutting speed, feed rate and depth of cut [17, 18]. The study is a multidisciplinary study between the machinery manufacturing industry and statistical disciplines. Although most researchers have studied the quality of the milling surface, the noise factor has mostly been neglected. In this paper, studies have been carried out to show that the quality of the milling surface and the noise factor should be taken into account as integral. It is thought that it will make significant contributions to the literature for the protection of the manufacturing sector and employee health with this study.

2 MATERIALS AND METHODS

Test samples were prepared in the dimensions of 100 × 80 × 70 mm (Length × Width × Thickness). Sample surfaces were cleaned of oil and oxide layers. The samples were not subjected to any heat treatment.The chemical components of the used AISI 2714 steel were given in Tab. 1.

Table 1 AISI 2714 chemical components

C	Cr	Mo	Ni	V
0.55	1.10	0.50	1.70	0.10

AISI 2714 steel: It is a nickel alloy die steel with high toughness values and hardenability to the core. It is the standard material in medium and large scale forging dies. It is used in the manufacture of stainless steel products, such as base fastening dies, partial press dies, punches for extrusion presses, protective piston liners and hot shear blades. Before starting the experiments, the surface roughness of the part was measured as 3.95 µm.

Produced by ZCC-CT Cutting Tools company, YBD152 quality carbide coated inserts with code ONHU08T508-PM were used with tool holders containing five cutting inserts. The photograph of the cutting tips used in the experiment is given in Fig. 1, the dimensions are given in Tab. 2 and the quality values in Tab. 3.

Figure 1 Cutter tips

Table 2 Cutter tips sizes

Type	Diameter / mm					Quality
	L	*øIC*	*S*	*ød*	*r*	
ONHU08T508-PM	8.39	20.2	5.77	5.3	0.83	YBD152

Table 3 Quality measures of cutting tips

Hardnes	Quality	Cutting parameter		
		V_c / m/min	f_z / mm/z	a_p / mm
180 - 280	YBD152	300 (200 - 400)	0.3 (0.2 - 0.6)	5

Sound intensity measurements were completed with the Smart Sensor Ar 844 Noise Meter Decibel Recorder. The recorded data was transferred to the computer via USB. Tab. 4 shows the technical specifications of the Smart Sensor Ar 844 noise meter and decibel recorder.

Table 4 Smart sensor Ar 844 decibel recorder technical features

Measuring Range	30 dB, ..., 130 dBA/35, ..., 130 dBC
Sensibility	±1.5 dB
Frequency range	31.5 Hz, …, 8.5 KHz
Screen resolution	0.1 dB
Dynamic Range	50 dB, …, 100 dB
Data Storage	4700
Frequency weight Characteristic	A and C
Main log bar graph	1 dB 1 /bar grafik
Screen	LCD
Weight	148 gr
Power source	4 Adet AA pil
Sizes	67 × 30 × 183

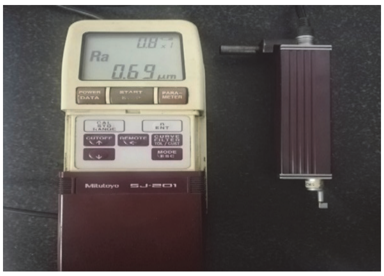


Figure 2 Mitutoyo SJ-201 brand surface roughness measuring device

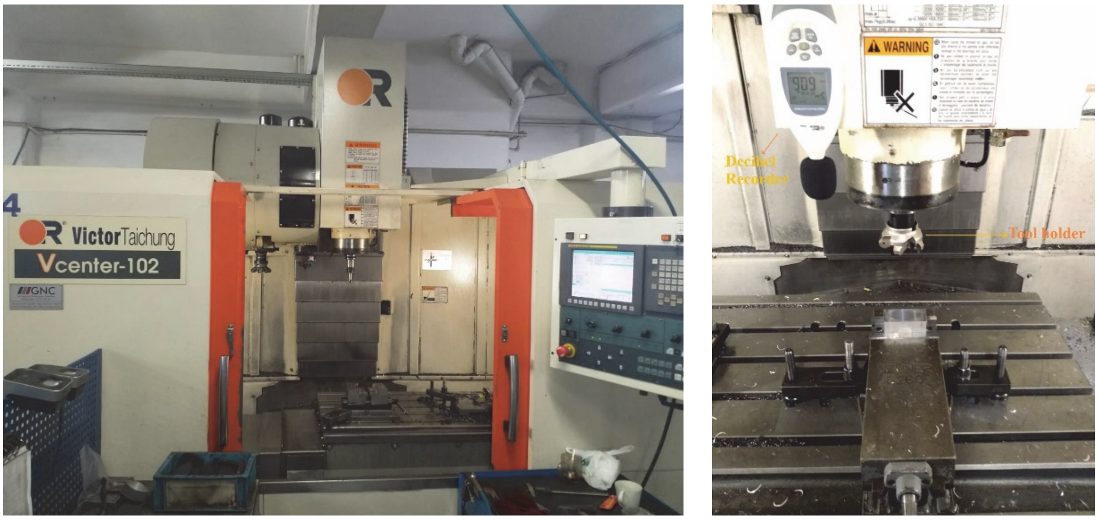
Surface roughness measurements of the prepared samples were made at three different points with Mitutoyo

SJ-201 brand surface roughness measuring device. Average roughness (*Ra*) values were found by taking the average of the values obtained as a result of the measurements. Fig. 2 shows the surface roughness of the Mitutoyo SJ-201 used during the measurements, and Tab. 5 shows the technical specifications of the Mitutoyo SJ-201.

Victor Taichung/Vcenter-102 brand/model CNC milling machine was used in the experiments. Fig. 3 shows the Victor Taichung brand/model CNC milling machine, tool holder and decibel recorder used during the experiments.

Table 5 Technical specifications of Mitutoyo SJ-201

Model	SJ-201
Measuring Range (*X*-*Z* Axis)	12.5 µm - 350 µm
Prob Type	Standart
Scan Method	Differential induction
Prob Tiğ	Diamond
Tip diameter	2 µm
Profiles	Primer, Roughness
Analysis Chart Standards	*Ra*, *Ry*, *Rz*, *Rt*, *Rp*, *Sm*, *S*, *Pc*, *R3z* DIN, ISO, ANSI



(a) (b)

Figure 3 (a) Victor Taichung brand/model CNC milling machine, (b) tool holder and decibel recorder

2.1 Design of Experiment

The experiments were carried out in accordance with the experimental plan determined in the central composite design of the Response Surface Method. The response surface method consists of 3 stages: experimental design, mathematical modelling and model verification. In the experiment design, which is the first step of the response surface method, Eq. (1) shown in 1 was used.

$$Y = f\left(x_1, x_2, x_3, ..., x_n\right) + \varepsilon \tag{1}$$

In this equation, Y is the dependent variable, X_n is the independent variables, and ε is the error term. In the experiments, cutting parameters (feed rate, cutting speed and depth of cut) were chosen as design parameters, considering that they will affect the surface roughness and sound intensity. These three parameters have been examined for two target functions determined at 3 levels. The variables and levels are given in Tab. 6, taking into account the cutting parameters used in the experiments, the catalog values of the cutting tool company and the machine capacity. Among the geometric parameters, it is defined as the feed rate (f), cutting speed (v_c) and depth of cut (a_p). Tab. 6 shows the highest level of parameters (1), the middle level (0), and the lowest level (−1). Within the scope of this study, 23 experiments were carried out in 20 models to investigate the contribution of the parameters given in Tab. 6 to the target function, and 3 tests were carried out for verification.

Table 6 Test parameters

Design Variables	Levels		
	−1	0	1
f, feed rate / mm/min	200	400	600
v_c, cutting speed / m/min	200	300	400
a_p, depth of cut / mm	0.5	1	2

A quadratic polynomial model was chosen to produce a mathematical model in the analysis of the data. The relevant values of the parameter levels that were not included in the validation of the model were applied to the mathematical model and verified with the results of the experimental study. YYY analysis results and graphs made with Minitab 18 program were examined separately for surface roughness and sound intensity. Then, the correlation between both results goals was investigated.

Surface roughness values and sound intensity of AISI 2714 steel obtained as a result of the experiments and experimental measurement results were analysed with Minitab 18 package program.

2.2 Response Surface Regression for Roughness Values and Sound Intensity

The effects of design parameters on surface roughness and sound intensity were examined and statistical information was obtained by looking at the usability of the relationship between parameters. Regression took place at 95% confidence interval.

For the surface roughness, it is seen that the interaction of feed rate, cutting speed, depth of cut, square of cutting speed and feed rate with the cutting speed is acceptable and the model is modeled with a validity rate of 93.92%.

Eq. (2) and Eq. (3), obtained through the ANOVA program, were defined to be used in mathematical modeling and model verification steps.

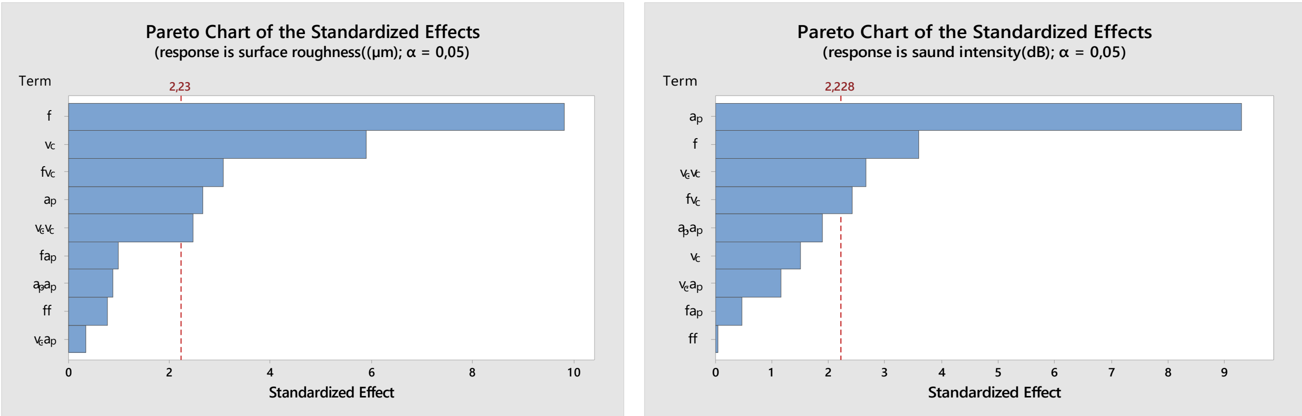
$$Ra = 2.04 + 0.00912 f - 0.0199 v_c + 0.815 a_p - \\ -0.000003 f \cdot f + 0.000035 v_c \cdot v_c - 0.0259 a_p \cdot a_p - \\ -0.000013 f \cdot v_c + 0.000545 f \cdot a_p - 0.00040 v_c \cdot a_p \tag{2}$$

$$Noise\text{, dB} = 79.9 + 0.0595 f - 0.228 v_c + 36.7 a_p - \\ -0.000002 f \cdot f + 0.000541 v_c \cdot v_c - 7.78 a_p \cdot a_p - \\ -0.000144 f \cdot v_c + 0.00370 f \cdot a_p - 0.0183 v_c \cdot a_p \tag{3}$$

3 EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Pareto Plot for Surface Roughness and Sound Intensity

The standardized effect pareto graph is shown in Fig. 4a for surface roughness values. As it is clearly seen in Fig. 4a, it has been observed that it has passed the 2.23 significance line for "f", "v_c", "fv_c", "a_p" and "v_cv_c" model and reached significant values. As stated in the literature, it is the feed rate that has the highest effect for surface roughness and this result is similar for AISI 2714 material [19-22]. In Fig. 4b, the standardized effect pareto graph for sound intensity is given. Factors greater than 2.228 significance line: It is seen that "a_p", "f", "v_cv_c" and "fv_c" factors are statistically significant.



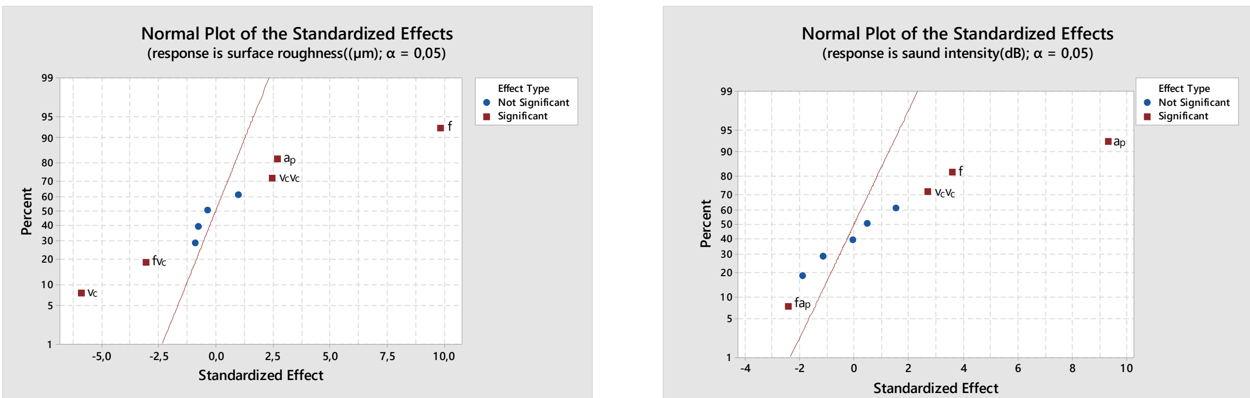
(a) (b)

Figure 4 Standardized effect pareto plot: (a) Surface roughness (b) Sound intensity

In the graphic given in Fig. 4a and Fig. 4b, information can be obtained about what the severity of the factor is, but no information is presented about the way the violence affects the result. The direction in which the factor affects the result can be seen in the normal curve of the standardized effect given in the following section.

3.2 Normal Curve of Standardized Effect

The normal curve of the standardized effect is given for AISI 2714 steel material in Fig. 5a and Fig. 5b. Values in the figure represent the same values as in the pareto chart. Fig. 5a shows the effects of cutting parameters on surface roughness. Round spots close to the line are factors that do not matter on the target function [21].



(a) (b)

Figure 5 Normal Curve of Standardized Effect; (a) Surface roughness (b) Sound intensity

While the increase of v_c and fv_c means the decrease of the surface roughness, the increase of f, v_cv_c and a_p means the increase of the surface roughness. Therefore, in the machining of AISI 2714 steel, while the feed rate, depth of cut and the square of the cutting speed are reduced, the interaction of the feed rate with the cutting speed and the cutting speed should be increased in order to reduce the surface roughness. Fig. 5b shows the effects of cutting parameters on sound intensity. While the increase of fv_c means the decrease of the noise, the increase of f, v_cv_c and

a_p means the increase of the noise. Therefore, in the machining of AISI 2714 steel, the interaction of feed rate and cutting speed should be increased while reducing the feed rate, depth of cut and the square of the cutting speed in order to reduce the sound intensity.

3.3 Three-Dimensional Surface Curves for Surface Roughness Values and Sound Intensity

While obtaining the surface roughness, all values that are kept constant are the optimum values of the relevant cutting parameters. Fig. 6 shows the surface graphics obtained for AISI 2714 steel material surface roughness values. In these graphs, while keeping one variable out of 3 cutting parameters constant, it is explained how the other two variables affect the target functions and how the variable 2 parameters should be in line with the desired target function.

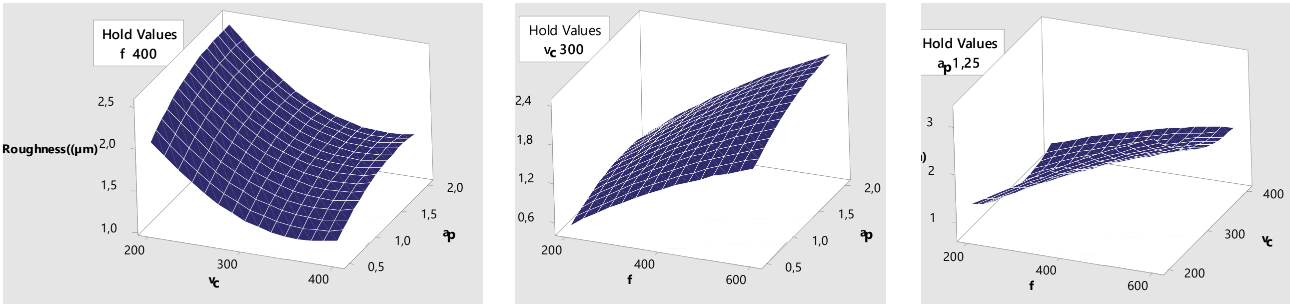


Figure 6 Three-dimensional surface curves for surface roughness values

According to Fig. 6, when the feed rate (f) is kept constant at 400 mm/min, the surface roughness decreased with the increase in cutting speed and the surface roughness increased with the increase in depth of cut. While the cutting speed (v_c) was kept constant at 300 m/min, the surface roughness increased with the increase in the feed rate and depth of cut. When the depth of cut (a_p) is kept constant at 1.25 mm, it is seen that the surface roughness increases with the increase in the feed rate and it is seen that the surface roughness decreases with the increase in the cutting speed. Therefore, it has been seen that the reduction of surface roughness values can be achieved by increasing the cutting speed at constant feed rate and constant depth of cut. It has been determined that when the cutting speed and depth of cut are constant, increasing the feed rate increases the roughness values.

Fig. 6 shows surface graphics for AISI 2714 steel material sound intensity values. One of the 3 cutting parameters was kept constant and the effect of the other two cutting parameters on the target function was determined.

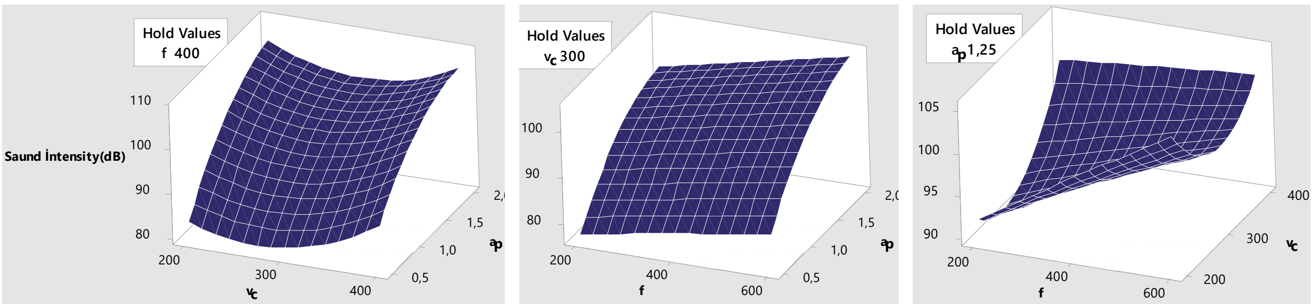


Figure 7 Three dimensional surface curves for sound intensity

According to Fig. 7, when the feed rate (f) is kept constant at 400 mm/min, the sound intensity first decreased and then increased with the increase in cutting speed. It is seen that the feed rate is constant and the sound intensity increases with increasing depth of cut. While the cutting speed (v_c) was kept constant at 300 m/min, the sound intensity increased with the increase in the feed rate and depth of cut. When the depth of cut (a_p) was kept constant at 1.25 mm, the sound intensity increased with the increase in the feed rate, and the sound intensity decreased and then continued to increase with the increase in the cutting speed. It has been determined that the parameters should be compatible with each other in the processing of AISI 2714 steel material in the milling machine and in preventing the increase in sound intensity. It was observed that the sound intensity increased at the points where the harmony of the parameters with each other was disrupted. Optimization of target functions is provided by optimization graphics.

3.4 Optimization of Target Functions

3.4.1 Optimizing Surface Roughness and Sound Intensity Together

In Fig. 8, the intersections of cutting parameters and optimum calculated values are given. The "d" value given in the graph in question represents the optimum value of the target function for the minimum roughness value and sound intensity. The "D" value in the concept of mixed desirability is the average of the "d" values in the minimum target functions.

As a target, minimization of surface roughness and sound intensity was determined. According to Fig. 4, the estimated sound intensity was obtained as 200 mm/min for the feed rate (f), 262.62 m/min for the cutting speed (v_c), and 0.5 mm for the depth of cut (a_p) and 75.93 dB, surface roughness value was found as 0.62 µm.

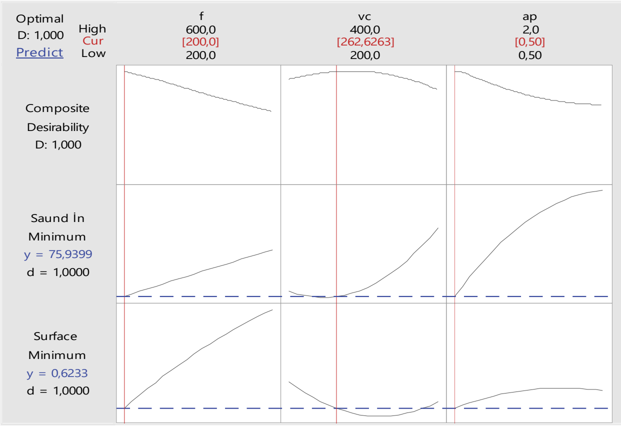


Figure 8 Optimization of surface roughness and sound intensity together

Tab. 7 shows the values of ideal cutting parameters for the minimum surface roughness values and sound intensity estimated as a result of experimental and model optimization of AISI 2714 steel. In this table, it is seen that the feed rate (f) and depth of cut (a_p) should be selected at a low level for the minimum surface roughness value and sound intensity. Therefore, it has been determined that the cutting parameters, the feed rate and depth of cut, are effective parameters in the evaluation of surface roughness and sound intensity together.

Table 7 The value of ideal cutting parameters

AISI 2714 Steel Material					
Parameters	Minimum	f / mm/min	v_c / m/min	a_p / mm	Result
Test Results	Roughness	200	400	0,5	0.63 µm
	S. Intensity		200		78 dB
Multiple Response Prediction	Roughness		321.21		0.49 µm
	S. Intensity		246.46		75,78 dB
Multiple Response Prediction for Two Target Functions	Roughness		262		0.62 µm
	S. Intensity				75.93 dB

3.5 Model Verification for Surface Roughness and Sound Intensity

The model needs to be validated to understand how precise the model created is and how much it represents real values. In this study, the effective parameters were changed and the results obtained from the mathematical model were compared with the experimental results. The cutting parameter values used in the verification experiment, which are not included in the created experiment plan, are given in Tab. 8. The parameter values in Tab. 8 were calculated according to Eq. (2) and Eq. (3) obtained as a result of the regression and the model estimation value was found. The machine was operated in accordance with the parameter values given in Tab. 8, and the roughness and sound intensity measurements were made. The obtained model and experiment results and error percentages are given in Tab. 9 and Tab. 10. Error percentage values occurred between 2.70 µm and 3.92 µm for surface roughness and between 0.66 dB and 2.31 dB for sound intensity. This error percentage shows that the model created according to the Multiple Response Estimation given in Tab. 11 and Tab. 12 and the experimental results are in harmony.

Table 8 Cutting parameters used in the validation experiment

Test No	Design Parameters		
	f / mm/min	v_c / m/min	a_p / mm
1	300	200	0.5
2	400	200	1.5
3	300	300	1

Table 9 Verifications results for surface roughness

TestNo	Design Parameters			AISI2714 surface roughness / µm		
	f / mm/min	v_c / m/min	a_p / mm	Model	Test	%Error
1	300	200	0.5	1.53	1.47	3.92
2	400	200	1.5	2.45	2.53	3.16
3	300	300	1	1.11	1.08	2.70

Table 10 Verification results for sound intensity

Test No	Design Parameters			AISI 2714 sound intensity / dB		
	f / mm/min	v_c / m/min	a_p / mm	Model	Test	%Error
1	300	200	0.5	80.1	82	2.31
2	400	200	1.5	102.2	104	1.73
3	300	300	1	89.4	90	0.66

In Tab. 6, the multi-response estimation chart for the surface roughness of AISI 2714 is given. As seen in this table, possible values for a value of 0.49 µm are in the range of 0.06 µm to 0.93 µm.

Table 11 Multiple response prediction chart for surface roughness

Response	Fit	95% PI
Roughness / µm	0.49	0.06; 0.93

Multiple response estimation chart for the sound intensity of AISI 2714 is given in Tab. 7. As seen in this table, possible values for a value of 75.79 dB range from 66.19 dB to 85.39 dB.

Table 12 Multiple response prediction chart for sound Intensity

Response	Fit	95% PI
Sound / dB	75.79	66.19; 85.39

4 CONCLUSIONS

In this study, experimental studies were carried out to investigate the effect of cutting parameters on surface roughness and sound intensity of AISI 2714 steel material in milling machine. In experimental studies, it was observed that the sound intensity was reduced and that the surface roughness was brought to an acceptable level by processing appropriate cutting conditions. Mathematical models were developed in order to predict sound and surface roughness by performing regression analysis of experimental results. Optimization of cutting parameters was achieved with the developed mathematical models and the control experiments performed for these models. Thus, while the desired surface roughness values were successfully obtained, the values where the sound intensity was reduced were determined. The results found are shown below.

In experimental studies, the lowest surface roughness value was measured as 0.63 µm, the lowest sound intensity was measured as 78 dB. The most ideal values of cutting parameters for the lowest sound intensity and surface roughness as the target function in the parameter optimization of AISI 2714 Steel, the feed rate was 200 mm/min, the cutting speed was 262 m/min, and the depth of cut was 0.5 mm, and the sound intensity was found to be 75.9 dB and the surface roughness value was 0.62 µm. It has been seen that the reduction of surface roughness values can be achieved by increasing the cutting speed at constant feed and constant depth of cut. It has been determined that when the cutting speed and depth of cut are constant, increasing the feed rate increases the roughness values. It was observed that especially the depth of cut had an important effect on the sound intensity and this effect was followed by the feed rate. It was observed that the most important parameter for the surface roughness was the feed rate, followed by the depth of cut. It has been determined that the cutting parameters should be compatible with each other in the processing of AISI2714 steel material on the milling machine and to prevent the increase in sound intensity. It was observed that the sound intensity increased at the points where the harmony of the parameters with each other was disrupted. In the regression equations obtained, the sound intensity of AISI 2714 steel was modelled with an accuracy rate of 92.34% and surface roughness with an accuracy rate of 93.92%.

When we examine the results, the regression equation, ANOVA analysis, surface and estimation graphs show that they are consistent with each other. It is thought that this method can be used safely for other similar studies. As seen in this study, it is foreseen that the cutting depth should be selected as low and the feed rate slow for minimum sound intensity in terms of occupational health and safety. The cutting speed did not have a significant effect on the sound intensity, but it had an effect on the surface roughness: the higher the cutting speed, the better the roughness ratio. It was seen that the cutting parameters were correlated with the sound intensity and surface roughness values.

5 REFERENCES

[1] Camposeco Negrete, C. (2013). Optimization of cutting parameters for minimizing energy consumption in turning of AISI 6061 T6 using Taguchi methodology and ANOVA. *J. Clean. Prod., 53*, 195-203. https://doi.org/10.1016/j.jclepro.2013.03.049

[2] Weck, M. & Melder, W. (1997). Problems in assessing the noise behavior of machine tools. *CIRP Annals*, *26*(2), 397.

[3] Hesselbach, J., Hoffmeister, H. W., Schuller B. C., & Loeis K. (2010). Development of an active clamping system for noise and vibration reduction. *CIRP Annals-Manufacturing Technology*, *59*(2), 395-398, https://doi.org/10.1016/j.cirp.2010.03.079

[4] Suraratchai, M., Limido, J., Mabru C., & Chieragatti R. (2008). Modelling the influence of machined surface roughness on the fatigue life of aluminium alloy. *Int. J. Fatigue*, 30, 2119-2126, https://doi.org/10.1016/j.ijfatigue.2008.06.003

[5] Hilbert, L. R., Bagge-Ravn, D., Kold, J., & Gram, L. (2003). Influence of surface roughness of stainless steel on microbial adhesion and corrosion resistance. *Int. Biodeterior. Biodegrad*, *52*(3), 175-185. https://doi.org/10.1016/S0964-8305(03)00104-5

[6] Singh, D. & Rao, P. V. A. (2007). A surface roughness prediction model for hard turning process. *Int. J. Adv. Manuf. Technol.*, 32, 1115-1124. https://doi.org/10.1007/s00170-006-0429-2

[7] Yan, J. & Li, L. (2013). Multi-objective optimization of milling parameters–the trade-offs between energy, production rate and cutting quality. *J. Clean. Prod.*, 52, 462-471. https://doi.org/10.1016/j.jclepro.2013.02.030

[8] Quintana, G., Ciurana, J., Ferrer, I., & Rodriguez, C. A. (2009). Sound mapping for identification of stability lobe diagrams in milling processes. *International Journal of Machine Tools and Manufacture*, *49*(3), 203-211, https://doi.org/10.1016/j.ijmachtools.2008.11.008

[9] Simunovic, G., Svalina, I., Simunovic, K., Saric, T., Havrlisan, S., & Vukelic, D. (2016). Surface roughness assessing based on digital image features. *Advances in Production Engineering & Management*, *11*(2), 93-104. https://doi.org/10.14743/apem2016.2.212

[10] Madhusudana, C. K., Kumar, H., & Narendranath, S. (2017). Face milling tool condition monitoring using sound signal. *International Journal of System Assurance Engineering and Management*, *8*, 1643-1653. https://doi.org/10.1007/s13198-017-0637-1

[11] Suresh Babu, P. V., Kumar, A., Suha, K., Shihab, S. K., Siddiquee, A. N. (2017). An investigation on Effects of End Milling process on Noise during Machining of Copper. *International Journal of Scientific & Engineering Research*, *8*(7), 119-124.

[12] Shiva, P., Padmakumar, M., & Sarada, B. N. (2019). Experimental investigation to assess the effects of trumpet hone on tool life and surface quality in milling of AISI4140 steel. *FME Transactions*, *47*(3), 437-441. https://doi.org/10.5937/fmet1903437s

[13] Khawaja, A. H., Jahanzaib, M., & Cheema, T. A. (2020). High-speed machining parametric optimization of 15CDV6 HSLA steel under minimum quantity and flood lubrication. *Advances in Production Engineering & Management*, *15*(4), 403-415. https://doi.org/10.14743/apem2020.4.374

[14] Kumar, J. & Verma, R. (2020). Experimental investigations and multiple criteria optimization during milling of Graphene Oxide (GO) doped epoxy/CFRP composites using TOPSIS-AHP hybrid module. *FME Transactions*, *48*(3), 628-635. https://doi.org/10.5937/fme2003628k

[15] Trung, D. D. (2020). Influence of Cutting Parameters on Surface Roughness during Milling AISI 1045 Steel. *Tribology in Industry*, *42*(4), 658-665. https://doi.org/10.24874/ti.969.09.20.11

[16] Fountas, N. A., Aslani, K. E., Kechagias, J. D., Kyratsis, P., & Vaxevanidis, N. M. (2022). Experimental and Statistical Study of Surface Roughness in CNC Slot Milling of AL

7075 Alloy Using Full and Fractional Factorial Design. *Tribology in Industry*. https://doi.org/10.24874/ti.1151.07.21.11
[17] Kopac, J. & Bahor, M. (1999). Interaction of the technological history of a workpiece material and the machining parameters on the desired quality of the surface roughness of a product. *Journal of Materials Processing Technology*, *92-93*, 381-387. https://doi.org/10.1016/S0924-0136(99)00239-3
[18] Puertas, A. I. & Luis Perez, C. J. (2003). Surface roughness prediction by factorial design of experiments in turning processes. *Journal of Materials Processing Technology*, *143-144*, 390-396. https://doi.org/10.1016/S0924-0136(03)00407-2
[19] Aslan, E., Camuşcu, N., & Birgoren B. (2007). Design optimization of cutting parameters when turning hardened AISI 4140 steel (63 HRC) with Al2O3+ TiCN mixed ceramic tool. *Materials and Deign*, *28*(5), 1618-1622, https://doi.org/10.1016/j.matdes.2006.02.006
[20] Ogawa, K., Aoyama, E., Inoue, H., Hirogaki, T., & Gunjima, M. (1997). Investigation on cutting mechanism in small diameter drilling for GFRP (thrust force and surface roughness at drilled hole wall). *Composite Structures*, *38*, 343-350. https://doi.org/10.1016/S0263-8223(97)00069-X
[21] Minitab 18 Statistical Software, State College, PA: Minitab, Inc. (http://www.minitab.com).
[22] Azizi, M. W., Belhadi, S., Yallese, M. A., Mabrouki, T., & Rigal, J. F. (2021). Surface roughness and cutting forces modeling for optimization of machining condition in finish hard turning of AISI52100 steel. *Journal of Mechanical Science and Technology*, *26*(12), 4105-4114. https://doi.org/10.1007/s12206-012-0885-6

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