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1st International Conference on Pioneer and Innovative Studies

June 5-7, 2023 : Konya, Turkey

ICPIS

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Investigation of Surface Roughness Changes in The Machining of Carbon Steel Under Sustainable Conditions

Mustafa Kuntoğlu [1], Kübra Kaya [2] and Rüstem Binali [*3]

[1] *Department of Mechanical Engineering, Faculty of Technology, Selcuk University, Konya 42130*

[*] *rustem.binali@selcuk.edu.tr*

Abstract – In this study, surface roughness analysis was performed in the turning of C45 steel under Minimum Quantity Lubrication (MQL) and dry machining conditions. For this purpose, turning experiments were carried out using two different cutting speeds and feed parameters. In order to improve the machinability of C45 steel, which is one of the most used industrial materials, a graphical and statistical evaluation was made as well as the optimization approach. With three different evaluations, both the positive effect of MQL on the roughness in the turning process has been explained and different perspectives have been created for C45 steel in terms of surface roughness. The optimum values of the best surface roughness were determined and the cutting conditions was revealed as the most important parameter effecting the roughness by analysis of variance.

Keywords – C45 Steel, Analysis of Variance, Optimization, Machinability, Surface Roughness

I. Introduction

The most preferred steels in the materials of the manufacturing sector are the alloys consisting of the combination of iron and generally different amounts of carbon. C45 steel is also called carbon steel because of the high amount of carbon it contains. However, due to its widespread use in the manufacturing sector, it also appears as manufacturing steel. In terms of usage area, C45 steels are used in large parts such as die sets, construction machines, vehicles and various vehicles, as well as in mechanical fasteners, which we can call the key part we come across in most of the smaller machines such as bolts, shafts, gears and studs. Production in the manufacturing industry is examined under two main headings as machining and chipless manufacturing. Chips separated from the surface of the part during production in machining methods are an important issue to obtain a sensitive surface on the workpieces. Chips also play a role in removing heat from the treated surface of the workpiece[1, 2]. Another important factor that is effective in removing heat from the workpiece is cutting fluids. The use of MQL or dry machining conditions during the process changes the impact of the heat occurring between the cutting tool and the part surface, but also leads to different results in the surface roughness [1, 3-5]. The main element in the mentioned machining conditions is the cutting fluid. In addition to the positive impact of the cutting fluid on the mechanical properties of the workpiece, its negative effect on the environment and the operator is too high to be ignored. If the negative effect is desired to be minimized, the quantity of cutting fluid used should be reduced. However, using the minimum quantity of cutting fluid causes the surface quality of the workpiece to decrease and the life of the cutting tool to decrease. Considering these reasons, the quantity of cutting fluid is a matter to be considered [1, 6, 7]. The Minimum Quantity Lubrication method has started to take its place among the preferred processing conditions with its feature of eliminating the disadvantages of wet and dry processing used in old manufacturing methods. Manufacturing methods applied in today's technology have created different requirements. In the study by Molaie et al., they investigated the MQL method is an environmental machining condition as it increases the lubricating property of the cutting fluid, which minimizes the friction between the cutting tool surface and the workpiece, and reduces the quantity of cutting fluid consumption [8]. Masoudi et al. focused the effects of nozzle position, workpiece hardness and tool type by turning in MQL environment using AISI 1045 steel. As a result of the study, it was observed that the MQL system greatly increased the cutting efficiency in machining, and at the same time, tool type, workpiece hardness and nozzle position had a great effect on the results. In addition, it has been stated that the MMY method has positive effects on the environmental factor and the health of the machine operator [9]. Abbas et al. conducted a sustainability assessment related to the power consumption and roughness characteristics in nanofluidic MQL assisted turning of AISI 1045 steel. As a result of the experiment, optimum results were obtained at a cutting speed of 116 m/min, a cutting depth of 0.25 mm and a feed of 0.06 mm/rev. In addition, it was concluded that a low feed rate for good surface quality and low control factors for reduced power consumption are good [10]. The working principle of the MQL method is that the recycled oil droplet is sprayed onto the cutting area or cutting tool with constant pressure air. Yıldırım et al. stated that spraying on the cutting area larger than 10 μm would not cause health problems [11]. In the study of Gürbüz et al., it was revealed that the MQL method reduces the cutting tool wear and cutting temperature, and increases the surface quality [12]. Demir and Gündüz studied the impact of artificial aging on the machinability of 6061 Al alloy. The effects of different cutting speeds and aging times on roughness and cutting force were investigated by performing their experiments at 180 $^{\circ}$C. As a result of their studies, it has been revealed that the aging time and cutting speeds are quite effective [13]. Kuzu et al., in their study, conducted on the fact that almost all of the shavings generated during manufacturing in the MQL method remained dry, helping to reduce the costs of sawdust recycling. In dry machining, which is another machining method discussed in this study, the removal of heat from the process area is carried out entirely with chips without using any cutting fluid [14]. Asiltürk et al. studied the impact of cutting speed, feed and cutting depth on surface roughness in dry turning method. As a result of the research, it was seen that the most important parameter in the dry processing method is the feed rate [15]. In another study, Ranganath et al. focused the cutting parameters of 6061 Al alloy on roughness under dry machining conditions. As a result of their experiments, they determined that the most important parameter affecting the surface roughness is the cutting speed, and they obtained the optimum values of the machining parameters under the conditions of the lowest depth of cut and feed [16].

In this study, the impact of the quantity of cutting fluid, which plays an important role in manufacturing, in terms of surface roughness will be examined over C45, which is known as manufacturing steel. When the previous studies on the MQL method are examined, it is predicted that the MQL technique made in accordance with the workpiece will replace the cooling technique made with traditional cutting fluid. With this study, it is expected to draw attention to the effects of the MQL method in terms of surface roughness in future turning operations and to benefit the manufacturing sector.

II. MATERIALS AND METHOD

C45 steel, which is an iron carbon alloy, was used in the experiments. The dimensions of the C45 steel were chosen to be 50 mm in diameter and 200 mm in length. Experiments were carried out on CNC Turning Victor V Turn-26 machine using TiC coated CCMT 09T308-304 cutting tool. Two different cutting speeds (60, 120 m/min) and feeds (0.05, 0.1 mm/rev) were used as machining parameters. The parameters used were evaluated in two different cutting environments, dry and MQL. The surface roughness control of the workpieces obtained as a result of the process was made with the Mahr Perthometer test device.

III. RESULTS

The results of the experiments carried out with C45 steel were interpreted using three different evaluation methods. In the graphical evaluation, parameters at different cutting speeds and feeds were evaluated in dry and MQL conditions. In statistical analysis, also known as variance analysis, the most important parameter affecting the roughness was investigated. In the last optimization evaluation, the values of all three parameters were obtained in terms of surface roughness, where the highest efficiency was obtained and positive results were obtained.

A. Graphical Evaluation

In this study, two different cutting speeds (60, 120 m/min) and feed (0.05, 0.1 mm/rev) were used. These values are evaluated separately for the dry machining method and for the MQL method. When the surface roughness change graph given in Figure 1 is examined according to the feed and cutting speed levels, when the cutting speed is fixed to 60 m/min and the feed is increased from 0.05 mm/rev to 0.1 mm/rev, it is seen that the surface roughness is observed in both dry machining and MQL method was found to increase. In another evaluation, a decrease in surface roughness was observed when the feed was fixed at 0.1 mm/rev and the cutting speed was increased from 60 m/min to 120 m/min. In the dry machining method and the MQL method, the highest roughness values were found in the experiment using 0.1 mm/rev feed and 60 m/min cutting speed parameters. The lowest roughness values in both methods were recorded at a feed of 0.05 mm/rev and a cutting speed of 120 m/min. When the graph given in Figure 1 is examined in general, it is seen that the roughness of the workpieces in the experiments made with the dry machining method reaches larger µm values than the ones made with the minimum amount of lubrication method.

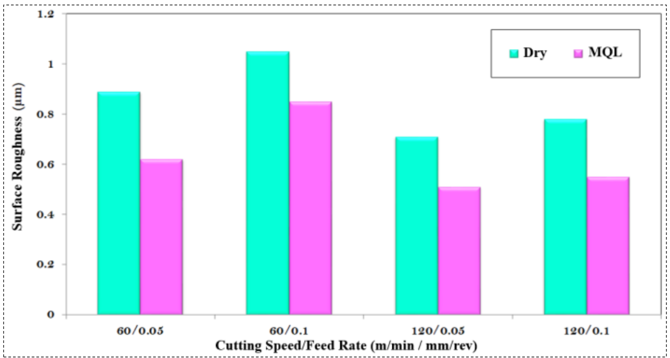

Fig. 1 Surface roughness change according to cutting speed and feed levels

B. Statistical analysis

Variance analysis, which is a statistical analysis method, was used to determine the effect of feed, cutting speed and cutting environment on surface roughness. The ANOVA results of the parameters on the roughness are given in Table 1. In the table given in Table 1, it is stated that the experiment is significant as the significance level (P) values are less than 0.05. The F value, on the other hand, is considered as the control factor, which is the largest value [17, 18]. When the result of the analysis of variance was examined, it was revealed that it was a significant analysis with the P values less than 0.05, and it was revealed that the parameter affecting the roughness values the most was the cutting environment, the cutting environment was followed by the cutting speed in order of importance, and the cutting speed was the last to be effective.

Table 1. Statistical effect of parameters on surface roughness

Factor	DF	SS	MS	F	P
Cutting speed	1	0.9245	0.9245	32.30	0.005
Feed rate	1	0.03125	0.03125	10.92	0.030
Cutting condition	1	0.10125	0.10125	35.37	0.004
Error	4	0.01145	0.002863	-	-
Total	7	0.2360	-	-	-

C. Optimization

At the last stage of the study, the optimum values of the parameters on the surface roughness were studied. Different parameters can be considered in evaluating the machinability of C45 steel. In this study, surface roughness was taken into account in terms of machinability. For the optimization of the control factors in the experiments, the graph of optimum values of the parameters on the roughness given in Figure 2 was created by using the S/N ratios. The optimization process was performed according to the lowest level. Thus, the lowest values read on the graph are considered optimum values. It was found that the optimum values for the machinability of the carbon steel, which is the material used, were obtained under the conditions where the cutting speed was 120 m/min, the feed was 0.05 mm/rev and the cutting medium was MQL. However, the most unfavorable parameters of carbon steel in terms of surface roughness were determined as 0.1 mm/rev feed, 60 m/min cutting speed and dry cutting medium.

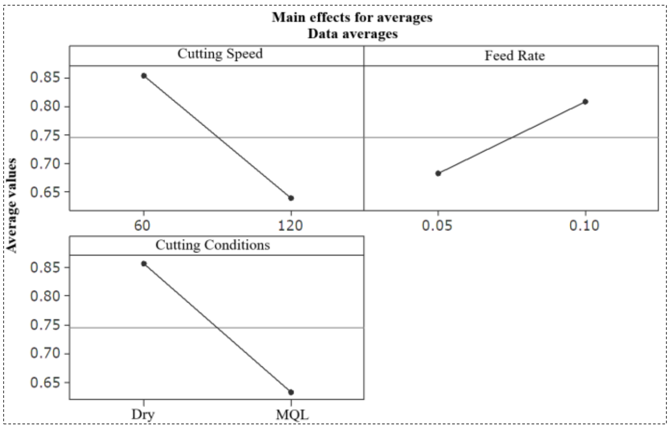

Fig. 2 Optimum values of the parameters on the surface roughness

IV. CONCLUSION

In this study, roughness analysis was performed in the turning of C45 steel under dry and MQL machining conditions. The results obtained in the study are given below.

- As a result of the variance analysis of the parameters on the roughness, the most important parameter is the cutting environment.
- As the feed is increased, the roughness value increases.
- As the cutting speed increases, the roughness decreases inversely.
- When the roughness values are compared in a dry environment with minimal quantity lubrication, the roughness value of the workpiece processed in a dry environment is higher than that of MQL.
- S/N ratios were used for the lowest surface roughness value. Optimum surface roughness values were obtained at a feed of 0.05 mm/rev, a cutting speed of 120 m/min and a MQL.

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