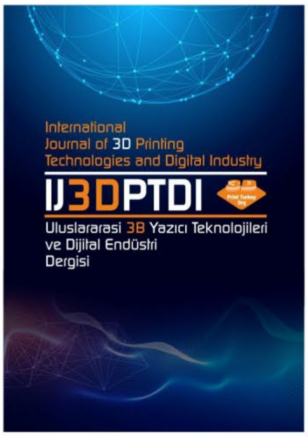

ULUSLARARASI 3B YAZICI TEKNOLOJİLERİ
VE DİJİTAL ENDÜSTRİ DERGİSİ

INTERNATIONAL JOURNAL OF 3D PRINTING
TECHNOLOGIES AND DIGITAL INDUSTRY

ISSN:2602-3350 (Online)

URL: https://dergipark.org.tr/ij3dptdi

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Bu makaleye şu şekilde atıfta bulunabilirsiniz (To cite to this article): *Bacak S., Karabıyık Ö., "The Effect of Atomized Soybean Oil Emulsions Used as Cutting Fluid on The Cutting Performance" Int. J. of 3D Printing Tech. Dig. Ind., 7(3): 550-560, (2023).*

DOI: 10.46519/ij3dptdi.1375591

Araştırma Makale/ Research Article

Erişim Linki: (To link to this article): https://dergipark.org.tr/en/pub/ij3dptdi/archive

THE EFFECT OF ATOMIZED SOYBEAN OIL EMULSIONS USED AS CUTTING FLUID ON THE CUTTING PERFORMANCE

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(**Received:** 13.10.23; **Revised:** 06.12.23; **Accepted:** 14.12.23)

ABSTRACT

Within the scope of sustainable production, a natural liquid mixture that will act as cutting fluid is sprayed with a different system. The liquid consisting of water and soybean oil was pulverized by ultrasonic atomization method and used by spraying with 4 bar compressed air. In this study, it was aimed to investigate the effects of AISI 4140 steel on machinability in CNC lathe by using uncoated carbide insert (SECO WNMG080404-M1). Three cutting speeds (150, 200, 250 m / min), three feed rates (0.1, 0.15, 0.2 mm / rev) with four cutting fluids (1%, 5%, 10% soy oil-water mixture and commercial cutting fluid) and the comparison was made by making experiments under dry cutting conditions. In all experiments, the cutting depth was 1 mm and the cutting length was 100 mm. As a result of the experiments, cutting force, surface roughness and tool wear values were examined and contact angle measurements of cutting fluids were made. The best results in all parameters were achieved by spraying a 10% soybean oil-water mixture using an ultrasonic atomizer. The best results in all parameters were achieved by spraying a 10% soybean oil-water mixture using an ultrasonic atomizer. The worst values occurred in experiments conducted under dry cutting condition. In addition, SEM photographs were taken to observe the type of tool wear.
The obtained values were analyzed with the ANOVA method and the results were evaluated with 3D surface graphics. After evaluating the analysis results, percentage impact rates, regression analysis equations and optimization values are proposed.

Keywords: Sustainable Production, Vegetable Cutting Fluid, Ultrasonic Atomizer, Tool Wear, Cutting Force, Surface Roughness.

1. INTRODUCTION

Machining is expressed as a product that is designed and produced in accordance with the purpose by removing the material from the workpieces. During machining, cutting tools become hot and subject to high wear, causing continuous interruptions in the production process to change tools. It is also seen that the most important parameter affecting the quality of the workpiece during machining is the surface roughness value of the cutting tools on the part, so long tool life is important. Various measures can be taken to minimize tool wear and overheating of the workpiece. The most common of these is the use of a suitable cutting fluid. [1].

The use of cutting fluid minimizes the thermal or mechanical damages that occur during the machining process due to its physical and chemical properties. In addition to cooling, the cutting fluid also undertakes tasks such as reducing friction by lubricating and removing the chips from the cutting area during cutting. In this way, it helps to extend the cutting tool life and increase the surface quality [2]. However, it should be kept in mind that the use of cutting fluid has some detrimental effects in terms of production costs and environment/ human health. As a result of a study conducted by an automobile company, it has been observed that the cost of cutting fluid has a share of approximately 13% in production costs [3]. According to another study, cutting tool cost in the machining industry corresponds to

4% to 8% of the total production cost, while the use of cutting fluid corresponds to a ratio varying between 7% and 17% of the total production cost due to reasons such as cooling system, storage and waste control [4]. Today, three basic methods are used to perform cooling-lubrication by reducing the amount of cutting fluid: dry, high speed machining and minimum quantity lubrication (MQL) [5]. Dry machining, besides being an environmentally friendly production, has an extremely low cost in terms of cooling-lubrication method. However, the negative effects are much higher in heavy cutting conditions where high processing efficiency is desired. For this reason, the MQL system, whose usage rate in machining is increasing day by day and which is known to have positive contributions to the manufacturing process, technologically, environmentally and economically, is preferred in the manufacturing industry [6]. Since the amount of cutting oil sprayed during processing is very small, it evaporates completely with the effect of the temperature in the cutting zone. This evaporation does not have a negative impact on worker health and the environment, and because the chips are almost completely dry, it makes recycling easier [7].

Looking at the oil seeds in the world, the most important ones with economic value are soybean oil, sunflower, canola, corn, olive, cotton, safflower, sesame and castor oils. Looking at the plants with the highest oil production, soybean ranks first with 31.2 million tons. One of the reasons why soybean oil is preferred in this study is its low cost due to its high production as well as its chemical properties.

Childers (2004), in his study, used soybean oil in the gear shaping process and stated that soybean oil was a better lubricant than metal cutting fluids obtained in petroleum product, and that the micro emulsion of soybean oil performed better than the micro emulsion of mineral oil. Jacob John et al. (2004) prepared emulsions from vegetable oils by using ionic and nonionic surfactants to be used as metalworking fluids in their studies. After examining the miscibility and anti-corrosion properties of soybean oil, the concluded that soybean oil could be modified to be an effective metal cutting fluid and prevent corrosion. Dolapçı (2010) stated in his research in the literature that there are not many studies on metal cutting fluids made with refined soybean oil and crude soybean oil and that soybean oil can be tried in such studies. Zhang et al. (2012), in their study, in order to show the usability of soybean oil as a cutting fluid, they subjected E52100 steel with high carbon and chromium alloy to turning process using a coated carbide insert. They sprayed dry cutting, semi-synthetic commercial cutting fluid and cutting fluids mixed with 5% soybean oil separately. The effects of tool wear and surface roughness of these liquids were examined, and they stated that the best values were obtained by spraying the soybean oil mixed liquid.

Jayaram et al. (2014), as a result of their examinations on the usability of vegetable oils as cutting fluid in the metal processing industry, stated that especially sunflower and soybean oil have high oleic acid. They also stated that these oils are oils that require less modification compared to other vegetable oils and have cutting fluid properties because of their high carrying capacity (resistance to tearing under high pressure, high temperature and high speed) and thermo-oxidative properties. Srikant and friend (2015), in their studies, tried to produce new sustainable cutting fluid by using sesame oil and coconut oil in the turning process of AISI 1040 steel and they stated that the performance of normal cutting fluid was better at high cutting force when they compared this fluid with petroleum-based normal cutting fluid in terms of cutting temperature, tool wear and surface roughness,

Chandra et al. (2012) investigated the cutting force, tool life and chip properties in the turning process of Ti-6AL-4V material by spraying the cutting fluid from the ACF nozzle system with an atomizer. They concluded that the cutting fluid sprayed with the ACF system provides an advantage between 40% and 50% compared to the normal system.

Kumar et al. (2014) measured the temperature changes in the cutting line in the turning process with the EN-31 aluminum SNMG120408 carbide cutting tool and performed both cooling and lubrication using soybean oil in the MQL (Minimum Quantity Lubrication) system. They stated that conventional cutting fluids cannot provide cooling and lubrication since they cannot reach the cutting line sufficiently. They evaluated the temperature differences of the MQL system at three different nozzle distances. In addition, as a result of the experiments, they stated that the MQL system using soybean oil reduces the danger in terms of human health and is more sensitive to nature.

According to the literature in the MQL system; there are many studies in which various vegetable oils such as soy, sunflower, canola, palm, olive oil, coconut, peanut oil were used as cutting fluid. Shokoohi et al. (2015). Ekinovic et al. (2015), Yu Sul et al. (2016), Senevirathne et al. (2017), Mia et al. (2018), Kaur et al. (2018), Ghuge et al. (2019). In these studies, experiments were carried out using different cutting tools on different materials. The common evaluation of all of them has been that the positive effects of the use of vegetable oil in the MQL system have emerged on surface roughness, cutting tool life and cutting forces. It is stated that the most important effect is enabling sustainable production.

In this study, soybean oil-water emulsion prepared in different proportions was tested in cutting fluid applications with an ultrasonic atomizer device. It is aimed to transform the emulsion sent to the ultrasonic atomizer into fog droplets and spray it to the cutter with constant compressed air and to meet the basic features expected from cutting fluids and to increase their productivity to higher levels. It has been thought that the liquid particles, which are turned into fog drops with an ultrasonic atomizer, adhere more to the cutting tool and thus increase the wettability. Parameters such as surface roughness, cutting forces, cutting tool life were investigated by subjecting AISI 4140 steel to machining with an uncoated carbide cutting tool in CNC turning process. Contact angle values were measured for all liquid mixtures. Comparison of experimental findings was made together with ANOVA and Regression analysis.

2. MATERIAL AND METHOD

Performance tests of the cutting fluid turned into fog drop with ultrasonic atomizer were carried out on ALEX ANL-75 branded CNC lathe. AISI 4140 reclamation steel was used as the material to be processed in the experiments. An uncoated carbide tool in the SECO WNMG080404-M1 geometry was used as the cutting tool. It has been paid attention that the processing parameter values are within the range of speed and feed rate recommended in ISO 3685 test standard. By selecting three different feed rates (0.10, 0.15, 0.20 mm / rev) and three different cutting speeds (150, 200, 250 m / min), 45 tests were designed with four different cutting fluids (1%, 5%, 10% soybean oil-water mixture, commercial cutting fluid) and dry cutting. Each experiment was repeated in itself until the insert was worn. The depth of cut was 1 mm in all experiments and the cutting length was 100 mm. The test pattern is shown in Table 1.

Table 1. Experiment pattern

Exp. No:	V (m/min)	f (mm/rev)	a (mm)	Cutting Fluids
1	150	0,10	1	%1 Mixture
2	150			%5 Mixture
3	150			%10 Mixture
4	150			C.Cutting Fluid
5	150			Dry Cutting
.	.			
.	.			
.	.			
.	.			
41	250	0,20	1	%1 Mixture
42	250			%5 Mixture
43	250			%10 Mixture
44	250			C.Cutting Fluid
45	250			Dry Cutting

2.1. Measurement of Contact Angle

KSV CAM 101 device was used for contact angle measurement, refrigerant samples were dropped on the cutting tool surface, and images were taken from the device camera after the triple phase consisting of mineral surface-liquid and air came to equilibrium. The angle obtained according to the spreading state of the drop from the images captured by the device on the metal tool surface is replaced by the Young-Laplace equation in the software and the contact angle formed by the liquid on the solid surface is given in degrees as θ left and θ right. It is obtained by averaging these two values while calculating the contact angle. This measurement was made for mineral-based commercial cutting fluid with all soybean oil-water mixing ratios and also for water for comparison. Contact angle results are given as average.

2.2. Measuring Cutting Forces

Kistler brand 9257B model dynamometer, Kistler brand 5070A11100 type amplifier and National Instrument brand DAQ 6062E type data acquisition card and interconnects were used to measure the cutting force signals. The cutting length for the materials to be processed was determined as 100 mm, and the cutting force signals in 3 axes (Fx, Fy, Fz) were received. It was determined as Fx = Fc (main cutting force), Fy = Fr (radial force), Fz = Ff (forward force). The raw signals received from the Cut-Pro software were processed with the MATLAB program and their arithmetic averages were obtained and the final cutting force values were obtained. During the calculations, the signals that the cutting tool touches the material first and makes exit are not included in the arithmetic average part.

2.3. Measurement of Surface Roughness Values

Surface roughness values were measured with the Hommel Werke T 500 instrument. The cutting length was 0.8 mm and the sampling measurement length was 17.5 mm from 3 separate regions on the cylindrical workpiece. . All measurements were carried out at approximately room temperature. The final surface roughness value was calculated by taking the arithmetic mean of the values obtained. Measurements were taken after the first metal removal of each new tool to minimize the impact of values on tool wear.

2.4. Tool Wear Measurements

A stereo zoom microscope was used in tool wear measurements obtained in the experiments performed according to the selected cutting parameters. VB average = 0.3 mm wear value specified in ISO 3685 was taken as basis and machining continued until this value was reached. After the turning process in each test parameter, the cutting edge was taken under examination and the wear values were measured. When the average value of VB reached 0.3 mm, the experiment was concluded for the present parameter and new experiments were started by changing the cutting tool tip.

2.5. ANOVA Analysis For Experimental Results

ANOVA analysis was performed for the cutting forces, tool wear and surface roughness values obtained depending on the cutting parameters at the end of the experiments. The effects of the examined factors on the output factors, the effects of different levels on the output values, and the statistical reliability of the results of the experiments were examined.

2.6. Experimental Scheme

In order to carry out the experiments, an external ultrasonic atomizer system was applied to the workpiece and cutter set connected to the CNC lathe. Thanks to the air coming from the compressor, a mixture of water, oil and air was sprayed to the workpiece and cutting tool friction area in the form of mist steam. The experimental setup is seen in Figures 1

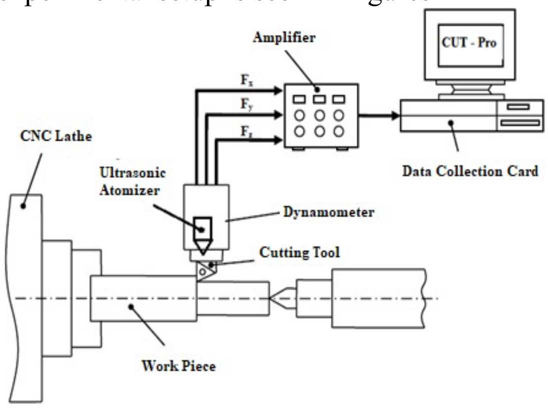

Figure 1. Experimental scheme

3. RESULTS and DISCUSSION

3.1. Contact Angle Findings

In addition to all liquids used in the experimental study, water contact angle measurements were made. Fluids were dropped onto the cutting tip and the right and left theta angles (θ o) were measured. The average values of both angles were calculated and the values obtained are given in a table in Table 2.

Table 2. Contact Angle Measurements

Fluids	θ º Right	θ º Left	θ º Avarage
%1 Soybean-Water	51.9	50.29	51.095
%5 Soybean-Water	39.11	34.78	36.945
%10 Soybean-Water	22.50	24.89	23.70
Commercial Cutting Fluid	40.34	38.89	39.615
Water	48.26	49.81	49.03

When the average theta angles (θº) were examined as a result of the measurements, it was seen that the liquid with the best wettability was a mixture of 10% soybean oil-water.

3.2 Cutting Force Findings

Five different cutting conditions (1%, 5%, 10% soybean oil-water, mineral-based commercial cutting fluid, dry cutting) to interpret the effects of ultrasonic atomizer applications on cutting force and the average values of force components (Fc, Ff and Fr) were measured during machining depending on the cutting speed.

When the experimental data and graphs were examined in terms of cutting fluids, it was observed that the measurements taken by spraying soybean oil-water mixtures with ultrasonic atomizer were better than commercial cutting fluid and dry cutting conditions, and there was a decrease of 5-14% in cutting forces. The reason for this is thought to be the better penetration of the sprayed liquid into the chip-tool interface, the cooling ability as well as the lubrication task.

In addition, when the rate of soybean oil (1%, 5%, 10%) in the mixtures sprayed with an ultrasonic atomizer increased, there was a decrease in cutting forces. It is thought that the amount of oil in the increasing mixture ratio decreases the friction force in the cutting zone. The friction coefficients calculated from the equations obtained from the calculation triangles used for the cutting forces were calculated for soybean oil-water mixtures at 0.1 feed at a cutting speed of 200 m / min, which is the optimum value. It is found that $\mu = 0.42$ for 1% mixture and $\mu = 0.39$ for 10% mixture. According to this, it has been observed that the friction force decreases as the mixing ratio increases.

The effect of the changes in soybean oil ratios examined at the smallest cutting speed (150 m / min) and feed rate (0.1 mm / rev) on the Fc main cutting force was found between 2% and 5%. It is thought that the liquid sprayed as pulverized provides rapid cooling in the hot zone, and the rapid evaporation of micron-sized particles causes a rapid decrease in the heat in the cutting zone.

When looking at the graphs, it is seen that the cutting forces tend to decrease with increasing cutting speed for all machining conditions (Figure 2). As the cutting tool-chip decreases with the increase of the cutting speed, the Fc cutting forces on the face decreased [7]. Compared to the increase in cutting speed around 25-33%, the reduction in cutting force was lower. However, this decrease occurred in a fluctuating manner at 250 m / min cutting speed and some parameters increased. At high cutting speed, as a result of the rapid increase of the temperature in the cutting zone, the rapid onset of wear on the cutting edge and the rapid evaporation of oil and water sprayed from the ultrasonic system, it could not fulfill its lubrication and cooling task sufficiently. It is seen that the advantages provided by this system are not effective at high cutting speeds.

When the changes in the cutting forces depending on the advance amount were examined in the experiments, it was observed that the cutting forces increased with the increase in the amount of feed. The reason for this situation is seen as the increase in the volume of chips removed, as well as the increase in the cutting forces with the increase in the plastic deformation rate of the cutting insert [20].

In Figure 2., the changes of the obtained cutting force values according to the speed and the amount of feed are shown with 3D surface graphics. Interactions for cutting fluids and dry cutting condition are evaluated in separate graphs. As stated in the literature, it is seen that the effect of cutting speed on cutting forces is less than the effect of the amount of feed [6].

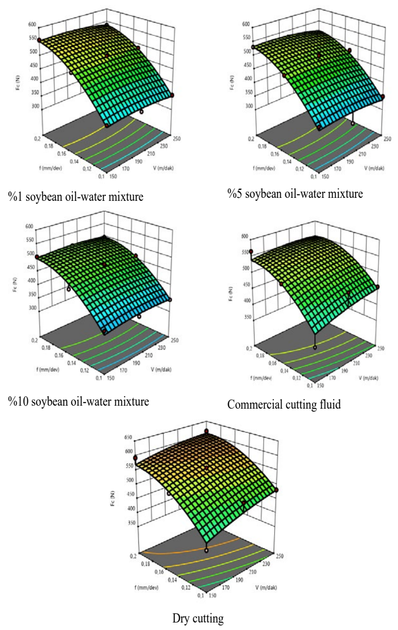

Figure 2. Display of share force depending on cutting speed and feed

3.2. Surface Roughness

When the graphics (Figure 3-5) are examined, surface roughness values with different feed rates have been compared. These results indicate that the feed rate is an effective parameter for surface roughness. The increase in the amount of feed causes surface roughness to increase as a result of the cutting tool not being able to fully remove the chips that it needs to remove and leaving particles [15]. In addition, the chip cross-section area that increases with the increase in progress prevents the chip from forming completely and negatively affects the surface quality. Another effective parameter on the surface roughness is the cutting speed. It is seen that there is a decrease in surface roughness values with the increase of cutting speed. Drops were observed intensively at a cutting speed of 200 m / min.

Cutting fluids are another parameter affecting surface roughness in machining. The difference in average surface roughness values between dry and wet cutting tests clearly express this approach. The addition of soybean oil-water mixtures in the graphs to the turning process by spraying with an ultrasonic atomizer has revealed lower surface roughness values compared to experiments using mineral based commercial cutting fluid. For this reason, the thin film layer formed on the insert is thought to reduce friction and provide better lubrication. In addition, as the oil mixture ratio increased, the lubricating property increased, an improvement was observed in the average surface roughness values. This change rate occurred between 11% and 27%. With the increasing feed and cutting speed, the effect of the mixing ratio on the surface roughness became more evident. The 10% mixing ratio provided lower surface roughness than the 5% and 1% mixing ratios. The high surface roughness values obtained in dry cutting experiments can be explained as the effect of the increasing temperature in the chip area, the high friction and the early start of the cutting tool's wear.

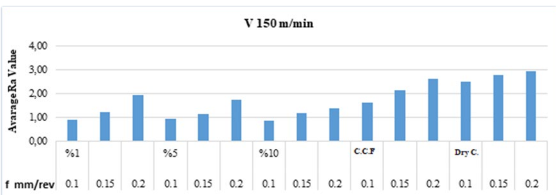

Figure 3. Average surface roughness graph at 150 m / min cutting speed

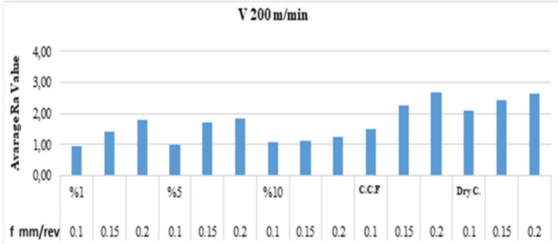

Figure 4. Average surface roughness plot at 200 m / min cutting speed

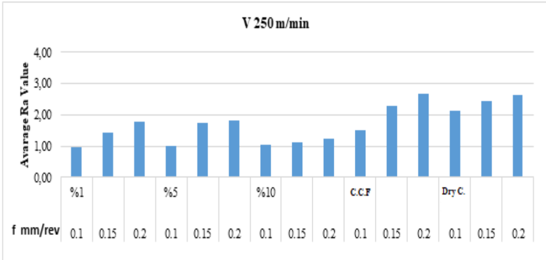

Figure 5. Average surface roughness plot at 250 m / min cutting speed

The lowest average surface roughness value was obtained by spraying with an ultrasonic atomizer at the lowest feed rate (0.1 mm / rev) at the highest mixing rate (10% soybean oil-water) at 200 m / min cutting speed. The highest surface roughness value was obtained at a feed rate of 0.2 mm / rev and the dry cutting condition at the lowest cutting speed (150 m / min). According to these results, it can be recommended to use ultrasonic atomizer at low cutting rates and with liquids with high mixing ratios

3.4 Tool Wear

Tool wear was examined during the cutting tests performed according to the previously determined test pattern. Photographs were taken with Scanning Electron Microscope (SEM) to determine the type of tool wear (Figure 6-9). Cutting speed 150, 200, 250 m / min and 0.2 mm / rev feed parameters, together with 10% soy oil-water mixture, insert images used in experiments conducted under commercial cutting fluid and dry cutting conditions were evaluated. In the examination, free flank wear on all inserts and chipping, called small breaks in the cutting tool tip, were seen.

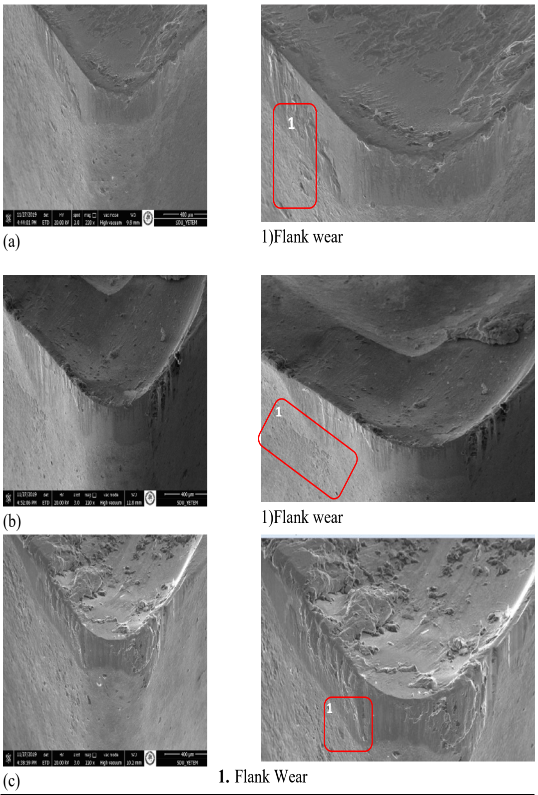

Figure 6. V = 150 m / min f = 0.2 mm / rev (a) 10% soybean oil - water, (b) commercial cutting fluid, (c) wear images under dry cutting conditions

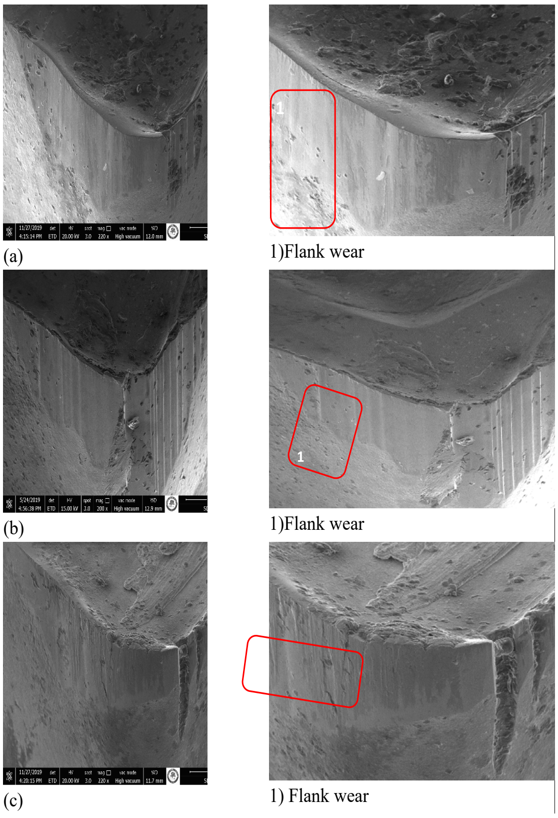

Figure 7. V = 150 m / min f = 0.2 mm / rev (a) 10% soybean oil - water, (b) commercial cutting fluid, (c) wear images under dry cutting conditions

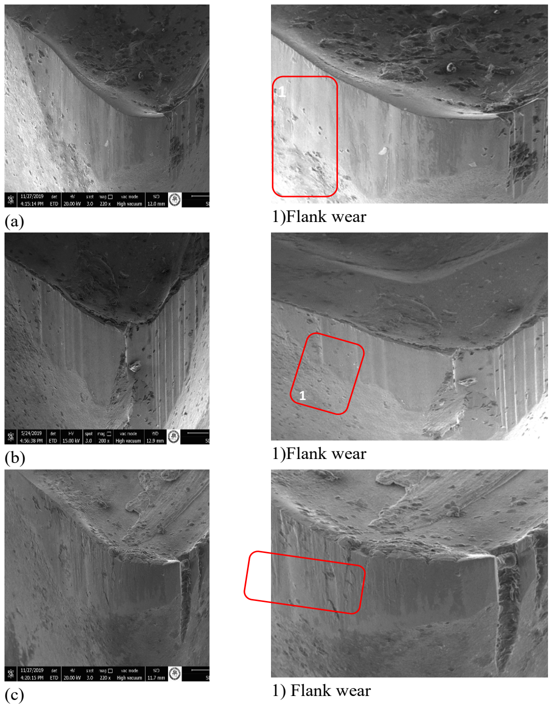

Figure 8. V = 200 m / min f = 0.2 mm / rev (a) 10% soybean oil - water, (b) commercial cutting fluid, (c) wear images under dry cutting conditions

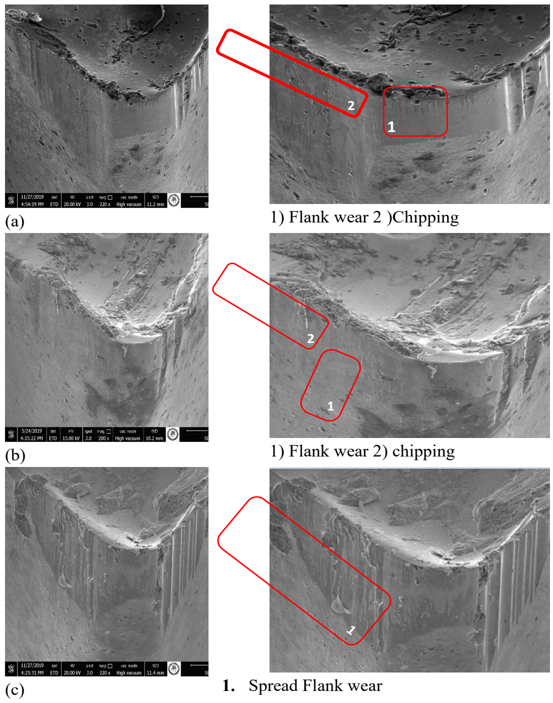

Figure 9. V = 250 m / min f = 0.2 mm / rev (a) 10% soybean oil - water, (b) commercial cutting fluid, (c) wear images under dry cutting conditions

It was determined that tool wear at 150 m / min cutting speed was slower than other cutting speeds (200 m / min, 250 m / min) and the flank wear on the tool was more uniform. As a reason, it can be interpreted that cutting temperatures are also low at low cutting speed, so the cutting fluids used have a better cooling function. When increasing the cutting speed (for 10% soybean oil-water mixture) from 150 m / min to 200 m / min, a 65% reduction in tool life, and when it was increased from 200 m / min to 250 m / min, a 51% shortening was detected. This is because, as stated in the literature, it can be said that increasing heat and pressure with the increase of cutting speed shorten the life of the cutting tool by increasing the effect of wear mechanisms [4].

On the other hand, it was observed that the wear occurred in the cutting tool with the increase of the feed, but this wear occurred more slowly than the wear in the cutting speed increase.

Considering the effect of cutting fluids on tool life, it was observed that soy oil-water mixtures (at all feed rates at V = 150 m / min) increased compared to mineral based commercial cutting fluid. Therefore, it is thought that the particles of soybean oil-water mixtures sprayed with ultrasonic atomizer penetrate the cutting tool better and provide higher lubrication than commercial cutting fluid. Tool life obtained from 10% soybean oil-water mixture at 0.1 mm / rev feed rate was over 7 minutes. At the same feed rate, the tool life time in machining with commercial cutting fluid was around 4 minutes. It has been emphasized that the increase in the mixture ratio and flow rate generally reduces the average flank wear and extends the tool life, which is because the MQL system reduces the friction at the cutting tool-chip interface [21]. A similar situation is observed with the increase in the oil ratio in the blends sprayed with ultrasonic atomizer. The values taken from the cutting fluid with 10% oil ratio were more positive than the other mixture ratios.

When the graphics (Figure 10.) are examined, the increases in cutting speed and feed rate negatively affected the tool life. The best results were obtained in the experiments performed at a feed rate of 0.1 mm / rev at a cutting speed of 150 m / min, while the worst results were obtained at a feed rate of 0.2 mm / rev at a cutting speed of 250 m / min. Cutting fluid is an important factor affecting tool life. It has been observed that the mixture of soybean oil and water sprayed with an ultrasonic atomizer has a positive effect on all cutting speeds. It is thought that micron-sized particles create a thin film layer on the cutting tool, reducing friction, and increasing the tool life by rapidly decreasing the temperature in the cutting zone.

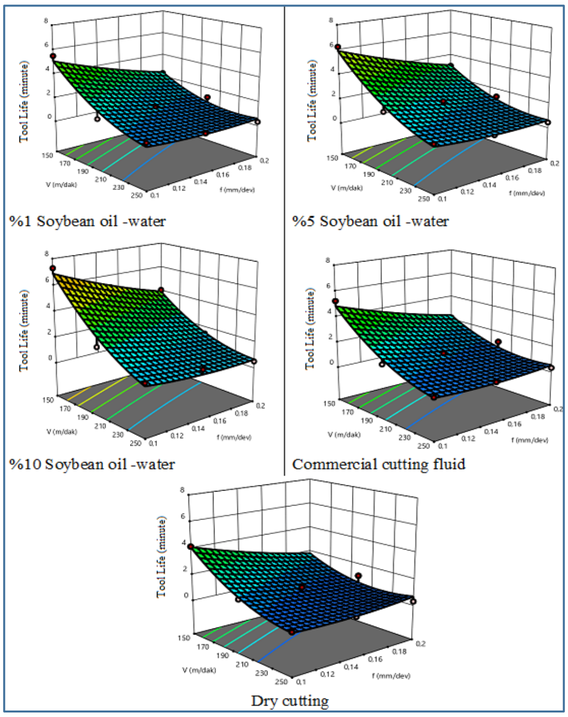

Figure 10. Display of tool life based on cutting speed and feed.

3.5.Fundamental Cutting Force Analysis

The ANOVA chart is usually prepared to find the input parameters that most affect the output results. The sources in the ANOVA table where the P value is less than 0.05 are considered as an important parameter for the relevant output response. ANOVA analysis for the main cutting force is presented in Table 3. In the analysis, the interactions of the cutting speed, feed rate and four fluids used in the experiments under dry cutting conditions were examined, and a P value less than 0.05 showed that some variables affect the main cutting force. Feeding amount (f), machining type (C) and combination of f (f2) are seen as parameters affecting the main cutting force.

Table 3. ANOVA findings for fundamental cutting force $P < 0.05$

Source	Sum of Squares	Degree of Freedom	Average of Squares	F Value	P Value	R^2 Value	S/N Ratio	% Distribution
Model	259500	17	15263.73	37.26	< 0.0001	0.95	18.357	
V	2000.83	1	2000.83	4.88	0.0358			%0.7
f	183900	1	183900	448.99	< 0.0001			%67.9
C-Processing Type	51251.64	4	12812.91	31.28	< 0.0001			%18.9
V*f	1328.45	1	1328.45	3.24	0.0829			
V*C	3038.67	4	759.67	1.85	0.1476			
f^2	11177.88	1	11177.88	27.29	< 0.0001			%4.1
Error	11060.33	27	409.64					%4
Total	270500	44						

Finding the coefficient of determination of the statistical model developed as a result of the analysis as R2 = 0.95 shows that the fit of the model is high. The effect of the feed on the main cutting force was 67.9%, the effect of the machining method was 18.9%, and that of the f component was 4.1%. The error percentage of the model was calculated as 4%. The best values in the fundamental cuttingr force measurements were found in 10% soybean oil-water mixture

3.6. Tool Life Analysis

Table 4. shows the interaction of V, f, and machining shape (C) on tool life (T) and Vf, VC, V2 components according to the results of ANOVA analysis.

Table 4. ANOVA findings for tool life P <0.05

Source	Sum of Squares	Degree of Freedom	Average of Squares	F Value	P Value	R^2 Value	S/N Ratio	% Distribution
Model	127.33	17	7.49	48.40	< 0.0001	0.96	26.234	
V	84.81	1	84.81	548.01	< 0.0001			%64.4
f	14.23	1	14.23	91.94	< 0.0001			%10
C-Processing Type	10.24	4	2.56	16.54	< 0.0001			%7.7
V*f	7.96	1	7.96	51.46	< 0.0001			%6
V*C	3.98	4	0.9960	6.44	0.0009			%3
f^2	5.37	1	5.37	34.69	< 0.0001			%4
Error	4.18	27	0.1548					%3.17
Total	131.51	44						

The optimum values for tool life optimization were analyzed as cutting speed 150 m / min, feed rate 0.1 mm / rev and cutting fluid using 10% soy oil-water mixture.

3.7. Surface Roughness Analysis

According to the results of the variance analysis given in Table 5., it is seen that the interaction of the amount of progress (f) and the way of processing (C) and the combination of these two factors have an effect on the surface roughness. The fact that the R2 value obtained as a result of the analysis is 0.97 indicates that the model is suitable.

Table 5. ANOVA findings for surface roughness P <0.05

Source	Sum of Squares	Degree of Freedom	Average of Squares	F Value	P Value	R^2 Value	S/N Ratio	% Distribution
Model	17,42	15	1,16	67,63	< 0.0001	0.97	22.428	
V	0,0572	1	0,0572	3,33	0,0783			
f	13,45	1	3,45	201,17	< 0.0001			%75
C-Processing Type	0.332	4	3,33	193,91	< 0.0001			%18.5
V*f	0,3604	4	0,0500	2,91	0,0386			%2,1
V*C	0,4980	29	0,0172					%2,7
f^2	17,92	44						

The most appropriate values for surface roughness were analyzed as the cutting speed was 150 m / min, the feed was 0.10 mm / rev, and the cutting fluid was used with a mixture of 10% soy oil and water.

4. RESULTS

In this experimental study, a sustainable cutting fluid in three different proportions (1%, 5%, 10%), which is a mixture of soybean oil and water, was obtained and cutting experiments were carried out in the form of spraying the cutting area with compressed air by turning it into fog with an ultrasonic atomizer. The findings obtained are compared with the results of tests conducted under commercial cutting fluid and dry cutting conditions. In this context; The wetting ability was found in 10% soybean oil-water mixture with an angle of θ = 23.70. In general, soybean oil-water mixed fluids sprayed with ultrasonic atomizer provide a 5-14% reduction in cutting forces in cutting forces compared to commercial cutting fluid and dry cutting condition, especially as the soy oil-water ratio increases, the reduction in cutting forces depends on the mixture ratio. has been changed as. In the experiments, it was seen that the highest Fc (main cutting) force (in dry cutting conditions, at 250 m / min cutting speed, at 0.2 mm / rev feed) was 613.12 N.

The smallest Fc force (10% soy-water mixture, 200 m / min cutting speed, 0.1 mm / rev feed) was measured as 340.26 N. It has been observed that increasing cutting speed has a positive effect on surface roughness. The lowest surface roughness value (10% soybean oil-water mixture, 200 m / min cutting speed, 0.1 mm / rev feed) was measured as 0.81 µm. The highest surface roughness value (in dry cutting conditions, 150 m / min cutting speed, 0.2 mm / rev feed) was determined as 2.91µm. The increase in soybean oil ratio in cutting fluids has had a positive effect on the average surface roughness results. Increasing the cutting speed wears the cutting tool rapidly and decreases the tool life. In experiments with uncoated carbide cutting tools, cutting tools have completed their life after reaching 0.3 mm side flank wear average value.

In the experiments (10% soybean oil-water mixture, cutting speed 150 m / min, 0.1 mm / rev feed) the best tool life was obtained from the experiment where the cutting fluid was sprayed with an ultrasonic atomizer. The cutting tool life reached its highest value in this parameter, 7.29 minutes. The worst tool life (at 250 m / min and 0.2 mm / rev feed) was measured as 0.33 min in experiments with mineral based commercial coolant and 0.3 min in experiments conducted under dry cutting conditions. In the experiments, not only the cutting speed, but also the tool life decreased as the feed increased. The positive effects on tool life caused by the use of soybean oil mixture by atomizing decreased after the feed and cutting speed increased. When SEM photographs of inserts used in experiments performed under commercial cutting fluid and dry cutting conditions with cutting speed, 150, 200, 250 m / min, 0.2 mm / rev, 10% soybean oil-water mixture are examined, free flank wear and small breaks on the cutting tool tip, called chipping, were observed on all of the inserts.

The results of ANOVA and Regression analysis performed in this study overlap with each other. In the analysis for the main cuttingforce, it was revealed that the interactions of feed, machining and feed resultant were significant. It has been calculated that these parameters affect the actual cutting force at 67.9%, 18.9%, 4.1%, respectively. The R2 value of the model is 0.95. In the ANOVA analysis for the surface roughness, it was seen that the progress, the way of processing and the combination of these two parameters affect the average Ra value. In the ANOVA analysis for the surface roughness, it was seen that the progress, the way of processing and the combination of these two parameters affect the average Ra value.

The percentage interactions of the parameters of the model with a R2 value of 0.97 were 75%, 18.5% and 2.1%, respectively. In the ANOVA analysis for tool life, it was seen that the components of cutting speed, feed, machining type, Vf, V2, VC (C = machining style) affect tool life. The percentage interactions of the model with the R2 value of 0.96 were 64.4%, 10%, and 7.7%, respectively. Percentage interactions of the components were 6%, 3% and 4%, respectively. Soybean oil is included in the literature as an oil suitable for machining in terms of its chemical properties among vegetable oils. Considering the results obtained, it is seen that the ultrasonic atomizer and soybean oil-water mixture can be applied in machining without adding additives.

Considering the results obtained as a result of experimental studies, it is concluded that vegetable-based cutting fluids can be used in terms of sustainable production.

Funding:
For this study, I would like to thank Süleyman Demirel University Scientific Research Projects Coordination Unit for their support for the project numbered 4994-D1-17.

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