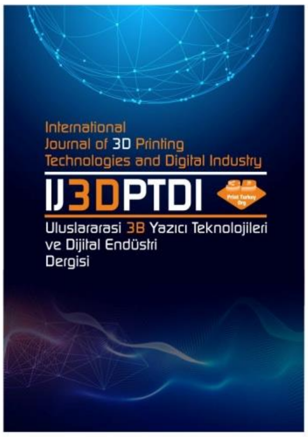

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EFFECTS OF VARIOUS VEGETABLE OIL AND WATER MIXTURES USED AS CUTTING FLUIDS ON TOOL WEAR AND SURFACE ROUGHNESS

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ABSTRACT

In the study, various vegetable oil and water mixtures were used as cutting fluid to be tested in machining. These fluids have been used as an alternative to cutting fluids made from synthetic and semi-synthetic oils, which have harmful effects on nature and humans, and their performance has been investigated. As vegetable oil, Soy, Sunflower and Canola oils were mixed with water each and separate cutting fluids were obtained. Vegetable oil and water were mixed at 7 % and 93 %, respectively, and turned into a homogeneous liquid. Dry cutting and commercial cutting fluid using for cutting was also performed in comparison turning. In the study, AISI 4140 steel was processed on a CNC turning machine using an uncoated carbide insert. In all experiments, the cutting speed was kept constant as 200 m/min, the feed rate as 0,2 mm/rev, and the depth of cut at 1 mm. Cutting fluids were used in two different ways in experiments as liquid and 4 bar pressure spraying. As a result of the experiments, tool wear and surface roughness values were studied. The best results in all processing terms have been found in experiments with pressurized spraying of a mixture of canola oil and water. The surface roughness value was measured as 1,35 μm and the tool wear value was measured as 0,13 mm. The worst values were obtained in experiments carried out under dry cutting condition. Surface roughness value was measured as 2,31 μm and tool wear value was measured as 0,24 mm.

Keywords: Vegetable Cutting Fluid, Tool Wear, Surface Roughness.

1. INTRODUCTION

The purpose of machining is to remove material from the workpiece in order to obtain the designed product. Sometimes it becomes difficult to achieve the dimensional standard due to the processes applied while obtaining the desired product. While trying to increase 7the quality of the product 4on the one hand, reducing production costs on the other hand has always been a priority in machining operation planning. Because the most important feature affecting the quality of the part is known as the surface roughness values caused by the cutting tool. The cooling and lubricating properties of cutting fluids help to increase the surface quality of the product by reducing the friction effect and removing the heat generated in the cutting area [1]. Most of the cutting fluids used today are synthetic and semi-synthetic fluids. On the other hand, it has been concluded that such liquids primarily expose various rashes and allergic reactions when they come into contact with the human body, on the other hand, the inhalation of the vapor caused by contact with high heat harms the human body [4].

There is a lot of evidence that the surface of materials processed by applying cutting fluid is in better condition than the surface of dry machined material. If the cutting fluid is appropriate for the material, applying cutting fluid positively affects the surface of the material [15,16]. While more than 100 million gallons of coolant are used in the US each year, nearly 12 million workers face the potential dangers of these cutting fluids. When all these reasons are listed, both researchers and industrial organizations have been making efforts to reduce the use of cutting fluid and find an alternative recently, due to the impact of the use of coolant on production costs and its harmful effects on the environment and human health [13]. Çakır, in his studies; stated that chemicals such as iron sulphate and acid are used to separate waste cutting oil and emulsion cutting fluids. He stated that the acids must be neutralized before they are sent to the sewerage network, the oil being separated is contaminated due to various processes until it is separated, and these oils can also be burned in special waste furnaces. He stated that it is not economical for the majority of workplaces to dispose of waste cutting fluids, so many companies get support from specialized private organizations for waste liquids and oils. In recent years, studies with cutting fluids have shown that vegetable oils can be used in machining, and it has been emphasized that these fluids have a lower cost than synthetic cutting fluids [5]. Julieb et al. stated in their research that, in the last five years, the studies have been continuing rapidly to develop environmentally friendly cutting fluids based on various vegetable oils, and most of the reported studies are related to soybean, sunflower and colza oil [8].

Belluco and Chiffre used 6 different cutting fluids to drill AISI 316L austenitic stainless steel using HSS-Co drill bits. They examined the effects of these cutting fluids on cutting tool wear, cutting force and chip shape. They concluded that by using plant-based cutting fluids, a 77% increase in tool life and a 7% reduction in thrust was achieved [2]. Birava et al., in their study, developed a vegetable-based emulsion instead of petroleum product emulsions used in machining operation. They concluded that when the vegetable based emulsion was tested in machining, its lubricating ability was better [3]. Xavior and Adithan investigated the effects of vegetable and commercial cutting fluids on cutting tool wear and surface roughness when machining AISI 304 stainless steel with carbide-coated cutting tools. In the experiments where Anova analysis was also applied, the results were examined, it was seen that the cutting fluids had positive effects on the surface roughness and tool wear. Experiments using coconut oil mixture have been reported to have better results than those using commercial oils [14]. When Shashidrhara et al. examined vegetable oils tribologically, they stated that vegetable oils can be used in the metal processing industry besides the cosmetics and food sector, and that the vegetable oil emulsions used in turning processes have high performance in terms of surface roughness and cutting tool life [11]. Yıldırım et al. conducted experiments at four different cutting speeds, fixed depth of cut and four different feed rates using alumina-coated carbide inserts in AISI 4340 turning. Vegetable and mineral oils were used as cooling fluid in these experiments. In terms of surface roughness, they explained that they achieved the best value in the use of vegetable cutting oil. The reason for this it is seen that vegetable oil has lower viscosity than mineral oil [13]. Sarıkaya et al. used the MQL system of vegetable oil, synthetic ester mineral oil and only mineral oil to spray the Haynes 25 superalloy in the turning process with an uncoated carbide cutting tool. As a result of turning tests, they compared the tool life and surface roughness values. They explained that the best results were obtained when spraying the vegetable oil with the MQL system [10].

2. MATERIAL AND METHOD

Turning speed, feed rate and cutting depth values were selected from ISO 3685 test standard and catalog values recommended by the cutting insert company in the turning of AISI 4140 tempered steel. WNMG080404-M1, an uncoated carbide cutting insert of SECO firm, was used as the cutting tool. The cutting speed was kept constant in all experiments as 200 m / min, feed rate 0.2 mm / rev and cutting depth 1 mm. Four different cutting fluids were used in the experiments (Commercial cutting fluid, canola oil and water, sunflower oil and water, soybean oil and water emulsions). Vegetable oil emulsions were mixed as 7% oil and 93% water until they became homogeneous. It is stated that the emulsion obtained by mixing 5-10% oil with water forms the most common cutting fluid wall [12]. Emulsions prepared according to this ratio were used in the experiments. Measurements were made with a refractometer to control the mixing ratio. All cutting fluids took part in the experiments in two different ways by spraying both in liquid form and at 5 bar pressure. In addition, by performing dry cutting tests, cutting insert wear and surface roughness results were compared and measured. Cutting length is taken as 100 mm in turning process. The usage purposes of the machinery and equipment used in the construction of the tests are shown in Table 1. and the test pattern in Table 2.

Table 1. Machinery and equipment used in experiments.

Device Name / Model	**Purpose of usage**
CNC Lathe / ALEX ANL-75	In the realization of processing experiments
Surface Roughness Tester / Hommel Werke T 500	Measurement of average surface roughness (Ra) of processed surfaces
Stereo Zoom Microscope / OLYMPUS SZ 61	Measurement of cutting tool wear
Refractometer / ATC	Measuring the mixing ratio

Table 2. Experiment pattern.

E.No:	V (m/min)	f (mm/rev)	a (mm)	Cutting Fluid
1	200	0,20	1	Commercial Cutting Fluid
2	200			%7 Canola Oil
3	200			%7 Sunflower oil
4	200			%7 Soya oil
5	200			Dry Cutting
6	200	0,20	1	Commercial Cutting Fluid (spraying)
7	200			%7 Canola Oil (spraying)
8	200			%7 Sunflower oil (spraying)
9	200			%7 Soybean Oil (spraying)

2.1. Tool Wear Measurements

In the experiments, tool wear measurements were made using a stereo zoom microscope. VB average = 0.3 mm wear value which was Specified in the ISO 3685 standard is based on. In each experiment, a new insert was installed, the values after the first metal removal were measured and compared.

2.2. Measurement of Surface Roughness Values

After the machining process was completed, the surface roughness values were measured with a Hommel Werke brand roughness device. Measurements with a cutting length of 0,8 mm and a sampling length of 17,5 mm were obtained from 3 separate regions on the workpiece. In the measurements made with the cutting length of 0,8 mm and the sampling length as 17,5 mm, values were taken from 3 separate regions on the workpiece. The arithmetic mean of the values obtained from the measurements made at room temperature was taken and the surface roughness values were calculated. In order to minimize the effect of tool wear on surface roughness, measurements were made after the first machining of each newly installed insert.

2.3. AISI 4140 Tempered Steel

AISI 4140 steel is the most widely used area of low alloy Cr-Mo tempered steels and is known as chromium-molybdenum steel.

Among the areas of use ıt can be saiad automobile and aircraft construction, crankshaft, axle shaft, gear wheel, etc. (Url-2, 2018).

Gaining benefit in experiments on a material with a high usage area will cause positive effects in the industry. Table 3. shows the chemical compositions of AISI 4140 steel.

Table 3. Chemical composition of AISI 4140 steel (Url-2).

Element	C	Mn	P	S	Si	Cr	Mo
% Weight	0,38-0,45	0,75-1,00	0,035 (max)	0,04 (max)	0,15-0,30	0,80-1,10	0,15-0,25

2.4. Uncoated Carbide Tools

Carbide tools are the most commonly used tool materials in machining. In the experiments, uncoated carbide tool with SECO WNMG080404-M1 geometry was preferred as the cutting tool. The insert has a total of six edges on the front and back surface. The data about the cutting tool used in the experiments are shown in Figure 1.

D1	Hole diameter	3.8 mm
EPSR	Angle	80^0
IC	Circle diameter	9,5mm
L	Cutting edge length	6,5mm
RE	Corner radius	0,40mm
S	Thickness	4,76mm

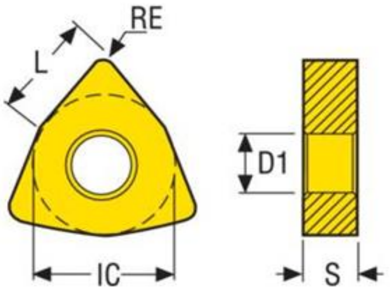

Figure 1. SECO Uncoated carbide cutting tool features [12].

2.5. Commercial Cutting Fluid

Blaser brand B-Cool 655 coded cutting fluid was used as commercial cutting fluid on CNC lathe. The product showing chemical and physical data about the cutting fluid in Table 4. is a chlorine-free low-mineral oil cutting fluid that is miscible with water [17].

Table 4. Properties of B-Cool 655 fluid.

Mineral oil content	% 24
Water Content	% 21
Density at 20^0C	1,01 g/cm^3
Viscosity at 40^0C	59,5 mm^2/s
Flash point	160 ^{0}C
Clour	Greenish brown

2.6. Soybean Oil

Soybean oil is obtained from soybean seeds, which contain 18-20 % oil. Soybean oil is among the linolenic oils. The non-saponification components of the oil such as triterpenes, sterols and tocopherols are found in different proportions in the content of soybean oil. Despite the high content of tocopherol, the amount of linolenic acid varying between 4-11 percent reduces the oxidative stability of soybean oil [7,9]. Cooling capacity of low viscosity liquids is higher. While the viscosity of soybean oil is 32,93 cm^2/sec. at 40 ^{o}C, it is 8,08 cm^2/sec. at 100 ^{o}C. In addition, the flash point of the oil is 240 ^{o}C.

2.7. Sunflower Oil

Sunflower oil is obtained by pressing sunflower seeds. The color of the crude sunflower oil obtained is described as light amber. It contains a high amount of linolenic acid (about 75-60 %) and a smaller amount of oleic acid (25-30 %). The flash point of sunflower oil, which has 68,9 mm^2/sec. viscosity value, is 209 ^{o}C [6].

2.8. Canola Oil

Canola oil is a vegetable oil extracted from the seeds of the canola plant. There is 40-45 % oil in its seeds. Its flash point is 238 ºC and its viscosity is 77,3 mm^2/sec. It is an oil type that contains 21,82 % linolenic acid content and 63,2 % oleic acid content [1].

3. RESULTS AND DISCUSSION

Measurements made after turning the AISI 4140 steel with uncoated carbide insert, surface roughness and tool wear values are given in Table 5. Values are interpreted as graphically.

3.1. Surface Roughness (Ra)

Cutting fluids are a parameter that affects the surface roughness in machining. The different surface roughness values between dry and wet cutting in the experiments clearly express the approach. When Figure 2. is examined, surface roughness values (Ra) obtained according to the use of different fluids in experiments are compared. By spraying cutting fluids using 5 bar air pressure, better surface roughness values were obtained in all liquids compared to normal use.

These results revealed that the pressure spraying method reaches between the cutting tool and the material better and reduces the friction more. In addition, the average surface roughness values of cutting fluids obtained from vegetable oil blends were better than the commercial cutting fluid values. As a reason for this, it is thought that vegetable oil emulsions provide better lubrication besides reducing friction. The best average surface roughness value has emerged in machining by spraying a mixture of canola oil and water. The reason for the high surface roughness value obtained in the dry cutting test can be expressed as the temperature increase of the friction in the chip area, and therefore the early wear of the cutting tool.

Table 5. Tool wear and surface roughness values.

Conditions	Liquid State		Pressure Spraying	
	VB Avg.(mm)	Ra Avg.(µm)	VB Avg.(mm)	Ra Avg.(µm)
Commercial Cutting Fluid	0,17	1,81	0,159	1,63
Sunflower Oil	0,151	1,76	0,145	1,57
Soybean O.	0,14	1,58	0,134	1,49
Canola O.	0,136	1,41	0,131	1,35
Dry Cutt.	0,24	2,31		

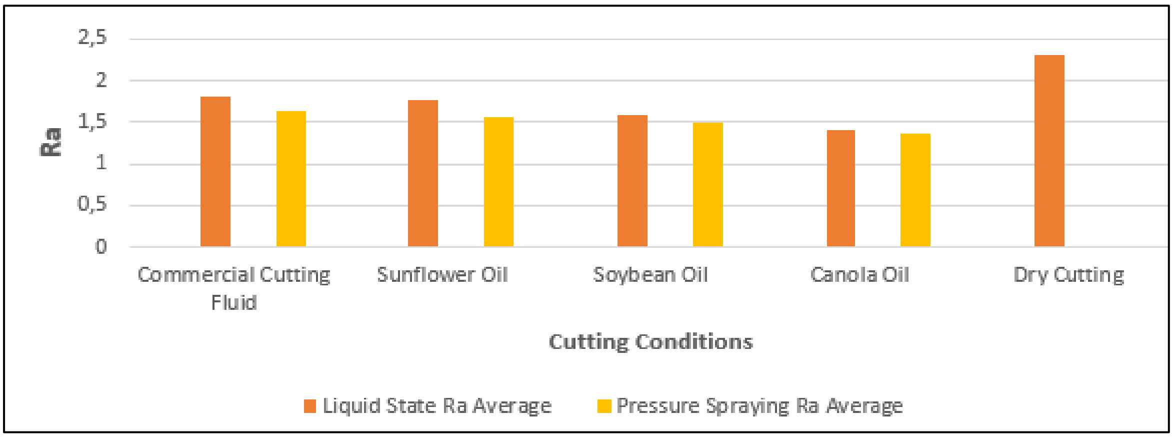

Figure 2. Average surface roughness change.

3.2. Tool Wear (VB)

Nose wear on the cutting tool (VB) or insert is an important parameter affecting tool wear. High temperature and friction in the chip zone increase wear. It is expected from cutting fluids is to reduce the temperature by good cooling and to minimize friction with its lubricating feature. When Figure 3. is examined, it is seen that better results are obtained in other cutting conditions compared to dry cutting, and the best result is obtained by spraying the canola oil mixture.

In the tool wear tests, sending the spray cutting fluids to the chip zone decreased the wear values. The reason for this can be interpreted as the fluids sent by spraying better penetrate the cutting tool and fulfill the duty of lubrication. It has been emphasized that cutting fluids sent to the chip zone by spraying systems such as MQL generally reduce the average flank wear and extend tool life, and as a reason a decrease in friction at the cutting tool-chip interface has been shown [10].

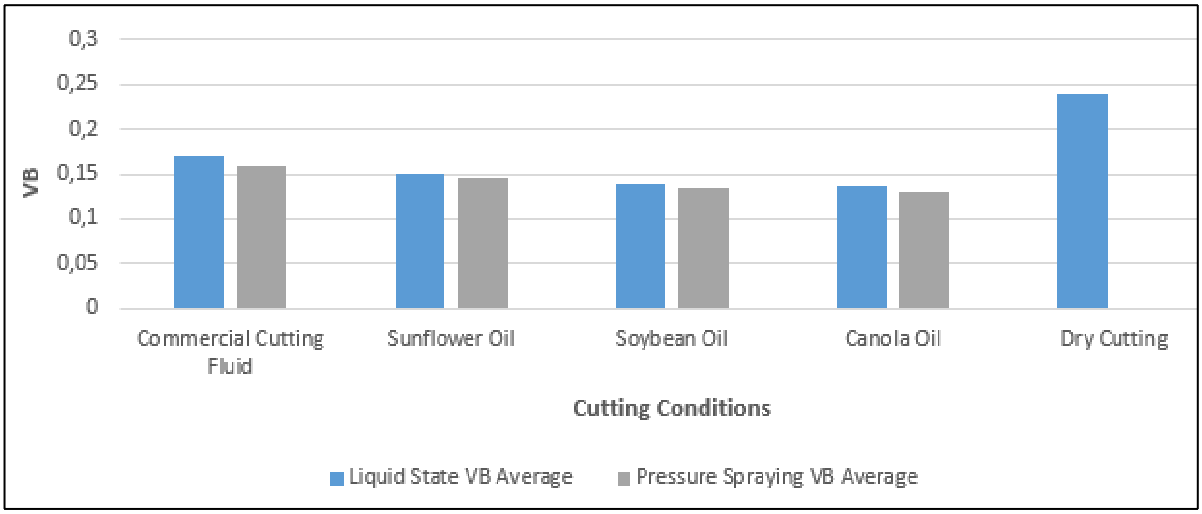

Figure 3. Average tool wear change.

4. CONCLUSIONS

In the study, the performance of AISI 4140 tempered steel in CNC lathe machining process was examined. Uncoated carbide cutting tool is preferred for better observation of wear. As a result of the experiments, average surface roughness and cutting tool wear values were examined, and the cutting speed, feed rate and cuttingg depth were kept constant. In cutting conditions, 3 kinds of vegetable oil and water mixture liquid and commercial cutting fluid were used. The comparison of these was also made with dry cutting conditions.

Cutting fluids were included in the experiments by flowing in liquid form, as well as being sprayed with air of 5 bars.

- It is also seen in the results obtained that emulsions consisting of vegetable oils can be used as cutting fluid.
- Sending cutting fluids to the chip zone by spraying gave more positive results in terms of surface roughness and tool wear values.
- The worst results in the experiments were obtained under dry cutting conditions.
- The best values among vegetable oil mixtures were obtained from the emulsion in the canola oil-water mixture.
- The use of a mixture of vegetable oil and water as cutting fluid has become an environmentally friendly waste and a healthier usage option for the machine operator.

Declaration of competing interest:
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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