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Influence of Cutting Fluids on Tool Wear and Surface Roughness During Turning of Aisi 316 Austenitic Stainless Steel

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Abstract— **The purpose of this experimental investigation is to determine the influence of cutting fluids on tool wear and surface roughness during turning of AISI 316 with carbide tool. An attempt has been made to identify the influence of coconut oil (vegetable based cutting fluid) to improve efficiency of machining process. The efficiency of machining process depends up on various parameters like surface roughness on the work piece, temperature developed on tool chip interface, tool wear etc. The machining process is carried out with the help of four different machining parameters namely cutting speed, depth of cut, feed rate and the type of cutting fluid used. By varying these parameters, the surface roughness and tool wear are measured for three different cutting fluids namely coconut oil, straight cutting oil (immiscible with water) and water soluble oil. It has been found that the performance of coconut oil in reducing the tool wear and surface roughness during turning of AISI 316 steel is better compared to the other two cutting fluids. Coconut oil is used as one of the cutting fluids in this work due to its thermal and oxidative stability which is comparable to other vegetable based cutting fluids used in the metal cutting industry.**

Keywords— ***Cutting fluids; Tool wear; Surface roughness; turning; coconut oil and austenitic steel.***

1. INTRODUCTION

During machining of AISI 316 the operators encounter certain difficulties such as premature tool wear (V_b) and poor surface finish due to high temperature at tool work piece interface. In order to overcome these difficulties, the use of vegetable based cutting fluids was started. The use of cutting fluids in metal cutting was first reported in 1894 by F. Taylor who noticed that cutting speed could be increased up to 33% without reducing tool life by applying large amounts of water in the cutting zone. Cutting fluids increase the tool life and improve the efficiency of the production systems providing both cooling and lubricating the work surface by dry and wet machining [1].

1.1 Austenitic Stainless Steel:

Austenitic stainless steels are characterized by high hardening rate, resistance to corrosion and low thermal conductivity. Austenitic stainless steels are widely used in cutlery, sinks, tubing, dairy, food and pharmaceutical equipment as well as in springs, nuts, bolts and screws due to their high strength and high corrosion and oxidation resistance. AISI 316 stainless steel finds its application in air craft fittings, aerospace components such as bushings, shafts, valves, special screws, cryogenic vessels and components for severe chemical environments. It is also being used for welded constructions in aerospace structural components. Other applications include Bursting discs, seals, bellows, gaskets, expansion joints, explosion panels, tubes, diaphragms and components in chemical, petrochemical and marine applications. Stainless steels are known for their resistance to corrosion. For better performance of any machining process, high machining rate and better surface finish and good power consumption are desirable. To achieve high cutting performance, selecting of cutting parameters is very important [2-3].

2. CUTTING FLUIDS

Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece thermal deformation, improving surface finish and flushing away chips from the cutting zone. The various cutting fluids used are:

2.1. Straight oils

Straight oils are non-emulsifiable and are used in machining operations in an undiluted form. They are composed of a base mineral or petroleum oil and often contains polar lubricants such as fats, vegetable oils and esters as well as extreme pressure additives such as Chlorine, Sulphur and Phosphorus. Straight oils provide the best lubrication and the poorest cooling characteristics among cutting fluids.

2.2. Soluble oils

Soluble Oil Fluids form an emulsion when mixed with water. The concentrate consists of a base mineral oil and emulsifiers to help produce a stable emulsion. They are used in a diluted form (usual concentration = 3 to 10%) and provide good lubrication and heat transfer performance. They are widely used in industry and are the least expensive among all cutting fluids.

2.3. Coconut Oil

Coconut oil has been used as one of the cutting fluids in this work because of its thermal and oxidative ability which is being comparable to other vegetable based cutting fluids used in the metal cutting industry. Coconut oil belongs to the unique group of vegetable oils called lauric oils. Chemical composition of coconut oil includes lauric acid (51%), myristic acid (18.5%), caprilic acid (9.5%), pamitic acid (7.5%), olcic acid (5%), stearic acid (3%), and linoleic acid (1%). Coconut oil is one of the vegetable oils, which remains as a white crystalline solid at a temperature below 20°C. More than 90% of fatty acids of coconut oil are saturated[4]. The iodine value of coconut which is a measure of unsaturation in coconut oil is 7-12. The saturated character of the oil imparts a strong resistance to oxidative stability. The specific density of coconut oil is o.93 g/cm3 and the cetane number is 37. The flash point and viscosity index of coconut oil is 294 and -130 respectively. Coconut oil has very high pour point (23-25) because of the predominantly saturated nature of its fatty acids constituents.

I. EXPERIMENTAL PROCEDURE

A. Cutting tool

The cutting tool used is WIDIA made carbide turning insert CNMG 120408-LM-TN2000

Insert thickness	*0.1875 inches.*
Nose radius	*0.0314 inches*
ISO number	*CNMG 120408-LM-TN2000*
No. of edges	*4*

TABLE 1. SPECIFICATIONS OF THE CUTTING TOOL INSERT

B Talysurf surface roughness Tester

It works on carrier modulating principle and it is an accurate method comparing with the other methods. The main part of this instrument is diamond stylus (0.002mm radius) and skid. The irregularities of the surface are traced by the stylus and the movement of the stylus is converted into changes in electric current. Surface roughness (Ra) in µm is measured by Talysurf surface roughness tester. Tool wear in mm is tested by tool makers' microscope.

II. EXPERIMENTAL PROCEDURE

N (rpm)	325 770 & 1200
DOC(mm)	0.6, 1.2 &1.8
Feed (mm/rev)	0.059, 0.159 & 0.260
Cutting fluids	Coconut oil, Straight cutting oil & Soluble oil

TABLE.2. MACHINING PARAMETERS

- Work piece is mounted on the spindle of the lathe and turning operation is performed up to 100mm length using the parameters taken using auto feed option in lathe machine.
- The inserts were clamped mechanically on a rigid tool holder before the machining process.
- After the machining process, the insert is removed and its flank wear is measured using tool maker's microscope. (Tool wear is noted by moving the micrometer screw from initial position of wear on insert to the final position of wear. The readings are note from the micrometer arrangement on tool maker microscope)
- The average surface roughness on the work piece is measured using Talysurf surface roughness tester and regular intervals. (Average surface roughness is calculated by stylus movement at 3 different intervals on the work piece and taking the average of readings)
- Experiments are to be conducted for different cutting fluids by varying the parameters as per the tables shown.
- Surface roughness and tool wear for every reading are noted and analyzed.

Fig. 1. *Machining process with cutting fluid.*

III. OBSERVATIONS

The following observations are made for tool wear and surface roughness at different machining parameters were tabulated while machining with different cutting fluids such as coconut oil, straight cutting oil and soluble oil[5-6].

N (rpm)	Vc (m/min)	d (mm)	f (mm/rev)	Ra (µm)	Vb (mm)
325	51.05	0.6	0.059	0.747	0.11
1200	188.495	0.6	0.059	0.677	0.13
770	120.951	0.6	0.059	0.557	0.12
325	51.05	1.2	0.26	2.749	0.12
1200	188.495	1.2	0.26	2.51	0.145
770	120.951	1.2	0.26	2.638	0.135
325	51.05	1.8	0.159	1.253	0.17
1200	188.495	1.8	0.159	1.612	0.29
770	120.951	1.8	0.159	1.414	0.264

TABLE 3. OBSERVATIONS FOR COCONUT OIL

N (rpm)	Vc (m/min)	d (mm)	f (mm/rev)	Ra (µm)	Vb (mm)
1200	188.495	1.8	0.26	3.349	0.715
770	120.951	1.8	0.26	2.531	0.66
325	51.05	1.8	0.26	2.185	0.255
1200	188.495	0.6	0.159	2.788	0.43
770	120.951	0.6	0.159	1.863	0.245
325	51.05	0.6	0.159	1.193	0.185
1200	188.495	1.2	0.059	1.493	0.375
770	120.951	1.2	0.059	1.236	0.245
325	51.05	1.2	0.059	1.127	0.235

TABLE 4. OBSERVATIONS FOR STRAIGHT CUTTING OIL

N (rpm)	Vc (m/min)	d (mm)	f (mm/rev)	Ra (µm)	Vb (mm)
770	120.951	1.2	0.159	2.663	0.27
325	51.05	1.2	0.159	1.883	0.225
1200	188.495	1.2	0.159	2.004	0.45
770	120.951	1.8	0.059	2.376	0.185
325	51.05	1.8	0.059	2.266	0.155
1200	188.495	1.8	0.059	2.362	0.305
770	120.951	0.6	0.26	2.959	0.465
325	51.05	0.6	0.26	2.501	0.365
1200	188.495	0.6	0.26	2.8	0.59

TABLE 5. OBSERVATIONS FOR SOLUBLE OIL

IV. RESULTS AND DISCUSSTION

The variation of surface roughness and tool wear with respect to cutting speed, depth of cut and feed rate for individual cutting fluid using the data from observations is studied in this chapter. Also these variations are compared for the three different cutting fluids (coconut oil, straight cutting oil, soluble oil) to determine the optimum cutting fluid for machining of AISI 316 stainless steel.

N (rpm)	Vc (m/min)	d (mm)	f (mm/rev)	Ra (µm)	Vb (mm)
325	51.05	0.059	0.6	1.583	0.133
770	120.951	0.159	1.2	1.536	0.173
1200	188.495	0.26	1.8	1.599	0.188

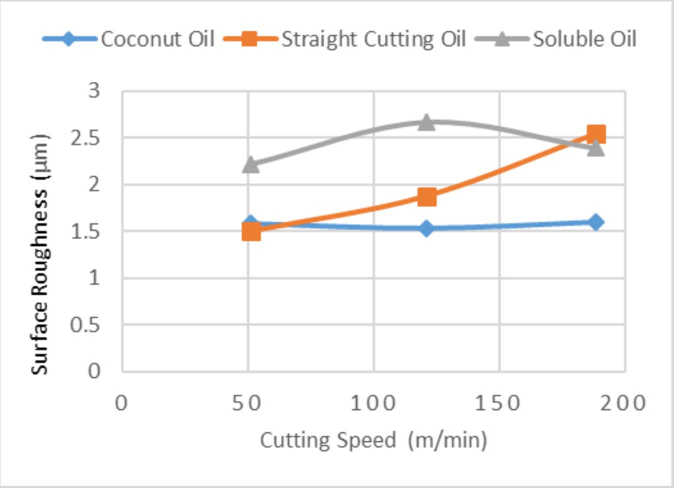
TABLE 6. VARIATION OF SURFACE ROUGHNESS AND TOOL WEAR FOR COCONUT OIL

N (rpm)	Vc (m/min)	d (mm)	f (mm/rev)	Ra (µm)	Vb (mm)
325	51.05	0.059	0.6	1.501	0.248
770	120.951	0.159	1.2	1.876	0.306
1200	188.495	0.26	1.8	2.543	0.448

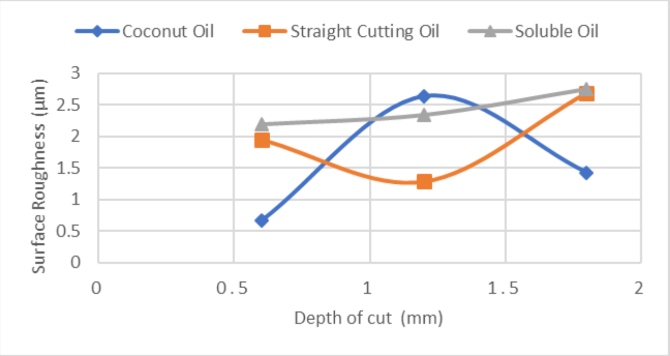
TABLE 7. VARIATION OF SURFACE ROUGHNESS AND TOOL WEAR FOR STRAIGHT CUTTING OIL

N (rpm)	Vc (m/min)	d (mm)	f (mm/rev)	Ra (µm)	Vb (mm)
325	51.05	0.059	0.6	2.216	0.225
770	120.951	0.159	1.2	2.666	0.383
1200	188.495	0.26	1.8	2.388	0.506

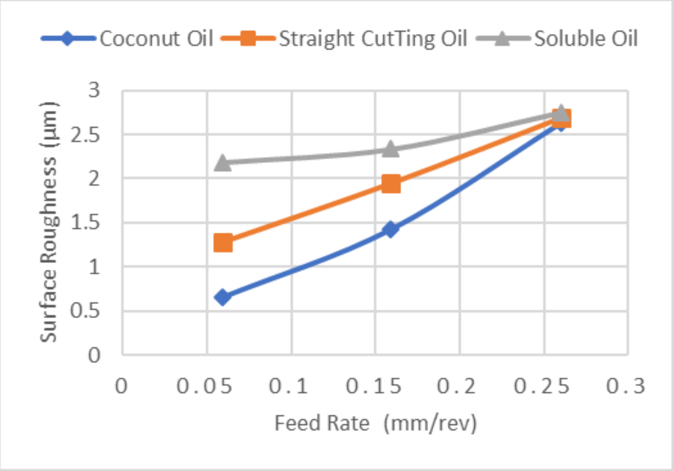
TABLE 8. VARIATION OF SURFACE ROUGHNESS AND TOOL WEAR FOR SOLUBLE OIL



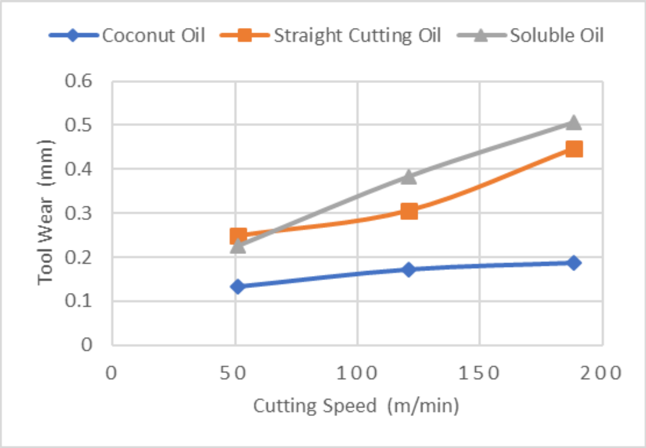
GRAPH 1. COMPARISON OF SURFACE ROUGHNESS WITH CUTTING SPEED



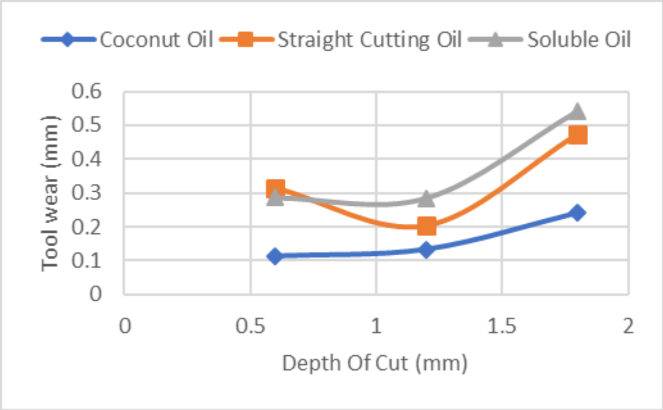
GRAPH 2. COMPARISON OF SURFACE ROUGHNESS WITH DEPTH OF CUT



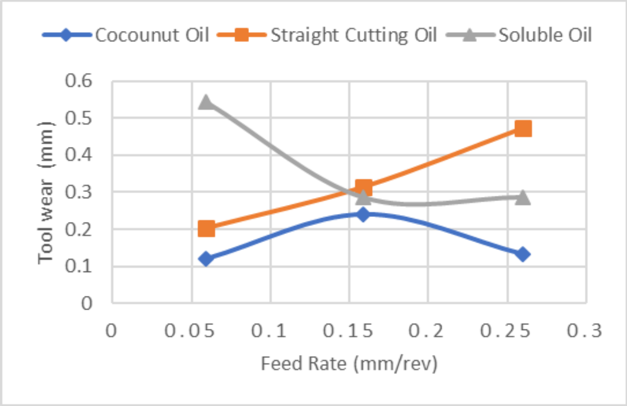
GRAPH.3. COMPARISON OF SURFACE ROUGHNESS WITH FEED RATE



GRAPH 4. COMPARISON OF TOOL WEAR WITH CUTTING SPEED



GRAPH .5. COMPARISON OF TOOL WEAR WITH DEPTH OF CUT



GRAPH 6. COMPARISON OF TOOL WEAR WITH FEED RATE

From the graphs obtained using the data, it has been observed that the tool wear and surface roughness values are low using the coconut oil as cutting fluid. It has also been observed that surface finish increases at lower feed rate and decreases at high cutting speeds.

V CONCLUSION

Effectiveness of the cutting fluids in reducing the tool wear and improving the surface finish was found by comparing the relative performance. Coconut oil was found to be a better cutting fluid than the conventional mineral oils in reducing the tool wear and surface roughness during machining of AISI austenitic stainless steel. Thus, the use of coconut oil increases the efficiency of machining stainless steels. Further it was found that surface finish increases at lower feed rates and increases at higher cutting speeds. Graphs were drawn between the various process parameters so as to understand more about their individual relationship and relative contribution to surface roughness and tool wear.

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