Study of the effect of Vegetable oil based cutting fluid on machining characteristics of AISI 316L Steel

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Abstract

In the present work, properties of the non-ionic surfactants have been identified to formulate vegetable based cutting fluid (VBCF) of castor oil for the formation of emulsion as non –conventional lubricant. The mineral oil based cutting fluid emulsion is also used for turning operation as conventional lubricant. Experimentation has been carried out for different combinations. Cutting fluid, cutting velocity, feed rate and depth of cut are considered as machining parameters. Then machining with conventional and non-conventional lubricants in wet condition has been carried out upon SS 316 L work piece with carbide cutting inserts tool, to evaluate cutting forces and tool wear. The results show that non-conventional lubricant performs better than conventional cutting fluid.

Keywords:-VBCF, non-ionic surfactants, Emulsion.

INTRODUCTION

SS 316L finds its strengthen applications in many industrial components like in air craft fittings, aerospace components such as bushings, shafts, valves, special screws, cryogenic vessels and components for severe chemical environments. They were also being used for welded construction in aerospace structural components. Most of the components require certain machining in different machines. In machining of parts, surface quality is one of the most specified customer requirements where major indication of surface quality on machined parts is the surface roughness value. Noordin et al.[1] determined that the surface roughness is dependent on the feed rate whereby use of lower feed rate produced better surface finish. In improving the efficiency of any machining process performance of cutting fluids in machining different work materials is of critical importance. Cutting fluids in metal cutting industries are required for performing the functions like improving tool life, efficiency of machining process, enhancing surface integrity, reducing cutting forces etc. The increasing attention to the environmental and health impacts of industrial activities by governmental regulations and by the growing awareness level in the society is forcing industrialists to reduce the use of synthetic cutting fluids. Mineral and synthetic cutting fluid involves in the ecological cycle with air, soil and water and their toxicity effect damages the ecosystem (Birova et.al.)[2]. Vegetable based cutting fluids (VBCF), minimum quantity lubrication (MQL) and near dry machining have the potential of use under these limitations. In MQL, due to the aerosol mixture of oil and water, consumption of cutting fluid is very less. The growing demand for biodegradable materials opened an avenue for using vegetable oils as an alternate to petroleum-based polymeric material, most especially in machining operations. VBCF are environmentally friendly, renewable, and less toxic and they reduce the waste treatment cost due to their inherently higher biodegradability. Vegetable oils, especially rapeseed and canola are some of the more promising candidates as base stocks for the biodegradable lubricants.

The triglyceride structure of vegetable oils provides qualities desirable in a lubricant. Long, polar fatty acid chains provide high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear. The strong intermolecular interactions are also resilient to changes in temperature providing a more stable viscosity, or high viscosity co-efficient. However, VBCFs have low oxidation and thermal stability which may reduce their potential use as cutting fluid. On contrary, formulated VBCFs with chemical additives in comparison to other types of cutting fluids displayed a lower co-efficient of friction, equivalent scuffing load capacity and better pitting resistance in the cutting zone (Fox & stachowaik)[3]. Chemical additives used in the composition of cutting fluids have a wide variety of functions. They are emulsification, corrosion prevention, pH regulation, binding, anti-foaming, odor prevention, improving the flash point, spreading and wetting. The main advantages of using a lubricating emulsion are many: Lower cost, much higher cooling rates than neat oils, higher machining speeds, no risk of fire, low oil mist and smoke emissions, cleanliness of the work environment, cleanliness of the work piece, low oil drag out of chips, and most importantly less consumption of oil resources. However, corrosion issues and potential trouble with electric control units are some of the disadvantage of emulsion. On contrary, using the surfactants prevents the emulsion from the formation of rust. (jayal and balaji)[4] studied the effects of different cutting fluid application methods on tool wear during machining of AISI 1045. Xavior and adithan[5] investigated the influence of cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel with carbide tool using three different types of cutting fluids(coconut oil, emulsion and neat cutting oil-immiscible with water).The experimentation work was based on taguchi's design of experiment(DOE) with L27(34) and ANOVA were applied and results indicated that coconut oil performed better than other two cutting fluids. Kuram et.al[6] , studied the effect of cutting fluid and cutting parameters on surface roughness and thrust force with three different vegetable-based cutting fluids (Sunflower oils and two commercial type). It was observed that sunflower oil shows better performance compared to other oils. Commercial mineral and synthetic based cutting fluids and mineral based emulsions are widely used in modern manufacturing industry. But unfortunately, limited work has been published regarding development of vegetable oil emulsion and its application for machining. Therefore, the purpose of this research work is to develope and formulate vegetable oil-in water emulsion using non-ionic surfactant and its application during the turning process of SS316L. The performance is evaluated in terms of cutting force(Fc) and tool flank wear(W). ANOVA analysis is carried out to obtain significant parameters influencing on cutting forces and tool wear.

EXPERIMENTAL PROCEDURE

In this study, SS316L with Rockwell hardness of B79 is used as the work piece material. Dimensions of the work piece is Ø50 mm × 250 mm. Typical chemical composition of SS316L is shown in Table 3.2 .Centre lathe (maxcut PRH175) of maximum power 2 Hp is used for experiments. The maximum RPM of the machine is 1535 rpm, photograph of the machine is shown in Fig 3.1. Machining operations are performed with tungsten (W) coated cemented carbide inserts. Kenna metal CNMG 120408 (K25M grade) inserts and PCLNR 25*25-M12 (Korlay make) are used for machining operations. Photograph of the setup is shown in the Fig1

Table1. Typical values of chemical compositions of SS316L

C	Mg	P	S	Si	Cr	Ni	Mo	N	I
0.03 max	2.00 max	0.045 max	0.03 max	0.75 max	16.00-18.00	10.00-14.00	2.00-3.00	0.10 max	Bala nce

The cutting insert will be withdrawn at regular intervals to study the pattern and extent of wear on main and auxiliary flanks for all the trials. The average width of the principal tool wear (W), is measured using transverse metallurgical microscope of 500X magnification range. The cutting force Fc is measured with Three component dynamometer. Cutting fluids are sprayed at tool-workpiece interface at 75° angle with single nozzle. Photograph of setup is shown in Fig1. Cutting fluid used in this study is: 1] Castor oil-in water emulsion-Non-conventional fluid (NC). 2] Soluble oil-in water emulsion-Conventional fluid(C). The results of Vegetable oil based emulsion are compared with mineral oil based emulsion. The vegetable oil based emulsion serves as non-conventional lubricant and mineral oil based emulsion serves as conventional lubricant. New developed VBCFs contain almost no harmful materials and are environmentally friendly, healthier for operators and having a higher rate of biodegradability.

A] Vegetable based cutting fluids:-

VBCFs were an oil-in water emulsion type consisted of base oil, non-ionic surfactants and additives in the formulae to meet specifications such as resistance to bacterial growth, corrosion, foaming and wear. In this study, the non-ionic surfactants concentrations in the formulae are added as 10% W/W, 12%W/W, 14% W/W . Non-ionic surfactants have a property of reducing

Fig.1: Details of Experimental Set up

Surface tension and increasing the wet ability of the fluid. Properties of surfactants used to formulate the vegetable oil-in water emulsion is shown in table (2). A general phenomenology used to formulate emulsions is the decade old hydrophile-lipophile balance(HLB) concept . The HLB value of surfactants required to solublize many different hydrocarbons and other organic liquids has been calculated from data such as phase inversion temperature. Zeta potential, surface tension, interfacial tension, turbidity, oil drop diameter and simple physical observation of phase separation are often used to estimate emulsion stability. In this study two VBCFs i.e. vegetable oil in water emulsion as non-conventional lubricant are prepared using two non-ionic surfactants Sin different proportions and their properties are shown in table (3) & (4). The properties of castor oil are shown in table (5). NC is prepared using the mixture of Tween (20) non-ionic surfactant.

Table 2.Properties of Non-ionic surfactant used

Type of surfactant	**Chemical name**	**Class**	**HLB**	**MA (g/mol)**	**Density (g/cm3)**
Tween 20	Polyoxyethylene (20) sorbitan monolaurate	Non-ionic	16.7	1228	1.10

The stability is evaluated by varying surfactant proportion. Higher the surfactant proportions higher the stability of the solution. Thus, maximum proportion of surfactant used is 20%w/w(Tween 20) . The oil-in water emulsion is prepared using the mechanical stirrer; the solution is stirred for 10 minutes still stability is achieved at 1400 RPM continuously. The stability of the emulsion is observed visually by keeping emulsion in a closed test tube for some hours and its dilution produces very stable cutting fluid emulsion maintaining the stability between oil and water phase up to 36 hrs. Viscosities of emulsion are one of the important parameter. Viscosity is measured using redwood viscometer at 400c. VBCFs are mixed with water in oil to water ratio of 1:100.

Table 3. Properties of castor oil-water emulsion using mixture of Tween(20)surfactant

Surfactant(w/w)	0.2 g	0.6 g	1.2 g
Viscosity(cSt)			
30°C	2.27	2.48	4.48
40°C	2.18	2.08	4.39
50°C	2.07	2.02	4.30
Density(g/cm3)	0.992	0.950	0.909
pH value	7.48	7.59	7.60

B] Turning conditions and experimental design:-Orthogonal array has been selected for experimental design. Type of cutting fluid, cutting velocity, feed rate and depth of cut are considered as turning parameters. The ranges of turning parameters are selected as recommended from the tool manufacturer. The turning factors and their levels are shown in Table (6). Cutting fluid is one of the parameters that do not have any quantitative levels but each oil is being considered as one level for experimentation. Accordingly there are four input parameters and for each parameter three levels were assumed. The response obtained from the trials conducted as p was recorded and further analyzed. Table (7) shows the actual cutting parameters used for each trial of experiment and the corresponding values of observed *W*(flank wear) and Fc cutting force obtained from experiments. Loss function is the main analysis parameter and calculated for the deviations between the experimental and desired values. In this study, cutting force, flank wear for obtaining of optimal conditions are investigated and the lower-the better is selected in the experimental plan, since the objective function is minimization.

Table 4. Thermo-chemical properties of vegetable oil.

Properties	Castor oil
Kinematic Viscosity@40°C(cSt)	258.8
Kinematic Viscosity@100°C(cSt)	48.54
Flash Point (°C)	349
Fire Point (°C)	366

STATISTICAL ANALYSIS OF EXPERIMENTAL RESULTS.

Analysis is performed for experimental results.

Levels of turning operation.

Code	Turning parameters	Unit	Level 1	Level 2	Level 3
A	Cutting velocity vc	mm/ min.	48	77	107
B	Depth of cut, d	mm.	0.25, 0.50, 0.75	0.25 ,0.5, 0.75	0.25, 0.5, 0.75
C	Feed ,f	mm/ rev.	0.067, 0.111, 0.133	0.067, 0.111, 0.133	0.067, 0.111, 0.133

Sr.No.	Vc(m/min)	D(mm)	F(mm/rev)	Fc C(N)	Fc NC(N)	%Decrease in Fc
1.	48	0.75	0.067	117.72	90. 45	23.16
2.	48	0.25	0.133	29.43	22.39	23.92
3.	48	0.5	0.111	88.29	64.66	26.76
4.	77	0.5	0.067	49.05	36.95	24.66
5.	77	0.25	0.111	19.62	15.30	22.01
6.	77	0.75	0.133	115.58	91.76	20.60
7.	107	0.75	0.067	115.58	89.12	22.89
8.	107	0.25	0.111	9.81	7.58	22.73
9.	107	0.5	0.133	88.29	65.27	26.07

Table 5. Responses of Experiment

From the obtained responses clearly it can be observed that as compared to Conventional coolant Non conventional coolant reduces cutting force as well as tool wear. To be precise Average cutting force reduction found to be by 24% and Average tool wear reduction by 27%.

CONCLUSION

This study focuses on experimental method for investigating of influence of the new developed VBCFs on the tool wear and cutting force during turning of SS316L. Experimental results clearly show that Conventional cutting fluid might be replaced with Nonconventional cutting fluid as it gives better performance.

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