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REGULAR ARTICLE

Experimental investigations of vibration and acoustics signals in milling process using kapok oil as cutting fluid

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Abstract. Vegetable oils are found as the feasible alternative for conventional minerals oils. There has been many environmental and health issues which are spotted with the use of conventional cutting fluids. There has been a great demand for developing new environmentally friendly vegetable based cutting fluids to reduce these harmful effects. In this present study, vegetable based kapok oil is used as a cutting fluid during milling to study its consequences over other conventional oils. The process parameters such as spindle speed, depth of cut and feed rate were optimized with respect to the flank wear (V_b) and surface roughness (R_a) respectively with the use of central composite design in response surface methodology (RSM). Further an attempt has been made to monitor the tool condition by measuring the cutting force, vibration and sound pressure simultaneously. Three different tool conditions such as dull, fresh and working were analyzed and their consequences were also reported. Also, the performance of the kapok oil is compared with the palm oil and mineral oil (SAE 20W 40). The feed rate has the major contribution for surface roughness and flank wear. It is found that the cutting force (F), sound pressure (p) and vibration (V) increases with the tool wear.

Keywords: Cutting fluids / kapok oil / surface roughness / flank wear / tool condition monitoring / RSM

1 Introduction

Milling is the basic machining process which tends to have high metal removal rate and mostly used for complex machining shapes. Cutting fluids have been used in the machining process to improve the tribological characteristics of the work piece and tool involved [1]. Cutting fluids assists in carrying away the heat produced and debris ejected during machining [2]. These aspects will help to diminish the tool wear and energy consumption during machining [3]. Cutting fluids improves the efficiency of machining process by enhancing tool life, surface finish of the workpiece, reducing cutting force and vibrations. Conventional mineral, synthetic and semi-synthetic cutting fluids involved in the ecological cycle with air, soil and water and their toxicity leads to environmental pollution [4]. Many research works have been undertaken on the application of vegetable based cutting fluids for machining applications and most of them were used as a straight cutting oils [5,6]. It is reported that 320 000 ton per year of metal working fluids were consumed by European Union alone of which at least two-third need to be disposed as wastage into the environment [7]. The disposal of waste is expensive and also it affects the environment. Cutting fluid processing involves waste treatment as well as pre-treatment. The cost for the treatment of fluid is higher than purchasing of new cutting fluids in most cases [8]. Thus, to reduce the mass usage of conventional mineral oil cutting fluids and also to minimize their effects on environment and operators, several alternatives are being extremely explored such as solid lubricants, dry machining, cryogenic cooling, minimum quantity lubrication (MQL) [9] technique and also by the application of vegetable oils [10–12]. Vegetable based cutting fluids minimizes the health and environmental effects as compared to the petroleum based oils which are biodegradable [13]. They possess good lubrication capability as compared to other conventional oils.

The effect of vegetable based cutting oil on cutting forces and power shows that they were equal or dominant than conventional mineral oil [14]. Vegetable based oils are considered as environmentally friendly because they are renewable, less toxic and holds high biodegradability. The vegetable based cutting fluids have been used for various mechanical processes such as drilling, turning,

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Table 1. Proprties of lubricant samples.

Properties	Kapok oil	Mineral oil	Palm oil
Kinematic viscosity at 34°C (RT) (cSt)	104.13	345.3	88.01
Kinematic viscosity at 100°C (cSt)	19.04	36.17	17.21
Density at 34°C (RT) (g/cc)	0.89	0.886	0.882
Flash point (°C)	185	194	182
Fire point (°C)	192	200	190
Cloud point (°C)	7	8	14
Pour point (°C)	−3	1	6

milling [15], grinding and reaming. In those investigations, tool life, tool vibration, tool wear, sound pressure, cutting force, torque and surface roughness are considered as parameters [16]. The flash point of vegetable oil is higher which relates less vapour pressure and volatility, also reduces hazards during usage [17]. Vegetable oil based lubricants can be operated at lower temperatures and possess high natural stability, a high viscosity index, and a low coefficient of friction [18]. On the other hand, vegetable oil possess low thermal and oxidation stability at high temperature [19]. There are many extensive efforts have been made to improve the tribological properties of the vegetable based lubricant. One of them is addition of nanoparticles to improve its friction, wear and extreme pressure behavior [20]. 5wt% of silicon dioxide (SiO_2) concentrated on the mineral oil reduces the tool wear and provides good surface finish during machining operation [21].

Kapok (Ceibapentandra) belongs to the Malvaceae family, and is a native of tropical America and West Africa and also found in various Asian regions [22]. Its utilization has mostly focused on its fiber content in various textile applications, which includes thermal and acoustic insulation buoyancy absorbent properties, spinning of kapok in blends with other fibers. A vegetable oil extracted from kapok (Ceiba pentandra) seeds was used as the cutting fluid in this work. The oil has a yellow colour, mild odour and it resembles cotton seed oil. It has an iodine value of 85–100, which makes it a nondrying oil [23].The kapok oil is similar to the plants of other mallow species, which contains sterculic, dihydrosterculic and malvalic acids. They are specified by cyclopropane and cyclopropane rings [22].The kapok oil have also been used for a biodiesel preparation through esterification and transesterification process [24]. The tribological properties of kapok oil was investigated using pin on disc and its effectiveness were compared with mineral oil and palm oil [25]. The kinematic viscosity of kapok oil is very high when compared to other vegetable oils. The properties of kapok oil is shown in Table 1. Thus, to best of our knowledge, there is no evidence regarding the usage of kapok oil as a straight cutting fluid in machining operations.

Tool condition monitoring is mandatory to obtain high product quality. Flank wear of the tool is one of the most important factor which affects the product performances [26]. The tool wear monitoring possess many economic advantages. The cutting force has the direct impact on generation of heat, tool breakage and surface finish of the machining component. The flank wear can be indirectly measured using monitoring cutting force, sound pressure and vibration [27]. Some of the researchers [28,29] have used cutting force signal and Artificial Neural Network (ANN) in tool condition monitoring for face milling process. But cutting force based tool condition monitoring is a costly proposition due to sensor cost and mounting problems.

In the present study, raw non edible kapok oil (Cieba Pentandra) was used as straight cutting fluid in milling operation. Surface roughness and flank wear are measured for various spindle speeds, depth of cut, and feed rate. The process parameters were optimized with respect to the flank wear and surface roughness respectively using RSM (response surface methodology). The cutting force, vibration and sound pressure were measured simultaneously for the optimized parameters while using kapok oil as cutting fluid. The obtained results are compared with the results under palm oil and a commercially available branded mineral oil (SAE 20W 40).

2 Experimental procedures

2.1 Milling operation

Milling operation was carried out in CNC vertical machining center LMILL55 which has a maximum spindle speed of 6000 rpm and spindle motor power of 11 kW. The workpiece material used was mild steel (AISI 1020). M680 tool holder of 25 mm diameter with three flutes with carbide insert (XDHT − 090308 HX PA120) was used. The insert geometry has a relief angle of 15°, tolerance of 0.025 mm and nose radius of 0.8 mm. Fresh inserts were used for each experiments. Workpiece used was mild steel (AISI 1020) whose dimensions are 100 mm × 50 mm × 50 mm. In this study, milling operation was carried out with different sets of machining parameters such as spindle speed, feed rate and depth of cut as shown in Table 2. The kapok oil was used as the cutting fluid and the flow rate was kept constant as 5 ml/min. Experiments were conducted for different values of input parameter in Response Surface Methodology (RSM) Central Composite Design (CCD) with the use of Design Expert software. The software generated values between low and high level factors and the measured response values were listed in Table 3. The surface roughness values were measured using surface roughness tester. The flank wear was measured using profile projector with 50× magnification. To avoid

Table 2. Process parameters and levels.

Factors	**Symbols**		**Coded level**		
	Uncoded	**Coded**	**−1**	**0**	**+1**
Spindle speed(rpm)	n	x_1	500	750	1000
Feed rate (mm/tooth)	f_z	x_2	0.08	0.10	0.12
Depth of cut(mm)	a_p	x_3	1	1.5	2

Table 3. CCD Experimental design.

Run order	Coded variables			Real variables		
	x_1	x_2	x_3	n	f_z	a_p
1	0	0	0	750.00	0.10	1.50
2	0	−1	0	750.00	0.08	1.50
3	−1	+1	−1	500.00	0.12	1.00
4	+1	−1	−1	1000.00	0.08	1.00
5	0	0	0	750.00	0.10	1.50
6	0	0	0	750.00	0.10	1.50
7	0	0	0	750.00	0.10	1.50
8	+1	−1	+1	1000.00	0.08	2.00
9	0	0	−1	750.00	0.10	1.00
10	−1	+1	+1	500.00	0.12	2.00
11	0	0	0	750.00	0.10	1.50
12	0	+1	0	750.00	0.12	1.50
13	−1	−1	−1	500.00	0.08	1.00
14	−1	−1	+1	500.00	0.08	2.00
15	−1	0	0	500.00	0.10	1.50
16	+1	+1	−1	1000.00	0.12	1.00
17	0	0	0	750.00	0.10	1.50
18	+1	0	0	1000.00	0.10	1.50
19	0	0	+1	750.00	0.10	2.00
20	+1	+1	+1	1000.00	0.12	2.00

the effect of noise factors and to improve precision, each experiment was repeated for thrice and their flank wear and surface roughness of each repetition was measured.

2.2 Tool condition monitoring

The cutting force, sound pressure and vibration signals were captured from the milling tool dynamometer, microphone and tri-axial accelerometer respectively. These signals were acquired for the optimal cutting parameters of 647 rpm spindle speed, 0.09 mm/tooth feed rate, 1.20 mm axial depth of cut and 25 mm radial depth of cut under kapok oil, palm oil and mineral oil (SAE 20W 40) as a cutting fluid respectively. Mild steel workpiece was fixed on the vice of the milling tool dynamometer that was placed on the table of the CNC machine for the prediction of cutting force as shown in Figure 1. The tri-axial accelerometer was mounted on the surface of the workpiece with the help of adhesive solution. The orientation of the accelerometer sensor location should coincide with machine table feed direction. The microphone is fixed near the workpiece with the use of a clamp. The milling tool dynamometer, microphone and tri-axial accelerometer were connected

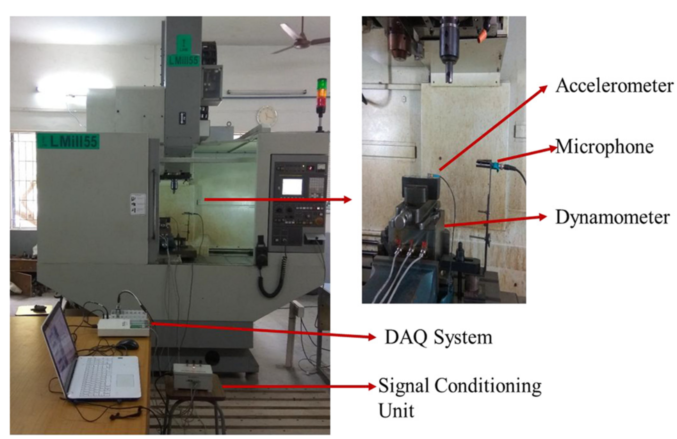


Fig. 1. Experimental setup.

Table 4. ANOVA for flank wear (V_b).

Source	Sum of squares	Degree of freedom	Mean of squares	F-value	P-value
Model	0.000339645	9	3.77383E-05	34.34693	<0.0001
A-Spindle Speed	3.87224E-05	1	3.87224E-05	35.24255	0.0001
B-Feed rate	0.000146823	1	0.000146823	133.629	<0.0001
C-Depth of cut	7.94329E-06	1	7.94329E-06	7.229453	0.0227
AB	9.8631E-05	1	9.8631E-05	89.76739	<0.0001
AC	1.5933E-05	1	1.5933E-05	14.50117	0.0034
BC	6.49801E-06	1	6.49801E-06	5.914059	0.0353
A^2	4.86215E-06	1	4.86215E-06	4.425208	0.0617
B^2	2.19777E-05	1	2.19777E-05	20.00263	0.0012
C^2	1.44159E-07	1	1.44159E-07	0.131204	0.7247
Residual	0.0000	10	1.099E-06		
Lack of Fit	3.684E-06	5	7.368E-07	0.5044	0.7647
Pure Error	7.304E-06	5	1.461E-06		
Cor Total	0.0004	19			

$R^2 = 0.9604$, $R^2_{adj} = 0.9247$ and $R^2_{pred} = 0.8648$. Adequacy Precision = 22.617.

using BNC noise free cable. The raw signals acquired were conditioned with a proper signal conditioning unit. The milling tool dynamometer has the accuracy of ±1% of full-scale voltage and force range of 0-5000 N. The tri-axial accelerometer (Dytran®) has the sensitivity of 10 mV/g, the range of 500 g and the frequency range of 1.5–10 000 Hz. The microphone has the sensitivity of 50 mV/Pa and frequency response of 5–10 kHz. The cutting force and vibration signals were captured from the cutting zone with the help of NI USB 6221 DAQ card. The sound pressure were acquired using NI USB 9274 DAQ. These signals are stored in a computer using LabVIEW software. The electrical noise signals were eliminated with the proper filtering process. The signals were acquired with the sample rate of 10K samples per second. These signals are acquired for three different tool conditions such as fresh (0 mm wear), working (0.2 mm wear) and dull (>0.3 mm wear).

3 Result and discussion

3.1 Process parameter optimization

The response of process parameters with respect to process characteristics, second order mathematical models of flank wear and surface roughness were developed through response surface methodology. To develop these models, a statistical software package Design Expert was used and the validity of full quadratic models were assessed using analysis of variances and coefficient of determination [30] i.e. R^2.The effect of process variables on flank wear and surface roughness have been examined by calculating the values of the different constants and their relevant data. The adequacy of the developed empirical relationships were examined using analysis of variance (ANOVA). ANOVA for responses, namely flank wear and surface roughness are presented in Table 4 and 5 respectively. The F-value and the probability values (P-value) are verified to confirm the significance of the empirical relationships. By using the F-values, the factors which have the major and minor contribution to the responses can be evaluated. From the F-value assessment, it was found that the feed rate is the most predominant factor which have direct influence on the flank wear and surface roughness. The determination coefficient (R^2) that indicates the goodness of fit for the model. In both the cases, the value of the determination coefficient R^2, adjusted R^2 and predicted R^2 near to 1 indicates the high significance of the empirical relationships. The final equations for correlating the mentioned responses are presented in terms of coded factors in equations (1) and (2).

$$\begin{aligned} V_b(\mathrm{mm}) = {} & 0.23605 - 2.72009\mathrm{E} - 004\mathrm{A} - 2.53426\mathrm{B} \\ & + 5.73792\mathrm{E} - 004\mathrm{C} + 1.96379\mathrm{E} \\ & - 003\mathrm{AB} + 3.18369\mathrm{E} - 005\mathrm{AC} \\ & - 0.25245\mathrm{BC} + 2.61632\mathrm{E} - 008\mathrm{A}^2 \\ & + 8.57585\mathrm{B}^2 + 1.13004\mathrm{E} - 003\mathrm{C}^2 \end{aligned} \tag{1}$$

$$\begin{aligned} \mathrm{Ra}(\mu\mathrm{m}) = {} & -39.89083 + 0.045563\mathrm{A} + 315.56887\mathrm{B} \\ & + 8.89995\mathrm{C} - 0.29828\mathrm{AB} - 9.70955\mathrm{E} \\ & - 003\mathrm{AC} + 0.84734\mathrm{BC} - 1.54038\mathrm{E} \\ & - 006\mathrm{A}^2 - 233.92539\mathrm{B}^2 - 0.60070\mathrm{C}^2 \end{aligned} \tag{2}$$

The comparisons of measured and predicted values from the mathematical models for surface roughness and flank wear are illustrated in Figure 2a and b. The results proved that the predicted values and experimentally measured values for each response are close. The average errors for surface roughness and flank wear were found to be 7.05% and 1.99% respectively. The results from mathematical models depicts that they can be applied for prediction of the surface roughness and flank wear. Figure 3a and b demonstrates the 3D surface plots of interaction effect of factors on surface roughness and

Table 5. ANOVA for Surface Roughness (R_a).

Source	Sum of squares	Degree of freedom	Mean of squares	*F*-value	*P*-value
Model	8.496590158	9	0.944066	26.94014	<0.0001
A-Spindle Speed	0.388418746	1	0.388419	11.08403	0.0076
B-Feed rate	4.278355742	1	4.278356	122.0884	<0.0001
C-Depth of cut	0.009633777	1	0.009634	0.274912	0.6115
AB	2.275484445	1	2.275484	64.93391	<0.0001
AC	1.48195328	1	1.481953	42.28946	<0.0001
BC	7.3205E-05	1	7.32E-05	0.002089	0.9644
A^2	0.016853961	1	0.016854	0.48095	0.5038
B^2	0.016352441	1	0.016352	0.466638	0.5101
C^2	0.040735368	1	0.040735	1.162437	0.3063
Residual	0.3504	10	0.0350		
Lack of Fit	0.1121	5	0.0224	0.4703	0.7864
Pure Error	0.2383	5	0.0477		
Cor Total	8.85	19			

$R^2 = 0.9687$, $R^2_{adj} = 0.9405$ and $R^2_{pred} = 0.8902$. Adequacy Precision = 24.188.

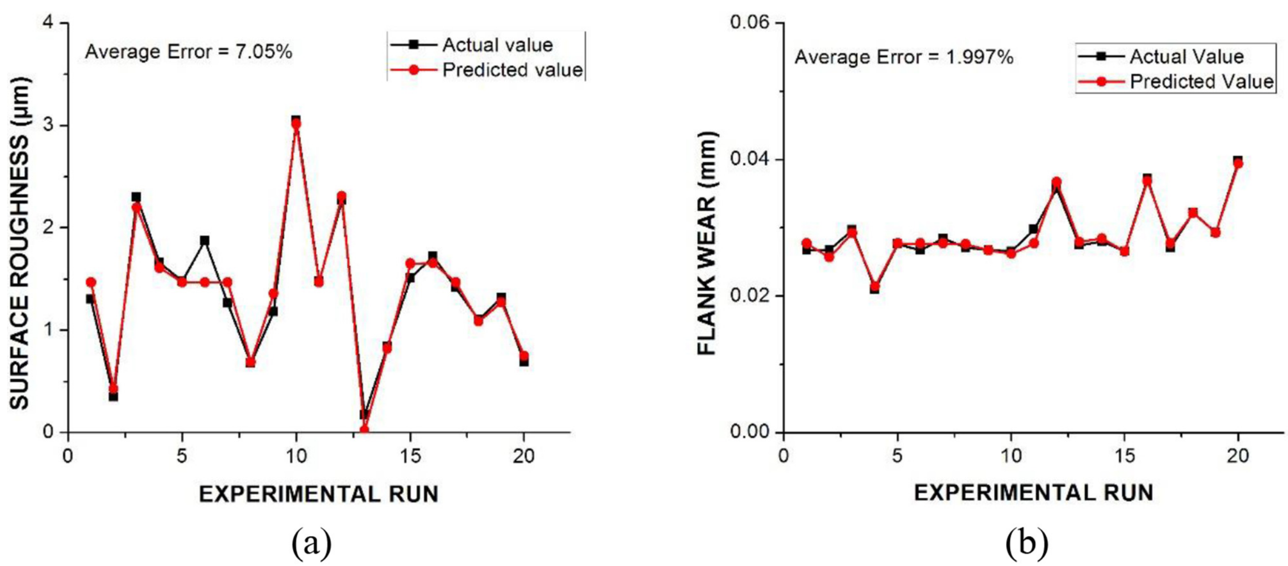


Fig. 2. Comparison of predicted and actual values for (a) Surface roughness and (b) Flank wear.

flank wear. From the interaction plot of feed rate and spindle speed (Fig. 3a1 and a2) it is clear that at low spindle speed, the surface roughness and flank wear increases by increase in feed rate. Further, at high feed rate, the surface roughness decreases and flank wear increases by increase in spindle speed. From the interaction plot of depth of cut and spindle speed (Fig. 3b1 and b2), it is seen that at low spindle speed, surface roughness increases and flank wear decreases with the increase of depth of cut. Further at high depth of cut, surface roughness decreases and flank wear increases with the increase of spindle speed. From the interaction plot of depth of cut and feed rate (Fig. 3c1 and c2), it is confirmed that at low feed rate, there is no considerable change in surface roughness and flank wear increases with the increase of depth of cut. Further at high depth of cut, surface roughness and flank wear increases with the increase of feed rate. Therefore, regardless of the machining condition minimum surface roughness and flank wear was obtained by selection of optimum parameters as shown in Table 6. The individual desirability for all the responses were calculated and it is considered for the selection of optimum parameter. The desirability value ranges from 0 to 1. The greater value of desirability function is chosen as the optimum parameter.

3.2 Effect of cutting force

The forces such as feed force (Fx), thrust force (Fy), and cutting force (Fz),were measured under kapok oil, palm oil and commercial mineral oil (SAE 20W 40) as a cutting fluid during the milling of mild steel. The resultant force was

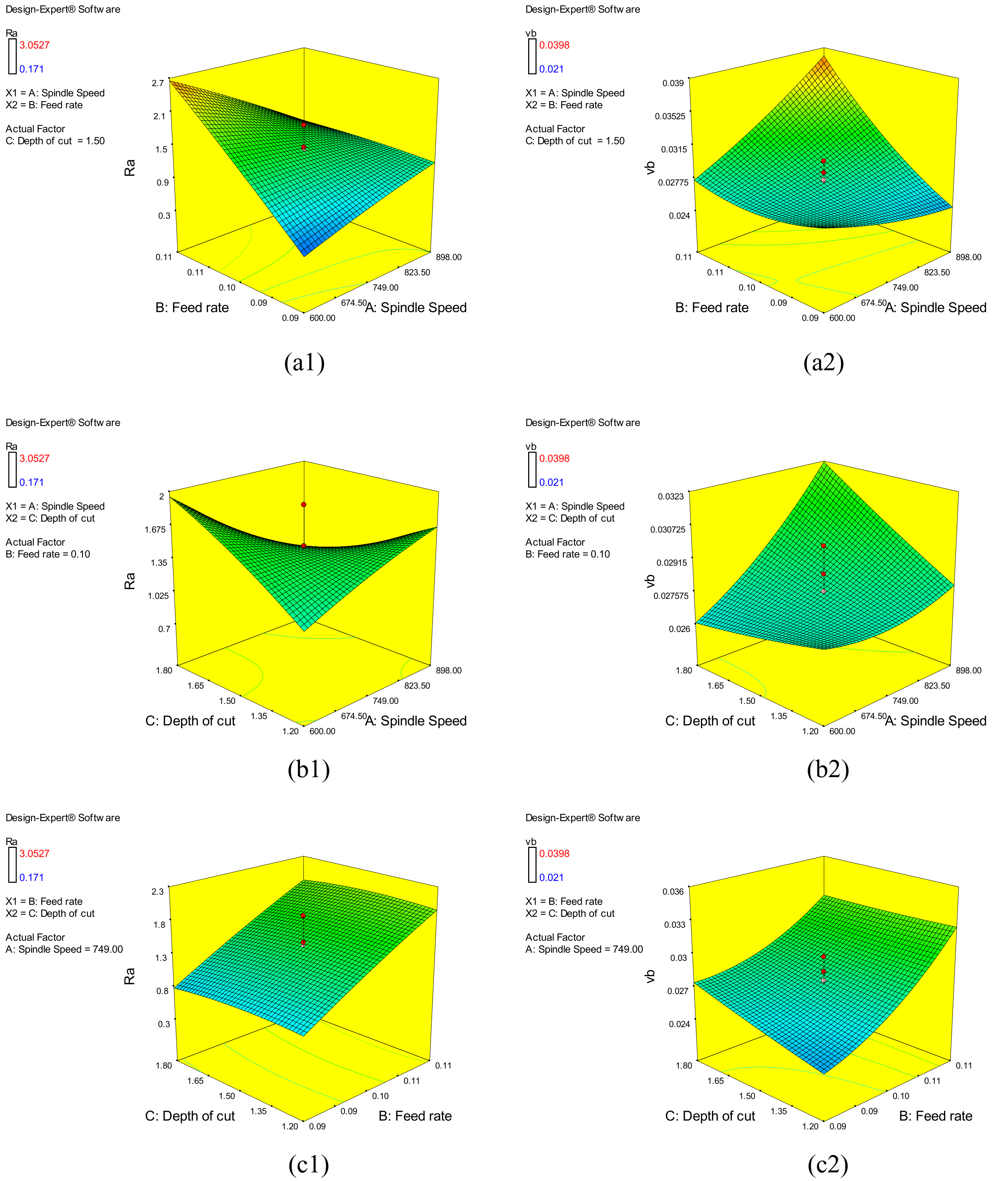


Fig. 3. 3D surface interaction plots of factors on 1. Surface roughness and 2. Flank wear (a) feed rate and spindle speed (b) depth of cut and spindle speed (c) depth of cut and feed rate.

calculated using the equation (3).

$$\mathrm{Fr} = \sqrt{\left(\mathrm{Fx}^2 + \mathrm{Fy}^2 + \mathrm{Fz}^2\right)} \tag{3}$$

The cutting signals were measured from dynamometer at sample rate of 10k per second. The average forces in all directions and their average resultant forces were calculated. The average resultant forces obtained at different tool

Table 6. Optimal results obtained from design expert.

Spindle speed, n (rpm)	Feed rate, f_z (mm/tooth)	Depth of cut, a_p (mm)	Flank wear, V_b (mm)	Surface roughness, R_a (μm)	Desirability
647.65	0.09	1.20	0.0265817	0.291432	0.821

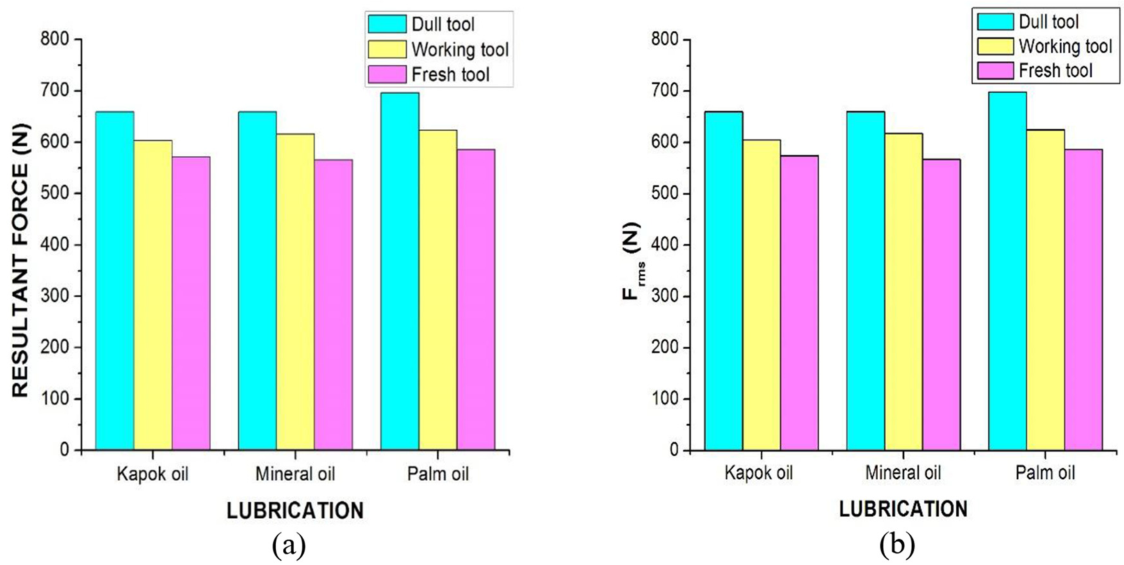


Fig. 4. Effect of various cutting fluids on (a) Resultant force (b) RMS value of force.

conditions are shown in Figure 4. From the (Fig. 4a), it is clear that resultant force of dull tool is between (650-700N) which is higher than that of the working (600-630N) and fresh tools (550-600N). The RMS value of force signals were also calculated and depicted (Fig. 4b). The result obtained is same as that dull tool requires maximum cutting force while machining aluminium alloy [31]. Machining with dull tool requires higher cutting force due to high friction between tool and work interface [32]. The fresh tool possess less cutting force due to no wear. This states that the cutting force increases with wear [33]. The performance of the kapok and mineral oil are nearly the same for all three tools. The vegetable based kapok oil had the significant influence on reducing the resultant cutting force followed by palm oil. The performance of the commercial mineral oil was better than other vegetable based oils due to the addition of mineral particles [34]. Figure 5 illustrates the average force along all the axis for the dull tool condition. From the trend, it is seen that the cutting force (*Fz*) is almost 10 times higher than the thrust force (*Fy*) and feed force (*Fx*) respectively. This is due to the vertical load applied on the workpiece during end milling operation. The cutting force of the kapok oil and mineral oil is low compared to palm oil. The palm oil has less feed force and thrust force than the other investigated oils.

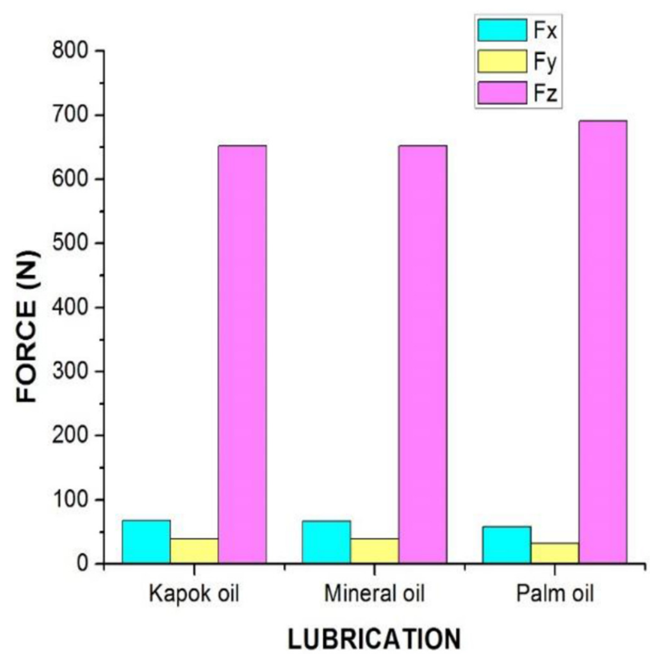


Fig. 5. Effect of various cutting fluids on feed (Fx), thrust (Fy) and cutting (Fz) forces.

3.3 Effect of vibration

The vibration signals (*Vx, Vy*, and *Vz*) from the three axes are acquired from the tri-axial accelerometer which is fixed on the workpiece by means of adhesives. The vibration signals are measured for the optimized parameter. The resultant vibration value was calculated from the three

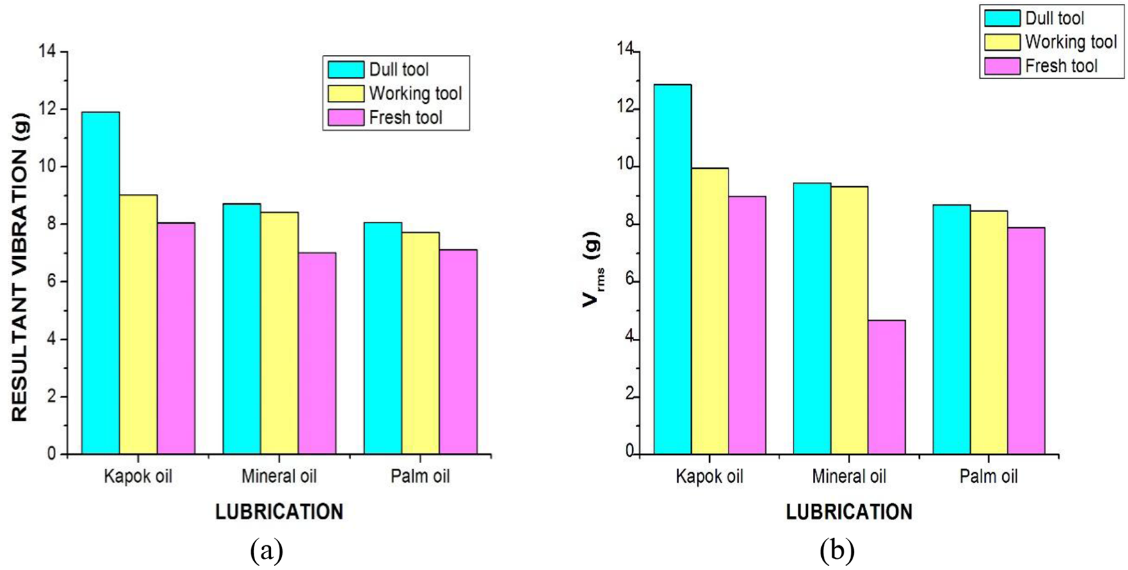


Fig. 6. Effect of various cutting fluids on (a) Resultant vibration (b) RMS value of vibration.

axes by using equation (4).

$$\mathrm{Vr} = \sqrt{\left(\mathrm{Vx}^2 + \mathrm{Vy}^2 + \mathrm{Vz}^2\right)} \tag{4}$$

The influence of cutting fluids on vibration is shown in Figure 6. (Fig. 6a) demonstrates the resultant vibration for dull, working and fresh tools under various cutting fluids respectively. In this study, the measurements were carried out with time domain features and the frequency domain analysis was not examined. The kapok oil exhibited the maximum vibration of 11.09 g. The resultant vibration response of mineral oil and palm oil are similar response (~8.5 g). The palm oil has a significant influence on vibration signals. The influence of kapok oil cutting fluid has a negative impact on the vibration signature. Based on the viscosity of the cutting fluids, a high viscous fluid reduces the vibration signatures. The utilization of high viscosity cutting fluid could reduce the cutting vibration [35]. The RMS value is usually calculated for quantifying the intensity of a signal. The RMS values of vibration signal are shown in Figure 6b. The trend shows that the dull tool exhibits the highest vibration regardless of the cutting fluid. The mineral oil has a low RMS value of vibration. This can be due to the added mineral particles with in the lubricant. The vibration along all axes are represented in Figure 7. It can be concluded that the vibration along the y-direction is high when compared to other directions. This result is similar to all tool conditions and cutting fluids presented in this study. It is seen that the vibration along y-axes (Vy) is thrice the vibration along z-axes (Vz).

3.4 Effect of sound pressure

The sound pressure (p) signals are measured with the help of microphone clamped near the tool holder and workpiece. The sound pressure signals were acquired for dull, working and fresh tool conditions and mentioned cutting fluids.

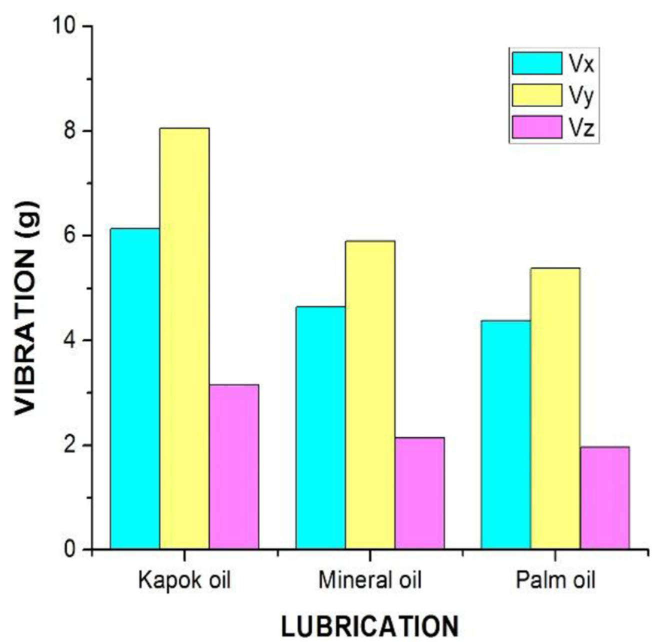
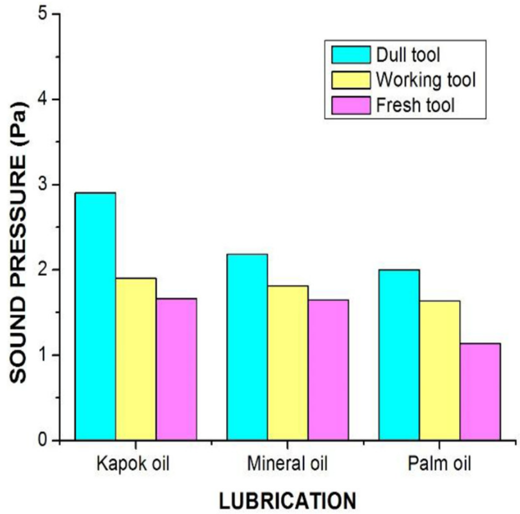


Fig. 7. Effect of various cutting fluids on Vx, Vy, Vz.

The effect of sound pressure on cutting fluids and tool conditions are depicted in Figure 8. The average sound pressure and RMS value of the sound pressure are shown in Figure 8a and b. The sound pressure increases parallel with the cutting speed, feed rate, vibration and surface roughness [36]. The experiments were conducted with the fresh tool which produces sound pressure in the range of 1 to 1.6 Pa. Further the experiment was carried out with working tool which produces sound pressure in the range of 1.65–1.9 Pa due to increase in wear of the tool. Next the machining was conducted with dull tool, it produces sound pressure around 2–3 Pa. From the findings, it is observed that sound pressure acquired for dull tool is relatively high. It can be stated that tool wear is one of the most important



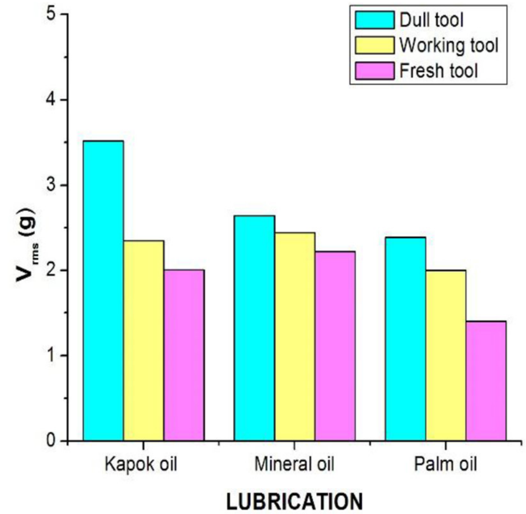


Fig. 8. Effect of various cutting fluids on (a) Average sound pressure (b) RMS value of sound pressure.

factor in noise generation during machining. These results are similar to the turning of carbon steel Ck15 [37]. The sound produced by the palm oil is less than that of mineral and kapok oil respectively. The sound pressure obtained for the kapok and mineral oil is similar while using fresh and working tools. In general, the increase in flank wear of tool increases sound pressure amplitude with high frequency. Therefore continuous monitoring of sound pressure helps to prevent the tool breakage and work piece damage.

4 Conclusions

In the present work, the kapok oil is effectively used as a cutting fluid for milling operation and the process parameters were optimized using response surface methodology. This study focuses on the performances of vegetable based oils (kapok and palm) with respect to commercial mineral oil in terms of cutting force, vibration and sound pressure. The following conclusions were drawn from the extensive research work:

- By performing optimization through desirability function, it was found that while using kapok oil as cutting fluid in milling operation, setting of 647.65 rpm spindle speed, 0.09 mm/tooth feed rate and 1.20 mm depth of cut causes desirability of 82.1% that yields lowest value of flank wear and surface roughness.
- The minimum resultant cutting force was obtained with commercial cutting fluid (Fr = 659.167N) and kapok oil (Fr = 659.217N). But there was a slight difference in the performance of commercial and kapok oil cutting fluid. Hence this variation can be shrug off.
- The mineral oil exhibited a very minimum resultant vibration than other two vegetable based cutting fluids. This has been due to high viscosity of mineral oil than the vegetable based cutting fluids.
- From the sound pressure, if the output value was less than 1.6Pa the tool condition was considered as fresh tool. If output value was between 1.65 and 1.9 Pa, the tool condition was considered as working tool. When the output value exceeds 2 Pa, the tool condition was considered as dull tool.

The obtained result shows that the kapok oil suits better cutting fluids in terms of optimum cutting force requirement and minimum vibration. Overall from the extensive study, it can be concluded that this system enables the monitoring of cutting process with high reliability.

Declaration of Conflicting Interests

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