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Investigation of Neem Seed Oil as an Altanative Metal Cutting Fluid

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Abstract Oil extracted from neem seed was investigated for use as alternative cutting fluid in metal machining operation using mild steel at three different values each of cutting speeds, depth of cut and oil ratios. Physicochemical properties that relate to cutting fluid's performance like cooling effect (temperature rise) and surface roughness were measured and compared to those of conventional cutting oil bought from the market and also with data obtained in dry metal cutting experiment with no lubricant. Results indicated that neem had flash point of 157°C, pour point of +8°C, kinematic viscosity of 8.08cSt at 100°C. Specific gravity at 14/40°C was 0.9304, sulpur content was 0.0293%, pH was 5.6 and free fatty acid (oleic acid) was 5.94%. Cooling effect was found to be comparable at different oil ratios and speeds, but dry machined surfaces produced the least cooling effect with temperature rise of up to 57.33°C at 710rpm at 0.5mm depth of cut. However, neem was found to perform slightly better than the soluble oils in most of the test results. Surface roughness for neem, soluble oil and dry machining were in the range of 0.002 µm and 1.427 µm. The least surface quality was obtained with neem oil at a speed of 250 rpm; depth of cut of 1mm at 50% oil and 50% water mixture. However all surface roughness was within the recommended standard that is the acceptable value for turned and machined surfaces with maximum value set at 25µm.

Keywords: *neem oil, cutting fluid, speed, cooling effect, surface roughness, sulphur content*

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1. Introduction

Renewable lubricant technology has tremendously grown and is no more revocable as more efforts are being made to reverse the effects of global warming, dwindling oil reserves, and high cost of oil, ethical corporate policies and government strategies which encourage biomaterial usage. This has led the direction to interest in vegetable oils based metalworking fluids (MWFs). People are interested in protection of the environment, protecting the health and safety of their employees and supporting the government economic policies that make many societies less oil dependent [1]. Primarily, cutting fluid contribute in three ways to machining process. First, it acts as lubricant by reducing friction, it reduces the heat generated. Secondly the cutting fluid must also act as an effective coolant, because frictional heating cannot be completely eliminated and often, not even substantially reduced. Finally, it should act as an anti-weld agent by washing away the chips to counteract the tendency of the work material to weld the tool under heat and pressure. Although, cutting fluids have greatly improved machining performance, conventional metal cutting fluids have more recently become a source of non-value added cost to businesses in machining industry. As environmental and regulatory burdens become onerous, profit margins for these enterprises decrease. With the introduction of ISO14000 environmental series legislation, industry users of lubricants are encouraged to reduce or eliminate or change metal cutting fluids from their processes to more environmentally friendly substances [2,3].

Vegetable oils have proven in many instances to be a viable option for use as cutting fluid especially considering the added advantage of environmental degradation. The challenge is finding out whether Neem seed oil obtained from Neem tree can be use as cutting fluid. If so, to what extend? Singh and Gupta [3] developed metal working fluids from vegetable oil. Their formulations consisted vegetable oil, emulsifier, co-surfactant, fungicides and additives. The base oils used were Neem, Karanja and rice bean oils. The metal working formulation was evaluated for physicochemical characteristics like emulsion, thermal stability, copper strip corrosion, iron chip corrosion deposit-forming tendency, on hot metal surfaces and lubricity. The work showed that oil water micro emulsions of these oils have higher stability. The emulsions were stable over a wide range of temperatures. Formulation based on neem oil gave better characteristics than Karanja oil and rice bean oil. Andres et al [4] used tapping torque test to compare the performance of five base oil feed stocks for metal working fluids; Naphthenic mineral oil, 50/50 blend of naphthenic oil and paraffinic mineral oil, soya bean oil and canola oil (75% oleic content) and TMP ester. The five oils were tested as straight cutting oils, as soluble oils and semi synthetic metal working fluids to understand the impact of emulsification on base oil performance. Machining performance was evaluated using a modification to the standard tapping torque test (ASTM D5619). Results indicated that as straight oils, vegetable oils based stocks performed significantly better than mineral oils. This trend held, though it was less pronounce after vegetable oil stocks were emulsified into soluble oil and semi synthetic metal working fluids. Results showed some vegetable base stocks had higher potentials for lubricity. It revealed that soya and TMP esters gave improved tapping torque efficiency than canola oil in emulsified metal working fluids.

Ojolo et al [5] investigated effect of some vegetable based oils on cutting force during cylindrical turning of mild steel, aluminum and copper. The results showed that bio oils are suitable as metal cutting fluids but that the effect of bio-oils on cutting force were material dependent. Groundnut oil exhibited the highest reduction in cutting force when aluminum was turned at a speed of 8.25m/min and feed rate of 0.10, 0.15 and 0.20mm/rev respectively. Palm kernel oil had the best result when copper was turned at feed rates lower than 0.15mm/rev. However, at higher feed rates, groundnut oil gave best result in copper turning. Coconut oil gave the highest cutting force in all three materials machined, followed by shear butter. They were very mild in reducing cutting force during cylindrical turning. Though the lubricating and cooling action was material dependent, groundnut oil was best amongst the four bio-oils investigated. Patrick et al [6] used soluble oil, water and palm kernel oil as coolant in machining operations. Tungsten carbide and HSS tool was used as cutter at a speed of 355rpm. Turning was done under dry condition and using these three coolants with microstructure, temperature and hardness recording at each cut of specimen. It was observe that variation in hardness of samples with progression in machining time was more with carbide tool than HSS tool. Samples cooled with water gave the highest hardness. Palm kernel oil performed well. The specific functions of soluble oil cutting fluid included good chip formation, reduction of heat generation and realization of a good surface finish and tool wear which was time dependent [5]. As cutting proceeds, tool wear increases gradually. Tool wear causes tool failure [7]. According to Anuar [8] and Janne [9]; failure of cutting tool occurred as premature tool failure (i.e. tool breakage) and progressive tool wear. Generally wear of cutting tools depends on such parameters as:

(a) Cutting conditions (cutting speed V, feed f, depth of cut d)
(b) Cutting tool geometry (tool orthogonal rake angle)
(c) Properties of work material and
(d) Cutting fluids and machine-tool characteristics, [7,8].

Based on these experiences, cutting speed is adjudged the most important factor. As cutting speed is increased, wear rate increases and same wear criterion is reached in less time, i.e., tool life decreases with cutting speed [8].

2. Experimental Materials and Methodology

2.1. Oil Properties Test

Neem oil was obtained from the National Research Institute for Chemicals Technology (NARICT), Zaria. The following physic-chemical properties related to effective use of oil as metal cutting fluids were determined in the laboratory [10]. Flash point was conducted using Pensky-Martens Closed cup tester (ASTM D93). Pour was determined using ASTM D97. Kinematic viscosity at100°C was determined using ASTM D445 procedures. Specific gravity was obtained with Hydrometer (ASTM 1298). PH was obtained using PH meter of model/serial No 7010/1886. Sulphur test was done using Horiba apparatus; model SLFA2800 and sulphur in oil was analyzed with X-ray machine. Free fatty acid (FFA as % oleic acid)) was determined using BSI 684 method.

2.2. Machining Procedure

Each work piece was mounted on a three jaw self centering chuck of TEX TRENCIN Lathe machine model SN40B and properly secured using a chuck key. A high speed steel (HSS) cutting tool (12mm X 200mm) was then mounted on lathe tool post or tool holder after it has been grounded to correct clearance and rake angles. Tool post was adjusted until approximately perpendicular to work piece. The thermocouple wire prop was set so that it just touched work piece at a point very close to cutting zone. A thermocouple was then connected to STEL digital Electronic Temperature indicating Regulator model TED-2001 with a range of between 0°C-400°C. This read the temperature or heat generated at the cutting zone. For the dry machining (that is, turning without lubricant) was carried out on three work pieces of mild steel using spindle speeds of 250rpm,180rpm and 710rpm and depth of cut 1mm, 0.75mm and 0.5mm respectively with automatic feed rate of 0.25mm for a length of 100mm and three passes [11]. Temperature measurement was carried out at end of turning as machine was just about to stop. Readings were taken in triplicates to arrive at an average temperature. The neem vegetable oil was poured into machine coolant pump and turning was done at speed of 250 and 1mm depth of cut. The turning was repeated with neem oil as coolant but at a speed of 180rpm, for 0.75mm depth of cut at 710rpm, 0.50mm depth of cut. Same speeds and dept of cuts were used for dry machining samples and readings taken correspondingly. Oil/water mixture in ratio 50%/50% was prepared and the above stated parameters were again used to machine another set of work pieces followed by machining with an emulsion mixture of 25% oil/75% water.

2.3. Photo-macrograghic Procedure

The cutting tool was photographed using PEL digital camera model C960 before being used for the turning process with oil as coolant and was photographed after the turning operation was completed with oil to be able to measure tool wear. After the machining process was completed, a portion (fraction to represent whole test piece) of the machined surfaces was obtained by taking work pieces to power hacksaw and cutting a length of 10mm to 15mm.The pieces were further taken to bench vice and to cut depth of 10-15mm. Each macro photograph test piece was washed in 95% methylated spirit (Isopropyl alcohol) to clean the surface. Snap shut of test pieces were then taken with lens of PEL digital camera model C960 of 3.5 mega pixel magnification to reveal the surface nature of the specimens [11].

2.4. Tool Wear Measurement

After machining with each of the five oils of interest, the cutting tool wear was measured using German WILL-WETZLAR microscope model No 378599. Measurement was taken at 10X10 magnifications (i. e. eye piece value X objective value) and a steel rule used to measure length of wear on tool flank.

2.5. Surface Roughness Test Measurement

Mild steel specimens were machined on TEX TRENCIN lathe machine model SN40B and surface roughness indices were obtained with digital inside surface roughness tester (code–ISR-16) measuring instrument serial No 1510090001. The prop of instrument was place on turned surface along the direction of tool travel. The prop was then allowed to travel to and fro on turned surface through a length of 5mm and the instrument instantly displayed roughness.

3. Results and Discussion

3.1. Oil Properties

The result of the properties tested agreed mostly with those of past related works of others. Results at 100°C showed kinematic viscosity of neem seed oil was 8.08cSt. This compares favorably with that of Singh and Gupta [3] but differed from 3.8cSt of Niraj [12]. Viscosity plays a vital role in ability of oil to flow and remain stable at a particular temperature for a period of time. Pour point for all the oil showed it can be poured with relative ease and flow was not a problem. Neem oil had pour point of 8°C and 9°C in some past works [3,13]. Standard maximum pour point for emulsifiable oil used as cutting fluids is 1.67°C (35°F). As Nigeria is situated in tropical region of the world where temperature rarely drops to 8°C, the oils are suitable for as coolants since they can be readily poured. PH was found to be 5.6 which compares favorably with results of other authors. Low pH supports the use of the oil as cutting fluids as it is less harmful to machine operators and the assistants. But means there could be a possibility of coolant corroding metal work piece or machine. However pH of 6-8 favors bacterial growth and a pH of 4.75-9.75 is acceptable to skin. Sulphur in neem oil was low (0.0293% wt). Sulphur is used as an extreme pressure additive in lubricants and cutting fluid [14]. Therefore, it is recommended that some be added to improve its function. Relative density of neem oil was 0.9304. This compares favourably with result of related works. Neem oil had free fatty acid (as %oleic acid) of 5.84%. Mohammed et al [15] got 7.10%; showing a difference of 1.26%. Table 1 shows result of property test on neem oil. Figure 1 shows pie chart of percentages of the different properties.

Table 1. Results of physicochemical analysis of selected local vegetable oils

S/No	Properties analyzed	Neem oil
1	Specific gravity (14/40)	0.9304
2	Flash point (0C)	157
3	Pour point	8
4	Kinematic viscosity (100 0C) cSt	8.08
5	Sulphur % Wt	0.0293
6	pH	5.6
7	FFA (as % Oleic acid)	5.84

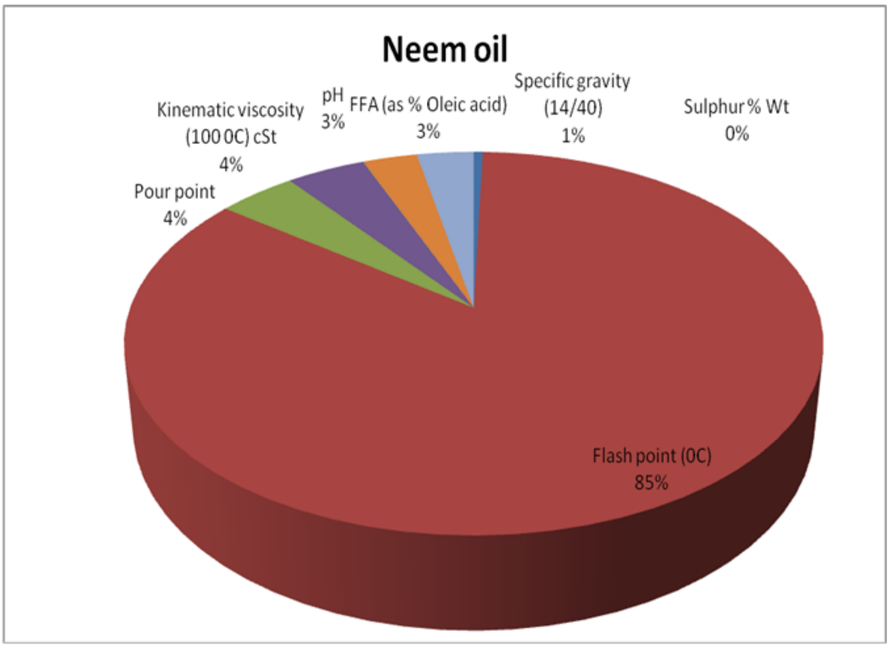

Figure 1. A pie chart showing the percentages of different properties

3.2. Machined Sample Temperatures

Machining temperatures at the three selected speed and three different oil ratios of 100, 50 and 25%, neem oil performed better than conventional cutting oil since temperatures obtained with neem oil were lower at the different oil ratios than conventional oil. This is clear from Figure 2 and Figure 4 respectively. It showed the oil ability to cool a work piece is comparable to conventional cutting oil in the market. This trend is replicated in the two oil/water ratios of 50% to 50% water and 25% oil/75% water. In all, dry machined samples produced the highest temperatures indicating less cooling effect as can be observed in Figure 2 to Figure 10 with only slight deviations. This proved that Neem oil can be utilized as a cooling medium in machining operations.

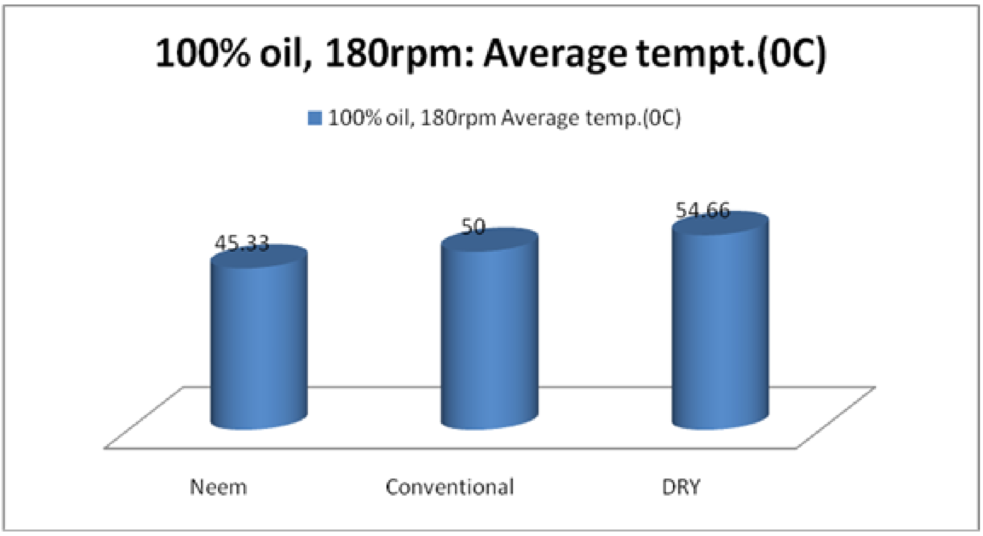

Figure 2. Average temperatures (°C) of samples machined with 100% straight oil and dry sample, 180rpm, 0.75mm depth of cut

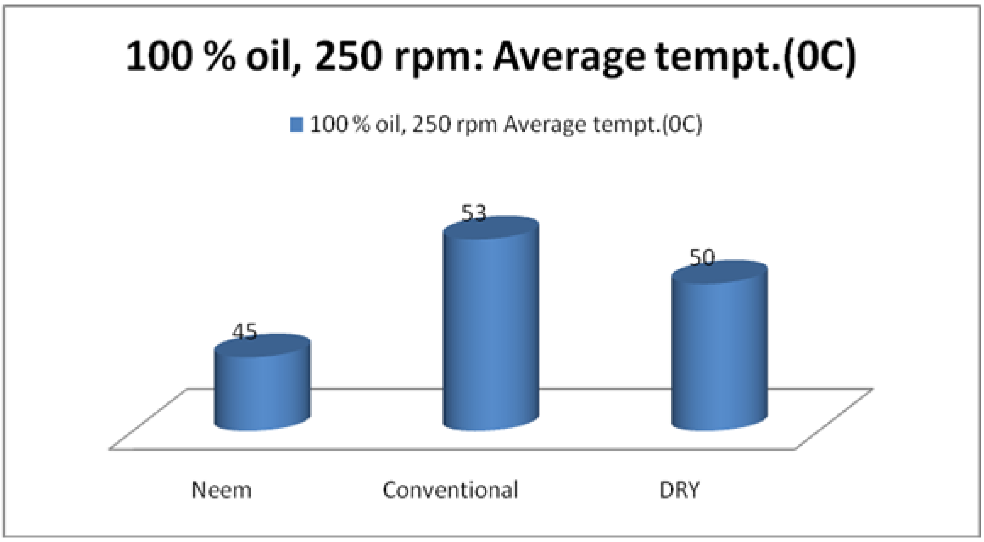

Figure 3. Average Temperatures in (°C) of samples machined with 100% straight oils and dry sample at 250rpm, 1mm depth of cut

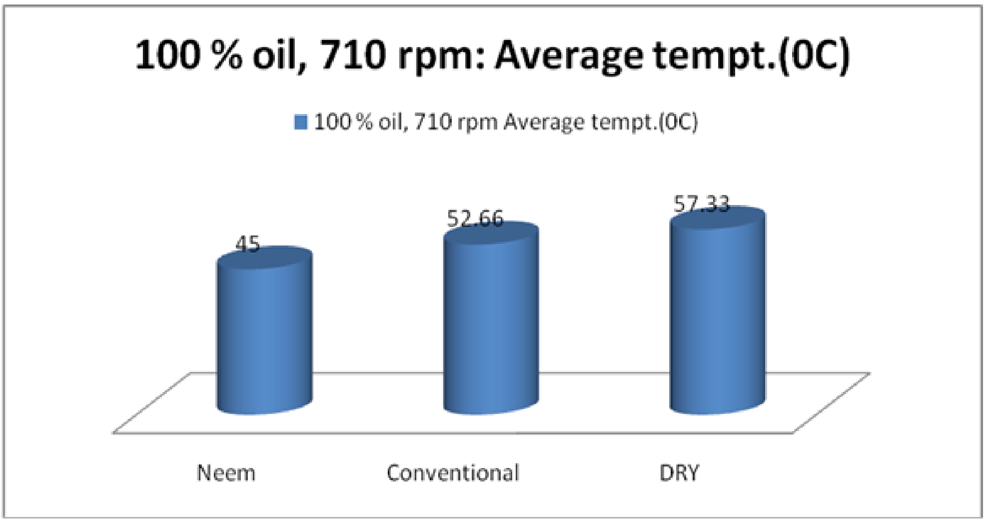

Figure 4. Average Temperatures (°C) of samples machined with 100% straight oils and dry sample, 710rpm, 0.5mm depth of cut

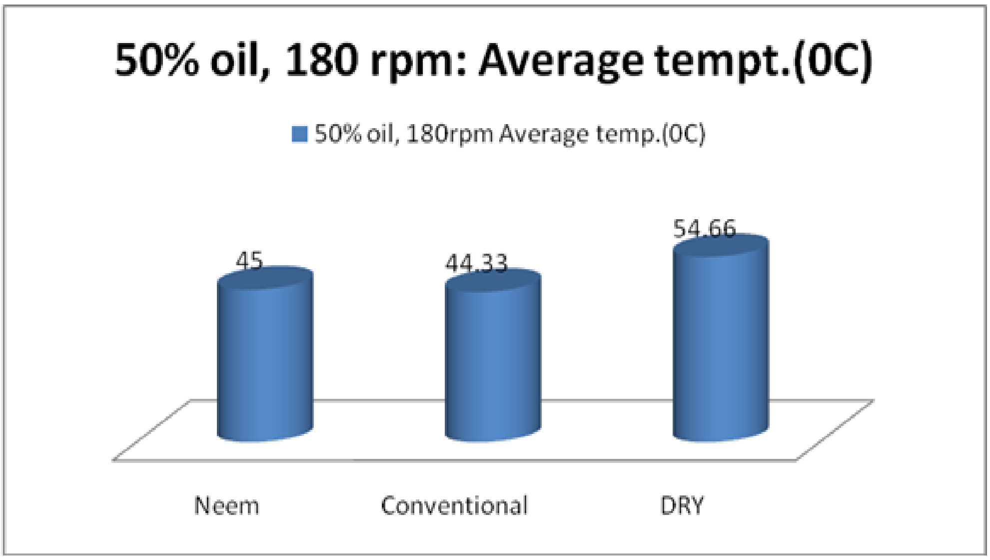

Figure 5. Average Temperatures (°C) samples machined with 50% oil/50% water ratio and dry sample, 180rpm, 0.75mm depth of cut

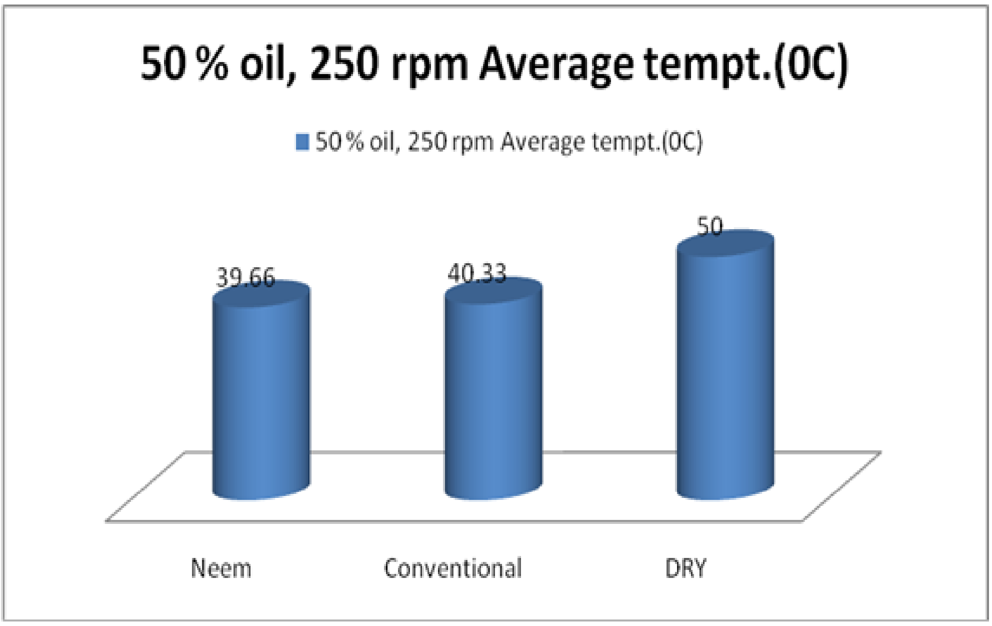

Figure 6. Average Temperatures (°C) of samples machined with 50% oil/50% water emulsion ratios and dry sample, 250 rpm, 1 mm depth of cut

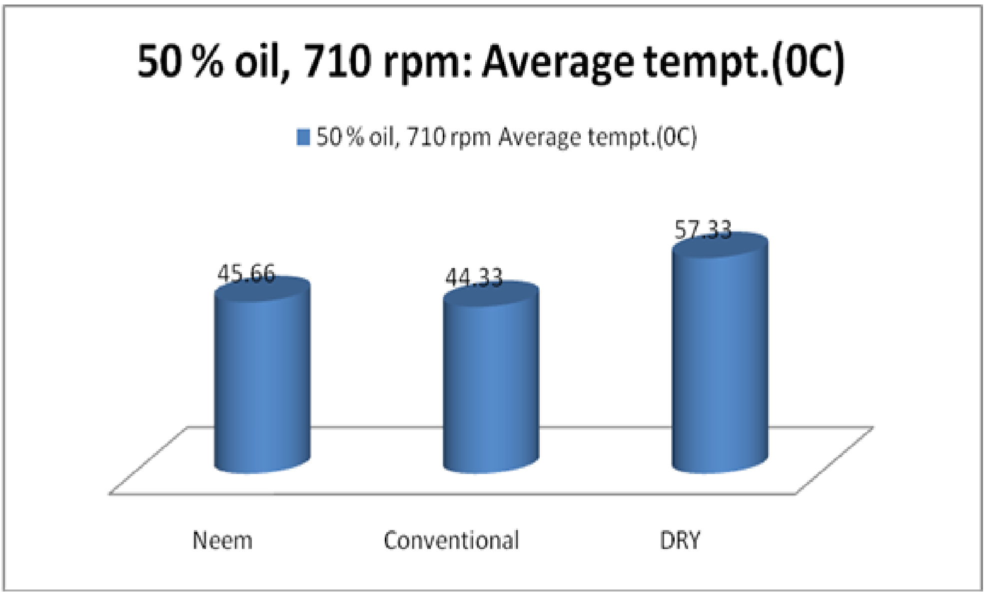

Figure 7. Average Temperatures (°C) of samples machined with 50% oil/50% water ratio and dry sample, 710rpm, 0.5mm depth of cut

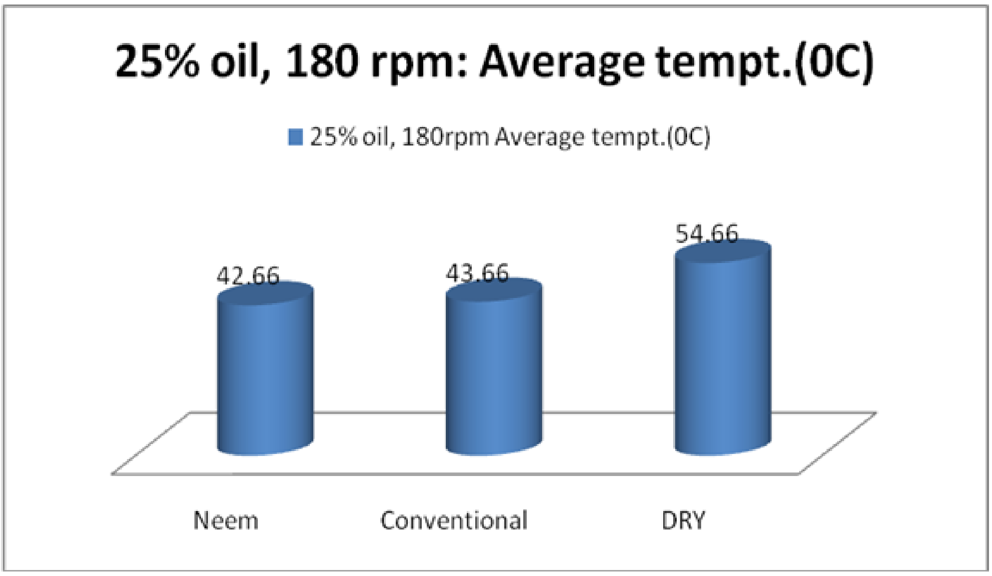

Figure 8. Average Temperatures (°C) of samples machined with 25% oil/75% water ratio and dry sample, 180rpm, 0.75mm depth of cut

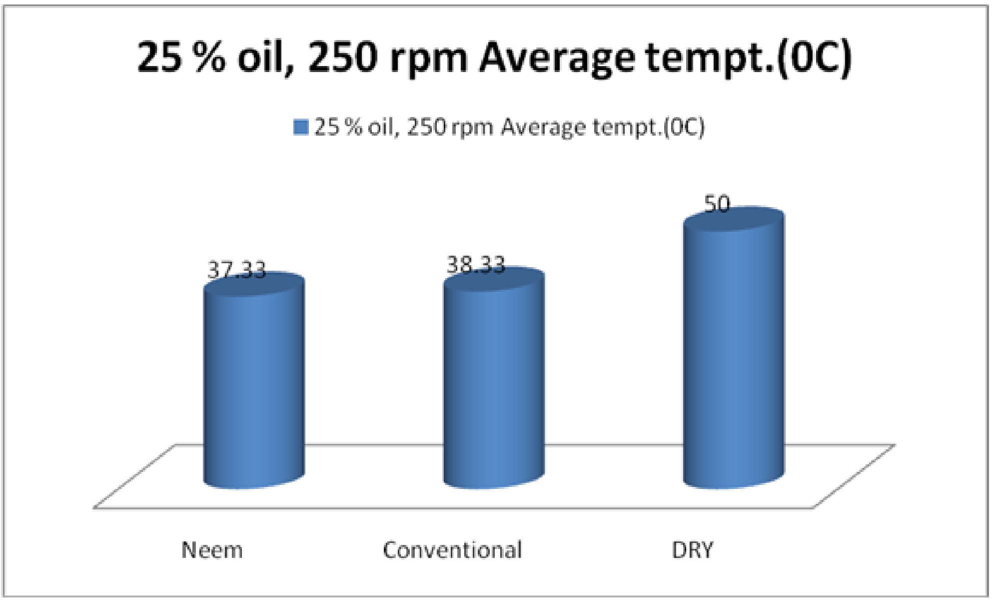

Figure 9. Average Temperatures (°C) of samples machined with 25% oil/75% water ratio and dry sample, 250rpm, 1mm depth of cut

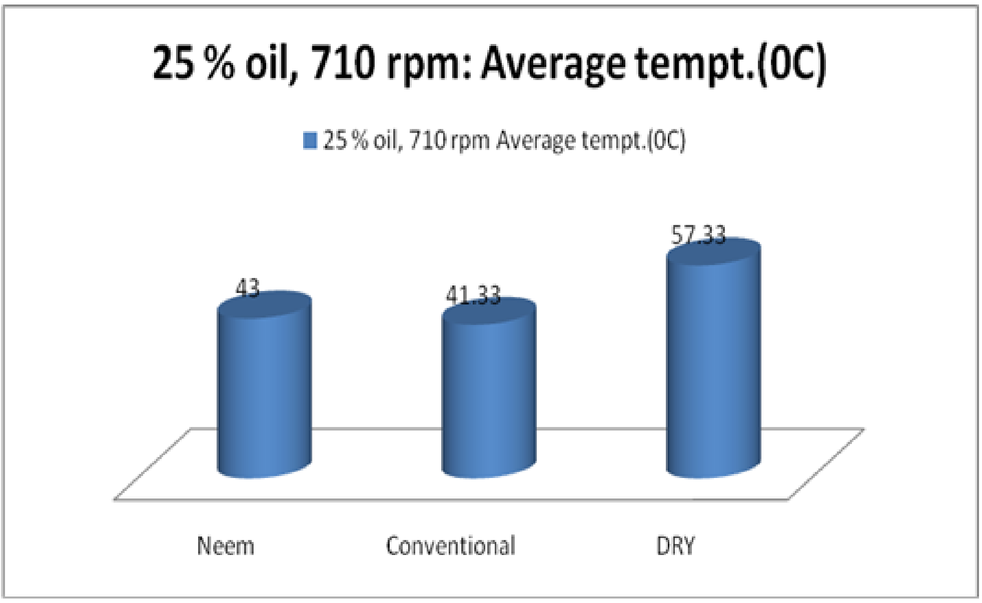

Figure 10. Average Temperatures (°C) of samples machined with 25% oil/75% water ratio and dry sample, 710rpm, 0.5mm depth of cut

3.3. Result of Tool Wear

The results of wear measurements obtained using from HSS tool for sample machining with Neem oil are as plotted in a chart of Figure 11.

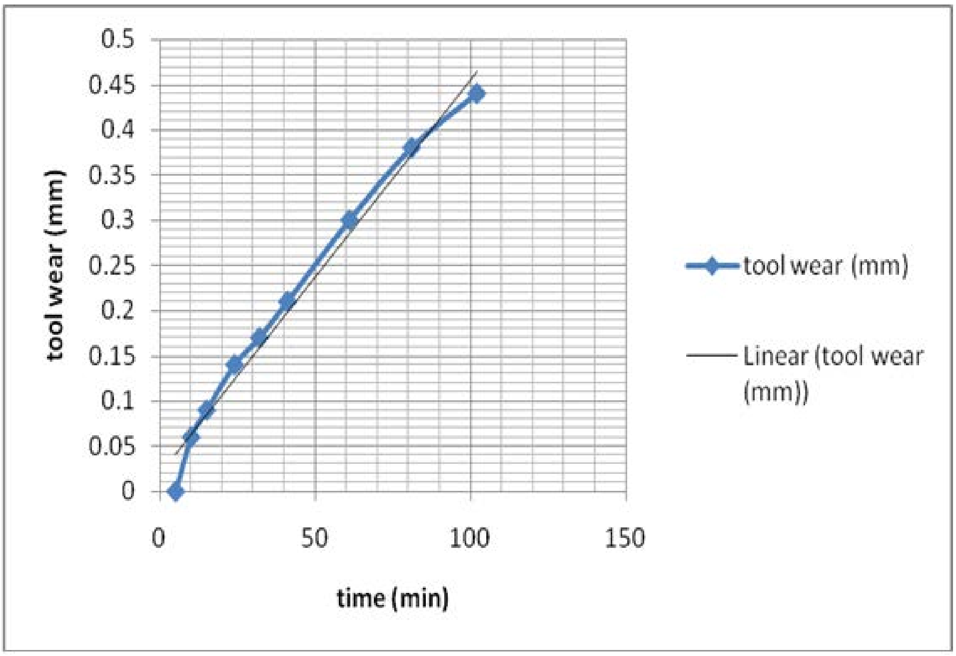

Figure 11. Plot of tool wear (mm) versus machining time (min) of HSS (12 X 200 mm) cutting tool

3.4. Result of Surface Roughness Test

The result of the surface roughness test obtained from the oils tested is as presented in Table 2 to Table 10. The comparative bar chart plots are as presented in 12 to 19.

Table 2. Surface roughness at 180 rpm, 0.75 mm depth of cut, 100% oil

S/No	Oil sample	Average Surface roughness[µm]
1.	Neem	0.002
2	Cutting	0.002
3.	Dry	0.002

Table 3. Surface roughness at 180 rpm, 0.75 mm depth of cut, 50 % oil

S/No	Oil sample	Average Surface roughness[µm]
1.	Neem	0.416
2	Cutting	0.003
3.	Dry	0.002

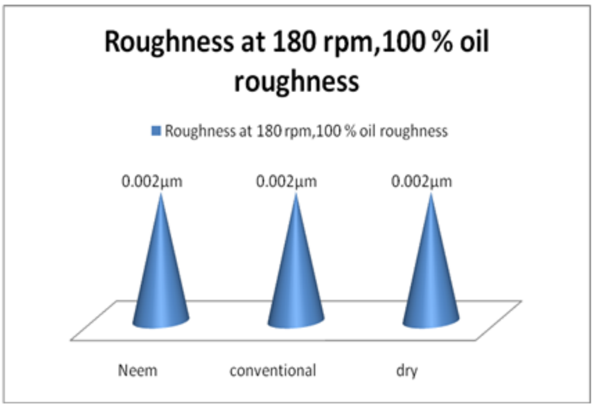

Figure 12. Plot of average roughness at 100 %, 180 rpm and 0.75mm depth of cut

Table 4. Surface roughness at 180 rpm, 0.75 mm depth of cut, 25 % oil

S/No	Oil sample	Average Surface roughness[µm]
1.	Neem	0.002
2	Cutting	0.002
3.	Dry	0.002

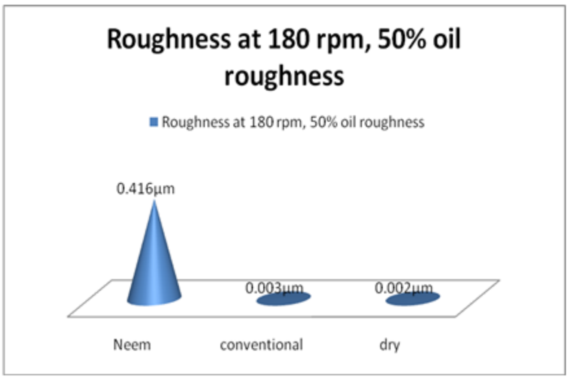

Figure 13. Plot of average roughness at 50 % oil, 180 rpm and 0.75 mm depth of cut

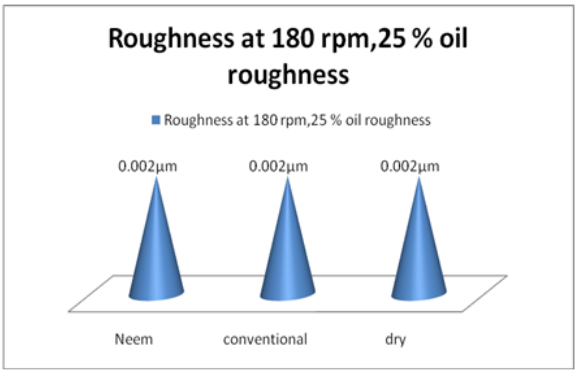

Figure 14. Plot of average roughness at 25 % oil, 180 rpm and 0.75 mm depth of cutand dry sample

Table 5. Surface roughness at 250 rpm, 1mm depth of cut, 100 % oil

S/No	Oil sample	Average Surface roughness[μm]
1.	Neem	0.323
2	Cutting	0.002
3.	Dry	1.311

Table 6. Surface roughness at 250 rpm, 1 mm depth of cut, 50 % oil

S/No	Oil sample	Average surface Roughness [μm]
1.	Neem	1.427
2.	Cutting	0.725
3	Dry sample	1.311

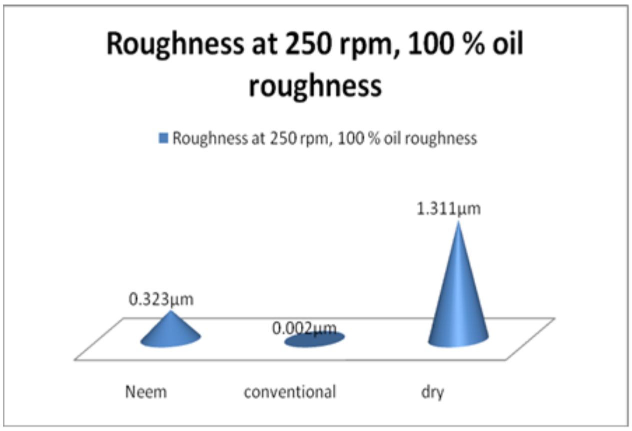

Figure 15. Plot of average surface roughness at 100 % oil, 250 rpm, 1mm depth of cut and dry sample

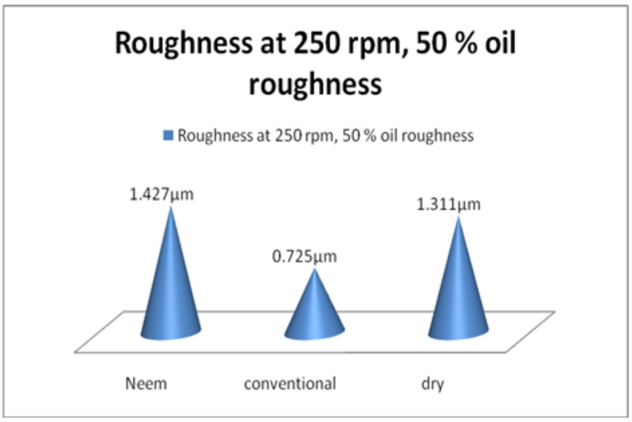

Figure 16. Plot of average surface roughness at 50 % oil, 250 rpm, 1mm depth of cut and dry sample

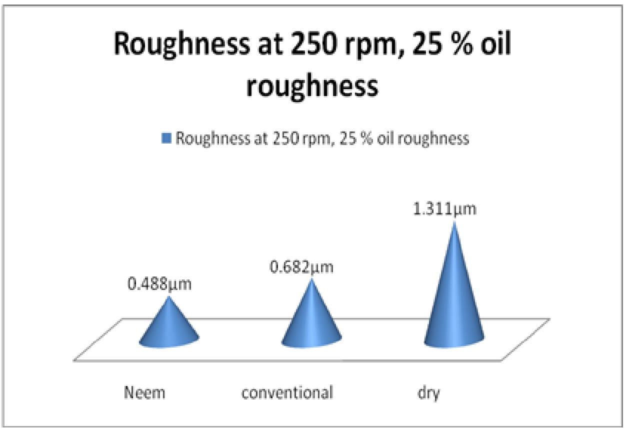

Figure 17. Plot of average surface roughness at 25 % oil, 250 rpm, 1 mm depth of cut and dry sample

Table 7. Surface roughness at 250 rpm, 1 mm depth of cut, 25 % oil

S/No	Oil sample	Average Surface roughness[μm]
1.	Neem	0.488
2	Cutting	0.725
3.	Dry	1.311

Table 8. Results of Surface roughness of machine samples at 100rpm, 0.5 mm depth of cut and 100 % oil and Dry sample

S/No	Oil sample	Average Surface roughness[μm]
1.	Neem	0.002
2	Cutting	0.002
3.	Dry	0.002

Table 9. Results of Surface roughness of machine samples at 710rpm, 0.5 mm depth of cut and 50 % oil and Dry sample

S/No	Oil sample	Average Surface roughness[μm]
1.	Neem	0.003
2	Cutting	0.003
3.	Dry	0.003

Table 10. Results of Surface roughness of machined samples at 710rpm, 0.5 mm depth of cut and 25% oil and Dry sample

S/No	Oil sample	Average Surface roughness[μm]
1.	Neem	0.003
2	Cutting	0.002
3.	Dry	0.003

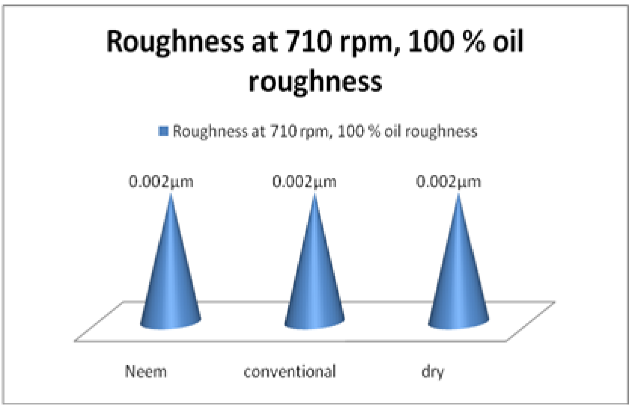

Figure 18. Plot of average surface roughness at 100% oil, 710 rpm, 0.5 mm depth of cut and dry sample

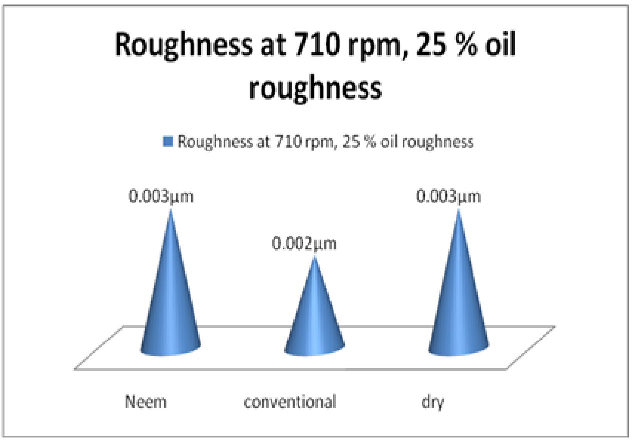

Figure 19. Plot of average surface roughness at 100% oil, 710 rpm, 0.5 mm depth of cut and dry sample

The lubricity of surface roughness results proved that neem oil effectively reduced frictional forces thereby improving surface quality. Surface finish obtained with the neem oil were comparable to that obtained from conventional cutting oil and much better than that of machined samples. Despite that the worst surface finish was obtained with neem cutting at mixture 50% oil/water, 250 rpm and 1mm depth of cut that is 1.427µm roughness. This is still quite comparable to that of dry machined sample surface that was 1.311µm. However, the results are all within acceptable limits for turning operations with an upper limit of 25 µm [16,17].

4. Conclusions

The work has shown that temperatures obtained on machining sample with neem oil dropped below those obtained when samples were machined dry and with conventional cutting oil. The result of the property analyses on the neem seed vegetable oil significantly indicated that the oil is suitable for use as machining/cutting fluid. The flash point of 157°C agreed with available literature and hence, it can be applied. Lubricity was very good which is why it produced surface finish that was comparable to the conventional cutting oil at most oil/water admixture ratios that were tested. However, it produced the worst surface finish at 50% oil/50% water emulsion at a speed of 250 rpm.

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