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Analysis Of Some Physicochemical Properties Of Selected Cutting Fluids

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***Abstract*— In work, this analysis of some physicochemical properties of cutting fluids is presented. The properties included cooling ability, corrosion resistance, viscosity and pH while the cutting fluids considered include; castor oil, distilled water, crude palm kernel oil (CPKO) and soluble oil (emulsion). Besides, mild steel samples were used as the study specimens. In the analysis, the cutting fluids were designated as follows; A for the CPKO, B for the castor oil, C for the soluble oil (emulsion) and D for the distilled water. The results showed that in terms of heat absorbed by the cutting fluids, the order of decreasing cooling ability (cutting fluid D > C > A > B) favours cutting fluid D (distilled water), and then followed by cutting fluid C (soluble oil) whereas the least is cutting fluid B (castor oil). In addition, the mean viscosities of the cutting fluids A (CKPO) was 57.00 ± 1.40, B (castor oil) was 771.5 ± 87.0, C (soluble oil) was 1.75 ± 0.40 and D (distilled water) was 1.20 ± 0.40 cPs, respectively. Also, cutting fluids, A and B had the least % corrosion (0.197%). The pH of the cutting fluids A (6.70 ± 0.30), B (7.00 ± 0.20) and D (7.50 ± 0.10) were nearly neutral, only cutting fluid C (12.10 ± 0.20) was basic as a results of ash content.**

Keywords — Physicochemical Properties, Cutting Fluids, Viscosity, Corrosion Resistance, Cooling Ability

1. Introduction

The mechanical properties of materials during machining operations are significantly influenced by a multitude of factors, one of which is the type of cutting fluid used (Purica, 2024; MacPhail-Bartley, 2024; Latour and Weibel, 2020). Cutting fluids, also known as coolants or lubricants do play a pivotal role in machining processes (Ravi, Gurusamy and Mohanavel, 2021). Each cutting fluid has unique characteristics and effects on the machining process, and consequently, on the mechanical properties of the machined material, including mild steel (Patole, Kulkarni and Bhatwadekar, 2021; Shaikh and Ali, 2021).

Again, mild steel, due to its versatility and affordability, is one of the most commonly used materials in the manufacturing industry ((Trzepieciński and Najm, 2024; Zhang and Xu, 2022). Its mechanical properties, such as strength, hardness, and ductility, can be significantly affected by the machining process, particularly by the type of cutting fluid used (Pawanr and Gupta, 2024; Sultana and Dhar, 2022). Therefore, understanding the key influence of different cutting fluids on the mechanical properties of mild steel is of paramount importance.

Furthermore, the environmental impact of cutting fluids is a growing concern. Different types of cutting fluids have varying levels of environmental impact, from their production to their disposal (Katna, Suhaib and Agrawal, 2020; Yıldırım, 2020). Consequently, an excellent understanding of the performance of these fluids in machining operations can contribute to the development of more sustainable machining practices. Accordingly, in this work, some physicochemical properties of the cutting fluids were determined and those properties included cooling ability, corrosion resistance, viscosity and pH. Also, the cutting fluids considered include; castor oil, distilled water, CPKO and soluble oil (emulsion).

2. Methodology

2.1 The Cutting Fluids and the Work Piece

In this study, some physicochemical properties of the cutting fluids were determined and those properties included cooling ability, corrosion resistance, viscosity and pH. This aspect was conducted in Chemical Engineering Laboratory, University of Uyo, Uyo. The following four (4) cutting fluids were considered in the study: castor oil, distilled water, CPKO and soluble oil (emulsion). In the analysis, the cutting fluids were designated as follows; A for the CPKO, B for the castor oil, C for the soluble oil (emulsion) and D for the distilled water. Also, the study used standardized cylindrical mild steel samples (work piece) labelled A, B, C and D were cut mild steel samples as presented in Figure 1.

(i) (ii) Note: Fliuds A, B, C and D in the bottles are crude palm kernel oil, castor oil, emulsion and distilled water; whereas cylindrical metals with label A, B, C and D are cut mild steel samples.

Figure 1: (i) Samples of work piece; and (ii) cutting fluids/cut mild steel samples

2.2 Cooling Ability of the Cutting Fluids

Cutting fluid, A (CPKO) was weighed using digital weighing balance as m_c1. The fluid was emptied into a prepared calorimetric vessel fitted with a stirrer and a digital thermometer. The content initial temperature was read as T_i. The hot air convection oven was set up at 1450C, and after about 10 minutes. The cut mild steel specimen A was later introduced and heated for 30 minutes. It was removed using sugar tong and dipped into the vessel containing the cutting fluid. The content of the vessel was stirred using the stirrer while its temperature was read at every two-minute interval for 16 minutes. Besides, the plot of final coolant temperature against cooling time was generated. The final maximum cutting fluid temperature was noted as $T_{f/max}$. However, heat lost by hot cut mild steel specimen A is equivalent to heat gained by the cutting fluid A. Hence, cooling ability in terms of amount of heat absorbed by the coolant A (CPKO) (H_{cj}) was calculated using Equation 3.1. However, the procedure was repeated using cut mild steel specimens B, C and D and cutting fluids B, C and D.

$$H_{cj} = m_{cj}\, C_{pcj}\, (T_{f/max} - T_i) \qquad (1$$

Where, H_{cj} is the amount of heat absorbed by j-cutting fluid (J), m_{cj} is the mass of cutting fluid, C_{pcj} is the specific heat capacity of the cutting fluid (kJ/kg.K), $T_{f/max}$ is final maximum temperature of the cutting fluid (°C), T_i is the initial temperature of the cutting fluid (°C) and letter "j" which could be A, B, C and D.

It is to be noted that a cutting fluid with the greatest H_{cj} is the one that cools the hot cut mild steel specimen quickly. Again, the specific heat capacity of soluble oil was computed as average specific heat capacity of palm oil (1.875 kJ/ kg.°C) and water (4.17 kJ/ kg.°C) since they were the major liquids used in producing the soluble oil (emulsion).

2.3 Corrosion Resistance of the Cutting Fluids

Four (4) cylindrical smaller workpieces, each 20.0 mm long, were weighed using digital weighing balance, dipped into containers that had cutting fluids of A, B, C and D separately, removed and kept in an open space on a metallic sheet for one (1) month. Thereafter, each was re-weighed. The percentage increase in masses was computed using Equation 3.2. However, the least % increase was the one with the greatest corrosion resistance.

$$\text{Corrosion resistance (\%)} = \frac{\text{Final mass (g)} - \text{initial mass (g)}}{\text{Initial mass (g)}} \times 100$$

2.4 Viscosity of the Cutting Fluids

Viscosity measurement was carried out at room temperature using Fan Viscometer (Model 35SA), shown in

Figure 2. Exactly 350 ml of each cutting fluid was measured using measuring cylinder. It was then poured into the viscosity cup, the knob turned on, and the gear set at 300 rpm. The viscosity was read as the fluid made contact with the bob and the rotor which generated a shear stress. Also, the reading at 600 rpm was taken using the same procedure when the knob was turned on. Plastic viscosity was computed using Equation 3.3.

PV = mean dial reading at 600 rpm – mean dial rea

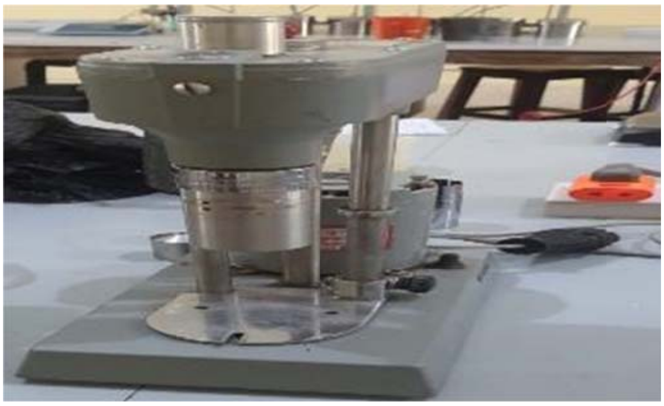

Figure 2: Fan Viscometer (Model 35SA)

2.5 pH of the Cutting Fluids

The pH of the cutting fluids was measured using a pH meter as shown in Figure 3. The pH meter was first calibrated using a buffer solution. The probe was inserted into different cutting fluids at a time and the reading allowed to steady before recorded.

Figure 3: pH meter

3. Results and discussion

3.1 The Results for the Cooling Ability of the Cutting Fluids

The variation of cutting fluids temperature against cooling time and heat absorbed by the cutting fluids are presented in Figure 4 and Table 1. From Figure 4, the initial cutting fluid temperature (29.5^{o}C) was raised as soon as the hot mild steel specimens were dropped in, to maximum final cutting fluid temperature. The mass (kg) and specific heat capacity (kJ/kgK) of the specimen are presented in Figure 5 and Table 1 while the Initial temperature of cutting fluids (oC) and Final maximum temperature of cutting fluids (oC) are presented in Figure 6 and Table 1. Also, the Hheat absorbed by the cutting fluids (J) is presented in Figure 7 and Table 1.

Cutting fluids, A, B, C and D recorded final maximum temperatures of 43.9^{o}C at 8 minutes, 44.1^{o}C at 10 minutes, 39.1^{o}C at 6 minutes and 42.5^{o}C at 8 minutes cooling time, respectively. Beyond these periods, temperature of the cutting fluid began to fall gradually. The greatest rise in temperature was found in cutting fluid B whereas the least was found in cutting fluid C. Cutting fluid B (castor oil) being the most viscous fluid had the greatest temperature rise whereas cutting fluid C (distilled water) recorded the least temperature rise as it is the least viscous fluid. As could be observed in Table 4.1, in terms of heat absorbed by the cutting fluids, the order of decreasing cooling ability (cutting fluid D > C > A > B) favours cutting fluid D (distilled water), and then followed by cutting fluid C (soluble oil) whereas the least is cutting fluid B (castor oil).

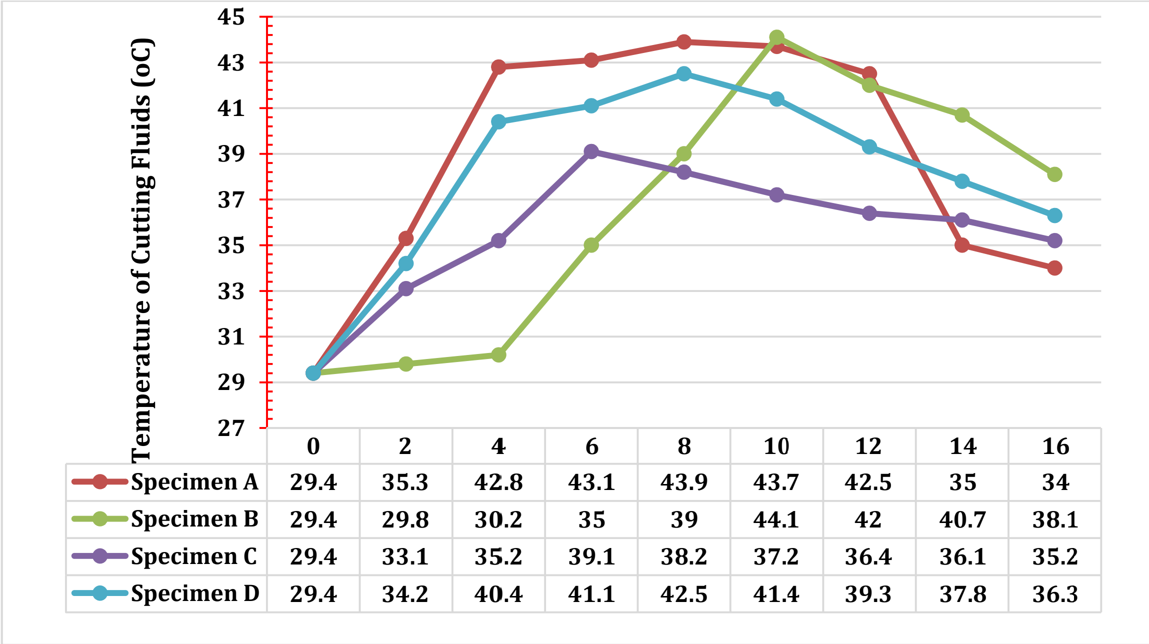

Figure 4: Variation of cutting fluids temperature against cooling time.

Table 1: Heat absorbed by the cutting fluids

Parameter	Specimen A	Specimen B	Specimen C	Specimen D
Mass (kg)	0.066	0.066	0.066	0.066
Specific heat capacity (kJ/kgK)	1.875	1.800	3.020	4.190
Initial temperature of cutting fluids (^{o}C)	29.400	29.400	29.400	29.400
Final max. temperature of cutting fluids (^{o}C)	43.900	44.100	39.100	42.500
Heat absorbed by the cutting fluids (J)	1.794	1.746	1.933	3.623

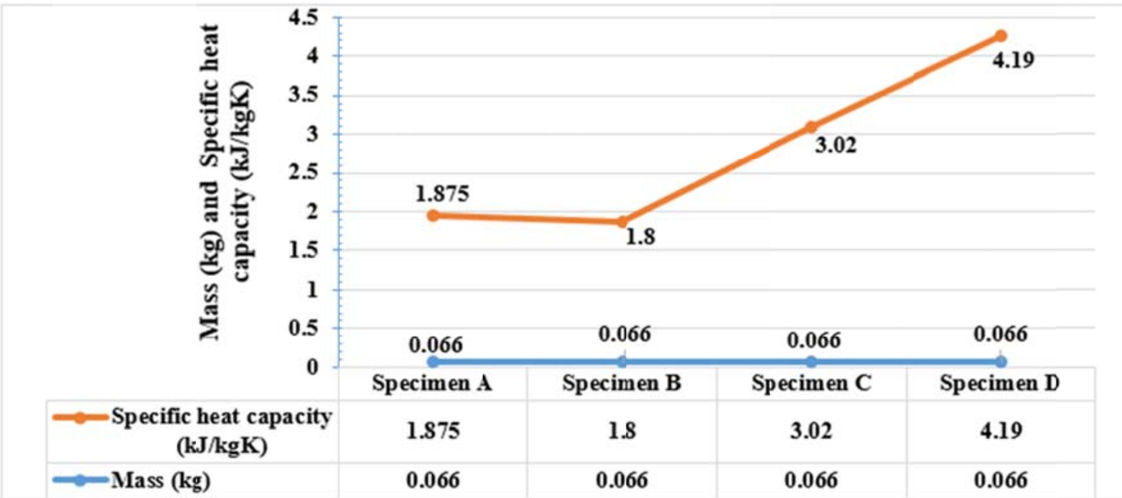

Figure 5: Mass (kg) and Specific heat capacity (kJ/kgK)

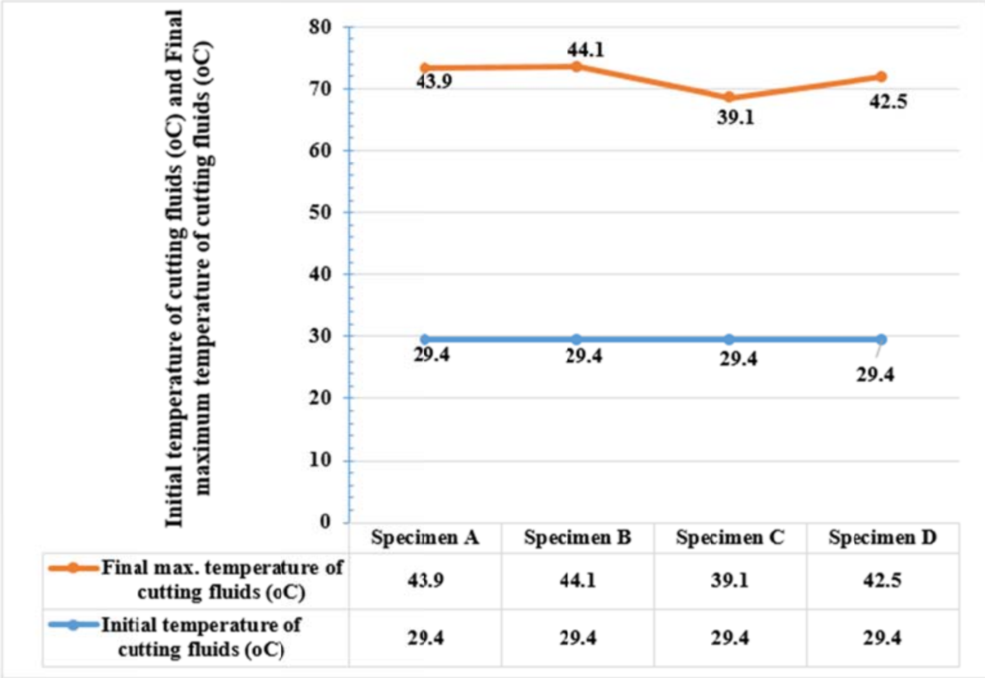

Figure 6: Initial temperature of cutting fluids (oC) and Final maximum temperature of cutting fluids (oC)

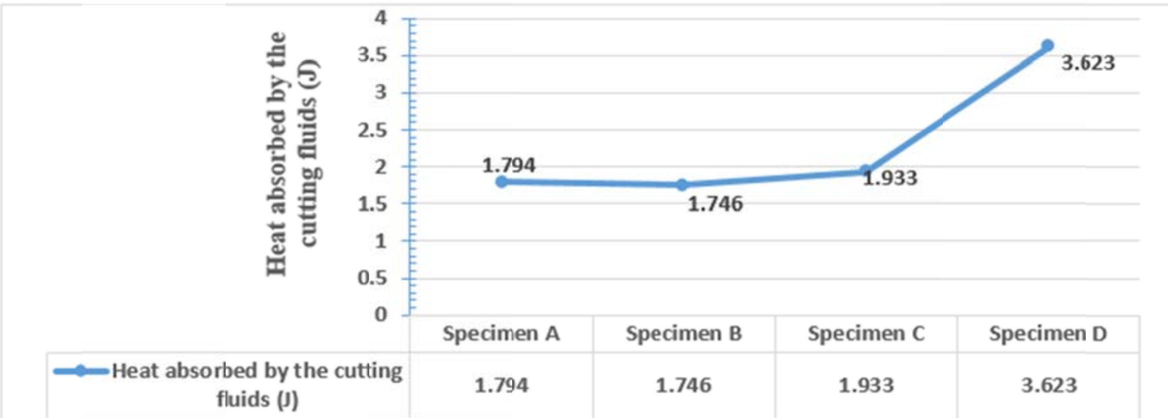

Figure 7 Heat absorbed by the cutting fluids (J)

3.2 Corrosion Resistance of the Cutting Fluids

The results on the corrosion resistance of the cutting fluids are presented in Figure 8 and Figure 9 and they showed that the mild steel pieces dipped in cutting fluids A and B; removed and kept had the least percentage increase in masses (0.197%) whereas those rubbed in cutting fluids C and D were 0.221 and 0.236% respectively. Hence, cutting fluids A and B were regarded as high corrosion resistance cutting fluids. These cutting fluids were oils and are expected to resist or limit oxidation / rusting of mild steel.

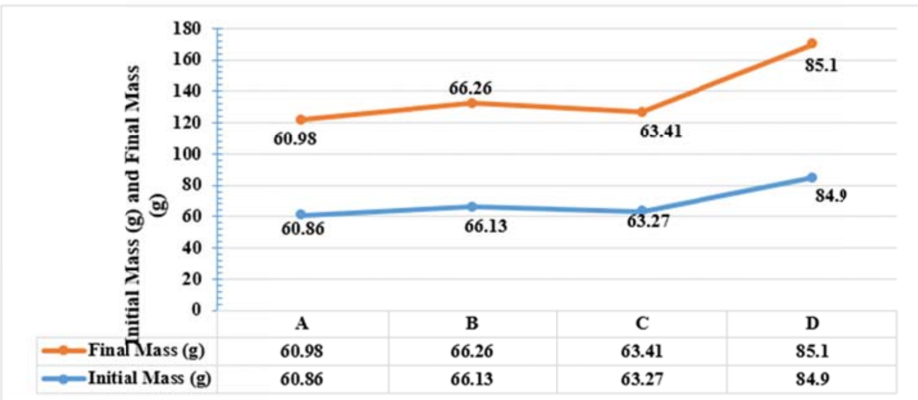

Figure 8 Initial Mass (g) and Final Mass (g) of the cutting fluids

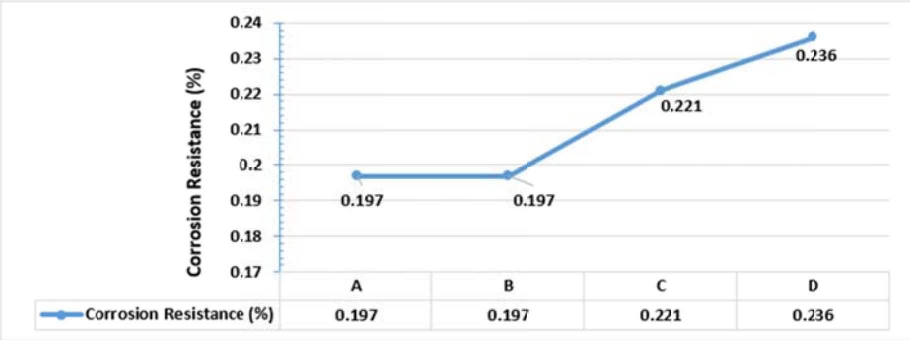

Figure 9 Corrosion Resistance (%)of the cutting fluids

3.3 Viscosity of the Cutting Fluids

The viscosities of the cutting fluids are presented in Figure 10 and Figure 11. From Figure 10 and Figure 11, the viscosities of the cutting fluids A, B, C and D were 57 ± 1.4, 687.5 ± 3.5, 1.75 ± 0.4 and 1.2 ± 0.4 cPs, respectively. The order of decreasing viscosity was cutting fluid B > A> C > D. Cutting fluid B (castor oil) was the most viscous cutting fluid used, whereas cutting fluid D (distilled water) was the least viscous. This is one of the rheological properties of the cutting fluids which measures the deformation in the flow pattern caused by the stress that is being developed on the fluid.

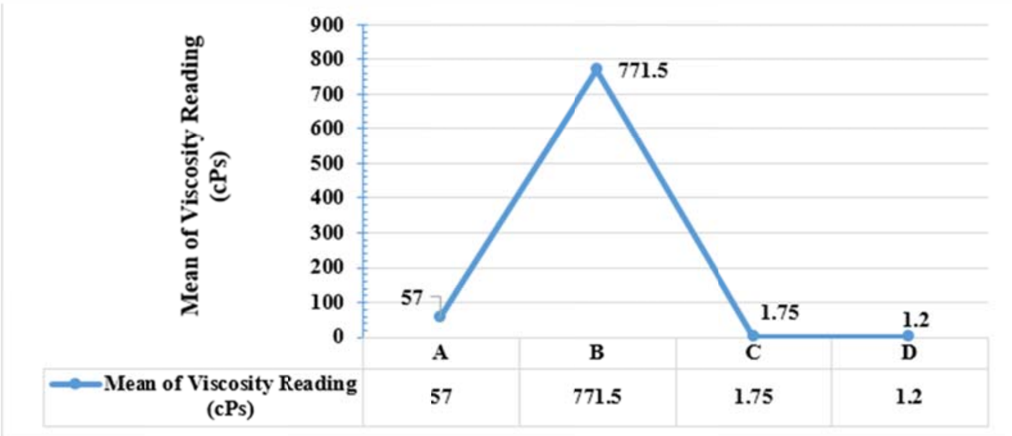

Figure 10 Mean of Viscosity Reading (cPs)

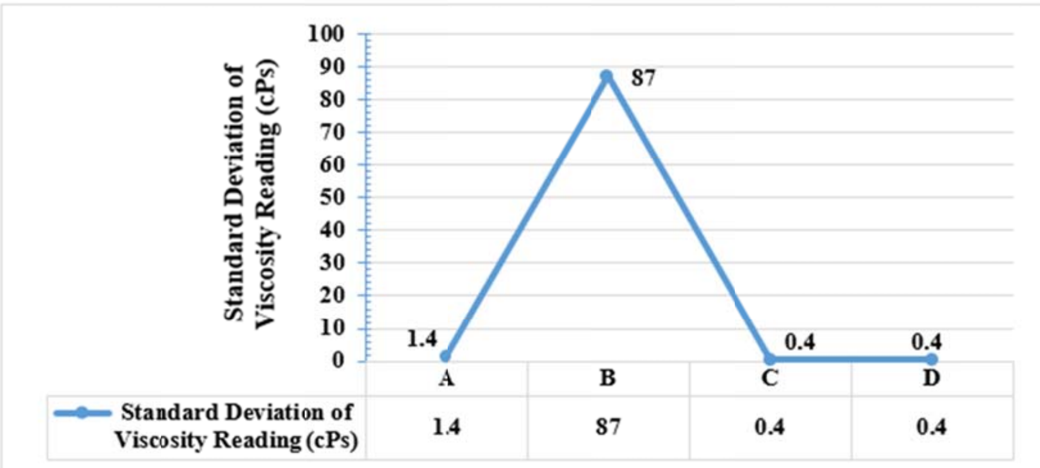

Figure 11 Standard Deviation of Viscosity Reading (cPs)

3.4 pH of the Cutting Fluids

The pH values of the cutting fluids are presented in Figure 12 and Figure 13. From Figure 12 and Figure 13, the pH values of the cutting fluids A, B, C and D were 6.7 ± 0.3, 7.0 ± 0.2, 12.1 ± 0.2 and 7.5 ± 0.1, respectively.

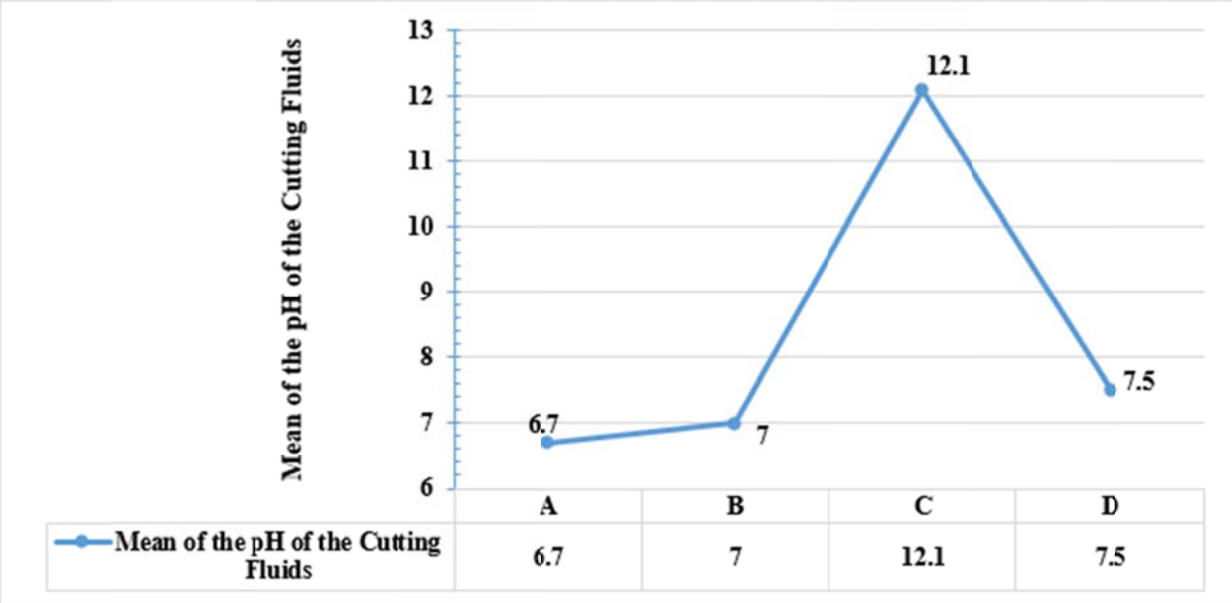

Figure 12 The mean of the pH of the Cutting Fluids

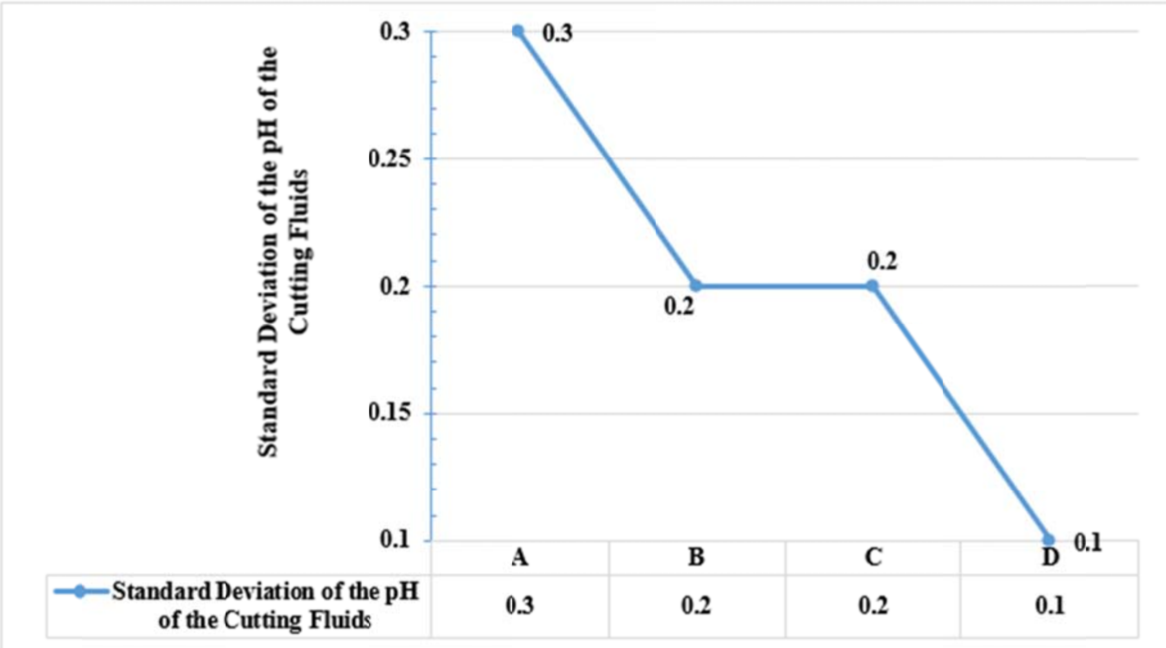

Figure 13 The Standard Deviation of the pH of the Cutting Fluids

4. Conclusion

This study presented analysis of the physicochemical properties some selected cutting fluids. The cutting fluids considered include; castor oil, distilled water, CPKO and soluble oil (emulsion). Also, some selected physicochemical properties were determined they include; the cooling ability, the corrosion resistance, the viscosity and the ph. Besides, mild steel samples were used as the study specimens. According to the results, the distilled water has the best cooling ability followed by the soluble oil. However, all the four (4) cutting fluids tested have cooling abilities that fall within the standard range of acceptable values.

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