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Research Article

EXPERIMENTAL INVESTIGATION TO STUDY THE VISCOSITY AND DISPERSION OF CONDUCTIVE AND NON-CONDUCTIVE NANOPOWDERS' BLENDED DIELECTRICS

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ABSTRACT

Nano fluids are nanotechnology-based colloidal dispersions engineered by stably suspending nanoparticles. The characteristics of nano fluids such as thermal and electrical conductivities, viscosity, specific heat, dispersion etc. were studied and analyzed by earlier researches at different particle concentrations with different nano fluids. It was established that nano fluids have a significant impact on the process due the improvised characteristics. Nano fluid viscosity and dispersion deserve the same attention as thermal conductivity in cases of nano dielectric fluids that are used in EDM as they influence the MRR. In this work, The viscosity and dispersion of the conductive and nonconductive Nano powders blended dielectrics are investigated as a function of volume fraction so as to evaluate the behavior of these nano fluids at different particle volume concentrations. Kerosene and deionized water based nano fluids blended with conductive (SiC) and non-conductive (boric acid) Nano particles are selected for the current study. It is observed that as the percentage volume fraction of nano particles (both SiC and boric acid) increased, the viscosity was found increasing when blended with DI water. But the viscosity behavior with kerosene blended with SiC and boric acid is not same. The existing experimental results about the nano fluids viscosity shows clearly that viscosity have a specific trend in variation with an increase of volume concentration. Boric acid blended with DIW and kerosene shows similar trend in dispersion. However, in case of SiC blended with DIW and kerosene showed some contradictory results giving scope for further investigation. The outcome of these experimental investigations will augment the works that are going on in studying its influence on MRR in EDM processes using nano blended dielectric medium.

Keywords: nanofluid; viscosity; dispersion; sonication; silicon carbide nano powder; boric acid nano powder.

INTRODUCTION

Nano fluids are generally the nano scale colloidal suspensions of metallic and nonmetallic nano particles in conventional base fluids. In general the base fluids that are used are deionized water, kerosene, ethylene glycol, transformer oil, etc. These essential fluids frequently employed in cooling are not sufficient to deal with the progress in the majority of areas predominantly in electronic chip as well as computing technologies. For this increasing demand, intensive research on nano fluids has been triggered using various types of nanoparticles. Kalpana Sarojini et al. [8] carried out extensive experiments to evaluate electrical conductivity of water and ethylene glycol mixed with metallic (Cu, Al_2O_3) and ceramic particles (CuO) for different volume fractions, particle sizes. Enhancement of electrical conductivity is observed in both water and ethylene glycol based nanofluids with increase in particle concentration and reduction in particle size.

Alina Adriana Minea et al. [6] presented electrical conductivity measurements carried out with Al_2O_3 nanoparticles diffused in distelled water (1–4% particle volume fraction) nanofluids at atmospheric pressure and different temperatures. It was reported that an enhancement of 379.6% for electrical conductivity of alumina nanofluid is observed at a volume fraction of 4%. It was subsequently disclosed that the escalation of electrical conductivity is a function of volume percentage of nanoparticles as well as temperature. Joohyun Lee et al. [3] made attempts to introduce a new method to track the sequential changes of the particle volume fraction and size distribution of DI water/Al_2O_3, DI water/SiO_2, DI water/Ag, EG/Al_2O_3, and EG/ZnO nanofluids. The change in particle volume fraction is determined by monitoring the suspension density using a hydrometer, and the dynamic light scattering (DLS) method is used to find the particle size distribution. The thermal conductivity of each of the nanofluids measured using the transient hot-wire method is found to be affected by the changes in concentration and the particle size distribution.

Wei Yu et al. [10] reported the results of experiments conducted to measure viscosity and thermal conductivity of Ethylene glycol (EG) based nanofluids containing ZnO nanoparticles. It is stated that the thermal conductivity of ZnO-EG nanofluids is independent of setting time from 20 to 360 min. Additionally it is claimed that thermal conductivity of ZnO-EG nanofluids is dependent fervently on particle concentration , which enhances nonlinearly with the volume percentage of nanoparticles. Seung Won Lee et al. [4] investigated the thermophysical properties of SiC (<100 nm)/DIW nanofluids for high-temperature heat transfer applications and concluded that values obtained would show an enviable path for further research in the fiels of nanofluids. It was reported that for stable dispersion of the SiC particles in DI water, a pH ~ 6 and above is appropriate. It was also reported that measured maximum relative viscosity and thermal conductivity data for the 3 vol% SiC/DIW nanofluids compared with DIW were 102% and 7.2% respectively.

Deepak Kumar Agarwal et.al. [1] measured viscosity, thermal conductivity and stability of kerosene-alumina nanofluid at low volume concentration (0.05–0.5% by volume) of nanoparticles (13 nm and 50 nm) to find its appropriateness in regenerative cooling channels of semi-cryogenic rocket engine. It has been found that 22% together with 10% advancement in thermal conductivity as well as viscosity at room temperature are attained for 13 nm particle dimension nanofluid respectively at 0.5% volume concentration. It was also reported that at higher nano particle size thermal conductivity and viscosity decreases. Ibrahim Palabiyik et al. [9] compared the results obtained from experiments conducted on propylene glycol based titania and alumina nanofluids (1, 6 and 9 wt%) with theoretical results. It was reported that there is no change when thermal conductivities of both Al_2O_3 and TiO_2 based nanofluids are compared with pure Propylene Glycol. Additionally, it is claimed that thermal conductivity of the product samples portrayed a non-linear escalation with the particle concentration as well as augmentation of thermal conductivity was not temperature dependant. Jung-Yeul Jung et al. [2] selected LiBr/Al_2O_3/H_2O/ binary nanofluids produced by a novel two step method to compare the thermal conductivity variation with time and visual inspection. It is reported that the predominant factor that influences thermal conductivity of binary nanofluids is their stability. It is also reported that the thermal conductivity of the binary nanofluids increases with the particle volume concentration and enhances by 2.2% at 0.1 vol% concentration condition. In a thorough review of literature made by I.M. Mahbubul et al. [5] concluded that research carried out mostly focused on the thermal conductivity of nano fluids and that viscosity of nanofluid also deserves the similar attention as thermal conductivity. It is also reported that temperature, particle size & shape and volume fractions have considerable effects over viscosity of nanofluids. It is also stated that based on earlier results increase in viscosity is observed as the particle volume fractions increase. Purna Chandra Mishra et al. [7] emphasized that viscosity of nanofluid is influenced on several parameters like particle size, base fluids, particle volume fraction, particle shape, temperature, pH value, shear rate, surfactants, dispersion techniques, particle size distribution and particle aggregation. It is stated that no existing theoretical formula is able to calculate nanofluid viscosity with good accuracy and the criterion for validating analytical results with experimental results still needs more attention. Also it is stressed that there is no data for optimum size of nanoparticles that can give better stability and less aggregation.

From the above discussion it is appropriate that most researches concentrated on characterization of different nano fluids to enhance thermal conductivity, electrical conductivity, etc., by varying particle shape, particle size and concentration when blended with metal oxides and metal powders (Al_2O_3, TiO_2, CuO, Cu, and Al). To the best knowledge of authors investigation on vicosity of and dispersion of different dielectric mediums when blended with conductive and non-conductive nano powders is not yet reported. Hence these two properties are investigated in this work.

MATERIALS AND EQUIPMENT

Base fluids and powders

Commercially availabe kerosene purchased from local market and deionized water available in the Chemistry Laboratory are considered as base fluids. Powders opted for present investigations are Silicon Carbide (conductive) and Boric Acid (non-conductive) of 50 nm size are procured from Sisco Research Laboratories Pvt. Ltd. (SRL) – India.

Equipment

An analytical balance shown in Figure 1, SHIMAZDU make, is used to weigh required weights of nanopowders. This balance has minimum and maximum weighing capacities as 10mg and 220g respectively.

A magnetic stirrer with 1litre stirring capacity, 150 Watt heating capacity and maximum speed of 1800 Rpm depicted in Figure 2 is used to stir the base fluid and nanopowder. An ultra sonicator with 500 W power rating, 20 kHz frequency and 110 V operating voltage capacity shown in Figure. 3 is used to diffuse the nanopowder in the basefluid for 1 hour after stirring.

Fig. 1. Analytical balance

Fig. 2. Magnetic stirrer

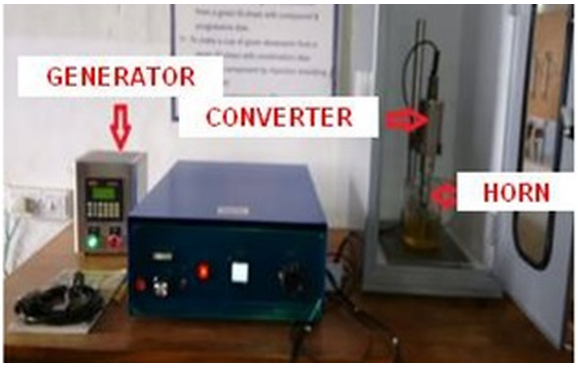

Fig. 3. Ultra sonicator

Fig. 4. Redwood viscometer – 1

Redwood viscometer – 1 shown in Figure 4 is used to find out viscosity of nanofluid. It accommodates a beaker in cylindrical shape furnished

Fig. 5. Turbidity Meter

with a check point, an orifice fabricated from metal at the bottom having a concave form from inside to assist a ball with brisk wire to behave like a valve to start or prevent oil stream. The outside section of the orifice jet is convex, in order that the oil under examination will never creep over the lower face of the oil beaker. The oil beaker is encompassed by a water bath with a circular electric powered immersion heating unit along with stirring equipment. A pair of thermometers is provided to measure temperatures of water bath and oil under examination. A round flat-bottomed flask of 50 ml grading, is made available underneath, to collect 50 ml of oil transfer against time. The water bath with oil cup is supported on a tripod stand with leveling screws.

To measure dispersion of nano powder in dielectrics, a turbidity meter lit with Tungsten filament lamp shown in Figure 5 is used. It operates in the range of 0–1000 NTU with an accuracy ± 2% and has resolution of 0.01 NTU on lowest range. It takes 6 seconds to respond for full step change without signal averaging in constant reading mode.

METHODS

Volume fraction of nano powder

The amount of nanopowder necessary for preparation of nano fluids is calculated using law of mixture formula shown in equation (1). A susceptible electronic balance with 0.001 grams resolution is employed to measure the requisite amount of nanoparticles. The weight of nanoparticles required for preparation of 100 ml nano fluid for a particular volume concentration is calculated by using the following relation.

Table 1. % volume concentration for different weights of SiC nano powder for both DI water and kerosene as base fluids

SiC weight (g)	% volume concentration for DI water and kerosene
0.1	0.000315
0.2	0.000631
0.3	0.000945
0.4	0.001260
0.5	0.001570

Table 2. % volume concentration for different weights of H_3BO_3 nano powder for both DI water and kerosene as base fluids

H_3BO_3 weight (g)	% volume concentration for DI water and kerosene
0.1	0.000692
0.2	0.001384
0.3	0.004152
0.4	0.002768
0.5	0.003460

$$\%\,\text{Volume fraction} = \frac{\left[\dfrac{\text{Weight}_{\text{nanopowder}}}{\text{Density}_{\text{nanopowder}}}\right]}{\left[\dfrac{\text{Weight}_{\text{nanopowder}}}{\text{Density}_{\text{nanopowder}}} + \dfrac{\text{Weight}_{\text{basefluid}}}{\text{Density}_{\text{basefluid}}}\right]} \quad (1)$$

Table 1 and Table 2 depict various volume fractions obtained when the weight of both nanopowders is varied from 0.1g to 0.5g for 100ml sample of both base fluids.

Nano fluid preparation

Initially 0.1 gm quantity of nano powder weighed using digital balance is dispersed partially in 100 ml of deionized water. Later the fluid is stirred for 4hours of duration without the application of heat. In order to disperse the nano particles equally across the fluid, solution is agitated at a frequency of 20 kHz by the method of ultra-sonication. Parameters considered for ultra-sonication are constant current = 0.49 Amperes, pulse on time = 2 seconds and pulse off time = 3 seconds. In order to achieve good results for the experimentation ultra-sonication is performed for 60 minutes. The time gap between one sonication to the other sonication is 10 minutes. So sonication is done for 2 hours by taking the time gap between the sonication also into consideration. SiC

Table 3. Different combinations considered for experimentation

	DI water	Kerosene
SiC	C_1	C_2
H_3BO_3	C_3	C_4

Fig. 6. SiC – Deionized water

– deionized water nano fluid sample prepared by above procedure is shown in Figure 6. The above procedure is repeated for other weights and different combinations. Different combinations considered for experimentation are depicted in Table 3 where C_i represents i^{th} combination.

Viscosity measurement of nano fluid

Soon after completion of the ultra-sonication, viscosity of nanofluid is measured by means of Redwood-1 viscometer. Prior to viscosity measurement the viscometer is cleaned with methanol in order to ensure that there are no dust particles left in the viscometer. Then the cylinder of the viscometer is filled till the required mark and the knob is placed in the viscometer such that no liquid flows out of the viscometer nozzle. Then a conical flask of 50 ml is placed under the viscometer to collect the liquid after removing the knob from the nozzle. Now time taken by the fluid to fill the 50 ml conical flask is noted by means of stop watch. This experiment is repeated for 3 times for having the accurate value for the viscosity. The time obtained in redwood seconds is noted down and the actual viscosity is found out according to the formula shown in equation (2).

$$V = [A \times t] - \left[\frac{B}{t}\right] \quad (2)$$

Dispersion measurement of nano fluid

Dispersion is measured by means of turbidity meter which basically functions on the principle of the scattering of light rays in the fluid. Initially the apparatus is calibrated using standard solution. After obtaining the reference value in the turbidity meter for the standard solution the experiments are carried out using the required nano fluids. Before pouring the nano fluid in the glass tube of the turbidity meter it is cleaned using methanol so that no dust particles are left in the glass tube. Now nano fluid is poured in the glass tube and placed in the turbidity meter for measuring the turbidity. Then glass tube is covered by using the lid in order to get the exact value of the turbidity. The value of turbidity is noted for the sample.

RESULTS AND DISCUSSION

The viscosity and dispersion properties of nano powder blended dielectrics are thoroughly investigated and the following observations are drawn.

Effect of nanopowder on dielectric viscosity

As the percentage volume fraction of nano particles increases the viscosity also increases in case of C_1 and C_3 as depicted in Figure 7 and Figure 8 respectively.

In case of kerosene as dielectric medium the viscosity increases with boric acid (C_4), but with silicon carbide (C_2) viscosity initially decreases and then gradually increases as depicted in Figure 9 and Figure 10.

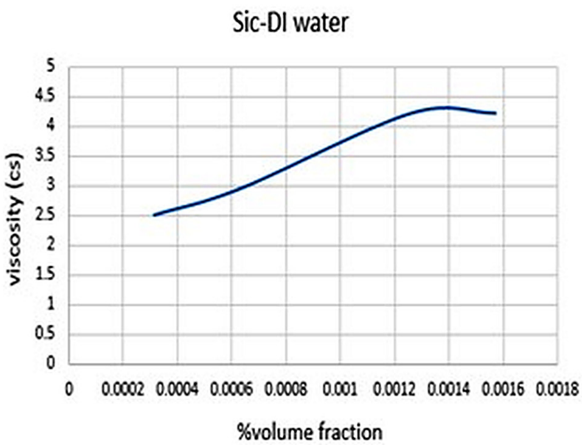

Fig. 7. Change in viscosity of SiC-DI water

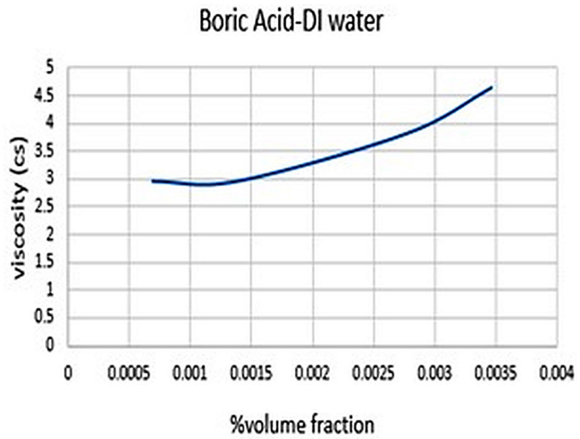

Fig. 8. Change in viscosity of H_3BO_3-DI water

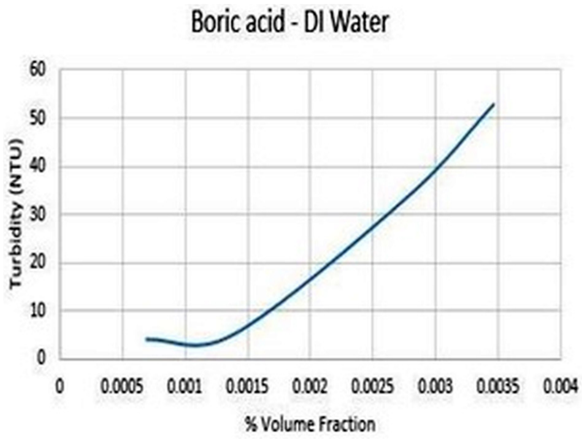

Fig. 11. Change in dispersion of H_3BO_3 in DI water

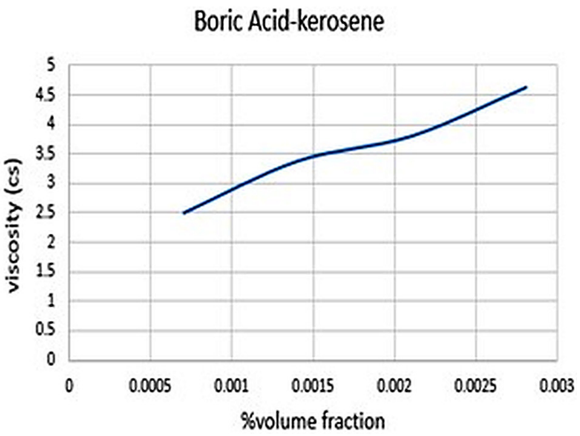

Fig. 9. Change in viscosity of H_3BO_3-kerosene

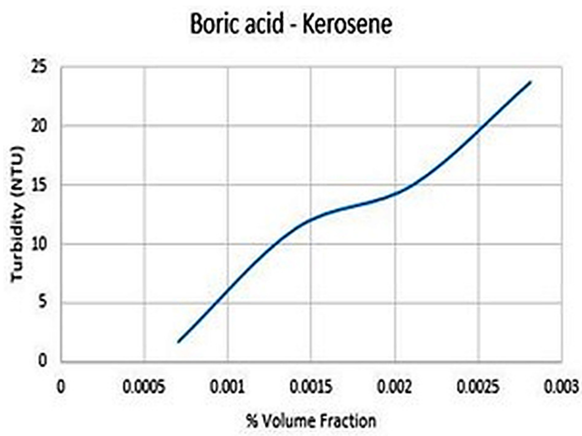

Fig. 12. Change in dispersion of H_3BO_3 in kerosene

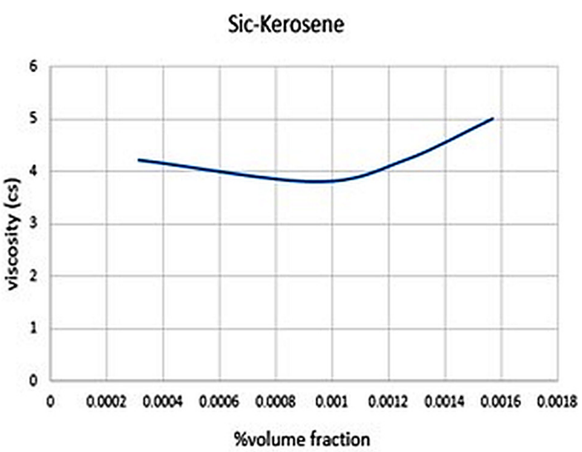

Fig. 10. Change in viscosity of SiC-kerosene

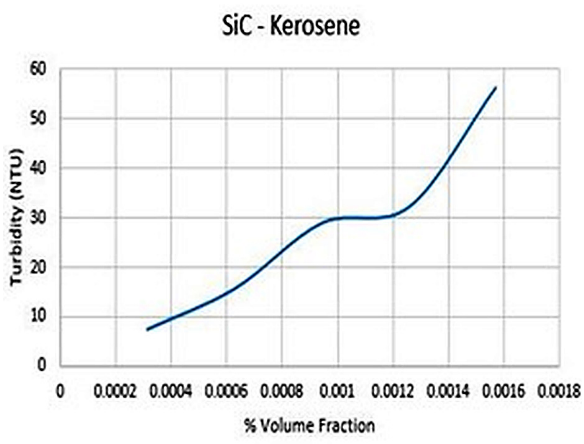

Fig. 13. Change in dispersion of SiC in kerosene

Effect of nanopowder on disperson

When the conductive and nonconductive Nano powders are blended in Dielectric mediums (DI water, Kerosene) an increment in dispersion is observed with increase in volume fraction as shown in Figure 11, Figure 12 and Figure 13.

But in the case of DI Water blended with Silicon Carbide surprisingly there was no turbidity as shown in Figure 14. This is due to the fact that the nanoparticles act like multiple refraction objects.

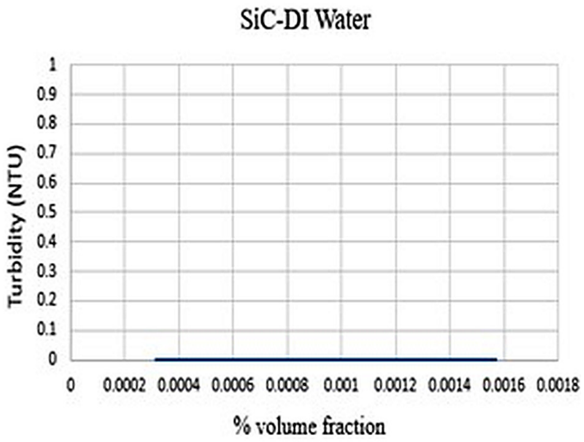

Fig. 14. Change in dispersion of SiC in DI water

CONCLUSIONS

This study concentrated on finding the variations in viscosity and dispersion of conductive (SiC) and non-conductive (H_3BO_3) nanopowders blended dielectrics. When silicon carbide is blended with kerosene, initially when the volume fraction is low the flowability of nano fluid increases which indicates the decrease in viscosity, and when the volume fraction is increased the flowability of nano fluid decreases which shows the sign of a lubricant. So it can be used as a lubricant in industrial application. It is observed that as the percentage volume fraction of nano particles (both SiC and boric acid) increased, the viscosity was found increasing when blended with DI water. But the viscosity behavior with kerosene blended with SiC and Boric acid is not same. The existing experimental results about the nano fluids viscosity shows clearly that viscosity have a specific trend in variation with an increase of volume concentration. Boric acid blended with DIW and kerosene shows similar trend in dispersion. However, in case of SiC blended with DIW and kerosene showed some contradictory results giving scope for further investigation. The outcome of these experimental investigations will augment the works that are going on in studying its influence on MRR in EDM processes using nano blended dielectric medium.

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