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ORIGINAL RESEARCH ARTICLE

Synthesis of thermal and physical properties of biodegradable hybrid nano fluid using two step method

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ABSTRACT

In the presence of green technology or biodegradable options, vegetable oils emerged as replacements for mineral oil as base oils due to their properties of high viscosity index, high flash point, low toxicity, low volatility, and high biodegradability. Nano fluids were a relatively new class of fluids that consisted of a base fluid with nano-sized particles (1–100 nm) suspended within them. The synthesis and characterization of biodegradable hybrid nano fluids and their combination with base materials were carried out in this paper, playing a vital role in machining operations. SiC and TiO_2 were used as nano particles, with the base fluid being palm oil, and sodium dodecyl sulphate (SDS) was employed as a surfactant to maintain fluid stability. All samples were prepared in individual and hybrid modes, including palm oil as the base fluid without any emulsifier/surfactant, palm oil + SiC with nano particle concentrations of 0.1%, 0.2%, and 0.3% by volume, palm oil + TiO_2 with nano particle concentrations of 0.1%, 0.2%, and 0.3% by volume, and palm oil + SiC + TiO_2 with nano particle concentrations of 0.1%, 0.2%, and 0.3% by volume. The FTIR results showed that the SiC + palm oil and SiC + TiO_2 + palm oil samples had better chemical composition and surface characterization as biodegradable hybrid nano fluids. The zeta potential values were observed to increase at volume concentrations of 1%, 2%, and 3%. Particularly, the biodegradable hybrid nano fluid samples (palm oil + 1% Vol. SiC + TiO_2) and (palm oil + 2% Vol. SiC) demonstrated increased stability as well as enhanced physical, thermal, and rheological properties in machining applications.

Keywords: biodegradable hybrid nano fluid; FTIR; zeta potential; MQL; nano particle

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1. Introduction

Biodegradable hybrid nano fluids is most prominently the best heat transfer industrial processes. In any industrial sector, the heat transfer process is most efficiently managed by the facilities of the heat transfer process, which include adding, removing, or moving in the engineering application. Basically, conventional heat transfer fluids like water, ethylene glycol (EG), industrial oil, biodegradable oil, vegetable oil, or oil seeds have better strength for cooling applications and their conduction. Experiments were done by adding the nano particles traditional fluids to improve their thermal performance. The performance of biodegradable hybrid nano fluids was, however, the most important role of nano fluids with the base fluids carrying a stable suspension, solving the demerits of conventional fluids and playing a vital role in cooling applications in industry. In the last three decades, nano materials or new class nano fluids, have improved the historical performance of heat transfer applications, especially industrial applications in manufacturing.

Synthesized Al_2O_3–Cu nano particle was mixed with the hydrogen reduction. It is investigated that a ratio of chemical analysis was 90:10 wt.%. In the Al_2O_3–Cu/water hybrid, nano fluids are prepared with the tow-step method, with the surfactant sodium lauryl sulphate (SLS) added using ultrasonic agitation techniques to dissolve the solution[1]. The researcher has to use various applications to improve the performance of hybrid nano fluids. Nano medicine is the most important application for their use of solar energy collected in media[2].

The stability of biodegradable hybrid nano fluids is a very enormous industrial application. The stability of hybrid nano fluids is one main investigation of thermal performance applications like solar energy absorption and high temperature energy storage[3]. The study focused on enhancing the stability of titanium dioxide through the addition of a surfactant. Various preparation methods were employed, including the two-step method, to synthesize nano materials. To ensure the stability of the resulting fluids, the surfactant Sodium Dodecyl Sulfate (SDS) was chosen, known for its effectiveness in the preparation of nano fluids. The investigation revealed that the stability of titanium dioxide was significantly improved when utilizing SDS as a surfactant in the preparation process, highlighting the efficacy of this method in maintaining the stability of nano materials[4]. According to the researchers are methodically analyzing hybrid nano fluids' physical and thermal properties, and the characterization of hybrid nano material is necessary for heat transfer applications[5]. Furthermore, the various nano particles are applicable in the analysis of hybrid nano material in hydrophobic processes. In this view, hydrophilicity is one of the characteristics of nano fluids, and the stability of nano fluids is an important factor in maintaining the performance of hybrid nano fluids and their enhancement of good stability to long-time use[6]. The stability of hybrid nano fluids was carried out by the zeta potential analysis, and various fractions, or wt.%, were used, like 1%, 2%, and 3%[7]. The performance of Al_2O_3/SiC hybrid nano material using machining applications like minimum quantity lubrication. The electrical conductivity, pH, thermal conductivity, and viscosity of SiC nano particle are mixed with the ethylene glycol to maintain the pH value of base fluids and maintain the temperature[8]. Moreover, the thermal conductivity of hybrid nano fluids is affected factors such as thermal conductivity, solid volume fraction, different base fluids, temperature, particle size, pH, sonication, and surfactants[9].

The SiC and TiO_2 nano particles are mixed with the base fluids as a diathermic oil with a volume fraction of 1%[10]. Furthermore, ethylene glycol is one of the best fluids used in TiO_2 and ZnO nano particle preparation. The thermal conductivity is increased by the two-volume concentrations of TiO_2 and SiO_2 hybrid nano fluids at maximum temperature[11]. Moreover, this research presents the analysis of the stability of fluids, such as zeta potential methods to determine the sedimentation period, spectral absorption, and centrifugation of hybrid nano fluids[12]. The silicon carbide nano particle and base fluids, such as water, were investigated and found to enhance their thermal and physical properties nano fluids[13]. The minimum quantity lubrication is one of the best methods to maintain the heat transfer rate at the time of turning operation. In this view, the surface finish, cutting forces, tool wear, lower cutting temperature, and cutting force are various results of the performance of this method[14]. The minimum quantity lubrication (MQL) technique is the better lubrication for the machining material as compared to the other available materials. Due to the addition of nano-fluids to MQL lubrication to minimize heat, surface irregularities, and tool life, it should be a more economical method of machining than conventional flood cooling and dry cooling[15]. The lubricants that reproduce the negative impacts on health, the environment, and machining performance are referred to as green lubricants. Basically, MQL machining is used to improve the surface roughness, temperature, chip reduction coefficient, tool wear, etc. The vegetable-based nano material is used to improve the machining by using the minimum quantity lubrication technique[16].

In the present study, the experiments of various nano particle combinations were carried out, such as: 1. estrified palm oil; 2. SiC + palm oil (1%, 2%, 3%); 3. TiO_2 + palm oil (1%, 2%, 3%) and combination of hybrid nano particle with biodegradable hybrid nano fluid; 4. SiC + TiO_2 + palm oil with volume % is (1%, 2%, 3%).

And all such combinations were analyzed by FTIR and Zeta potential analysis. In the FTIR method used and analyzed, the properties of hybrid nano material have to be increased, and the stability of hybrid nano material also increased given sample. The main purpose of this investigation is to investigate the biodegradability of hybrid nanomaterials used in the application of minimum quantity lubrication using turning operations in the machining process.

2. Experimentation

2.1. Preparation of sample

In this investigation of present study, the preparation of hybrid nano fluids by using Tow Step methods, the present study was Silicon carbide (SiC) and Titanium Dioxide (TiO_2) Nano particles are used and dispersed with the base fluid as a palm oil with the combination nano particle % volume concentration. This combination was dispersed in palm oil with volume fractions of nano particle like 1%, 2%, and 3%. To maintain the stability of such combination was using the surfactant as a Sodium dodecyl Sulfate (SDS). The SiC, TiO_2 nano particle and palm oil properties and surfactant are details in **Tables 1–6**, respectively. In order to attempt the characterization of particular sample. The Physical and Thermal properties of are carried out with FTIR and Zeta Potential Analysis.

Table 1. Properties of silicon carbide (SiC).

Parameter	Value
Thermal conductivity	120–170 w/m-k
Thermal expansion	4.0–4.5 μm/mk
Melting point	2730 °C–4946 °C
Density	3.0–3.2 g/cm^3

Table 2. Silicon carbide (SiC) particle analysis in Sisco research laboratories Pvt. Ltd.

Test parameter	Standards	Actual result
Appearance (Color)	Green to grey	Green to grey
Appearance (Form)	Powder	Powder
Assay	Min. 98%	Min. 98%
APS	50 nm	50 nm

Table 3. Properties of titanium dioxide rutile nano powder.

Parameter	Value
Thermal conductivity	4–11.8 w/m-k
Thermal expansion	9×10^{-6} μm/mk
Melting point	1843 °C
Density	4 g/cm^3

Table 4. Titanium dioxide rutile nano powder (TiO_2) particle analysis in Sisco research laboratories Pvt. Ltd.

Test parameter	Standards	Actual result
Appearance (Color)	White	White
Appearance (Form)	Powder	Powder
Assay	Min. 92%	92%
APS	20 nm	20 nm

Table 5. Properties of palm oil.

Parameter	Value
Temperature	20 °C–300 °C
Viscosity m pass	106.8–1.434
Heat capacity, kj/kg-c	1.848–2.857
Conductivity, W/m-C	0.1726–0.1564
Density, kg/m	890.1–776.9
Viscosity, ST	119.99–1.8557

Table 6. Laboratory analysis of palm oil in the Indian Biodiesel Corporation.

Parameter	Value
Density	0.859 gm/cc
Viscosity m pass	106.8–1.434
Calorific value	37.00 MJ/kg
Flash point	103 °C
Density	0.859 gm/cc

To use the magnetic stirrer for the suitable mixing of nano particle and base fluids. Each sample was stirring with 4 h. The stability and sedimentation of the samples have well, it was observed that in the long time before the experiments. To maintain the stability of biodegradable hybrid nano fluid was used surfactant as a Sodium dodecyl Sulphate (SDS). **Figure 1** shows the preparation of hybrid nano fluid for individual and hybrid mode.

1) Palm oil (base fluid standard base without any emulsifier/surfactant)
2) Palm oil + SiC, nano particle (0.1% Vol, 0.2% Vol, 0.3% Vol)
3) Palm oil + TiO_2, nano particle (0.1% Vol, 0.2% Vol, 0.3% Vol)
4) Palm oil + SiC + TiO_2, nano particle (0.1% Vol, 0.2% Vol, 0.3% Vol)

Figure 1. To preparation of hybrid nano fluid.

2.2. Thermal and physical properties of biodegradable hybrid nano fluids

In the present work all sample are analysed by Indian Biodiesel Corporation, Baramati. All samples are prepared with Individual and Hybrid mode, 1) palm oil (Base fluid Standard base without any emulsifier/surfactant), 2) palm oil + SiC, nano particle (0.1% Vol, 0.2% Vol, and 0.3% Vol), 3) palm oil + TiO_2, nano particle (0.1% Vol, 0.2% Vol, 0.3% Vol), 4) palm oil + SiC + TiO_2, nano particle (0.1% Vol, 0.2% Vol, 0.3% Vol) are shown in **Figure 2**. To measure the Density, calorific value, flash point and thermal conductivity of all samples are given in **Table 7**.

The thermal conductivity of SiC and TiO_2 of hybrid nano fluid was measured by using a KD2 Pro thermal property analyzer (Decagon Devices). KD2 Pro analyzer was battery operated deceive. The controller module contains a battery, a 16-bit microcontroller/AD converter, with power control circuitry. Thermal conductivity measures some important measurement such as i) the long heat source can be treated as an infinitely long heat source (ii) the medium is both homogeneous and isotropic and at uniform initial temperature. The sensor needle used was KS-1 which is made of stainless steel having a length of 60 mm and a diameter of 1.3 mm, and closely approximates the infinite line heat source which gives least disturbance to the sample during measurements[1].

To find the calorific value of such combination was find out the calorimeter, the amount heat energy present in fuel and which is determined by the complete combustion of specified quantity at constant pressure and in normal conditions.

The flash point is an impotent concept in fire investigation and fire protection because it is lowest temperature at which a risk of fire exists with a given liquid, a brass cup mounted on an electric heater with a temperature controller and a thermometer.

Figure 2. Prepared samples.

Table 7. All individual and hybrid mode samples reading.

Sample	Density gm/cc	Calorific value MJ/KJ	Flash point °C	Thermal conductivity °C
Palm oil (base fluid standard base without any emulsifier/surfactant)	0.859	37.000	103	37
Palm oil + SiC, nano particle (1%)	0.858	37.500	105	37
Palm oil + SiC, nano particle (2%)	0.859	37.800	109	35
Palm oil + SiC, nano particle (3%)	0.859	37.800	111	37
Palm oil + TiO_2, nano particle (1%)	0.857	37.500	107	35
Palm oil + TiO_2, nano particle (2%)	0.858	37.660	105	35
Palm oil + TiO_2, nano particle (3%)	0.860	37.790	113.000	37
Palm oil + SiC + TiO_2, nano particle (1%)	0.859	37.600	106.00	38
Palm oil + SiC + TiO_2, nano particle (2%)	0.858	37.690	110.00	35
Palm oil + SiC + TiO_2, nano particle (3%)	0.858	37.900	113	30

As per recorded value of density of all sample 0.859 to 0.858 gm/cc with better results are attain. The calorific value of sample is up to 37.00 to 37.900 MJ/KJ is also good results, flash point was also 103–113 °C and thermal conductivity of 30–38 °C. as per requirement of all sample’s readings are better to application.

3. Characterization of biodegradable hybrid nano fluids

Characterization is the techniques which is used to find out the properties of nano fluid. The Fourier Transform Infrared (FTIR) we have to techniques used to find out the characterization are as follows.

Fourier Transform Infrared (FTIR) techniques

Fourier Transform Infrared Spectroscopy, also known as FTIR Analysis or FTIR Spectroscopy, is an analytical technique used to identify organic, polymeric, and, in some cases, inorganic materials. The FTIR analysis method uses infrared light to scan test samples and observe chemical properties. All infrared spectroscopies act on the principle that when infrared (IR) radiation passes through a sample, some of the radiation is absorbed. The radiation that passes through the sample is recorded. The principle of Fourier transform spectroscopy is that a spectrum can be obtained by Fourier transforming a coherent signal measured in the time domain. FTIR is a very versatile tool for surface characterization of nano particles. Under specific conditions, the NPs surface chemical composition can be determined, and additionally, the reactive surface sites responsible for the surface reactivity can be identified. Using FTIR, one can analyze the chemical makeup of a material, by examining the chemical bonds and composition. FTIR is useful for both organic and inorganic material. It also measures covalent bonding pairs and functional groups within a material.

As per the characterization techniques and availability of laboratory in given characterization is Fourier transform infrared (FTIR) techniques is attained to all samples. All the **Figure 3–12** are shown in given bellow.

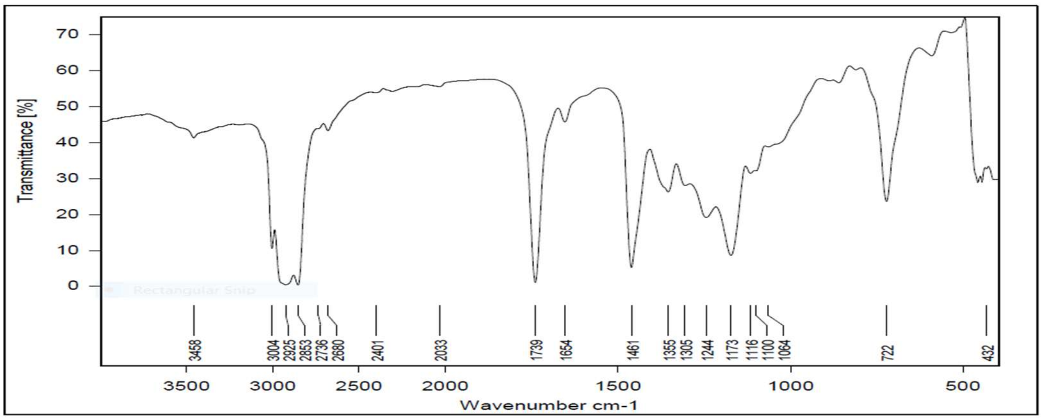


Figure 3. Palm oil (base fluid standard base without any emulsifier/surfactant).

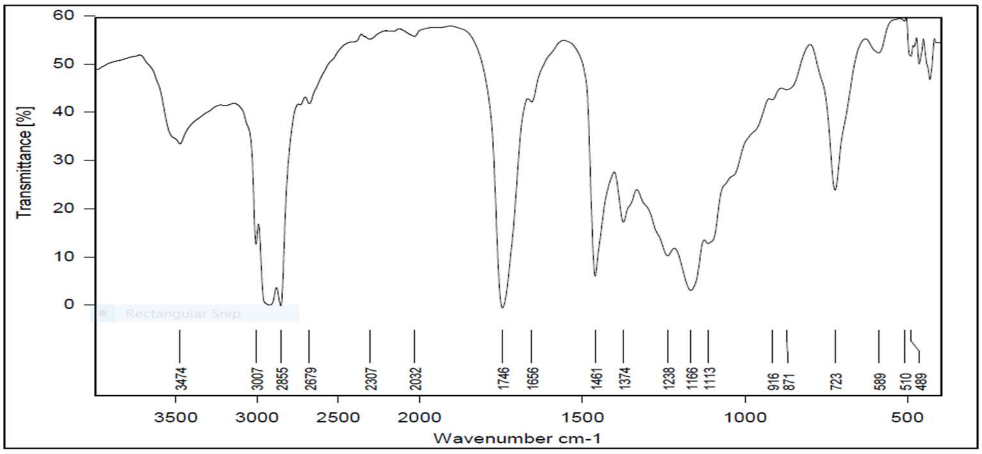


Figure 4. Palm oil + SiC, nano particle (1% Vol).

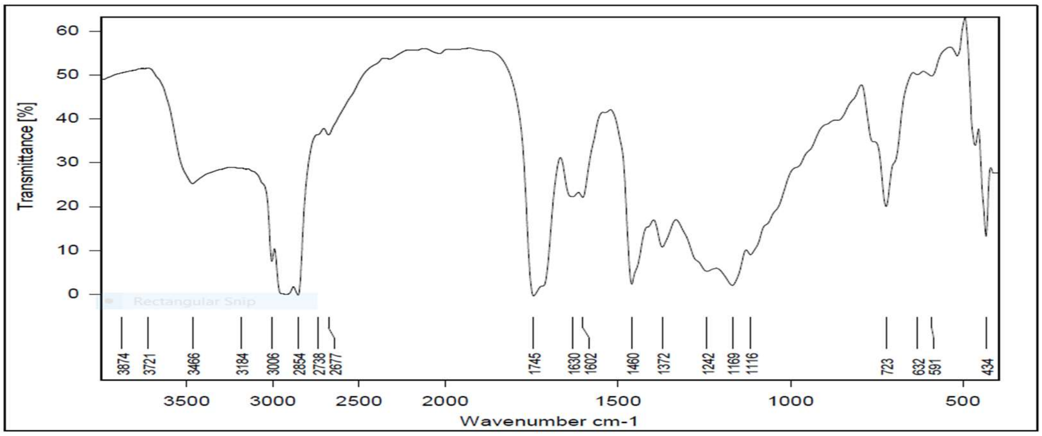


Figure 5. Palm oil + SiC, nano particle (2% Vol).

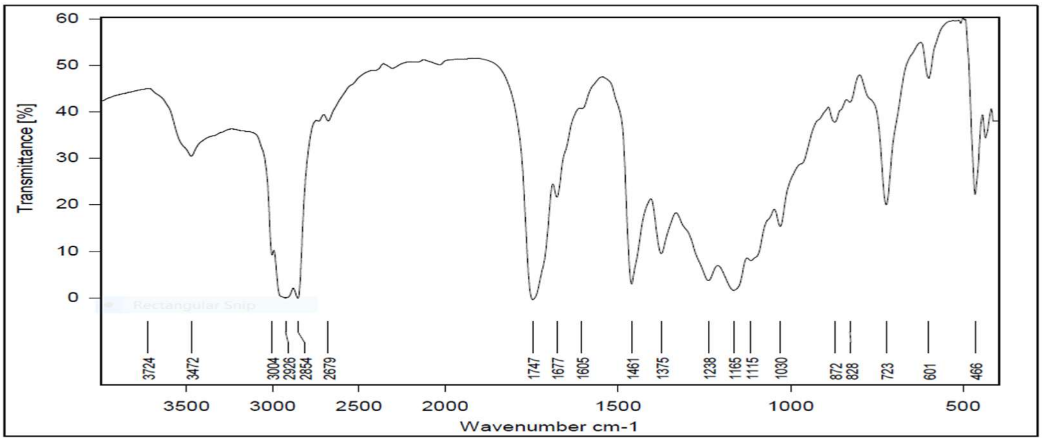


Figure 6. Palm oil + SiC, nano particle (3% Vol).

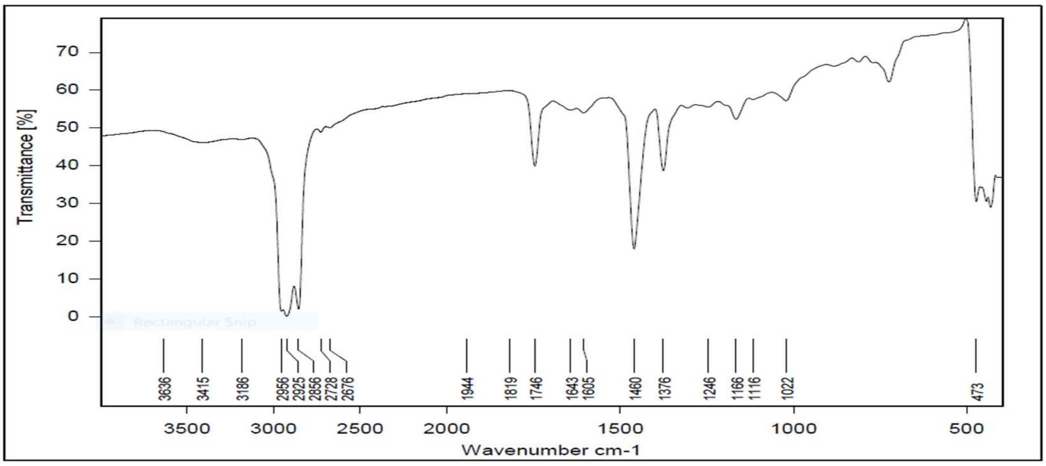


Figure 7. Palm oil + TiO_2, nano particle (1% Vol).

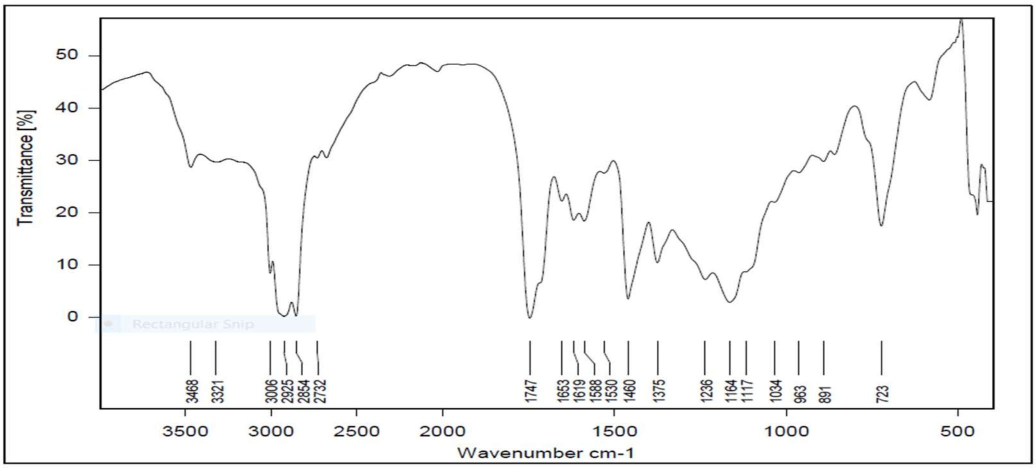


Figure 8. Palm oil + TiO_2, nano particle (2% Vol).

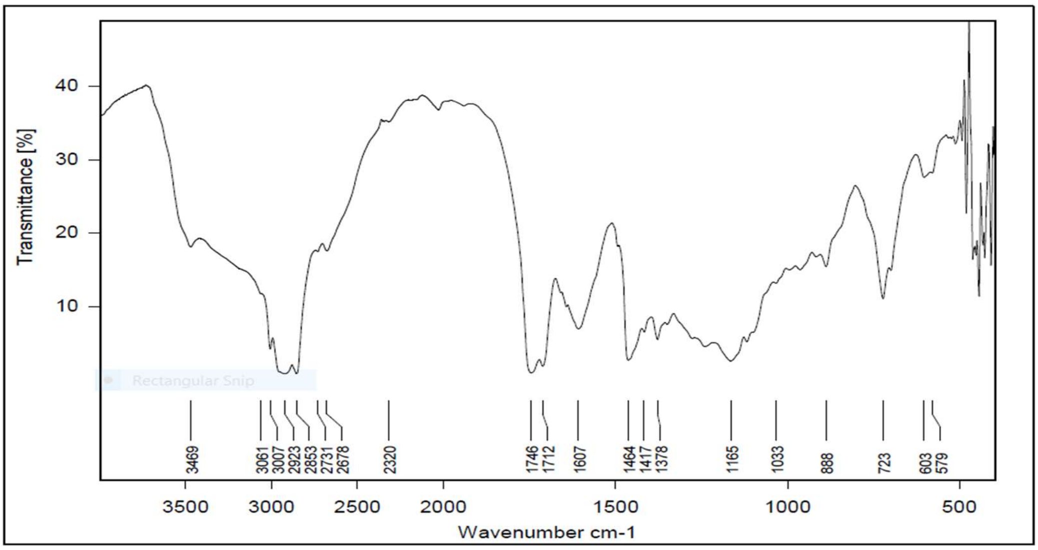


Figure 9. Palm oil + TiO_2, nano particle (3% Vol).

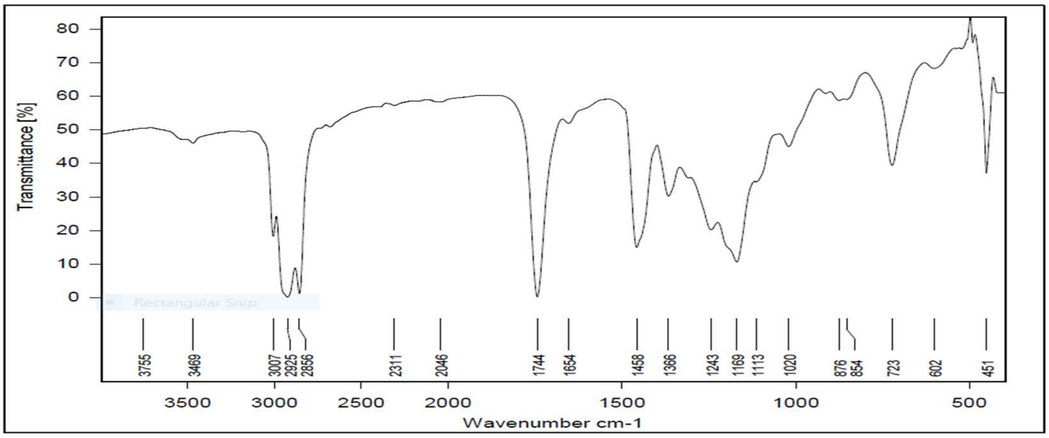


Figure 10. Palm oil + SiC + TiO_2, nano particle (1% Vol).

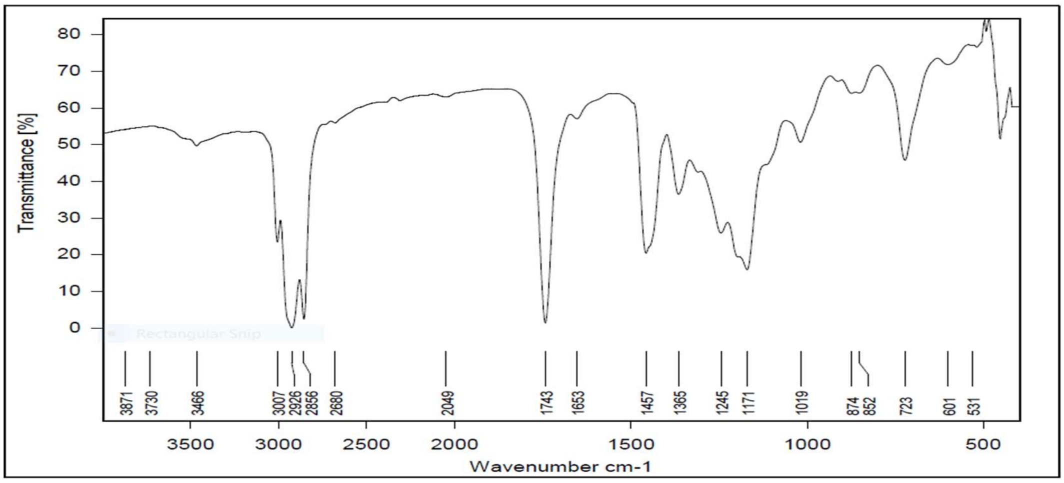


Figure 11. Palm oil + SiC + TiO_2, nano particle (2% Vol).

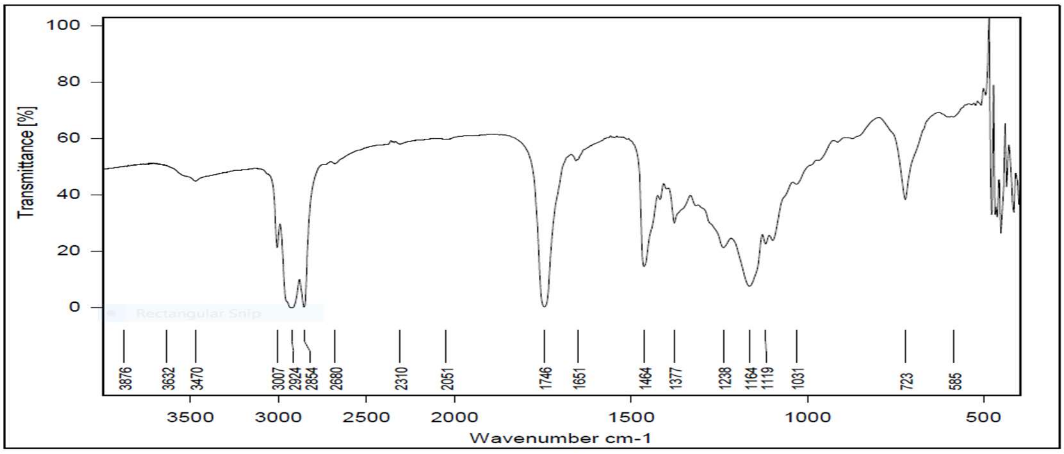


Figure 12. Palm oil + SiC + TiO_2, nano particle (3% Vol).

All the biodegradable nano fluids and Hybrid nano fluids samples are analyzed or characterized by FTIR methods and results shows that the sample no. 8, 9 and 10 biodegradable Hybrid nano fluids is better than the biodegradable nano fluids of sample no. 1 to 7. And it's shown the **Tables 8–17**. The properties of all to 1 to 10 samples in that samples no. 8, 9 and 10 biodegradable of hybrid nano fluids is better thermal and physical properties are to be analyzed and cauterized by graphical reassertion of that samples is shows the high thermal conductivity of samples as well as its increases with its physical and rheological properties of biodegradable hybrid nano fluids.

Table 8. Functional group frequencies of sample 1 palm oil.

Wave number (cm^{-1})	Type of vibration	Functional groups
3458	Stretch, H-bonded	Alcohol (O-H)
3004	Stretch	Acid (O-H)
2925	Stretch	Alkane (C-H), Acid (O-H)
2853	Stretch	Alkane (C-H), Acid (O-H)
2736	Stretch	Acid (O-H)
2680	Stretch	Acid (O-H)
1739	Stretch	Ester (C=O)
1654	Stretch	Amide (C=O)
1461	Bending	Alkane (-C-H)

Table 8. (*Continued*).

Wave number (cm^{-1})	**Type of vibration**	**Functional groups**
1355	Bending	Alkane (-C-H)
1244	Stretch	Ester (C-O), Ether (C-O)
1173	Stretch	Ester (C-O), Ether (C-O)
1116	Stretch	Ester (C-O), Ether (C-O)
1100	Stretch	Ester (C-O), Ether (C-O)
722	Bending	Alkene (=C-H), Alkane-(CH_2)-

Table 9. Functional group frequencies of sample 1 palm oil.

Wave number (cm^{-1})	**Type of vibration**	**Functional groups**
3474	Stretch, H-bonded	Alcohol (O-H)
3007	Stretch	Acid (O-H)
2855	Stretch	Alkane (C-H), Acid (O-H)
2679	Stretch	Acid (O-H)
1746	Stretch	Ester (C=O)
1656	Stretch	Amide (C=O)
1461	Bending	Alkane (-C-H)
1374	Bending	Alkane (-C-H)
1238	Stretch	Ester (C-O), Ether (C-O)
1166	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane-(CH_2)-

Table 10. Functional group frequencies of sample 3 palm oil + SiC, nano particle (2% Vol.).

Wave number (cm^{-1})	**Type of vibration**	**Functional groups**
3466	Stretch, H-bonded	Alcohol (O-H)
3184	Stretch	Acid (O-H)
3006	Stretch	Acid (O-H)
2854	Stretch	Alkane (C-H), Acid (O-H)
2738	Stretch	Acid (O-H)
2677	Stretch	Acid (O-H)
1745	Stretch	Ester (C=O)
1630	Stretch	Amide (C=O)
1460	Bending	Alkane (-C-H)
1372	Bending	Alkane (-C-H)
1242	Stretch	Ester (C-O), Ether (C-O)
1169	Stretch	Ester (C-O), Ether (C-O)
1116	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane-(CH_2)-

Table 11. Functional group frequencies of sample 4 palm oil + SiC, nano particle (3% Vol).

Wave number (cm^{-1})	**Type of vibration**	**Functional groups**
3472	Stretch, H-bonded	Alcohol (O-H)
3004	Stretch	Acid (O-H)

Table 11. (*Continued*).

Wave number (cm^{-1})	Type of vibration	Functional groups
2926	Stretch	Alkane (C-H), Acid (O-H)
2854	Stretch	Alkane (C-H), Acid (O-H)
2679	Stretch	Acid (O-H)
1747	Stretch	Ester (C=O)
1677	Stretch	Carbonyl (C=O)
1461	Bending	Alkane (-C-H)
1375	Bending	Alkane (-C-H)
1238	Stretch	Ester (C-O), Ether (C-O)
1165	Stretch	Ester (C-O), Ether (C-O)
1030	Stretch	Ester (C-O), Ether (C-O)
872	Bending	Alkene (=C-H), Alkane-(CH_2)-
723	Bending	Alkene (=C-H), Alkane-(CH_2)-

Table 12. Functional group frequencies of sample 5 palm oil + TiO_2, nano particle (1% Vol).

Wave number (cm^{-1})	Type of vibration	Functional groups
2956	Stretch	Alkane (C-H), Acid (O-H)
2925	Stretch	Alkane (C-H), Acid (O-H)
2856	Stretch	Alkane (C-H), Acid (O-H)
1819	Stretch	Carbonyl (C=O)
1746	Stretch	Ester (C=O)
1460	Bending	Alkane (-C-H)
1376	Bending	Alkane (-C-H)
1166	Stretch	Ester (C-O), Ether (C-O)
1116	Stretch	Ester (C-O), Ether (C-O)
1022	Stretch	Ester (C-O), Ether (C-O)

Table 13. Functional group frequencies of sample 6 palm oil + TiO_2, nano particle (2% Vol).

Wave number (cm^{-1})	Type of vibration	Functional groups
3468	Stretch, H-bonded	Alcohol (O-H)
3006	Stretch	Acid (O-H)
2925	Stretch	Alkane (C-H), Acid (O-H)
2854	Stretch	Alkane (C-H), Acid (O-H)
2732	Stretch	Acid (O-H)
1747	Stretch	Ester (C=O)
1653	Stretch	Amide (C=O)
1460	Bending	Alkane (-C-H)
1375	Bending	Alkane (-C-H)
1236	Stretch	Ester (C-O), Ether (C-O)
1164	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane-(CH_2)-

Table 14. Functional group frequencies of sample 7 palm oil + TiO_2, nano particle (3% Vol).

Wave number (cm^{-1})	Type of vibration	Functional groups
3469	Stretch, H-bonded	Alcohol (O-H)
3061	Stretch	Acid (O-H)
3007	Stretch	Acid (O-H)
2923	Stretch	Alkane (C-H), Acid (O-H)
2853	Stretch	Alkane (C-H), Acid (O-H)
2731	Stretch	Acid (O-H)
2678	Stretch	Acid (O-H)
1746	Stretch	Ester (C=O)
1712	Stretch	Ketone (C=O), Carbonyl (C=O)
1607	Stretch	Amide (C=O)
1464	Bending	Alkane (-C-H)
1417	Bending	Alkane (-C-H)
1378	Bending	Alkane (-C-H)
1165	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane-(CH_2)-

Table 15. Functional group frequencies of sample 8 palm oil + SiC + TiO_2, nano particle (1% Vol).

Wave number (cm^{-1})	Type of vibration	Functional groups
3469	Stretch, H-bonded	Alcohol (O-H)
3007	Stretch	Acid (O-H)
2925	Stretch	Alkane (C-H), Acid (O-H)
2856	Stretch	Alkane (C-H), Acid (O-H)
1744	Stretch	Ester (C=O)
1654	Stretch	Amide (C=O)
1458	Bending	Alkane (-C-H)
1366	Bending	Alkane (-C-H)
1243	Stretch	Ester (C-O), Ether (C-O)
1169	Stretch	Ester (C-O), Ether (C-O)
1113	Stretch	Ester (C-O), Ether (C-O)
1020	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane (CH_2)-

Table 16. Functional group frequencies of sample 9 palm oil + SiC + TiO_2, nano particle (2% Vol).

Wave number (cm^{-1})	Type of vibration	Functional groups
3466	Stretch, H-bonded	Alcohol (O-H)
3007	Stretch	Acid (O-H)
2926	Stretch	Alkane (C-H), Acid (O-H)
2856	Stretch	Alkane (C-H), Acid (O-H)
1743	Stretch	Ester (C=O)
1653	Stretch	Amide (C=O)
1457	Bending	Alkane (-C-H)
1365	Bending	Alkane (-C-H)

Table 16. (*Continued*).

Wave number (cm^{-1})	Type of vibration	Functional groups
1245	Stretch	Ester (C-O), Ether (C-O)
1171	Stretch	Ester (C-O), Ether (C-O)
1019	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane-(CH_2)-
3466	Stretch, H-bonded	Alcohol (O-H)

Table 17. Functional group frequencies of sample 10 palm oil + SiC + TiO_2, nano particle (3% Vol).

Wave number (cm^{-1})	Type of vibration	Functional groups
3470	Stretch, H-bonded	Alcohol (O-H)
3007	Stretch	Acid (O-H)
2924	Stretch	Alkane (C-H), Acid (O-H)
2854	Stretch	Alkane (C-H), Acid (O-H)
2680	Stretch	Acid (O-H)
1746	Stretch	Ester (C=O)
1651	Stretch	Amide (C=O)
1464	Bending	Alkane (-C-H)
1377	Bending	Alkane (-C-H)
1238	Stretch	Ester (C-O), Ether (C-O)
1164	Stretch	Ester (C-O), Ether (C-O)
1119	Stretch	Ester (C-O), Ether (C-O)
723	Bending	Alkene (=C-H), Alkane-(CH_2)-

4. Stability of biodegradable nano fluid and biodegradable hybrid nano fluid

Stability of hybrid nano fluids is important. Because the aggregation of nano particle causes sedimentation and clotting. Due to which the thermal conductivity of nano fluid leads to decrease. In the view there are following types, stability evaluation methods like sedimentation and centrifugation methods, zeta potential analysis and spectral absorbency analysis are discussed. In this research we find the zeta potential analysis, the researchers found that less sedimentation leads to stable nano fluid.

Zeta potential analysis

Zeta potential analysis is an additional method for calculating the stability of hybrid nano fluids. The, however, but this method has some restrictions of the viscosity and concentration of hybrid nano fluids. The Zeta potential is an electric potential in the interfacial double layer at the location of the slipping plane versus a point in the bulk fluid away from the interface, it was shows that prospective difference between the mixing stage and stationary layer of liquid added to disperse particle was shown in **Figure 13**. the stern layer was a very thin layer of positive charge are mostly around the negative charged particle, the stern layer it was diffuse layer and national boundaries occurs. The zeta potential is called as the electrical potential plane of shear or hydrodynamic slip plane are adjacent to a solid surface are allowed to liquid, the zeta potential analysis is very much useful to the dispersed to coagulate. Stability of nano fluids is very important factor of fluids; those fluids are coagulated with base fluids and nano particle with its volume concentration. The zeta potential is one of best method to measure the stability of hybrid nano fluids. The electric potential interfacial double layer was located in slipping plane with point of interface. There are two types of layers was charged called stern layer and charged with positive charge. The electrical potential plane hydrodynamic slip plane is adjusted to the liquid. Mostly the positive and negative values are there and 25 mV is taken from that collides with zeta potential at 40 mV to 60 mV, and exceed up to 60 mV. For higher stability fluids[17], the agglomeration of nano particles results in not only the settlement and clogging of micro channels but also the decreasing of thermal conductivity of nano fluids. So, the investigation on stability is also a key issue that influences the properties of nano fluids. For application, it is necessary to study and analyze influencing factors to the dispersion stability of nano fluids. This section will contain (a) the stability evaluation methods for nano fluids, (b) the ways to enhance the stability of nano fluids, and (c) the stability mechanisms of nano fluids[3].

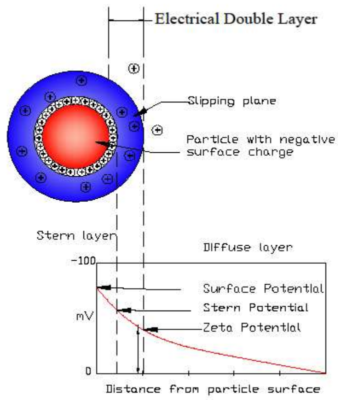
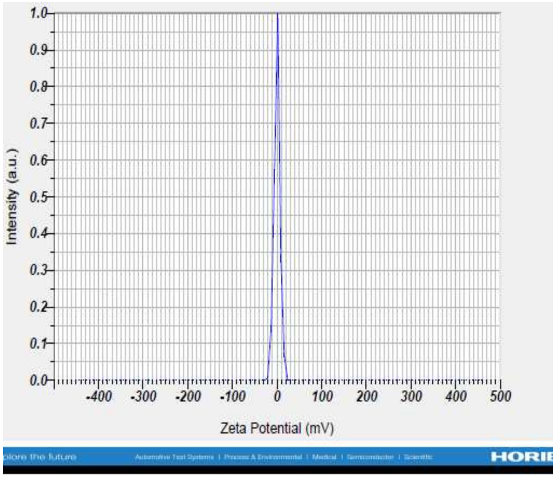


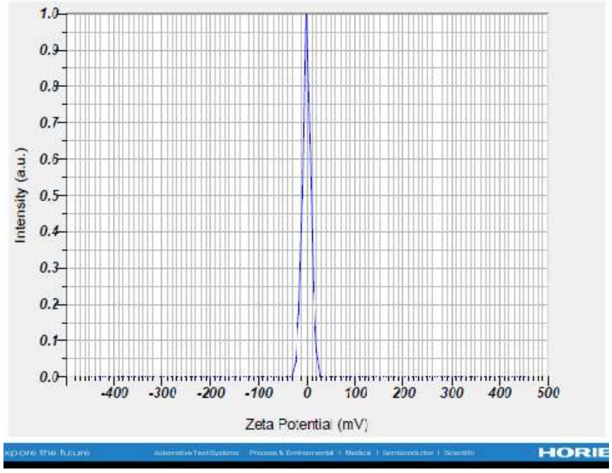
Figure 13. Zeta potential of nano fluids[17].

The sample was analyzed by the HORIBA Scientific SZ-100 analyzer, all the following samples are synthesized with the better results occurred, palm oil + SiC (1%, 2%, 3%) volume %, palm oil + TiO_2 (1%, 2%, 3%) volume, palm oil + SiC + TiO_2 (1%, 2%, 3%) volume. The analysis graph shows that **(a)–(i)** are stated below.

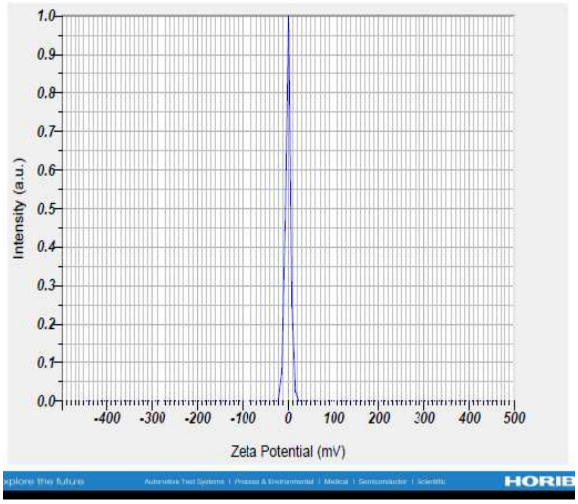
The stability of all samples was analyzed and stated in all **Figure 14(a–i)**, generally the stability of nano fluids. The suspension is poor when absolute magnitude of zeta potential (>30 mV) is the inductive stability. Now their prepared hybrid nano fluids the zeta potential values were found to increases when volume concertation is 1%, 2% and 3%. (palm oil + 1% Vol. SiC + TiO_2), (palm oil + 2% Vol. SiC + TiO_2), (palm oil + 3% Vol. SiC + TiO_2). The volume concentration of palm + SiC 2% are the highest stability of all the samples are analyzed by the zeta potential method. The biodegradable hybrid nano fluids is the best combination of that concentration and to shows the highest stability of that sample. The results shows that 28 mV is resulted vales of stability of biodegradable hybrid nano fluids.



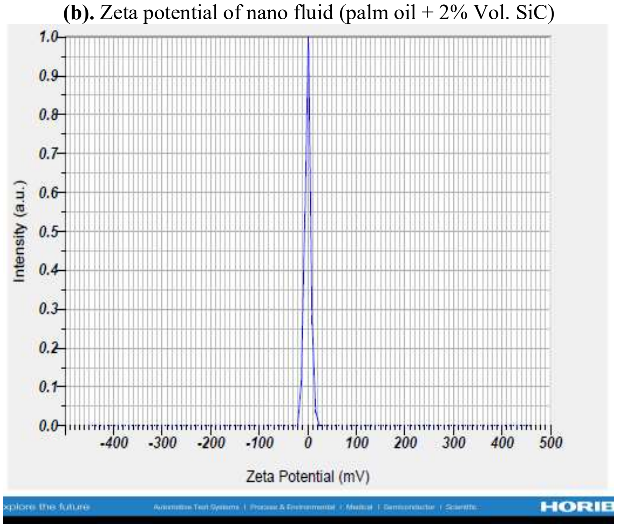
(a). Zeta potential of nano fluid (palm oil + 1% Vol. SiC)



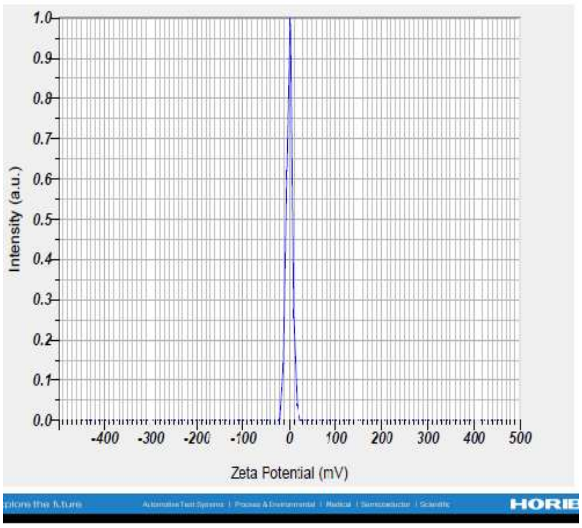
(b). Zeta potential of nano fluid (palm oil + 2% Vol. SiC)



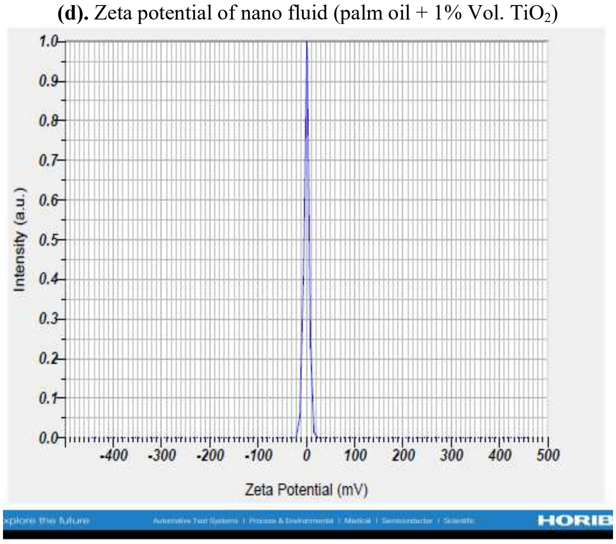
(c). Zeta potential of nano fluid (palm oil + 3% Vol. SiC)



(d). Zeta potential of nano fluid (palm oil + 1% Vol. TiO_2)

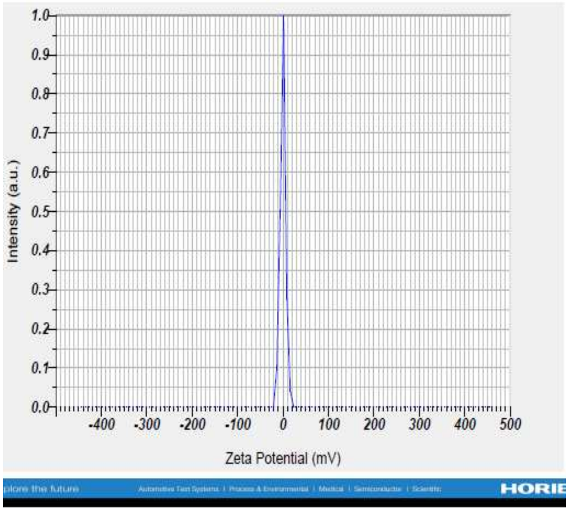


(e). Zeta potential of nano fluid (palm oil + 2% Vol. TiO_2)

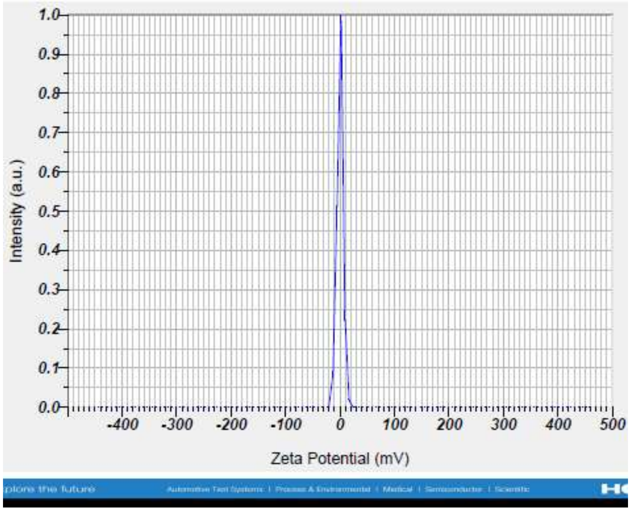


(f). Zeta potential of nano fluid (palm oil + 3% Vol. TiO_2)

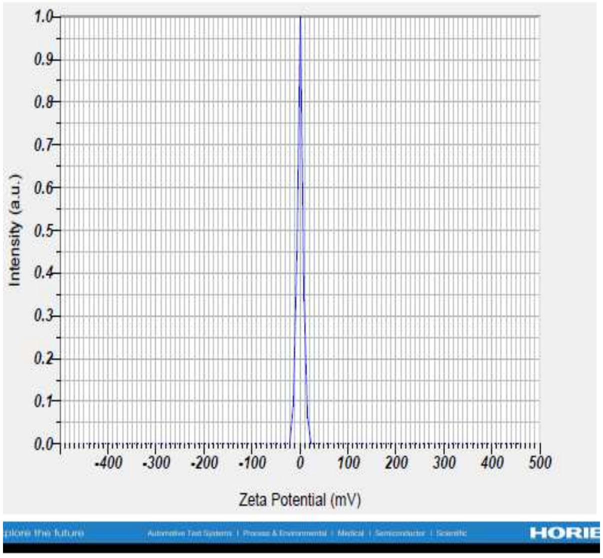
Figure 14. (*Continued*).



(g). Zeta potential of nano fluid (palm oil + 1% Vol. SiC + TiO_2)



(h). Zeta potential of nano fluid (palm oil + 2 % Vol. SiC + TiO_2)



(i). Zeta potential of nano fluid (palm oil + 3% Vol. SiC + TiO_2)

Figure 14. Analysis of Zeta potential for nanofluids.

5. Conclusion

From all the experimental investigations, it has been shown that

1) From the research, it was found that the thermal conductivity analysis of SiC + TiO_2 + palm oil as biodegradable hybrid nano fluids was greater than the conductivity of SiC + palm oil and TiO_2 + palm oil nano fluids.
2) The base fluid of palm oil also increases the thermal concavity. The ratio of highest thermal conductivity of 1%, 2%, and 3% of biodegradable hybrid nano fluids is almost 70% (SiC + TiO_2+ palm oil). The best composition of nano particles increasing the biodegradable hybrid nano fluid thermal conductivity, which is significant at 3% volume fraction, increases thermal conductivity by 30% and 40% palm oil.
3) Now it shows that there is a significant increase in palm oil at a low volume fraction of 1%. Visually, the higher volume concentration of hybrid nano particles in the sonication or agglomeration of hybrid nano fluids is higher.
4) The biodegradable hybrid nano fluids wettability is better with an increasing volume fraction; biodegradable hybrid nano fluids with a volume fraction of 2% and 3% are hydrophobic, while others are hydrophilic.

5) The biodegradable hybrid nano fluid is agglomerated longer than TiO_2 nano fluids faster than SiC nano fluids.
6) The combination of SiC and TiO_2 nano particle suspensions with base fluids is palm oil in the same volume fraction of hybrid nano fluids such as 1%, 2%, and 3%. The stability of SiC + Tio_2 + Palm oil is higher than that of nano fluids of SiC + palm oil and TiO_2 + palm oil.
7) The physical and thermal properties of such samples was better determined by the FTIR method. All samples were carried out by machining operations such as turning or using a minimum quantity of lubrication.
8) The sample of palm oil + SiC 2 vol% was analyzed by the Zeta potential method, and results show that (graph b) 28 mV results in varying levels of stability of biodegradable hybrid nano fluids.
9) Palm oil is one type of vegetable oil or biodegradable oil and is concentrated with SiC and TiO_2 nano particle at 75–80%. It shows that the palm oil has more agglomeration with SiC and TiO_2.
10) In the future, the palm oil and SiC nano particle will be the best combination-based coolant used in Inconel 718 for machining operations.

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Author contributions

Conceptualization, DPK and VMA; methodology, DPK; software, DPK; validation, DPK; formal analysis, DPK; investigation, DPK; resources, DPK; data duration, DPK; writing—original draft preparation, DPK; writing—review and editing, DPK; visualization, DPK; supervision, DPK and MA; project administration, VMA; funding acquisition, VMA. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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