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The study of the Blending Techniques used for making Nanofluids and their Characterization– A Review

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Abstract : Nanoparticles have emerged as a new category of materials having better physical, chemical and mechanical properties than their macro particles. Nanoparticles are mixed in some base fluid to make the nanofluid which is having improved properties than the basic fluid. The nanofluids exhibit better heat transfer, anticorrosive, lower density, erosion resistance, low vapor pressure and better tribological properties. The type of blending technique used for making the nanofluid is very important as the stability of the nanofluid depends on it. In the current study various blending techniques have been discussed for various nanoparticles like metallic, nonmetallic and mixture of nanoparticles. The aim of the review is to compare the various blending techniques and try to find the optimum blending techniques for different conditions. The techniques for the characterization of nanofluid like Transmission Electron Microscopy (TEM), UV–Vis spectrophotometer, Zeta potential test, Sediment photograph capturing, Transmission Electron Microscopy (TEM) and Scanning Electron Microscope (SEM) have also been discussed briefly.

Keywords: Nanoparticles, Nanofluids, Blending Technique, Characterization, TEM, SEM.

1. INTRODUCTION

Nanofluids are the dispersion of nanoscaled particles like ZnO, SiO_2, CuO, Al_2O_3, TiO_2, Fe_3O_4, Fe_2O_3, AlN, Cu, Ag. Au and sometimes the mixture of more than one nanoparticles in the fluid like water, Ethanol, Ethylene Glycol, transformer oil, lubricating oil and oleic acid etc. The nanofluid may be Newtonion or non Newtonion in nature as investigated from the rheological studies [1,2]. The nanofluid preparation is a complex phenomenon in which the nanoparticles can be synthesized and mixed simultaneously in the nanofluid. This method of preparation of nanofluid is called One-Step Method. The most common for preparation of nanofluid is Two-Step method, in this method the nanoparticles synthesized previously are blended in the nanofluid using the different blending techniques [3]. The nanofluid are having improved mechanical and chemical properties than the original fluid such as better thermal conductivity [4], low specific heat [5] solar absorption [6], high viscosity [7], wear resistance etc. because of presence of ultrafine nanoparticles. The preparation of stabile nanofluid is one of the main concerns as there may be a chance of aggregation and sedimentation of nanoparticles after some time. To ensure the stability of the nanofluid one can use pH control [8], ultrasonic mixing [9] and surfactants [10,11]. The stability of nanofluid can be measured by various techniques such as UV–Vis spectrophotometer [12], Zeta Potential test [13], Sediment photograph capturing [14], TEM/SEM inspection [15], and Sedimentation balance method [16].

2. MECHANISM OF PREPARATION OF NANOFLUID

The stability of nanofluid is the prerequisite of the preparation method. The nanoparticles are having small size and their shape may be considered as spherical so the particle's sedimentation velocity can be calculated by Stoke's Law [17].

$$V= 2gR^2 (\rho_p - \rho_l)/9u \quad (1)$$

Where:
V: Particle's Sedimentation Velocity.
R: Radius of Particle
ρ_p: Particle Density
ρ_l: Solvent Density
u: Solvent Velocity

Form equation (1) we can say that to reduce the particle's sedimentation velocity following measures may be taken: i) decrease the radius of the nanoparticles to be mixed in the solvent; if the radius of the nanoparticles is below the critical radius then no sedimentation takes place [18]. ii) Reduce the density gap between the nanoparticles and the Solvent. iii) Increase the flow velocity of the solvent.

2.1 Different techniques for producing the Nanofluid based on physical method:

2.1.1 Single Step Technique:

In single step technique there is a simultaneous synthesis of nanoparticles and preparation of nanofluid. The nanofluid is directly prepared by synthesis of nanoparticles in the solvent by chemical method or physical vapor deposition technique. The pH value of the nanofluid is kept constant during the synthesis [19]. Due to the simulation synthesis of nanoparticles and nanofluid there is very less chance of aggregation and sedimentation. So the nanofluid we get is homogenous in nature and remain homogenous for a long time. The main disadvantage of this method is that the solvent should have low vapor pressure and the size of the nanoparticles can't be controlled precisely [20,21].

2.1.2 Two Step Technique:

In this technique the previously synthesized nanoparticles are blended into the solvent to produce a nanofluid. Due to the high surface energy of nanoparticles there is always a chance of aggregation and clustering of nanoparticles. Later on these aggregated nanoparticles may sediment at the bottom. So it is very challenging to make a homogenous solution using two step method [22]. There are some techniques like ultrasonic homogenizing which may be applied to get a homogenous nanofluid. The method is most suited for the nonmetallic nanoparticles. To increase the repulsion between the nanoparticles some surfactants may also be used [23]. The advantage of this technique is that the nanoparticles used for nanofluid may be purchased having standard size and shape but the aggregation and sedimentation free blending is to be done to make a homogenous solution.**2.3 Types**

There are many options available for biometric analysis and the respective methods employed to take them as inputs by the biometric system. This includes: DNA Matching, Ear**,** Iris Recognition, Retina Recognition, Face Recognition, Fingerprint Recognition, Vein Recognition, and etc.

Several function-specific factors, such as, the environment in which the process of verification takes place, the profile of user, the requisites for testament accuracy and throughput, the total system expenditure (space and time of program), and ethical issues determine the choice of biometric system [4]. Some of the frequently used biometrics are explained here.

2.2 Preparation of non-metallic nanofluids based on type of material

2.2.1 ZnO Nanofluids:

Zafarin et al. got dried out ZnO nanoparticles by warming them 110^0C for 24 hr. The nanoparticles then added with polyethylene glycol and sonicated. The aggration of particles was seen in the nanofluid bringing about more noteworthy size nanoparticles at that point at first included [24].

Moosavi et al. synthesized the ZnO and ethylene glycol Nanofluid by using magnetic stirrer for homogenous mixing and stability of nanofluid. Ammonium Citrate was included as dispersant in the proportion 1:1 with the nanoparticles. The nanofluid watched, was free from sedimentation and agglomeration [25].

Raykar et al. added acetylacetone in water soluble ZnO the solution was ultrasonically homogenized and due to the presence of acetylacetone the size of nanoparticles reduced by chemical reaction and the nanoparticles remains homogenously suspended in the nanofluid [26].

Wei et al. proposed ethylene glycol as base fluid for ZnO nanoparticles. The ultrasonic homogenization was utilized to homogenize the nanoparticles in solute yet the molecule collection couldn't be controlled and the measure of nanoparticles in the nanofluid expanded 10-20 times [27].

Chung et al. prepared the nanofluid by scattering ZnO powder in deionized water. The colloidal solution was kept at 25^0 C and stirred for 30 min, and afterwards it was sonicated using different agitation systems such as, a single piezoactuated bath, a solenoid-actuated bath and a static bath with immersed horn. Ammonium polymethacrylate was blended as a dispersant. It was concluded that the size reduction rate was maximum in sonication by ultrasonic horn and the minimum achievable size, and sedimentation rates [28].

Lee et al. dispersed ZnO and Ethylene glycol Nanofluid using pulsed wire evaporation. The nanoparticles got scattered directly into Ethylene glycol with no surface contamination [29].

Kole and Dey suspended the ZnO nanoparticles in water as solvent and applied ultrasonification. The examination was directed to get ideal time of sonification. As the sonication time increased the size of nano particles decreased but after optimum value increase in time increased the nanoparticle size [30].

Suhanthi et al. used ZnO nanoparticles and sodium hexametaphosphate as dispersant in 5:1. They were blended with water as solvent by ultrasonic homogenization. The nanofluid observed after several days was found to be stable [31].

2.2.2 SiO_2 Nanofluids:

Yang and Liu thought about the dependability of nanofluid by utilizing of surfactant (trimethyoxysilane) and without the utilization of surfactants. The nanofluid which was set up without surfactant i.e. the blending of nanoparticles was just by utilizing ultrasonication, the sedimentation happened. The utilization trimethyoxysilane of with mass fraction of 0.115 felicitated the homogenous mixing of SiO_2 nanoparticles in H_2O and there was no sedimentation observed after 12 months of the sample preparation [32].

Timofeeva et al. added silica nanoparticles organic fluid using Benzalkonium chloride, Benzethonium chloride and cetyltrimethyl ammonium bromide as surfactants for the stability of nanofluid. The preparation of nanofluid went through a stepwise procedure, initially the solvent was enriched with the surfactants and then the nanoparticles in powder form were blended. The nanofluid was then homogenized using string and ultrasonic homogenization. Dynamic light scattering method and Scanned Electron Microscope both demonstrated that smallest particles size was obtained by Benzalkonium chloride followed by Benzethonium chloride and cetyltrimethyl ammonium bromide the nanofluid with no surfactant indicated biggest molecule measure [33].

Kulkarni et al. made a solvent of 60 % ethylene glycol ($C_2H_6O_2$) and 40 % water the silica nanoparticles were homogenized in the solvent by using ultrasonication.

Dynamic light scattering shows that the nanoparticles were dispersed uniformly [34].

Anoop et al. dispersed silica nanoparticles in DI water as solvent and the colloidal suspension was homogenized by ultrasonic homogenizer. For stability of the nanofluid the pH was kept to 4.5 by using Nitric acid [35].

Darzi et al. dispersed SiO_2 a nanoparticle in added distilled water mixing was done by magnetic stirrer for 2 h [36].

Fazeli et al. blended the silica nanoparticles in distilled water and then ultrasonic homogenizing was done for uniform dispersion of the nanoparticles in the nanofluid [37].

2.2.3 CuO Nanofluids:

Byrne et al. blended CuO nanoparticles in water with and without the use of surfactant. CTAB was used as surfactant in 1:1 by volume to the nanoparticles. The homogenization was done by ultrasonic vibrator. Dynamic light scattering results shows that when no surfactant was used and concentration of CuO was 0.1%, the average size of nanoparticle in the nanofluid decreases from 3000 nm to 300 nm after 4 h. with CuO concentration 0.1% nanofluid and CTAB was used as surfactant the average particle size of about 200 nm was observed. The outcome demonstrates that by using the surfactant the average particle size of the nanoparticles decreased [38].

Lee et al. looked at the CuO nanofluid created by both sonication of CuO nanoparticles in DI water (two step method) and preparation CuO nanofluid by pulsed laser (one step method). The nanofluid prepared by one step method was more steady having smaller nanoparticles [39].

Rohini Priya et al. prepared CuO nanofluid with water as solvent. To avoid aggregation of nanoparticles in the nanofluids tironas was added as surfactant. The optimum ratio of tironas and CuO was calculated as 1:2.5 [40].

Harikrishnan dispersed CuO nanoparticles in oleic acid to prepared the nanofluids the homogenazition of the nanoparticles in nanofluid was done by ultrasonic viberations. As the mass fraction of nano particles increased from 0.5 to 2.0% by weight. The sonication time increased from 30-45 minutes. The solution prepared was a collidal mixing of CuO nanoparticles and oleic acid [41].

Suresh et al. synthesized copper oxide nanoparticles in powder form by sol-gel method. The nanoparticles were dispersed in water by sonicating it for 6 h for the homogeneity. The pH of the prepared nanofluid was reported around 4.83 for stability [42].

Kannadasan et al. synthesied CuO nanoparticles by the chemical precititation method. These CuO nanoparticles were sonicated in water to get the nanofluid. As the sample was observed after 25 days there was some sedimentation of nanoparticles observed [43].

Saeedinia et al. blended CuO nanoparticles in oil by using an ultrasonic homogenizer (400Wand 24 kHz) to stay away from the aggregation of nanoparticles in the nanofluid. The sedimentation of nanoparticles was observed after a few days [44].

Chang et al. dispersed copper oxide nanoparticles into water using, NaHMP (CuO:NaHMP=1:3.12 by wt) as dispersant. The homogenization of the solution was done by ultrasonic vibrator. It was observed that when the CuO content was more than 0.40 vol.%, the nanofluid was very unstable and the CuO nanoparticles sediment within several minutes [45].

Lui et al blended CuO nanoparticles in deionized water. The colloidal solution was homogenized for 10 h in an ultrasonic water bath. The pH of the nanofluid was kept at 7 [46].

2.2.4 Al_2O_3 Nanofluids:

Sonawane et al. dispersed Al_2O_3 nanoparticles into aviation turbine fuel (ATF). The experiment was conducted to find the correct amount of surfactant to be added to the nanofluid for stability. At first the Al_2O_3 nanoparticles were dispersed in ATF by ultrasonic sonication and no surfactant was used, the time of sonication was different for different samples but sedimentation was observed in all the samples within few minutes of the sonication. Oleic acid and Polyoxyethylene Sorbitan Monolaurate (known as 'Tween' 20 LR) was used as surfactant and after several trails it was concluded that in ATF (10 ml) with 1% Al_2O_3 (by volume) is 3 drops (0.026 ml) each of Oleic Acid and 'Tween' 20 LR to be added for the stability of the nanofluid. As the amount of nanofluid increased the amount of surfactant to be added increased proportionally, the sonication time doesn't affect the stability of nanofluid [47].

Gharagozloo diluted 20% weight concentration Al_2O_3-water nanofluid with deionized water. The pH of the nanofluid was kept at 5.5 by adding nitric acid. The nanofluid was homogenized using ultrasonic homogenizer and remained stable for several days [48].

Hung etal. prepared a solvent of water and chitosan 0.5% by weight. Chitosan acts as catonic dispersant in distilled water. Then Al_2O_3 nanoparticles were ultrasonically homogenized in the solution [49].

Suresh et al. used the chemical vaporization process to synthesize the Al_2O_3 nanoparticles. The nanoparticles were used for preparing the nanofluid having water as the base fluid. The colloidal solution was treated with ultrasonic vibrations for 6 h and afterwards the pH of the nanofluid was maintained at 4.9 for stability of nanofluids [50].

Beck et al. blended the Al_2O_3 nanoparticles in ethylene glycol and the colloidal was subjected to ultrasonic homogenization. The solution remained stable without any surfactant due to the surface charge present on the surface of solute [51].

Soltani et al. prepared the solvent having distilled water added with carboxy methyl cellulose 0.5% by weight. The Al_2O_3 nanoparticles were added to the solvent and mixed first by mechanical method and after that ultrasonically [52].

Jian etal added HCl to water to make the pH at 4.9. The Al_2O_3 nanoparticles were added and ultrasonically homogenized, the resultant nanofluid was stable without any traces of aggregation [53].

Singh et al. dispersed Al_2O_3 nanoparticles in ethylene glycol and water. The Al_2O_3-water nanofluids were stabilized through electro-static technique, the pH of the nanofluid was kept at 4 by adding hydrochloric acid for stability of nanofluid. The Al_2O_3-water nanofluid was stable for a few days. Al_2O_3 nanoparticles were sonicated in ethylene glycol and Al_2O_3-ethylene glycol based nanofluid was observed homogenous and stable [54].

Ho et al. dispersed Al_2O_3 nanoparticles into the bottle of ultra-pure Milli-Q water the colloidal suspension was then blended by utilizing attractive magnetic stirrer for 2 h. The pH value of the nanofluid kept at pH 3. The suspension was stable for at least two weeks [55].

Teng et al. dispersed Al_2O_3 nanoparticles in water blended using ultrasonic vibration and electromagnetic stirring. The chitosan (0.3 wt.%) was used as surfactant for stability of nanofluid. There was no sedimentation and aggregation observed in the nanofluid after numerous days [56].

Yousefi et al. observed that as the concentration of Al_2O_3 nanoparticles increased more the 4% vol., the stability of solution decreased. Triton was used as dispersant and ultrasonic vibrator was used for homogenizing the nanofluid [57].

Heyhat et al. dispersed Al_2O_3 nanoparticles into the distilled water and sonicate the mixture consistently for 1 h at 400Wand 24 kHz. The characterization was done by SEM and zeta potential shows that the nanofluid was homogenous and physical stable [58].

Lee et al. dispersed Al_2O_3 nanoparticles in DI water and sonicated the suspension. The pH was kept constant at 6.04. The sonication time was variable and the zeta potential test show that the optimum time for sonication was 5h [59.]

Pandey and Nema blended Al_2O_3 nanoparticles in distilled water using ultrasonic sonication for 8-16 h. The nanofluid was stable and no sedimentation was seen [60].

Hegde et al. dispersed Al_2O_3 nanoparticles in DI-water and sonicated the colloidal solution. Although the nanoparticles used were of very small size but there were no signs of any aggregation found initially [61].

Esmaeilzadeh et al. prepared their nanofluid by ultrasonic mixing of Al_2O_3 naoparticles in DI- water for 4 h and then by electromagnetic stirring. There were no signs of aggregation and sedimentation as observed by TEM and XRD [62].

Jacob et al. dispersed Al_2O_3 nanoparticles in Deionized water and the pH value of the suspensions was controlled. The colloidal solution was sonicated for homogeneity [63].

2.2.5 TiO_2 Nanofluids:

Mo et al. blended TiO_2 nanoparticles in deionized water in three different concentrations 0.3% wt., 0.5% wt., 0.7% wt. Amonia was added to keep the pH value to 8 and sodium dodecyl sulfate was added as a surfactant. The colloidal suspension was magnetically stirrer for 10 min and ultrasonically homogenized for 40 min. The nanofluid with concentration of 0.3% wt. and 0.7% wt. was stable for several days but nanofluid with concentration 0.5% wt. demonstrated sedimentation [64].

Fedele et al. dispersed TiO_2 nanoparticles in distilled water, the mixing was done by ultrasonic homogenizer. The pH of the nanofluid was controlled to avoid sedimentation of the nanoparticles. The characterization was done by dynamic light scattering method. It was watched that following a few day the extent of nanoparticles in the nanofluid diminished because of halfway precipitation, however after sonication the nanoparticles procured a similar size starting size [65].

Kayhani et.al. added TiO_2 nanoparticles and hexamethyldisilazane by mass ratio 2:1 the mixing was done by ultrasonic means for getting homogeneity. The resultant mixture was mixed with distilled water and again ultrasonic homogeneity of the nanofluid was done for 3-5 h. The nanofluid showed no sedimentation [66].

Duanthongsuk and Wongwises prepared the water based nanofluid having TiO_2 nanoparticles. To prevent the sedimentation and aggregation of the nanoparticles in the nanofluid surfactants were used and ultrasonic homogenization was used for uniform distribution of nanoparticles in the nanofluid [67].

He et.al prepared TiO_2 – DI water Nanofluid by using ultrasonic homogenization. The nanofluid then processed in a medium mill to reduce aggregation of nanoparticles. . The pH of the nanofluid was kept consistent to keep the aggregation of nanoparticles [68].

Murshed et.al. blended TiO_2 nanoparticles in DI water and it was observed that the size of nanoparticles in the nanofluid incremented due to accumulation. To enhance the stability of the nanofluid cetyltrimethyl ammonium bromide surfactants were added to the nanofluid [69].

Sajadi and Kazemi mixed TiO_2 nanoparticles in DI water by stiring process and then the ultrasonic homogenization was used for uniform distribution and stability of nanoparticles in the nanofluid [70].

Abbasian Arani and Amani mixed TiO_2 nanoparticles in distilled water. The solution was homogenized by ultrasonic vibrator and magnetic stirrer. The pH of the nanofluid was kept 5.67-7 to avoid sedimentation. CTAB was used as surfactant. The nanofluid was observed stable after several days [71].

Chen et al. prepared TiO_2 nanotube and ethylene glycol nanofluid using dry titanate nanotubes which were integrated based on the alkali hydrothermal transformation. The TiO_2 nanotube and ethylene glycol mixed by gentle stirring, preceded by ultrasonic homogenization. The nanofluid was stable over the period of two months [72].

2.2.6 Fe_3O_4 and Fe_2O_3 Nanofluids:

Abareshi et al. dispersed Fe_3O_4 nanoparticles in deionized water, and tetramethyl ammonium hydroxide was used as a dispersant. The pH estimation of the nanofluid was kept consistent to enhance the crystallinity of Fe3O4 nanoparticles. The zeta potential test indicates nanofluids have great scattering and soundness [73].

Li et al. prepared two types of nanofluids of Fe_3O_4 nanoparticles in deionized water. In the first nanofluid Fe_3O_4 nanoparticles prepared by the chemical precipitation oleic acid was added as a dispersant. The distinctive particle volume fraction of the sample was obtained by diluting the original sample of the nanofluid. In second technique the nanoparticles were blended directly using ultrasonic vibrator in deionized water. Sodium dodecylbenzenesulfonate was added for stability of the nanofluid [74].

Yu et al. synthesized Fe_3O_4 nanoparticles by coprecipitation. Oleic acid was used as surfactant. After 1 h, kerosene was added as solute to the blend. The suspension was blended slowly by stirring. The phase-transfer process occurred spontaneously, resulting in distinct phase between the aqueous and kerosene. The aqueous phase was expelled using a pipette and Fe_3O_4-kerosene nanofluid was obtained having volume concentration 1% [75].

Sundar et al. added Fe_3O_4 nanoparticles in water and balanced the pH value to 3, using sulfuric acid (H_2SO_4). The colloidal suspension was sonicated for 2h. The nanofulid was having uniform dispersion of the nanoparticles [76].

Sheikhbahai et al. added Fe_3O_4 nanoparticles in ethylene glycol using ultrasonic mixing. DI-water was then added to nanofluid under vigorous agitation. No sedimentation was seen in the nanofluid [77].

Sundar et al. added Fe_3O_4 nanoparticles in the solvent having diverse concentrations of ethylene glycol and water mixture. The colloidal solution ultrasonically homogenized and was observed stable after several days. [78].

Asadzadeh et al. added Fe_3O_4 nanoparticles in ethylene glycol, the suspension was stirred and then sonicated. There was no sedimentation evident in the nanofluid [79].

Phuoc and Massoudi added Fe_2O_3 nanoparticles in deionized water. Polyvinyl pyrrolidone (PVP) or Poly (ethylene oxide) (PEO) were used as a dispersant. The blending was carried out using a magnetic blender and ultrasonic sonication. It was discovered that the nanofluids were stable for several days when the particle concentration was less than 2% and as the concentration was high the stability of the nanofluid decreased [80].

Abareshi et al. added α-Fe_2O_3 in glycerol. The homoginazation of the colloidal suspension was done using ultrasonic vibrator [81].

Guo et al. added Fe_2O_3 nanoparticles in the blend of ethylene glycol and deionized water. Sodiumoleate was used as dispersant. The nanoparticles were mixed to the solvent with continuous stirring. Then the suspension was stirred using disperse mill and ultrasonication. It was found that the average size of nanoparticles in the nanofluid was 1200 nm without surfactant and about 150 nm with surfactant [82].

2.2.7 AlN Nanofluids:

Yu et.al. dispersed AlN nanoparticles in ethylene glycon and propylene glycon by stirring and ultrasonic homogenation. Due to aggregation the average particles size of nanofluids increased as observed by Scanning Electron Microscope (SEM) [83].

Woznik et.al.dispersed AlN nanoparticles in polypropylene glycon (PPG 425 & PPG 2000) in powder form. The colloidal suspension was stirred magnetically homogenous mixture. It was observed that the sedimentation of nanoparticles was more in PPG 425 as compared to PPG 2000 and after 30h sedimentation rate of nanoparticles was more than 90% and remained constant thereafter. The Zeta potential of both PPG 425 and PPG 2000 reported as negative [84].

Hu et.al. dispersed AlN nanoparticles in gaseous phase produced by plasma arc in ethanol and castor oil was used as surfactant. The mixing was done by magnetic stirrer at high speed after this the ultrasonic homogenization was done for 10 min. The nanofluid was characterized under Transmission Electron Microscopy (TEM) and it was observed that it remained stable for more than 2 weeks [85].

2.3. Preparation of metallic Nanofluids:

2.3.1. Cu Nanofluids:

Xuan and li dispersed copper nanoparticles in transformer oil oleic acid was added 22 % by weight of Cu nanoparticles as dispersant the homogenization of the nanofluids was done by ultrasonic homogenizer [86].

Li et al. dispersed copper nanoparticles in water using CTAB and SDBS surfactant. The pH of the nanofluid was controlled using HCl and NaOH. The average particle size of the nanoparticles obtained in the absence surfactant was 6770 nm and in the presence of SDBS as surfactant and pH= 8.5-9.5 was 207 nm. The suspension with CTAB as dispersant was found stable without sedimentation after a week [87,88].

Peng et.al. mixed Cu nanoparticles in R113 referegrant by plasma evaporation techniques. Sodium dobecyl sulfate, cetyltrimethyl ammonium bromide and sorbitam monooleate were used as surfactants. The colloidal mixture was homogenized results [89].

Kathiravan et al. prepared copper nanoparticles by the sputtering method and dispersed them in water with 9.0% SDS anionic surfactant. The suspension was sonicated for 10 h. The nanoparticles were found dispersed in water evenly with some agglomerates [90].

Kole and Dey dispersed Cu nanoparticles in distilled water the colloidal solution was homogenized by using magnetic stirrer there was no sedimentation observed but due to aggregation the average particles sized increased [91].

2.3.2. Au and Ag Nanofluids:

Patel et.al. synthesized Au and Ag nanoparticles by citrate reaction. The gold nanoparticles were also prepared using two-phase reduction of AuC14- by sodium borohydride in the presence of an alkanethiol were present with thiolate covering in a medium of water and toluene. The nanofluid was stable after several months [92].

Asirvatham et al. added silver nanoparticles in deionized water using ultrasonic vibration. The pH values were measured different for different volume concentration, 7.4, 7.1 and 6.8 for volume concentrations of 0.3%, 0.6% and 0.9%, respectively. The agglomeration of the nanoparticles was observed in the nanofluids [93].

Paranetthanuwat et.al. dispersed silver nanoparticles in water and sonication was done the nanofluids was stable up to 48h [94].

Tamjid and Guenther used colloidal solution of silver nanoparticles produced by sputtering on running liquid technique having volumetric concentration of solid 4.37%. The colloidal solution was sonicated in diethylene glycol to make the homogenous nanofluids [95].

Sharma et al. prepared silver nanofluids by single step technique using silver nitrate as precursor, ethylene glycol as reducing agent, and poly acrylamide-co-acrylic acid as dispersant. The size of nanoparticles and dispersion stability are controlled by the controlling the concentration of poly acrylamide-co-acrylicacid and the reaction conditions [96].

Hajian et.al. dispersed silver in DI water by chemicals reduction of Ag ions. The nano fluids was sonicated afterwards [97].

Parametthanuwat et al. dispersed silver nanoparticles in DI-water. The suspension was sonicated to get the stable nanofluid [98].

Paul et al. synthesized nano-gold and silver nanoparticles dispersed water by wet chemical bottom up approach. The nanofulid was found stable without agglomeration and sedimentation as observed after 48 h [99,100].

Chaudhary et al. synthesized the gold nanoparticles in aqueous medium from HAuCl4 by chemical reduction and continuous stirring. The size of nanoparticles in the nanofluid can be controlled by controlling the rate of reaction and stirring. The nanofluid was stable after many days [101].

2.4. Mixture of Nanoparticles:

Cho et al. mixed combination of Al_2O_3 and AlN nanoparticles with n-hexane and a proper amount of oleic acid as pH controller. The mixture was subjected to ZrO_2 bead-milling in a vertical super-fine grinding mill and ultrasonic reaction bath. The excess of oleic acid was removed by ultra filtration membrane. The naoparticles then mixed with transformer oil, and then the n-hexane was removed using a rotary vacuum evaporator [102].

Kim et al. prepared the nanofluid having ZnO, TiO_2, Al_2O_3 as nanoparticles and water and ethylene glycol as solvent. The mixing was done by ultrasonic homogenization and .05 M Sodium dodecyl sulfate was used as surfactant for stability of nanofluid [103].

Utomo et al. dispersed 30-40 wt.% of TiO_2 and Al_2O_3 in distilled water; the colloidal solution was ultrasonic homogenization keeping pH constant, Large aggregation was observed even after sonication [104].

Longo and Zilio prepared Al_2O_3-water (15 wt.%, 30 nm) and TiO_2-water (25 wt.%) nanofluids. The colloidal solution of nanofluid was first subjected to mechanical stirring, and then it was sonicated at 25 kHz for 48 h. The characterization of the nanofulid by Malvern nano-sizer shows that Al_2O_3-water and TiO2-water nanofluid show less aggregation and better stability when homogenized using sonication. The nanofluid remained stable for more than a month [105].

Qu and Wu dispersed Al_2O_3 and SiO_2 in water. The nanofluids was obtained in a stepwise procedure. At first the pH value of the nanofluids was adjusted to 9.7 and 4.9 for the SiO_2 and Al_2O_3 nanofluids respectively. Then nanoparticles and water colloidal solution ultrasonically vibrated for 4 h. The TEM characterization shows that the Al_2O_3 nanoparticles were dispersed homogenously as compared to SiO_2 nanoparticles [106].

3. CHARACTERIZATIONS OF NANOFLUIDS:

The stability of the nanofluids is the key issue. There are some methods and instruments present that can measure the stability of the nanofluids. It includes UV–Vis spectrophotometer, zeta potential test, sediment photograph capturing, TEM (Transmission Electron Microscopy) and SEM (Scanning Electron Microscopy), and sedimentation balance method.

3.1 UV–Vis spectrophotometer:

The basic principle of UV–Vis spectrophotometer is that when the light passes through a fluid its intensity of the light becomes different by absorption and scattering. The working wavelength of the UV–Vis spectrophotometer is 200–900 nm on which it measures the absorption of light by sample liquid and compared with the standard liquid which will give the total sedimentation in the liquid. The stability of suspension is measured by measuring the sediment volume versus the sediment time [107]. This method is less efficient for nanofluid dispersions with a high concentration and especially for CNT nanofluids [108].

3.2 Zeta potential test:

Zeta potential test is one of the most critical reliable method to check the stability of the nanofluids by studing its ectrophoretic behavior [8,9]. According to the stabilization theory [110], if zeta potential has a high absolute value (negative or positive) the electrostatic repulsions between the particles increase which then results in a good stability of the suspensions. The particles having like charge repel each other; due to this repulsion the suspension of the particles in the fluid will be better. The nanofluid having zeta potential below 30 mV is having less stability and the nanofluid having zeta potential more than 30 mV are stable. The table below shows the stability behavior of nanofluid according to the zeta potential value.

Table1: Suspension stability according to Zeta potential [111]

Zeta potential [mV]	Stability behavior of the colloid
0 to ±5	Rapid coagulation or flocculation
±10 to ±30	Incipient instability
±30 to ±40	Moderate stability
±40 to ±60	Good stability
more than ±61	Excellent stability

3.3 Sediment photograph capturing:

Sedimentation of nanofluids can also be found out by photo capturing. The photographs of the nanofluid are taken after a certain period of time. These photographs are compared and by comparing these photos sedimentation of suspended nanoparticles in the nanofluid can be observed [112].

3.4 Transmission Electron Microscopy (TEM) and Scanning Electron Microscope (SEM):

TEM and SEM are very useful instruments to measure the shape, size and distribution of nanoparticles. Cryogenic electron microscopy (Cryo-TEM, Cryo-SEM) can show the real situatihe nanofluid. These instruments can measure the aggregation structure of the nanoparticles in nanofluids [18].

Standard procedure used for the analysis of nanofluid in SEM/TEM:[113]

(1) Take the sample of nanofluid.
(2) Take the sticky tape and drop one drop of nanofluid on its top surface of the SEM specimen holder (carbon grid in the case of TEM).
(3) Heat it to dry the liquid and obtain the solid nanoparticles.
(4) Obtain solid particle.
(5) Bring into the vacuum chamber of SEM/TEM for picture after coating with Au and Pd.

Sedimentation balance method

The stability of the nanofluid can be also measured by sedimentation balance. The tray of a sedimentation balance is immersed in the nanofluid. The weight of sediment nanoparticles during a certain period of time is measured [87].

The suspension fraction (Fs) of nanoparticles at an accepted time is calculated by the formula

$Fs = (W_0 - W)/W_0$

where W_0 = the total weight of all nanoparticles

W = the weight of the sediment nanoparticles at a certain time

4. CONCLUSION

This paper deals with the recent development in the field of nanofluids. Various methods are suggested for preparation of nanofluid. There are two techniques for the producing the nanoparticles. 1) In single step technique there is a simultaneous synthesis of nanoparticles and preparation of nanofluid. 2) In two step technique the previously synthesized nanoparticles are blended into the solvent to produce a nanofluid. The nanofluids were studied on the basis of the type of nanoparticles; metallic and non metallic and then we have also studied the nanofluid having the mixture of nanoparticles.

The preparation of the non metallic nanofluid such as ZnO, SiO_2, CuO, TiO_2, Fe_3O_4, Fe_2O_3, Al_2O_3 nanofluid have been studied. In the study we have included the different base fluid/solvent which were used by different researchers for the development of their nanofluid. The study shows that the majority of non metallic nanofluid were prepared by two step method.

The metallic nanofluid such as Cu, Au, Ag nanofluid were prepared by using both single step technique and two step technique.

The researches have included the three different techniques for proper mixing of nanoparticles in the nanofluid. 1) The ultrasonic mixing of nanoparticles in the nanofluid is used for evenly distributing the previously synthesized nanoparticles in the solvent and resulting in a homogeneous nanofluid. The sonication also results in reducing the size of nanoparticles in the nanofluid and results in high value of zeta potential which indicate the stability of nanofluid.

2) The use of surfactants enhanced the stability of the nanofluid by reducing the rate of sedimentation of the nanoparticles in the nanofluid.

3) The pH of the nanofluid while mixing the nanoparticles is kept constant at a desired value. This will result in the mutual repulsion of the nanoparticles hence the stability of the nanofluid increased.

The paper also includes the characterization method for the various nanofluid such as UV–Vis spectrophotometer, zeta potential test, sediment photograph capturing, TEM (Transmission Electron Microscopy) and SEM (Scanning Electron Microscopy), and sedimentation balance method. The most used method for the characterization is zeta potential test and electron microscopy.

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