International Journal of Advance Research in Engineering, Science & Technology(IJAREST),
ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2, Issue 6, June - 2015, Impact Factor: 2.125

Experimental Investigation on TiO2 Nano Fluid Preparation and its Properties

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Abstract

Nanofluid is a new type of heat transfer fluid with superior thermal performance characteristics, engineered by dispersing metallic or non-metallic nanoparticles with a typical size of less than 100 nm in the conventional heat transfer fluids. It's use remarkably augments, the heat transfer potential of the base liquids.In this paper, TiO_2 nano fluid made of different proportion of nano particles is prepared by ultrasonic probe method and its stability is checked with different time period of sonication.Various properties of nano fluid were studied and observed the improvement in thermal properties as compared to base liquid. It is found that Nano fluid is very effective in cooling than the conventional cooling fluid and this can be used in many heat transfer applications.

Keywords—Nanofluid, Sonication, TiO_2, Al_2O_3.

I. INTRODUCTION

Nanofluids were first invented by**[1]** at the Argonne National Laboratory, USA. Compared with traditional solid-liquid suspensions containing millimeter or micrometer sized particles, nanofluids as coolants in the heat exchangers have shown better heat transfer performance because of the small size of suspended solid particles. It causes that nano- fluids have a behavior similar to base liquid molecules. Because of their excellent thermal performance, nano- fluids have attracted attention as a new generation of heat transfer fluids in building heating, in heat exchangers, in chemical plants and in automotive cooling applications. Recently there have been considerable research findings highlighting superior heat transfer performances of nanofluids.

Heat transfer coefficient of different nano fluid is higher than that of the base liquid and increase with increasing the Reynolds number and particle concentrations. In the pressure drop, it is also shown that the pressure drop of nano fluids was slightly higher than the base fluid and increases with increasing the volume Concentrations.[6,7,9,15]. Internal combustion engine performance will be improved by 5-10% by using Nano particle suspended commercial engine coolant. [5]. The viscosity of the nano fluid increases with increasing nano particle concentration and decreases with an increase in temperature. [8,13]. The heat transfer enhancement of about 40% with Al_2O_3 nano fluid can be obtained compared to the base fluids. [10]. Thermal conductivity of nano fluids with MWCNT can be increased up to 150% [11].For CuO-water nano fluid at 2% volume concentration, the overall heat transfer coefficient and pumping power are more than that of base fluid.[12].Both relative viscosity and thermal conductivity ratio of dispersions of sub-micron TiO_2 particles vary linearly with particle concentration. By increasing the time of ultrasonication, sub-micron dispersions of lower relative viscosity and higher thermal conductivity ratio can be produced.[14].Nano coolant of MWCNT has a higher heat exchange capacity and efficiency than EG/W[16].Heat transfer rate and effectiveness is increased with increase in volume concentration of nano particles (ranging from 0% to 1% of Al_2O_3). More pumping power is needed for a radiator using nano fluid compared to that radiator using only base fluid.[18]. CFD Analysis results matches fairly with the experimental results of nano fluid performance in automobile radiator[19].Thermal conductivity, viscosity, and density of the nano fluid increase with the increase of volume concentrations. However, specific heat of nano fluid was found to be decreased with the increase of nano particle volume concentrations. Moreover, by increasing the temperature, thermal conductivity and specific heat were observed to be intensified, while the viscosity and density were decreased.[21],[22].There is increase in thermal conductivity andreduction in viscosity with ZnO–EG nano fluids compared to their respective base fluids.[20]The average heat transfer rates for TiO_2 nano fluids as a cooling media are higher than those for the water which is also used as cooling media, and this increases with concentration of nano fluid composition[24].The heat dissipation capacity and the EF of the NC are higher than EG/W, and that the TiO_2 NC is higher than the Al_2O_3 NC according to most of the experimental data.[25]

Advantages Of Nano Fluid

Nano fluid has the following advantages compared to base fluid:

(i) high dispersion stability with predominant Brownian motion of particles
(ii) reduced particle clogging as compared to conventionslurries, thus promoting system miniaturization
(iii) reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification
(iv) adjustable properties, including thermal conductivity and surface wet-ability, by varying

particle concentrations to suit different applications

(v) High specific surface area and therefore more heat transfer surface between particles and fluids

(vi) Low Cost compared to EG base fluid

II. Nano Fluid Preparation

The nano particles in form of powder when dispersed in the base liquid, it is called nano fluid. In order to improve the thermal conductivity of the nano fluid, preparation of nano fluid using nano particles is important task. There are mainly two methods of producing nano fluids.

1. Single step method and
2. Two step method.

These methods have been utilized using different types of chemical and physical techniques to make sure that the solid-liquid mixture is stable to avoid agglomeration, additional flow resistance, possible erosion and clogging, poor thermal conductivity, and poor heat transfer. It is observed in the literature that nano fluids with oxide nano particles and carbon nano tubes are produced well by the two-step method, while it is not suitable for nano fluids with metallic nano particles.

2.1.1. One-step technique

In one-step technique, the nano particles are simultaneously made and directly dispersed into the base fluid. There are fourteen different methods are used to produce nano particles[39].This method is preferable to produce nano fluids containing high thermal conductivity metals to avoid erosion and oxidation of particles. The advantage of this process lies on minimizing of nano particles agglomeration. This behavior increases the stability of the suspensions and uniform dispersion in the host liquids. The disadvantage of one-step technique is the limit of quantity of the production due to the slow of the production process, low concentration of nano particles, and the high cost. Different methods have been used to reduce the time and cost using evaporation, physical or chemical one-step methods.

2.1.2. Two-step technique

In two-step method of producing nano fluid, the nano particles are produced first separately and then this nano particles are dispersed into a base fluid into particular measured quantity.

The advantage of this method is that it is easily and economically produced. On the other hand, the disadvantage of this method is the quick agglomeration of individual particles before the achievement of complete dispersion due to Vander Waals attractive forces between nano particles. This agglomeration is a big obstruction to achieve high heat transfer performance due to the quick settling of particles out of the base fluids and it becomes worse as the volume concentration increases. The agglomeration is not only a problem in nano fluid technology, but it is also a critical issue in all nano powder technology especially during drying, storage, and nano particle transportation stage.

Many different methods have been used to avoid agglomeration using two-step process to initiate the move towards commercialization by facilitating the mass production of nano fluids. Two-step methods such as stirrer, ultrasonic bath, ultrasonic disrupter, and high pressure homogenizer are the popular methods of two-step technique. Eastman et al. [29], Lee at al. [30], and Wang et al. [31] used ultrasonic equipment to disperse Al_2O_3 in the base fluid with less agglomeration. Moreover, Hong et al. [32, 33] utilized ultrasonic equipment produced Fe nano fluids by mixing Fe nano crystalline powder in ethylene glycol. Ultrasonic equipment was also used to produce TiO_2–water nano fluid as introduced in Murshed et al. [34]. Metallic nano fluids were produced by using different two-step methods. ,Chakraborty et al. [36] and Duangthongsuk and Wong wises [37] produced Al_2O_3 and TiO_2 nano fluids by dispersing nano particles in distilled water, using continuous ultrasonication for 30 min and ultrasonic stirring for 20 min, respectively. Sajadi and Kazemi [38] mixed the proper amount of TiO_2 nano particles with distilled water by a mixer for 10 min. Then, an ultrasonic cleaner was used to disperse nano particles for 30 min.

2.2 Selection of Nano particles

Titanium dioxide is widely applied in many fields, including nano fluids preparation .From a production perspective TiO_2 nano particle are easily obtained as they are readily produced in large industrial scales. Concerning their physicochemical profile, they have an excellent stability when dispersed in a fluid even without stabilizer addition [10] The thermal conductivity enhancements reported for those TiO_2 nano fluids which use EG, PG or paraffin oil as base fluids seem to be predominantly lower than those based on water.[28] A-TiO_2 nano fluids exhibit thermal conductivities slightly higher than those for (A + R-TiO_2). A similar conclusion can be drawn whether the thermal conductivities of (A-TiO2/W) nano fluids are compared to those of R-TiO_2/W nano fluids [28].For the same above mentioned reason the anatase grade of TiO_2 nano particles are used for preparation of nano fluid

2.3 Selection of Base Liquid

Many host liquids have been used to produce nanofluids such as aqueous and organic liquids (ethylene glycol, and oils) to enhance thermal conductivity. It isfound that the thermal conductivity enhancement increases as the thermal conductivity of the base fluid decreases[27]

It is observed that thermal conductivities enhancements for TiO2 nanofluids which use ethylene glycol, propylene glycol or paraffin oil as base fluids seem to be predominantly lower than those based on water [28]. For this reason distilled water is preffered as the base fluid for the preparation of nano fluid.

2.4 Selection of Nano particles Size

The size of particle plays a significant role in thermal conductivity and heat transfer enhancement in base fluids. Different suspension sizes of millimeter and micrometer particles in host liquid have been used to increase the thermal conductivity, but the particles agglomerate quickly and settled out of the liquid. Nano particles are formed to decrease the size of the particles so that the time of sedimentation decreases to reach in some cases to more than few weeks or months. The size of nano particles are in the range of 1–100 nm and as the size decreases the thermal conductivity increases due to the increase of the relative surface area [27]. The much larger relative surface area of nano particles, besides significantly improving thermal conductivity capabilities, should also increase the stability of the suspensions. In addition, it is observed that as the size of nano particle reduced, the Brownian motion will be induced [27]. Furthermore, there are some researches indicate that the thermal conductivity enhanced with nano particles increment to ≈60nm and vice versa for greater values [42]. The size of nano particles in the host liquid is too important to the modern science and technology.

In this experimental work of preparing nano fluid, the TiO_2 nano particles of size 25 ± 5 nm, as provided by Nano wings Pvt. Ltd, has been used

2.5 Preparation of TiO2 Nano fluid

In this experiment of preparing nano fluid, Anatase TiO2 Nano particles of average size of 25 nm and purity of 99.9% were used as purchased from the Nano wings Pvt. Ltd Company, Khamam, India. The size of the nano particles supplied by supplier and used in this experiment is 20 – 30 nm.

The base working fluid is distilled water because boiling characteristics of the base fluid (water) is well known and the TiO_2 nanoparticles are commercially available. No surfactant or buffer was added in the nanofluids during dispersion process. Mixture of nanoparticles and the base fluid was sonicated with an ultrasonic probe for an hour to obtain nanofluid.

The nano fluid was prepared in three different proportions, 0.25%, 0.5% and 1% by wt% in distilled water. To disperse the nano particles in the distilled water as base fluid, Oscar ultrasonic machine PR- 1000 was used, this facility was provided by Saurashtra University, Rajkot.

First of all 0.25% by wt of TiO_2 nano particles were scaled and dispersed in the distilled water. Then this mixture is sonicated in the above mentioned ultrasonic machine for 1 hour. No surfactant was used in this method for preparation of nano fluid. The nano fluid prepared in this way remains stable for about a week without agglomeration. Different concentration of TiO_2 and different time of sonication were used to check the stability of solution mixture.

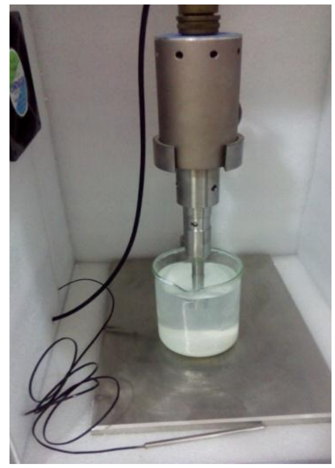

Fig 2.1:Preparation of nano fluid in ultra sonic horn machine

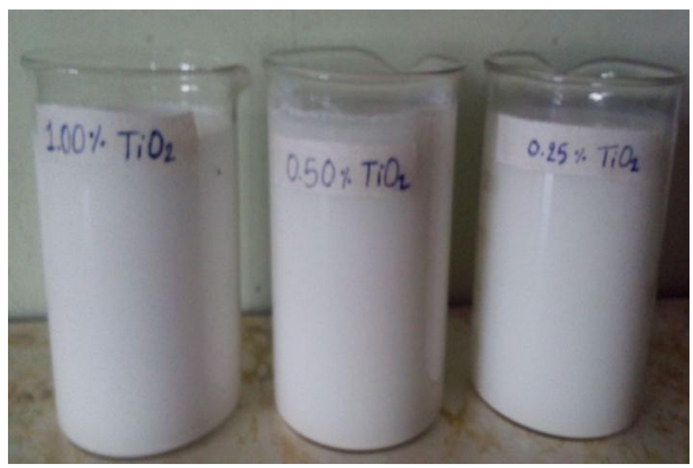

Fig. 2.2: TiO_2 Nano Fluid prepared

2.6 Test rig for ultrasonic mixing of Nano particles and base fluid

The mixing of Nano particles and base fluid were carried out in the Oscar horn type ultrasonic reactor (Figures 1 and 3). In horn type reactor the horn is attached with the transducer which produces ultrasonic irradiation in the mixture. Ultrasonic processor frequency is ranging from 25 kHz to 30 kHz and time limit is ranging from 3 min to 30 min. the power supply can be varied from 100 W to 1000W in the step of 100W.There is an integrated arrangement for

International Journal of Advance Research in Engineering, Science & Technology(IJAREST), ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2, Issue 6, June - 2015, Impact Factor: 2.125

supporting the beaker (500 ml) so as the transducer horn should be submerged in the mixture. The horn of the transducer was submerged approx. 4 cm in the mixture of nano particles and base fluid. The nano particles started to mix with base fluid as the ultrasonic vibration starts.

Fig. 2.3:Photograph of ultrasonic horn type processor

The reaction is carried out by ultrasonic irradiation from the acoustic rod horn incorporated with the transducer. Cavities are created by the irradiation of power ultrasonic with sufficient energy in mixture liquid (TiO_2 nano particles and distilled water) as a result micro fine bubbles are formed and these bubbles are collapsing at various place of the reactor and disturb the phase boundary between two immiscible liquid and resulted in emulsification of mixture

Fig. 2.4:Power unit of ultrasonic horn

Fig. 2.5:Control unit of ultrasonic horn

III. ResultandDiscussion

Table 3.1 and table 3.2 gives the all the required properties of the TiO2 nano particles and the distilled water as base fluid. And Table 3.3 shows the properties of the nano fluid with varying proportion of the nano particles.

Table: 3.1 Major Properties of Prepared TiO2 Nano Particles

Powder phase	Density g/cm^3	Specific Surface Area m$^{2/}$g	Thermal Conductivity W/mK	Specific Heat KJ/KgK
Anatase	0.2-0.4	60	6	0.69

Table:3.2 Major Properties of Distilled Water as base fluid.

Powder phase	Density Kg/l	Thermal Conductivity W/mK	Specific Heat KJ/KgK	Viscosity CST
Pure Water	1000	0.58	4.18	1.79

Table:3.3 Major Properties of Prepared TiO_2 Nano Fluid with water as base.

Nano particles	Proportion	Density g/cm^3	Kinematic Viscosity CST	Thermal Conductivity W/mK	Specific Heat KJ/KgK	Boiling Point K
TiO_2	0.25%	0.9991	0.2822	0.68	4.166	379

	0.50%	0.9998	0.2931	0.72	4.156	383
	1.00%	0.9999	0.3035	0.88	4.141	387

3.1.1 Stability of nano fluid prepared with ultrasonic method

The nano fluid was prepared using ultrasonic probe machine at 25 KHz frequency with 500W power and mechanical stirrer method with 400 rpm. The stay ability period of nano particles in the base fluid is observed in Table 3.4 and 3.5 respectively.

Table: 3.4 Stay ability of nano fluid with Ultra sonic probe process

For 0.25% TiO_2 nano fluid			For 0.5% TiO_2 nano fluid		
Sr. No.	Time of sonication	Stay ability period	Sr. No.	Time of sonication	Stay ability period
1	15 min.	18 days	1	15 min.	16 days
2	30 min.	20 days	2	30 min.	18 days
3	45 min.	25 days	3	45 min.	23 days
4	60 min.	30 days	4	60 min.	28 days

3.1.2 Stability of nano fluid prepared with Mechanical Stirrer.

Table: 3.5 Stay ability of nano fluid with Mechanical stirrer process

For 0.25% TiO_2 nano fluid			For 0.5% TiO_2 nano fluid		
Sr. No.	Time of stirrer	Stay ability period	Sr. No.	Time of stirrer	Stay ability period
1	15 min.	2 hrs	1	15 min.	1.5hrs
2	30 min.	5 hrs	2	30 min.	3.5 hrs
3	45 min.	8 hrs	3	45 min.	6 hrs
4	60 min.	12hrs	4	60 min.	9 hrs

From the above table it can be observed that as the time of sonication is increased for mixing of nano particles and base fluid, the stay ability period of nano particles increased. Similarly in mechanical stirrer method, as the stirring time increased the stay ability time increased, but for the ultrasonic sonication method stay ability is much more than the mechanical stirrer method

Moreover it is clear from the above experiment that the stay ability period increases with lesser % proportion of nano particles in both the method. As the % proportion of the nano particles increase separation of nano particles from base fluid occurs rapidly.

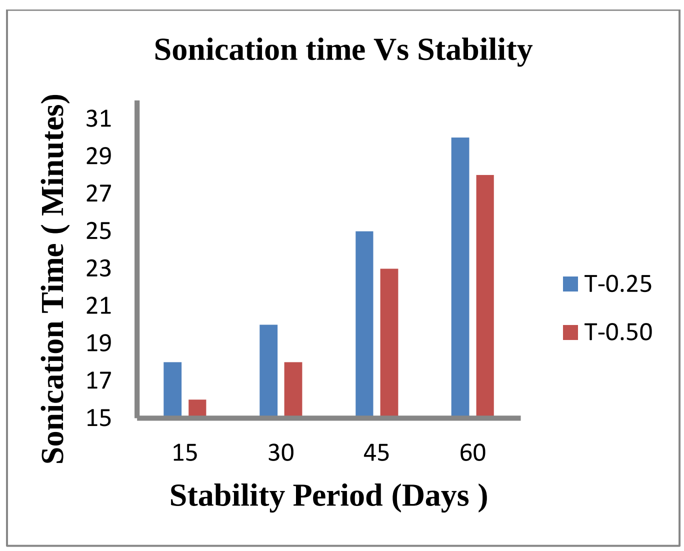

Fig.3.1 Effect of sonication time on Stayability of nano particles

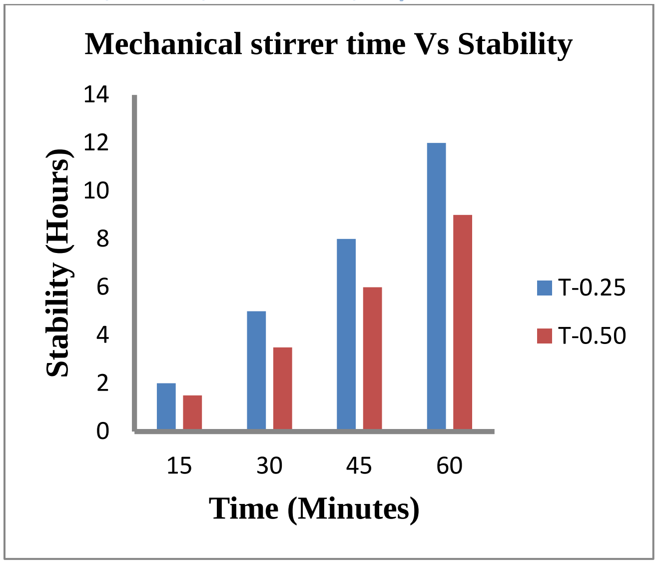

Fig.3.2 Effect of mechanical stirring time on stayability of nano particles

From above figure-3.1 and figure-3.2 it is concluded that stayability of nano fluid increases with the time of sonication. Further it is clear that stayability for 0.25% TiO_2 nano fluid is more as compared to 0.50% TiO_2 nano fluid.It has been also judged that ultra sonic mixing of nano particles in base fluid shows greater stayability than with mechanical stirrer method.

Fig.-3.3 T-0.25 nano fluid on first day (15 minutes sonication)

Fig.-3.4 T-0.25 nano fluid on 20th day (15 minutes sonication)

Fig.-3.5T-0.25 nano fluid on first day(30 minutes sonication)

Fig.-3.6 T-0.25 nano fluid on 20th day (30 minutes sonication)

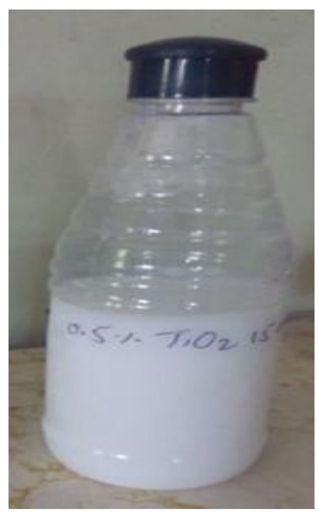

Fig.-3.7T-0.50 nano fluid on first day (15 minutes sonication)

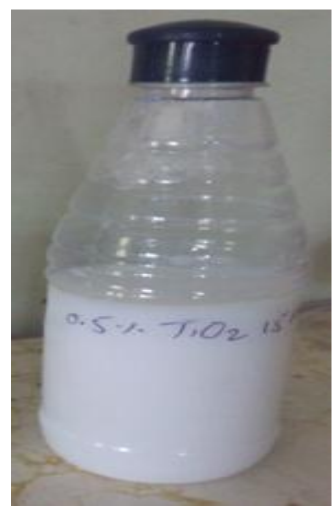

Fig.-3.8T-0.50 nano fluid on 16th day (15 minutes sonication)

Fig.-3.9T-0.50 nano fluid on first day (30 minutes sonication)

Fig.-3.10T-0.50 nano fluid on 18th day (30 minutes sonication)

Fig.-3.3 to Fig.-3.10 shows the photographic views of nano fluid prepared with o.25% and 0.50% concentration of TiO_2 Nano particles. It shows the agglomaration period of particles in the fluid.

3.1.3 Properties Of Nano Fluid

Fig.-3.11 shows the variation of different physical and thermal properties of TiO_2 nano fluid with the proportion of nano particles. It is concluded from the above results that Thermal conductivity can be enhanced with increase of nano particles. There is a little decrease in specific heat of nano fluid with increase of nano particles as shown in Fig.-3.12. But Kinematic viscosity and density of nano fluid increases by normal value with the increase of % of nano particles. Boiling temperature of nano fluid also rises with the addition of nano particles in the base liquid and further increases with the increase of particles proportions

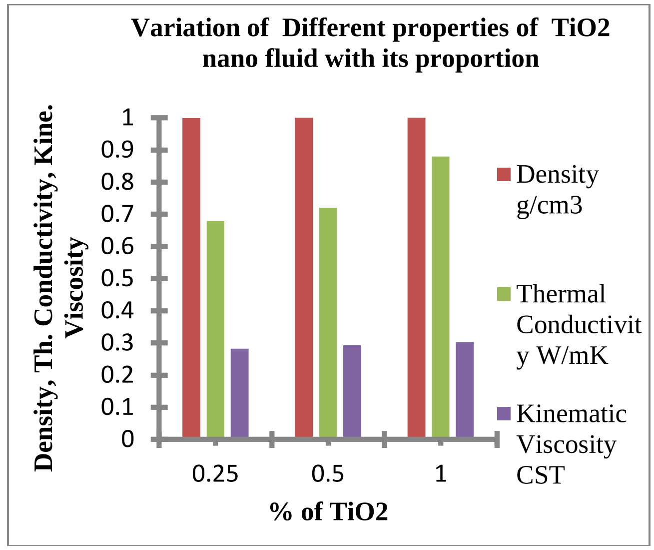

Fig.5.11 Effect of nano particles proportions on Kinematic viscosity, Density, and thermal conductivity

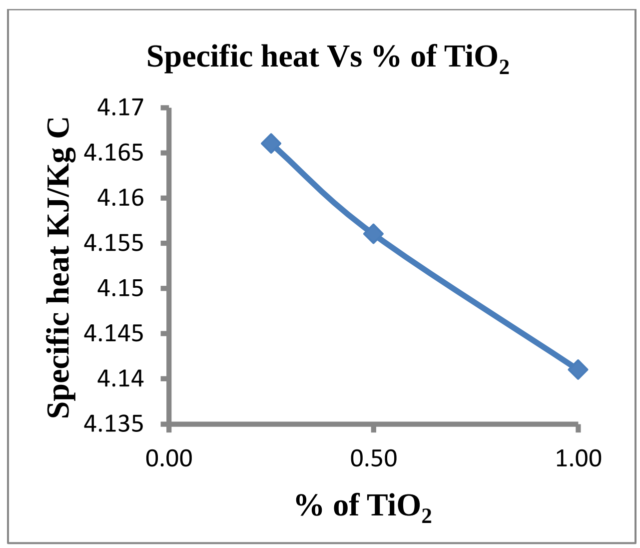

Fig.3.12: Effect of nano particles proportions on Specific heat of coolant

IV. CONCLUSION

In this researcharticle, Nano fluid with TiO_2 nano particles of 0.25%, 0.50% and 1.00% concentration were prepared and observed for their stability. The properties like specific heat, thermal conductivity, density and viscosity of nano fluid prepared were observed and compared with base fluid. Following results were obtained.

[1] There is a 84% improvement in kinematic viscosity and 51% improvement in thermal conductivity was observed.

[2] Anegligible variation is observed in density.
[3] The specific heat of the nano fluid reduced marginally by 0.95%
[4] The boiling temperature also increased by 1% with the nano fluid.
[5] Stability of the nano fluid is improved with ultra sonic method.
[6] Lower concentration of nano particles in the fluid has high stability whereas the stability reduces as the concentration of nano particles increase in the nano fluid.
[7] Stability is improved with the increment of sonication time. As long as 30 days stability was obtained with T-0.25 nano fluid and one hour sonication.
[8] The nano fluid prepared with mechanical stirrer has very poor stability in the range of one day.

From the above results it is concluded that nano fluid is prepared best way by ultra sonic process and stability is improved.Moreover the properties like Kinematicviscosity, Thermal conductivity and the boiling point of the nano fluid is considerably increased whereas the density and specific heat has shown nominal variation..

IV. ACKNOWLEDGEMENT

The authors would like to express their appreciation to the Commissioner,CTE,Gujarat, India for Granting deputation for PG. The author would like to express special thanks to PG Co-ordinator, Govt. Engineering College Bhuj, India, for their interest and support of this work.

First and foremost I offer my sincerest gratitude and respect to my supervisors. I am very thankful to **Mr. Jayantibhai** manager Inter Tek Lab. Gandhidham, for their technical support during preparation and Validation of Nano fluid.

I would also like to thank Saurashtra University,Rajkot and their staff for providing experimental set up facility and helping hands towards me in various ways during my work.

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