THERMO-PHYSICAL PROPERTIES OF FERRO NANO PARTICLE DISPERSED IN ENGINE OIL

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***Abstract -** Cooling plays an important role in the development of energy-efficient heat transfer fluids which are required in many industries and commercial applications. Conventional fluids, such as water, engine oil and ethylene glycol are normally used as heat transfer fluids. Improving of the thermal conductivity is the key idea to improve the heat transfer characteristics of conventional fluids. The use of solid particles as an additive suspended into the base fluid is a technique for the heat transfer enhancement since a solid metal has a larger thermal conductivity than a base fluid. The recent advance in materials technology has made it possible to produce nanometer-sizes particles. Innovative heat transfer fluids-suspended by nanometer sized solid particles are called 'nanofluids'. These suspended nanoparticles can change the transport and thermal properties of the base fluid significantly. In the present work synthesis of Fe_3O_4 nanometer sized particles were prepared and further dispersed in SAE20 W 50 engine oil which is used as base fluid. Preparation of Nano fluid was done by using two step methods for four independent volume fractions namely 0.1%, 0.2%, 0.3%, 0.4%. To study the influence of Fe_3O_4 in engine oil, the thermo-physical properties were evaluated at different temperatures. Further flash point and fire point was also experimentally determined using suitable apparatus.*

***Key Words*: Nano fluid, Nanoparticles, Volume fraction, Thermal Properties, Flash point, Fire point.**

1. INTRODUCTION

Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra high cooling applications. Scientists have put efforts to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory for effective properties of mixtures. Fine tuning of the dimensions of these solid suspensions to millimeter and micrometer ranges for getting better heat transfer performance have failed because of the drawbacks such as still low thermal conductivity, particle sedimentation, corrosion of components of machines, particle clogging, excessive pressure drop etc. Downscaling of particle sizes continued in the search for new types of fluid suspensions having enhanced thermal properties as well as heat transfer performance.

Modern nanotechnology offers physical and chemical routes to prepare nanometer sized particles [7] or nanostructured materials engineered on the atomic or molecular scales with enhanced thermo-physical properties [1] compared to their respective bulk forms. Researchers have shown that it is possible to break down the limits of conventional solid particle suspensions by conceiving the concept of nanoparticle-fluid suspensions. These nanoparticle-fluid suspensions are termed nanofluids, obtained by dispersing nanometer sized particles in a conventional base fluid like water [2], oil, ethylene glycol etc.

A Nano fluid is a mixture of base fluid and suspended metallic nanoparticles approximately 0.1-1000nm in size. Since the thermal conductivity of metallic solids is typically orders of magnitude higher than that of fluids it is expected that a solid/fluid mixture will have higher effective thermal conductivity [4] compared to the base fluid. Thus, the presence of the nanoparticles changes the transport properties of the base fluid there by increasing the effective thermal conductivity and heat capacity [6], which ultimately enhances the heat transfer rate of nanofluids. Nanofluids are extremely stable and exhibit no significant settling under static conditions, even after weeks or months.

2. PREPARATION OF NANOFLUIDS

There are two methods for preparation of Nano fluid. One step method consists of making and dispersing the nanoparticles in the base fluid at the same time. Many steps like drying, storage, transportation and dispersion of nanoparticles are done away within this process. This reduces the agglomeration considerably and increases the stability of the Nano fluid. One step method is highly successful in dispersing the nanoparticles uniformly and provides greater stability. The most common method used for the preparation of Nano fluid is two step methods [10]. Nano materials are made into a dry powder using physical or chemical means. The next step involves the dispersion of Nano sized powder into a base fluid using magnetic force agitation, ultrasonic agitation, high shear mixing, homogenizing and ball milling, which is the most economic method for the preparation of nanofluids.

2.1 Preparation of Ferro Nano fluids

Nano fluid is prepared by a two-step method. In this preparation we have taken $FeCl_3$ (ferric chloride) and $FeSO_4$ (ferrous sulphate) .Considering 2Moles of Ferric chloride and 1Mole of Ferrous sulphate. By calculation it is weighted as 3.24gm and 2.78gm by the following formula.

Number of moles = Weight of substance / molecular weight of substance

Ferric chloride of 3.24gm is added to 100ml of distilled water. Ferrous sulphate of 2.7gm is added to another 100ml of distil water. Now 2M of Ferric chloride and 1M of Ferrous sulphate are combined before titration as shown in Fig-2.1. The solution is titrated with Ammonium hydroxide and subjected to ultrasonication as shown in Fig-2.2. After the titration was completed a magnet was kept at the bottom of the beaker. This has to be kept for sometime without disturbing it until the Ferro particles settle down at the bottom of the beaker as shown in the Fig- 2.3. After the Ferro particles are settled down the precipitate is washed repeatedly with distilled water to remove excess ammonia and prepared precipitate is used in the preparation of Ferro Nano fluid. The water from the container has to be decanted. After the process a wet Ferro fluid is observed. To remove remaining water the Ferro fluid is kept in oven and heated up to certain temperature. Ferro particles are formed in the form of flakes. These ferrous flakes are to be grinded into fine powder.

Fig-2.1 Combination of $FeCl_3$ and $FeSO_4$
(Before titration)

Fig-2.2 Titration of $FeCl_3$ and $FeSO_4$ using Ultra Sonication.

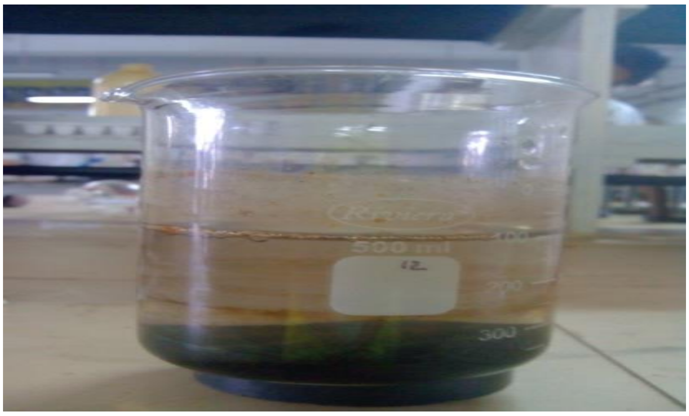


Fig-2.3 Separation of Magnetic Ferro fluid at the bottom of the container with a strong magnet.

Considering SAE20W50 engine oil as base fluid and calculating the volume fraction by the below formula Nano fluid is prepared.

$$\% \text{ volume concentration}, \phi = \left[\frac{\left(\frac{W_{nf}}{\rho_{nf}}\right)}{\left(\frac{W_{nf}}{\rho_{nf}} + \frac{W_{bf}}{\rho_{bf}}\right)}\right] \times 100$$

Where

W_{nf} = Weight of Nano fluid, W_{bf}= Weight of base fluid, ρ_{nf}= Density of Nano fluid, ρ_{bf} = Density of base fluid.

Using the above formula volume fraction is calculated as 0.1%, 0.2%, 0.3%, 0.4%. For 0.1% volume fraction 500ml of engine oil and 2.95gm of Nano powder is added and it was subjected to ultrasonication for one hour. Similarly for 0.2%, 0.3% and 0.4% volume fractions 500ml of engine oil for each volume fraction and 5.91gm, 8.868gm and 11.36gm of Nano powder is added respectively and it was subjected to ultrasonication for one hour each. After ultrasonication is completed the Nano fluid is kept into observation for 24hrs, to see whether the nanoparticles are settled down or not. It is observed that nanoparticles do not settle down. Thus the required four samples of Nano fluid are prepared.

2.2 CHARACTERIZATION OF NANO PARTICLES

A scanning electron microscope (SEM) is used to produce images of the sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. From Fig-2.4 shows the observed image produced by SEM analysis for a given Nano powder. Fig-2.5 reveals the qualitative analysis of Fe and O_2 which are present in the prepared sample.

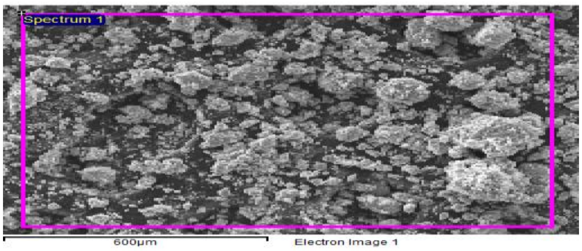


Fig-2.4 SEM analysis image of Ferro Nano powder

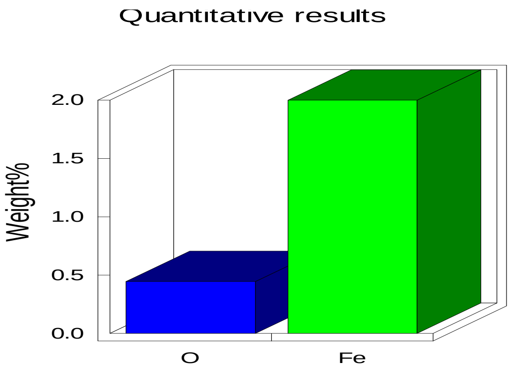


Fig-2.5 Elements present in Ferro Nano powder

3. MEASUREMENT OF THERMO-PHYSICAL PROPERTIES

In engineering applications material properties are required for accurate prediction of their behavior as well for design of components and systems. From literature that thermal conductivity of nanofluids depends on several parameters which include thermal conductivity of the base fluid, temperature and volume fraction. In the current investigation, four different volume concentrations of Ferro nanofluids are prepared independently Φ = 0.1, 0.2, 0.3 and 0.4 Thermal conductivity of these four concentrations and base fluid are studied. Thermal conductivity is measured with KD2 pro a fully portable field and lab thermal properties analyzer. Initially engine oil is poured into the test tube and latter nanofluids are transferred. At first thermal conductivity of fluids were studied at room temperature. From Fig 3.1 for calculating thermal conductivities of four samples including base fluid are studied at temperatures 35°, 40°, 45°, 52°C by heating them using water bath.

Fig-3.1 KD2 Pro instrument with water bath

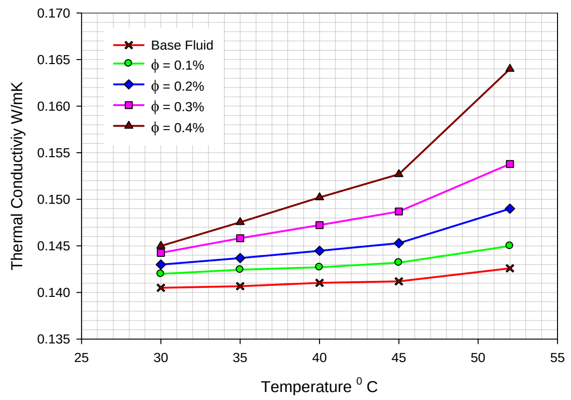
Viscosity is the property of a fluid that determines its resistance to flow. It is an indicator of flow ability of a lubricating oil; the lowest the viscosity, greater the flow ability. It is mainly due to the forces of cohesion between the molecules of lubricating oil. In present work, viscosity of Nano fluids for the four samples and base fluid are studied by using Redwood viscometer- I. Redwood viscometer – I consists of a metal cup with an axially placed orifice in the base The metal cup can be heated and the oil stirred to ensure uniform temperature throughout the oil. When the ball is removed, a thin stream of oil runs into a small graduated glass flask and the time to fill the flask is recorded. This time in seconds is called "seconds Redwood I" and is a measure of viscosity. These seconds Redwood I are converted into stokes of kinematic viscosity using the empirical formula

$$\nu = AT - (B/T)$$

where A and B are viscometer constants and T is seconds Redwood I. Viscosity of Nano fluids of four volume fractions and also base fluids are studied at temperatures 30° C, 40° C, 50° C and 60° C. Viscosity readings of five samples are recorded and data is further used. The flash point is the minimum temperature at which an oil gives out sufficient vapor to form an ignitable mixture with air, and gives a momentary flash on application of a small pilot flame. In the present work Flash and Fire point of four samples and base oil are determined by using Cleveland open cup apparatus. Cleveland open cup apparatus consists of an open oil cup which is about 5cm diameter and 5cm deep. A standard thermometer is inserted into the oil cup and it is fixed to the stand. The oil cup is heated by using electric heater. A test flame is introduced above the oil cup. When the flash is observed the temperature readings shown in the thermometer were noted similarly when the fire is observed the temperature reading shown in the thermometer were recorded. Temperature readings for flash and fire point of four samples and base oil are recorded.

4. Results

The thermo-physical properties of Nano fluids were experimentally estimated for various volume fractions. From Fig- 4.1 It was found that thermal conductivity of Nano fluid increased with increasing operating temperature. The increasing trend of thermal conductivity of the Nano fluids is due to the increasing Brownian motion of the nanoparticles because of the increasing bulk temperature, which is synonymous to an increase in the distribution of nanoparticles in the base fluid. Fig-4.2 clearly states that the thermal conductivity was found increasing proportionately with increase in concentration of nanoparticle in the base fluid.



Fig–4.1 Variation of thermal conductivity with temperature for different volume fractions of Ferro Nano fluid.

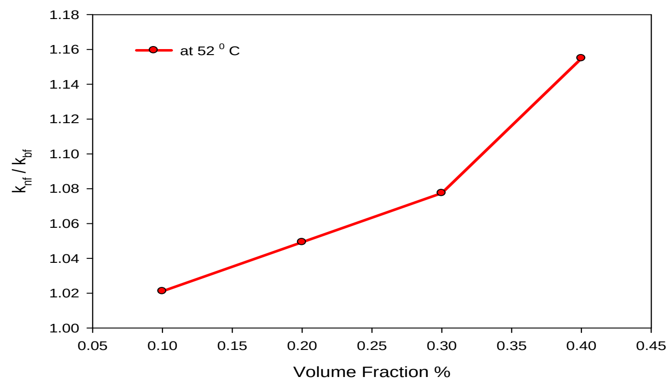


Fig- 4.2 Variation of K_{nf} / K_{bf} with volume fraction of Ferro Nano fluid.

The variation of viscosity with temperature was also experimentally verified as literature reveals an increase in viscosity with increase concentration of Nano particles in the base fluid. Fig- 4.3 shows the variation of viscosity with temperature, which reveals that viscosity increase with increase in volume fraction and decrease with increase in temperature. As concentration increases viscosity also increases because as concentration increases nanoparticles agglomerate and create larger and symmetric particle, which prevent movement of oil layers on each other.

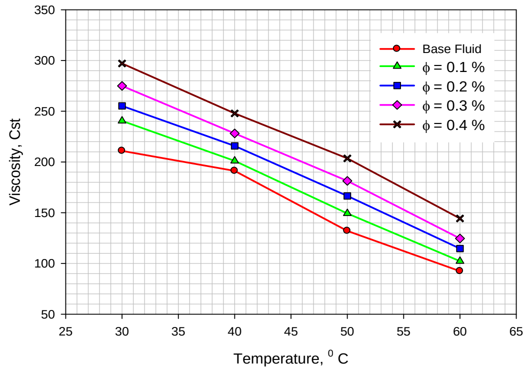


Fig – 4.3 Variation of viscosity with temperature at different volume fractions of Ferro Nano fluid.

The trend changes of flash point as a function of Ferro nanoparticle concentration shown in Fig – 4.4. It can be observed that adding Ferro nanoparticles to the base oil causes an increase in the flash point of the base oil. It can be concluded that the increase of thermal conductivity through adding of nanoparticles is attributed to the increase of oil resistance against ignition. Also, flash point and fire point has a direct relation with concentration of nanoparticles, although this relation is not linear and the intensity changes in lower concentrations are more than the changes in higher concentrations.

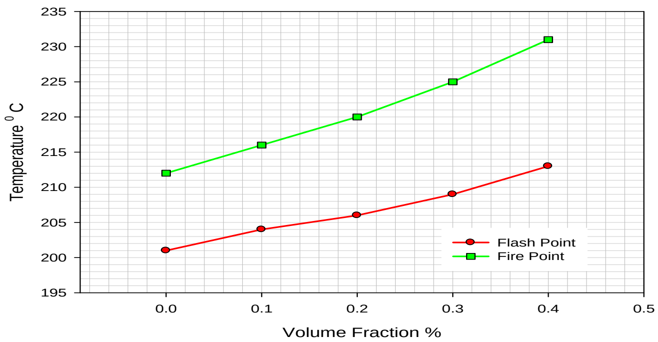


Fig- 4.4 Variation of Flash and fire point with temperature of Ferro Nano fluid

7. CONCLUSION

The following conclusions are made from the experimental observations are Thermal conductivity of Ferro Nano fluid increased with increase in temperature by an average of 15%. In addition the increase of thermal conductivity is observed with increase in the volume fraction of Ferro Nano particle in Nano Fluid. Viscosity of Ferro Nano fluid was found increasing with increase in volume fraction of nanoparticles on an average of 54%. Viscosity decreases with increase in temperature. Flash point and Fire points of Ferro Nano fluid increased with increase in concentration of nanoparticles by an average of 5% & 8%..

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