EFFECT OF NANOFLUID ON EFFICIENCY OF CENTRIFUGAL PUMP

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Abstract

Various nano sized particles are mixed in a base fluid to prepare nanofluid. Typical nanoparticles used are of metals, oxides or carbides which are mixed in base fluids like water, ethylene glycol or oil depending upon the application. Generally, nanofluids are used to enhance heat transfer rate. Because of application of nanofluid, resistance to fluid flow increases which increases the friction factor and reduces the flow rate. This phenomenon also affects the performance of centrifugal pump. In the present paper, an experimental investigation is carried out to determine the effect of various concentration of Al_2O_3 nano-dispersion and CuO nanoparticles mixed in water as base fluid on efficiency of centrifugal pump. The Al_2O_3 and CuO nanofluid prepared in volume concentrations of 0.001 %, 0.002 %, 0.003 % and 0.004 % by using two step method. The results show that the efficiency of centrifugal pump decreases with increase in volume concentration of Al_2O_3 nano-dispersion and CuO nanoparticles compared to water.

Keywords: *Nanofluid, Efficiency, Centrifugal Pump, Al_2O_3 Nano-dispersion, CuO Nanofluid.*

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1. INTRODUCTION

Nanofluid is a prepared by mixing nano sized particles in a fluid. The Most commonly used nanoparticles are made of metals, oxides or carbides having sizes up to 100 nm. They are mixed with fluid known as base fluids like water, ethylene glycol or oil. Thermo physical properties of nanofluid are different than the base fluid. Commonly thermal conductivity and viscosity of nanofluids are higher than the base fluid. Hence, the research is carried out to evaluate the effect of nanofluid in enhancement of heat transfer rate in different heat transfer devices. The increase in heat transfer rate mainly depends on type of nanoparticles, size of nanoparticles, shape of nanoparticles, type of base fluid and concentration of nanoparticles in base fluid. Along with the increase in thermal conductivity of the nanofluid, viscosity of the nanofluid also increases, which affects the pumping characteristics of the centrifugal pump used in the heat transfer devices. Many researchers have studied numerically and experimentally the phenomenon of effect of nanofluid on pumping power in different applications. The recently published studies have been referred and presented here.

Chavda N. K. et. al. [1] have experimentally investigated the effect of various concentration of Al_2O_3 nano-dispersion mixed in water as base fluid. They have employed volume concentrations of Al_2O_3 nanofluid 0.001 %, 0.002 %, 0.003 % and 0.004 %. They have found that friction factor and loss coefficient of different pipes and pipe fittings increase with increase in volume concentration of Al_2O_3 nano-dispersion compared to water. Said Z. et. al. [2] have analyzed entropy generation, heat transfer enhancement capabilities and pressure drop for a flat-plate solar collector operated with single wall carbon nanotubes (SWCNTs) based nanofluids as an absorbing medium. They have observed that using SWCNTs nanofluid reduces the entropy generation by 4.34% and enhances the heat transfer coefficient by 15.33% theoretically compared to water as an absorbing fluid. They have also found that there is a penalty in pumping power to operate solar collector which is 1.20% higher than the water as a working fluid.

Syam Sundar L et. al. [3] have experimentally estimated the convective heat transfer coefficient and friction factor for fully developed turbulent flow of MWCNT–Fe3O4/water hybrid nanofluids for particle loadings of 0.1 % and 0.3 % flowing through a uniformly-heated-at-constant-heat-flux circular tube. Their results indicate enhancement in Nusselt number with a penalty of increase of pumping power as compared to base fluid data.

Mital M. [4] has studied the effect of nanofluid with goals to evaluate heat transfer improvement of a nanofluid heat sink with developing laminar flow forced convection, taking into account the pumping power penalty. Their statistical analysis of the model showed that the volume fraction is the most significant factor impacting the heat transfer enhancement ration, followed by the particle diameter.

Gherasim I. et. al. [5] have presented the numerical investigation of heat transfer enhancement capabilities of coolants with suspended nanoparticles (Al_2O_3 dispersed in water) inside a confined impinging jet cooling device. Their results indicate that heat transfer enhancement is possible in this application using nanofluids. They have also noticed that increase in associated pumping power may impose some limitations on the efficient use of this type of nanofluid in a radial flow configuration.

Most of the researchers have studied the pumping power phenomenon of the nanofluid along with the heat transfer characteristics for particular application using different nanofluids. The separate study related to the effect of nanofluid on efficiency of centrifugal pump is required to explore the effect of nanofluid.

In actual practice, several heat transfer equipments are connected in serial and/or parallel to transfer the heat as per requirements of the process/product along with furnaces, columns etc. The heat transfer fluid has to flow through them which require the use of centrifugal pumps. Thus it becomes essential to evaluate the effect of nanofluid efficiency of centrifugal pump separately rather than considering along with heat transfer characteristics for a particular application. Therefore, the effect of nanofluid prepared by dispersing Al_2O_3 nano-dispersion in water and CuO in water in different volume concentration on efficiency of centrifugal pump have been evaluated experimentally in the paper.

2. EXPERIMENTAL SETUP AND PROCEDURE

The experimental setup required to evaluate the effect of nanofluid on efficiency of centrifugal pump is available in fluid power engineering laboratory of mechanical department of A. D. Patel Institute of Technology. Detailed specifications and procedure for experimentation are as follow.

2.1 Apparatus for Centrifugal Pump

The apparatus is shown in Figure 1.

Fig 1- Apparatus of Centrifugal Pump

Centrifugal pump having discharge capacity of 360 LPM and speed 1440 rpm is coupled with electric motor in the apparatus having arrangement to measure suction pressure, discharge pressure, single phase energy meter with constant of 180 rev/kWh to measure input power, measuring tank of area 0.49 m^2 to measure the discharge through the pump and a storage tank to store the fluid for experimentation. The difference of height between suction and discharge pressure gauge is 0.28 m.

2.2 Experimental Procedure for Centrifugal Pump

The experimental procedure for centrifugal pump is described below.

(1) Fill the tank with the water.
(2) Prime the pump if necessary, open the delivery valve partially and switch on the unit.
(3) Adjust the delivery valve and required delivery pressure.
(4) Record the delivery and suction pressure.
(5) Close the drain valve of measuring tank and record the time for 10 cm rise of water level in the measuring tank.
(6) Record the time taken for 1 revolution of energy meter also.
(7) Repeat the experiment (step 3 to step 6) for different delivery pressure.
(8) Empty the storage and measuring tank completely.
(9) Prepare the nanofluid using Al2O3 nano-dispersion in water in different volume concentration and fill the storage tank with the same.
(10) Repeat the experiment step 3 to step 7 for Al2O3 nanofluid.
(11) Empty the storage and measuring tank completely.
(12) Prepare the nanofluid using CuO nanoparticle in water in different volume concentration and fill the storage tank with the same.
(13) Repeat the experiment step 3 to step 7 for CuO nanofluid.
(14) Empty the storage and measuring tank completely.

2.3 Calculation Steps for Centrifugal Pump

The calculation steps for evaluation of efficiency of centrifugal pump are as below.

(1) Calculation of head generated by the centrifugal pump

$$H = \frac{P_d \times 10^4}{\rho_{liquid}} - 0.0136 \times P_s + \frac{(V_d^2 - V_s^2)}{2 \times g} + (Z_s - Z_d)\ m^2 \text{.....(1)}$$

The length of suction and deliver pipe is very small as the laboratory scale experimental set up is used. Due to this reason, the value of the term $\frac{(V_d^2 - V_s^2)}{2 \times g}$ is very very small, thus it is neglected.

(2) Calculation of discharge through the pump

$$Q = \frac{Volume\ \ of\ Water\ \ Collected}{Time}\ \ m^3/sec \text{ ....…..... (2)}$$

(3) Power required to drive the pump

$$P = \frac{\rho g Q H}{1000}\ kW \ \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

(4) Power supplied to the pump

$$P = \frac{3600 \times Number\ of\ Revolution}{\left\{\begin{matrix} Energy\ Meter \\ Constant \end{matrix}\right\} \times \left\{\begin{matrix} Time\ Required\ for\ no.\ of \\ Revelution\ in\ Energy\ Meter \end{matrix}\right\}}\ kW \ldots\ldots(4)$$

(5) Calculation of Efficiency of the Pump

$$\eta = \frac{Power\ Required\ to\ Drive\ the\ Pump}{Power\ Supplied\ to\ the\ Pump} \ldots\ldots\ldots(5)$$

3. PREPARATION OF NANOFLUID

Two techniques are used to make nanofluids viz. (1) the single-step direct evaporation method, which simultaneously makes and disperses the nanoparticles directly into the base fluids and (2) the two-step method which first makes nanoparticles and then disperses them into the base fluids. In either case, a well-mixed and uniformly dispersed nanofluid is needed for successful reproduction of properties and interpretation of experimental data. For nanofluids prepared by the two-step method, dispersion techniques such as high shear and ultrasound can be used to create various particle/fluid combinations.

In the present analysis, two-step method has been employed to prepare nanofluid. Al_2O_3 nano-dispersion (AlO(OH)) and CuO nanoparticles has been purchased from M/s. Jyotirmay Overseas, Rajkot. Al_2O_3 nano-dispersion of 50 nm size has 1190 kg/m^3 density and 10 cps viscosity. CuO nanoparticles are of 40 nm size has 6310 kg/m^3 density.

The proportion of Al_2O_3 nano-dispersion and CuO nanoparticles to be mixed with base fluid i.e. water for different volume concentration is calculated using equation number 7 and density of nanofluid is calculated using equation number 8.

For different volume concentrations, the mass of nanoparticle to mix with the water is presented in Table 1. The CuO nanofluid prepared is shown in Figure 2.

$$\emptyset = \frac{Volume\ of\ Nanoparticle\ \times 100}{Volume\ of\ Nanoparticle\ + Volume\ of\ water} \ldots\ldots(6)$$

$$\emptyset = \frac{\frac{W_{nanoparticle}}{\rho_{nanoparticle}}}{\frac{W_{nanoparticle}}{\rho_{nanoparticle}} + \frac{W_{water}}{\rho_{water}}} \times 100 \ldots\ldots\ldots(7)$$

$$\rho_{nanofluid} = \emptyset \rho_{nanoparticle} + (1 - \emptyset)\rho_{water} \ldots\ldots(8)$$

Table -1: Mass of Al_2O_3 and CuO Nanoparticles to Mix with the Water for Different Volume Concentration

Volume Concentration, φ	0.001 %	0.002 %	0.003 %	0.004 %
Case Number	Case B	Case C	Case D	Case E
Mass of Al_2O_3 Nano-dispersion to be mixed with water in grams	2.023	4.046	6.069	8.092
Mass of CuO Nanoparticles to be mixed with water in grams	10.73	21.45	32.18	42.91
Quantity of Base Fluid i.e. Water in litres	170	170	170	170

Fig. 2: CuO Nanofluid

4. INTEGRATED RESEARCH METHODOLOGY

The integrated methodology adopted to evaluate the effect of nanofluid on efficiency of centrifugal pump is as under.

(1) Fill the water in apparatus for centrifugal pump and conduct the tests as per the experimental procedure for centrifugal. This is termed as Case A.
(2) Calculate the efficiency of the centrifugal pump as per the calculation steps for water.
(3) Empty the water from the both the tanks of apparatus for centrifugal pump.
(4) For Case B, prepare the nanofluid by mixing 2.023 grams of Al_2O_3 nanoparticles in water of 170 liters.
(5) Perform the experimentation for Case B as per the step number 1 to 3 of integrated research methodology.
(6) Perform the experimentation for Case C, Case D and Case E as per the step number 1 to 3 of integrated research methodology.
(7) For Case B, prepare the nanofluid by mixing 10.73 grams of CuO nanoparticles in water of 170 liters.

(8) Perform the experimentation for Case B as per the step number 1 to 3 of integrated research methodology.
(9) Perform the experimentation for Case C, Case D and Case E as per the step number 1 to 3 of integrated research methodology.
(10) Compare the results.

5. RESULTS AND DISCUSSION

Actual experimentation on apparatus of centrifugal pump has been carried out as per integrated research methodology. The results for centrifugal pump are tabulated in Table No. 2 and represented graphically in Figure No. 3.

Table -2: Result for Centrifugal Pump

Type of Fluid used in Centrifugal Pump	Case Number	Efficiency of Pump in %	
		Type of Nanofluid	
		Al_2O_3	CuO
Water	Case A	24.04	24.04
Nanofluid with Φ=0.001%	Case B	19.06	20.85
Nanofluid with Φ=0.002%	Case C	18.80	18.47
Nanofluid with Φ=0.003%	Case D	18.16	18.06
Nanofluid with Φ=0.004%	Case E	17.73	17.97

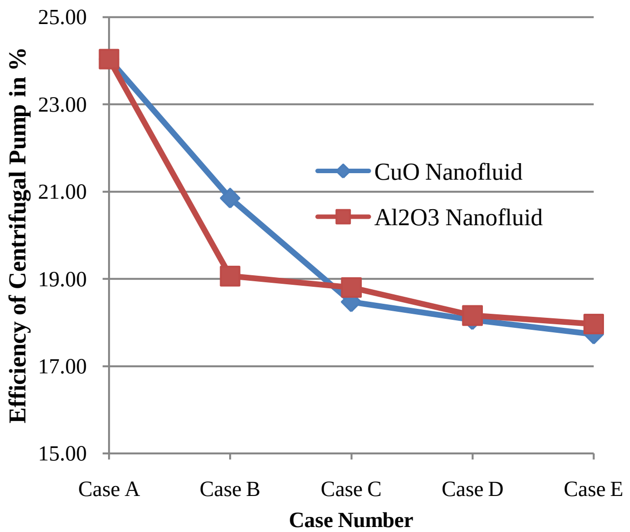

Fig -3: Result of Centrifugal Pump

The efficiency of centrifugal pump decreases with increase in volume concentration of Al_2O_3 and CuO nano-particles in water. The maximum percentage of decrease in efficiency of centrifugal pump found for the volume concentration of 0.004 % of Al_2O_3 and CuO nano-particles in water are 25 % and 26 % respectively.

6. CONCLUSION

An experimental investigation is carried out to determine the effect of various volume concentrations of Al_2O_3 and CuO nano-particles mixed in water as base fluid on efficiency of centrifugal pump. The volume concentrations of Al_2O_3 ans CuO nanofluid prepared are 0.001 %, 0.002 %, 0.003 % and 0.004 %. It has been found that the efficiency of centrifugal pump decreases with increase in volume concentration of Al_2O_3 and CuO nano-particles as compared to base fluid i.e. water.

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BIOGRAPHIES

Dr. N. K. Chavda has completed M. E. (Mech) from SVNIT, Surat and Ph. D. from The M. S. University of Baroda. He has 19 years of teaching experience and published many papers in International Journals/Conference. He has been awarded with "**Best Polytechnic Teacher"** by ISTE, New Delhi and **"The Dronacharya Award"**, for the admirable contribution in teaching-learning and overall development of students adjudged by ADIT and CVM.

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