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EXPERIMENTAL SETUP INVESTIGATION OF NANO PARTICLES OF ALUMINIUM AND HEAT TRANSFER RATE IN A WATER BASED NANO FLUID

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ABSTRACT

The purpose of this project is to explore relationship between volume fraction of nano particles of aluminium and heat transfer rate in a water based nano fluid. Experimental investigation setup will be fabricated. It will resemble a heat exchanger and consists of hot water pump, G.I tubes, flow control valve and temperature measuring devices. Experimental investigation is done. The values are noted down in tables and the changes are noted in this phase. The patterns are noted down and conclusions are derived. In this phase the properties of heat transfer fluid is found including heat transfer and specific heat capacity.

INTRODUCTION

Nano technology

Nanotechnology is the manipulation of matter on an atomic, molecular, and supra molecular scale. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macro-scale products, also now referred to as molecular nanotechnology. A more generalized description of nanotechnology was subsequently established by the National Nanotechnology Initiative, which defines nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometres. This definition reflects the fact that quantum mechanical effects are important at this quantum-realm scale, and so the definition shifted from a particular technological goal to a research category inclusive of all types of research and technologies that deal with the special properties of matter that occur below the given size threshold.

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Nano fluid

The nano fluid is prepared by mixing aluminium nanoparticle of size 900nm with water. The fluid is prepared in different volume fractions that is 5, 10, 15 and 20. Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes.

Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra-high cooling applications. Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory (Maxwell, 1873) for effective properties of mixtures.

Fig. 1.3 Nano Fluid

Properties of nano fluid

It may be noted that particle size is an important physical parameter in nano-fluids because it can be used to tailor the nano-fluid thermal properties as well as the suspension stability of nanoparticles. Researchers in nano-fluids have been trying to exploit the unique properties of nano particles to develop stable as well as highly conducting heat transfer fluids. The nano fluid is prepared by colloidal suspension of nano particle in a base fluid. Typically they are made of metals, oxides, carbides or carbon nano tubes. Common base fluids include water, ethylene glycol and oil. They exhibit enhanced thermal conductivity and convective heat transfer coefficient compared to base fluid.

Preparation of nano fluid

Single step preparation method is used. The single-step preparation process indicates the synthesis of nano fluids in one-step. The nano fluid is prepared by dispersion of aluminium into water as base fluid. The particle size is 900 nm. The factors to be kept in mind while preparing is that the compatibility between nano particles and the base fluid. If they are not compatible this will lead to agglomeration causing poor stability and low heat transfer capacity.

Applications of nano fluid

Realizing the modest thermal conductivity enhancement in conventional nano-fluid, a team of researchers at Indira Gandhi Centre for Atomic Research Centre, Kalpak am developed a new class of magnetically polarisable nano-fluids where the thermal conductivity enhancement up to 300% of base fluid is demonstrated. Fatty-acid-capped magnetite nanoparticles of different sizes (3-10 nm) have been synthesized for this purpose.

Water based Nano Fluids

Nano-fluids with different combinations has been investigated covering a wide range of surface superheat. Boiling curve has also been constructed for nano-fluids having surfactant as a stabilizer. Finally, repeated test runs have been taken using the same the boiling surface to investigate the effect of surface roughness. The effect of nano particle can depends on number of parameter like composition, shape, size, concentration agglomeration etc. Therefore, it is too early to predict generalize the heat transfer behaviour of nano-fluids. A large number of systematic experiments under controlled conditions are needed to ascertain the effect of each parameters of the nano-fluid on boiling heat transfer.

PROBLEM DESCRIPTION AND PROPOSED SOLUTION

Problem Description

Heat transfer enhancement requirement is increased day by day. Nano-fluid technology is used in heat transfer applications efficiently. Therefore, researchers are interested in this field. Researches will be based on thermal properties of different nano fluid combinations. Those are metals, oxides, nitrides with various cooling liquids. There are no literatures clearly available over hybrid combination of copper, aluminium and water based nano fluid.

Proposed solution

In the present scenario the need for efficient heat transfer is more with less wastage. Mostly the heat transfer used in industrial cases are for reducing the heat output and also for reducing the energy consumption and wastage for the case of heat transfer an appropriate medium is required. This is because the heat transfer is done mostly on the basis of indirect heat transfer. That is as in case of an indirect heat exchanger a medium is used to transfer heat and most importantly the medium should not be in contact.

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EXPERIMENTAL INVESTIGATION

Table 1.1 Experimental Readings

Sl.no.	Volume Fraction (%)	Total Heat Rejection of Water (W)	Heat Rejection of Water to Atmosphere (W)	Heat Transfer of Nano Fluid (W)
1	5	6633.2	61.83	6571.37
2	10	8244.12	60.2064	8183.91
3	15	9476	61.83	9414.17
4	20	10518.36	62.81	10455.55

Experimental Procedure

Heat transfer rate is calculated from temperature difference between initial and final temperatures of water. Initial temperature is measured at inlet of two liquids at start up of the experiment.

Final temperature is measured at outlet. Velocity of water and nano fluid for circulation is constant for all volume fractions of Nano-Fluid (Different volume fractions of Water-Aluminium Nano-Fluid will be prepared for experimentation). Hot water is pumped from reservoir and circulated through shell side. Tube side, nano fluid is pumped.

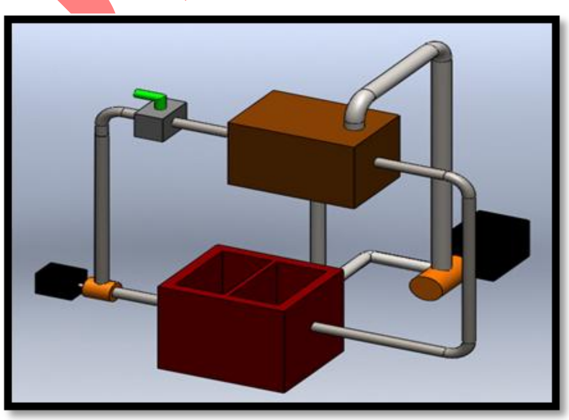

Fig. 1 Experimental Setup

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Equipment Details

Pump

Centrifugal pump is used for circulate water, it collects hot water from container and circulates through pipe. Then, water is delivered to cold water tank same for nano fluid. Pump configuration for experiment is as follows:

Speed (S)	:	2880 Rpm
V & I	:	230Volt @ 3.2 Amps (Current)
Power (P)	:	0.5HP
Head (H)	:	20m
Discharge (Q)	:	16 LPM

Experimental Data

Table 1.2 Total Heat rejection of Water

Sl.No.	Volume fraction (%)	Nano Fluid Inlet Temp (°C)	Nano Fluid Outlet Temp (°C)	Water Fluid Inlet Temp (°C)	Water Fluid Outlet Temp (°C)
1.	5	26	29	65	58
2.	10	26	29.5	65	56.3
3.	15	26	30.1	65	55
4.	20	26	30	65	53.9

Heat transfer is calculated from following formula:

$$Q = m_w * C_{pw} * (T_1 - T_2)$$

Heat rejection to atmosphere is calculated as following: $Q_a = U\ A\ (T_1 - T_2)$

Table 1.3 Heat rejection of Water to atmosphere

Volume of N.F (Container) (m^3)	Density (Kg/m^3)	Fraction	Fractioned Volume (m^3)	Mass (Kg)
0.03656	705	0.05	0.001828	1.28874
0.03656	705	0.1	0.003656	2.57748
0.03656	705	0.15	0.005484	3.86622
0.03656	705	0.2	0.007312	5.15496

Table 1.4 Heat absorbed by Nano fluid

S.No.	Volume Fraction (%)	Overall Heat transfer co-efficient ($W/m^2.K$)	Surface Area (m^2)	Temp Difference (°C)	Heat Transfer (W)
1	5	11.3	0.288	19	61.83
2	10	11.3	0.288	18.5	60.2064
3	15	11.3	0.288	19	61.83
4	20	11.3	0.288	19.3	62.81

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Table 1.5 Specific heat capacity of nano fluid

S.No.	Volume Fraction (%)	Heat Transfer of Nano Fluid (W)	Mass Flow rate (Kg/s)	Temp Difference (°C)	Specific heat capacity (J/Kg.°C)
1	5	6571.37	0.54	3	4056.40
2	10	8183.91	0.54	3.5	4330.11
3	15	9414.17	0.54	4.1	4358.41
4	20	10455.55	0.54	4	4840.53

Measured by filling tank concept. Volume of tank is known. Then, liquid is filled in tank and time is measured to fill the tank. From that, mass flow rate is calculated. [Q / sec = V of tank / time to fill the tank in sec].

Table 1.6 Mass of Aluminium Particles Used for Experiments

S.No.	Volume Fraction (%)	Mass Flow rate (Kg/s)	Specific heat capacity (J/Kg.°C)	Temp Difference (°C)	Heat Transfer (W)
1	5	0.23	4120	7	6633.2
2	10	0.23	4120	8.7	8244.12
3	15	0.23	4120	10	9476
4	20	0.23	4120	11.1	10518.36

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Model Calculation

i. Total heat rejection of water

$Q = mc_p (T_1 - T_2)$

$= 0.23 * 4120 * 7$

$= 6633.2$ W

ii. Heat rejection of water to atmosphere

A = Surface area of shell

Length = 420 m

Breadth = 300 mm

Width = 200 mm

$A = 2*(l*w) + (2*(b*w))$

$= 2*(0.42*0.2) + (2*(0.3*0.2))$

$= 0.288$ m^2

$Q = UA\,\Delta T$

$= 11.3*0.288*19$

$= 61.83$ W

iii. Heat absorbed by nano fluid

Heat transfer of nano fluid = total heat rejection of water–heat rejection of water to atmosphere = 6633.2 - 61.83

= 6571.37 W

iv. Specific heat capacity of nano fluid

$Q = UA\,\Delta T$

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$6571.37 = 0.54 * c_p * 3$

$c_p = 4056.4$ J/kg^{o}C

RESULTS

By recording the readings and tabulating it we get the following readings. A graph can be plotted for the values. Hence a curve can be observed. The curve

Table 1.7 volume fraction vs heat transfer

Si no	Volume fraction	Heat transfer[W]
1	5%	6571.37
2	10%	8183.91
3	15%	9414.17
4	20%	10455.55

Shows that as the volume fraction increases the heat transfer also increases.

The curve shows a positive change during the addition of nano particles and more over increases as the volume fraction increases. This graph is roughly plotted to observe the nature in which the heat transfer changes. Further in detail a curve is plotted using a MATLAB software. studying it will give the detailed change in characters while nano fluid is used.

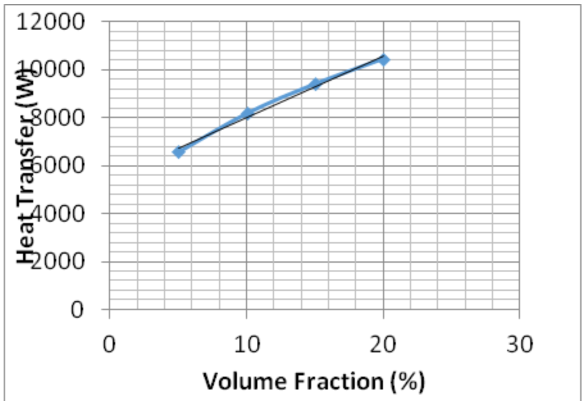

Figure 2 heat transfer Vs volume fraction

By simply plotting these values in a table we obtain the following graph hence we could learn the trends.

Si no	Volume fraction	Specific heat capacity
1	5%	4056.40
2	10%	4330.11
3	15%	4358.41
4	20%	4840.53

Table 5.9 volume fraction vs specific heat capacity

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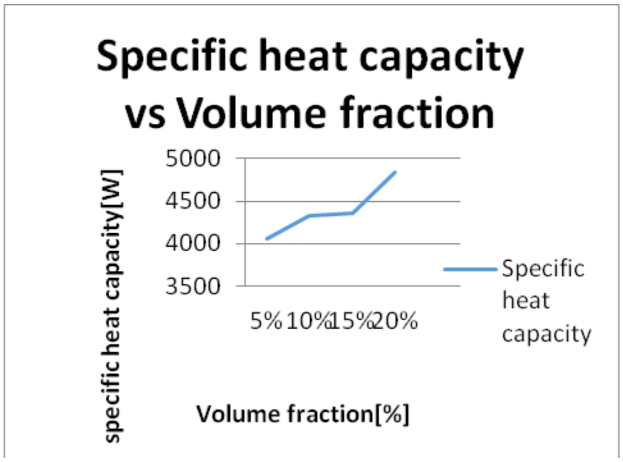

Figure 3 volume fraction vs specific heat capacity

The detailed studies can be done by using the graph plotted by the MATLAB software. By this we could obtain the following curve as shown. The curves are in such a way that the specific heat capacity increases as the volume fraction increases. The main advantage is that we could choose particular volume fraction fluid according to the need of the situation. Since different situation need different heat transfer the fluid selected must be varied with it. This purpose can be easily served using this project.

MATLAB readings

Based on the readings obtained during the experiments done the readings can be tabulated. And these readings were plotted by using MATLAB. Curve fitting is done using experimental data in scientific computing tool MATLAB. From that, specific heat capacity of water aluminium nano fluid as a function of volume fraction of nano particles in base fluid is obtain. Fitted curve and function is given below. In this relation x is volume fraction and f(x) is the dependent specific heat capacity of nano fluid, the coefficient are determined to polynomial curve fitting method with R-Square equal to 1. The following is the empirical relation between volume fractions to specific heat capacity of nano fluid in the range of 5 to 20.

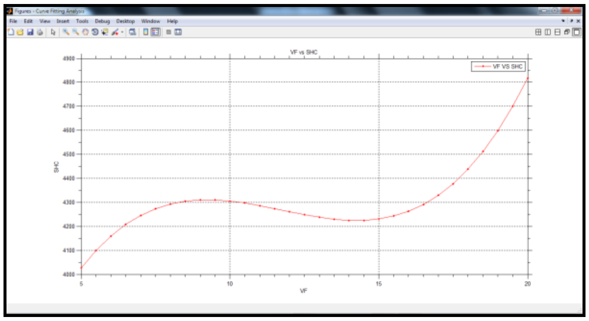

Figure 4 Fitted Curve

From the graph obtained we could see that actually the heat transfer increases with increase in volume fraction up to the limit 20%. In between there is a slight decline in curve. We could see this is between the values 10% and 15%. After the 15% the curve starts to gain value. Hence the heat transfer increases as there is an increase in specific heat capacity.

Empirical Relation

F(x) = 1.355x3 – 47.71x2 + 534.3+ 2379

where F(x)= specific heat capacity

x= volume fraction

CONCLUSION

From literature review, we concluded that nano fluid technology is developing field. Many researches are going on this to study properties and fraction prediction for getting desirable properties. Literature is done in point of benefit of nano fluids, pure metal nano fluids, water based nano fluids and fraction influence of nano particles in base fluid. From review, we have decided to concentrate on influence volume fraction of aluminium nano particles in water. It will lead to get relationship between heat transfer rate and volume fraction of aluminium-water nano fluid in volume fractions 5%,10%,15%,20%.

The purpose of this project is to explore relationship between volume fraction of nano particles of aluminium and heat transfer rate in a water based nano fluid. Experimental investigation setup will be fabricated. It will resemble a heat exchanger and consists of hot water pump, G.I tubes, flow control valve and temperature measuring devices. Experimental investigation is done. The values are noted down in tables and the changes are noted in this phase . The patterns are noted down and conclusions are derived . In this phase the properties of heat transfer fluid is found including heat transfer and specific heat capacity.

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MATLAB CODE FOR CURVE FITTING

```
%Curve Fitting Code
clc;
clear all;
 %Data
VF = [ 5    10    15    20];
SHC = [4026.818 4305.425    4230.463    4817.995];
 % Set up figure to receive data sets and fits
f_ = clf;
figure(f_);
set(f_,'Units','Pixels','Position',[1 41 1366 595],'NumberTitle','off','Name','VF vs SHC');
% Line handles and text for the legend.
legh_ = [];
legt_ = {};
% Limits of the x-axis.
xlim_ = [Inf -Inf];
% Axes for the plot.
ax_ = axes;
set(ax_,'Units','normalized','OuterPosition',[0 0 1 1]);
set(ax_,'Box','on');
grid(ax_,'on');
axes(ax_);
hold on;
```

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```
% --- Plot data that was originally in data set "SHC vs. VF"
VF = VF(:);
SHC = SHC(:);
h_ = line(VF,SHC,'Parent',ax_,'Color',[0.333333 0 0.666667],...
    'LineStyle','none', 'LineWidth',1,...
    'Marker','.', 'MarkerSize',12);
xlim_(1) = min(xlim_(1),min(VF));
xlim_(2) = max(xlim_(2),max(VF));
legh_(end+1) = h_;
legt_{end+1} = 'SHC vs. VF';
% Nudge axis limits beyond data limits
if all(isfinite(xlim_))
    xlim_ = xlim_ + [-1 1] * 0.01 * diff(xlim_);
    set(ax_,'XLim',xlim_)
else
    set(ax_, 'XLim',[4.8499999999999996, 20.149999999999999]);
end
% --- Create fit "VF vs SHC"
ok_ = isfinite(VF) & isfinite(SHC);
if ~all( ok_ )
    warning( 'GenerateMFile:IgnoringNansAndInfs','Ignoring NaNs and Infs in data.' );
end
ft_ = fittype('poly3');
```

```
% Fit this model using new data
cf_ = fit(VF(ok_),SHC(ok_),ft_);
% Plot this fit
h_ = plot(cf_,'fit',0.95);
set(h_(1),'Color',[1 0 0],'LineStyle','-', 'LineWidth',2,'Marker','none', 'MarkerSize',6);
% Turn off legend created by plot method.
legend off;
% Store line handle and fit name for legend.
legh_(end+1) = h_(1);
legt_{end+1} = 'VF vs SHC';
% Finished fitting and plotting data. Clean up.
hold off;
% Display legend
leginfo_ = {'Orientation', 'vertical', 'Location', 'NorthEast'};
h_ = legend(ax_,legh_,legt_,leginfo_{:});
set(h_,'Interpreter','none');
% Remove labels from x- and y-axes.
xlabel(ax_,'');
ylabel(ax_,'');
```

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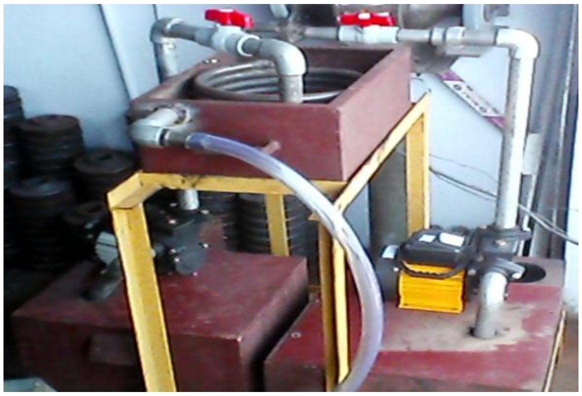
PHOTOGRAPHIC VIEW OF THE EXPERIMENTAL SETUP



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