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CFD Analysis of Nano Fluid through Channel

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ABSTRACT

In this paper experimental study conducted on behaviors of Nano fluid to improve the performance of a circular heat pipe. An experiment setup is designed and constructed to study the heat pipe performance under different operating conditions. The effect of volume fraction of Nano particle in the base fluid and heat input rate on the thermal resistance is investigated. The study of Nano fluids has lately gained scientific interest, due to their enhanced thermal conductivity, which would significantly improve the performance of heat transfer equipment. The aim of the present work is to determine pressure and pipe friction analysis on different size of channel. The objective of this study is to highlight the heat transfer enhancement using water + Al_2O_3, Water +CuO as a Nano fluids compared to the base fluid (e.g. Water). The different Nano particles used in this study are Al_2O_3 and CuO at 1% particle volume fraction and 0.05W and 0.5W pumping power. The experimental data is compared to the available data from the simulation work on ANSYS.

Keywords: Pipe friction apparatus, Nano fluid, Volume fraction, Pumping power, Al_2O_3 + Water, CuO + Water, Simulation

NOMENCLATURE

A	Area, m^2
C_p	Specific Heat, J/kg.K
°C	Celsius
D	Diameter of pipe
°F	Fahrenheit
F	Friction factor
g	Acceleration due to gravity, m/s^2
h	Convective heat transfer coefficient, $W/m^2.K$

h_f	Head difference, m
K	Thermal conductivity, W/m.K
L	Length of pipe, m
m	Mass flow rate, kg/s
P	Pressure, Pa
Q	Discharge, m^3/sec
S_m	Specific gravity of mercury
S_w	Specific gravity of water
v	Velocity of flow, m/s
ρ	Density, Kg/m^3
μ	Dynamic viscosity, Pa.s
Φ	Volume Fraction particles
[ ]	References

1. INTRODUCTION

Nano fluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. Common base fluids include water, ethylene glycol and oil. Nano materials can be metals, ceramics, polymeric materials, or composite materials whose size is in the range of 1-100 nanometers (nm). Nano fluids are suspensions of metallic or nonmetallic Nano powders in base liquid and can be employed to increase heat transfer rate in various applications.

Nano fluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, nuclear reactor coolant, in grinding, machining, in space technology, defense and ships and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Heat transfer coefficient increases by increasing the concentration of nanoparticles in Nano fluid.

Traditional heat transfer fluids such as water, ethylene glycol and oil have inherently low thermal conductivity relative to metals and even metal oxides. In particular, large particles tend to quickly settle out of suspension and thereby in passing through micro channels cause severe clogging and increase the pressure drop considerably.

Modern technology makes it possible to produce ultrafine metallic or nonmetallic particles of nanometer dimensions, which makes a revolution in heat transfer enhancement methods. Considering very small particle size and their small volume fraction, problems such as clogging and pressure drop increasing become insignificant for Nano fluids.

Fig.1.1 shows the pipe friction Apparatus with and without use of Nano fluid particles.

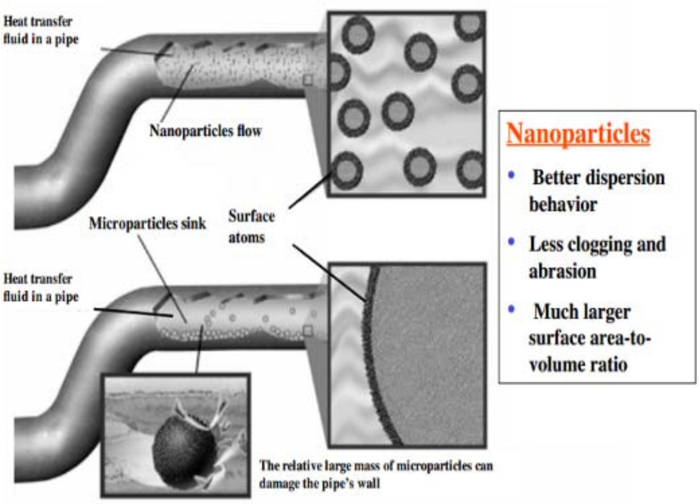


Fig 1.1. Images of pipe analysis with and without Nano fluid particles

Therefore, when used to improve the design and performance of thermal management system, Nano fluids offer several benefits.

2. Experimental Analysis And Simulation Of Pipe Friction Apparatus By Adding Nano Fluid Particles

The pipe friction apparatus as shown in Fig 2.1 consists of tube with different diameters of 10 mm, 20 mm and 8 mm. Closed conduit refers to a channel that is completely enclosed by its solid boundary and is fully floating. If it is not fully floating then it has to be considered to be an open channel. Majority of closed channel have circular cross section. Pipe is an example of closed conduits.

Head loss occurs due to friction in pipe and change in velocity or direction. These head loss have to be found out in order to find out the total power requirement for transporting the fluids in pipes and other conduits. The head loss for liquids in closed conduits is directly proportional to the length of the conduit and the square of the velocity of the fluid. These parameter are included in Darcy's equation:

$$h_f = \frac{flv^2}{2gD}$$

Head difference in terms of water is given by,

$h_f = h_m (S_m - S_w)$

Where,

h_m = Difference of head in terms of mercury.

S_m = Specific gravity of mercury = 13.6

S_w= Specific gravity of water = 1

L = Length of pipe = 1000mm

H = Height of tank = 10 m

Fig.2.1. Model of a Pipe Friction Apparatus

Calculation steps for the 10 mm diameter pipe for the Pumping power,
For 10 mm diameter pipe:
h_1 = 32.5 cm
h_2 = 21.5 cm

$$h_m = h_1 - h_2$$
$$= 32.5 - 21.5 \quad = 11\text{cm} = 0.11 \text{ m}$$
$$h_f = h_m (S_m - S_w)$$
$$= 0.11\ (13.6 - 1)$$
$$= 1.386 \text{ m}$$

Area (A) = $\frac{\pi}{4} d^2 \;\; = \frac{\pi}{4} (0.010)^2 = 7.85 * 10^{-5}$ m^2

Discharge (Q) = $\frac{\text{volume of measuring tank}}{\text{time required}} = \frac{0.016}{55.57} = 2.879 * 10^{-4}$ m^3/sec

Velocity (V) = Q/A = $2.879 * 10^{-4} / 7.85*10^{-5}$ = 3.6678 m/s

Friction factor (f) = $\frac{hf*2*g*D}{L*V^2} = \frac{1.386*2*9.81*0.010}{1*3.6678^2}$ = 0.02021

Mass flow rate (m) = ρAV = $1000*\ 7.85*10^{-5}*3.6678$ = 0.2879 Kg/s

Pressure (P) = ρ g h_m = 1000 * 9.81 * 1.386 = 13596.66 Pa

2.1 Simulation of 10 mm diameter circular pipe by using Ansys :

After testing the apparatus the geometry will be made in Ansys and different simulation approach will be done in the Ansys software by adding the different Nano fluid particles.Fig. 2.2 shows the mesh model of the circular pipe geometry.

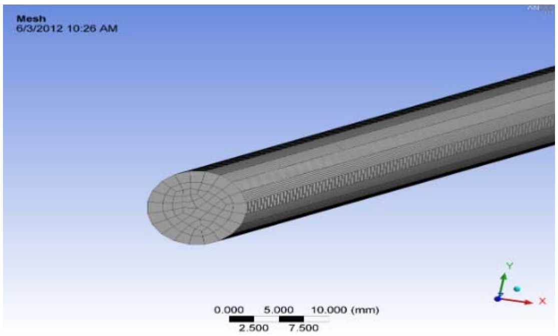


Fig.2.2. Meshed Model of a circular pipe geometry

Boundary condition applied for the 10 mm diameter pipe is shown below;

Boundary type:	Inlet
Boundary details:	Mass flow rate (m = 0.2879 kg/s)
Boundary type:	Outlet
Boundary details:	Static pressure (p = 0 Pa)
Materials:	Water (liquid)

Material properties:

Density (ρ) :	1000 kg / m^3
Specific heat:	4181.7 J / kg.K
Dynamic viscosity:	0.0008899 kg / m.s

Pressure counter diagram for water as a fluid is shown in Fig.2.3.

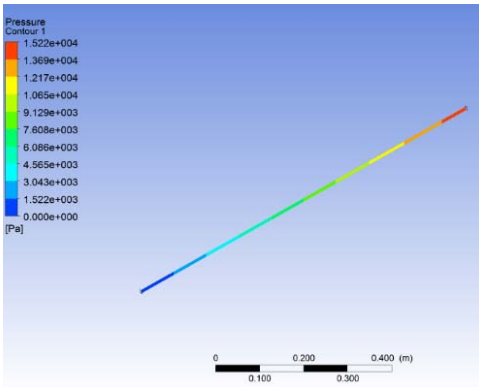
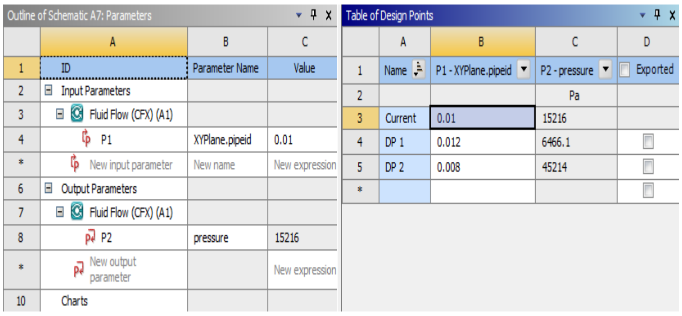


Fig.2.3. Pressure counter diagram for water (liquid)

The analysis of pressure on different sizes of the channel is shown by parameter result as shown in Fig.2.4.


Outline of Schematic A7: Parameters

	A	B	C
1	ID	Parameter Name	Value
2	⊟ Input Parameters		
3	⊟ Fluid Flow (CFX) (A1)		
4	P1	XYPlane.pipeid	0.01
*	New input parameter	New name	New expression
6	⊟ Output Parameters		
7	⊟ Fluid Flow (CFX) (A1)		
8	P2	pressure	15216
*	New output parameter		New expression
10	Charts		

Table of Design Points

	A	B	C	D
1	Name	P1 - XYPlane.pipeid	P2 - pressure	Exported
2			Pa	
3	Current	0.01	15216	
4	DP 1	0.012	6466.1	
5	DP 2	0.008	45214	
*				

Fig.2.4. Pressure reading at different diameter for Water (liquid)

Comparison with Experimental value and Simulation value for Water particles:
Experimental Value = 13596.66 Pa
Simulation Value = 15216 Pa
% Error = 10.64

2.2 The simulation result for Al_2O_3 (Nano fluid) + water (liquid) for 1 % fraction volume and 0.05 w pumping power

Now after adding different Nano particles with water the heat transfer capability of the all heat transfer devices including heat pipe is limited by the working fluid transport properties. To overcome these limitations, the thermo physical properties of the working fluid have to be improved. The heat transfer rate of heat transfer devices can be improved by adding additives to the working fluids to change the fluid transport properties and flow features.

Pressure counter diagram for Al_2O_3 (Nano fluid) + water (liquid) as a fluid for 1 % fraction volume and 0.05 w pumping power is shown in Fig.2.5.

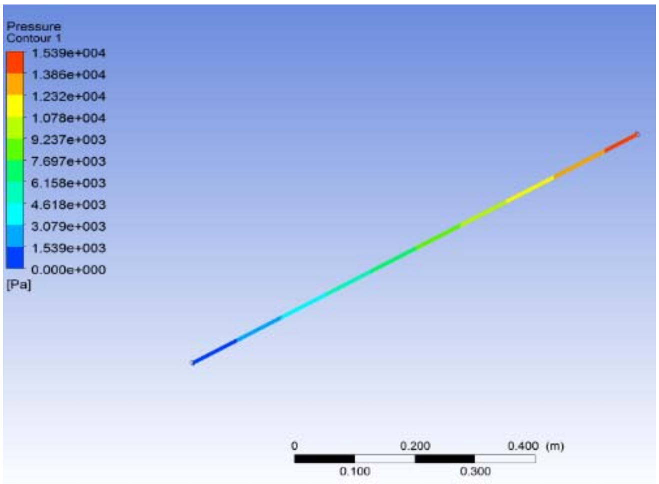
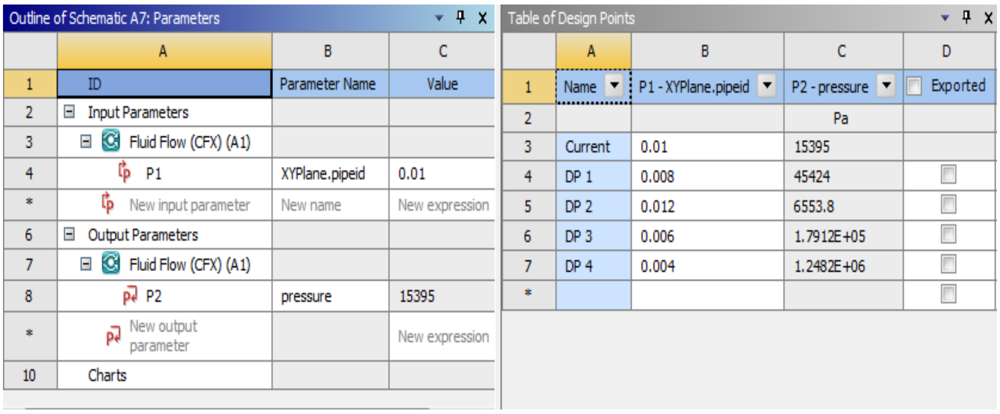


Fig.2.5. Pressure counter diagram for Al_2O_3 + water (liquid) particles

The analysis of pressure on different sizes of the channel is shown by parameter result as shown in Fig.2.6.



Outline of Schematic A7: Parameters

	A	B	C
1	ID	Parameter Name	Value
2	Input Parameters		
3	Fluid Flow (CFX) (A1)		
4	P1	XYPlane.pipeid	0.01
*	New input parameter	New name	New expression
6	Output Parameters		
7	Fluid Flow (CFX) (A1)		
8	P2	pressure	15395
*	New output parameter		New expression
10	Charts		

Table of Design Points

	A	B	C	D
1	Name	P1 - XYPlane.pipeid	P2 - pressure	Exported
2			Pa	
3	Current	0.01	15395	
4	DP 1	0.008	45424	
5	DP 2	0.012	6553.8	
6	DP 3	0.006	1.7912E+05	
7	DP 4	0.004	1.2482E+06	
*				

Fig.2.6. Pressure reading at different diameter for Al_2O_3 +water (liquid)

2.3 The simulation result for CuO (Nano fluid) + water (liquid) for 1 % fraction volume and 0.05 w pumping power :

Pressure counter diagram for CuO(Nano fluid) + water (liquid) as a fluid for 1 % fraction volume and 0.05 w pumping power is shown in Fig.2.7.

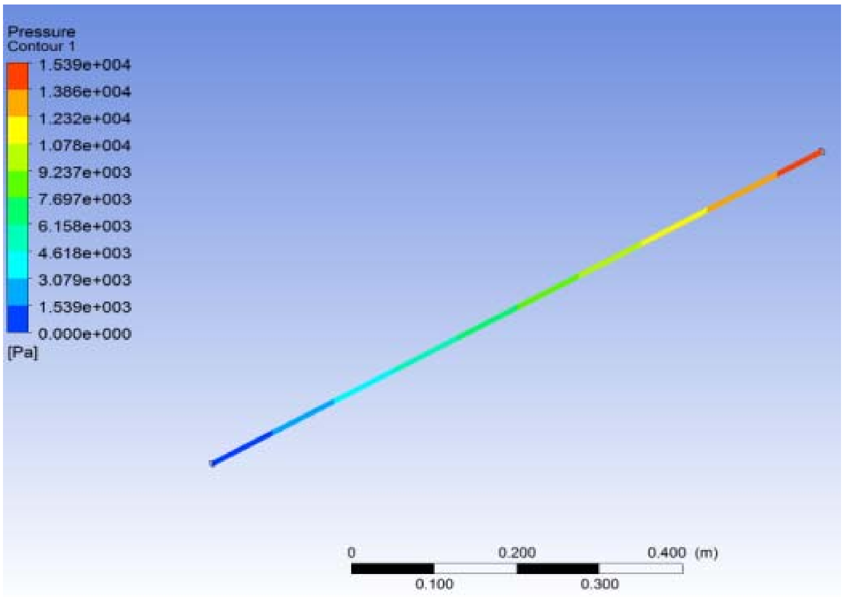


Fig.2.7. Pressure counter diagram for CuO + water (liquid) particles

The analysis of pressure on different sizes of the channel is shown by parameter result as shown in Fig.2.8.

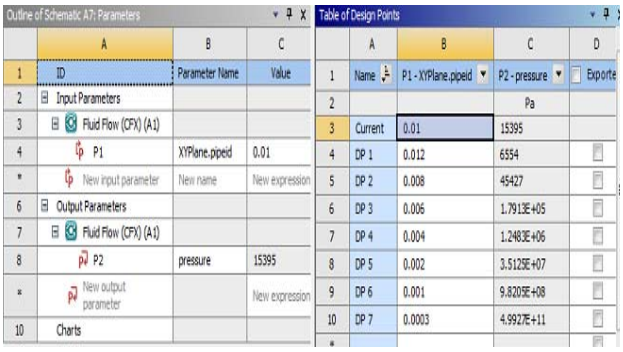


Fig.2.8. Pressure reading at different diameter for CuO + water (liquid)

3. RESULT TABLE:

Following Table 3.1 shows the simulation result for 1 % particle volume fraction and 0.05 w pumping power.

Table 3.1: 0.05 w pumping power 1 % particle volume fraction

PIPE DIA.	PRESSURE (Pa)		
D (mm)	Water (liquid)	Al_2O_3 + water	CuO + water
12	6466.1	6553.8	6554
10	**15216**	**15395**	**15396**
8	45214	45424	45427
6	178920	179120	179130
4	1247800	1248200	1248300
2	35123720	35124000	35125000
1	$9.7502*10^8$	$9.7503*10^8$	$9.8205*10^8$
0.3	$4.7810*10^{11}$	$4.7820*10^{11}$	$4.9927*10^{11}$

Following Table 3.2 shows the simulation result for 1 % particle volume fraction and 0.5 w pumping power.

Table 3.2: 1 % particle volume fraction and 0.5 w pumping power

PIPE DIA.	PRESSURE (Pa)		
D (mm)	Water (liquid)	Al_2O_3 + water	CuO + water
12	6554	6656.4	6466.1
10	**15295**	**15589**	**15308**
8	45427	45895	45214
6	179130	180500	178620
4	1248300	1254800	1246300
2	35125000	35202000	35085000
1	982050000	983000000	981430000
0.3	$4.9927*10^{11}$	$4.9967*10^{11}$	$4.9888* 10^{11}$

Fig.3.1 shows the Pressure versus diameters reading for different cases like Water (liquid), CuO + Water and Al_2O_3 + Water.

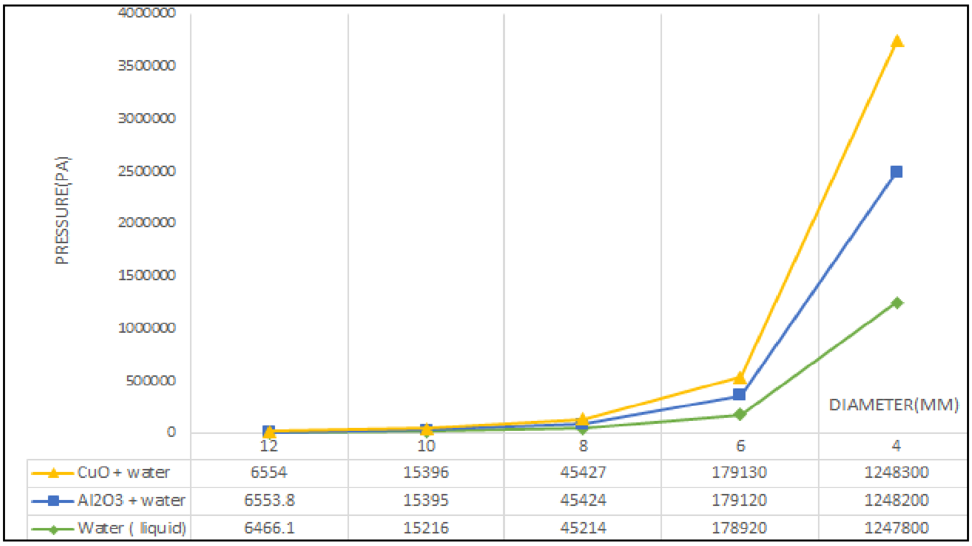


Fig.3.1. Pressure versus diameters reading for Nano fluids

4. CONCLUSION

The heat transfer analysis of the 10 mm diameter pipe by experimentally and also done the simulation of same in ANSYS Fluent. So that the simulation procedure is validated in (Table 3.1).

Comparison with Experimental value and Simulation value for water particles:

Experimental Value = 13596.66 Pa

Simulation Value = 15216 Pa

% Error = 10.64

Further studies can be done using this study as base. Now adding different diameter parameter the value of pressure is directly measured.

The heat transfer rate of heat transfer devices can be improved by adding additives to the working fluids to change the fluid transport properties and flow features.

After adding Nano particles the value of the pressure is increases as shown in Table 3.1 and Table 3.2.

The simulation result for Al_2O_3 (Nano fluid) + water (liquid) for 1 % fraction volume and 0.05 w pumping power is **15395 Pa** at 10 mm diameter pipe, while without adding Nano particles the value is **15216 Pa**, by using the same parameter study the value for CuO (Nano fluid) + water (liquid) is **15396 Pa** which shows that the pressure is increases after adding Nano fluid into water (liquid). The result values by using different Nano particles are shown in result Table 3.1 and Table 3.2.

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