EFFECT OF NANOFLUID ON FRICTION FACTOR OF PIPE AND PIPE FITTINGS: PART II EFFECT OF COPPER OXIDE NANOFLUID

N. K. Chavda[1], G. V. Patel[2], M. R. Bhadauria[3], M. N. Makwana[4]

[1]*Associate Professor, Department of Mechanical Engineering, A. D. Patel Institute of Technology, New Vallabh Vidyanagar – 388 121*
[2]*Assistant Professor, Department of Mechanical Engineering, A. D. Patel Institute of Technology, New Vallabh Vidyanagar – 388 121.*
[3]*Assistant Professor, Department of Mechanical Engineering, A. D. Patel Institute of Technology, New Vallabh Vidyanagar – 388 121.*
[4]*Assistant Professor, Department of Mechanical Engineering, A. D. Patel Institute of Technology, New Vallabh Vidyanagar – 388 121.*

Abstract

A nanofluid is prepared by mixing nano sized particles of size up to 100 nm and a base fluid. Commonly used nanoparticles are made of metals, oxides or carbides, while base fluids may be water, ethylene glycol or oil. Normally, the application of nanofluids is to enhance the heat transfer rate. Due to mixing of nanoparticles in the base fluid, the thermo-physical properties of the resulting mixture (base fluid + nanoparticles) changes. Therefore, resistance to flow of nanofluid increases which increases the friction factor and reduces the flow rate. In the part I of paper, an experimental investigation has been carried out to determine the effect of various concentration of Al_2O_3 nano-dispersion mixed in water as base fluid on Friction Factor of Pipe and Pipe Fittings. The present study deals with the effect of CuO nanofluid on the Friction Factor of Pipe and Pipe Fittings. The friction factor and loss coefficient of different pipes and pipe fittings increase with increase in volume concentration of CuO in water as compared to water.

Keywords: *Nanofluid, Friction Factor, Pipe Friction, Pipe Fitting, CuO Nanoparticles.*

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1. INTRODUCTION

A nanofluid is a suspension of nano sized particles in a base fluid. Most commonly used nanoparticles are made of metals, oxides or carbides which are mixed with base fluids like water, ethylene glycol or oil. A nanofluid exhibits different thermo physical properties as compared to the base fluid. Commonly thermal conductivity of nanofluids is higher than the base fluid which increases the heat transfer rate. 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.

There are two types of head loss during fluid flow viz. (1) Major Head Loss and (2) Minor Head Loss. Major head loss is due to friction during the fluid flow while minor head loss is due to disturbance in fluid flow pattern during the flow of fluid through sudden enlargement, sudden concentration, bend, elbow etc. When the nanofluid is flowing through the pipe, it offers more resistance to fluid flow due to friction. Many researchers have studied numerically and experimentally the phenomenon of effect of nanofluid on friction factor. The studies reported recently in literatures have been referred and presented here.

Chavda N. K. et. al. [1] have carried out experimental investigation to determine the effect of various concentration of Al_2O_3 nano-dispersion mixed in water as base fluid in the part I of the paper. 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.

Akhavan-Behabadi M. A. et.al. [2] have investigated the convective heat transfer of the heat transfer oil-copper oxide nanofluid flow in horizontal smooth and microfin tubes experimentally. They have used pure heat transfer oil and nanofluid with the weight concentrations of 0.5%, 1% and 1.5% as working fluids. They reported that combining use of nanoparticles and the microfin tube leads to the heat transfer enhancement up to 230%, in comparison with the base fluid flow in the smooth tube. Rimbault B. et. al. [3] have presented an experimental investigation of the hydraulic and thermal fields of a 29 nm CuO nanoparticle–water nanofluid with various volume fractions, 0.24%, 1.03% and 4.5% flowing inside a rectangular microchannel heat sink under both laminar and turbulent conditions. For a given fluid flow rate, experimental results show an increase of the pressure drop and the friction factor with respect to water along with slight heat transfer enhancement with respect to water for nanofluids with low particle volume fractions, 0.24% and 1.03%, while for the 4.5% fraction a clear decrease of heat transfer was found.

Chandrasekaran P. et. al. [4] have investigated the solidification characteristics of water based NFPCM (nanofluid phase change material) prepared by dispersing copper oxide nanoparticles and a nucleating agent in the base PCM (phase change material). They have found from the experimental results that considerable energy saving potential is possible. Nabeel Rashin M. and Hemalatha J. [5] have evaluated viscosity of novel coconut oil based copper oxide nanofluids of various concentrations prepared by ultrasonically assisted two step method theoretically and experimentally. They have propsed new empirical correlations for predicting viscosity of CuO–coconut oil nanofluid at various temperatures and concentrations.

Kole M. and Dey T. K. [6] have reported the study related to effect of aggregation on the viscosity of copper oxide–gear oil nanofluids. They reported that viscosity of the nanofluids enhance by near about 3 times of the base fluid with CuO volume fraction of 0.025, while it decreases significantly with the rise of temperature. Suresh S. et. al. [7] have compared the thermal performance of helical screw tape inserts in laminar flow of Al_2O_3/water and CuO/water nanofluids through a straight circular duct with constant heat flux boundary condition. They reported that thermal performance factor of helical screw tape inserts using CuO/water nanofluid is found to be higher when compared with the corresponding value using Al_2O_3/water. Chang M. H. et. al. [8] have reported the procedure to prepare CuO–water nanofluid for enhancing the thermal conductivity using various CuO contents and surfactant concentrations.

The investigations reported in the literatures are related to the friction factor 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 in pipe and pipe fittings are not presented in open literature.

In order to evaluate the effect of nanofluid in pipe and pipe fittings separately rather than considering along with heat transfer characteristics for a particular application, separate experimentations need to be carried out. Therefore, the effect of nanofluid prepared by dispersing Al_2O_3 nano-dispersion in water in different volume concentration on friction factor of pipe and pipe fittings have been evaluated experimentally in the part I of the paper and the same of CuO nanoparticles have been evaluated in the paper.

2. EXPERIMENTAL SETUP AND PROCEDURE

Two experimental setups viz. (1) Apparatus for Pipe Friction and (2) Apparatus for Pipe Fittings are required to evaluate the effect of nanofluid on friction factor of pipe and pipe fittings experimentally. Detailed specifications and procedure for experimentation are exactly same as reported in part I of the paper.

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.

Two-step method has been employed to prepare nanofluid. CuO nanoparticles have been purchased from M/s. Jyotirmay Overseas, Rajkot. CuO nanoparticles are of 40 nm size has 6310 kg/m^3 density. The proportion of CuO nanoparticles to be mixed with base fluid i.e. water for different volume concentration is calculated using equation number 1 and density of nanofluid is calculated using equation number 2. 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 1.

$$\emptyset = \frac{\frac{W_{nanoparticle}}{\rho_{nanoparticle}}}{\frac{W_{nanoparticle}}{\rho_{nanoparticle}} + \frac{W_{water}}{\rho_{water}}} \times 100 \quad (1)$$

$$\rho_{nanofluid} = \emptyset\rho_{nanoparticle} + (1-\emptyset)\rho_{water} \quad (2)$$

Table 1: Mass of 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 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. 1: CuO Nanofluid

4. INTEGRATED RESEARCH METHODOLOGY

The integrated methodology adopted to evaluate the effect of nanofluid in friction factor of different types of pipe and pipe fittings are as under.

(1) Fill the water in apparatus for pipe friction and conduct the tests as per the experimental procedure for pipe friction. This is termed as Case A.

(2) Calculate the friction factor for different types of pipes as per the calculation steps for pipe friction for water.

(3) Empty the water from the tank of apparatus for pipe friction.

(4) Fill the water in apparatus for pipe fittings and conduct the tests as per the experimental procedure for pipe four types of fittings one by one. This is termed as Case A.

(5) Calculate the loss coefficient for different types of pipe fittings as per the calculation steps for four types of pipe fittings for water.

(6) Empty the water from the tank of apparatus for pipe fitting.

(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 6 of integrated research methodology.

(9) Perform the experimentation for Case C, Case D and Case E as per the step number 1 to 6 of integrated research methodology.

(10) Compare the results.

5. RESULTS AND DISCUSSION

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

Table -2: Result for Pipe Friction

Sr. No	Case No.	Friction factor			
		GI Pipe of 17 mm Inside Dia.	GI Pipe of 21 mm Inside Dia.	Cu Pipe of 14.5 mm Inside Dia.	Al Pipe of 12.5 mm Inside Dia.
		Pipe A	Pipe B	Pipe C	Pipe D
1	A	0.04295	0.02423	0.02280	0.01215
2	B	0.04844	0.02696	0.02622	0.01354
3	C	0.04882	0.02822	0.02682	0.01385
4	D	0.05772	0.03117	0.02826	0.01409
5	E	0.05897	0.0339	0.02977	0.01463

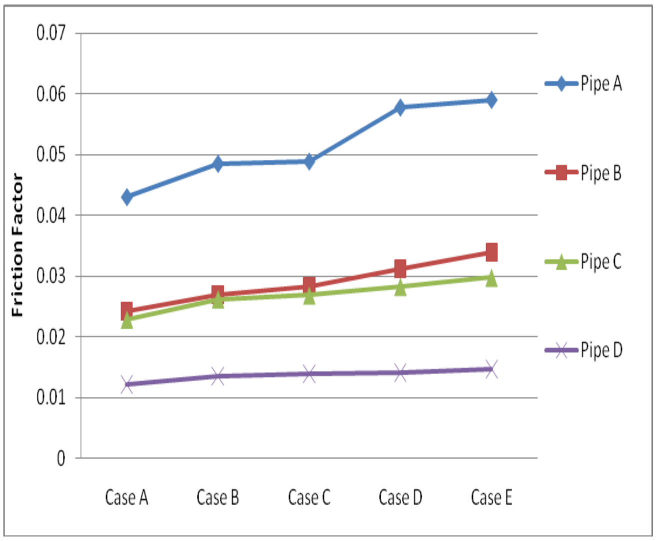

Fig.2: Result of Pipe Friction

The value of friction factor for different pipes increases with increase in volume concentration of CuO nano-particles in water. The maximum increase in friction factor for G.I. pipe having 17 mm inside diameter, G. I. pipe having 21 mm inside diameter, Copper pipe having 14.5 mm inside diameter and Aluminum pipe having 12.5 mm inside diameter for 0.004 % CuO nanofluid is 37 %, 40 %, 31 % and 20% respectively compared to base fluid i.e. water.

Table -3: Result for Pipe Fittings

Sr No	Case No.	Loss Coefficient			
		Elbow	Bend	Sudden Contraction	Sudden Expansion
1	A	1.50623	1.58946	0.52477	0.12392
2	B	1.81570	1.60687	0.54164	0.12639
3	C	2.14890	1.69457	0.64801	0.12654
4	D	2.48980	1.75489	0.65890	0.13165
5	E	2.55390	1.87774	0.71744	0.14125

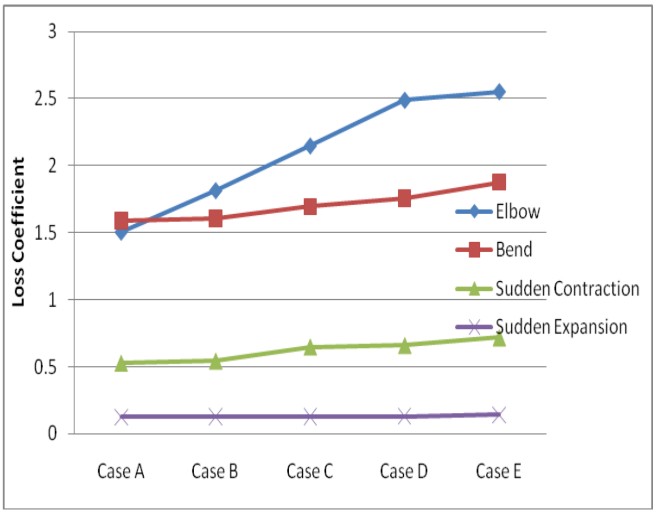

Fig.2: Result of Pipe Fitting

The value of loss coefficient for different pipes fittings increases with increase in volume concentration of CuO nano-particles in water. The maximum increase in loss coefficient for elbow, bend, sudden concentration, sudden expansion for 0.004 % CuO nanofluid is 69 %, 18 %, 37 % and 14% respectively compared to base fluid i.e. water.

6. CONCLUSION

An experimental investigation is carried out to determine the effect of various concentration of CuO nano-particles mixed in water as base fluid. The volume concentrations of CuO nanofluid prepared are 0.001 %, 0.002 %, 0.003 % and 0.004 %. The conclusion derived for the study is that friction factor and loss coefficient of different pipes and pipe fittings increase with increase in volume concentration of CuO nano-particles as compared to 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.

G. V. Patel accomplished his post-graduation with specialization in CAD/CAM and having more than 6 years of teaching experience. He has presented/published number of papers in international & national conferences & Journals in the areas of CFD

Ms. Madhuri Bhadauria completed her post-graduation with specialization in Thermal Engineering from Nirma University, Ahmedabad.

Prof. M.N Makwana accomplished his post-graduation from the MSU, Vadodara with specialization in Jet Propulsion and gas Turbine Plants and having more than 8 years of teaching experience. He has presented/published number of papers in international & national conferences & Journals in the areas of CFD, Nano fluid heat transfer, and Renewable Energy.