International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

Experimental Investigation on Transient State Performance of Natural Circulation Loop

G.Narendar
Asst. Professor,
Department of Mechanical Engineering
Osmania University
Hyderabad, India

AVSS Kumara Swami Gupta
Professor,
Department of Mechanical Engineering
Jawaharlal Nehru Technological University Hyderabad
Hyderabad, India

A. Krishnaiah
Professor,
Department of Mechanical Engineering
Osmania University
Hyderabad, India

***Abstract* - Natural circulation loop is a passive system, without the aid of power operating devices, the working fluid circulates due to temperature difference existing within the loop. A vertically placed pipe loop equipped with two heat exchangers placed at its lower end and upper end of the loop for heating and cooling of the loop fluid forms the natural circulation loop. The bottom heat exchanger acts as 'heat source' and the top one acts as 'heat sink'. The heat is transferred from source to sink through the circulation of loop fluid. The fluid circulates in the loop due to density difference caused by the temperature variation between heat source and heat sink, there by transporting loop fluid from the source to the sink without the aid of any external mechanical device like pump.**

For transient state experiments, the performance of natural circulation loop with different concentrations of nanofluids with continuous increase in temperature of heat source from 50 °C to 90 °C are investigated. During transient state operation the average fluid flow rate is more for CuO nanofluid than Alumina nanofluid.

Key words:- Natural circulation loop, nanofluid, hot end heat exchanger, cold end heat exchanger.

I. INTRODUCTION

Natural circulation loops circulate the working fluid from a heat source to a heat sink without using any mechanical devices or power consuming devices like pumps. The motive force for the flow is buoyancy force which is generated within the loop simply because of temperature difference within the loop caused due to the presence of the heat source and the heat sink maintained at different temperatures.

Natural circulation systems consist of a heat source, heat sink and the pipes connecting them. In natural circulation loops, the heat sink is located at certain height above the heat source to promote natural circulation. The pipes are connected to the source and sink in such a way that it forms a continuous fluid circulation path. Fluid circulation can commence in the natural circulation loop by filling the flow path with a working fluid, adding heat to the working fluid in the heat source and cooling the working fluid in the heat sink. With both the source and sink temperature difference is maintained, fluid circulation starts from heat source to heat sink, which can continue indefinitely if the working conditions of the closed loop are maintained. The Fig.1 shows the schematic diagram of natural circulation loop.

Vijayan et al. [1] described the working principle, functions and advantages of Natural circulation loops to transport heat from a heat source to a heat sink. The natural circulation principle is used in natural circulation boilers, transformer cooling, solar water heaters, heat utilisation in geothermal power plants, cooling of engines, gas turbine blades, and nuclear reactor core cooling.

Misale [2] addressed issues like the problem of the stability of the loops, that is of interest in many industrial applications, has not been solved by researchers. The study is focused on the experimental aspects that could be interesting in the investigation of natural circulation systems. With the study, Misale revealed that the thermo-hydraulic behaviour of a single-phase natural circulation loop depends on interaction between the fluid properties, material utilised to construct the loop, heaters and coolers displacement and numbers, horizontal parallel channels in new nuclear reactors loop inclination and the properties of loop fluid.

Vijayan et al.[3] studied the steady state and stability behaviour of natural circulation loops and generalised dimensionless groups (scaling parameters) which are not loop-specific. The steady state flow in uniform or non-uniform diameter single-phase natural circulation loops can be expressed as Reynolds number as a function of Grashoff number and geometric factor.

Misale et al. [4] studied the influence of the wall thermal capacity and axial conduction over a single-phase natural circulation loop using a 2-D numerical method. The dependency of the temperature and velocity field on the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

power input and the wall thermal capacity has been analysed.

Nayak [5] has studied the natural circulation phenomenon in a rectangular loop and mathematically simulated the stability characteristics. The stability behaviour of natural circulation in a rectangular loop has been mathematically modelled using the linear and nonlinear analysis.

Vijayan et al. [6] investigated the effect of the heater and cooler orientations on the single-phase natural circulation in a rectangular loop. From steady state considerations, the maximum flow for a specified operating condition is achievable for the orientation with both the heater and the cooler horizontal. Steady state flow rate can be predicted with reasonable accuracy using the generalized equation.

Vijayan et al. [7] investigated the heat transport capability of natural circulation loops which is directly proportional to the flow rate it can generate. As the driving force is low, to enhance the flow is to reduce the frictional losses. This can be done by increasing the loop diameter which can be easily adopted in pressure tube designs such as the Advanced heavy water reactor and the natural circulation boilers employed in fossil-fuelled power plants. The instability threshold is found to decrease with increase in loop diameter. Linear analysis showed that the unstable region shifts up with decrease in loop diameter. It is identified that small diameter loops are more stable than large diameter loops.

Nayak et al. [8] investigated on the stability and transient behaviour of a boiling two-phase natural circulation loop with Alumina nanofluid at different operating pressures. The study revealed that while the natural circulation flow behaviour with rise in power is similar with water and Alumina nanofluid in single-phase condition, however, the buoyancy induced flow rates are found to be relatively higher with nanofluid than with water alone for corresponding operating conditions

Lot of research work is being done worldwide on natural circulation loops and its applications. Literature review revealed that some researchers carried out experimental works on natural circulation loops by supplying heat flux and made an attempt using electrical coil heating at the heat source of the natural circulation loop. In many situations, electrical heating at the heat source may not reflect or simulate practical conditions existing in the heat source of natural circulation loop. Hence, a heat exchanger is placed as the heat source that reflects the practical situations existing in the heat source of natural circulation loop. Continuously increasing temperature of water is supplied into the heat exchanger (i.e. heat source) to investigate the transient state performance of natural circulation loop.

2. METHODOLOGY

The performance of natural circulation loop with working fluid of CuO and Al_2O_3 nanofluid for different concentrations viz., 0.25, 0.5, 0.75 and 1.0% (by wt.) is studied with continuously increasing the temperature of heat source from 50 °C to 90 °C. The temperature of heat source is increased by supplying hot water from a hot water bath in which water is heated by electric heater with constant power supply, so that the temperature of water increases at a constant rate. The stirrer in the hot water tank is used to mix water for maintaining uniform temperature in the tank.

The heat from the heat source of natural circulation loop is taken away by working fluid. The working fluid circulates and loses its heat in the heat sink. In the heat sink, tap water is supplied into the heat exchanger (heat sink) to extract the heat from the working fluid. Thereby loop fluid gets cooled down and circulates continuously in the loop.

The parameters such as fluid flow rate, total flow and variation of loop fluid temperature at various locations are recorded. Similarly, experiments are carried out using Al_2O_3 nanofluid as working fluid in the natural circulation loop. CuO and Al_2O_3 nanofluids of 0.25%, 0.5%, 0.75% and 1.0% (by wt.) are prepared using probe sonication process and shown in figure 2. Experimental setup is shown in fig.3.

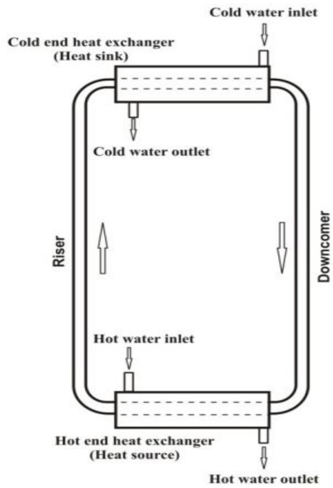

Fig. 1. Schematic diagram of Natural circulation loop


Fig. 2. Probe sonicator used for preparation of CuO and Alumina nanofluid

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

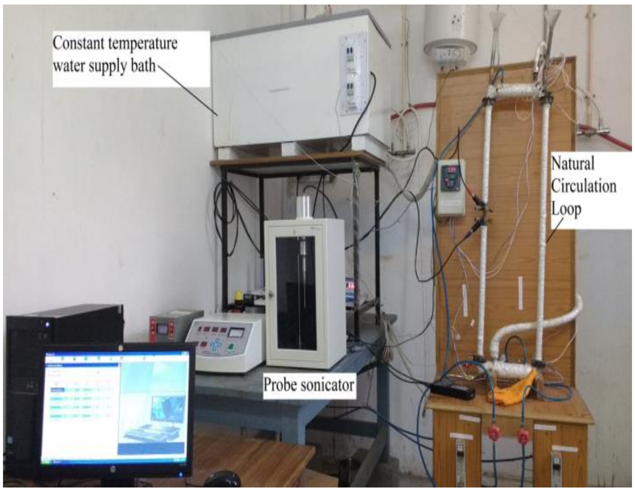

Fig. 3 Experimental setup

3. RESULTS

The transient state performance of natural circulation loop is investigated for various concentrations of CuO and Alumina nanofluids. Performance evaluation of natural circulation loop with continuously varying the temperature of heat source from 50 ºC to 90 ºC and CuO nanofluid of various concentrations viz. 0.25%, 0.5%, 0.75% and 1.0% (by wt.) are taken as loop fluid. Hot fluid is supplied from 'hot water bath' into the hot end heat exchanger (i.e. heat source) whose temperature is increased continuously from 50 °C to 90 °C. During the experiments, the parameters such as flow rate, loop fluid temperatures at various locations are measured and recorded for different concentrations of CuO and Alumina nanofluid. A representative graph for variation of flow rate with time with 0.25% of CuO nanofluid and heat source temperature increased from 50 °C to 90 °C is shown in fig.4.

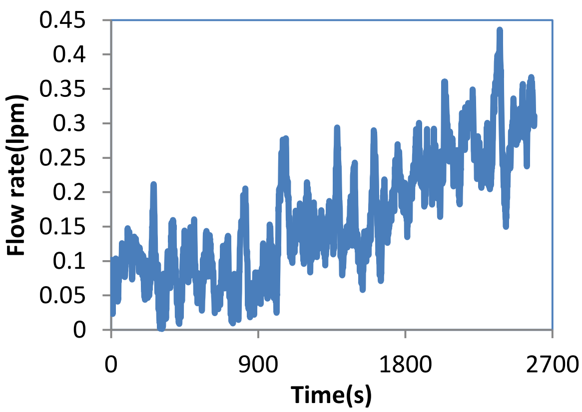

Fig. 4 Variation of flow rate with time with 0.25% of CuO nanofluid and heat source temperature increased from 50 °C to 90 °C

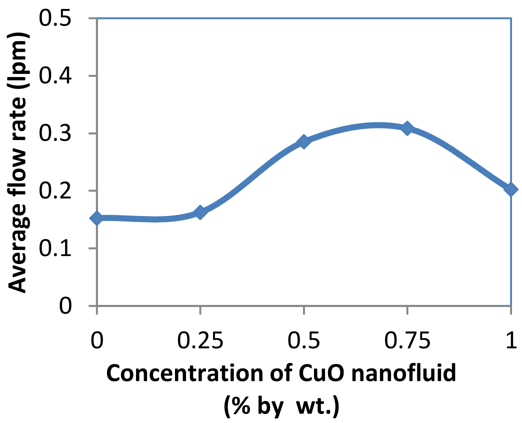

Fig. 5 Variation of average fluid flow rate with time for various concentrations of CuO nanofluid and for heat source temperature increased from 50 °C to 90 °C

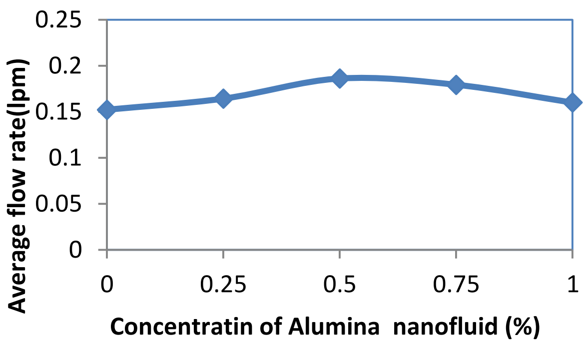

Fig. 6 Variation of average flow rate with time for various concentrations of Alumina nanofluids and heat source temperature increased from 50 °C to 90 °C

From the transient stat experiments with CuO as loop fluid, it is found that enhancement in the loop fluid flow rate with continuous increase in temperature of heat source from 50 °C to 90 °C. The highest average fluid flow rate of 0.308 lpm is found at 0.75% concentration of the nanofluid. The investigation revealed that, the flow rate in the loop is increased with increase of concentration of CuO nanofluid up to 0.75% and then decreased towards 1% concentration as shown in figure 5. This decrease in flow rate is due to higher density, viscous effects and heat affecting the properties at higher temperature and at the higher concentration above 0.75% of CuO nanofluid.

In transient state experiments, for Alumina nanofluid, the highest average fluid flow rate of 0.187 lpm is found at 0.5% concentration of the nanofluid. The investigation revealed that, the fluid flow rate in the loop is increased with increase of concentration of Alumina nanofluid up to 0.5% and then decreased towards 1.0% concentration as shown in figure 6. This decrease in flow rate is due to higher density, viscous effects and heat affecting the nanofluid at higher temperatures and at the higher concentrations above 0.5% of Alumina nanofluid.

4. CONCLUSIONS

From the experimental investigation, the following conclusions are drawn:

- In transient state experiments, the temperature of heat source is increased continuously from 50 ºC to 90 ºC. When CuO nanofluid is used, the average fluid flow rate is increased up to 0.75% concentration and thereafter decreased till 1.0% concentration. The highest average fluid flow rate of 0.308 lpm is found at 0.75% concentration of the nanofluid. After 0.75% concentration, the nanofluid properties are more influenced by temperature, and hence average flow rate is decreased.

- In transient state experiments, when Alumina nanofluid is used, the average flow rate is increased up to 0.5% concentration of nanofluid and thereafter decreased till 1.0% concentration. The highest average fluid flow rate of 0.187 lpm is found at 0.5% concentration of the nanofluid. After 0.5% concentration, the Alumna nanofluid properties are more affected by temperature, and hence average fluid flow rate is decreased.

ACKNOWLEDGMENTS

The authors would like to acknowledge and express sincere thanks to the OU-DST-PURSE Program for supporting the project.

REFERENCES

[1] Vijayan, P.K., and A.K. Nayak, *Natural circulation in water cooled nuclear power plants: phenomena, models, and methodology for System reliability assessments.* Conference Proceedings of International Atomic Energy Agency, 2005(November 2005): p. 89-99.

[2] Misale, M., *Overview on single-phase natural circulation loops.* Proc. of the Intl. Conf. on Advances in Mechanical and Automation Engineering – MAE 2014, 2014.

[3] Vijayan, P.K., *Experimental observations on the general trends of the steady state and stability behaviour of single-phase natural circulation loops.* Nuclear Engineering and Design, 2002. **215**(1–2): p. 139-152.

[4] M. Misale, P.R., M. Frogheri, *The influence of the wall thermal capacity and axial conduction over a single-phase natural circulation loop: 2-D numerical study*. Heat and Mass Transfer, 2000, Volume 36, Number 6, Page 533, 2000. **36**(6): p. 533.

[5] Nayak, A.K., et al., *Mathematical modelling of the stability characteristics of a natural circulation loop.* Mathematical and Computer Modelling, 1995. **22**(9): p. 77-87.

[6] Vijayan, P.K., M. Sharma, and D. Saha, *Steady state and stability characteristics of single-phase natural circulation in a rectangular loop with different heater and cooler orientations.* Experimental Thermal and Fluid Science, 2007. **31**(8): p. 925-945.

[7] Vijayan, P., et al., *Steady State Behaviour of Single-Phase and Two-Phase Natural Circulation Loops.* 2nd RCM on IAEA CRP, Corvallis, Oregon State University, USA

[8] 8.Nayak, A.K., P.P. Kulkarni, and P.K. Vijayan, *Study on the transient and stability behaviour of a boiling two-phase natural circulation loop with Al2O3 nanofluids.* Applied Thermal Engineering, 2011. **31**(10): p. 1673-1681.