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Investigating the Orientation of the Heater and Cooler on the Performance of a Mini Natural Circulation Loop with Cu-Water Nanofluid

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ABSTRACT: The main objective of this paper is to investigate the effects of the orientation of heater and cooler on the mass flow rate and temperature distribution in a natural circulation loop. The governing equations of the natural circulation loop – mass conservation, momentum, and energy- are written in the non-dimensional form. Cu-Water nanofluids considered as the working fluid and the effect of nanoparticles percentage on mass flow rate is investigated. Also, the effects of other parameters such as pipe diameter, height of the loop, loop inclination angle and the heater power on the mass flow rate of the loop and temperature distribution are investigated. The results show the mass flow rate increases 43% when the diameter of pipes increases 20% for all orientations of the heater and cooler. For heater power 50 W, the mass flow rate increases 12.8% almost, when the percentage of nanoparticles increases 2%. The mass flow rate increases 22.4% almost as the power heater increases from 20 W to 30 W (50 % increasing) for all orientations. For heater power 20 W and 2% nanoparticles, the temperature at the end of heater (hot leg) for horizontal heater and horizontal cooler and vertical heater and vertical cooler is 34 ºC, and 97 ºC, respectively.

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1- Introduction

A simple rectangular Natural Circulation Loop (NCL) consists of a heater, a cooler, cold leg and a hot leg. The main aim of NCLs is heat transfer from a heat source to a heat sink without using a mechanical pump. NCL is used in various energy systems, such as solar heaters, nuclear reactors, geothermal power production, and engine and computer cooling. The capability of heat transfer depends on the mass flow rate in an NCL that the latter is a function of cooler and heater orientations. In a rectangular NCL, there are four orientations for the heater and cooler that are [1]: (1) Horizontal Heater and Horizontal Cooler (HHHC), (2) Horizontal Heater and Vertical Cooler (HHVC), (3) Vertical Heater and Horizontal Cooler (VHHC) and (4) Vertical Heater and Vertical Cooler (VHVC). Fig. 1 shows the schematic of four orientations. Vijayan et al. [2] obtained the steady state mass flow rate as a function of just one similarity group. In 2002, the effect of loop diameter on the stability of single phase natural circulation in rectangular loops was investigated by Vijayan [3]. An experimental investigation of single-phase natural circulation behavior in a rectangular loop with Al2O3 nanofluids was performed by Nayak et al [4]. In 2011, a generalized flow equation was proposed for cases where a single friction law is not applicable for the entire loop by Swapnalee and Vijayan [5]. The proposed equation is tested with experimental data generated in a uniform diameter rectangular loop and is found to be in good agreement. In 2018, Seyyedi et al. [6] studied the behavior of a rectangular natural circulation loop at steady state. They considered HHHC orientation for loop and investigated the effects active parameters on the mass flow rate and temperature of fluid. In 2019, the behavior of a rectangular natural circulation loop was analyzed experimentally and numerically by Seyyedi et al. [7] and Hashemi-Tilehnoee et al. [8]. The type of their loop was HHHC and pure water was considered as working fluid. In the present work, a rectangular single-phase natural circulation mini-loop is considered and the effects of heater and cooler orientations are investigated on the steady state mass flow rate and the steady state fluid temperature. Cu-Water nanofluid is considered as the working fluid and the influences of active parameters such as heater power, diameter of tube, the height of loop, nanoparticle volume fraction and so on are investigated.

2- Governing Equations

The non-dimensional form of governing equations (momentum and energy) can be written as follows [7]:

$$\frac{d\omega}{d\tau} = \frac{Gr_m}{Re_{ss}^3} \oint \theta dZ - \frac{pL_t \omega^{2-b}}{2DRe_{ss}^b} \qquad (1)$$

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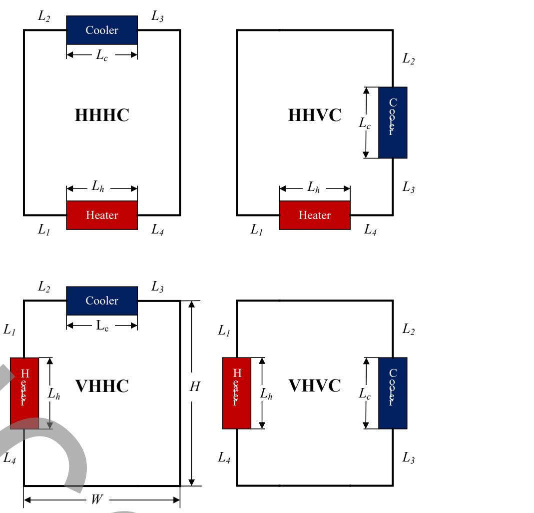

Fig. 1. Schematic view of natural circulation loop with different orientation

$$\frac{\partial\theta}{\partial\tau}+\frac{L_t}{H}\omega\frac{\partial\theta}{\partial S}=\begin{cases}\frac{L_t}{L_h}\text{ for heater }(0<S\le S_h) \\ 0\quad\text{for pipes }(S_h<S\le S_{hl}\text{ and }S_c<S\le S_t) \\ -St_m\theta\quad\text{for cooler }(S_{hl}<S\le S_c)\end{cases}\qquad(2)$$

3- Results and Discussion

Fig. 2 presents the steady state mass flow rate versus the heater power for three values of volume fraction of nanoparticles for HHHC orientation. The figure shows that the mass flow rate increases as the nanoparticle volume fraction increases for each value of heater power. For example, the mass flow rate increases 12.8% when the nanoparticle volume fraction increases from 0 to 2% for heater power 50 W.

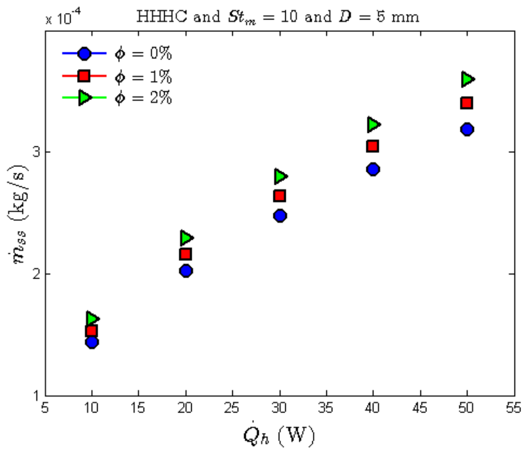

Fig. 2. Mass flow rate versus heater power for three different values of nanoparticle volume fractions

Fig. 3 demonstrates the steady state mass flow rate at three values of heater power for different orientations of heater and cooler. The figure shows that the mass flow rate for HHHC is more than other orientations and VHVC is less than other orientations for each heater power. Also, the mass flow rate ascends with increasing the heater power. For example, the mass flow rate increases 22.4% as power heater increases from 20 W to 30 W for all orientations.

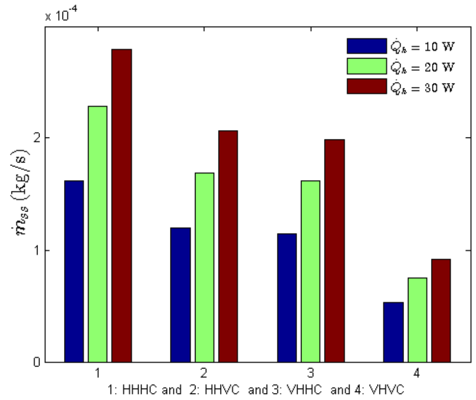

Fig. 3. Mass flow rate at different heater powers for all orientations

Fig. 4 shows the effects of loop diameter on the mass flow rate for all orientations. The figure shows that the mass flow rate increases 43.47%, 41.59%, 43.62% and 43.84% for HHHC, HHVC, VHHC, and VHVC, respectively when loop diameter increases from 5 mm to 6 mm.

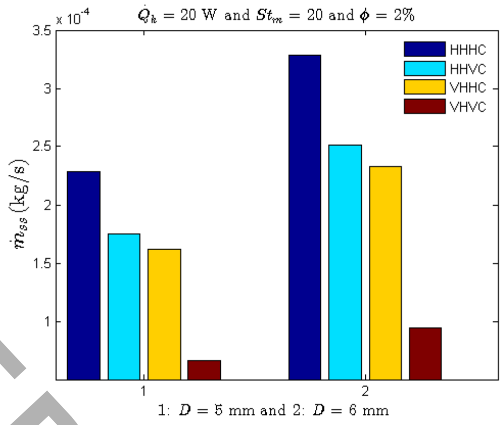

Fig. 4. Mass flow rate at different diameters for all orientations

Fig. 5 illustrates the nanofluid temperature along the loop for all orientations. For a constant location of the loop, the nanofluid temperature for VHVC is more than other orientations and HHHC is less than other orientations. For example, the nanofluid temperature at the end of heater is 31ºC and 97ºC for HHHC and VHVC, respectively.

4- Conclusion

In the present work, the performance of a rectangular natural circulation mini loop was investigated. The working fluid was selected Cu-water and the effects of active parameters such as hater power, and loop diameter was studied on the mass flow rate and nanofluid temperature. The results show that for heater power 50W, the mass flow rate increases 12.8% almost when the percentage of nanoparticles increases 2%. Also the results show the mass flow rate increases 43% when the diameter of pipes increases 20% for all orientations of the heater and cooler.

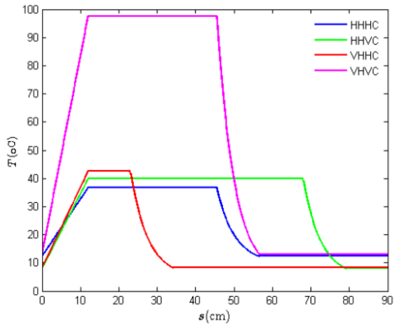

Fig. 5. Temperature distribution at $\dot{Q}_h = 20\,\mathrm{W}$ for different orientations

5- References

[1] Y. Zvirin, A review of natural circulation loops in pressurized water reactors and other systems, Nuclear Engineering and Design, 67(2) (1982) 203-225.

[2] P. Vijayan, A. Nayak, D. Saha, M. Gartia, Effect of loop diameter on the steady state and stability behaviour of single-phase and two-phase natural circulation loops, Science and technology of nuclear installations, 2008 (2008).

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

[4] A. Nayak, M. Gartia, P. Vijayan, An experimental investigation of single-phase natural circulation behavior in a rectangular loop with Al2O3 nanofluids, Experimental thermal and fluid science, 33(1) (2008) 184-189.

[5] B. Swapnalee, P. Vijayan, A generalized flow equation for single phase natural circulation loops obeying multiple friction laws, International Journal of Heat and Mass Transfer, 54(11-12) (2011) 2618-2629.

[6] S.M. Seyyedi, M. Hashemi-Tilehnoee, Parametric study of a rectangular single phase natural circulation loop at steady state, Modares Mechanical Engineering, 18(2) (2018) 413-422.

[7] S. Seyyedi, N. Sahebi, A. Dogonchi, M. Hashemi-Tilehnoee, Numerical and experimental analysis of a rectangular single-phase natural circulation loop with asymmetric heater position, International Journal of Heat and Mass Transfer, 130 (2019) 1343-1357.

[8] M. Hashemi-Tilehnoee, N. Sahebi, A. Dogonchi, S.M. Seyyedi, S. Tashakor, Simulation of the dynamic behavior of a rectangular single-phase natural circulation vertical loop with asymmetric heater, International Journal of Heat and Mass Transfer, 139 (2019) 974-981.