An Experimental Investigation and CFD Analysis of Heat Transfer Enhancement on Concentric Tube in Tube Heat Exchanger by using Zno-W+PVP Nanofluid

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Abstract - *Heat exchangers are the commonly used equipment in many process industries. Heat exchangers are used to transfer heat between two process streams. With its simple design and ability to operate under high pressures, the concentric tube heat exchanger is a valued resource in many industries for a range of purposes, from food preparation to material processing. Now days to achieve high heat transfer rate, different techniques have been used. One of the advanced techniques among them is suspension of nanoparticle in the base fluids as water, ethylene glycol, oil. In the present work the concentric tube heat exchangers are tested by using the water-water and nanofluid-water streams. The ZnO (with polyvinylpyrrolidone)/water (0.03v/v%) nanofluid has been used as the cold stream. The heat transfer rate and overall heat transfer coefficients in heat exchangers are measured as a function of hot and cold streams mass flow rates. The experimental results show that the heat transfer rate and overall heat transfer coefficients of the nanofluid in the heat exchangers is higher than that of the base liquid (i. e. water) .The heat transfer rate and overall heat transfer coefficients increases with increase in mass flow rates of hot and cold streams. Also, the computational fluid dynamics code is used to simulate the performance of concentric tube heat exchanger. The results are compared to the experimental data and showed good agreement. It is shown that the computational fluid dynamics is a reliable tool for investigation of heat transfer of nanofluids in the various heat exchangers.*

***Key Words*: Nanofluid, heat transfer rate, mass flow rate, LMTD, computational fluid dynamics.**

1. INTRODUCTION

Concentric tube heat exchanger: The concentric tube heat exchanger consists of two tubes that are concentrically arranged. One of the fluids (either hot or cold fluid) flows through the tube and the other through the annulus. For a CTHX, two types of flow arrangements are possible - concurrent and counter-current flow. In the parallel or co-current arrangement, the flow direction of the hot fluid will be the same as that of the cold fluid. In the counter-current arrangement, the flow directions of the hot and the cold fluids are opposite to each other Nano fluids are dilute liquid suspended nano particles which have only one critical dimension smaller than ~100nm. Much research work has been made in the past decade to this new type of material because of its high rated properties and behavior associated with heat transfer The thermal behavior of nano fluids could provide a basis for an huge innovation for heat transfer, which is a major importance to number of industrial sectors including transportation, power generation, micro manufacturing, thermal therapy for cancer treatment, chemical and metallurgical sectors, as well as heating, cooling, ventilation and air-conditioning.

2. Materials selection

Many different particle materials are used for nanofluid preparation. Al2O3, CuO, SiO2, ZnO nanoparticles are frequently used in nanofluid research. Base fluids mostly used in the preparation of nanofluids are the common working fluids of heat transfer applications such as, water, ethylene glycol and engine oil. From available materials we have selected water as base fluid and Zno as nanoparticles because thermophysical properties of nanofluid is good and availability and safe to use.

2.1 Thermo physical properties

Table 1 Zinc Oxide Nano Fluid Properties

Volume Fraction	Thermal Conductivity (W/m-K)	Specific Heat (J/Kg-K)	Density (Kg/m^3)	Viscosity (Poise)
0.01	1.1097	3798.58	1091.736	1.05315×10^{-3}
0.03	1.4269	3475.68	1175.27	1.10033×10^{-3}
0.07	1.6394	3076.77	1325.576	1.178525×10^{-3}
0.15	1.9634	2334.98	1550.97	1.379125×10^{-3}

3. Experimental setup

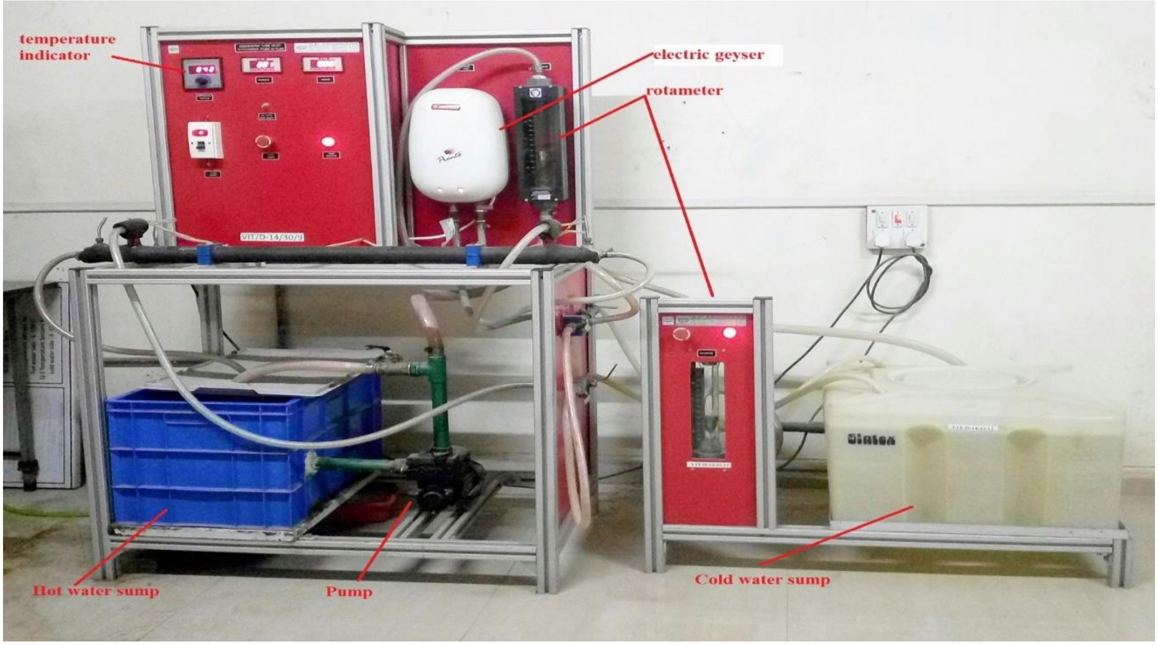


Figure 1 Actual experimental setup of concentric tube in tube heat exchanger.

3.1 Preparation of Nanofluid

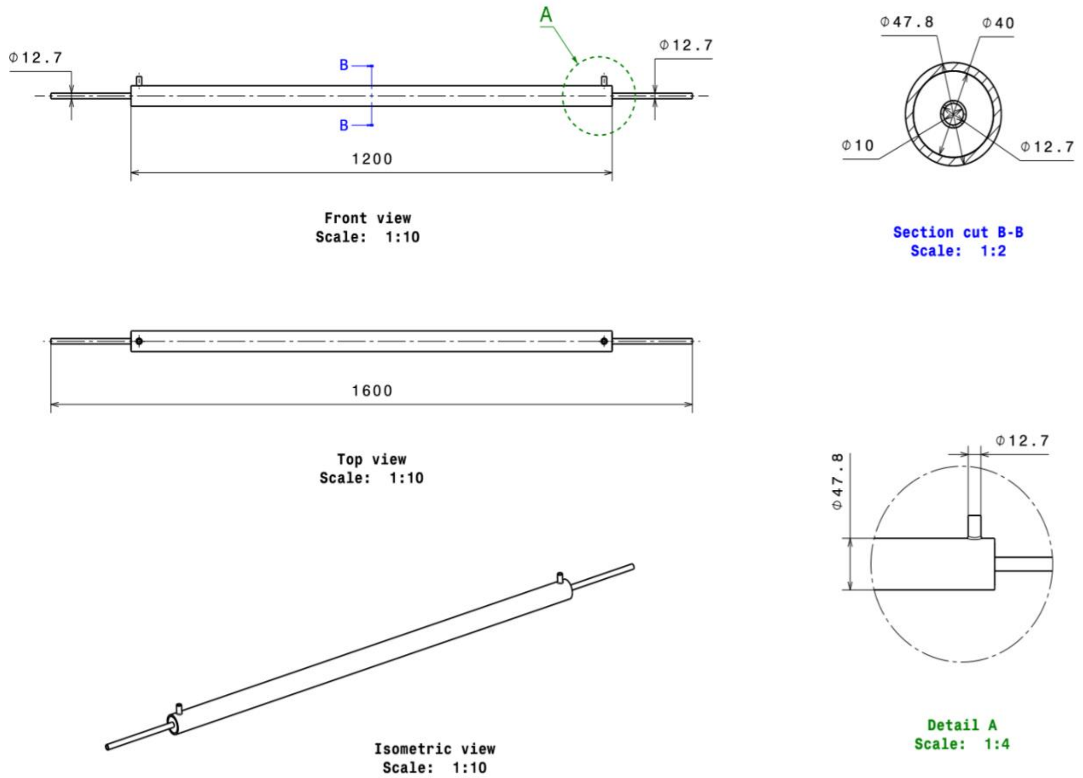
Preparation of nanofluid is the most important step. Nanoparticles Zno of particles diameter size 50 nm were purchased from Autus nanolab private limited, Mumbai. Nanofluid is prepared with the help of mechanical stirrer. This method is based on Das et al. (2008), Mahendran et al., 2012, Han and Rhi (2011) and Lee et al. (1999). It was found that the nanofluid prepared with this method can be stable and after some day's sedimentation will occurs. It was found that as the concentration increases there is improvement in thermal conductivity with viscosity and density.[11]

ZnO–W nanofluids were prepared with PVP surfactants and it was observed that, ZnO–W nanofluids with PVP were most stable. Very little sedimentation was seen after 2 weeks.

Table 2. The Percentage increase in heat transfer rate and Percentage increase in Overall heat transfer coefficient (EXPT)

Sr.no	M_h (LPH)	M_c (LPH)	Percentage increase in heat transfer rate (%)	Percentage increase in Overall heat transfer coefficient (%)
1	300	350	29.57237	38.58938
2	300	400	30.41496	43.2343
3	300	450	32.36842	48.4934
4	300	500	30.59211	46.99926
5	300	550	29.02477	46.24815

4. CFD GEOMETRY



5. Comparison of the CFD Results with Experimental Results

Table 3. heat transfer rate comparison

CASES	M_h (LPH)	M_c (LPH)	Heat transfer rate in watt (EXP)	Heat transfer rate in watt (CFD)	Percentage change (%)
water-water	300	350	928.8889	1104.971	15.93544989
	300	400	1260.038	1358.036	7.216156273
	300	450	1741.667	1746.63	0.284147186
	300	500	1857.778	1898.417	2.14067826
	300	550	1973.889	2106.563	6.298126379
Water-nanofluid	300	350	1203.583	1519.348	20.78292794
	300	400	1643.278	1878.305	12.51271758
	300	450	2305.417	2439.997	5.515580552
	300	500	2426.111	2634.405	7.906681015
	300	550	2546.806	2858.264	10.89675411

Table 4- Overall heat transfer coefficient comparison

CASES	M_h (LPH)	M_c (LPH)	Overall heat transfer coefficient in W/m²·K (EXP)	Overall heat transfer coefficient in W/m²·K (CFD)	Percentage change (%)
water-water	300	350	1116.276	1368.09	18.4062452
	300	400	1573.806	1732.245	9.146454457
	300	450	2322.804	2350.109	1.161861003
	300	500	2477.658	2578.202	3.899772012
	300	550	2632.512	2914.634	9.679500068
Water-nanofluid	300	350	1547.04	1969.245	21.43994272
	300	400	2254.23	2574.321	12.43399716
	300	450	3449.364	3607.985	4.396387457
	300	500	3642.139	3898.56	6.577325987
	300	550	3861.345	4388.126	12.00469175

The comparison of the results of the experimental output & the output of the CFD is done for the heat transfer rate and Overall heat transfer coefficient .The change in the values is within 15%-20% which is acceptable due to the reasons explained below. The changes are shown in the table

6. Result and Discussion

6.1 Experimental Result

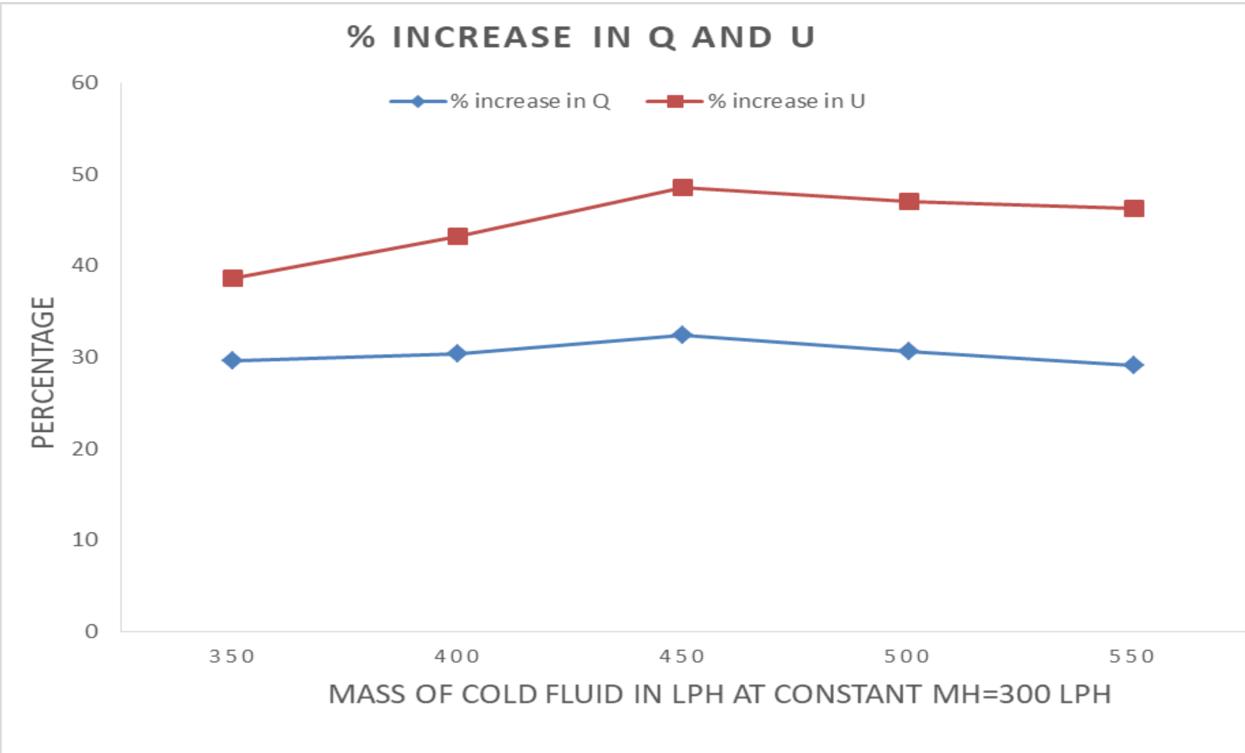


Figure 2 Percentage increase in heat transfer rate and Overall heat transfer coefficient (EXP)

6.2 Cfd Result

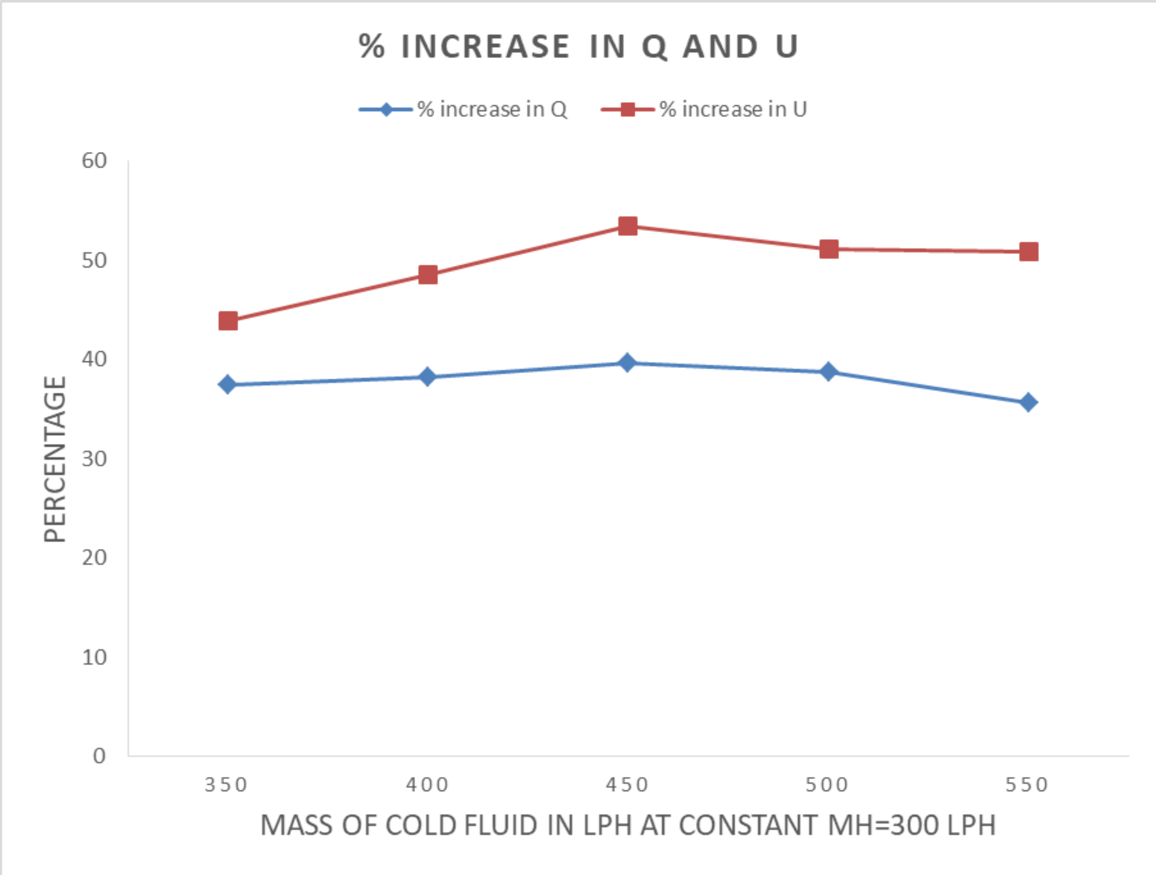


Figure 3 Percentage increase in heat transfer rate and Overall heat transfer coefficient (CFD)

6.3 Heat Transfer Rate Vs Mass of Cold Rate

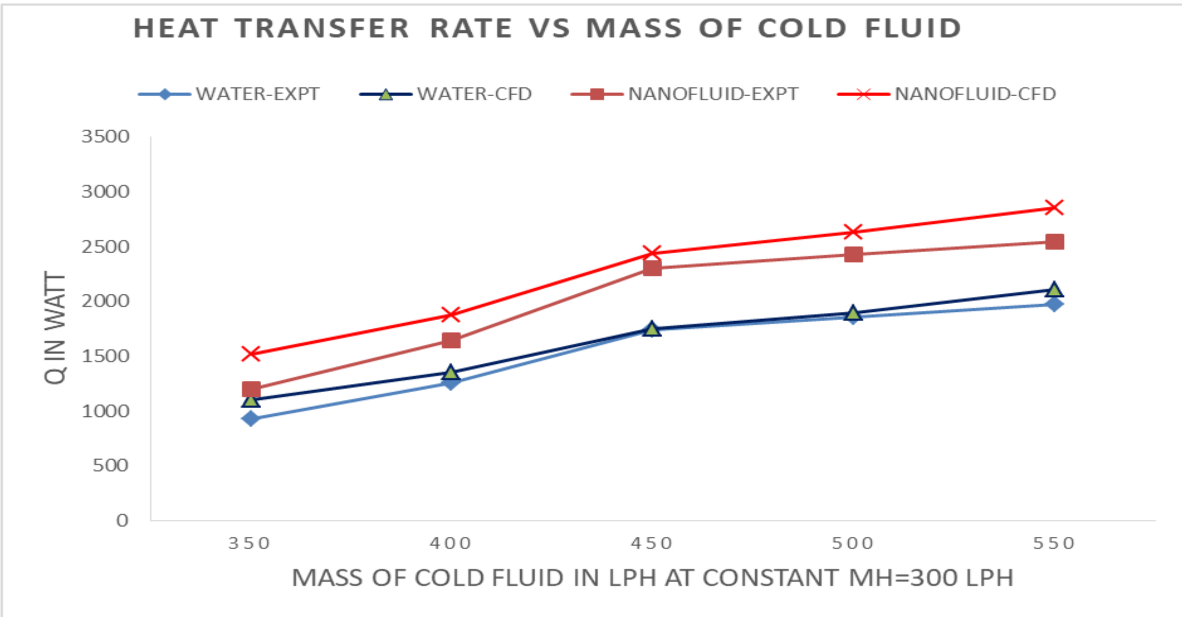


Figure 4 Heat transfer rate Comparison between CFD predictions and experimental data in concentric tube heat exchanger.

6.4. Overall Heat Transfer Rate Vs Mass Of Cold Rate

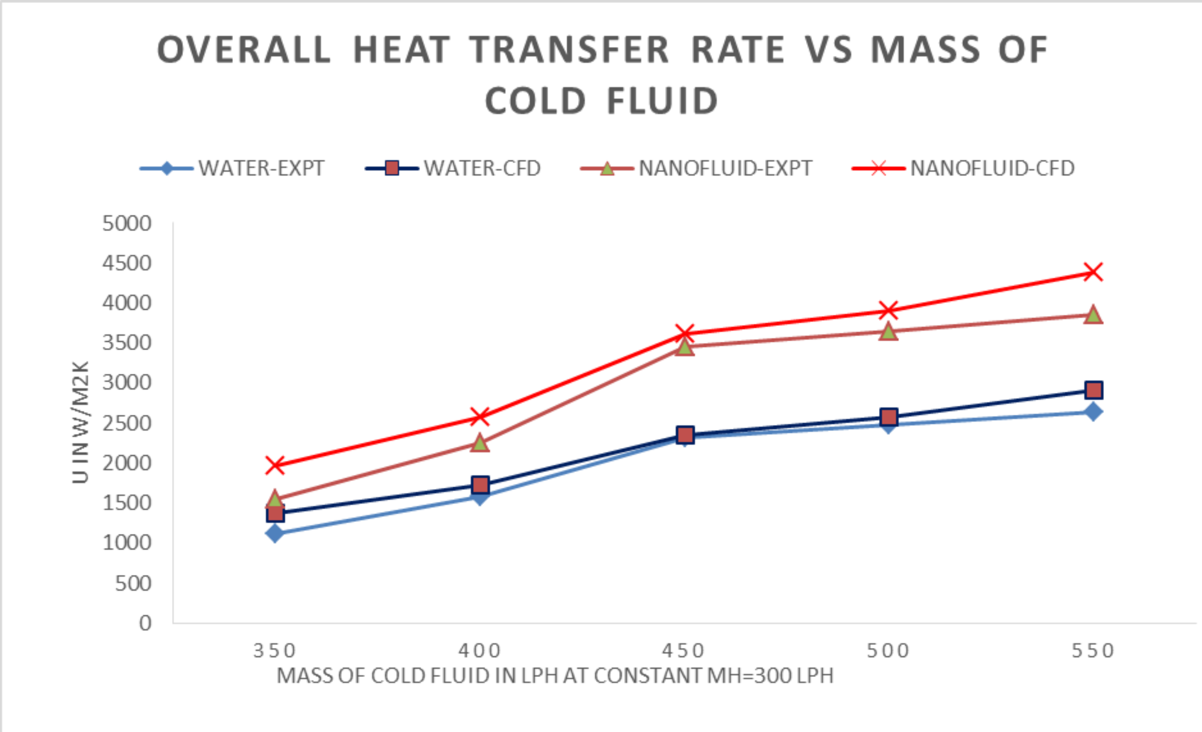


Figure 5 Overall heat transfer coefficient Comparison between CFD predictions and experimental data in concentric tube heat exchanger.

7. Conclusions

In this research, 0.03 vol.% of ZnO–W (with PVP) nanofluid, and water were used concentric tube heat exchanger for experimentally investigating the performance and the CFD simulations have been developed to predict the heat transfer rate and overall heat transfer coefficient of ZnO/water nanofluid in a concentric tube heat exchangers. The results are concluded as below:

1. Mass or volumetric flow rates of the working fluids have significant effect on the performance of the heat exchanger. changing of Outer tube side mass flow rate(cold fluid) with constant inner tube side mass flow rate(hot fluid) it is found in that, for 0.03 vol.% of ZnO–W (with PVP) nanofluid highest performance can be obtained at 450 LPH of outer tube side and 300LPH of inner tube side mass flow rate compared to water -water as working fluid .
2. Experimentally, about 32.36% and 48.49% enhancement in actual heat transfer rate and overall heat transfer coefficient has been observed for 0.03 vol.% of ZnO–W (with PVP) nanofluid compared to water -water working fluid, respectively.
3. From CFD analysis 39.69% and 53.52% enhancement in heat transfer rate and overall heat transfer coefficient has been observed for 0.03 vol.% of ZnO–W (with PVP) nanofluid compared to water -water working fluid, respectively.
4. The CFD results when compared with the experimental results for different conditions were found to be within the error limits
5. The heat transfer rate and overall heat transfer coefficient variation between the experimental and CFD results were within 1% to 12 % which was found satisfactory.
6. The temperatures obtained from the CFD were within the limits and was accepted. The variation was not much than the experimental readings.
7. Using 0.03 vol.% For Reference & Find the Values For 0.01 vol.% & 0.07 vol.% For Mh=300LPH & Mc=450LPH.

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