THE APPLICATION OF FE3O4 / ETHYLENE GLYCOL AS NANOFLUID FOR COOLING SYSTEMS IN PETROLEUM INDUSTRIES

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ABSTRACT

The promising technology that used for e improvement thermal performance for heat transfer processes is using nanofluids as a good choice to replace the conventional fluids. The heat exchangers are the wide range application equipment that used for different industrial applications and therefore, the properties and the behavior of the fluid media are the main control parameters in equipment design of the heat exchangers. Natural convection heat transfer of ferrite nanofluid in rectangular cavity has been investigated experimentally in this work. The cavity is subjected at constant wall temperature ,the upper side is maintained at cold temperature and lower side is maintained at hot temperature ,then it is filled with nanofluid consist of an ethylene glycol (EG) as a base fluid and ferrite (Fe_3O_4) *a nanoparticles. The flow feature are incompressible , laminar, Newtonian nanofluid at arrange of Rayleigh number between* $(7.2\times10^3-3.4\times10^4)$ *.The volume fraction of nanoparticales in the base fluid considered between (0-0.2).Results showed that increase in Nusselt number with increasing of volume fraction of nanofluid and Rayleigh number .Viscosity* (μ) *and heat transfer enhancement thermal ,conductivity (k) increase when the volume fraction of nanoparticles increased.*

KEY WORDS: *Nanofluid, Ethylene Glycol, Cooling Systems, Ferrite, Thermal Conductivity.*

I. INTRODUCTION

Heat transfer is one of the most important industrial processes. Heat must be efficiently added, moved or removed from one process stream to another [1]. Heat exchangers are broadly used in many engineering implementation, for example, application in power production, chemical industry, food industry, waste heat recovery, environment engineering, air conditioning and refrigeration. Nowadays high prices of energy motivate industry to apply energy saving methods as much as conceivable in their aperient [2] .For decades, effort shave been made to increase heat transfer of heat exchangers to reduce the heat transfer time and finally improve energy utilization efficiency .These efforts originally include passive and active sort such as creating turbulence, extending the exchange surface or the use a fluid with higher thermo physical properties [2] .Mainly the convection heat transfer is the dominant type of heat transfer that control the efficiency of the heat exchanger which consist both the forced and the natural (free) convection heat transfer .**S.M.S. Murshed and et al.** [3] studied experimentally the particle size and shape that have effects on the enhancement of thermal conductivity For TiO2 particles of ϕ 10 nm × 40 nm and ϕ 15 nm dimensions with maximum 5% volume fraction, the enhancement is observed to be nearly 33% and close to 30%, respectively over the base fluid. **María José Pastoriza-Gallego et al**.[4] determined experimental thermal conductivity and viscosity at temperatures extend from 283.15 K to 323.15 K using an apparatus based on the hot-wire method and a rotational viscometer, respectively. It has been found that both thermal conductivity and viscosity increase with the concentration of nanoparticles, whereas when the temperature increases the viscosity diminishes and the thermal conductivity rises. **Hyun Jung Kim and et al** [5] investigated natural convection from horizontal cylinders with longitudinal plate fins. We also suggested an empirical correlation for estimating the Nusselt number in the range 300000 <

RaL < 1000000, 1/6 < H/D < 1/2, and 9 < N < 72. **L. Syam Sundar et al** [6] studied experimentally and theoretically thermal conductivity and viscosity of Fe_3O_4 nanofluid for heat transfer applications both experiments are conducted in the volume concentration range 0.0% to 2.0% and the temperature range 20 °C to 60 °C. The thermal conductivity and viscosity of the nanofluid are increased with an increase in the particle volume concentration. **Mahesh Juneja1 and D. Gangacharyulu.** [7] investigated experimentally the impact due to temperature and concentration on thermophysical properties (thermal conductivity, viscosity and density) for Al_2O_3/water/ethylene glycol based. The volume fractions of nanoparticles used are 0.1%, 0.25%, 0.50% and 1.0%.
This work is done in the organization of the college of engineering in the university of Babylon .

II. EXPERIMENTAL SETUP

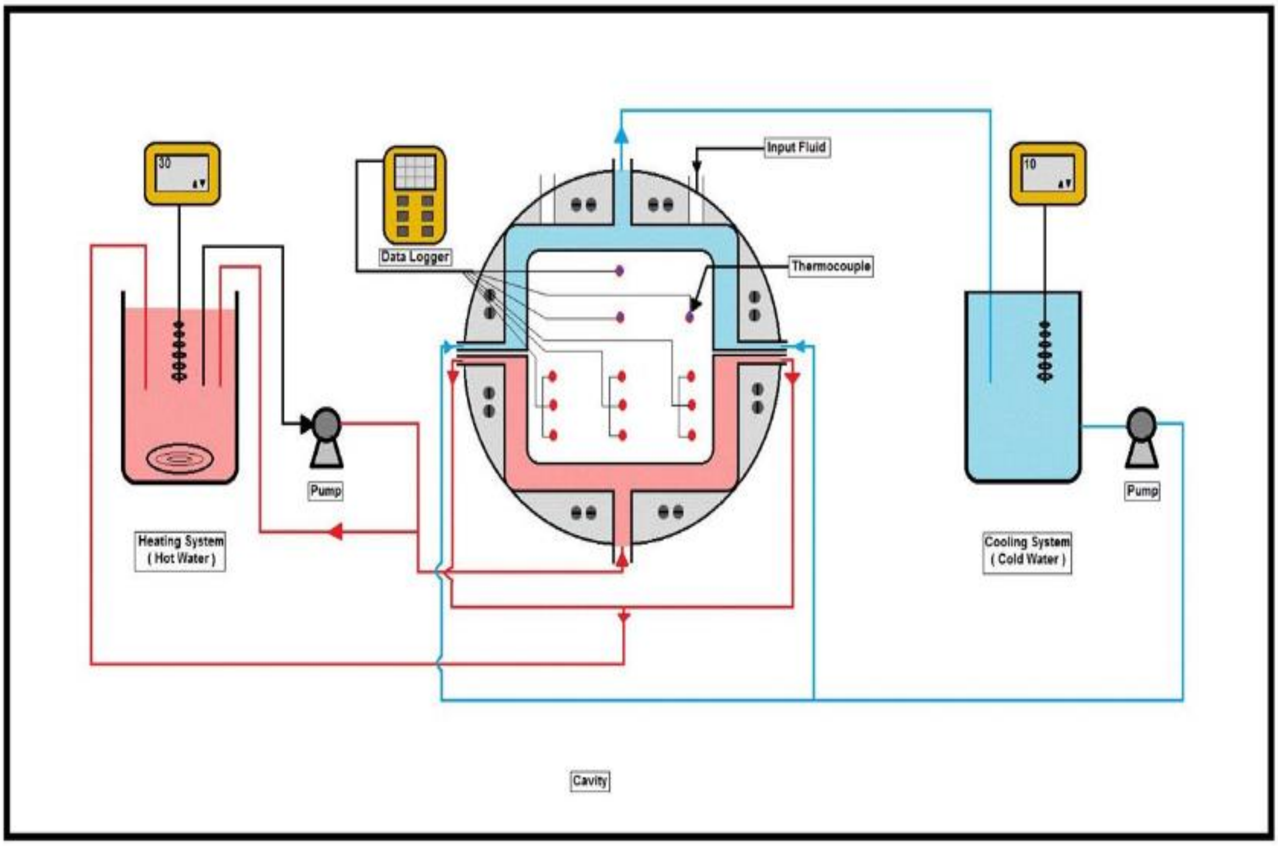


Fig. (1): The Schematic of Experiment Setup.

Fig. (1) Shows the schematic of experimental setup configuration under consideration. The apparatus used in this experiment consists of the test cavity, cooling system, temperature controller and data logger .The cavity is constructed primarily from the Perspex and Teflon. The dimensions of the cavity are (110 mm) length, (90mm) width and (20cm) thickness. The copper channels have a dimension of (20×10) mm supported on the boundaries of the cavity as shown in fig. (2) .The hot water enter the lower part of copper channels from the bottom and collected from the both sides of the hot part of the channels as show in fig.(1) where the cold water enter the cold section of the copper channels from both sides and exit from the upper point of the channels. Location of thermocouples in the cavity explained in table (1).Properties of (Fe_3O_4) Nanoparticle show in table (2).

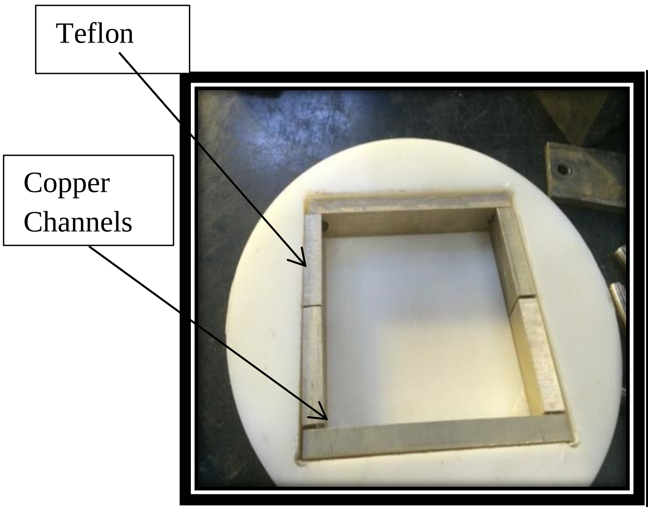


Fig.(2): A Photograph of Copper Channels. **Fig.(3):** A Photograph of the Cavity.

Table1: Location of thermocouples in the gravity

Number of thermocouple	**Coordinate (x, y)**	**Groups of thermocouples**
T1	(0.5, 0.5)	LV1:T1,T2,T3,T4
T2	(0.5, 2.5)	LV2:T5,T6,T7,T8,T9
T3	(0.5, 5)	
T4	(0.5, 7.5)	LV3:T10,T11,T12
T5	(4.5, 0.5)	
T6	(4.5, 2.5)	LH1:T1,T5,T10
T7	(4.5, 5)	
T8	(4.5, 7.5)	LH2:T2,T6,T11
T9	(4.5, 10)	
T10	(8.5, 0.5)	LH3:T3,T7,T12
T11	(8.5, 2.5)	
T12	(8.5, 5)	

2.1 Effective properties of nanofluid

The effectiveness of heat transfer is described by the convective heat transfer coefficient, which is a function of a number of thermo- physical properties of the nanofluid, the most significant ones being density, specific heat, viscosity and thermal conductivity [8].

the density of the nanofluid

$$\rho_n = \rho_s \chi + \rho_f (1 - \chi) \quad (1)$$

the heat capacity of nanofluid

$$Cp_n = (\rho_s \mathrm{Cp_s} \chi + \rho_f \mathrm{Cp_f} (1 - \chi))/\rho_n \quad (2)$$

the viscosity of nanofluid

$$\mu_n = \frac{\mu_f}{(1 - \chi)^{2.5}} \quad (3)$$

the thermal conductivity of nanofluid

$$\frac{k_n}{k_f} = \frac{k_p + 2k_f - 2(k_f - k_p)\chi}{k_p + 2k_f + \left(k_f - k_p\right)\chi} \quad (4)$$

Table (2): Properties of (Fe_3O_4) Nanoparticle.

Property	**(Ferrite) Fe_3O_4**
Thermal conductivity	80 w/m .k
heat capacity	670 J/k
Density	5180 kg/m^3
Thermal expansion coefficient	0.00052 1/k
Particle size	20nm
ContentFe_3O_4	>=99%
Other content	Ca(0.023),Cr(0.002%),K(0.002%),Mn(0.084%) SiO_2(0.141%)

2.2 Nanofluid Experimental Procedure:

The nanofluid used for the experiments has different volume fraction (0.02,0.04,0.1 and 0.2) four temperature of hot water have been applied in each concentration (30°C,40°C,50°C and 60°C).The cooling system is applied at Tc 10 °C at constant of temperature .Nanofluid is put in the cavity .The data logger are switched on and set .The thermocouple readings recorded each second and saved in Temperature Recorder (data logger) by SD-RAM .their reading are observed with time until become constant ,at that time data logger is switched off and SD-RAM is drown.

2.3 Experimental Data Analysis and equations.

In order to determine the local Nusselt number by natural convection at each time ($Nu = hL/k_f$), a thermal balance is performed as follows:

$$q_w = h(T - T\infty) \quad (5)$$

$$h = -\frac{K\frac{dT}{dX}}{Tw - T\infty} \quad (6)$$

And $Nu = \frac{h.L}{K}$

$$Nu = \left(\frac{T_w - T_i}{T_h - T_c}\right).\frac{L}{\Delta X} \quad (7)$$

The average Nusselt number can be calculated by integrating local Nusselt number along the heat source as follows:

$$Nuav = \frac{1}{L}\int_0^L Nu\,dy = \frac{1}{L}\int_0^L \left(\frac{T_w - T_{i.}}{T_h - T_c}\right).\frac{L}{\Delta X}\,dy. \quad (8)$$

This average Nusselt number may be calculated by applying Simpson's rule.

III. RESULTS AND DISCUSSION

3.1 Temperature Distribution

Fig. (8) and Fig. (5) Show the experimental results at χ =0 and χ =0.02 respectively, pure Ethylene glycol (E.G). It can be recognized that there is a fluctuation in temperature change all over the cavity .This was a periodic transient behavior of natural convection that is theoretically expected .However; there was some differences in temperature values between LV1 and LV2 due to unsymmetrical behavior of convection. Moreover, the higher effect in temperature was LH1 at the lower hot wall and more specific at T5 where the increase in temperature at this point higher than other points.

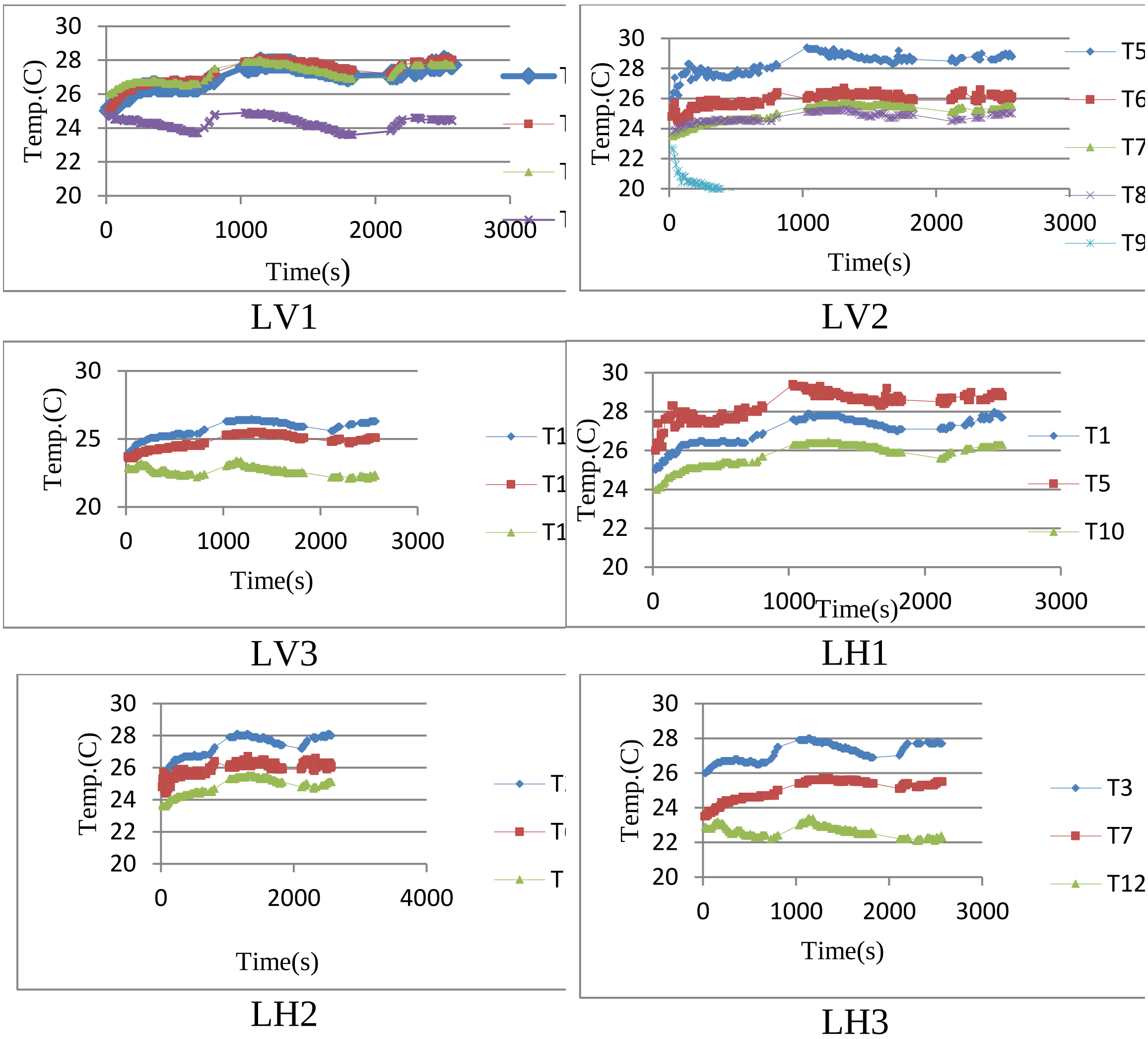
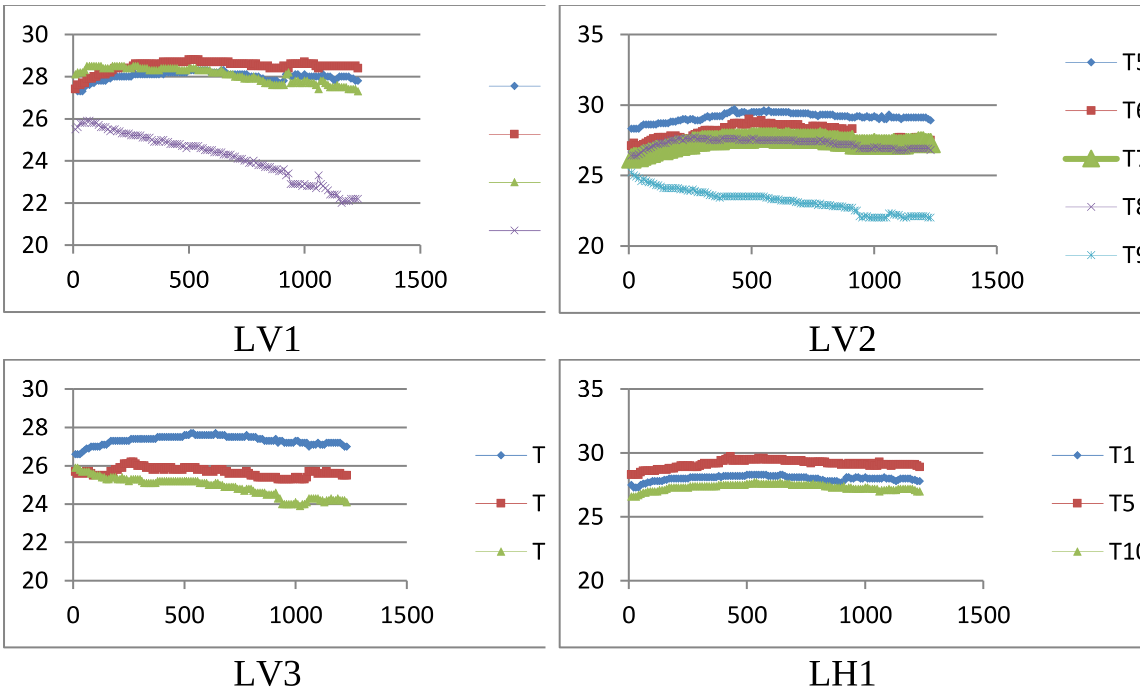
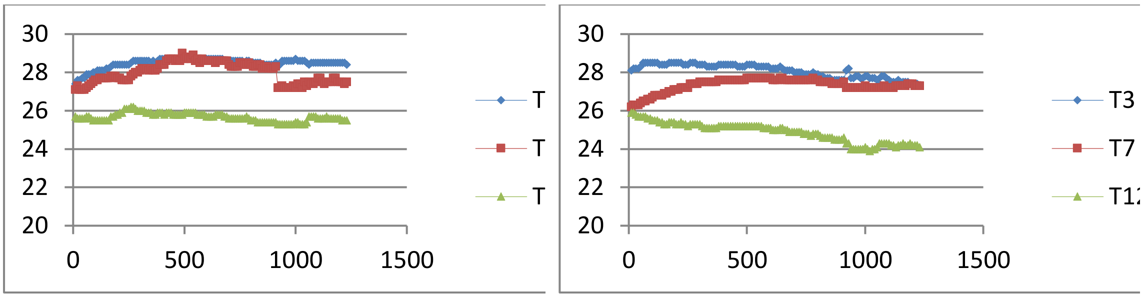


Fig.(4): Experimental transient distribution temperature at (χ = 0) volume fraction of Fe_3O_4





LH2 LH3

Fig.(5): Experimental transient distribution temperature at (χ = 0.02) volume fraction of Fe_3O_4

3.2 Nusselt Number

Fig.(6) at experimental values of Rayleigh number (7.2×10^3 ,1.2×10^4, 3.4×10^4) at the higher volume fraction leads to crowded particles means transferring more heat energy. Another effect with high concentration reduced the elapsed time to reach the steady state. Fig.(7) shows the empirical correlation is developed for predicting the average Nusselt number of lower part section of the cavity .In order to describe the relation between the dependent variable (Nusselt number) and the independent variables (Rayleigh number and volume fraction of nanofluid), a correlation have been made based on the following simplified version:

$$Nu, avg = f(Ra\,, x) \qquad (9)$$

Such correlation may be solved by Lewis Square Method (LSM), with multiple correlation coefficient (R) =0.82138 which explains the differences between the observed and predicted values.

$$Nu, avg = 0.5899\, Ra^{0.146}\,(1-x)^{-4.385} \qquad (10)$$

Fig.(8) show the variation of Ehancement with volume fraction and the effect of increasing the Rayleigh number of experimental present work .Also concluded when increase concentration of nanoparticles and the Rayleigh number increases, The irregular motion of nanoparticles due to Brownian force can disturb the laminar boundary layer, which can enhance the heat transfer of natural convection and the velocity of the nanofluid became bigger and the convection heat transfer of the nanofluid enhancedment. Additionally, (E) increases as (Ra) is increased .The enhanecement of Nusselt number according to the following equation:

$$E\% = \frac{Nu(nanofluid) - Nu(base\ fluid)}{Nu(base\ fluid)} \times 100\% \qquad (11)$$

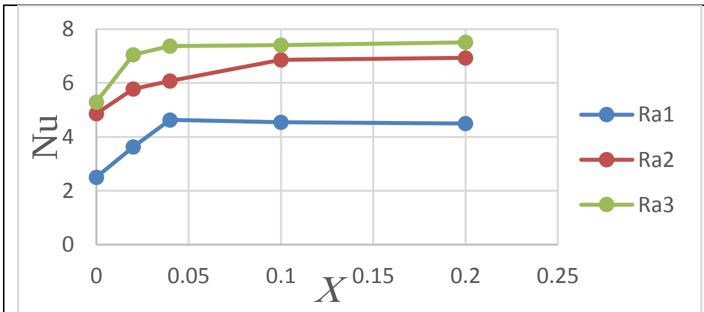


Fig.(6): Variation Nuseelt number (Nu) versus volume fraction (χ) at experimental results for (Ra1 ,Ra2,Ra3)

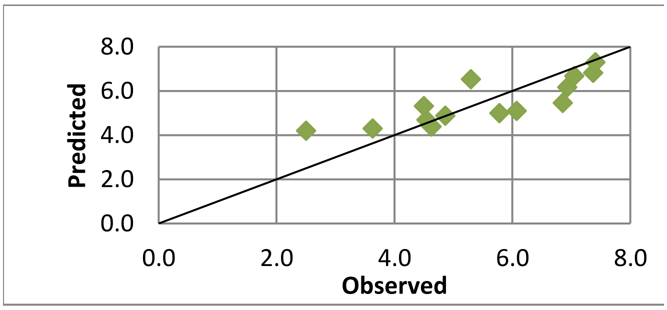


Fig.(7): Average Nusselt number from present work

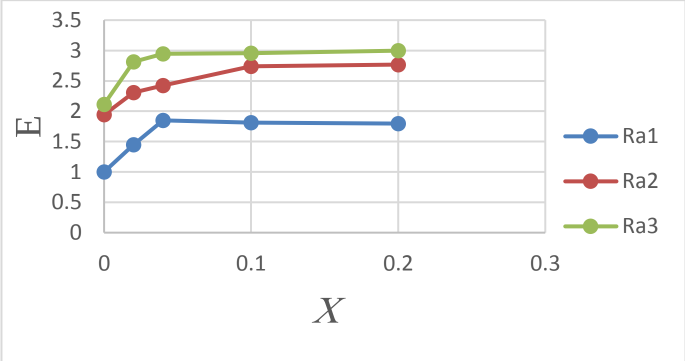


Fig.(8): Experimental varation of Ehancement (E) versus volume fraction (χ) for (Ra1 ,Ra2,Ra3).

IV. Conclusions

1. The nanofluid consists of (Fe_3O_4–E.G) shows higher Nusselt number compared with the base fluid (Ethylene Glycol).
2. Thermal conductivity (k) and viscosity (μ) increase when the volume fraction of nanoparticles increased.
3. The Heat transfer enhancement increases with increase nanoparticles volume fraction and Rayleigh number.
4. The temperature distribution in (LH1) has high temperature at point (T5) because that located at the bottom of the cavity .In general the temperature decreases when the distance increases for the vertical component (LH1, LH2).
5. The average Nuseelt number increases when the temperature, Rayleigh number and volume fraction of nanoparticles increase.

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