University of Thi_Qar Journal for Engineering Sciences ISSN 2075-9746
http://www.doi.org/10.31663/tqujes.10.1.360(2019)
Vol10 No.1 (May 2019) Available at http://jeng.utq.edu.iq
engjrnal@jeng.utq.edu.iq

Numerical investigation the performance of micro channel heat sink with different cooling mediums

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Abstract

This study aims to study the effect of different cooling fluids (pure fluids, Nanofluids and microencapsulated phase change materials suspensions) and the cooling performance of rectangular micro-channel heat sink. Three types of Nanofluids (Al_2O_3-water, Cu-water,Tio_2-water), three types of microencapsulated phase change materials suspensions(MEPCM) are(RT44-water, paraffin wax water, n-octed-water) and three pure fluids(Water, Oil ,Ethylene Glycol) were used with constant heat flux(100 W /cm^2) applied on the base of heat sink. The volumetric concentrations of Nanofluids and MEPCM suspensions (1%, 3%, and 5%) and (100 to 900) is the range of Reynolds number used in this study. The results showed that, using different types of Nanofluids and MEPCM suspensions lead to enhance the cooling performance of the micro channel heat sink (MCHS), since it lead to increase the heat transfer compared with pure fluids. The heat transfer in (MCHS) for MEPCMs is higher than that for Nanofluids. Also, the performance of heat sink increases with increase the concentration of Nanofluids and MEPCMS at certain volumetric concentration. Additionally, the pressure drop for MEPCM suspensions and Nanofluids increased compared with pure fluids.

Key words: Micro channel, heat sink, Nano Fluid, MEPCMs , Numerical Investigation.

NOMENCLATURE:

c_p specific heat (J/Kg. K)
C volumetric concentration (%)
K thermal conductivity (W/m.K)
m mass flow rate (kg/s)
P total pressure (Pa)
q heat transfer rate (W)
T temperature (K)
U fluid x-component velocity (m/s)
V fluid y-component velocity (m/s)
W fluid z-component velocity (m/s)
W width (m)
H height (m)
h heat transfer coefficient (W/m^2 K)
X axial coordinate (m)
Y vertical coordinate (m)
Z horizontal coordinate (m)
ΔP pressure drop across heat sink (Pa)

Greek Symbols:
ρ density (kg/m^3)
µ dynamic viscosity (m^2 /s)
ß Melting fraction
ϕ Mass fraction

Abbreviation:
B Base
C Channel
PCM Phase change material
H.S Heat sink

MCHS Micro-channel heat sink
MEPCMs Microencapsulated phase change material suspension
V volume
η The overall performance factor

1. Introduction

Micro-channel technique has been widely used to introduce highly capable heat sink cooling apparatuses. Micro channel heat sink can be considered as a new and efficient cooling apparatus to extract a great amount of heat from a small area. Generally, heat sink is manufactured from low cost materials, like aluminum, brass or copper. Heat sink is represents a heat exchanger that allows to transfer heat produced in electronic apparatuses to a fluid medium, generally a fluid medium that used air or pure fluids to recognize heat generated from apparatuses. Heat sinks are used to cool CPUs or any other electronic apparatuses.

The phase change materials are materials have great heats from fusion, also it has ability to absorb a lot of energy before melting or solidifying, according to latent heat and melting temperature, it can be used to improve the thermal performance of a micro channel heat sink. Also, Nanofluids are an expression of particles of solid materials mixed with the fluid, The nanoparticles appearance great thermal conductivity which is normally caused improved convection between the nanoparticles and base liquid surfaces Nanofluids are important for increase the heat transfer in (MCHS) and advance cooling performance in apparatuses. There are many researchers in literature studied the performance of heat sink and using of phase change materials and Nano fluids. Investigated numerically the heat transfer in micro channel heat sink with more types of Nanofluids. They found that the greatest heat transfer improvement can be found in using Al_2O_3-water Nanofluid. The heat transfer performance of Al_2O_3-water and Diamond-water Nanofluids was 21.6 % best than that of pure water [1]. Experimentally investigated of the effects of PCM, heat sink designs and power levels on PCM based heat sinks performance for cooling of electronic apparatuses. PCMs commonly suffer from low thermal conductivities. Six types of PCMs were used containing paraffin wax (as reference material), two materials based on mixture of inorganic hydrated salts, two materials based on mixture of organic materials and one material based on a mixture of both organic and inorganic materials. They found that PCMs important to improve the cooling performance [2]. Studied the heat transfer description of Nano fluids cooling in the mini- rectangular heat sink. (Tio2-water) is the Nano fluid used. They found that normal heat transfer rates for Nano fluids as a coolant are greater than those for the water [3]. Used Nano encapsulated phase change material (NEPCM) slurry as a cooling fluid instead of pure fluid. Their results show, a Lower temperatures across the electronic device can be reached at high heat flux compared with using water as the only cooling fluid, Therefore using Nano encapsulated phase change material to enhance thermal performance of a micro channel heat sink**[**4]. Numerically investigated of a micro channel heat sink with extended micro channels and used three types of Nanofluids (Cu-water, Al_2O_3-water and Diamond-water) with volume concentration (1 – 5) %, The shapes of micro pin fins were used to heat transfer improvement(square and triangular) to study and develop the cooling performance of micro channel heat sink. He found that the overall performance of micro channel heat sink increased with increasing the expansion ratio or decreasing the expansion length. Also using of Nanofluids lead to enhance the heat transfer [5]. Numerically studied of the thermal performance of a transferable electronic apparatuses by using PCM in heat sink. They used PCM (n-eicosane) with a melting point of 36.5C. They discussed that, the power of the natural convention in the melting and the effect of the natural convention in the melting. Their results showed that, the PCM is melting for increasing ambient temperature and decreasing in the latent heat phase is noted by increasing in the stages for the power input [6]. Numerically Investigated of the phase change materials (PCMs) in a micro-channel heat sink (MCHS).The (paraffin wax, neicosane, p116 and RT41) with different shapes have been used as cooling mediums in different types and different shapes at different ambient temperatures. And, initially the air is used in heat sink. Constant heat flux is applied on the base of heat sink. They found that using of the phase change material should be certain according to its melting temperature and lead to advance the cooling performance of micro heat sink [7]. Numerically Investigated to study the microencapsulated phase change materials (MEPCM) suspension as a coolant instead of pure fluids in the micro channel heat sink (MCHS), The MEPCM suspension used in this study contain of microcapsules created of (n-octadecane, RT44) as a phase change materials (PCM) and shell materials are poly-methylmthacrylate (PMMA), poly-alpha olefin (PAO), these capsules are suspended in(pure water, ethylene glycol and pure oil) in a concentration of (0–20)% and have been used as a cooling mediums at different ambient temperatures. They found that using of MEPCM suspensions as a coolant in micro heat sink instead of conventional cooling with pure fluid lead to improve the cooling performance of micro heat sink [8].

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2. Problem description:

The model studied in this study is 3D micro-channel heat sink contains of 6 channel as shown in **Fig.1.a** which symbolizes the micro channel heat sink (MCHE) which contains from rectangular channel and the flow is consider single phase. The length of the micro channels heat sink is 10mm, width 100μm and height 100μm. Flow in this model is conjugating heat transfer where the 3D governing equations used to solve this model are continuity, momentum and energy required be solved in the solid and fluid zones simultaneously. A unit contains of one channel as shown in **Fig.1.b,** will be used for solving and symbolizing the complete heat sink to simplify the numerical solution.

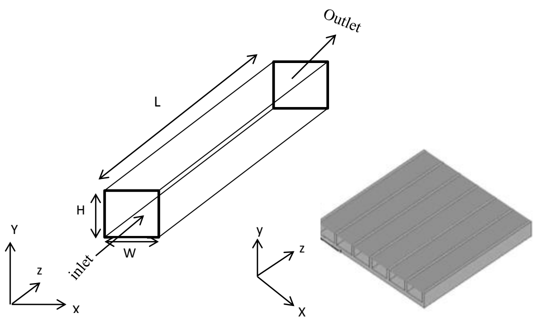

Figure.1.b Schematic of micro channel heat sink unit

Figure 1:.a Schematic of micro channel heat sink

Figure 1:.a Schematic of micro channel heat sink.
Figure.1.b Schematic of micro channel heat sink unit.

3- MATHEMATICAL MODEL:

3-1- Governing equations
The governing equations for this conjugated heat transfer problem can be written as follows:[8],[9]and[10]
The continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad \text{.......... (1)}$$

Momentum equations:

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\mu\rho\left(\frac{\partial 2u}{\partial x2}+\frac{\partial 2u}{\partial y2}+\frac{\partial 2u}{\partial z2}\right) \quad \text{.......(2)}$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial y}+\mu\rho\left(\frac{\partial 2v}{\partial x2}+\frac{\partial 2v}{\partial y2}+\frac{\partial 2v}{\partial z2}\right) \quad \text{..... (3)}$$

$$u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial z}+\mu\rho\left(\frac{\partial 2w}{\partial x2}+\frac{\partial 2w}{\partial y2}+\frac{\partial 2w}{\partial z2}\right) \quad \text{... (4)}$$

Energy equation:

$$\rho Cp\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=k\left(\frac{\partial 2T}{\partial x2}+\frac{\partial 2T}{\partial y2}+\frac{\partial 2T}{\partial z2}\right) \quad \text{.............(5)}$$

3-2- Model boundary conditions:

The boundary conditions are required to complete the mathematical models :
1- At the inlet the finite values of velocity and temperature were used
T = 293 K , W=W_i
2- The bottom wall have Constant heat flux=100 w/cm^2

3- other outer surfaces of the model (right, left and top walls) are assumed insulated walls

4-At the end wall of the channel(stagnation pressure =0),fully developed flow

The heat transfer rate is the amount of heat removed by heat sink
$q = m\ cp\ \Delta T$............(6)
The inlet velocity is calculated based on Reynolds number.

$$Re=\frac{\rho\ wD_h}{\mu}$$

Where:
D_h is the hydraulic diameter.
And the pressure drop is the difference between the total pressure at the inlet and outlet.

$$\Delta p = p_i - p_o$$

٤- Properties of Nanofluids:

For calculated the thermo-physical properties of Nano fluid the following equations will be used: [9],[12]
The density and specific heat are calculated by using

$$\rho_{nf}=(1-\emptyset)\rho_{nf}+\emptyset\rho_s \quad \text{............. (7)}$$

$$cp_{nf}=\frac{(1-\emptyset)\rho_f cp_f+\emptyset\rho_s cp_s}{\rho_{nf}} \quad \text{................(8)}$$

The viscosity of the Nano fluid was calculated from the relation:

$$\mu_{nf}=\frac{\mu_f}{(1-\emptyset)^{2.5}} \quad \text{.....................(9)}$$

To calculate the thermal conductivity of Nano fluid following relationship was used:

$$\frac{k_{nf}}{k_f}=\frac{k_s+2k_f+2\emptyset(k_f-k_s)}{k_s+2k_f+\emptyset(k_f-k_s)} \quad \text{...........(10)}$$

5- properties of the MEPCM and Suspensions:

The properties of the suspension of phase change material are a combination of the properties of the microcapsules and suspending fluid using a mass and energy balance:[8[,[13]

5-1-properties of the MEPCM:

In fig 2. Shows the MEPCM particle during melting
The density and specific heat are calculated by using

$$\rho_{PCM}=\frac{10}{7}\left(\frac{d_c}{d_{PCM}}\right)^3\rho_{PCM} \quad \text{.......... (11)}$$

$$cp_{PCM}=\frac{(7Cp_c+3\ Cp\ _{wall})\ \rho_c\ \rho_{wall}}{(3\ \rho_c+7\ \rho_{wall})\ \rho_{PCM}} \quad \text{............ (12)}$$

The calculation of thermal conductivity of the microcapsules by using compound sphere approach is given by:

$$\frac{1}{K_{PCM}\ d_{PCM}}=\frac{1}{K_c\ d_c}+\frac{d_{PCM}-dc}{K\ _{wall}d_{PCM}\ \ dc} \quad \text{............ (13)}$$

In fig 2. Shows the MEPCM particle during melting

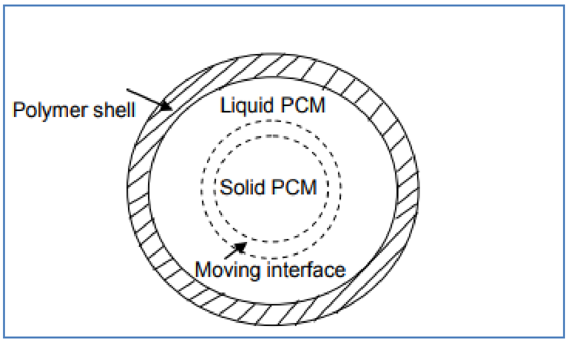

Figure ٢: sketch of single MEPCM particle during melting

5-2-properties of the suspension

$$\rho_f = c\rho_{PCM} + (1-c)\,\rho_w \;\ldots\ldots\ldots\ldots \quad (14)$$

$$Cp_f = \varphi\, cp_{PCM} + (1-\varphi)\, cp_w \;\ldots\ldots \quad (15)$$

Where φ is the mass fraction which can be calculated by:

$$\varphi = \frac{c\rho_{PCM}}{((\rho_w + c(\rho_{PCM} - \rho_w))} = \frac{c\rho_{PCM}}{\rho_f} \;\ldots\ldots (16)$$

The viscosity of the suspension was calculated from the relationship:

$$\mu_f = \mu_w\,(1 - c - 1.16c^2)^{-2.5} \;\ldots\ldots\ldots\ldots (17)$$

To calculate the thermal conductivity of suspension PCMs following relationship was used:

$$K_f = \frac{(2kw + kPCM + 2C(Kpcm - kw))}{(2 + KPCM\,kw - C(kPCM/Kw - 1))} \;\ldots\ldots\ldots (18)$$

To calculate the performance of heat sink the ratio of heat transfer to the pumping power we used as an overall performance factor indicator

$$\eta = q/p.p \;\ldots\ldots\ldots\ldots (19)$$

Where P.P is the pumping power and calculated from :

$p.p$ = Δp. V. …………….. (20)

To calculate the pressure drop from the following equation:

$\Delta p = P_{out} - P_{in}$………..…(21)

6-Assumption of channel flow:

1-. Steady fluid flow and, Incompressible fluid.

2- Laminar flow

3- Negligible radiation heat transfer.

4- Constant solid and fluid properties.

-The concentration for suspensions of phase change material and Nanofluid used in this study were (1%, 3%, and 5%) and water is the base fluid used for them. The properties of Three types of pure fluid, Nanofluids and suspensions of phase change material are listed in tables.

Table 1:Thermo-physical properties of pure fluids.[10]

Material	ρ(kg/m^3)	Cp(J/kg K)	K(W/m K)	μ(kg/m s)
Pure Water	998.2	4182	0.613	0.001003
Ethylene glycol	1117.48	2382.1	0.2492	0.022
Oil	888.23	1880.3	0.145	0.8451

Table 2.Thermo-physical properties of Oxide material.[2]

Material	ρ(kg/m^3)	Cp(J/kg K)	K(W/m K)	μ(kg/m s)
Al_2O_3	3970	765	40	---
Cu	8954	383	400	---
TiO_2	4250	686.2	0.358	---

Table 3:Thermo-physical properties of phase change materials.[3]

material	ρ(kg/m^3)	Cp(J/Kg.K)	K(W/mK)	μ(kg/m s)	L.H(KJ/Kg)	ΔT
RT44	780	2	0.2	---	255	TL=45C TS=41C
Paraffin wax	880	2.8	0.212	---	173.6	TL=58C TS=56C
n-octed	771	2.2	0.358	---	243.5	TL=27.7C TS=27.7C

7-Numerical solution:

The governing equations and boundary conditions are numerically solved by using finite volume method. (FLUENT 3.6) is applied to solve the above set of governing equations with the approved boundary conditions to calculate the distribution of velocity, pressure and temperature. For solve the problem of combination to calculating the flow variables by solving the continuity, momentum, energy equations SIMPLE algorithm is used. To find out the suitable mesh size that gives highly accurate solution, A mesh has been chosen in recognized size since a mesh refinement has been made. Table 4 include many attempts of meshes, in this table shows the different meshes selected and through this table it can be understood that, the solution suits independent of mesh size after the third mesh. Thus, the fourth mesh will be used for completely next solutions.

Table 4:Grid independent study

Mesh size	Outlet temperature(K)
mesh1(account size=10*40*10)	302.6549
mesh2(account size=20*60*20)	294.52
mesh3(account size=35*80*35)	293.473
mesh4(account size=12*100*12)	293.4

The convergent measures used to check the numerical solution is $10^{-6}$for both momentum and energy equations.

A Fluent 6.3 software has been used to do the numerical solution.

8-Results and discussions:

8-1- Validation

This model is validated with numerical model presented in [10]. To check the validity of used numerical model presented in [10]. Micro-channel heat sink have vertical height 180µm length 10mm and width 57µm. For this study the boundary conditions applied on this model at inlet temperature of 25C, inlet velocity 1m/s and constant heat flux of 100 W/cm^2 subjected on the bottom wall of micro channel heat sink of the model. **Fig.3** shows the relationship of the numerical results and results of present model [10] for the heat transfer of heat sink. It can be recognized from this figure that the agreement between results is suitable where the maximum error is 0.31%.and **Fig.4** the relationship between the numerical results and results of present model [10] for the pressure drop of heat sink. It can be illustrious from this figure that the agreement between results is suitable where the maximum error is 0.34%.

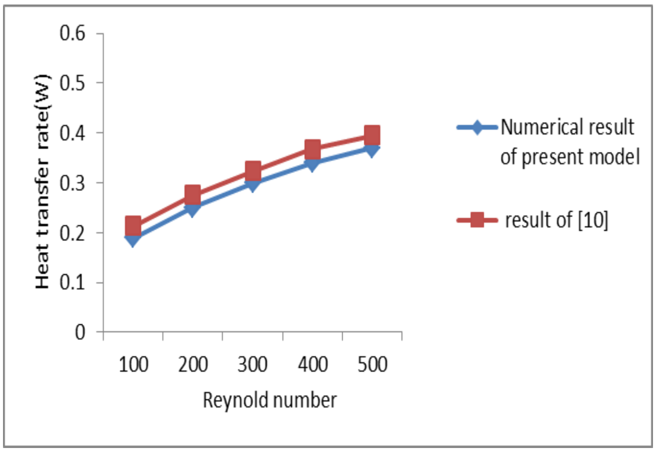

Fig. 3 : Variation of heat transfer with Reynolds number for micro channel heat sink as comparison between result of present model for pure water[10]

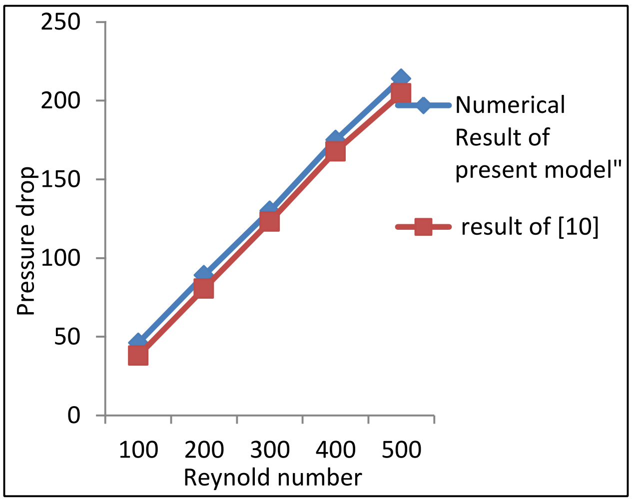

Fig. 4: Variation of the pressure drop and Reynolds number for micro channel heat sink as comparison between result of present model for pure water[10]

8-2- Results:

In this study, a 3D micro-channel heat sink with using the rectangular channel, pure fluids, Nanofluids, and suspensions phase change materials are numerically investigated. Initially, the model is solved with pure fluid(Water, Oil ,Ethylene Glycol). Then select of pure water to mixed with Nanoparticles and PCMs with different concentrations as a cooling mediums. To find out the best case that gives greater performance and cooling of heat sink for different types of MEPCM suspensions and Nanofluids.

Fig. 5 shows the Variation between the heat transfer rate and Reynolds number of pure fluids for micro channel heat sink. From this figure it can be seen that the heat transfer increased with increasing Reynolds number for studied fluids due to increase mass flow rate which case increase in amount of heat transfer, pure oil give higher value of heat transfer due to it has higher velocity than pure water and pure Ethylene Glycol. **Fig.6** explains the Variation of the Nusselt number with Reynolds number of pure fluids. From this figure it can be seen that Nusselt number of the pure Oil is higher than pure water and pure Ethylene Glycol, due to it higher value of heat transfer rate caused with using pure oil as indicated in fig. 4.

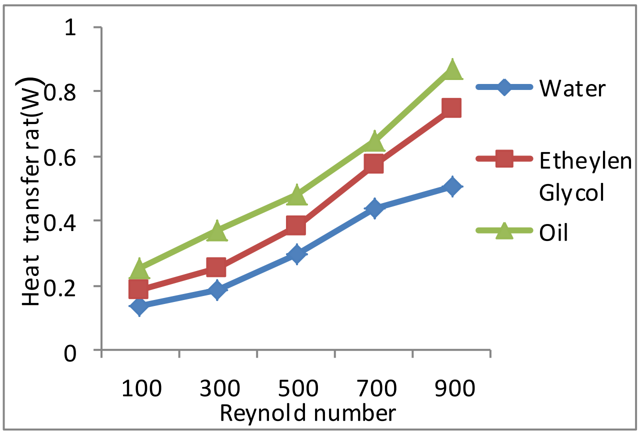

Fig 5: Variation between the heat transfer with Reynolds number of pure fluids for micro channel heat sink

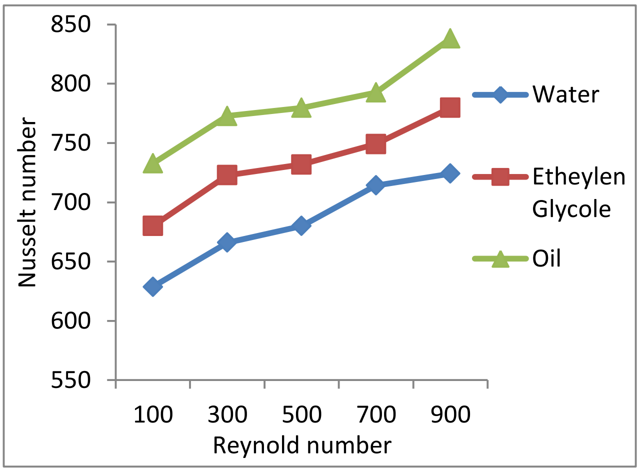

Fig. 6: Variation between the Nusselt number with Reynolds number of pure fluids for micro channel heat sink.

Fig. 7illustrated the Variation of the pressure drop and Reynolds number of pure fluids for micro channel heat sink. From this figure it can be seen that the pressure drop increase with increasing Reynolds number due to increase velocity for all pure fluids. And the pure oil is give higher value of the pressure drop than pure water and pure Ethylene Glycol due to it has greated viscosity and density. **Fig.8** Shows the Variation of the overall performance factor (Ƞ) and Reynolds number of pure fluids for micro channel heat sink. It can be seen Note from this figure that the overall performance factor is decrease with increase Reynolds number for all pure fluids dependent on the velocity. Also, the pure water gives higher value of overall performance factor compared with pure Ethylene Glycol and pure oil due to the pure water has lower pressure drop.

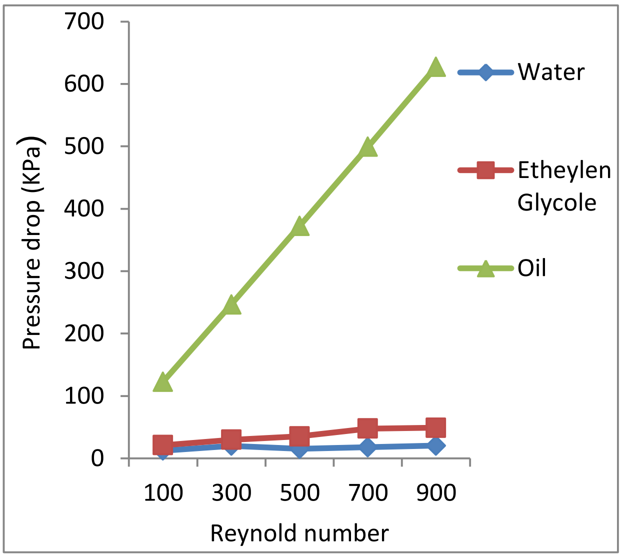

Fig. 7:Variation between the pressure drop and Reynolds number of pure fluids for micro channel heat sink

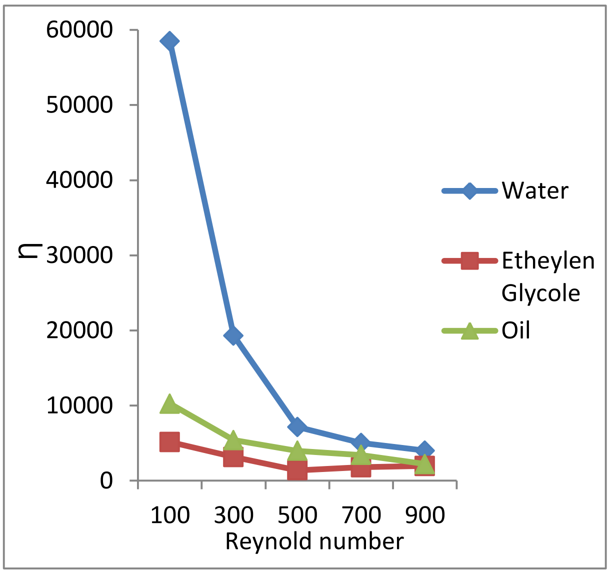

Fig. 8:Variation of the overall performance factor(Ƞ) with Reynolds number of pure fluids for micro channel heat sink.

Figs. (9, 10, and 11) shows the Variation of the heat transfer rate with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink for all different concentrations(1%,3%,5%). From these figures that it can be seen that the MEPCM suspension gives a higher value of heat transfer for all volume concentrations compared with Nanofluids and pure water for microchannel heat sink due to it absorb extra amount of heat as a latent heat through melting heat and enhance the heat transfer process is greated than Nanofluids and pure water. While, Nano fluids exhibit moderate heat transfer in comparison with PCMs but higher than the pure water due to high thermal properties. **Figs (12,13 and 14)** represent the Variation of the Nusselt number with Reynolds number of MEPCM suspension, Nanofluids and pure water for micro channel heat sink for all volumetric concentrations(1%,3%,5%).From these figures it can be seen that MEPCM suspensions gives a higher value of Nusselt number for all concentrations compared with Nanofluids and pure water due to it has heat transfer coefficient (h) higher than Nano fluids and pure water, Which is may be due to smaller thickness of layers boundary. While, heat transfer coefficient (h) of Nanofluids are more than pure water therefore the Nusselt number production of Nanofluids is greater than that of pure water.

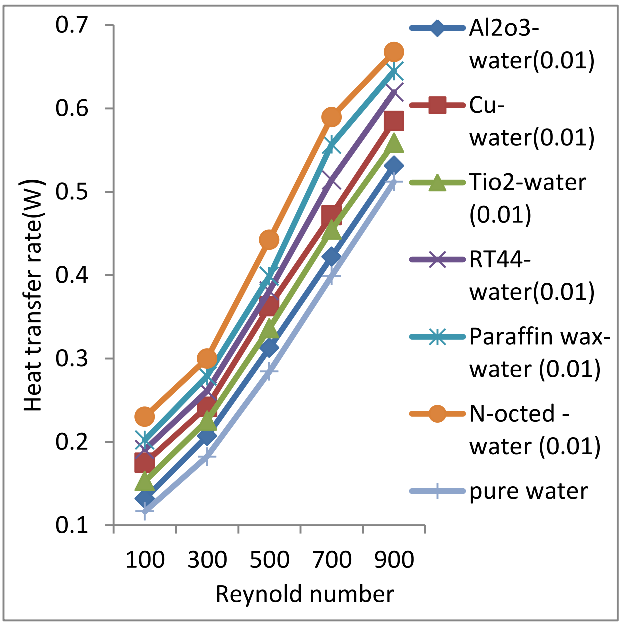

Fig 9:Variation of the heat transfer rate with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at concentration 1%

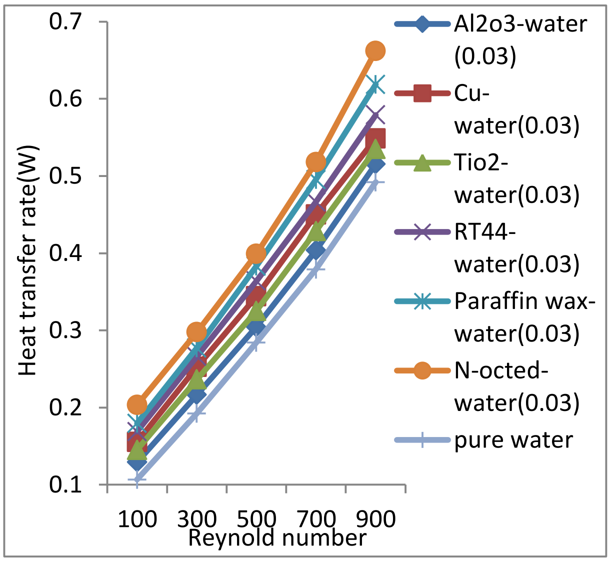

Fig 10.Variation of the heat transfer with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at volumetric concentration 3%

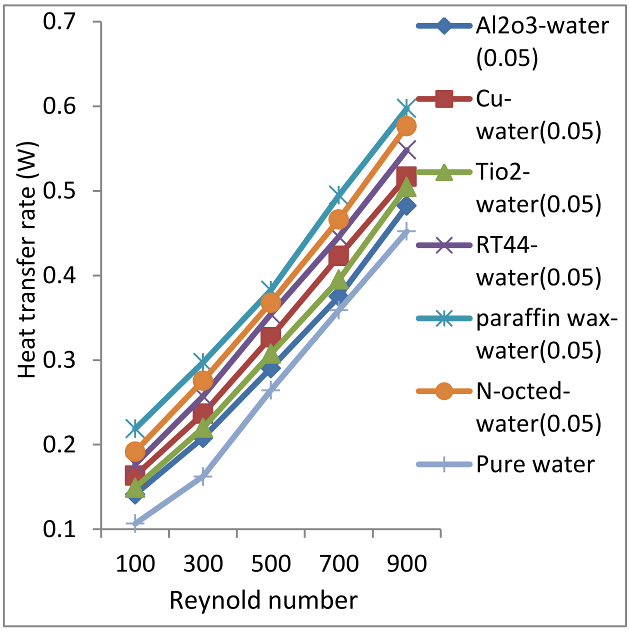

Fig 11.Variation of the heat transfer with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at volumetric concentration 5%

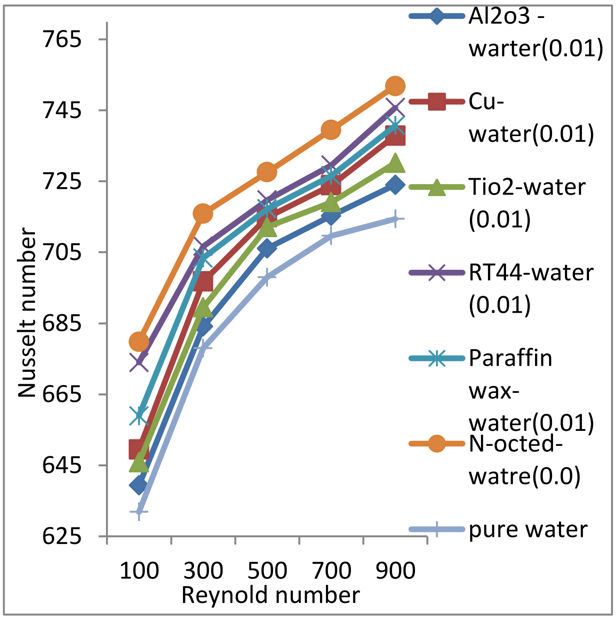

Fig. 12.Variation of Nusselt number with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at volumetric concentration 1%

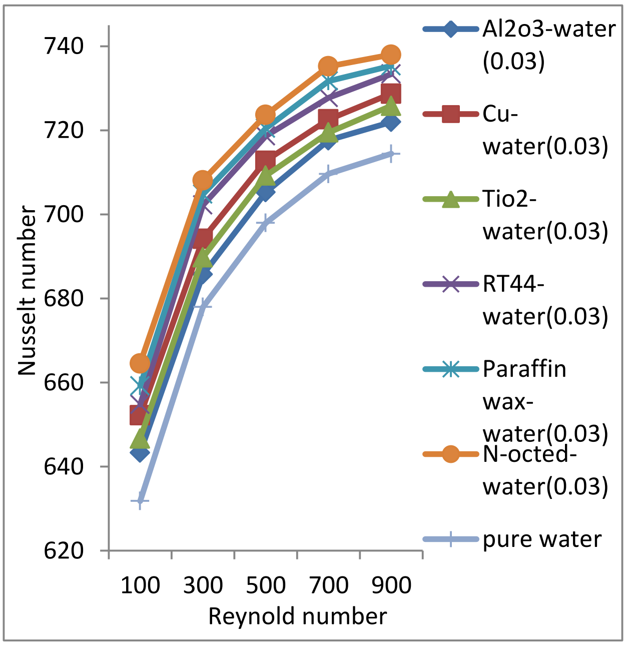

Fig 13:Variation of the Nusselt number with Reynolds number of MEPCM suspensions, Nano fluids and pure water for micro channel heat sink at volumetric concentration 3%

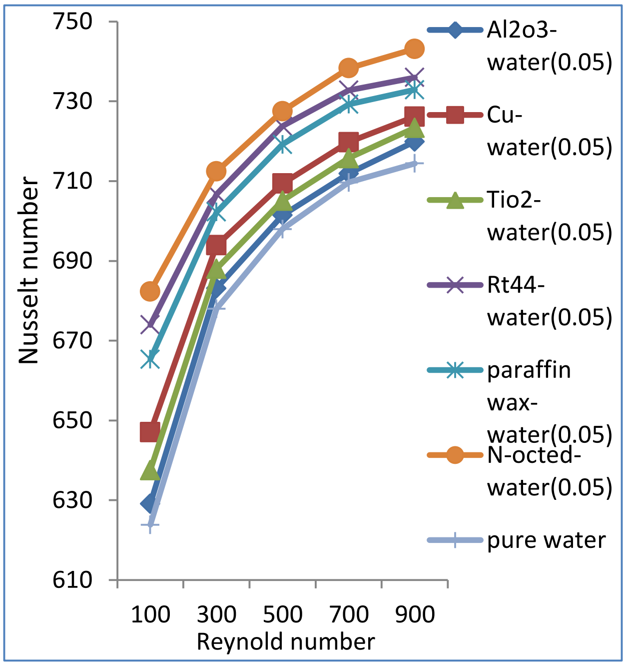

Fig 14.Variation of the Nusselt number with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at volumetric concentration 5%

Figs. (15, 16 and 17) shows the Variation of the pressure drop with Reynolds number of Nanofluids and pure water for micro channel heat sink for all volumetric concentration, From these figures it can be seen that the pressure drop increased with increasing Reynolds number. And the Nanofluids for all volumetric concentrations have increase in pressure drop due to higher values of viscosity. the pressure drop of Nanofluids is higher than of the pure water, also due to higher viscosity.

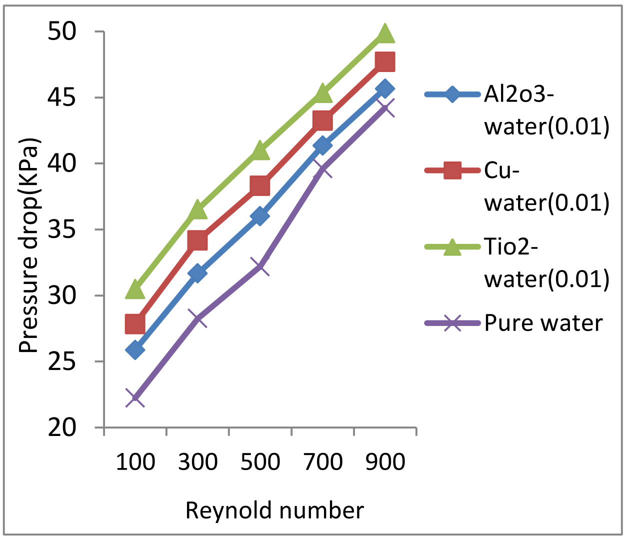

Fig 15.Variation of the pressure drop with Reynolds number of Nanofluids and pure water for micro channel heat sink at volumetric concentration 1%

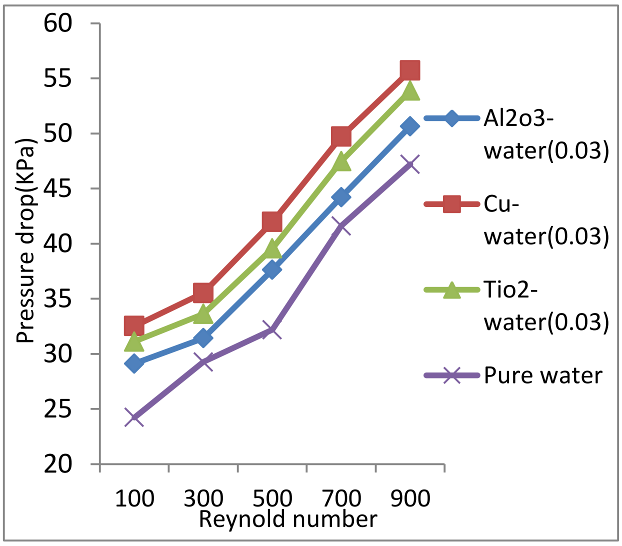

Fig. 16:Variation of the pressure drop with Reynolds number of Nanofluids and pure water for micro channel heat sink at volumetric concentration 3%

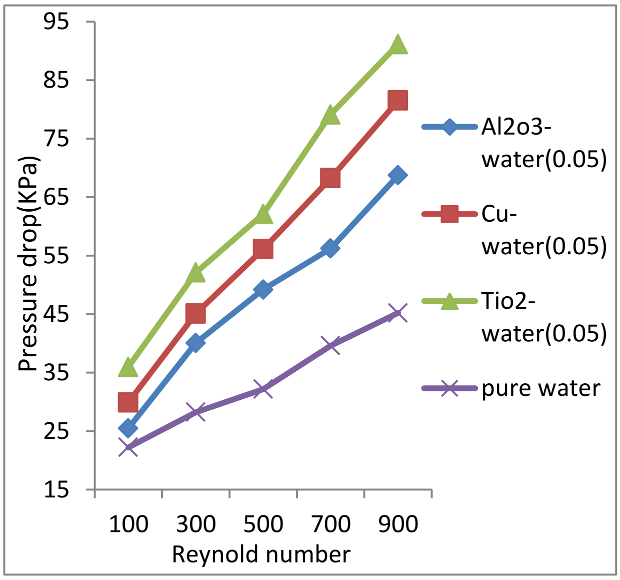

Fig. 17.Variation of the pressure drop with Reynolds number of Nanofluids and pure water for micro channel heat sink at volumetric concentration 5%.

Figs. (18, 19 and 20) shows the Variation of the pressure drop with Reynolds number of MEPCM suspensions and pure water for micro channel heat sink for all volumetric concentration, From these figures it can be seen that the pressure drop increased with increasing Reynolds number. And the phase change materials for all volumetric concentrations have increase in pressure drop more than Nanofluids as shown in Figs. (14,15 and 16) and pure water due to higher values of viscosity. Also, the pressure drop of MEPCM suspensions is higher than of the pure water due to higher viscosity.

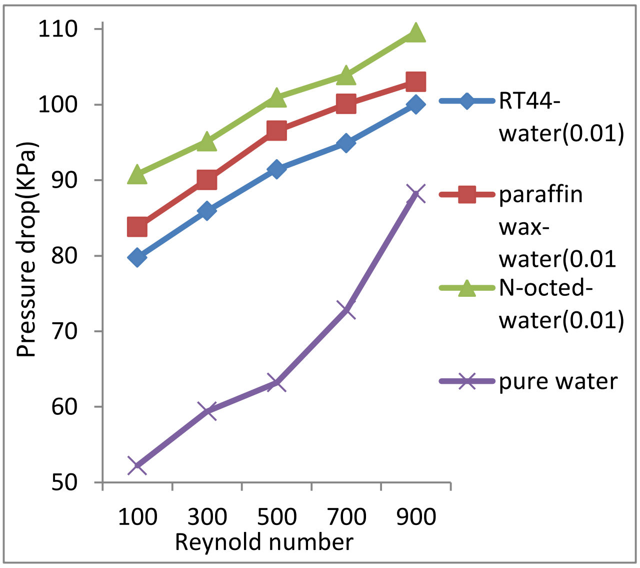

Fig 18.Variation of the pressure drop with Reynolds number of MEPCM suspensions and pure water for micro channel heat sink at volumetric concentration 1%

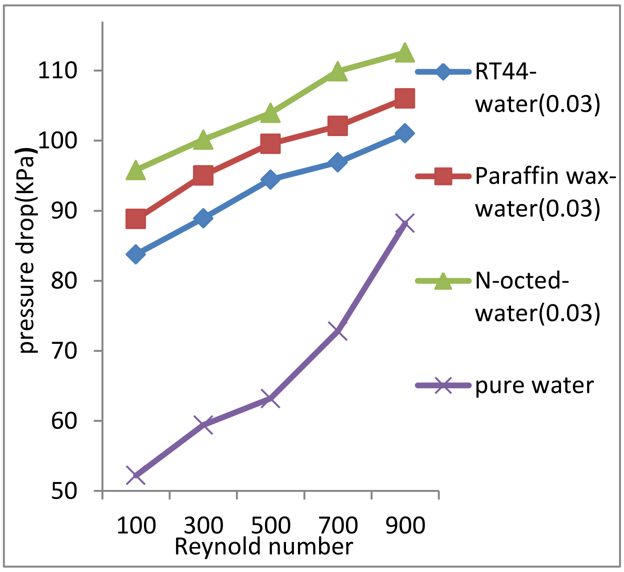

Fig 19.Variation of the pressure drop with Reynolds number of MEPCM suspensions and pure water for micro channel heat sink at volumetric concentration 3%

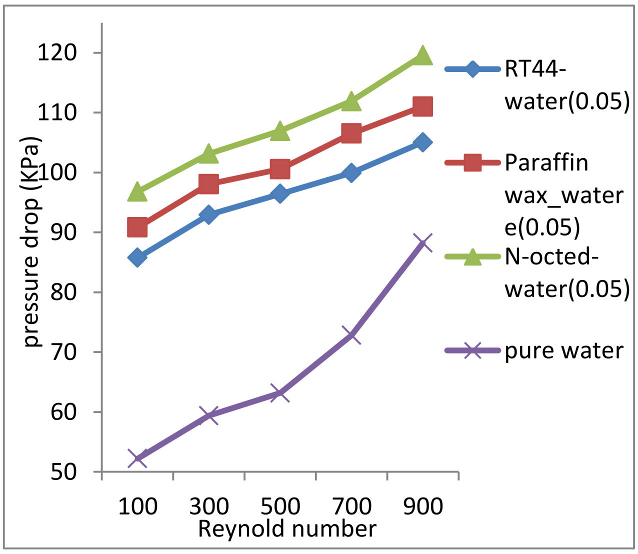

Fig. 20.Variation of the pressure drop with Reynolds number of the phase change materials and pure water for micro channel heat sink at volumetric concentration 5%

Figs. (21, 22 and 23) explain the Variation of the overall performance factor(Ƞ) with Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink for all volumetric concentrations. From these figures it can be note that the overall performance factor (Ƞ) for the Nanofluids is decreased with increasing of Reynolds number. And (Ƞ) for Nanofluids is more than that for pure water due to heat transfer rate is higher than compared with than that for pure water for all values of Re Ƞ $=q/p.p$.While the overall performance factor for pure water is higher than from that for MEPCM suspensions due to decrease pressure drop in pure water, While .the phase change materials having higher pressure drop. And with increase the volumetric concentration lead to increase the accurate of the result gradually.

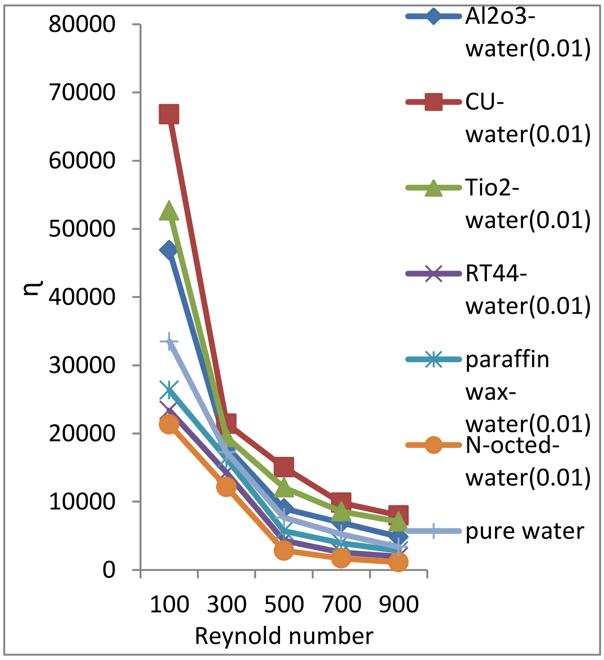

Fig. 21.Variation between the overall performance factor (Ƞ) and Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at volumetric concentration 1%

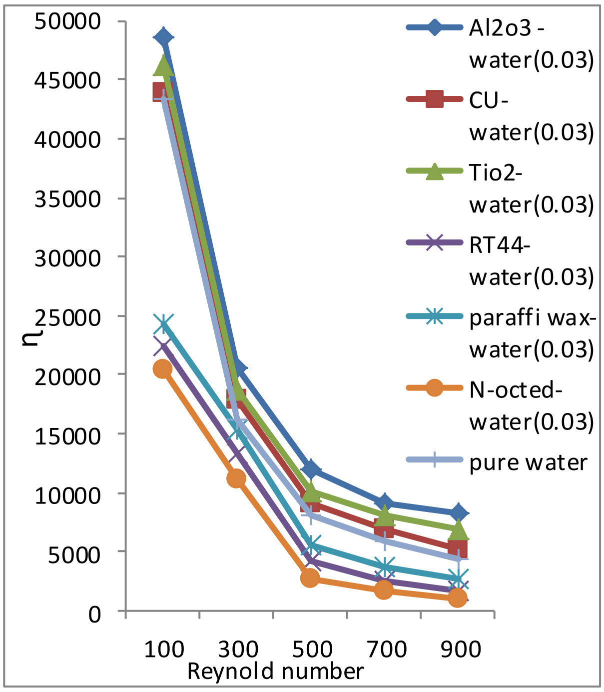

Fig. 22.Variation between the overall performance factor (Ƞ) and Reynolds number of MEPCM suspensions, Nanofluids and pure water for micro channel heat sink at volumetric concentration 3%

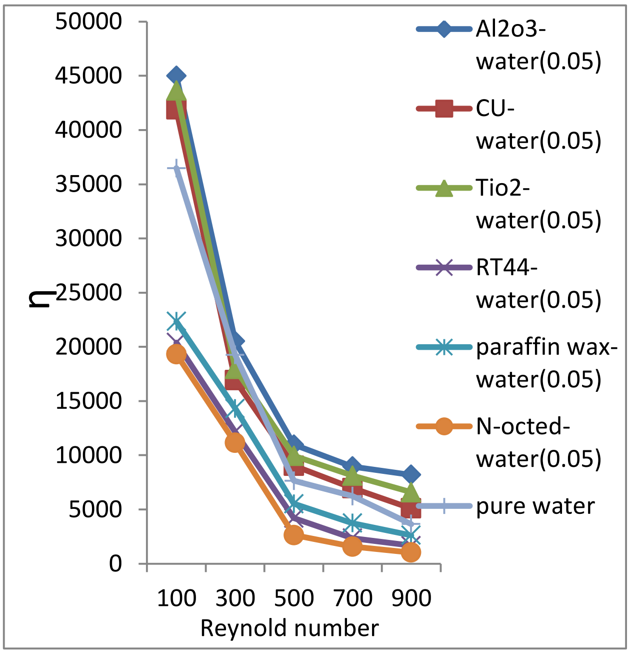

Fig. 23.Variation of the overall performance factor (Ƞ) with Reynolds number of the phase change materials, Nanofluids and pure water for micro channel heat sink at volumetric concentration 5%

Fig. 24 Shows the Variation of the Heat transfer rate with volumetric concentrations of MEPCM suspensions and Nanofluids for micro-channel heat sink at Re=100. From this figure it can be seen that heat transfer rate increased with increasing the concentrations due to enhancing thermo physical properties. Also the heat transfer rate of MEPCMs is higher than Nanofluids due to absorb extra amount of heat as latent heat during melting process. The concentration (0%) represent pure water.

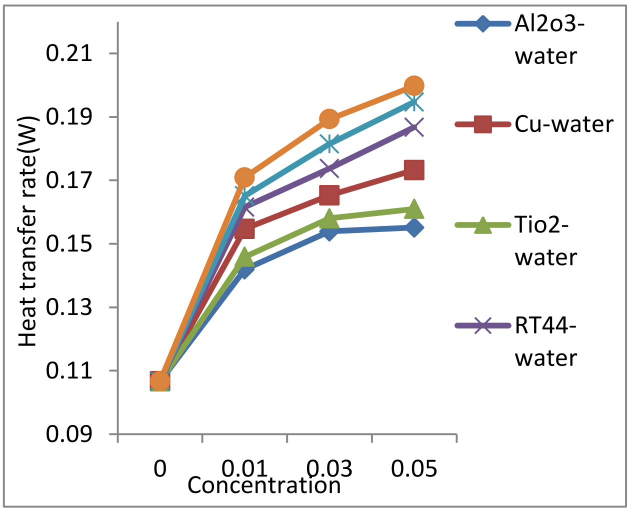

Fig. 24.Variation of the Heat transfer with volumetric concentration of MEPCM suspensions and Nanofluids for micro channel heat sink at Re=100

Figs. (25 and 26) express the Variation of the pressure drop with volumetric concentrations of phase change materials and Nanofluids for micro-channel heat sink at Reynolds number(100). From these figures it can be seen that the pressure drop is increased with volumetric concentrations due to increasing the viscosity for all studied suspensions, but the increasing in pressure drop of phase change materials is higher than Nanofluids due to higher value of viscosity and the velocity. The concentration (0%) represent pure water**. Fig. (27)** Explains the Variation of the Nusselt number with volumetric concentrations of MEPCM suspensions and Nanofluids for micro-channel heat sink. From this figure it can be seen the Nusselt number of phase change materials at Re=100 is increased with volumetric concentrations due to enhancing thermo physical properties and the Nu for MEPCM suspension is higher than that for nanofluids which is may be due to more thinning in boundary layer**. Figs. (28 and 29)** represent the Variation of the overall performance factor(Ƞ) with volumetric concentrations of MEPCM suspensions and Nanofluids at Reynolds number (100). From these figures it can be seen that the overall performance factor (Ƞ) of MEPCM suspensions and Nanofluids is decreased with increasing concentration due to increasing the pressure drop and dominating the increasing in heat transfer rate. While, the overall performance factor of Nanofluids is increased with increasing concentration due to decrease the increasing in heat transfer is higher than the increasing pressure drop and dominating on it.

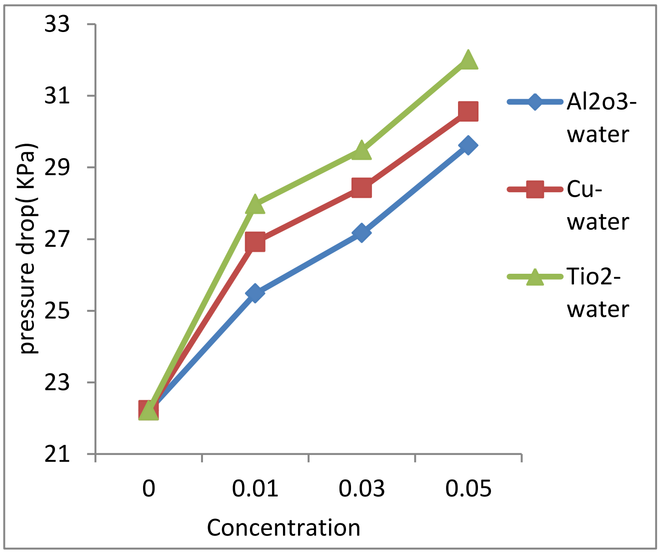

Fig 25.Variationof the pressure drop with volumetric concentration of Nanofluids for micro-channel heat sink at Re=100

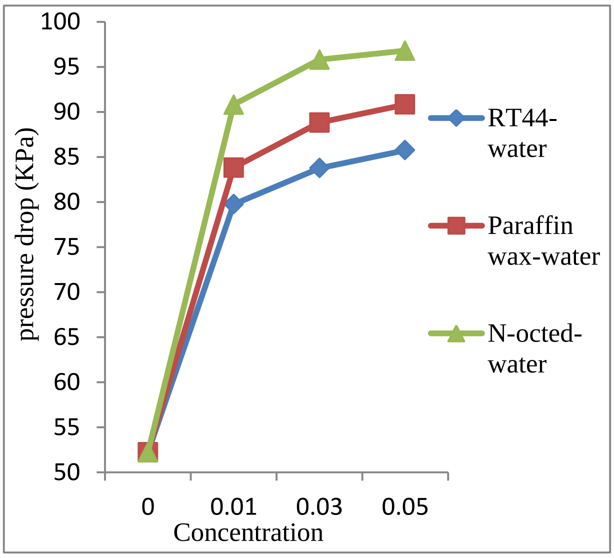

Fig. (4.26) Variation of the pressure drop with volumetric concentrations of MEPCM suspensions for micro-channel heat sink.

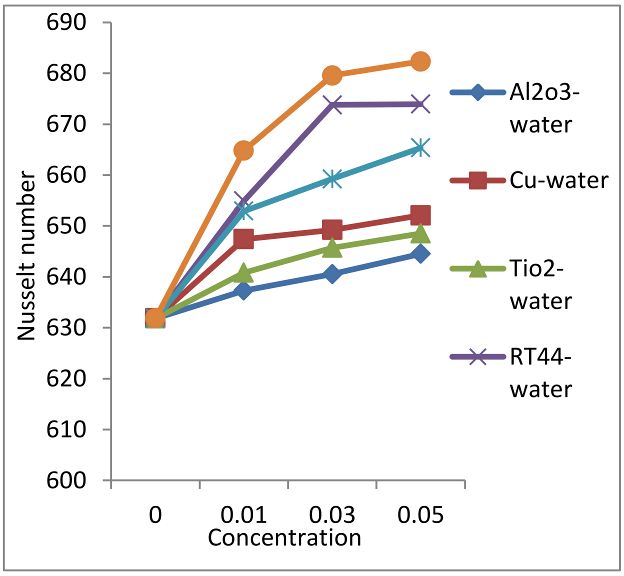

Fig. (4.27) Variation of the Nusselt number with volumetric concentrations of MEPCM suspensions and Nanofluids for micro-channel heat sink.

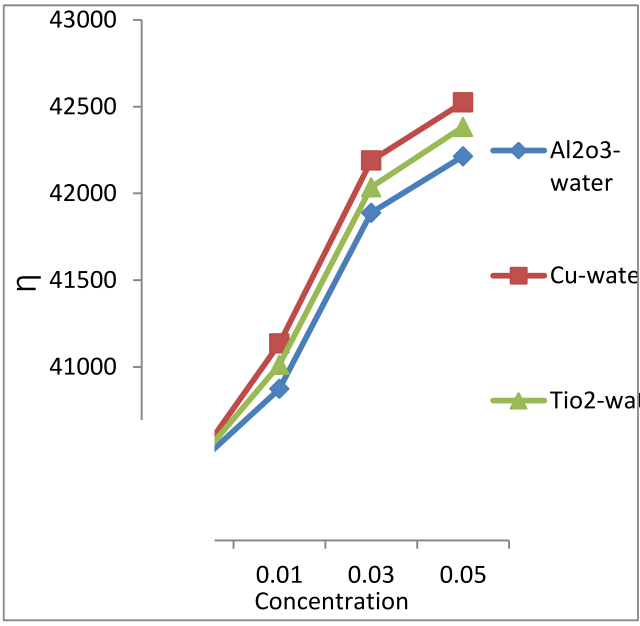

Fig 28.Variation of the overall performance factor (Ƞ) with volumetric concentration of Nanofluids for micro channel heat sink at Re=100

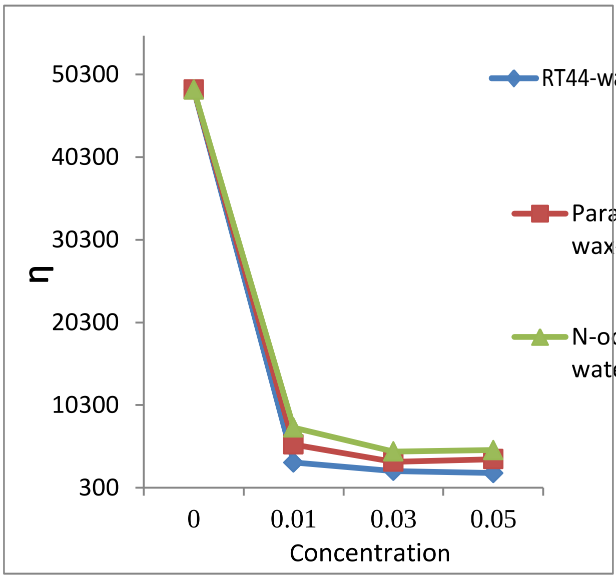

Fig. 29:Variation between the overall performance factor(Ƞ) and volumetric concentration of MEPCM suspensions for micro channel heat sink at Re=100

CONCLUSION:

In this study different cooling mediums (MEPCM suspensions, Nanofluids and pure fluids) have been numerically studied with the micro-channel heat sink for cooling of the electronic apparatuses. Different types of the cooling mediums are studied PCMs (RT44-water, Paraffin wax-water, and n-octed-water) ,Nanofluids (Al_2o_3-water, Cu-water and Tio_2-water) and pure fluids (water, Oil ,Ethylene Glycol).In order to compare lie from these different types of contain on the performance of MHS. From obtained results the following decisions can be made:

1- Using the suspension fluids (MEPCM suspensions, Nanofluids) leads to increasing in the cooling performance of micro channel heat sink.

2-The use MEPCM suspensions of at all concentrations leads to increase the pressure drop across microchannel heat sink compared with Nanofluids and pure fluids that lead to decrease the overall performance(**Ƞ**).

3- The heat transfer is increased in MHS with using Nanofluids due to increase in thermal conductivity and mass flow rate with compared using pure water.

4-Nusselt number is increase in MCHS with using MEPCM suspensions as cooling fluids compared with Nanofluids and pure water due to the thermal conductivity of PCMs is high heat transfer coefficient(h) than Nano fluids and pure water. While, the Nusselt number production of Nano fluid is higher than pure water due to the thermal conductivity and heat transfer coefficient(h) of pure water is little $Nu=\frac{h.D_h}{k}$.

5- The obtained results indicated that MEPCM suspension can considered the best coolant for MCHS which improve the performance compared to Nano fluids and pure water

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