JOURNAL PAPER ON HEAT TRANSFER ENHANCEMENT OF MINI CHANNEL USING MWCNT NANOFLUID

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ABSTRACT: The present investigation is primarily intended to study experimentally the heat transfer performance of rectangular and circular mini channel cooled with different coolants like water and multi walled carbon nanotubes nanofluid. The study is carried out under forced convection turbulent flow of fluid with steady state and constant heat flux condition. Effect of flow rate on various parameters like heat transfer coefficient, friction factor, pressure drop and pumping power for both the fluid and in both the channels is represented here. It is known fact that with increasing demand in the minturization of various devices the development in research field of nanofluid and mini channel has increased drastically. In the present experimental investigation it is found that with small concentration of carbon nanotubes particles in base fluid enhances the heat transfer ability of fluid and it is also found that rectangular mini channel are less prone towards pressure drop compare to circular mini channel.
Keywords: Mini channels, heat sink, MWCNT nanofluid, rectangular mini channels, circular mini channels.

I. INTRODUCTION

The heat transfer occurrences are familiar in every engineering application. The present development is increasing the scope in the field of technologies that give the concepts of very small scale devices for higher performance. The higher performance of devices has considerably generates excess heat compare to lower performance devices. Due to the space limitation and excess heat generation and also limitation of cooling, the development of mini and micro scale instrument of warmth convey has considered the same as one of the technique for more amount of high temperature removal. Hence many researchers have studied about the high temperature eliminate and fluid flow characteristics of small and micro channel. There are many conventional fluids such as helium, water, mineral oil;Freon,ethylene glycol and air have been used in different heat transfer processes and industries like power plant industries, electronic industries, refrigeration and air conditioning industries, medical industries etc. But due to limitation in thermal conductivity of these conventional fluids, researchers have diverted their attention towards new coolants termed as “nano fluids”. The nano fluid contains the nanoparticles of size less than 100nm of different materials such as copper, aluminum, silver, gold, zinc, carbon nanotubes suspended in base fluids like water, ethylene glycol, engine oil etc. Therefore, keeping the advantages of nanofluid and mini channels in heat transfer enhancement, the present investigation is focused on experimental comparative study of different geometries of mini channels subjected to flow of multiwall carbon nano tubes nano fluids.

II. NOMENCLATURE

ρ_{nf} = density of nanofluid
ρ_{bf} = density of base fuid
$\emptyset$ = volume fraction of nanoparticles
ρ_p = density of particles
C_{pnf} = specific heat of nanofluid
C_{pbf} = specific heat of base fluid
C_{pp} = specific heat of particle
κ_{nf} = thermal conductivity of nanofluid
κ_p = thermal cnductivity of particle
κ_{bf} = thermal conductivity of base fluid
μ_{nf} = viscosity of nanofluid
μ_{bf} = viscosity of base fluid
(V/V) = volume by volume

1. Applications Of Mini Channels

Expanding heat transfer era in mechanical and electronic devices has prompted offering a huge number of new logical arrangements for cooling techniques. The application of mini channels in engineering field has been worked for eliminating more and more heat in less span of time so as to improve the thermal performance characteristics of different devices. The major applications of heat transfer enhancement techniques are used in the field of refrigerators, automobiles, air-conditioning equipment, thermal power plants, process industries, heat as well as cooling of evaporators and cooling of electronic circuits etc.

2. Needs of Mini channels

The reduction in the size of many devices has created a problem of more heat generation. Therefore an efficient technique is required to enhance the rate of heat transfer from the small devices. Therefore use of mini channels for heat transfer improvement proves to be one of the best techniques. Use of mini channels as a heat sink in electronic devices improves the performance and efficiency. Use of mini channels improves the convective heat transfer coefficient. Use of mini channel tubes in heat exchanger devices progress the heat transfer ability.

3.Heat Transfer Using Minichannels

The smaller size of electronic devices results in high rate of thermal energydissipation, so that, it's cooling is a troublesome task. The extended rate of heat time and the purpose of restriction of air cooling in such traditionaldevice incited the usage of liquid cooling with minichannels. For liquid cooling, there are particular conditions of coordinates in different sizes are available. The target of the usage of minichannels has the most compelling measure of heat from the devices. Channel capacities to accomplish two objectives: (i) transmit the liquid into the section dividers and (ii) convey new liquid towards the dividers and take away the liquid from the dividers .The coordinates having estimations in the solicitation of mm can be named as minichannels.Channels can be miniaturized into smallersize than normal or scaled down scale channels, it relies upon its water driven breadths. It is understood that the higher rate of heat move results in the extended rate of weight drop, it qualities to the extended supply of pumping power. The utilization of minichannels for cooling framework lessens the measure of the gadgets. The underneath figure demonstrates a rectangular minichannel plan which can be utilizedfor conveying heat as a part of various heat exchange forms.

4. Carbon Nanotubes (MWCNT)

Multiwall carbon nanotubes are allotropes of carbon. It consists of multiple rolled layer of graphene (concentric tubes). Some properties of MWCNT that is particularly intriguing in favour of engineering. (i) The Carbon Nanotubes are having the sameelectrical conductive as copper, the mechanical superiority of Carbon Nanotubes is15 or 20 times more as compare to steel as well as 5 times less weight, (ii) The MWCNTs available in packs of length ~1 - 20µm. (±1.5µm) Individual tube length has not been resolved. Width 20-30nm, Length-3-8µm, (iii) the multi wall carbon Nano Tubes are non-friendly.

5. Nanofluid

Nanofluids are shaped by scattering nanometer-sized particles (1-100nm) or beads into heat trannsfer liquids. Nano particles have unique properties, for example, huge surface range to volume proportion, measurement subordinate physical properties and lower active vitality, which can be abused by the nanofluids, at the same time, expansive surface zone improve nano particles and all partices are more steadily scattered in base liquids. Contrasted and small scale liquids or milli liquids, nanofluid stay more steady, so nanofluides are promising for viable applications without bringing about issues. A most atractive normal for nanofluids is that even by the expansion of little measure of nanoparticles, they indicate anomalaus improvement in warm conductivity more than 10 times more than the theoritically precdicted. Subsequently, the exploration theme of nanofluids has been getting expanded consideration wordwide.Nanofluid has produced for achive ultra elite and can possibly be cutting edge coolants. In the field of ventures and common applications like transport vitality supply, aerating and cooling and ellectronic cooling. Etc.using heat exchange liquid, for example, water, oils, glycols and fluorocarbons. Utilized however characteristically heat exchange execution are poor because of their low warm conductivities. The innovative work exercises are being completed to enhance the warmth transport properties of liquids. Utilizing strong metallic materials, are alumina, CuO,Sic. What's more, carbon nanotubes has much higher warm conductivity then warmth exchange liquid. It is an inventive thought attempting to improve the warm conductivity by including strong particle interested during warmth trasfer liquids.Nano fluids has an another class of warmth exchange liquids which are designed by dispersion nano meter dimension clanging or non-metallic strong particle or tube inside customary heat exchange liquids, for example,MWCNTs, SWCNTs,ethylene glycol, water, and motor oil. The nano fluids has a better coolant fluid that are used in the field of nano science, nano technology and also in thermal engineering.

III. CRITICAL REVIEW

The development has been done for the purpose for miniaturized technology. The concept of mini and micro-components created for the enhancement in heat transfer coefficients. There are some experimentally work done on the mini channels has explained.Vikas kumar, Arun kumar Tiwari, et al [1] in this paper shows the experimentally work on plate heat exchanger with variable spacing for the measuring heat enhancement for different nanofluid, Tio2, Al2o3,Zno, Ceo2,CuAl2o3, MWCNT and grapheme nano plate. Rupesh D.khorgade and R.S.shelk [2] they have study on mini channel for enhancement in heat transfer using different nanofluid with different concentration. There are two nanofluid Al2o3-H2o and Cuo-H2o are used and also comparing the result with pure water of both nanofluid.Rabia sabir et al [3] Studies using gold/water nanofluid. They are measuring the gold convective heat transfer characteristic experimentally using one step method.Pyshar Yi. [4] In this study work for micro fluidic system in micro channel heat transfer. They have work on many nanofluid, (Cro2) chromium oxide nano-rod, and Feo3 magnetic nano-particle. The de-ionized water as for the coolant in channel poydimethyl siloxane (PDMS) based micro fluids for thermal conductivity enhancement.Melanie M. Derby et al[5] studies on mini and micro channel improvement in heat transfer. They have used hydrophilic and hydrophobic pattern.Paisarn Naphon et al [6] study on the rectangular mini channel using Tio2 nanofluid with base fluid de-ionized water. The Comparing result with base fluid de-ionized water. The numerical results verified with experimental results.F. Illan-G.omez et al [7] in this study work on multiport tube mini channel in two phase heat transfer coefficient and also friction pressure drop consider inside the tube using R123yf and R134a fluid. They have measured pressure drop during diabetics and adiabatic in two phase flow. Zan Wu et al [8] in this paper work for measurement on rheology properties of MWCNTs and alumina based nano-particles. They have used water with MWCNTs and alumina.C. Bi, G.H. Tang and W.Q. Tao.[9]They work on dimple and cylindrical grooves in mini channel heat sink. They have numerically investigated using synergy principle.Reza Kamali et al[10] this work performed for micro channel heat sink using Al2o3-water, MWCNT-water and pure water also. They are work on rectangular duct made up of aluminum. They have compared the result of Al2o3-water and MWCNTS-water.Tun-Ping Teng et al [11] they have used water assisted synthesis system and also using the fabricated carbon with the water nanofluid (CWNFs). Saad Ayub Jajja et al [12] the experimentally work on microprocessor cooling heat sink mini channels. They have considering heat sink with different spacing. They have considered water working fluid as a coolant in mini channel heat sink. J.P.merey et al [13] experimentally study about transitional regime of smooth tube. The tub made up of copper. They have used multi-walled carbon Nano-tube with water. O. Deriabina et al [14] they are work on the dispersion measurement of Carbone nanotubes mixture for bad or good solvent. They have used MWCNTs/water for binary mixture, water and 1-Cyclohexyl-2- pyrrolidone (CHP). Julie A et al [15] the three mini channels made up of aluminum for radiation absorption are used for efficiency and enthalpy check with incident angle 0 to 20 degree. Result shows that the circular mini channel has 68% maximum efficiency as compare to triangular, squire mini channel. J.G. cartoon et al[16] in this paper studies accumulation of water droplet motion in mini channel for proton energy membrane. They have used volume of fluid and computational fluid dynamics method. Manoj Kumar Moharana, et al [17] they did the work on rectangular mini channel single phase flow. They have investigated both numerically and experimentally using de-ionized water as working fluid, flow consider laminar to turbulent transition and also 3D numerical CFD model consider. These studies applicable for mini/micro scale heat flux removed. S. M. Sohel Murshed and C. A. Nieto de Castro[18] they have experimentally worked on mini channel by the force convective method. They have used Tio2-nanofuid, water, engine oil and ethylene glycol. M. Venkatesan et al [19] in this study work for bubble length elongated in mini channel with the effect of diameter. They have used air and water as a working fluid. They have used CMOS high speed camera for identify the sludge length. Performed by the Gerardo Diaz [20] they have did work on mini channel evacuated tube for solar collector. They are mainly work for the decreasing in emission of greenhouse effect and pollutant using U-shaped mini channel tube comparison with slandered u-shaped round tube solar collector. They are analyzed numerically performers of min channel based evacuated tube also shows the improvement in efficiency. Hans Ludwig Hartangel et al [21] they have done the concept of micro-wave device based on carbon nanotubes properties. This paper described the physical properties of carbon nanotubes and their fictionalization process. They are found that the carbon nanotubes are huge motilities with their properties are astonishing and also tunable band gapes current currying high, for the transport at room temperature ballistic ally but gives a concept thoroughly, work performed. Yi Fan, Yiferg fu et al [22] they have worked on micro channel coolers using carbon nanotubes as a coolant with pure water also carbon nanotubes as stable homogeneous suspension was produced. The micro channel coolers are made up of silicon. It has prepared by the using technique of deep ion reactive etching. They have getting finally result CNT suspension coolant are not exhibit extra pressure drop. Yulong Dinget al [23] experimentally work on horizontal tube using multi-walled carbon nanotubes and result comparing with pure water, measuring PH effect on the concentration of CNTs. They have used Arabic gum in CNTs concentration. The heat transfer related to the axial distance.

In general the coolant used for heat transfer mostly copper, aluminum, pure water, titanium oxide, single wall carbon nanotubes as well as fabricated carbon through water nanofluid (CWNFs), water and 1-Cyclohexy l-2- pyrrolidone (CHP) also multi wall carbon nanotubes with pure have been used. Thus in present study no one has been used the multi wall carbon nanotubes in the normal water in addition to compare to the result of base liquid; also I have found that the work on aluminiummini channels has null.

9.Objectives

- To functionalize the multi wall carbon nanotubes (MWCNT) using sulfuric and nitric acids (H_2SO_4 /HNO_3) acids with distilled water.
- Comparing the result of SEM-images of F-MWCNT with without functionalize MWCNT.
- To comparing the results of heat transfer coefficient, Nusselt number, friction factor, pumping power and pressure drop of multi-walled carbon nanotubes based nanofluid (MWCNT nanofluid) coolant in rectangular mini channel with its base fluid.
- To discover the outcome of Reynolds number in entry region and in fully developed region in rectangular and circular mini channels with different concentration of (MWCNT) in MWCNT nanofluid.
- To comparing the results of heat transfer coefficient, Nusselt number, friction factor, pumping power and pressure drop of multi wall carbon nanotubes based nanofluid (MWCNT nanofluid) coolant in circular mini channel with its base fluid.

10. Functionalization process ofMWCNT

Multi divider carbon nanotubes MWCNT are typically hydrophobic, so they are not promptly scattered in water. An assortment of various systems can be utilized to portray the surface science or structure of MWCNT. The consolidation of oxygen particles into the CNT surfaces is the most well-known covalent adjustment. For instance, oxygen practical gatherings are intentionally consolidated into MWCNT utilizing different treatment strategies (e.g., plasma, oxidation, sonicator) to adjust scattering properties.The functional groups are built-in after cleansing procedures to expel indistinct carbon and remaining metal particles, or as a consequence of MWCNT presentation to oxidants display in nature. Aggressive oxidative treatments (H_2SO_4/HNO_3), are necessary to decrease the magnitude of shapeless carbon adsorbed on the MWCNT surface, increase in hydrophilic character of carbon nanotubes. The Multi wall carbon nanotubes(MWCNT) samples were purchased from NANOHEL LLC, USA. The nanotubes has specified diameter of 40–70 nm. Purity is greater than 95%.The functionalization process are described below.

Step: 1. Preparation for acidic solution

- In the first step for functionalization process we have prepare the sulphuric acid in addition to nitric acid separate solution and after that we mixed it to prepare finally 600ml solution of sulphuric and nitric acid with the ratio of 3:1 (v/v) sulphuric and nitric acid with distil water (i.e. concentrated sulphuric and nitric acid and distil water).

- A solution of H_2SO_4/HNO_3 in the ratio of 3:1(v/v)has prepared at a concentration of 20% eachsulphuric and nitric acid (diluting with distil water) present in solution. The solution of sulphuric acid as well as nitric acid with distil water is maintained at a normal temperature for the mixing of Multi wall carbon nanotubes(MWCNT).
- Samples of multi-walled carbon nano tubes are weighed in weighing machine and then added at the amount of 100mg of MWCNT per 600ml acidic solution of (H_2SO_4/HNO_3) in the ratio of 3:1 (v/v)

Step: 2. Stirring process

- The process of heating and stirring is started after mixing of Multi-walled carbon nanotubes(MWCNTs)in acidic solution has heated and stirred at a temperature up to 100°C for one hour in a magnetic stirrer with 1000 rpm. During the stirring process using aluminium foil for cover the beaker.
- The process of starring and heating to solution have been work continuously in a two litter beaker for one hour after that stopping the magnetic stirrer and then leave the solution for coolingup to 30 minutes or up to normal temperature.

Step: 3. Centrifugation process

- In this process using four centrifuge tube, centrifuge machine and distilled water for washing the Multi-walled carbon nanotubes(MWCNTs).
- After stirring process, we have taken four centrifuge tubes of 100ml and putting the solution into centrifuge tubes 40% and mixing with distilled water 40% in each tubes and putting into the centrifuge machine for the purpose of washing the Multi-walled carbon nanotubes(MWCNTs) until natural PH.
- This mixture washing with distilled Water at 10000rpm up to 10minuts every 10minutes we have changing the distilled water from centrifuge tube and put a new one, this cycle repeat up to natural PH.

Step: 3. Dry F- MWCNT

- In this process using a poetry plate for the purpose of drying the wetted Multi-walled carbon nanotubesMWCNT. The poetryor oven (glass plate) plate has in small size.
- The drying process is carried out in a drying machine at 60oC for 24 hours
- The functionalized Multi wall carbon nanotubesF-MWCNT is ready to use for mini channels.

Step: 4. Take a SEM-images

- Take SEM-images of dry functionalized Multi wall carbon nanotubes(F-MWCNT) sample and also take SEM-images un-functionalized Multi-walled carbon nanotubes(MWCNT).
- To compare the SEM-images for both sample and analyse the result.

Step: 5. Preparation for CNT-nanofluid

- Take three samples (1g, 2g, and 3g) of functionalized Multi wall carbon nanotubes(F-MWCNT) for the preparation for CNT-nanofluid for three different concentrations is prepared.
- To preparing the CNT-nanofluid using base fluid as normal water with functionalized Multi wall carbon nanotubes(F-MWCNT). The percentage of mixing of functionalized Multi wall carbon nanotubes(F-MWCNT) for one litter water is 0.01% by volume is used. The Same process for sample 0.02% and sample 0.03% is used.
- When we have mixed the functionalized Multi wall carbon nanotubes(F-MWCNTs) in its base fluid then using a sonicator to sonicator the solute on for proper mixing of sample with its base fluid Sonicator (350 W, 40 KHz) for one hours at 26℃. After sonicator the CNT-nanofluid has prepared to use in mini channel.

11.Mini Channel Setup

The sketchy outline for exploratory setup utilized for in attendance work has demonstrated as follows. The setup has mainly consists of reservoir tank for storing the fluid at a normal temperature initially. The pump work has to circulate the fluid passing from the flow meter to the mini channels circuit. The flow meter has measured the quantity of fluid discharging from the flow mater to mini channels. The flowing of fluid through the flow meter to mini channels, flow meter has passes the fluid to mini channels with particular flow rate as per adjusted by the operators. The film heater has heated the test section and a heat exchanger to cool the fluid coming out of the heated channel. The thermal insulation has provided over and under the test section for avoiding the heat loses through the heat exchanger. The d. c. power supply has maintained the voltages and current flow to the system. The system shows the variation in temperature of thermocouple for the particular time and the particular flow of fluid in mini channels.

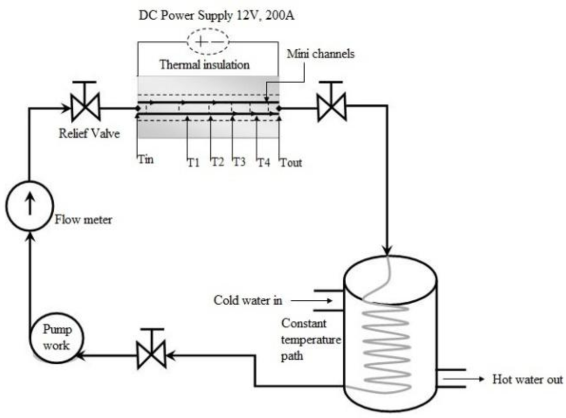

Fig.3. Schematic diagram of experimental set up

12. Equipment needed for conducting experiment

a) Flow meter:The flow meterhas used in this system to point out the rate of flow of the fluid for a particular flow rate of fluids or it has maintain the flow rate of system. They can also switch the rate of flow if they have fitted out with a flow regulator valve. The Rota meterhas a certain type of flow meter, built on the variable areas principle. They offer a simple, accurate and efficient means of representing flow rates in fluid systems. This variable area has a principle to comprise of three elementary fundamentals: A uniformly tapered flow tubes, a float, and a measurement scales. A control valve is added to switch the preferred flows.

b) T-type thermocouple: These thermocouples has set on smaller than normal channels to gauge the temperature contrast at the bay and outlet of the channel with the aim of computing the temperature of the liquid at the gulf and outlet of the channels. Thethermocouples have appropriate measurement of temperature ranges from 34°C to 150 °C ranges. The thermocouple has a sensitivity of about to detect the temperature increases in flowing fluids.

c) Thermocouples: Thermocoupleshas held in reserve at different points of the top surface of the mini channel with the purpose of calculation of the surface temperature difference of the channels. It has cheap, and wide selections of probes are accessible in its range. This thermocouplehas stated at a time when enhancing in that point of thermocouple temperature or progress in heating of thermocouple with increasing with time.

d) Pump: The experimental setup has contained a centrifugal pump to supply the fluids continuously from the reservoir to mini channels. The constant flow of fluid in experimental setup has achieved by using pump. The pump has a device that flow the fluids uses impellerin the pump setup to flow the fluids in the system or through by mechanical work. The pump has worked by some system (responding or revolving), and expend vitality to perform mechanical work by moving the liquid. The pump has diverse classifications expressed by the way they have used to transport the liquid. (a) Direct lift, (b) Displacement, and (d) Gravity pump. The Pumps has work through numerous vitality bases, including manual operation, power, motors, or wind control, come in many sizes, from minute to vast mechanical pumps. In this experimental setup we has used displacement pump which draws fluid from the reservoir tank to make it passes through the rest of the channels.

e) Reservoir:The reservoir may be natural or non-natural system has been used for the purpose of enclosing water. It has can be used in a number of ways to control the water flows through a channels or through a number of pipes in the system. Even if the large reservoirs has used in keeping water in dams during rainy season, but new purpose reservoirs can be manufactured for laboratories to execute experiments for research and development. The description of these reservoirs should be such that it can work at exciting experimental environments. The working fluid has stored should not act in response with the walls of the reservoir, therefore the sides of the reservoirs should be made with materials which do not react with the walls of the reservoir i.e. uncreative corrosions. The determination of the materials to produce the store relies on upon the way of the working liquid. In this experimental setup, reservoir hassteal wall and also it has accumulate the fluids at least 20litres of working fluidshas providing continuous supply of fluids to the system.

f) Control valves: These valves has operated by fully or partially opened or closed to control the flow of the fluids as per the necessity of fluids. The valves has control the flow of fluids or maintain flow rate of fluid for a particular time as per requirements.The opening or shutting of the actuator has typically done naturally by electrical, pressure driven or pneumatic actuators. The control valve has keeping up the stream of liquids to keep up the framework work ceaselessly.

g) Power supply:The d. c. control supply has an electronic gadget that provided the electric current to the framework according to necessity. The main reason for a power supply needs to change one type of electrical vitality to another and, the outcomes, control a supply has now and again alluded to as electric power converters.The power supply has two types and they are a. c. and d. c. power supply. It has been possible to supply voltage with a fixed polarity to the load, with dc power supply. The d. c. power supply may be powered with a. c. or d. c. power source. The d. c. power supply has gets powered with an AC source, it has been required for a transformer to convert into a higher or lower AC voltage from its input voltage. The d. c. power supply has been used in the system for the pump work and also maintaining the systems requirements.

h) Heat Exchanger: In this experimental system the heat exchanger has used as mini channels of two type's rectangular and circular mini channels. The part of apparatus has made for effective heat transfer from one medium to another. The medium may have been divided by a solid wall to avoid mixing or they may be in direct contacts. They has broadly used surface heating of heat exchanger , refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. There are three major categorizations of heat exchangers on the basis of their flow procedure. In parallel flow heat exchangers, the two fluids go into the exchanger at the same end, and travel in parallel to one another to the other side. In counter flow heat exchangers the fluids enter the exchanger from opposite ends. The heat exchanger or mini channel used in this experimental setup has made up of aluminum. The mini channels contain fourteenth number of channels in each mini channels also all channels are in mini scale. The nanofluid has passes from the channels in that case heat carries nanofluid from the surface of mini channels. In this channels heat has flow with coolant fluid fast as compare to other channels. The coolant fluid has passing through heat exchanger to exchange the temperature between fluid flow and mini channels of heat exchanger.

i) Thermal insulation: The thermal insulation has a cover on the thermocouple with the insulation plate that prevents the flow of heat to surrounding. The faultless insulator hascreating problem in the work. Since insulator has a small numbers of mobile charges (charge carriers) which can transfer current. The some materials such as glass, paper and Teflon has greater resistivity and also electrical insulations. In the experimental set up asbestos has used as an insulating element. This covers has the mini channels in order to resist the flow of heat from channels to the surroundings.

13. Test Section:

The test section has used in this experimental set up basically consists of one set of minichannel as per the required geometry. The minichannel has fitted with film or strip heater at its bottom part, and further it has connected with inlet header/plenum for flow of fluid (inflow) and outlet header/plenum for discharging (outflow) of the fluid, the upper surface of minichannels should be fixed with K-type thermocouple at equal distance throughout the length of channel. The T-type thermocouple has attached with inlet and outlet flow of fluid and also the pressure transducer wire has kept at inlet and outlet section of fluid flow to measure pressure drop. The whole assembly has kept in between insulated covering (insulation does not allow loss of heatfrom any part of minichannels) such that upper part of insulating material has transparent so that minichannels can be visible. The inlet header/plenum has provided with inlet opening for flow of fluid and in same way outlet headed/plenum has provided for outlet opening discharge of fluid.

14. Experimental set up:

The experimental set-up has consists of above listed equipment along with test section, the fluid from reservoir has pumped to test section at desirable flow rate which can be controlled by flow control valve. The fluid first enter the inlet header of test section where its inlet temperature and pressure has measured and then it flows into heated minichannel tubes and from tubes the heated fluid will come out form the channel and then from where it has recalculated once again. Before sending to the reservoir it is passed through heat exchanger in order to cool the fluid. The setup for heat sink mini channels has better designed. The experimental set-up contain centrifugal pump that has attached with reservoir, it has shown in experimental set-up at the bottom part of the experimental set-up. The thermal insulation has attached with heat sink (mini channels) during working time that has also shown in schematic diagram at upper part. The measurements of temperature, voltages, current and also switch of motor has shown in board of set up.

15.Parameters considered for present work:

- Kinematic viscosity of nanofluid
- Dynamic viscosity of nanofluid
- Specific heat of nanofluid
- Thermal conductivity of nanofluid
- Density of nanofluid
- Prandtl number of nanofluid
- Reynolds number (Turbulent flow)
- Nusselt Number
- Hydraulic diameter of rectangular and circular mini channels
- Heat transfer coefficient
- Friction factor of nanofluid and its bas fluids
- Pressure drop
- Pumping power.

16.The Formula Used

The properties of multi wall carbon nano tubes, density, Specific heat, thermal conductivity, dynamic viscosity, kinematic viscosity, as mentioned byPaisarn Naphon and Lursukd Nakharintr [6]

i). Density of nanofluid

$$\rho_{nf} = (1-\emptyset)\rho_{nf} + \emptyset_{\rho\emptyset} \quad (1)$$

ii). Specific heat of nanofluid

$$C_{pnf} = \{(1-\emptyset)(\rho C_p)bf + \emptyset(\rho C_p)p\} / \rho_{nf} \quad (2)$$

iii). Thermal conductivity

$$\kappa_{nf} = \{\kappa_p + 2\kappa_{bf} + 2(\kappa_p + \kappa_{bf})\emptyset\}/\{\kappa_p + 2\kappa_{bf} - 2(\kappa_p - \kappa_{bf})\emptyset\} \quad (3)$$

iv). Dynamic Viscosity

$$\mu_{nf} = \mu_{bf}(1+2.5\emptyset) \quad (4)$$

v) Kinematic viscosity

$$V = \mu_{nf} / \rho_{nf} \quad (5)$$

vi). Prandtl number

$$P = \mu \times C_P / \kappa \quad (6)$$

vii) Hydraulic diameter of rectangular mini channels

$$D_h = 4(w \times h)/2(w+h) \quad (7)$$

viii) T_S = average temperature of the thermocouple

$$T_s = (T_1 + T_2 + T_3)/3 \quad (8)$$

ix) T_∞ = average of inlet and outlet temperatures

$$T_\infty = (T_5 + T_6)/2 \quad (9)$$

x) The film temperature

$$T_\infty = (T_\infty + T_\infty)/2 \quad (10)$$

xi) Velocity of water

$$Q = A_1 U_1 \quad (11)$$

xii) Reynolds Number

$$R_e = (U + D_h)/V \quad (12)$$

xiii) Nusselt number

$$N_u = 0.023 \times {R_e}^{0.8} \times {P_r}^{0.4} \quad (13)$$

xiv) Heat transfer coefficient

$$h = (N_u + \kappa)/D_h \quad (14)$$

xv) Friction factor

$$f = N_u / 0.125 \times R_e \times {P_r}^{0.33} \quad (15)$$

xvi) Pressure drop due to friction

$\Delta P_{\mathrm{f}} = \mathrm{f} \times \rho \times (\mathrm{L}/\mathrm{D}) \times (U^2/2)$ (16)

xvii) Pumping Power

$P = \Delta P_{\mathrm{f}} \times Q$ (18)

IV. RESULTS AND DISCUSSION

An experimental study is carried out on the rectangular and circular mini channels. The hydraulic diameter of 2.4mm and a length of 250mm are taken for rectangular mini channel and the hydraulic diameter of circular mini channel is 2mm. An array of 10 channels is used for the present study. The channels heated with constant heat flux condition are cooled by flowing water with different flow rates (0.25, 0.5, 0.75 and 1.0 lpm). The study is done under steady state with forced convection as well as turbulent flow condition. The results obtained are explain as.

17.Scanning Electron Microscopy Analysis

A suggested voltage would be 10 and 2 keV (or less) for a field emission SEM. Therefore this section presents SEM images of MWCNT, before functionalization and after functionalization are obtain these.

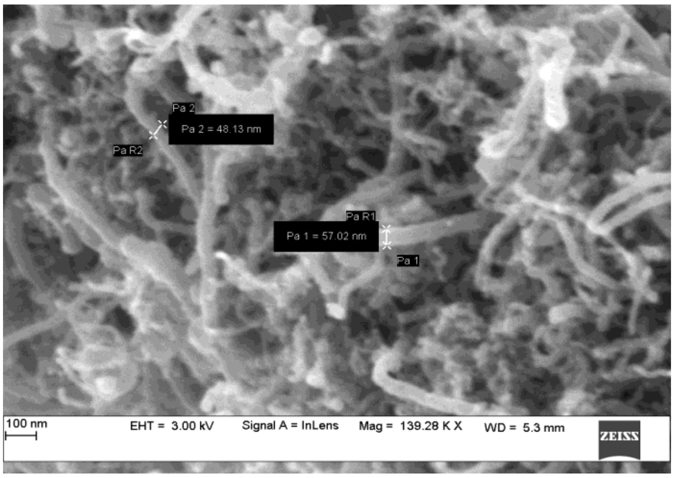

Fig. 4. SEM image of MWCNT before Functionalization

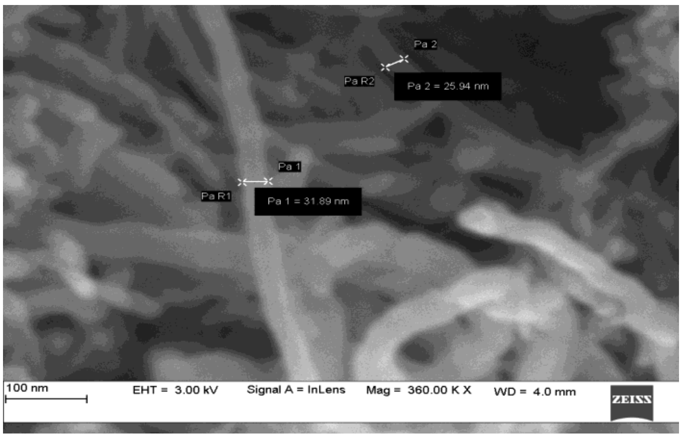

Fig. 5. SEM image of MWCNT after Functionalization

Figure 4.Represents SEM image of CNT before functionalization and Figure 5 represents SEM image of CNT after functionalization. On a scale of 100nm and at a voltage of 3KV, the average diameter of individual MWCNT is 52nm before functionalization. Figure 5. showsSEM-images of MWCNT after functionalization on a same scale and voltage, the diameters of the tube is reduced to an average of 28nm and also the length of the tubes is reduced due to the chemical vapor deposition technique (CVD) adopted to oxidize the functional groups and refinement forms used to expel nebulous carbon and leftover metal particles or as a consequence of CNT presentation to oxidants exhibit in the earth.

18. Results Analysis of Rectangular Mini Channel

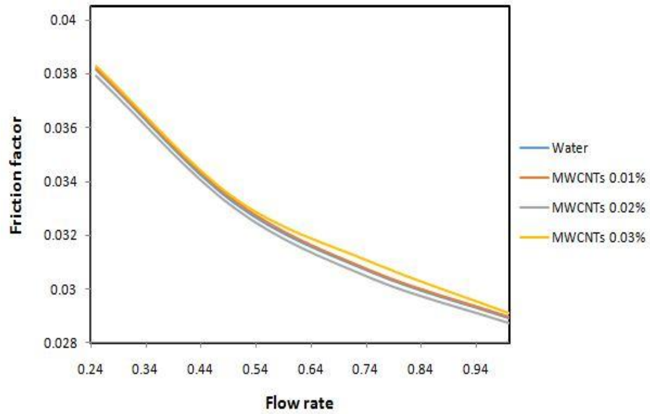

Fig. 6.Flow rate v/s friction factor

Figure 6 shows the effect of flow rate on friction factor when CNT Nanofluid is used as coolant in rectangular mini channel. When we mix the multi wall carbon nanotubes MWCNT with 0.01% in one litre of normal water then the physical properties of fluid will get changed. From the figure it is clear that with the use of MWCNT nanofluid in mini channels with increase in the flow rate the friction factor decreases but at initial value of flow rate the friction factor is more in case of MWCNT nano fluid compare to water this is due to increase in the viscosity of nanofluid which may lead to further increase the friction between walls of the channel and fluid layer

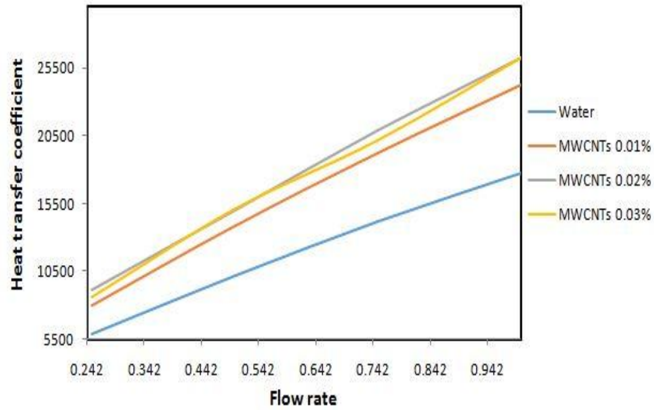

Fig. 7. Flow rate V/s heat transfer coefficient

Figure 7 illustrate the effect of flow rate on heat transfer coefficient when both nano fluid and water are used as coolant. It is observed that with increase in the flow rate the convective heat transfer coefficient also increase but one thing to be noted that is with increase in the concentration of nano particles in the base fluid the heat transfer coefficient also increases. This fact is due to increase in the velocity of flow as well as increase in the conductivity of fluid used. A huge difference is observed in heat transfer coefficient between water and carbon nanotubes nano fluid with less concentration of nano particles. Therefore we can say that heat transfer performance of a fluid can be progressed with the usage of lesser amounts of nano particles.

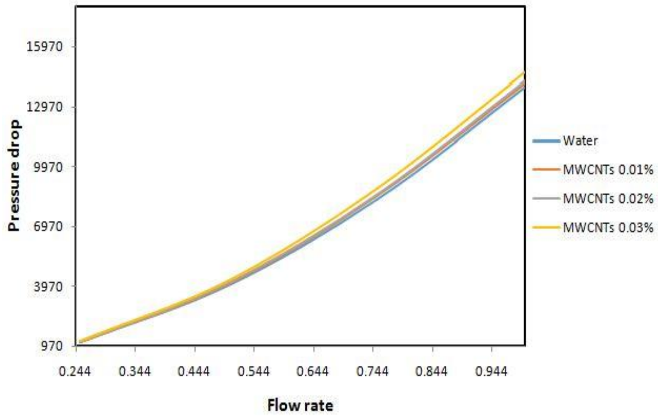

Fig. 8. Flow rate v/s Pressure drop

The above figure 8 depicts the effect of flow rate on pressure drop in rectangular mini channels cooled with water and MWCNT nanofluid. The figure says that with increase in the flow rate the pressure drop for both the fluids also increases this impact is mainly due to increase in the velocity of flowing fluid as it is known fact that as the velocity of flowing fluid increases the pressure in the fluid decreases. It is also observed that for water he drop n pressure is less as compare to the MWCNT nano fluid this is mainly because of presence of nanoparticles in base fluid and these particles enhance the friction between the channel and fluid layers hence causing the pressure to drop by a margin.

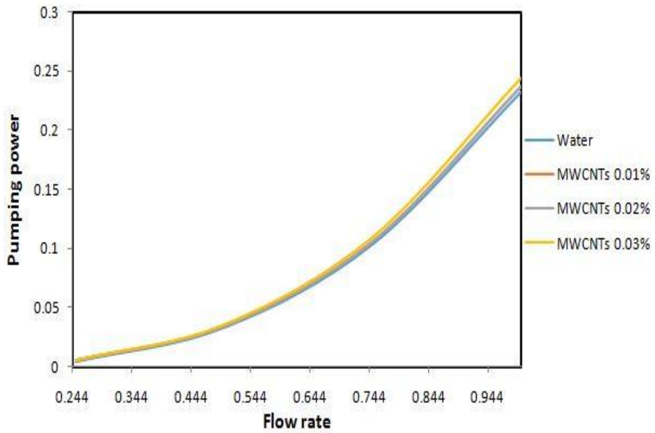

Fig.9. Flow rate v/s pumping powers

The above 9 depicts the change in pumping power through flow rate, it has notice that with raise in flow rate of fluid, the pumping power also increases, and it is known fact that the velocity and pressure are inversely proportional to each other in a flowing fluid as the velocity of the fluid increases the pressure decreases which leads to overall drop of pressure throughout the length of the channel. The values of above figure shows that the normal water pumping power has less as compare to the one gram MWCTs used (CNT-nanofluid) in coolant.

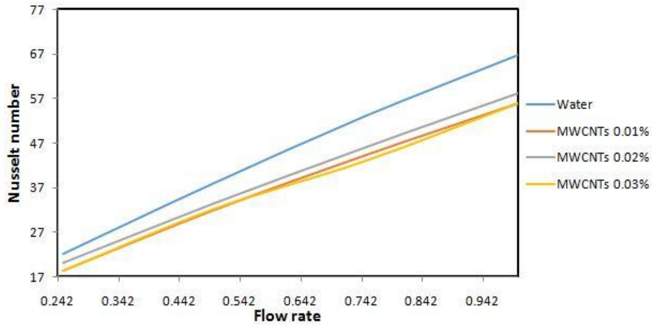

Fig.10. Flow rate v/s Nusselt number

The above figure 10shows the variation of Nusselt number with flow rate for both CNT and water at fully developed flow condition, from the figure we can say that as the flow rate increase then the Nusselt number also increase, this is mainly due to increase in velocity of fluid which further increases the coefficient for convective heat transport. The Nusselt number in favor of water is high when compared to CNT-nanofluid this is due to the warm conductivity for CNT-nanofluid high which is in reverse comparative for the Nusselt number.

19. Result Analysis ofCircular Mini Channel

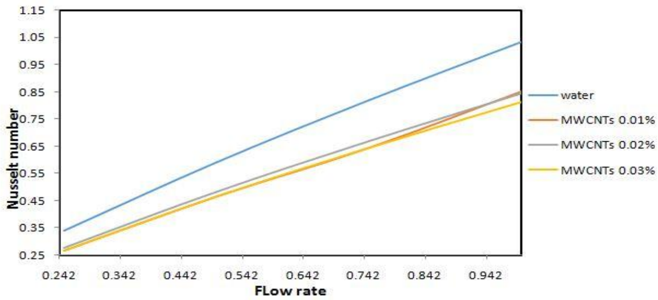

Fig. 11. Flow rate v/s Nusselt number

Figure 11 shows the variation in Nusselt number with flow rate for water and CNT nanofluid. It is clear from above figure that the Nusselt number for water as a coolant is high when compare from CNT-nanofluid. The Nusselt number of the water (normal water) as comparing to the Nusselt number of different concentration of CNT-nanofluid is high, also it can be said that with increase in flow rate the Nusselt number also increases.

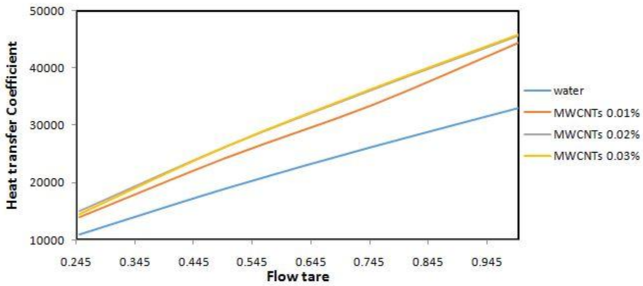

Fig.12. Flow rate v/s Heat transfer coefficient

Figure 12 depicts the heat transfer coefficient variation with flow rate as the flow rate increases the heat transfer coefficient also increases. The heat transfer coefficient of water coolant as compare to the CNT-nanofluid has less enhancement. The different concentration of MWCNTs using in the CNT-nanofluid clearly reveals that as the amount of MWCNTs increases in the CNT-nanofluid more enhancement into heat transfer coefficient is visible.

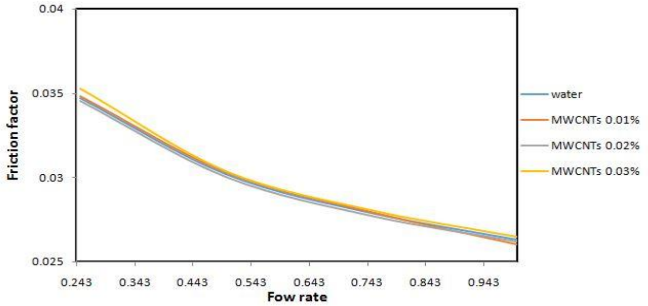

Fig. 13. Flow rate v/s Friction factor

The figure 13 illustrates the effect of flow rate of fluid on friction factor. It is seen that as the flow rate of fluid increases the friction factor get decreased this decrement in friction factor is more for water as compare to different concentrations of CNT nanofluid. As this is majorly due to presence of nanoparticles in nanofluid which may tend to enhance the viscous force in fluid layer hence causing the friction between the layers of fluid as well as between the fluid and channel walls to get increased, So in terms of friction factor water proves to be good coolant compare to CNT nano fluid.

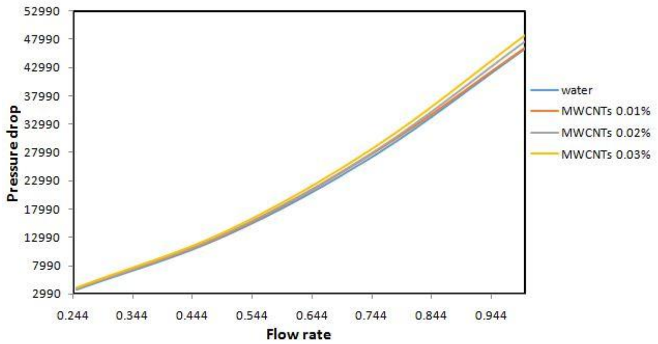

Fig. 14. Flow rate v/s Pressure drop

Figure 14 indicates the impact of flow rate on pressure drop in flowing fluid along the length of the channel. Flow rate of following fluid increase then the Pressure drop also increase. The graphically comparison of pressure of the different coolant ravels that water coolant has slightly lower values as compare to the CNT-nanofluid.The pressure of the water coolant fluid has lower values as compare to the nanofluid. The flow rate of coolant fluid has incresed then the pressure drop of coolant also increases but the values for the coolant comparision to base fluidis greater. The graphical analysis of the pressure drop of coolant reveals that it has the temperature dependent. The pumping power of coolant flow rate has increases then the pressure drops also increases with the higher values. The nanofluid has inreased more more pressure drop as percentage of multiwalled carbon nanotubes increases in the nanofluid. In general we can say that the amount of multiwalled carbon nanotubes in nanofluid increases then the pumping power will increased with flow rate of fluid and also pressure drop will increased.

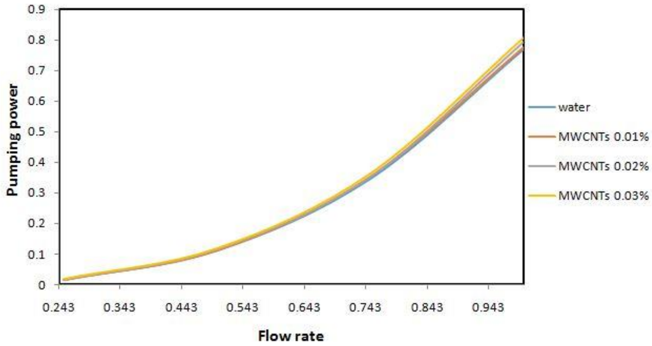

Fig.15. Flow rate v/s Pumping power

Figure 15 shows that the pumping power of coolant with different flow rate, the pumping power of coolant has approximate same values. The pumping power of water as compare to the CNT-nanofluid has lower and also the pumping power of high concentration CNT-nanofluid is slightly more. The graphical view of pumping power of coolant reveals that the flow rate of coolant raise then the pumping power for coolant will increase. The nanofluid pumping power depends on the concentration of multiwalled carbon nanotubes mixed with base fluid. The figure also state that water coolant has used less pumping power as compare to nanofluid coolants. The nanofluid has more concentration then the pumping power of higher concentration of nanofluid has high as comparision to lower concentration of nanofluid.

V. CONCLUSION

The experimental work is carried out on rectangular along with circular mini channel subjected to multi wall carbon nanotubes (MWCNT), MWCNT-nanofluid and normal water as a working fluid. The experiments were conducted for constant heat flux steady state turbulent flow conditions. During the time of experiments the following concluding remarks were disclosed.

- It has been observed that within the entry region, both heat transport and friction issue changes considerably. Friction factor of MWCNT-nanofluid is more as compare with water as well as observed that the flow rate of fluid enhance then the friction nanofluid is reduce in addition to rate of heat transfer coefficient increase.
- It has been seen that the Reynolds number increase then Nusselt number also increases in both channel geometries under fully developed flow condition.
- It has been seen that the friction factor in both channels is more in case of MWCNT-nanofluid, match up to base fluid.
- For the constant discharge the pressure drop is more in case of MWCNT nanofluid since comparing for fluid. The pump work required is more for the MWCNT nanofluid, comparing their fluid.
- When the concentration of multi wall carbon nanotubes (MWCNT) increases then the coefficient of warmth removes has increase for both mini channel. The heat transfer rate of 0.01%multi wall carbon nanotubes (MWCNT) is less than the 0.02% and 0.02% multi wall carbon nanotubes (MWCNT)

transfer for heat rate is lower than 0.03% multi wall carbon nanotubes (MWCNT) used during both the mini channels.

- We have observed that, flow rate is increase then pumping power and pressure drop also increases in every concentration for multi wall carbon nanotubes, MWCNT nanofluid.

SCOPE FOR FUTURE STUDY

- The study can be further investigated through using different fluid by dissimilar cross section of mini channels with different concentrations.
- The study can be done for turbulent flow in transient condition for the different materials of mini channels.
- The numerical study can be performed by using commercial available software like, Fluent (CFD).
- The study on rectangular mini channel can be done with different nanofluid concentration and size and shape of Nano particles.
- Fluid flow analysis can be done by using flow visualization technique.
- The work on characterisation of multi-walled carbon nanotubes (MWCNTs) using surfactants.

REFERENCES

[1] Vikas Kumar, Arun Kumar Tiwari and Subrata Kumar Ghosh, Experimentally work on Effect of variable spacing on performance of plate heat exchangerUsing different nanofluid like TiO2, Al2O3, MWCNT, water, ZnO and CeO2, EnergyAugust 2016, Department of Mechanical Engineering, Indian School of Mines, Dhanbad 826004 India.

[2] Rupesh D. Khorgade, R. S. Shelke. Did an experimental study on improvement of heat transfer of mini channels heat sink using nanofluid, International Journal of Advanced Engineering and Global Technology, Vol-03, Issue-06, June 2015

[3] Rabia Sabir1, Naveed Ramzan, Asim Umer and Hina Muryam, they have worked don Experimental study of forced convective heat transfer characteristic of gold waternanofluid in laminar flow.

[4] Pyshar Yi. Work on Nanoparticles for Heat Transfer Enhancement in Micro fluidic Systems. August 2014. College of Science Engineering and Health RMIT University

[5] Melanie M. Derby, Abhra Chatterjee, Yoav Peles, Michael K. Jensen. Flow condensation heat transfer enhancement in a minichannelwith hydrophobic and hydrophilic patterns. Derby M. M. Chatterjee, A. Peles Y.& Jensen M. K. (2014). International Journal of Heat and Mass Transfer, 68, 151-160.

[6] Paisarn Naphon, Lursukd Nakharintr, and Turbulent two phase approach model for the nanofluid heat transfer analysis flowing through the mini channels heat sinks. Department of Mechanical Engineering, Faculty of Engineering, Srinakharinwirot University, 63 Rangsit-Nakhornnayok Rd., Ongkharak, Nakhorn-Nayok 26120, Thailand

[7] F. Illan-Gomez, A. Lopez-Belchi, J.R. Garcıa Cascales, F. Vera-Garcia. Experimental two-phase heat transfer coefficient and frictional pressure drop inside mini-channels during condensation with R1234yf and R134a. 30 November 2014.

[8] Zan Wu, Zhaozan Feng, Bengt Sunden, Lars Wadso. A comparative study on thermal conductivity and rheology properties of alumina and multi-walledcarbon nanotubes nanofluid, Department of Energy Sciences, Lund University, Lund, SE-22100, Sweden, Department of Energy Engineering, Zhejiang University, Hangzhou, 310027, China, Division of Building Materials, Lund University, Lund, SE-22100, Sweden. 2014

[9] C. Bi, G.H. Tang*, W.Q. Tao. Experimental work on Heat transfer enhancement in mini-channel heat sinks with dimples and cylindrical grooves. Engineering, School of Energy and Power Engineering, Xi’an Jiaotong University, Xi’an 710049, China, 7 March 2013.

[10] Reza Kamali, Yaghoub Jalali, Alireza R. Binesh, Investigation of multiwall carbon nanotubes-based nanofluid advantages in microchannel heat sinks. School of Mechanical Engineering, Shiraz University, Shiraz 71348-51154, Iran, 26th April 2013

[11] Tun-Ping Teng, Li Lin, and Chao-Chieh Yu.Preparation and Characterization of Carbon Nanofluid by Using a Revised Water-Assisted Synthesis Method, Department of Industrial Education, National Taiwan Normal University, No. 162, Section 1, He-ping E. Road,Ad-an District, Taipei City 10610, Taiwan25 September 2013

[12] Saad Ayub Jajja, Wajahat Ali, Hafiz Muhammad Ali, Aysha Maryam Ali.Water cooled minichannel heat sinks for microprocessor cooling: Effect of fin spacing. Department of Mechanical and Aeronautical Engineering, 4 December 2013

[13] J.P. Meyer, T.J. McKrell, K. Grote. The influence of multi-walled carbon nanotubes on single phase heat transfer and pressure drop characteristics in the transitional flow regime of smooth tubes, Massachusetts Institute of Technology 77 Massachusetts Avenue, Cambridge, MA 02139-4307, USA.

[14] O. Deriabina, N. Lebovkaa, L. Bulavin, A. Goncharuk. Regulation of dispersion of carbon nanotubes in a mixture of good and bad solventsInstitute of Biocolloidal Chemistry named after F.D. Ovcharenko, NAS of Ukraine, 42, blvr. Vernadskogo, Kyiv 03142, Ukraine

[15] Julie A. Horvath, Rebecca N. Webb. Experimental study of radiation absorption by minichannels of varying geometry. Department of Mechanical and Aerospace Engineering, University of Colorado at Colorado Springs, Colorado Springs, CO 80918,

USA

[16] J. G. Carton, et al.The droplet ofwater accumulation and motion through pem fuel cell for the mini channel test, Upper Austria University

[17] Manoj Kumar Moharana, et al. The axial flow single phase simultaneously developing flowing in a mini channel forrectangular group, Mechanical Engineering Department, IIT, Kanpur, 18 January 2011

[18] S. M. Sohel Murshed, et al.The heat Transfer through Convective Forced using Nanofluid as a flowing fluid through Minichannels, University of LisbonPortugal, Molecular Sciences and Materials.

[19] M. Venkatesan1, et al. Consequence of tube diameter of extended Bubble Length in Mini channels, Department of Mechanical Engineering, IIT Madras, 2010.

[20] Gerardo Diaz, show analysis with design optimization of minichannels evacuatetube solar collector, School of Engineering University of California, 2008 ASME International Mechanical Engineering, 2008

[21] Hans'sLudwig Hartagel. Did the experiment on "New microwave concepts based on carbon nanotubes", Institute four Hochfrequenztechnik technische universitaet Darmstdt Mercksstasse 25, D-64283 Darmstadt, Germany

[22] Yi Fan, Yifeng Fu, Teng Wang, Johan Lm. 1'2, Van Zhang, Xiaojing Wang, Zhaonian Cheni,Heat Removal of Microchannel Coolers with Carbon Nanotubes Suspension as the Coolant. Department of Microtechnology and Nano sciences (MC2) 3 Chalmers university of Technology, SE-412 96 Gothenburg, Sweden

[23] Yulong Ding, et al. heat transfer of aqueous suspension ofcarbon nanotubes(CNT-nanofluid), Institute of Particle Science and Engineering, University of Leeds, Leeds LS2 9JT, UK

