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Preparation and application of nanofluid withmicrochannel and its experimental and theoretical thermal performance - A Review

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Abstract: **-** This paper concerned with the heat transfer behaviour of aqueous suspension of nanoparticle i.e. nano fluid, a procedure for preparing a nanofluid its importance, application and challenges of nanofluid. Apart of these the theoretical study of the thermal conductivity of nanofluids is introduced. Some factors such as particle size, particle shape the volumefraction and properties of the nanoparticles are discussed. A theoretical model and empirical equation for the effective thermal conductivity of Nanofluid is proposed to describe heattransfer performance of the nanofluid. Other thermophysical properties of nanofluid like as effective viscosity, effective density, effective specific heat are also reviewed by various model presented by researcher. In addition of this nanofluid its application in microchannel with various geometrical configurations and various specific nanofluids are studied under various boundary conditionsare reviewed here.

Keywords: *- Nanofluid; Enhanced heat transfer; microchannel heat Exchangers (MCHS); Thermal conductivity; Viscosity; Volume concentration*

I. INTRODUCTION

Improvement of heat transfer i.e. energy transfer from hot to cold medium by conduction,&convection are most promising way to transfer heat from in thermal devices such as heat exchangers and electronic equipment became an important factor in industry. For this purpose, various techniques have been proposed as the use of various class of high heat carrying capacity fluid but no one fluid can as effective as a new modern smart fluid called as nanofluid,amixture of high conductive nanoparticle in a base fluid.Nanofluid is the suspension of nanoparticles in a base fluid. Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100 nm) suspended within them. These particles are generally a metal or metal oxide. Some typical Nanofluids are ethylene glycol based copper Nanofluids and water based copper oxide Nanofluids. Nanofluids are promising fluids for heat transfer enhancement due to high thermal conductivity. Experimental studies are discussed in terms of the effects of some parameters such as particle volume fraction, particle size, and temperature on the thermal conductivity of Nanofluids. The term 'Nanofluid' refers to a two-phase mixture usually composed of a continuous liquid phase and dispersed nanoparticles in suspension (i.e. extremely fine metallic particles of size below 50 nm). Several nanoparticle dispersions of engineering interest are readily available from various commercially sources [1].
Serrano et al. [03] provided excellent examples of manometer in comparison with millimetre and micro meter to understand clearly as seen in Fig. 1.

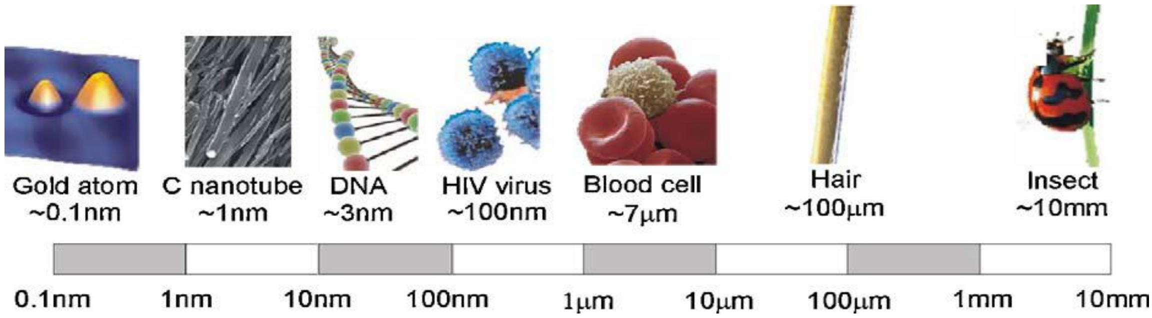


Fig: 1Length scale and some examples related [2].

Due to very large specific surface areas and small sizes of the nanoparticles, nanofluids have superior properties likeminimal clogging, high thermal conductivityin flow passages, homogeneity and long-term stability. Hence, nanofluids have a wide range of prospectiveclaims like electronics, automotive, and nuclear uses where enhanced heat transfer or effective heat indulgence is required. Choi [4] conceived the concept of nanofluids in 1995 which can improve heat transfer without a large pumping power increase at Argonne National Laboratory of USA. Subsequent researches of Eastman et al. [5] and Choi et al. [6] triggered great interest in nanofluids when they reported shows sudden high thermal conductivities of nanofluids at low nanoparticle concentrations. Hence in the past few years, many experimental examinations on the thermal conductivity of nanofluids have been stated which showed that nanofluids demonstratemuch higher thermal conductivities than their base fluids even when the concentrations of suspended nanoparticles are very low and the nanofluid thermal conductivity increase significantly with nanoparticle volume concentration. Reported results of the effective thermal conductivity of nanofluids from various research groups were well summarized here.

In this literature review emphasis is directed on:

- Nano fluid – preparation, heat transfer application and stability.
- Nano fluid- thermal conductivity, measurement process, effect of various aspects on thermal
- Conductivity and experimental and theoretical models.
- Nano fluid- convective heat transfer technology and its experimental investigation.

1.1 Nano fluid – preparation, heat transfer application and stability

*KaufuiV.Wong and Omar De Leon [02]*they review the application of nano fluid and their use in industry, nuclear power plant , electronic industry as well as biomedicine and food. They conclude nanofluid as a smart fluid, which can use to enhance cooling effect by heat transfer. These study emphases on the expansive range of applications of nanofluid in present and future. They also show the temperature difference of water and nanofluid in evaporators and condense.

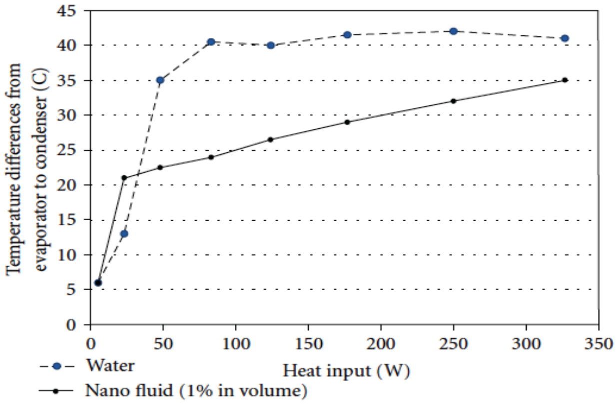


Fig 2 Effect of nanofluid on heat transport capability in an OHP

D. Wen et al.[07] this paper presents a various factor that play a significant role in enhancing the critical property of nanofluid thermal characteristics. They deal with Nanofluids formulation technique like the two-step method (top-down method) and one-step method (bottom-up approach) and Influence of nanofluids on effective properties and its mechanics. They also state the effect of aggregation on nano fluid property.

*Gupta H.K, Agrawal G.D, Mathur J [08]*this paper presents overview about nanofluid, an exciting new class of heat transfer fluid, in terms of application, barriers and further research. It is concluded that nanofluids are important because they can be considered as a potential candidate for numerous applications involving heat transfer and their use will continue to grow. It was also found that the use of nanofluids appears promising, but the development of the field faces several challenges. Nanofluid stability and its production cost are major factors in using nanofluids. The problems of nanoparticle aggregation, settling, and erosion all need to be examined in detail in the applications. We can say that once the science and engineering of nanofluids are fully understood and their full potential researched, they can be reproduced on a large scale and used in many applications. It is also suggested that further research still has to be done on the synthesis and applications of nanofluids so that they may be applied as more efficient and compact heat transfer systems, maintaining cleaner and healthier environment and unique applications.

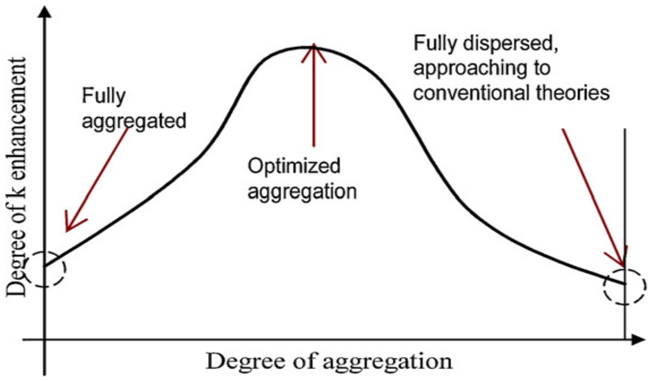


Fig 3.Aggregation effect on the effective thermal conductivity.

Wei Yu and HuaqingXie [09] this paper presents a review on nanofluid preparation, stability evaluation (1.sedimentation and centrifugal method 2. Zeta potential analysis 3.Spectral absorbency analysis) stability enhancement technique (1.Use of surfactants 2. Surface modification technique etc.) Andnanofluids application areas.

1.2 Nano fluid- thermal conductivity, measurement process, effect of various aspects on *thermal conductivity and experimental and theoretical models*

Y Nagasakat and A Nagashima [10] in this paper describe the thermal conductive measuring technique by use of transient hot-wires method of electrically conductive liquid. In this apparatus use metallic wire coated with a thin electrical insulation layer instead of just the bare metallic wire. They study the effect of thickens of insulation on measurement of thermal conductivity, reference temperature and thermal contact resistance. They also deal with the accuracy of measurement that is estimated near to$\pm$ 0.5%.

Eastman et al. [11] invented a method which helps to describe the significant augmented effective thermal conductivities of ethylene glycol-based nanofluids encompassing of copper nanoparticles. It is shown that a ‘‘nanofluid’’ containing of copper nanoparticles dispersed in ethylene glycol has a much developed effective thermal conductivity base fluid. The effective thermal conductivity of ethylene glycol is incremented to 40% for a nanofluid consisting of 0.3 volume% Cu nanoparticles of mean diameter, 10 nm. This result help to predict the effect of particle shape on the effective nanofluid thermal conductivity.

Xie and Wang et al. [12] examine thermal conductivity performances of nano sized Al_2O_3 Suspensions. The experimental outcomes show that enhancement of thermal conductivities of nanofluid and also effect of volume fraction of nanoparticles in thermal conductivity. They study and conclude the effect of PH value of aqueous solution, specific area of nanoparticle. For the suspensions comprising the same nanoparticles, the thermal conductivity ratio is condensed with the increase thermal conductivity of the base fluid.

H.E.Patel et al. [13] investigatethermal conductivities of bare and single layer protected metal nanoparticle based nanofluids. Here Thermal conductivity enhancement of Au nanoparticles was measured in water and toluene media. The water soluble particles having 10–20 nm in mean diameter, showed thermal conductivity enhancement of 5 to 21% in the temperature range of 30 to 60 °C at a loading of 0.000 26 by volume. The effect on thermal conductivity was also investigated for Au particles with OctaDecanethial and found 7 to 14%. This result concludes the various chemical factors like as the direct contact of solvent with metal surface etc. are also responsible for thermal conductivity enhancement of nanofluid.

Jang and Choi [14]] this paper shows the effect of Brownian motion in the thermal conductivity of nanofluids. They describe the four modes of enhancement of thermal conductivity of nanofluid based on Brownian motion that are key mechanism of the thermal behaviour of nanoparticle–fluid suspensions. This paper prepares a theoretical model that investigates the dynamic behaviour nanoparticle in nanofluids. This models also deals with the study of particle size on thermal conductivity which help to broad its applications areas such as next-generation coolants with industrial and biomedical applications in high-heat-flux cooling.

Chon et al. [15] derivate Empirical relationship to discover the character of temperature and particle size for nanofluid thermal conductivity enhancement. They find an experimental correlation for the ratio of thermal conductivity of Al_2O_3 nanofluids and thermal conductivity of base fluid as a function of nanoparticle size ranges from 11 to 150 nm nominal diameters for temperature ranging from 21 to 71 °C. Thermal conductivity of nano fluid is given by-

$$\frac{k_{nf}}{k_{BF}} = 1 + 64.7\emptyset^{0.7460}\left(\frac{d_{BF}}{d_{np}}\right)^{0.3690}\left(\frac{k_{np}}{k_{BF}}\right)^{0.7476} Pr^{0.9955} Re^{1.2321} \quad \text{.......}(1)$$

Calvin li and G. Peterson [16] have worked on identification of the possible mechanisms that contribute to the enhanced effective thermal conductivity of nanoparticle suspensions (nanofluids). The mixing effect of the base fluid in the immediate vicinity of the nanoparticles caused by the Brownian motion was analyzed, modelled and compared with existing experimental data available in the literature. The simulation results using CFX 5.5.1 software indicate that this mixing effect can have a significant influence on the effective thermal conductivity of nanofluids. They have found pressure, velocity and temperature profile around the nanoparticles. A developing laminar forced convection flow of a water–Al2O3 nanofluid in a circular tube, submitted to a constant and uniform heat flux at the wall, has been numerically investigated by Bianca et al. (2009). CFD method was used to simulate the model equations. A single and two-phase model (discrete particles model) was employed with either constant or temperature dependent properties. The maximum difference in the average heat transfer coefficient between single- and two-phase models results was found about 11%. Convective heat transfer coefficient for nanofluids was found as greater than that of the base liquid. Heat transfer enhancement increases with the particle volume concentration, but it is accompanied by increasing wall shear stress values. Higher heat transfer coefficients and lower shear stresses were detected in the case of temperature dependents models. Theheat transfer always improves, as Reynolds number increases.The available models are reviewed and the possible reasons for the unusually high effective thermal conductivity of nanofluids are analyzed and discussed.

$$\frac{k_{nf}}{k_{BF}} = 1 + \frac{3(\propto-1)\emptyset}{(\propto+2)(\propto-1)\emptyset} \qquad \text{..}(2)$$

K.S.Hong et al [17] investigate Thermal conductivity of Fe nanofluids depending on the cluster size of nanoparticles . This work focuses on the effect of the clustering of nanoparticles on the thermal conductivity of nanofluids. Large enhancement of the thermal conductivity is observed in Fe nanofluids sonicated with high powered pulses. The average size of the Nano clusters and thermal conductivity of sonicated nanofluids are measured as time passes after the sonication stopped. It is found from the variations of the Nano cluster size and thermal conductivity that the reduction of the thermal conductivity of nanofluids is directly related to the agglomeration of nanoparticles. The thermal conductivity of Fe nanofluids increases nonlinearly as the volume fraction of nanoparticles increases. The nonlinearity is attributed to the rapid clustering of nanoparticles in condensed nanofluids. The thermal conductivities of Fe nanofluids with the three lowest concentrations are fitted to a linear function. The Fe nanofluids show a more rapid increase of the thermal conductivity than Cu nanofluids as the volume fraction of the nanoparticles.

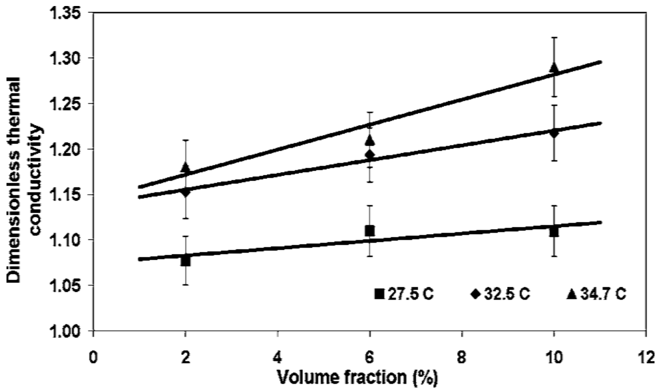


Fig4Dimensionless thermal conductivity of Al2O3/water suspensions vs. volume fraction.

Min-Sheng Liu et al. [18]investigate Enhancement of thermal conductivity with Cu for nanofluids using chemical reduction method the enhancement of the thermal conductivity of water in the presence of copper (Cu) using the chemical reduction method is presented in this study. It is the first time that the chemical reduction method for synthesis of nanofluids containing Cu nanoparticles in water is reported. No surfactant is employed as the dispersant. The volume concentration of Cu–water nanofluids is below 0.2 vol. %. Without the addition of dispersant and surfactant, the thermal conductivity of the produced nanofluids reveals a time-dependent characteristic. The thermal conductivity is the largest at the starting point of measurement and decreases considerably with elapsed time. The results show that Cu–water nanofluids with low concentration of nanoparticles have noticeably higher thermal conductivities than the water base fluid without Cu. For Cu nanoparticles at a volume fraction of 0.001 (0.1 vol. %), thermal conductivity was enhanced by up to 23.8%.
W. Evans et al [19] investigate Effect of aggregation and interfacial thermal resistance on thermal conductivity of nano composites and colloidal nanofluids. We analyzed the role of aggregation and interfacial thermal resistance on the effective thermal conductivity of nanofluids and nano composites. We found that the thermal

conductivity of nanofluids and nano composites can be significantly enhanced by the aggregation of nanoparticles into clusters. The value of the thermal conductivity enhancement is determined by the cluster morphology, filler conductivity and interfacial thermal resistance. We also compared thermal conductivity enhancement due to aggregation with that associated with high-aspect ratio fillers, including fibres and plates.

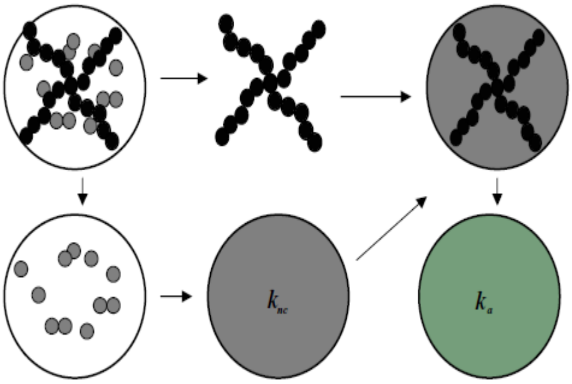


Fig5 Schematic of a single aggregate consisting of the backbone (black circles) and dead ends (gray circles).

N.R. Karthikeyan et al. [20] investigate the Effect of clustering on the thermal conductivity of nanofluids. We investigated the parameters influencing the thermal conductivity enhancement in water and ethylene glycol based nanofluids of CuO nanoparticles of average diameter 8 nm. The thermal conductivity enhancement observed with 1 vol. % of CuO nanoparticles is 54%, which is the highest value reported for CuO nanofluid. The large enhancement in thermal conductivity is attributed to the smaller particle size and mono disparity of particles. The thermal conductivity of nanofluid increases nonlinearly with the volume fraction of nanoparticles. The time-dependent thermal conductivity of water based CuO nanofluid shows that the thermal conductivity decreases with elapsed time due to clustering of nanoparticles. The clustering of nanoparticles is also confirmed microscopically. The experimental results show that the nanoparticle size, poly disparity, particle clustering and the volume fraction of particles in the suspensions have significant influence on thermal conductivity of suspensions.

*Ravikanth S. Vajjha, Debendra K. Das [21]*this paper experimentally the thermal conductivity of three nanofluids containing aluminium oxide, copper oxide and zinc oxide nanoparticles dispersed in a base fluid of ratio by mass 60:40. In this ethylene glycol and water is taken as base fluid with volumetric concentration tested was up to 10% and the temperature ranging from 298 to 363 K. The results show intensification in the thermal conductivity of nanofluids paralleled to the base fluids and its increment with increasing volumetric concentration of nanoparticles and temperature. Here nanofluid thermal conductivity is calculate with –

$k_{nf}(\emptyset,T) = A(\emptyset) + B(\emptyset)T + C(\emptyset)T^2$……………………………………………………………………………(3)

where The coefficients A, B, C are polynomial functions of concentration $\emptyset$.

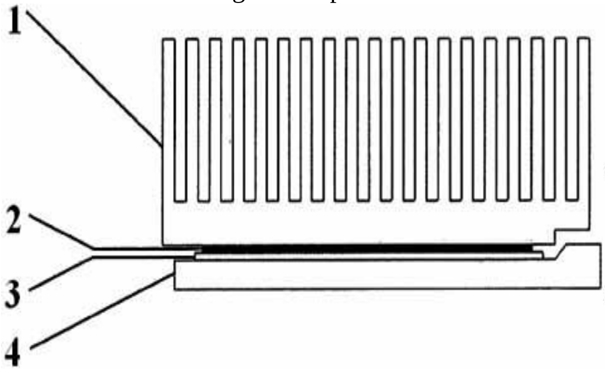
A.K.Tiwari et al. [22] ***i****nvestigation*of thermal conductivity and Viscosity of nanofluids. A colloidal mixture of nano-sized (<100 nm) particles in a base liquid called nanofluid, which is the new generation of heat transfer fluid for various heat transfer applications where transport characteristics are substantially higher than the base liquid. This review summarizes and analyses the empirical correlations for the effective thermal conductivity and dynamic viscosity of the nanofluid based on experimental data and theoretical model available in the literature. The review shows that the thermal conductivity ratio of the nanofluid to the base liquid for spherical and cylindrical nanoparticles increase appreciably with the increase of nanoparticle concentration and temperature. In addition, the viscosity ratio of the nanofluid to the base liquid also increases with the increase of nanoparticle concentration. This paper also surveys the mathematical models for estimation of thermal conductivity and viscosity of nanofluids and their limitations.

1.3 Nano fluid- convective heat transfer technology and its experimental investigation.

*W. Dongsheng, D. Yulong [23]*this paper reports an experimental work on the convective heat transfer of Nanofluids, made of Al_2O_3 nanoparticles and de-ionized water, flowing through a copper tube in the laminar flow regime. The results showed considerable enhancement of convective heat transfer using the Nanofluids. It was also shown that the heat transfer behaviour of Nanofluids. Possible reasons for the enhancement were discussed. Migration of nanoparticle, and the resulting disturbance of the boundary layer.

*S.K.Das et al [24]*This article presents an exhaustive review of Abnormal enhancement of thermal conductivity, Stability, Small concentration and Newtonian behaviour, Particles size dependence, synthesis and preparation of nanoparticles, convection in nanofluids, boiling in nanofluids etc.

Lixin Cheng [25] he discussed the various heat transfer technology incorporated with nanofluid its current and future development. The study of nanofluid heat transfer (especially two phase flow and thermal physics) is still in its infancy. Many controversies exist with numerous conflicting experimental results and trends. In general, nanofluids were found to increase, decrease or have no effect on nucleate pool boiling but consistently to increase CHF. Through this comprehensive literature review, in order to put the available patented nanofluid heat transfer technologies into practice and to further invent new patents,



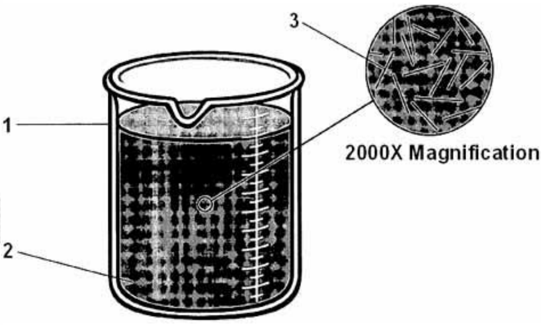


Fig6 Multi-microchannel used for computer chipcooling: 1- Multi-microchannel Vessel; Evaporators; 2- Connector; 3- Spreader; 4- Computer chip

Fig7 Schematic of nano rods dispersed in a fluid: 1- 2- Base fluid; 3-Nanorod

*A.K.Santra et al. [26]*Study of heat transfer due to laminar flow of copper–water nanofluid through two isothermally heated parallel plates. Effect of copper–water nanofluid has been studied as a cooling medium to simulate the heat transfer behaviour in a two-dimensional (infinite depth) horizontal rectangular duct, where top and bottom walls are two isothermal symmetric heat sources. The governing continuity, momentum and energy equations for a laminar flow are being discretized using a finite volume approach using a power law profile approximation and has been solved iteratively, through alternate direction implicit, using the SIMPLER algorithm. The thermal conductivity of nanofluid has been determined by model proposed by Patel et al. Study has been conducted considering the fluid as Newtonian as well as non-Newtonian for a wide range of Reynolds number (Re = 5 to 1500) and solid volume fraction (0.00_φ _0.050). It has been observed that the heat transfer augmentation is possible using nanofluid in comparison to conventional fluids for both the cases. The rate of heat transfer increases with the increase in flow as well as increase in solid
Volume fraction of the nanofluid. Unlike natural convection the increase in heat transfer is almost same for both the cases.

SadikKakaçand AnchasaPramuanjaroenkij[27] Review of convective heat transfer enhancement with nanofluids. The literature survey shows that nanofluids significantly improve the heat transfer capability of conventional heat transfer fluids such as oil or water by suspending nanoparticles in these base liquids. Further theoretical modelling and experimental works on the effective thermal conductivity and apparent diffusivity are needed to demonstrate the full potential of nanofluids for enhancement of forced convection. The understanding of the fundamentals of heat transfer and wall friction is prime importance for developing nanofluids for a wide range of heat transfer application. Although there are recent developments in the study of heat transfer with nanofluids, more experimental results and the theoretical understanding of the mechanisms of the particle movements are needed to understand heat transfer and fluid flow behaviour of nanofluids. Further work is also needed for the treatment of nanofluids as a two-phase flow since slip velocity between the particle and base fluid plays important role on the heat transfer performance of nanofluids.

II. MATERIALS AND PREPARATION

Various nano material are used for heat transfer application in nanofluid preparation some are Al_2O_3, CuO, TiO_2, SiC, TiC, Ag, Au, Cu, and Fe. These nanoparticles are used frequently to prepare Nanofluid. The preparation technique of nanoparticle and nanofluid are discussed below.

2.1 Nanoparticle

Production of nanoparticle can be divided into two main categories, namely, physical synthesis and chemical synthesis. *D. Wen et al* [7] listed the common production techniques of Nanofluids as follows. Physical Synthesis: Mechanical grinding, inert-gas-condensation technique. Chemical Synthesis: Chemical precipitation, chemical vapour deposition, micro-emulsions, spray pyrolysis, thermal spraying.

2.2 Nanofluids

There are mainly two methods of Nanofluid production, namely, two-step technique and one-step technique. In the two-step technique, the first step is the production of nanoparticle and the second step is the dispersion of the nanoparticle in a base fluid. Two-step technique is advantageous when mass production of Nanofluids is considered, because at present, nanoparticle can be produced in large quantities by utilizing the technique of inert gas condensation [7]. The main disadvantage of the two-step technique is that the nanoparticle form clusters during the preparation of the Nanofluid which prevents the proper dispersion of nanoparticle inside the base fluid [7].One-step technique combines the production of nanoparticle and dispersion of nanoparticle in the base fluid into a single step. There are some variations of this technique. In one of the common methods, named direct evaporation one-step method, the Nanofluid is produced by the solidification of the nanoparticle, which is initially gas phase, inside the base fluid [11]. The dispersion characteristics of Nanofluids produced with one-step techniques are better than those produced with two-step technique. The main drawback of one-step techniques is that they are not proper for mass production, which limits their commercialization [7].

2.3 Theoretical model and empirical equation for the effective thermal conductivity of Nanofluid

Conductivity theories of solid/liquid suspensions, such as the Maxwell, Bruggemen, Hamilton and Crosser, and other macro scale approaches cannot explain that Nanofluids have anomalously high thermal conductivity at very low volume fraction of nanoparticle, size-dependent conductivity.

Recently, Yu and Choi , Xuan et al, Koo and Kleinstreuer, Chon et al.[13] Prasher et al. Jang and Choi[14] and others have constructed a theoretical model based on nanoparticle liquid layering ,Brownian motion, and clustering phenomenon [21,22]. Jang and Choi [14]have constructed a theoretical model based on Brownian motion. The following analysis is based on Jang and Choi's model [14]. The thermal conductivity of Nanofluids involves four modes of energy transport in Nanofluids. They are as follows-

2.3.1 First mode: (*collision between base fluid molecules*)

The first mode is collision between base fluid molecules, which physically represents the thermal conductivity of the base fluid. Assuming that the energy carrier travels freely only over the mean-free path, $\boldsymbol{l}$,after which the base fluid molecules collide, the net energy flux $\boldsymbol{q}$ across a plane at *z* is given by

$$\mathbf{q} = -\frac{1}{3}\mathbf{l}_{\mathbf{BF}}\hat{\mathbf{c}}_{\mathbf{v,BF}}\bar{\mathbf{c}}_{\mathbf{BF}}(\mathbf{1}-\emptyset)\frac{\mathbf{dT}}{\mathbf{dz}} = -\mathbf{k}_{\mathbf{np}}\frac{\mathbf{dT}}{\mathbf{dz}}(\mathbf{1}-\emptyset) \quad \textbf{(4)}$$

2.3.2 Second mode: (<u>*thermal diffusion in nanoparticles in fluids*</u>)

$$\boldsymbol{q} = -\frac{1}{3}\boldsymbol{l}_{\boldsymbol{np}}\hat{\boldsymbol{c}}_{\boldsymbol{v,np}}\bar{\boldsymbol{v}}_{\boldsymbol{np}}\emptyset\frac{\boldsymbol{dT}}{\boldsymbol{dz}} = -\boldsymbol{k}_{\boldsymbol{np}}\frac{\boldsymbol{dT}}{\boldsymbol{dz}}\emptyset \quad (5)$$

Kapitza investigated that thermal conductivity of a single particle whose size is smaller than the mean free path of the energy carrier and developed a theoretical model for the thermal conductivity of the single particle k_{np} given by

$$\mathbf{k}_{\mathbf{np}} = \mathbf{k}_{\mathbf{bulk}}\frac{\mathbf{0.75}\frac{\mathbf{d}_{\mathbf{np}}}{\mathbf{L}_{\mathbf{np}}}}{\mathbf{0.75}\frac{\mathbf{d}_{\mathbf{np}}}{\mathbf{L}_{\mathbf{np}}}+\mathbf{1}} \quad (6)$$

Where k_{bulk}, d_{nano} and L_{np} are the thermal conductivity of bulk material, characteristic length of nanoparticle, and mean free path of nanoparticle, respectively.

2.3.3 Third mode: (collision between nanoparticles due to Brownian motion)

The third mode is the collision of nanoparticle with each other by translational motion of nanoparticle. This physical meaning indicates that flux of energy is transported by collision of nanoparticle with each other. Nanoparticle collision due to Brownian motion is very slow processes by an order-of-magnitude analysis .we have found that this mode is much smaller than the other modes as given by so we can neglect the effect of the third mode.

2.3.4 Fourth mode: (*thermal interactions of dynamic or dancing nanoparticles with base fluid molecules*)

Even though the random motion of nanoparticles is zero when time averaged, the vigorous and relentless interactions between liquid molecules and nanoparticles at the molecular and nanoscale level translate into conduction at the macroscopic level, because there is no

Bulk flow. Therefore, we postulate that Brownian motion of nanoparticles in nanofluids produces convection like effects at the nano scale. So, the last mode can be defined by The Brownian motion causes nanoparticle to vary any direction many millions of times per second.

$$q = h(T_{np} - T_{BF})\emptyset = h\delta_T\emptyset\frac{(T_{np} - T_{BF})}{\delta_T} \sim -h\delta_T\emptyset\frac{dT}{dz} \quad (7)$$

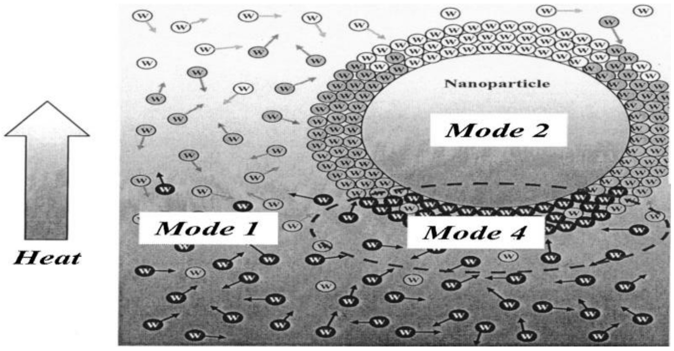


FIG. 8 .Modes of energy transport in nanofluids. The first mode is collision between base fluid molecules; the second mode is the thermal diffusion in nanoparticles suspended in fluids; the third mode is collision between nanoparticles (not shown) and the fourth mode is thermal interactions of dynamic or dancing nanoparticles with base fluid molecules. [12]

2.3.5 THERMAL CONDUCTIVITY OF NANOFLUID:

To predict the thermal conductivity of solid particle suspended in base fluid various theoretical and empirical equations has been given; some of them are tabulated here with considering their basics. [14, 15, 16, 21, 22, 2

Table 1 Theoretical and empirical equations of thermal conductivity of nanofluid.

Sn.	Model	Expression	Remarks
1	Maxwell model	$\frac{k_{nf}}{k_{BF}} = \frac{k_{np} + 2k_{BF} + 2(k_{np} + k_{BF})\emptyset}{k_{np} + 2k_{BF} - (k_{np} - k_{BF})\emptyset}$	**1.** good for spherical shaped particles 2. low particle volume concentrations
2	Bruggemen implicit model	$\emptyset\left(\frac{k_{np} - k_{nf}}{k_{np} + 2k_{nf}}\right) + (1-\emptyset)\left(\frac{k_{BF} - k_{nf}}{k_{BF} + 2k_{nf}}\right) = 0$	1.spherical particles with no limitations on the particle volumetric concentrations
3	Hamilton and Crosser model	$\frac{k_{nf}}{k_{BF}} = \frac{k_{np} + (n-1)k_{BF} - (n-1)(k_{BF} + k_{np})\emptyset}{k_{np} + (n-1)k_{BF} + (k_{BF} + k_{np})\emptyset}$	**1.** micro/millimeter sized particles **2.** based on shape factor(n) of particle
4	Yu and Choi (modified Maxwell model)	$\frac{k_{nf}}{k_{BF}} = \frac{k_{pe} + 2k_{BF} + 2(k_{pe} + k_{BF})(1+\chi)^3\emptyset}{k_{pe} + 2k_{BF} - (k_{pe} - k_{BF})(1+\chi)^3\emptyset}$	1.include the effect of a Nano layer surrounding the particles 2. Based on the effective medium theory
5	Xuan model	$\frac{k_{nf}}{k_{BF}} = \frac{k_{np} + 2k_{BF} - 2(k_{BF} + k_{np})\emptyset}{k_{np} + 2k_{BF} + (k_{BF} + k_{np})\emptyset} + \frac{\rho_{np}\emptyset c_{p_{np}}}{2}\sqrt{\frac{kT}{3\pi\mu_{BF}r_c}}$	1.Brownian motion of nanoparticles 2.aggregation of nanoparticle

6	Koo and Kleinstreuer model	$\frac{k_{nf}}{k_{BF}} = \frac{k_{np} + 2k_{BF} - 2(k_{BF} + k_{np})\emptyset}{k_{np} + 2k_{BF} + (k_{BF} + k_{np})\emptyset} + 5 \times 10^4 \emptyset \beta \rho_{BF} c_{p_{BF}} \sqrt{\frac{kT}{\rho_{np} d_p}} f(T, \emptyset, etc.)$	1.account the effect of particle size, particle volumetric concentration, temperature and properties of base fluid as well as nanoparticles subjected to Brownian motion
7	Chon et al[.15]	$\frac{k_{nf}}{k_{BF}} = 1 + 64.7\emptyset^{0.7460} \left(\frac{d_{BF}}{d_{np}}\right)^{0.3690} \left(\frac{k_{np}}{k_{BF}}\right)^{0.7476} Pr^{0.9955} Re^{1}$	1.experimental data using Buckingham-Pi theorem with a linear regression scheme 2. Brownian motion of the suspended nanoparticle
8	Jang and Choi model[14]	$k_{nf} = k_{BF}(1 - \emptyset) + \beta_1 k_{np} \emptyset + c_1 \frac{d_{BF}}{d_{np}} k_{BF} Re^2{}_{d_{np}} Pr\emptyset$	1. four modes contributing to the energy transfer
9	Prasher et al	$\frac{k_{nf}}{k_{BF}} = (1 + ARe^m pr^{0.333}\emptyset) \left(\frac{[k_{np}(1 + 2\alpha) + 2k_m] + 2\emptyset[k_{...}}{[k_{np}(1 + 2\alpha) + 2k_m] - \emptyset[k_{n...}}\right.$	**1.** introduced a convective–conductive model, 2. convection caused By the Brownian motion of suspended nanoparticles.
10	C.J.Ho et al. [28]	$\frac{k_{nf}}{k_{BF}} = \frac{2 + \left(\frac{k_{np}}{k_{BF}}\right) + 2\emptyset\left[\left(\frac{k_{np}}{k_{BF}}\right) - 1\right]}{2 + \left(\frac{k_{np}}{k_{BF}}\right) - \emptyset\left[\left(\frac{k_{np}}{k_{BF}}\right) - 1\right]}$	**1.** good for spherical shaped particles 2. low particle volume concentrations

III. FACTORS INFLUENCING THERMAL CONDUCTIVITY OF NANOFLUID

Particle volume concentration: as particle volume concentration is increases, thermal conductivity nanofluid also increased up to certain limit. Above this limit conjugate thermal conductivity decreases due to agglomeration of nanoparticle.

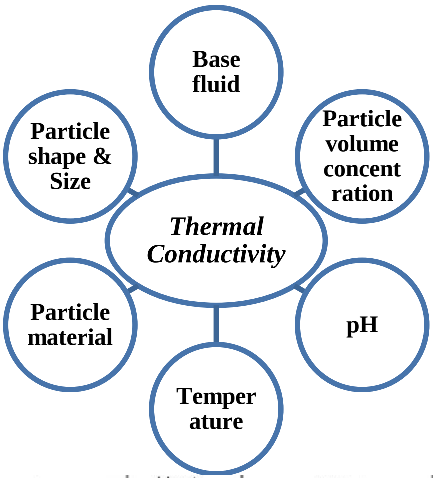
PH: It shows the basicity or acidic value on nanofluid. It mostly effect at the time of preparation of nanoparticle, its limiting value decide the size of nanoparticle as well as its thermal conductive effectiveness of any nanofluid.

Temperature: Das et al [29] measured the thermal conductivity of aqueous nanofluids containing Al2O3 and CuO at temperatures between 20 and 50 ºC. They observed that the thermal conductivity increased as the temperature increased and speculated that this behaviour is typical of nanofluids over greater temperature ranges as well.

*Particle material & base fluid:*Many different particle materials are used for Nanofluid preparation. Al_2O_3, CuO,,SiC, TiC, Ag, Au, Cu, and Fe nanoparticles are frequently used in Nanofluid research. Carbon annotates are also utilized due to their extremely high thermal conductivity. Similar different nanoparticle is use in hobbit as per requirement the thermal conductivity of various metallic. Non-metallic and fluid are represented graphically.common liquids, polymers and solids [3].

Base fluids: mostly used in the preparation of Nanofluids are the common working fluids of heat transfer applications; such as, water, ethylene glycol and engine oil. In order to improve the stability of nanoparticle inside the base fluid, some additives are added to the mixture in small amounts.

*Particle size:*Nanoparticle used in Nanofluid preparation usually is below 100 nm diameter. Particles of diameter 10 nm have been used in Nanofluid research Eastman [11].



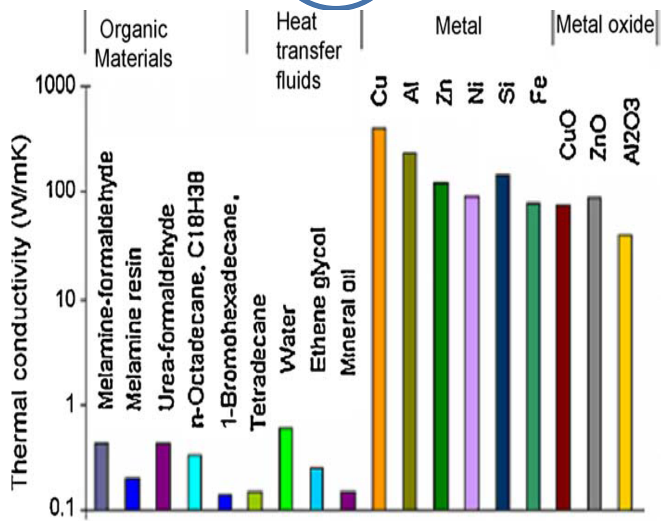


Fig 9:factor effect thermal conductivity of nanofluid.**Fig.10**Comparison of the thermal conductivity of material

When particles are not spherical but rod or tube-shaped, the diameter should be below 100 nm, but the length of the particles may be in the order of micrometres. It should also be noted that due to the clustering phenomenon, particles may form clusters with sizes in the order of micrometres.

*Particle shape:*Spherical particles are mostly used in Nanofluids. However, rod-shaped, tube-shaped and disk-shaped nanoparticle is also used. On the other hand, the clusters formed by nanoparticle may have fractal-like shapes

IV. OTHER THERMO PHYSICAL PROPERTIES OF NANOFLUIDS

It can be estimated by theoretically derived formula:

1. Nano fluid Effective viscosity [38]

$$\mu_{nf} = \mu_{BF}(1 + 2.5\emptyset) \quad (8)$$

2. Nano fluid Effective density [38]

$$\rho_{nf} = (1 - \emptyset)\rho_{BF} + \emptyset\rho_{np} \quad (9)$$

3. Nano fluid Effective specific heat [39]

$$C_{nf} = \frac{(1 - \emptyset)(\rho c)_{BF} + \emptyset(\rho c)_{np}}{\rho_{nf}} \quad (10)$$

V. APPLICATIONS OF NANOFLUIDS

Nanofluids can be used to increase heat transfer and energy effectiveness in a variety of thermal arrangements. Much of the work in the field of nanofluids is being done in national laboratories and university and is at a stage beyond discovery exploration. Recently, the number of companies that see the potential of nanofluid technology and are in active development work for specific industrial applications is increasing. In the transportation industry, GM and Ford, among others, have ongoing nanofluid research projects.

5.1 Transportation:An ethylene glycol and water mixture, the nearly universally used automotive coolant, is a relatively poor heat transfer fluid compared to water alone. Engine oils perform even worse as a heat transfer medium. The addition of nanoparticles to the standard engine coolant has the potential to improve automotive and heavy-duty engine cooling rates. Such improvement can be used to remove engine heat with a reduced-size coolant system. Smaller coolant systems result in smaller and lighter radiators, which in turn benefit almost every aspect of car and truck performance and lead to increased fuel economy.

5.2 Electronic applications:Due to higher density of chips, design of electronic components with more compact makes heat dissipation more difficult. Advanced electronic devices face thermal management challenges from the high level of heat generation and the reduction of available surface area for heat removal. So, the reliable thermal management system is vital for the smooth operation of the advanced electronic devices. In general, there are two approaches to improve the heat removal for electronic equipment. One is to find an optimum geometry of cooling devices; another is to increase the heat transfer capacity. Nanofluids with higher thermal conductivities are predicated convective heat transfer coefficients compared to those of base fluids. Recent researches illustrated that nanofluids could increase the heat transfer coefficient by increasing the thermal conductivity of a coolant.

5.3 Industrial cooling applications:The application of nanofluids in industrial cooling will result in great energy savings and emissions reductions. Experiments were performed using a flow-loop apparatus to explore the performance of polyalphaolefin nanofluids containing exfoliated graphite nanoparticle fibres in cooling. It was observed that the specific heat of nanofluids was found to be 50% higher for nanofluids compared with polyalphaolefin and it increased with temperature.

5.4 Space and defence: Due to the restriction of space, energy and weight in space station and aircraft, there is a strong demand for high efficient cooling system with smaller size. Research of nanofluids will lead to the development of next generation of cooling devices that incorporate nanofluids for ultrahigh-heat-flux electronic systems, presenting the possibility of raising chip power in electronic components or simplifying cooling requirements for space applications.

5.5 Energy applications: For energy applications of nanofluids, two remarkable properties of nanofluids are utilized, one is the higher thermal conductivities of nanofluids, enhancing the heat transfer, and another is the absorption properties of nanofluids.

*5.5.1 Energy storage**:***The temporal difference of energy source and energy needs made necessary the development of storage system. The storage of thermal energy in the form of sensible and latent heat has become an important aspect of energy management with the emphasis on efficient use and conservation of the waste heat and solar energy in industry and buildings. Latent heat storage is one of the most efficient ways of storing thermal energy.

*5.5.2 Solar absorption:*Solar energy is one of the best sources of renewable energy with minimal environmental impact. The conventional direct absorption solar collector is a well-established technology, and it has been proposed for a variety of applications such as water heating; however the efficiency of these collectors is limited by the absorption properties of the working fluid, which is very poor for typical fluids used in solar collectors. Recently this technology has been combined with the emerging technologies of nanofluids and liquid-nanoparticle suspensions to create a new class of nanofluid-based solar collectors.

5.6 Mechanical applications:Nanoparticles in nanofluids form a protective film with low hardness and elastic modulus on the worn surface can be considered as the main reason that some nanofluids exhibit excellent lubricating properties. Magnetic fluids are kinds of special nanofluids. Magnetic liquid rotary seals operate with no maintenance and extremely low leakage in a very wide range of applications, and it utilizing the property magnetic properties of the magnetic nanoparticles in liquid.

5.6.1 Friction reduction: Advanced lubricants can improve productivity through energy saving and reliability of engineered systems. Tribological research heavily emphasizes reducing friction and wear. Nanoparticles have attracted much interest in recent years due to their excellent load-carrying capacity, good extreme pressure and friction reducing properties.

. *5.6.2 Magnetic sealing:*Magnetic fluids are kinds of special nanofluids. They are stable colloidal suspensions of small magnetic particles such as magnetite (Fe3O4). The properties of the magnetic nanoparticles, the magnetic component of magnetic nanofluids, may be tailored by varying their size and adapting their surface coating in order to meet the requirements of colloidal stability of magnetic nanofluids with non-polar and polar carrier liquids

5.7 Biomedical application:For some special kinds of nanoparticles, they have antibacterial activities or drug delivery properties, so the nanofluids containing these nanoparticles will exhibit some relevant properties.

*5.7.1 Antibacterial activity:*Organic antibacterial materials are often less stable particularly at high temperatures or pressures. As a consequence, inorganic materials such as metal and metal oxides have attracted lots of attention over the past decade due to their ability to withstand harsh process conditions. The antibacterial behaviour of ZnO nanofluids shows that the ZnO nanofluids have bacteriostatic activity against.

5.7.2 Nano drug delivery: Over the last few decades, colloidal drug delivery systems have been developed in order to improve the efficiency and the specificity of drug action. The small size customized surface, improved solubility and multi-functionality of nanoparticles open many doors and create new biomedical applications. The novel properties of nanoparticles offer the ability to interact with complex cellular functions in new ways

5.8 Other applications: Cancer Therapeutics. Nano cryosurgery, Sensing and Imaging, Cryopreservation, Nano fluid Detergent. Intensify micro reactors, Nanofluids as vehicular brake fluids; Nanofluids based microbial fuel cell, Nanofluids as optical filters, Refrigeration (domestic refrigerator, chillier).

VI. MICROCHANNEL

6.1 Introduction

Micro-channel heat sinks constitute an innovative cooling technology for the removal of a large amount of heat from a small area. The heat sink is usually made from a high thermal conductivity solid such as silicon or copper with the micro-channels fabricated into its surface by either precision machining or micro-fabrication technology. These micro-channels have characteristic dimensions ranging from 10 to 1000 nm, and serve as flow passages for the cooling liquid. Micro-channel heat sinks combine the attributes of very high surface area to volume ratio, large convective heat transfer coefficient, small mass and volume, and small coolant inventory.

6.2 Background

Tuckerman and Pease (1981) first made use of miniaturization for the purposes of heat removal, within the scope of a Ph.D. study in 1981. Their publication titled "High Performance Heat Sinking for VLSI" is credited as the first study on microchannel heat transfer. Their pioneering work has motivated many researchers to focus on the topic and microchannel flow has been recognized as a high performance heat removal tool ever since. This leads to an increasing demand for highly efficient electronic cooling technologies. To meet this demand, various electronic cooling schemes have been developed. Comprehensive reviews of the

Different heat transfer techniques employed in electronic cooling were provided by Mudawar [32]. In progress of this various design are fabricated and investigate experimentally and numerically to evaluate its performance with or without nanofluid and comparative studies are taken, inconsideration of employ of microchannel in industrial uses.

- Microchannel – experimental & numerical investigation of heat transfer with common fluids.
- Microchannel- experimental & numerical investigation of heat transfer with nano fluids.

6.2.1 Microchannel – experimental & numerical investigation of heat transfer with common fluids.

*X.F. Peng et al [30]*had investigated experimentally the single-phase forced convectiveheat transfer characteristics of water/methanol flowing through micro-channels with rectangular cross section of five different combinations, maximum and minimum channel size varying from (0.6 × 0.7 mm2) to (0.2 × 0.7 mm2). The results provide significant data and considerable insight into the behaviour of the forced-flow convection in micro-channels

Peng& Peterson [31] had also investigated experimentally the single-phase forcedconvective heat transfer micro channel structures with small rectangular channels having hydraulic diameters of 0.133–0.367 mm and distinct geometric configurations. The results indicate that geometric configuration had a significant effect on single-phase convective heat transfer and flow characteristics. The laminar heat transfer found to be dependent upon the aspect ratio i.e. the ratio of hydraulic diameter to the centre to centre distance of micro channels. The turbulent flow resistance was usually smaller than predicted by classical relationships

WeilinQu, IssamMudawar [32] have performed experimental and numerical investigations ofpressure drop and heat transfer characteristics of single-phase laminar flow in 231 $\mu m$by 713 μmchannels. Deionized water was employed as the cooling liquid and two heat flux levels, 100 W/cm2 and 200 W/cm2, defined relative to the platform area of the heat sink, were tested. Good agreement was found between the measurements and numerical predictions, validating the use of conventional Navier–Stokes equations for micro channels. For the channel bottom wall, much higher heat flux and Nusselt number values are encountered near the channel inlet.

WeilinQu, IssamMudawar [33] conducted a three-dimensional fluid flow and heat transfer analysis for a rectangular micro channel heat sink using a numerical method similar to that proposed by both Kawano et al. (1998) , and Fedorov and Viskanta. (2000) This model considered the hydrodynamic and thermal developing flow along the channel and found that the Reynolds number would influence the length of the developing flow region. It was also found that the highest temperature is typically encountered at the heated base surface of the heat sink immediately adjacent to the channel outlet and that the temperature rise along the flow direction in the solid and fluid regions can both be approximated as linear

*H.Y. Wu, P. Cheng [34]*an experimental investigation has been performed on the laminar convective heat transfer and pressure drop of water in silicon microchannel. It is found that the values of Nusselt number depend greatly on different geometric parameters. The experimental results also show that the Nusselt number increases almost linearly with the Reynolds number at low Reynolds numbers (Re < 100), but increases slowly at a Reynolds number greater than 100. Finally, an evaluation of heat flux per pumping power and per temperature difference is given for the microchannel used in this experiment.

J. D. Mlcak [35] Heat transfer and laminar fluid flow in a parallel microchannel etched on a silicon substrate with water as the circulating fluid was studied numerically. The fluid region consisted of a microchannel with a hydraulic diameter of 85.6 µm and aspect ratios ranging from 0.10 to 1.0. A constant heat flux of 90 W/cm^2 was applied to the y = H face of the computational domain, which simulates thermal energy generation from an integrated circuit. Generalized transport equations were discretized and solved in three dimensions for velocities, pressure, and temperature. Apparent friction coefficients were found to increase linearly with Reynolds number. Inlet and outlet thermal resistance values monotonically decreased with increasing Reynolds number and increased with aspect ratio

L. Chai et al. [36] the heat transfer enhancement of microchannel heat sinks with periodic expansion–constriction cross sections is investigated both experimentally and numerically. Each heat sink consists of 10 parallel microchannels with 0.1 mm wide and 0.2 mm deep in constant cross-section segment and each microchannel consists of an array of periodic expansion–constriction cross-sections. Three-dimensional laminar numerical simulations, based on the Navier–Stokes equations and energy equation, are obtained for pressure drop and heat transfer in these microchannel heat sinks under the same experimental conditions. Multi-channel effect, entrance effect, conjugate heat transfer, viscous heating and temperature dependent properties are considered. It is found that the numerical predictions of apparent friction factor and Nusselt number are in good agreement with experimental data. The influences of periodic expansion–constriction cross sections on pressure drop, heat transfer and thermal resistance are discussed, respectively. The effects of the entrance and exit plenum regions and the lateral parts of silicon wafer on fluid flow and heat transfer are discussed. Special attentions are given to analyse the variation of thermal resistance for each term with pumping power, corresponding to three stages of heat release at the substrate of heat sink.

Table 2:Summary of microchannel dimension of various experimental and numerical studies

Investigator	microchannel				Wall		plate		fluid
	shape	width	depth	length	width	material	width	length	
X.F. Peng et al [30]	rectangular	0.6/0.2/0.2 mm	0.7 mm	45 mm	3/3.4/2/3.8/2.4 mm	Stainless steel	18 mm	45 mm	methanol
Peng& Peterson [31]	rectangular	0.1 to 0.4 mm	0.2 to 0.3 mm	45 mm	2.1 to 4.1 mm	Stainless steel	18 mm	45 mm	water
WeilinQu, IssamMudawar [32]	rectangular	231 µm	713 µm	44.8 mm	236 µm	copper	10mm	44.8 mm	Deionised water
WeilinQu, IssamMudawar [33]	rectangular	57 µm	180 µm	10mm	43 µm	Silicon wafer	-	10mm	water
H.Y. Wu, P. Cheng [34]	trapezoidal	61.62 to 1375.86 µm	56.22 to 110.7 µm	-	-	Silicon/sio_2	-	-	Deionised water
J. D. Mlcak [35]	rectangular	47.6 to 86.6 µm	86.6 to 476 µm	-	-	Silicon	-	-	water
L. Chai et al. [36]	Expansion-constructioncross section	0.1 mm	0.2 mm	20 mm	3.5 mm	silicon	10 mm	20 mm	Deionised water
ReiyuCheinand Jason Chuang [37]	trapezoidal	500 µm(top) 358.39 µm(bottom)	100 µm	4 inch	500 µm	Silicon wafer	-	4 inch	CuO-water nanofluid
Jaeseon Lee, IssamMudawar [38]	rectangular	215 µm	821 µm	4.48 cm	-	Oxygen free copper	1 cm	4.48 cm	*Al_2O_3-water and HFE-7100 base* nanofluid
D. *Lelea [39]*	square	50 µm	50 µm	4.48 cm	36 µm	-	1 cm	4.48 cm	*Al_2O_3 water* nanofluid
C.J.Ho et al. [28]	rectangular	238 µm	800 µm	50 µm	300 µm	copper	-	50 µm	*Al_2O_3 water* nanofluid
Tu-Chieh Hung et al. [40]	rectangular	44 ,45,50 µm	320,287,302 µm	-	56,55,20 µm	silicon	-	-	*Al_2O_3/ Diamond/ CuO/TiO_2 /Cu/Ag and water* nanofluid
DorinLelea&IoanLaza [41]	Micro tube	Dia. 900 µm	150 µm	1 mm	-	Silicon	-	-	*Al_2O_3-water* nanofluid

6.2.2 Microchannel- experimental & numerical investigation of heat transfer with nano fluids.

C.J.Ho et al. [28] this paper is based on Experiments investigation of Al_2O_3/water nanofluid with copper microchannel heat sink for forced convection cooling. This MCHS is built with 25 parallel rectangular micro channels of length 50 mm having c/s 283 x 800 in width and height for each microchannel. Results show that the nano fluid cooled heat sink gives better performance than pure water and also having significantly higher average heat transfer coefficient. This cause markedly lower wall temperature thermal resistance and wall temperature at high pumping power for designed microchannel.

*ReiyuCheinand Jason Chuang [37]*in this paper, a silicon microchannel heat sink (MCHS) are analysed using nanofluids as coolants. This microchannel was made of silicon and fluid mixture $CuO–H_2O$ without a dispersion agent was used as the coolant medium. In this particle volume fraction is taken in the range of 0.2 to 0.4%. It concludes that nanofluid-cooled Micro Channel Heat exchangers could engross more energy than water-cooled Micro Channel Heat exchangers when the rate of flow of fluid was low. If the flow rate is made to high, the heat transfer was influenced by the volume flow rate but absorption is not effected by nanoparticles volume flow rate. It was found as the bulk temperature of nanofluid is increased; it could prevent the particles from being a larger one and form particle clusters. This study also state that the pressure is slight rise in nanofluid flow.

*Jaeseon Lee, IssamMudawar [38]*this study is an assessment of the effectiveness of Al2O3 nanoparticles at enhancing heat transfer in micro-channel heat sinks with consideration as single-phase and two-phase. This study does demonstrate the effectiveness of nanoparticles at enhancing the single-phase heat transfer coefficient by increasing the nanofluids thermal conductivity, it also shows only a miniscule enhancement in cooling effectiveness compared to the pure fluid, and reveals several important disadvantages.

D. *Lelea [39]*this paper present the numerical modelling of the heat transfer and fluid flow in rectangular microchannel with taking nanofluid (Al_2O_3/water) as working fluid medium. Here in this study laminar flow regime was reflected along with viscous indulgence. The MCHS with hydraulic diameter (D_h) 50μm is considered and heat flux was fixed to 35 W/m2 with different cases like heating and cooling. The Nanofluid of mixture Al_2O_3 and water was analyzed with numerous volume concentrations of between 1—9% and three diameters of the particle d_p= 13, 28 and 47 nm.

*Tu-Chieh Hung et al. [40]*this paper involve study of Heat transfer enhancement in a three dimensional microchannel heat sink by using nanofluids as a working fluid is investigated by a numerical study. This investigation suggests the heat transfer enhancement can be obtained by use of Al2O3–water nanofluid. The result concludes that thermal resistance first decreases and then increases with increase of particle volume fraction. So to get a best performance, have to adjust the volume fraction and pumping power with the geometrical condition.

*DorinLelea&IoanLaza [41]*the numerical simulations are made for nanofluid heat transfer and fluid flow in micro-heat sink with straight micro tubes and multiple tangential inlet jets. The Al2O3 water based nanofluid was used in simulations. The heat flux spread through the bottom surface of the heat sink was q = 50 W/cm^2. Re from 15 to 100 was considered to simulate the laminar fluid flow. It is observed that the conclusions are strongly dependent on the analysis constraint. Moreover the surface temperature difference is not very much improved by using the nano fluid

Table 3: Summary of experimental and numerical studies on thermal conductivity of Nanofluids

Investigator	Particles type	Size (nm)	Fluids	Observations
Xie et al. [12]	Al_2O_3	12.2–302	water, EG, PO	pH value, SSA, crystalline phase
Li and Peterson [16]	Al_2O_3/CuO	36/29	water	enhancement with volume fraction and temperature
Ravikanth S. Vajjha, Debendra K. Das [21]	Al_2O_3/CuO	52,29,77	water, EG	Increase in thermal conductivity of nanofluid with volume concentration and temperature
Das et al. [24]	Al_2O_3/CuO	38.4/28.6	water	2–4 fold increase over range of 21 ∘C to 52∘C
ReiyuCheinand Jason Chuang[37]	Cuo	LxW =80x20 (nanorod)	water	Absorb more heat than pure fluid, low increase in pressure drop.
Lee and Mudwar [38]	Al_2O_3	24.4,38.4/18. 6,23.6	water, HFE 7100 base	20% improvement for 4 vol% Cuo/EG mixture
D. Lelea [39]	Al_2O_3	13,28,47	water	Heat transfer is higher in heating than cooling for low pumping power
C.J.Ho et al. [28]	Al_2O_3	-	water	5.4 % improvement for 2 vol% Al_2O_3 /watermixture
Tu-Chieh Hung et al. [40]	Al_2O_3/ Diamond/ CuO/TiO_2 /Cu/Ag	38	water	251.6% better heat transfer than base fluid
DorinLelea&IoanLaza [41]	Al_2O_3	13 , 28, 36, 47	water	For swirl flow thermal conductivity and viscosity is higher but specific heat is lower than base fluid

VII. OUTLOOK

A recent work reported a preparation technique of nanofluid in which it is found that two step approaches is best suited for preparation of nanofluid, because its better disperse possibility.The effective thermal conductivity of nanofluids can be adjustedby proper control of the particle shape and size, particle volume concentration, PH valueand nano material properties and differentnanoparticle structures. Such a novel finding supports theparticle aggregation and structure theory for effective thermalconductivity and opens a new window for engineering uniquenanofluid properties for different applications. The influence of particle structure on other effectiveproperties, viscosity andspecific heat, need to be assessed carefully. The gain from thermalconductivity could be offset by the viscosity and specificheat effects. Other areas of future research should pay moreattention.

7.1 Future Scope

In this section we highlight some future directions in each of these challenging areas.

- Investigation of the effects of different nanoparticles, volume fraction and particle size on the heat transfer performance of MCHS is required.
- Development of theoretical equations for thermo physical properties of nanofluids is the grey area to be explored
- Experimental study can be performed for the analysis of heat transfer in microchannel.
- The effect of nanoparticles size on heat transfer and friction characteristics of nanofluids can be taken up for investigation.

VIII. RESULT AND CONCLUSIONS

The above review of both nanofluid and microchannel and combined study of heat transfer in microchannel with base fluid and nanofluid conclude that are shown in table.

Nanofluids provide an auspicious technical selection for enhancing heat transfer. Revolutionary nanofluids research has encouraged physicists, chemists, and engineers around the world. These characteristic features of nanofluids make them appropriate for the next generation of flow and heat-transfer fluids.By using the information of making nano-

Table: 4 comparisons of criteria between conventional and nanofluid

Criteria	**Convectional (like as micro fluid)**	**Nanofluids**
Stability	Settle	Stable
Surface/volume ratio	Low	High
Thermal conductivity	Low	High
Clogging	High	Low
Pumping power	Large	Small

Fluid and weget from literature review we are going to design anddevelop a Heat Exchanger by using nanofluids. Weare also using design software to design heatexchanger.

Nomenclature

A	channel flow area, $(m2^{)}$
C_p	specific heat at constant pressure, (J/kg K)
C_v	specific heat at constant volume, (J/kg K)
$\widetilde{C_p}$	Heat capacity per unit volume
$\bar{C}$	Mean speed, (m/s)
C_{np}	Characteristics length of nano particle
D_h	hydraulic diameter, (μm)
F	friction factor
h	heat transfer coefficient , (W/m^2K)
H	height, (μm)
k	thermal conductivity, (W/mK)
Kept	equivalent thermal conductivity of particle
L	length, (mm)
Nu	Nusselt number
n	exponential shape factor
P	channel wet perimeter, (μm)
P_{in}	inlet pressure, (Pa)
Pr	Prandlt number
q	Net heat flux at wall, $(W/m^2$
r_c	mean radius of gyration
Re	Reynolds number
S	distance between two microchannels, (μm)
T	temperature, (K)
x, y, z	spatial (Cartesian) coordinates
u, v, w	velocity components in x,y,z coordinates respectively (m/s)
$\vec{v}$	Mean speed of electron or phonon

Greek symbols

α	thermal diffusivity, (m^2/s)
Ø	(%) particle's volume fraction
μ	Viscosity, (Pa-s)
ρ	density , $(kg/m^3$
β	fraction of liquid volume
λ	mean free path
σ_T	thickness of thermal boundary layer
$\chi = t/r$	(ratio of nano layer thickness and particle radius)
β_1	constant consider Kapitza resistance
C_1	proportionality constant

Subscripts

ch	channel
bf	base fluid
nf	nanofluid
i	inlet
O	outlet
w	wall
p	particle
np	nanoparticle

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