ANALYSIS OF ENTROPY GENERATION IN MICRO-MINI CHANNEL OPERATED WITH NANOFLUIDS FOR TURBULENT FLOW

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RESEARCH REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ENGINEEERING

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ORIGINAL LITERARY WORK DECLARATION

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ABSTRACT

With the advancement of nanotechnology, thermal science and thermal engineering, it is a high interest to develop the new generation of heat transfer fluids called nanofluid. Nanofluid as a new kind engineering material consisting of nanometer-sized additives and base fluids, offered compactness and high surface to volume ratio compared with conventional flow system. It has attracted great attention of researcher for its superior thermal properties and many potential applications. The superior thermal properties of nanofluids is the advantage to improve the thermal properties of base fluids used in many diverse industries including chemical engineering, electronics, transportation, microelectronics, aerospace and manufacturing.

Second law of thermodynamic states that processes occur in a certain direction. During the energy convert from one form to another form, there is often degradation of the supplied energy into a less useful form. Entropy is refer to the less useful form of energy. The entropy generation or another term is irreversibility caused by factors friction, mixing of two fluids, unrestrained expansion, heat transfer across a finite temperature difference, electric resistance, inelastic deformation of solids and chemical reaction.

Overview of the thesis is the analysis of entropy generation ratio and entropy generated by nanofluids caused by heat transfer and fluid friction flow in constant diameter of circular tube channel. The analysis conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-EG and Al_2O_3-EG. Also the analysis conducted under the influences of diameter size of circular tube channel. Entropy generation ratio decrease with increasing volume fraction nano particles in base fluids. Entropy generation ratio is decrease due to thermo-physical properties of nanofluids such as thermal conductivity, viscosity and density increase as volume fraction nano particles

increase in base fluids. Entropy generation rate by heat transfer and fluid friction of nanofluids decrease as the volume fraction nano particles in the base fluids increase and decrease as the circular micro-mini channel diameter increase. Nano particles copper and alumina both effective according to the suitability with the thermo physical properties and size diameter of tube channels. Journal on the entropy generation due to heat transfer and flow have the findings which supported the thesis.

However further research is required for better understanding of nanofluids. The thermo physical properties of nanofluids can be a function of parameters such as particle shape, particle agglomeration and particle polydispersity.In order to clarify these variables, a number of experiments will be necessary to be conducted. Due to the limitations of production preparation of nanofluids is a challenge to enhance the knowledge about nanofluids.

ABSTRAK

Dengan perkembangan yang maju di dalam bidang nanoteknologi , bidang sains haba dan kejuruteraan haba, menggalakan minat yang dalam kajian pembentukan bahan generasi baru bendalir pemindahan haba yang digelar "Bendalir bersaiz Nano". "Bendalir bersaiz Nano" adalah bahan baru di dalam kejuruteraan mengandungi bahan penambah dengan skala dan saiz nano-meter dan bendalir asas menyediakan ketahanan dan permukaan yang luas dibandingkan nisbah dengan sistem aliran yang konvesional. Ini menarik perhantian yang besar pengkaji di atas sifat haba yang baik dan lain lain potensi applikasi. Teknologi applikasi akan memenuhi permintaan yang tinggi di dalam pelbagai bidang industri seperti kejuruteraan kimia, elektronik, pengangkutan, mikroelektroniks, angkasawan dan pembuatan.

Hukum tenaga termodinamik yang kedua menyatakan semua proses yang berlaku mempunyai arah tujuan. Semasa tenaga di tukar daripada satu kelas ke kelas yang lain, selalu berlaku pengurangan di dalam tenaga kepada penghasilan nilai tenaga yang tidak dapat digunakan. Entropi dirujuk kepada penghasilan tenaga yang tidak dapat digunakan. Penghasilan entropi atau ketidak boleh balikkan proses disebabkan oleh faktor faktor seperti geseran bendalir, pengembangan tidak sekata dan pemindahan haba merentasi perbezaan suhu yang sekata, rintangan elektrik, pembentukan semula yang tidak elastik pada bahan solid dan reaksi kimia.

Keseluruhan tesis adalah berkaitan mengenai analisis tentang nisbah penghasilan tenaga yang tidak dapat digunakan dan penghasilan oleh faktor pemindahan haba dan geseran bendalir di dalam tiub diameter geometri bulat yang tetap. Analisa juga dilakukan di bawah pelbagai kuantiti bahan bersaiz nano menghasilkan Cu-H_2O, Al_2O_3-H_2O, Cu-EG dan Al_2O_3-EG. Analisa juga dilakukan di bawah pelbagai saiz diameter tiub bergeometri bulat yang tetap. Nisbah penghasilan tenaga yang tidak dapat digunakan berkurang disebabkan oleh

peningkatan sifat-sifat termo fizikal seperti pengaliran haba, kelikatan dan ketumpatan dengan penambahan bahan bersaiz nano di dalam bendalir asas. Penghasilan tenaga yang tidak dapat digunakan disebabkan oleh pemindahan haba dan geseran bendalir berkurang dengan penambahan bahan bersaiz nano di dalam bendalir asas. Juga apabila saiz diameter tiub mikro-mini bergeometri bulat bertambah. Kedua dua bahan bersaiz nano kuprum dan alumina adalah berkesan bergantung kepada kesesuaian sifat-sifat termo fizikal dan saiz diameter tiub. Jurnal berkaitan penghasilan tenaga yang tidak dapat digunakan disebabkan oleh pemindahan haba dan geseran bendalir mempunyai pendapat berdasarkan keputusan-keputusan yang menyokong tesis ini.

Walau bagaimanapun kajian dikehendaki untuk pemahaman yang lebih baik mengenai bahan bersaiz nano ini. Sifat-sifat termo fizikal boleh dikaji sebagai bahan kajian lebih mendalam untuk menggambarkan pembentukan , penggabungan dan pembubaran.Oleh sebab itu banyak ujikaji bahan yang perlu dilakukan. Dengan kekurangan pendedahan mengenai penyediakan bahan bendalir ini adalah cabaran untuk pengkaji mendalami ilmu ini.

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CHAPTER 4.0 : RESULT AND DISCUSSION

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LIST OF SYMBOLS AND ABBREVIATIONS

Nomenclature

BF Base fluid

C_k Thermal conductivity coefficient

$C\mu$ Viscosity coefficient

C_p Specific heat, J/kg K

D *D*iameter of tube, m

f Friction factor

k Thermal conductivity, W/m K

ṁ Mass flow rate, kg/s

NFs Nanofluids

NF nanofluids

NP nanoparticles

$\dot{S}'_{gen}$ Entropy generation per unit length, W/m K

q'' Heat flux per unit length, W/m

Greek symbols

ρ Density

φ Volume fraction

μ Viscosity

CHAPTER 1.0-INTRODUCTION

1.1 OVERVIEW

Overview of the thesis is the analysis of entropy generation ratio and entropy generated by nanofluids caused by heat transfer and fluid friction flow in turbulent flow regime in constant diameter of circular tube channel. The analysis conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-EG and Al_2O_3-EG. Also the analysis conducted under the influences of diameter size of circular tube channel. Both results of entropy was calculated used theoretical Bejan's equation.

1.2 BACKGROUND OF STUDY

Nanofluids with the superior thermal properties fluids is highly demand in industrial, civil application, electronic cooling, transportation, energy and air-conditioning system. Tradition fluid such as water, oil and glycol has poor thermal performance due to their low thermal conductivities. Research and development has been carried out to improve the thermal performance of fluid. Solid metallic materials and non-metallic materials have much higher thermal conductivity than base fluid. Nanofluids is form by the suspension of nano-sized particle smaller than 100 nm in the base fluid. Nanofluids are attracting a great intension with their vast potential to provide enhanced performance properties, especially with the respect to heat transfer (Choi, et al., 1995).

Second laws of thermodynamics stated that energy transformation direction is moving from high quality energy to low quality energy. Quality of energy during a process was measured by the quantitative measurement exergy, potential work and entropy generation, non-potential work affect towards the performance of engineering system. Focusing towards the entropy generation rates to measure the irreversibility's such as friction, mixing, chemical reaction, heat transfer through a finite temperature difference in a system (Socolow,1975) and (Bejan,1980). Researchers have carried out the irreversibility analysis of different systems and have showed that irreversibility or entropy generation analysis is a powerful tool to decide which installation or process is efficient (Cengal,et al.,2006). Analysis is focus on the irreversibility or entropy generation nanofluids flow in micro and mini circular tube channel in turbulent flow regime.

Nanofluids possess the following advantages compared to conventional solid–liquid suspensions for heat transfer intensifications such as high specific surface area promote more heat transfer surface between particles and fluids, high dispersion stability with predominant Brownian motion of particles, reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification, reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization, adjustable properties, including thermal conductivity and surface wet ability and by varying particle concentrations to suit different applications (Choi,et al.,1995).

Improvement of this thesis analysis of entropy generation in the nanofluids flow in the complex geometry. The comprehensive study and details contributes to the improvement of engineering devices of specific application areas such as engine cooling, engine transmission oil, diesel electric generator ,boiler exhaust flue gas recovery, heating, cooling of buildings, cooling of electronics, cooling of welding, nanofluids in transformer cooling oil, nuclear systems cooling, solar water heating, nanofluids in drilling and refrigeration (domestic refrigerator, chillers) (Choi,et al., 1995).

1.3 PROBLEM STATEMENT

Due to rapid development of modern technology , equipments used in the industry such cooling of electronics, chillers, domestic refrigerators, engine cooling, vehicle thermal management, diesel combustion, solar water heating etc generates huge amount of heat. Therefore cooling agent is needed to remove the heat. Nanofluids is the potential cooling agent with various advantages. It is better medium for large heat transfer, ideal conducting fluids medium where high heat loads are encountered, prevent clogging and practical in miniaturized systems.

1.4 OBJECTIVES OF STUDY

The analysis conducted under two analysis conditions with nanofluids flow inside constant circular tube channel with turbulent regime. First condition is conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-EG and Al_2O_3-EG. Second condition is conducted under the influences of diameter size of constant circular tube channel. Objectives of the thesis under two analysis conditions are : -

(a) To determine and analyze the minimum entropy generation ratio.

(b) To determine and analyze the minimum entropy generation generated caused by heat transfer and fluid friction.

1.5 SCOPE AND LIMITATION OF STUDY

The scope of study is analysis of entropy generation ratio and entropy generated by nanofluids caused by heat transfer and fluid friction flow in turbulent flow regime in constant diameter of circular tube channel. Circular tube channel with diameter size

20μm,40 μm and 60 μm call as micro channel and circular tube channel with diameter size 200μm,400 μm and 600 μm call as mini channel.

The analysis conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-EG and Al_2O_3-EG. Also the analysis conducted under the influences of diameter size of circular tube channel. Both results of entropy was calculated used theoretical Bejan's equation.

heat away.

Limitation of this study are long time taken to stabilize the nanoparticles dispersion, addition of excess surfactant has a harmful effect on nanofluid thermophysical properties and higher cost production. Nanofluids form aggregates due to very strong van der Waals connection in long time period and surfactant need to be add to reduce the formation of aggregates. But addition of excess surfactant has a harmful effect on nanofluid thermophysical properties (NETL,2009). Nanofluids is produced by either a single step that simultaneously makes and disperses the nano particles into base fluids or a two-step approach that involves generating nano particles and subsequently dispersing them into base fluid. Both process preparation required highly cost, advance and sophisticated equipments .

Future researcher need to enhance knowledge on nanofluid parameters such particle shape, particle agglomeration, particle polydispersity etc. Experimental activities should be carried out to understand nanofluid parameters behaviour to improve the limitations on the nanofluids production preparation (Sarit ,2006).

1.6 ORGANISATION OF REPORT

The thesis consists of five sections as below

Chapter one introduces the overview, background, problem statement, objectives, scope, limitations and organisation of the thesis topic.

Chapter two addresses literature review which compiles the methods, enhancement, experimental data, results and discussion on the entropy generated by heat transfer and fluid friction in turbulent flow . The journals related to the entropy generation due to convective, natural and mixed convection heat transfer and flow features in different type of geometry such as square, two concentric pipes and vertical square channel also presented.

Chapter three addresses the methodology to determine the objectives of the thesis. The contents are input data for micro-mini channel, table for material properties, table for material constant, mathematical equations entropy generation ratio and mathematical equations for entropy generated by heat transfer and fluid friction.

Chapter four addresses all the results and analysis of entropy generation ratio, entropy generated by heat transfer and fluid friction in micro-mini channel operated with nanofluids for turbulent flow under. The analysis conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-EG and Al_2O_3-EG. Also the analysis conducted under the influences of diameter size of circular tube channel.

Chapter five is a conclusion to achieve the objectives of the thesis and recommendation for future enhancement. Comparison with other data and validation also being discuss. Future enhancement is research works focusing on the characteristics of production preparation of nanofluids.

CHAPTER 2.0-LITERATURE REVIEW

2.1 NANOFLUIDS

Nanofluids are relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100nm) provided excellent examples of nanometer in comparison with millimeter and micrometer suspended in the base fluid within them (Serrano,et al.,2009). Two types of liquids are metallic liquids and nonmetallic liquids. Example of metallic liquid is sodium and nonmetallic liquids are water (H_2O), ethylene glycol (EG) and engine oil(EO) (Xiang,et al., 2007). Two types of solids are metallic solid and nonmetallic solids. Example of metallic solids are copper (Cu) and aluminum (Al). Example of nonmetallic solids are silicon(Si) and alumina(Al_2O3) (Xiang,et al., 2007).Nanoparticles of metallic solid type copper was dispersed in water form nanofluid Cu-H_2O and nonmetallic solid type alumina was dispersed in water form nanofluid Al_2O3-H_2O. Nanoparticles of metallic solid type copper was dispersed in ethylene glycol form nanofluid Cu-Eg and nonmetallic solid type alumina was dispersed in ethylene glycol form nanofluid Al_2O3-Eg.

2.1.1 Advantages of nanofluids

The advantages of nanofluids are improved heat transfer and stability, cooling agent without clogging, practical in miniaturized systems and reduction in pumping power. Nanofluids have good heat transfer characteristics caused by size nano particles finer than size 20 nm that will carry 20% of their atoms on their surface. The higher quantity atoms on the surface provide more surface for thermal interaction (Choi,et al., 2004). More thermal interaction on the surface means more heat was removed from the system.

It is better medium for large heat transfer, high heat loads and ideal conducting fluids medium. Nanofluids is the best engineering performance cooling without clogging because the ultra-fine size of particles in the tiniest of channels such as micro-mini channels. Sedimentation less occur due to the nano particles are small and gravity becomes less important cause nanofluids more stable. Nanofluids is practical in miniaturized systems. Miniaturized system enable the smaller and lighter design of heat exchanger systems. This advantage give an option on the current industrial trend toward component and system miniaturization. Reduction in the inventory of heat transfer fluid will result in cost savings (Murshed,et al., 2009). Nanofluids can reduce the pumping power. In order to increase pumping power is to increase the heat transfer of conventional fluids by increasing the thermal conductivity by a factor of three, the heat transfer in the same apparatus was doubled (Choi,et al.,1995). Addition of small volume fraction give the high thermal conductivity of nanofluids translates into higher energy efficiency, better performance, and lower operating costs. Prevention of rapid settling and reduce clogging in the walls of heat transfer devices with better stability of nanofluids. Reduction in energy consumption for pumping heat transfer fluids. Smaller inventories of fluids where nanofluids can be used and thermal systems can be smaller and lighter. In vehicles, smaller components result in better gasoline mileage, fuel savings, lower emissions and cleaner environment (Murshed,et al., 2009)

2.1.2 Application of nanofluids

Nanofluids used in transportation industry, micromechanics, instrumentation, heating, ventilating, air-conditioning systems and medical applications. Nanofluids used in the transportation industry to improve performance of vehicle heat transfer fluids and enhancement in cooling technologies is also desired. Due to current engine coolants, engine oils, automatic transmission fluids, and other synthetic high temperature fluids inherently poor heat transfer capabilities. Since nanofluids which have higher thermal conductivity would give an alternative to lighter engines, for smaller components such as pumps, radiators and other components. Lighter engines use less fuel consumption and more cost saving. In addition burning less fuel will lead to lower emissions and reduce environment pollution. Nanofluids in micromechanics and instrumentation. Since 1960s, miniaturization has been a major trend in science and technology. During operation micro electro mechanical systems (MEMS) generate a lot of heat. Conventional MEMS coolants cannot sustain high load heat because the cooling capability is not enough. Moreover, the large-sized solid particles are not practical in cooling system especially in narrow cooling channels required by MEMS. The nano sized solid particles can flow in micro channels without clogging which be suitable coolants. Enhancement of cooling of MEMS under extreme heat flux conditions. Nanofluids used in heating, ventilating and air-conditioning systems. The innovative concepts are now in consideration where pumping of coolant and refrigeration is distance in location. Nanofluids technology could make the process more energy efficient and cost effective. Nanofluids used in medical applications as magnetic nano particles inside human body fluids. It can be used as delivery vehicles for drugs or radiation providing new cancer treatment techniques by more adhesive to tumor cells than normal cells.

2.2 THERMO PHYSICAL PROPERTIES

Thermal Conductivity

Literature review reported that experimental studies showed increasing the volume fraction of nano particles in base fluids increase the thermal conductivity. The addition quantity of 5% nanoparticles Al_2O_3 and Cu inside water increase the thermal conductivity of nanofluids to 29% and 60% compare to base fluids (Eastman,et al.,1997). The addition quantity of 0.052% nanoparticles Cu inside base fluid HE-200 oil increase the thermal conductivity of nanofluids to 44%. Another literature review showed a moderate enhancement of thermal conductivity for dispersed Al_2O_3 and CuO in water and ethylene glycol (Lee,et al.,1999). For instance, addition of 4.0% volume fraction of nano particle Cu in ethylene glycol a 20% enhancement in the thermal conductivity reported addition of 4.0% nano particles Cu of 50 nm in water significant 17% increase in the thermal conductivity (Wang,et al.,2009*)*. Recently measured the thermal conductivity of nanofluids , disperse Cu with nano particle sized 29 nm in water and Al_2O_3 with nano particle sized 36 nm in water . Thermal conductivity of nanofluids increased by 52% and 22% (Li,et al., 2006).

Viscosity

Literature reviews showed increase volume fraction increase the nano particle–water suspensions increases the viscosity (Wu,et al., 2009*)*. The viscosity increment in nanofluids linearly to the increasing particle concentration in the suspension. (Pantzali,et al.,2009) reported that the substitution of conventional fluids by the substitution of nano particle in base fluids in industrial heat exchangers is needed. The large volumes of nanofluids are necessary and turbulent flow is usually developed. Reported that with increment of volume fraction of nanofluids are limited to less than 0.2% in practical systems the viscosity increased so rapidly (Lee,2009). Although some review articles emphasized the significance of investigating the viscosity of nanofluids (Eastman et al.,1997; Keblinski,et al.,2005; Das,et al.,2006*)*. The thermo physical properties as critical as thermal conductivity in engineering systems that employ fluid flow. Pumping power is proportional to the pressure drop which in turn is related to fluid viscosity. It observed that by adding volume of 5 % of nano particles Al_2O_3 (particle size 28 nm) in base fluids water the nanofluid effective viscosity increased by about 86%. In their case, a mechanical blending technique was used for dispersion of

Al_2O_3 nano particles in distilled water. Observed that 3.5% nano particles Al_2O_3 in base fluid ethylene glycol, EG also resulted in increasing the effective 40% in viscosity. Their results indicate that the viscosity of nanofluids depends on dispersion methods. Also (Pak&Cho,1998) found that at 10 vol% concentration of nano particles, Al_2O_3 (13 nm) in base fluids water the viscosities of nanofluids are several times greater than that of base fluids water (Das,et al.,2003; Putra, et al., 2003) measured the viscosity of Al_2O_3 and Cu water based nanofluids as a function of shear rate and showed Newtonian behavior of the nanofluids for a range of volume percentage between 1% and 4%. Another literature review show addition nanoparticle alumina and copper inside base fluid observed an increase in viscosity (Das,et al.,2003).

Specific Heat

Due to lack of experimental data on their temperature dependence the specific heat of the nanofluids are assumed to be a linear function of volume fraction. With the increasing of the volume fraction the specific heat is decrease (Das,et al.,2008). Literature review reported that addition of copper in ethylene glycol and alumina in ethylene glycol nanofluids exhibit lower specific heat compared to base fluids. An ideal coolant should possess higher value of specific heat which enable the coolant to remove more heat (Namburu,et al., 2009).

Density

There is lack of experimental data to study the relationship between volume fraction and density of the nanofluids. Literature review assumed density linear function of volume fraction. With the increasing of the volume fraction the density is increase (Namburu,et al., 2009).

2.3 LAW OF THERMODYNAMIC

First Law of Thermodynamics and Second Law of Thermodynamics have different expression toward energy principles in terms of direction of energy transformation and quality of energy. First law of thermodynamics explains that energy convert from one form to another and quantity of energy at initial and final stage is same. Quality of energy during a process and energy transformation direction was not described in the First law of thermodynamics.

Second law of thermodynamics stated that energy transformation direction is moving from high quality energy to low quality energy, also quality of energy during a process was measured by the quantitative measurement exergy, potential work and entropy, non potential work. Quality energy during a process and energy transformation direction was described in the Second law of thermodynamics.

The performance of engineering system is degraded due to the irreversibilities. A reversible process defined process between both working systems (thermodynamics system and the surroundings) returned to their initial states at the end of the process without leaving any trace on its surroundings. Reverse of the reversible is irreversibilities. The process which was process between both working systems (thermodynamics system and the surroundings) not returned to their initial states at the end of the process and leaving trace on its surroundings.

2.4 IRREVERSIBILITIES AND ENTROPY GENERATION

There are factors the process become irreversibilities process. The factors are friction, mixing of two fluids, unrestrained expansion, and heat transfer across a finite temperature difference, electric resistance, inelastic deformation of solids and chemical reaction.

The irreversibility factors cause the process not to return to initial states at the end of process since some of the energy is used to overcome energy to oppose the motion to go back to the initial states. Energy cannot be convert into work due to oppose friction forces, which the motion develops at the interface of these two bodies and it, convert into heat. The surface of the interface is in hot. When direction is reversed to the initial position the surface of the interface is not cooled and heat cannot be reversed into work.

Same goes when there is the finite temperature difference, heat transfer move from high to low temperature. In the reverse, the heat transfer will not occur from low to high temperature. Then the system is not reversible process. Irreversibilities magnitudes present during the process are determine. The measurement of it is called as entropy generation which created during the process. Entropy generation in micro-mini channel system nanofluids in turbulent flow in this thesis is focus to irreversibility's factors of friction and heat transfer.

Researchers have carried out the irreversibility analysis of different systems and have showed that irreversibility or entropy generation analysis is a powerful tool to decide which installation or process is efficient (Cengal,et al., 2006). Entropy generation in a system is the measure of entropy created by the irreversibility's such as friction, mixing, chemical reaction, heat transfer through a finite temperature difference and others (Socolow ,1975). In his studies on entropy generation of fundamental convective heat transfer (Bejan ,1979; Bejan ,1982) derived the equations for entropy generation for forced convective heat transfer for various geometries like round tube, boundary layer over a flat plate and single cylinder in cross-flow. Entropy generated due to flow and heat transfer in nanofluids has been studied by (Ratts & Atul ,2004; Pawan et al.,2010). In this paper alumina-water has been used as nanofluids. Since entropy generation is very sensitive to diameter, it has divided into three different tube diameters which are micro channel (0.1mm), mini channel (1mm), conventional channel (10mm).

Furthermore, different regimes are also considered in those tube diameters. Two different models have been used to represent experimental and theoretical values in order to consider the effect of viscosity and conductivity. The alumina-water nanofluids with high viscosity are suitable for use in mini channels and conventional channels with laminar flow and micro channels and mini channels with turbulent flow. From the result we indicate that flow friction irreversibility is more significant at lower tube diameter and at thermal irreversibility is more significant at higher tube diameter. There is an optimum diameter at which the entropy generation rate is minimum for both laminar and turbulent flow for a given nanofluids.

Literature review has investigated on convective heat transfer and flow features of nanofluids. In order to investigate the flow features and convective heat transfer of the nanofluids in a tube, an experimental system was built. The convective heat transfer coefficient and friction factor of sample nanofluids for turbulent flow are being measured. In this paper, the convective heat transfer feature and flow performance of Cu-water nanofluids in a tube have been investigated by experiment. The suspended nano particles have enhanced heat transfer process and the nanofluids has larger heat transfer coefficient than the original base liquid with the same Reynolds number. The heat transfer feature of nanofluids proportionally increases with the volume fraction of nano particles. A new type of the convective heat transfer correlation for nanofluids in a tube has been proposed by considering the micro convection and micro diffusion effects of the suspended nano particles. This correlation will mainly effect the nanofluid heat transfer and can be use to correlate experimental data only. The friction factor for the dilute nanofluids consists of water and Cu nano particles are approximately the same as water. The low volume fraction of nanofluids of the suspended nano particles incurs almost no penalty of pump power. (Yimin,2003)

Literature review has studied the enhancement of heat transfer and entropy generation analysis of nanofluids turbulent convection flow in square section tubes. In this study Al_2O_3-water have been used as nanofluids and develop its turbulent forced convection flow in a square tube, subjected to constant and uniform wall heat flux, is numerically investigated. The mixture is employed to simulate the nanofluids flow and investigation for particles size equal to 38nm has been accomplished. In order to find the optimal working condition for the given geometry under given boundary conditions an entropy generation analysis has been proposed. The evaluation of the entropy generation has been made by using a simple analytical procedure and its results are compared with the numerical calculations, and it shows a very good concurrence. In this study, comparison between resulting Nusselt numbers and experimental correlations is accomplished. Furthermore, the optimal Reynolds number also has been determined in order to minimize entropy generation. The inclusion of nano particles produced a considerable increase of the heat transfer with respect to the base fluid. Heat transfer enhancement increased with the particle volume concentration and it increases together with the wall shear stress values. For the highest Reynolds number, the enhancement was higher for each concentration value. While for entropy generation analysis, it shows that at low Reynolds number value, the entropy generation, due to the irreversibility of heat transfer, dominates, whereas with increasing Reynolds number value and particles concentration, the entropy generation due to friction loss, becomes more important. Thus, the optimal value of Reynolds number decreases as particles concentration increases (Vincenzo Bianco & Oronzio Mancha,2011).

Entropy generation in a variable viscosity fluid flowing between two concentric pipes with a convective cooling at the surface by using second law analysis has been studied by (Tshehla,2011). According to Newton's cooling law, the outer system is assumed to exchange heat with the ambient, and the fluid viscosity model varies as an inverse linear function of temperature. By using the fourth Order Runge-Kutta scheme, the resulting equations and the boundary conditions are solved. In order to obtain expression for volumetric entropy generation numbers, irreversibility distribution ratio and Bejan number on the flow field, numerical expressions for fluid velocity and temperature have been derived and utilized. From the result in this paper it shows that both the fluid velocity and temperature increase with the increasing values of boundary condition, viscosity variation parameter and Brinkman number, *Br* and decreases with increasing values of Biot number, *Bi*. Furthermore, the entropy generation in the flow field will reduce if the boundary condition, viscosity parameter and Brinkman number are decrease.

Literature review has studied the forced convective heat transfer of nanofluids in micro channels. Rectangular micro channels were used to measure convective heat transfer coefficient and friction factor of nanofluids. An integrated system has been used, consisting of a single micro channel on one side, and two localized heaters and five poly silicon temperature sensors along the channel on the other side were fabricated. In order to investigate the effect of the volume fraction of the nano particles to the convective heat transfer and fluid flow in micro channels, alumina (Al_2O_3) with diameter of 170 nm nanofluids with various particle volume fractions were used in experiments. From the experiment we understand that the convective heat transfer coefficient of alumina nanofluids in laminar flow was measured to be increased up to 32% compared to the distilled water at a volume fraction of 1.8 volume percent without major friction loss. In the other hand, in laminar flow regime, the Reynolds number increased together with the Nusselt number measured. Thus, based on thermal conductivity of nanofluids the Nusselt number measured turned out to be less than 0.5 was correlated with Reynolds number and Prandtl number. From the experimental result, an enhancement of the convective heat transfer coefficient of the nanofluids with the base fluid of water and a mixture of water and ethyl glycol at the volume fraction of 1.8 volume percent was obtained without major friction loss (Jung-Yeul & Ho-Young ,2009).

Literature has done a numerical study of entropy generation in vertical square channel packed with saturated porous media and subjected to differentially heated isothermal walls. In this thesis the effect of Reynolds, Darcy and Eckert numbers on entropy generation was investigated. It was found that the entropy generation is proportional with Eckert number but to be inversely proportional with Reynolds and Darcy number. As the Reynolds and Darcy numbers were increasing, the Bejan number decreases. In the other hand, while the Eckert number increases, the irreversibility due to heat transfer increases. From the results in this thesis it shown that the irreversibility due to fluid friction dominates for higher Darcy numbers, but while the Darcy number decreases, the irreversibility dominates due to the heat transfer. For a given Reynolds number, when the Eckert number increased, the irreversibility due to fluid friction also increased (Abdulhassan,2011)

Literature review reported the study of single-phase thermal transport of nanofluids in a minichannel. In this experimental work, alumina-water nanofluids in a circular mini channel with 1.09 diameters have been used. The convection heat transfer coefficients and friction factor have been determine for nanofluids of various volume concentrations up to 5% and has been compared with the base fluid. The Reynolds number from 600 to 4500 has been used, covering three regimes of flow, which are laminar, transition and early developed turbulent flow. In laminar region it was found that the nanofluids exhibit pronounced entrance region behaviors, both hydro dynamically and thermally. Moreover, in laminar region, the convective heat transfer of nanofluids is enhanced with the penalty of increased pressure drop. Both heat transfer and pressure drop increments are proportional with the nano particles volume concentration. Due to the particle-fluid interaction, the critical Reynolds number at which the onset of transition from laminar region to turbulent region occurs is delayed in nanofluids which damp the instabilities in the flow. When the flow regimes becomes fully developed turbulent, the suppression of turbulence is lessening. Same goes with the convective heat transfer of nanofluids degenerate in the transition and the early developed turbulent regions and slowly recovers after the fully developed turbulence. The single-phase pressure drop and heat transfer of nanofluids of established conventional correlations cannot be fully predict, especially in the transition and turbulent regions, although the effective thermo physical properties were taken into consideration. In order to yield enhanced heat transfer performance for engineering application, nanofluids should be used in either the laminar flow or turbulent flow with sufficiently high Reynolds number (Yu,2009).

Another analysis of nanofluids with second law has been conducted. In the literature review it used alumina-water and ethylene glycol-alumina in order to examined the effect of adding nano particles on the entropy generation and nanofluids flow through a circular pipe under uniform wall heat flux thermal boundary condition in both laminar and turbulent regimes. For density and specific heat, approved formulations of mixtures are used. In this research it is found that by adding nano particles, it improves the thermal performance of alumina-water flow with Reynolds number less than 40,000 and ethylene glycol-alumina flow with Reynolds number less than 11.It has confirmed that by adding the nano particles leads to increased entropy generation in the cases that fluid flow pressure (pressure drop irreversibility is dominant). Furthermore for both laminar and turbulent, optimum conditions (based on entropy generation sense) are obtained (Mostafa & Saed ,2011).

A review conducted on entropy generation in natural and mixed convection heat transfer for energy systems. The second law of thermodynamics in enclosures due to buoyancy-induced flow for energy system. It has defines entropy generation minimization. Recent works on entropy generation in buoyancy-induced flows in cavity and channels, and some studies of mixed convection have been summarized in this paper. At different shaped enclosures and duct under buoyancy-induced force a presentation was performed for flow in porous media and viscous fluid filled media. From the reviewed literature, heat transfer and fluid friction in a thermal system with buoyancy force are the main reasons of entropy generation. The analysis of entropy generation is crucial for all thermal systems to reduce energy and control of heat transfer and fluid flows have been observed from the results. Rayleigh number is the most important parameter on entropy generation in natural convection. As the Rayleigh number increase, together the entropy generation also increase due to increasing of heat transfer and fluid friction. Entropy analysis indicates where energy losses high in the physical model or systems. In addition, Darcy number also one of the effective parameter for entropy generation in porous media filled systems. The entropy generation increase as the Darcy number increase. For mixed convection case, the entropy generation decrease as the Richardson number increase due to decreasing of heat transfer. Besides Richardson and Rayleigh number, another effective parameter is Hartmann number. It is effective in magneto hydrodynamics studies with electrically conductive fluids. When Hartmann number increase, it will decrease the flow velocity and the entropy generation is reduced. Besides, the application direction of magnetic force is also important to minimize the entropy generation. While the irreversibility ratio is decrease, the entropy generation is decrease too. Even at constant Rayleigh number, the geometrical shape and aspect ratio of the cavity change the entropy generation. Moreover, the type of fluid with Prandtl number also places important role (Hakan,2011).

Experimental investigation of convective heat transfer coefficient of CNTs nanofluid has been conducted under constant heat flux. In this paper, heat transfer behavior of aqueous suspension of multi-walled carbon nano tubes flowing through a horizontal tube under constant heat flux is being concerned heat transfer coefficient of CNTs nanofluid sin laminar regime has being measured. From the results we know that there are enhancements in convective heat transfer coefficient of nanofluids. Depends on the CNTs concentration and flow condition (Reynolds number), the increment was significant in entrance length. Furthermore, the enhancement in convective heat transfer is a function of axial distance from inlet and decreasing trend. In this thesis, it has concluded that the addition of multi wall carbon nano tubes to water increases the local convective heat transfer coefficient. Thus, the enhancement decrease with developing thermal boundary layer (Rashidi,2011).

Study on flow, thermal, and entropy generation characteristic inside a porous channel with viscous dissipation was conducted. Both analytical and numerical analyses of fully developed forced convection and entropy generation in a fluid-saturated porous medium channel bounded by two parallel plates have been presented in this paper. The Darcy-Brinkman momentum equation has been used to describe the flow in the porous material and differentially heated isothermal walls are selected as thermal boundary conditions. After simplifying and solving the governing differential equations with reasonable approximations, analytical expressions for velocity, temperature, Nusselt number, entropy generation rate and heat transfer irreversibility are obtained. From the results obtained by numerical calculations, it shows a great agreement with analytical results. Conduction like temperature profile is obtained from high Darcy number. In the other hand, for moderate and low Darcy numbers, the fluid inside the channel is heated by viscous dissipation consequently a non-linear distribution in temperature is observed. The cold wall act as an energy sink for all Darcy numbers whereas the hot wall behaves as energy source at small Darcy numbers. Besides, the hot wall acts as a combination of an energy source and energy sink, at moderate Darcy numbers, with the dividing neutral point moving towards the outlet of the channel with increasing Darcy numbers (Shohel mahmud,2005).

The role of entropy generation on thermal management during natural convection in porous square cavities with distributed heat sources was studied. In this study, based on second law of thermodynamics, material processing by thermal convection may be carried out in an energy efficient way. Furthermore, during laminar natural convection the entropy generation in porous square cavities with distributed heat sources has been studied in the current work. Refer to the location of the heat sources on the walls of the cavities, four different configurations of heated cavities are considered. Galerk in finite element method has been used to solve the equations. Finite element basis sets has been used to evaluate the entropy generation terms and based on the functions within adjacent element, the derivatives at particular nodes have been estimated. Thus simulations have been performed for the range of Rayleigh number (10^3-10^6), Darcy number (10^{-6}-10^{-3}) and for various fluids (Prandtl number 0.015,0.7,10 and 1000).An analysis on the effect of Darcy number on entropy generation due to fluid friction, heat transfer based on their local distribution in various cases is presented. From the results it was found that the maximum values if heat transfer are found to occur near the hot-cold junctions while the maximum values of fluid friction are found at various locations on the walls of the cavity depending on the circulation cells in various configurations. Moreover, in the interior regions a significant fluid friction is also being observed due to friction between counter rotating circulation cells. For higher Prandtl number, the dominance of fluid friction is found to be high as well. In the other hand, the entropy generation rate is found to increase together with Darcy number and the average of Bejan number is found to be less than 0.5, indicating the dominance of fluid friction irreversibility at higher Darcy number in all cases for various fluids. In conclusion, the thermal mixing, temperature uniformity has been correlated with average Bejan number and total entropy generation for all distributed heating cases and the thermal management via enhanced thermal mixing versus optimal entropy production for efficient thermal processing of various fluids in porous media have been proposed (Ram Satish,2011).

The study of entropy generation in turbulent natural convection due to internal heat generation has been studied. Numerical predictions of entropy generation in turbulent natural convection due to internal heat generation in a square cavity have been studied in this paper. By solving the entropy generation equation, the results of entropy generation analysis were obtained. In this paper, by improving the thermal lattice-BGK model, the values of temperature and velocity which are inputs of the entropy generation equation were obtained. The analyzed range is from the steady laminar symmetric state to the fully developed turbulent state. Various Rayleigh number, Prandtl numbers and Eckert number for distribution of entropy generation are given. In this study, by using an improved lattice Boltzmann model, the entropy generation in turbulent natural convection due to internal heat generation was calculated numerically. From the result, it was found that when Rayleigh number is less than 10^{10}, the time-volume-averaged Bejan number almost equal to one and then decreases quickly against Rayleigh number increasing. Although the maximum of entropy generation number increases quickly with Rayleigh number, the time-averaged total entropy generation number changes in the opposite trend. Viscous irreversibility begins to dominate heat transfer irreversibility for increasing Rayleigh number. Hence, at small Rayleigh numbers the entropy generation is spread over the whole domain, but is confined to the neighborhood of the boundaries at high Rayleigh numbers. From the results, it shown that the time-averaged total entropy generation number, time-volume-averaged Bejan number, and the maximum of entropy generation number decrease quickly against Prandtl number increasing. Finally, the time-volume average Bejan number decreases quickly as the Eckert number is increasing (Sheng Chen,2009).

The application of nanofluids for heat transfer enhancement of separated flows encountered in a backward facing step. Numerical investigation of heat transfer has been conducted over a backward facing step (BFS) using basefluids. In the base fluid there are different volume fractions of nano particles besides different type of nano particle shave been used. In order to solve the momentum and energy equations, the finite volume technique has been used. Thus the distributions of Nusselt number at the top and bottom walls of the BFS are obtained. In the other hand, for Cu nano particles, at the top and bottom walls there was an enhancement in Nusselt number except in the primary and secondary recirculation zones where insignificant enhancement is registered. It was found that nano particles having thermal conductivity have more enhancements on the Nusselt number especially at the outside circulation zones. Hence, within recirculation zones, nano particle having low thermal conductivity have better enhancement on heat transfer. Finally, the average Nusselt number is increase with the volume fraction of nano particles for the whole range of Reynolds number is known (Abu-Nada ,2008).

Thermal performance of nanofluid flow in micro channels research have been conducted. In this research two effective thermal conductivity models for nanofluids were compared in detail. The new KKL (Koo-Kleinstreuer-Li) model, based on Brownian motion induced micro-mixing, achieved good agreement with the current experiment data sets. In this research, the thermal performance of nanofluid flow in trapezoidal micro channel was analyzed using pure water as well as a nanofluid (CuO-water), with volume fractions of 1% and 4% CuO-particles with diameter 28.6mm,and employing the commercial Navier-Stokes solver CFX-10 (Ansys Inc, Canonsburg, PA) and user-supplied pre- and post- processing software. Finally, from the results it is confirmed that nanofluids do measurably enhance the thermal performance of micro channel mixture flow with a small increase in pumping power. The thermal performance increases together with volume fraction, but pumping power or pressure drop will decrease the beneficial effects. In the future, micro channel heat sinks with nanofluids are expected to be good candidates for cooling devices. (Jie li ,2008).

From all the literature reviews, the objectives of this thesis is close to the present study which provides a theoretical investigation of the entropy generation analysis due to flow and heat transfer in nanofluids. In the journal the most common alumina water nanofluids are considered as the model fluid. Since entropy is sensitive to diameter, three different diameters of tube in their different regimes have been taken. Those are microchannel (0.1 mm), minichannel (1 mm) and conventional channel (10 mm). To consider the effect of conductivity and viscosity, two different models have been used to represent theoretical and experimental values. Findings is to evaluate entropy generation ratio, entropy generation by heat transfer and fluid friction. Other literature reviews compiles the methods, enhancement study, experimental data, results and discussion on the entropy generated by convective heat transfer, natural heat tranfer and mixed heat transfer in turbulent flow in various type of geometry .

CHAPTER 3.0-METHODOLOGY

The methodology of analysis of entropy generation ratio and entropy generated by nanofluids caused by heat transfer and fluid friction flow in turbulent flow regime in constant diameter of circular tube channel was further explain below. The analysis conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-Eg and Al_2O_3-Eg. The volume fraction is the percentage of nanoparticles disperse in base fluids and in this thesis the volume fraction of nanoparticles is 2%,4% and 6% . Also the analysis conducted under the influences of diameter size of circular tube channel. Two types of circular tube channel are micro channel and mini channel. Both results of entropy was calculated used theoretical Bejan's equation.

3.1 INPUT DATA

3.1.1 Micro-mini channel diagram

Figure 3.1 show the micro channel diagram to illustrate the nanofluids flow through a circular micro channel of constant cross section. Circular micro channel with tube diameter sizes of 20µm,40µm and 60µm.

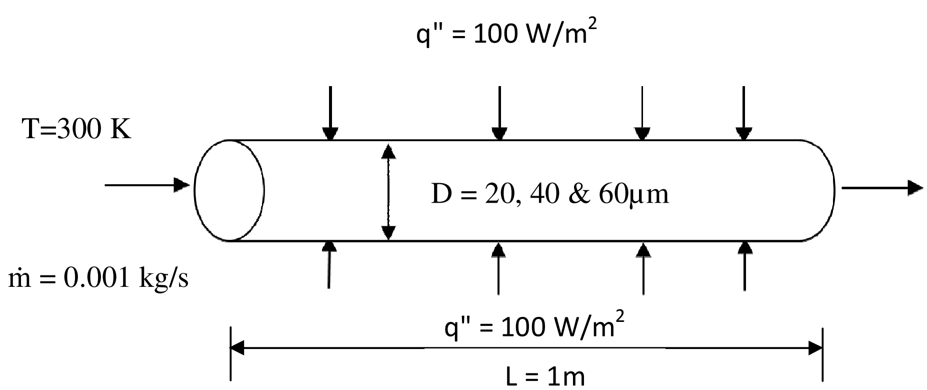

Figure 3.1 - Circular micro channel of constant cross section

Figure 3.2 show the mini channel diagram to illustrate the nanofluids flow through a circular mini channel of constant cross section. Circular mini channel with tube diameter sizes of 200µm,400µm and 600 µm.

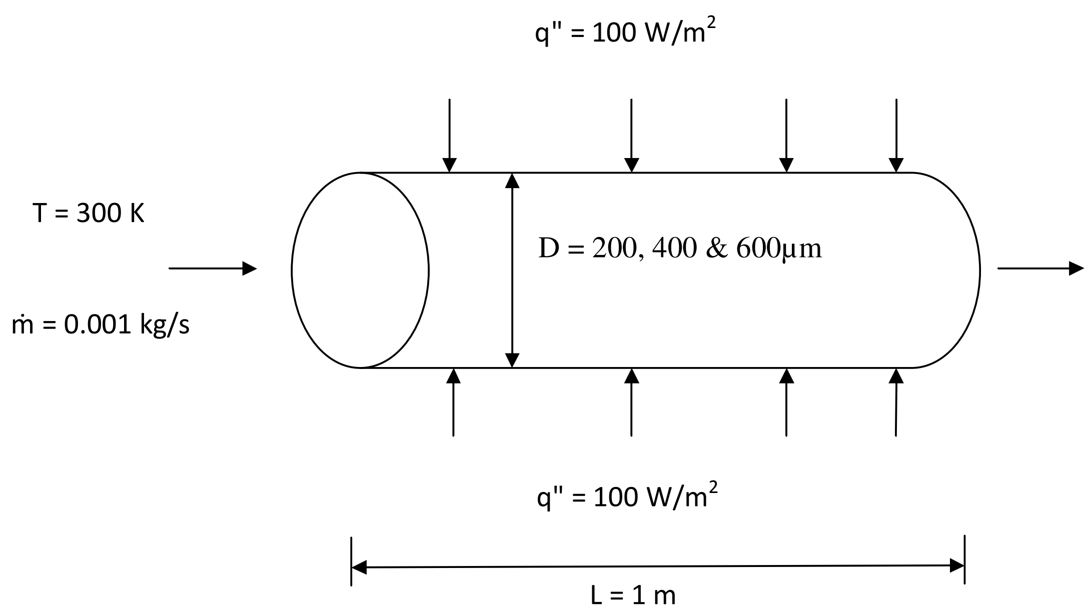

Figure 3.2 - Circular mini channel of constant cross section

3.1.2 Material properties and constant

All constants and general material properties are tabulated in Table 3.1.

Table 3.1 - Material properties and constants considered in analysis.

Parameters	**Values**
Reynold Number (Re)	10 000
Prandtl Number (Pr)	1
Nusselt Number (Nu)	$0.023\ Re^{0.8}\ Pr^{0.4}$
Friction factor (f)	$0.316\ Re^{-0.25}$
T_{in}	300 K
ΔT	5 K

Continue Table 3.1

Mass flow rate	0.001 kg/s
Length of channel	1 m
Heat flux	100 W/m^2
Thermal conductivity coefficient, C_k	2.5
Viscosity coefficient, C_μ	3

The base fluids was analyzed are water and ethylene glycol. The nano particles was analyzed are copper and alumina. Table 3.2 shows the properties of base fluids and nano particles.

Table 3.2 - Properties of base fluids and nano particles.

Properties	**Basefluids**		**Nanoparticles**	
	H_2O	**EG**	**Al_2O_3**	**Cu**
Density, ρ (kg/m^3)	1000	1114.4	3900	8490
Thermal conductivity, k (W/m.K)	613 x 10^{-3}	252 x 10^{-3}	40	401
Viscousity, μ (Ns/m^2)	855 x 10^{-6}	1.57 x 10^{-2}	Not required	Not required
Specific heat, C_p (J/kg.K)	4180	2415	880	385

3.2 MATHEMATICAL EQUATIONS

3.2.1 Thermo physical properties

Thermal Conductivity

Refer to Hamilton–Crosser model itself has provision for taking shape into consideration through this parameter 'n' which takes different values for different shapes (Praveen, et al., 2007). For spherical particles and higher thermal conductivity of particle, the Hamilton–Crosser reduces thermal conductivity by equation. Thermal conductivity of nanofluids is calculated according to the input data required .

$$k_{NF}=k_{BF}(1+C_k\Phi) \quad (1)$$

Where

k_{NF} - Thermal conductivity nanofluid

k_{BF} - Thermal conductivity base fluid

C_k - Thermal conductivity coefficient

Φ - Volume fraction nano particle

Viscosity

Refer to Einstein's for the study of rheological properties of colloids or suspensions for viscosity. Viscosity of nanofluids is calculated according to the input data required (Praveen,et al.,2007).

$$\mu_{NF}=\mu_{BF}(1+C_\mu\Phi) \quad (2)$$

Where

μ_{NF} - Viscosity nanofluid

μ_{BF} - Viscosity base fluid

C_μ- Viscosity coefficient

Density

Density of nanofluids are not much being debated and the behaviour is same way as any other suspension or mixture. Density of nanofluids is calculated according to the input data required (Eastman,et al.,1997).

$$\rho_{NF}=(1 - \Phi)\rho_{BF}+\Phi.\rho_{NP} \quad (3)$$

Where

ρ_{NF} - Density nanofluid

ρ_{BF} - Density base fluid

ρ_{NP} - Density nano particle

Specific Heat

Specific heat of nanofluids are not much being debated and specific heat can be taken on volume fraction or on mass average. Specific heat is taken on the basis of mass average and is calculated according to the input data required (Eastman,et al.,1997).

$$C_{P,NF} = \frac{(1-\Phi)\rho_{BF}.C_{PBF} + \Phi.\rho_{NP}}{\rho_{BF}(1-\Phi) + \rho_{NP}.\Phi} \tag{4}$$

Where

$C_{P,NF}$ - Specific heat nanofluid

$C_{P,BF}$ - Specific heat base fluid

3.2.2 Entropy generation equations

Derivation of entropy generation rate.

Equation (5) is general entropy generation rate (Pawan,et al.,2010).

$$\dot{S}'_{gen} = \frac{q''^2\pi D^2}{kT^2 Nu((Re)_D, Pr)} + \frac{8\dot{m}^3}{\pi^2\rho^2 T}\frac{f((Re)_D)}{D^5} \tag{5}$$

Where

$\dot{S}'_{gen}$- Entropy generation per unit length

q"- Heat flux

π- Pi

D- Diameter

$\dot{m}$ -Mass flow rate

f- Friction factor

Re- Reynold Number

T- Temperature

Nu - Nusselt Number

Pr - Prandtl Number

Equation (7) is entropy generation rate divide by 2 parts. The 2 parts are entropy generation rate contribute by heat transfer and fluid friction.

$$\dot{S}'_{gen} = (\dot{S}'_{gen})_{heat\ transfer} + (\dot{S}'_{gen})_{fluid\ friction} \tag{6}$$

Equation (5) is reduced in terms of C_{1t} and C_{2t} constant.

$$\dot{S}'_{gen} = \mu^{0.25}\left(C_{1t}\frac{\mu^{0.15}}{T^2k^{0.6}C_{p0.4}}\right) + \frac{C_{2t}}{T\rho^2} \tag{7}$$

Where C_{1t} and C_{2t} are constant and defined as

$$C_{1t} = \frac{43.478q''^2\pi D^2}{\left(\frac{4\dot{m}}{\pi D}\right)^{0.8}} \tag{8}$$

$$C_{2t} = \frac{10.112\dot{m}^3}{\pi^2 D^5}\left(\frac{4\dot{m}}{\pi D}\right)^{-1/4} \tag{9}$$

Entropy generation ratio in micro channel for turbulent flow.

Equation (1) can be reduced to compare nanofluids and base fluids. Entropy generation ratio is ratio between entropy generation rate nanofluids and base fluids. Input the Dittus-Boelter and Blausius equations ($Nu = 0.023Re^{0.8}Pr^{0.4}$ and $f + 0.316Re^{-1/4}$) in equation (1) and reduce to the entropy generation ratio in micro channel (11) at turbulent flow equation. Entropy generation ratio in micro channel turbulent flow is calculated according to the input data required (Pawan,et al.,2010).

$$\frac{\dot{S}'_{genNF}}{\dot{S}'_{gen}} = \frac{\mu_{NF}^{0.25}}{\mu^{0.25}}\cdot\frac{\rho^2}{\rho_{NF}^2}\cdot\frac{T}{T_{NF}} \tag{10}$$

if $T=T_{NF}$

$$\frac{\dot{S}'_{genNF}}{\dot{S}'_{gen}} = \frac{\mu_{NF}^{0.25}}{\mu^{0.25}}\cdot\frac{\rho^2}{\rho_{NF}^2} \tag{11}$$

Entropy generation ratio in minichannel for turbulent flow.

Equation (1) can be reduced to compare nanofluids and base fluids. Entropy generation ratio is ratio between entropy generation rate nanofluids and basefluids. Input the Dittus-Boelter and Blausius equations ($Nu = 0.023Re^{0.8}Pr^{0.4}$ and $f + 0.316Re^{-1/4}$) in equation (1) and reduce to the entropy generation ratio mini channel (12) at turbulent flow equation Entropy generation ratio in mini channel turbulent flow is calculated according to the input data required (Pawan,et al.,2010).

$$\frac{\dot{S}'_{genNF}}{\dot{S}'_{gen}} = \frac{\rho^2}{\rho_{NF}^{\ 2}} \cdot \frac{C_P^{\ 0.4}}{C_{PNF}^{\ 0.4}} \cdot \frac{T^2}{T_{NF}^{\ 2}} \text{ x } \frac{(1+0.25C_\mu\Phi-0.6C_k\Phi)(C_{1tNF}\rho_{NF}^{\ 2}+C_{2tNF}C_{pNF}^{\ 0.4}T_{NF})+(0.6C_k\Phi+0.25C_\mu\Phi)}{C_{1t}\rho^2\mu^{0.15}+C_{2t}k^{0.6}C_p^{\ 0.4}T} \tag{12}$$

Entropy generation rate by heat transfer in micro-mini channel for turbulent flow influences of volume fraction.

Input data use is a circular micro channel with diameter 20µm and mini channel with diameter 200µm of constant cross section. Entropy generation rate by heat transfer in micro-mini channel turbulent flow is calculated according to the input data required (Pawan,et al.,2010).

$$\dot{S}'_{gen\ Heat\ Transfer/Thermal} = \frac{q''^2\pi D^2}{kT^2 Nu((Re)_D,Pr)} \tag{13}$$

Entropy generation rate by heat transfer in micro-mini channel for turbulent flow influences of size diameter circular tube.

Input data use is thermo physical properties with volume fraction nano particles 2% in circular micro channel with diameter 20µm,40µm and 60µm and mini channel with diameter 200µm,400µm and 600µm of constant cross section. Entropy generation by heat transfer in micro-mini channel turbulent flow is calculated according to the input data required (Pawan,et al.,2010).

$$\dot{S}'_{gen\ Heat\ Transfer/Thermal} = \frac{q''^2\pi L^2}{C_k kT^2 Re^m Pr^n} D^2 \tag{14}$$

Entropy generation rate by fluid friction in micro-mini channel turbulent flow influences of volume fraction.

Input data use is a circular micro channel with diameter 20μm and mini channel with diameter 200μm of constant cross section with volume fraction nano particles. Entropy generation rate by fluid friction in micro channel and mini channel turbulent flow is calculated according to the input data required (Pawan,et al.,2010).

$$\dot{S}'_{\text{gen fluid friction}} = \frac{8\dot{m}^3}{\pi^2\rho^2 T}\frac{f((\mathrm{Re})_D)}{D^5} \tag{15}$$

Entropy generation rate by fluid friction in micro-mini channel for turbulent flow influences of size diameter circular tube.

Input data use is thermo physical properties with volume fraction nano particles 2% in circular micro channel with diameter 20μm,40μm and 60μm and mini channel with diameter 200μm,400μm and 600μm 200μm of constant cross section. Entropy generation rate by fluid friction in micro-mini channel turbulent flow is calculated according to the input data required (Pawan,et al.,2010).

$$\dot{S}'_{\text{gen fluid friction}} = \frac{1}{8}\frac{\pi\mu^3 \mathrm{Re}^{(b+3)}}{\rho^2 T}\ D^{-2} \tag{16}$$

CHAPTER 4.0-RESULT AND DISCUSSION

The thesis contain results of thermo physical properties, minimum entropy generation ratio and minimum entropy generated by heat transfer and fluid friction.

4.1 THERMO PHYSICAL PROPERTIES

4.1.1 Thermal conductivity

Thermal conductivity of nanofluid is determine use equation (1) with varies volume fraction nanoparticles. Figure 4.1 show results thermal conductivity of nanofluids.

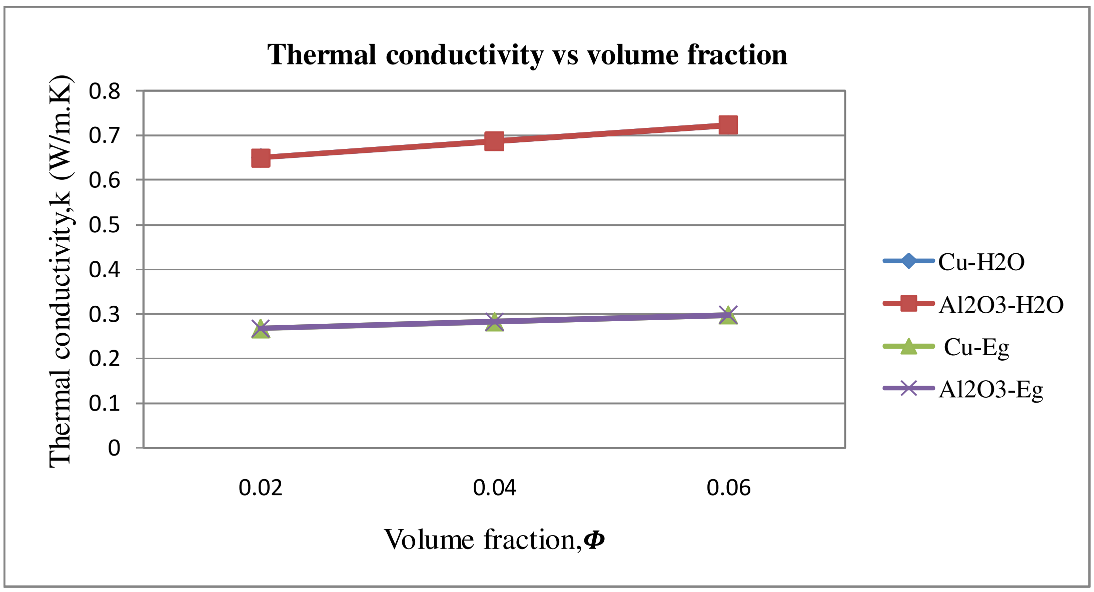

Figure 4.1 - Graph of thermal conductivity

Thermal conductivity of nanofluids increase linearly with the addition of nano particle. Nano particle volume fraction of 2%,4% and 6% in the base fluid H_2O increase thermal conductivity of nanofluids by 6% ,12% and 18%. Addition of nano particles 2%,4% and 6% in the base fluid Eg increase values of thermal conductivity of nanofluids by 6% ,12% and 18%. Thermal conductivity of Cu-H_2O and Al_2O_3-H_2O is higher than Cu-Eg and Al_2O_3-Eg because thermal conductivity of H_2O is higher compare to Eg.

4.1.2 Viscosity

Viscosity of nanofluid is determine use equation (2) with varies volume fraction nanoparticles. Figure 4.2 show results viscosity of nanofluids.

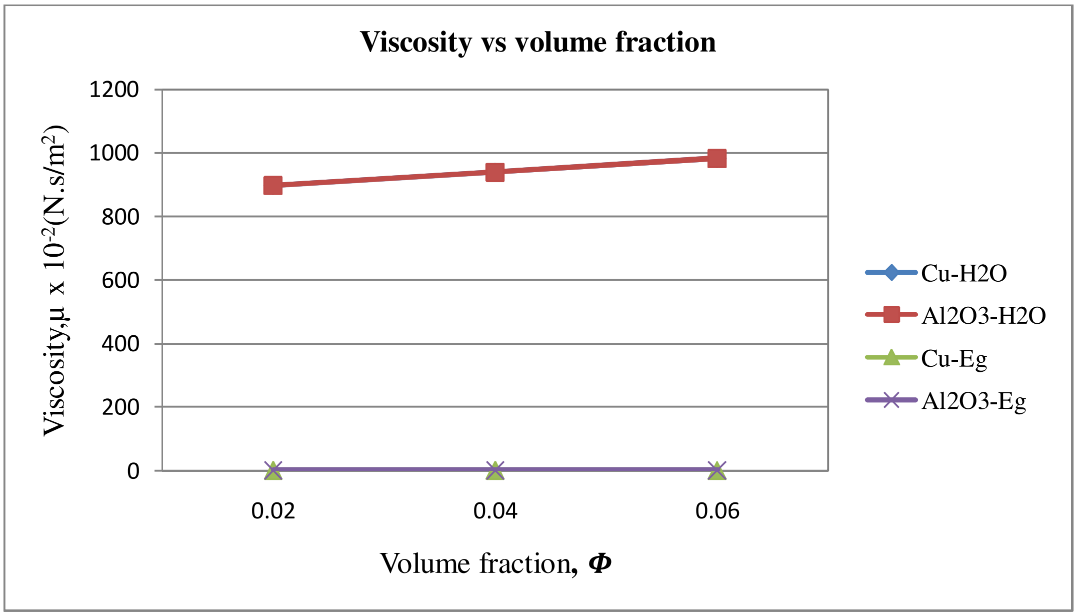

Figure 4.2 - Graph of viscosity.

Viscosity of nanofluids increase linearly with the addition of nano particle. Nano particle volume fraction of 2%,4% and 6% in the base fluid H_2O increase viscosity of nanofluids by 5%,10% and 15% . Nano particle volume fraction of 2%,4% and 6% in the base fluid Eg increase viscosity of nanofluids by 5%,10% and 14%. Even though the increment percentage is same but value of Cu-Eg and Al_2O_3-Eg value is higher than Cu-H_2O and Al_2O_3-H_2O due to the viscosity in Eg is higher compare to H_2O.

4.1.3 Density

Density of nanofluid is determine use equation (3) with varies volume fraction nanoparticles. Figure 4.3 show results density of nanofluids.

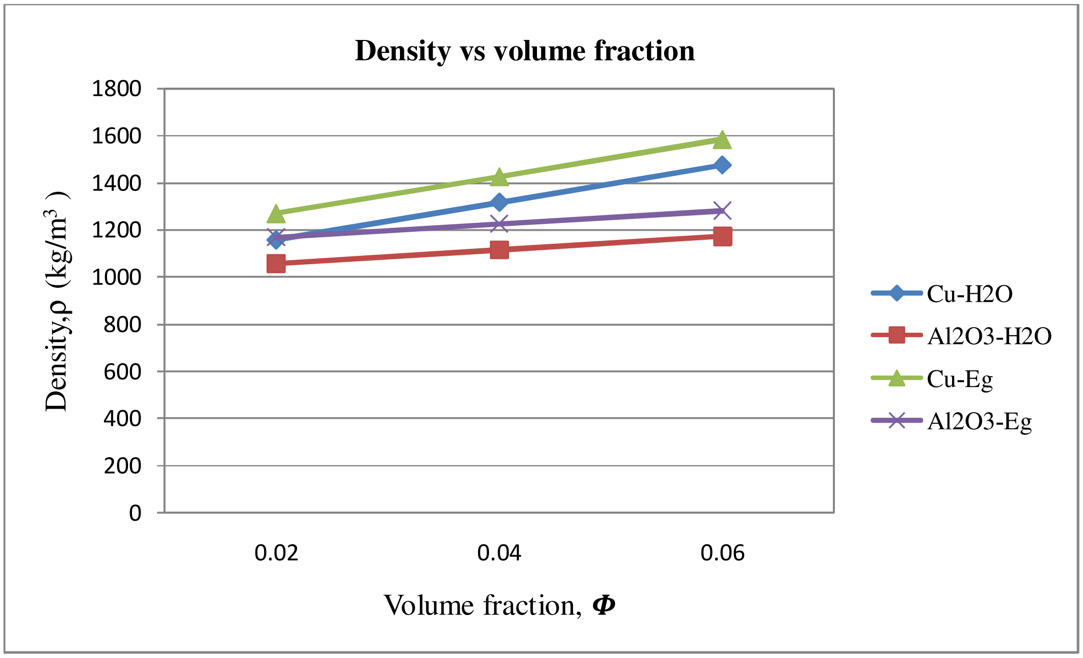

Figure 4.3 - Graph of density.

Density of nanofluids increase linearly with the addition of nano particle. Nano particle copper volume fraction of 2%,4% and 6% in the base fluid H_2O increase density by nanofluids by 16%,32% and 48%. Nano particle volume alumina fraction of 2%,4% and 6% in the base fluid H_2O increase density by nanofluids by 6%,12% and 18%. Nano particle volume copper fraction of 2%,4% and 6% in the base fluid Eg increase density by nanofluids by 14%, 28% and 42%. Nano particles volume Alumina of 2%,4% and 6% in the base fluid Eg increase density of nanofluids by 5%,10% and 15%. Even though the increment is linearly proportional but descending density values is follow by Cu-Eg,Cu-H_2O,Al_2O_3-Eg and Al_2O_3-H_2O. The sequence is due to the nano particle copper have higher density values compared to alumina.

4.1.4 Specific heat

Specific heat of nanofluid is determine use equation (4) with varies volume fraction nanoparticles. Figure 4.4 show results specific heat of nanofluids.

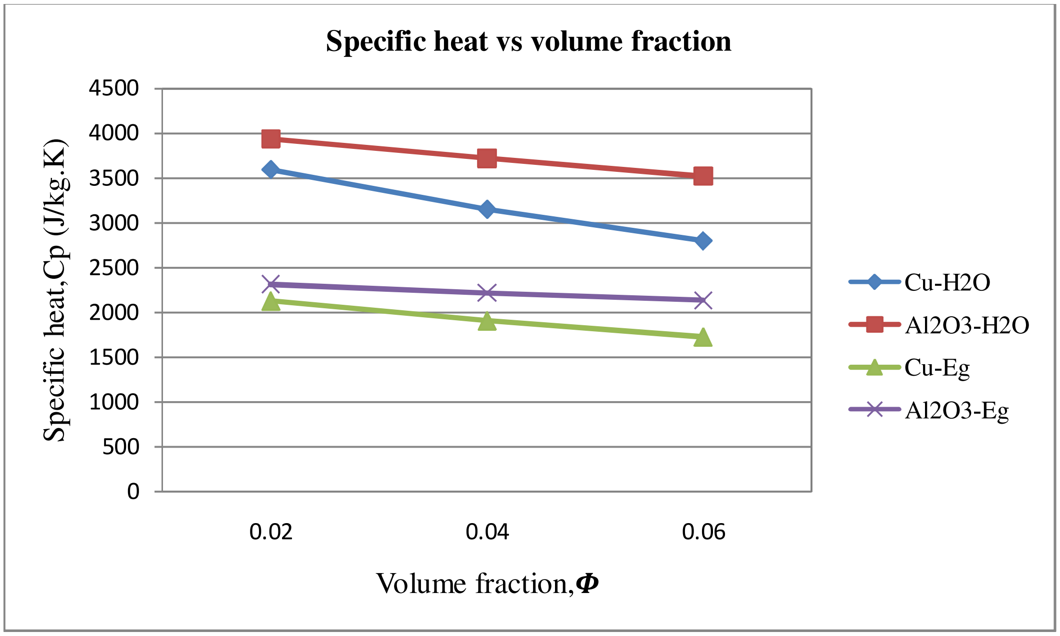

Figure 4.4- Graph of specific heat.

Specific heat of nanofluids decrease linearly with the addition of nano particle. Nano particle volume copper fraction of 2%,4% and 6% in the base fluid H_2O decrease specific heat by nanofluids by 14%,24% and 32% . Nano particle volume alumina fraction of 2%,4% and 6% in the base fluid H_2O decrease specific heat nanofluids by 6%,11% and 16%.Nanoparticle volume copper fraction of 2%, 4% and 6% % in the base fluid Eg decrease specific heat by 12%,21% and 29%. Nano particle volume alumina (Al_2O_3) of 2%,4% and 6% in the base fluid Eg decrease specific heat of nanofluids by 4%,8% and 12%. Even though the decrement is inclined proportional but descending values specific heat is follow by Al_2O_3-H_2O, Cu-H_2O ,Al_2O_3-Eg and Cu-Eg. The sequence is due to base fluid H_2O have higher specific heat values compared to base fluid Eg.

4.2 DISCUSSION THERMO PHYSICAL PROPERTIES

Thermo physical properties increase linearly with the addition of nano particle. Thermal conductivity, viscosity and density increase as the volume fraction nano particles increase in the base fluids. Opposite for the specific heat, the property decrease as the volume fraction nano particles increase in the base fluids.

Nano particles increasing the transition amount of heat in base fluids. The transition amount of heat is increase due to the increase brownian motion, crystalline solid interface and due to particles in nanofluids are close together promote to the coherent phonon heat flow among the particles.

The brownian motion can be defined as a motion of nano particles moving through the liquid and colliding with each other. The collision is the direct solid–solid transmit of heat from one to another and ultimately increase thermal conductivity . Brownian motion effectiveness is measured by comparing time scale of nano particles, solid motion with that of heat diffusion in the liquid. By comparing the time required for a nano particles to move by the distance equal to its size in the base fluid and bulk liquid for heat diffusion by the same distance. It showed that Brownian motion by adding nano particle solid could have an important and indirect role which in turn could enhance thermal conductivity.

Base fluid layer on the nano particle is crystalline solid interface. The interface effect could enhance thermal conductivity, by which liquid layer atomic structure significantly more ordered compare to bulk liquid. Crystalline solids interface showed thermal transport better than liquids. Crystalline solids interface performance is the same as that of the solid. The resultant larger effective volume of the particle-layered-liquid structure would enhance the thermal conductivity.

Nano particles as the crystalline solids state heat is carried by phonons for instance by propagating lattice vibrations in base fluid. Theory of heat transport justify that phonons are created at random, propagate in random directions and are scattered by each other or by defects. The particles in nanofluids are close together even at relatively low packing factions. Due to Brownian motion locally the particles move constantly. There are much closer and thus enhance coherent phonon heat flow among the particles.

4.3 ENTROPY GENERATION RATIO

4.3.1 Entropy generation ratio in micro channel for turbulent flow.

Entropy generation ratio in micro channel turbulent flow is calculated according to the input data required with varies volume fraction use equation (11). Figure 4.5 show results of entropy generation rate ratio in micro channel of nanofluids.

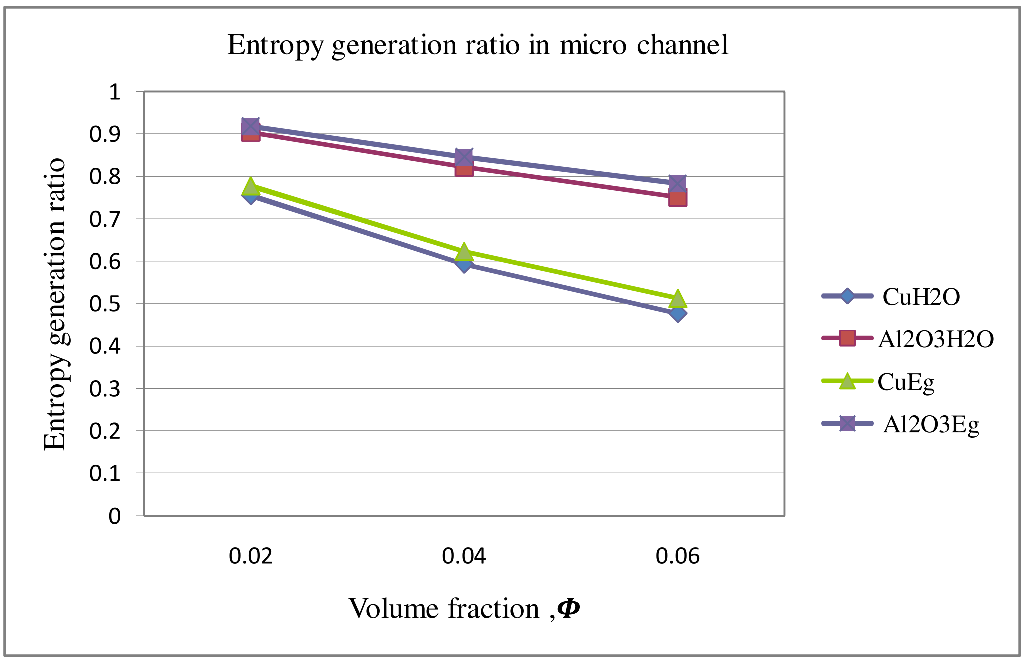

Figure 4.5- Graph of entropy generation ratio in micro channel.

Entropy generation ratio decrease with nano particle volume fraction addition in the base fluid of H_2O and Eg .The entropy generation ratios value for all nanofluids less than one. Addition of copper in the base fluid H_2O decrease the entropy generation ratio in nanofluid by 21% to 36%. Addition of alumina in the base fluid H_2O decrease the entropy generation ratio in nanofluid by 9% to 16% . Addition of copper in the base fluid Eg decrease the entropy generation ratio in nanofluid by 20% to 34%. Addition of alumina in the base fluid Eg decrease the entropy generation ratio in nanofluid by 8% to 14%.

Difference entropy generation ratio between Cu-H_2O and Cu-Eg with addition of copper is 3%,5% and 8%. Nano particle copper in base fluid Eg have higher value than in base fluid H_2O. Difference entropy generation ratio between Al_2O_3-H_2O and Al_2O_3-Eg with addition of alumina is 1.5%,3% and 4.2 %. Nano particle alumina in base fluid Eg have higher value than in base fluid H_2O.

Difference entropy generation ratio between Cu-H_2O and Al_2O_3-H_2O with different type of nano particle is 19%,58% and 37%. Nano particle alumina in base fluid H_2O have higher value than nano particle copper in base fluid H_2O. Difference entropy generation ratio between Cu-Eg and Al_2O_3-Eg with different type of nano particle is 18%,36% and 53%. Nano particle alumina in base fluid Eg have higher value than nano particle copper in base fluid Eg. Entropy generation ratio is in circular micro channel diameter varies 20µm,40µm and 60µm of constant cross section is higher use nano particle alumina compare to copper is due to higher thermo physical property density in copper compare to alumina.

4.3.2 Entropy generation ratio in mini channel for turbulent flow.

Entropy generation ratio in mini channel turbulent flow is calculated according to the input data required with varies volume fraction use equation (12). Figure 4.6 show results of entropy generation ratio in mini channel of nanofluids.

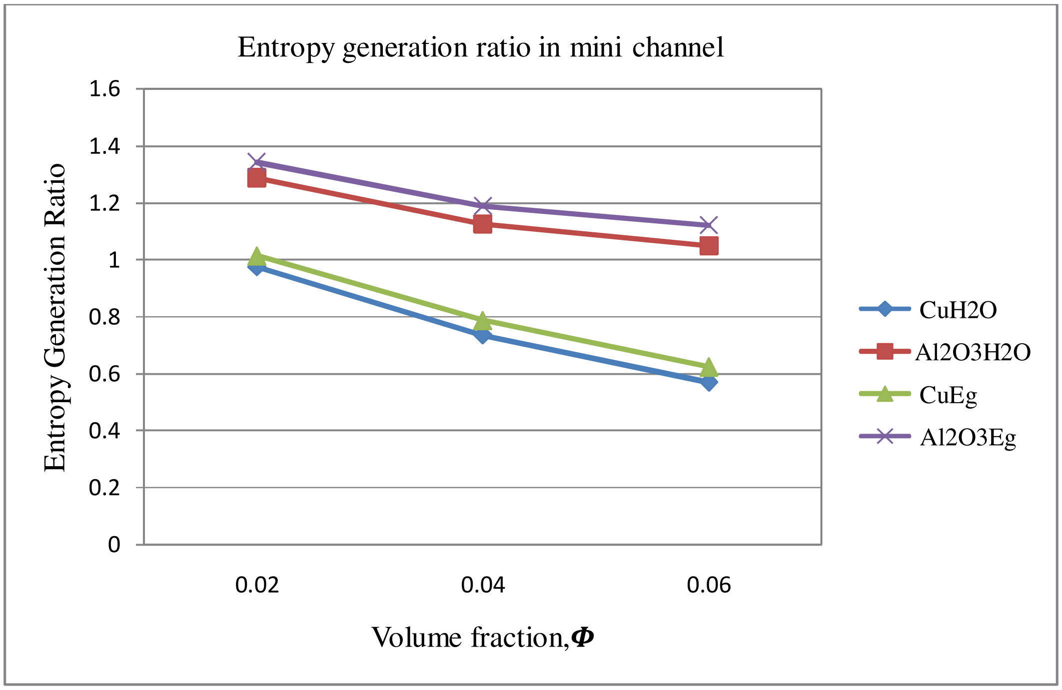

Figure 4.6- Graph of entropy generation ratio in mini channel

Entropy generation ratio decrease with nano particle volume fraction addition in the base fluid of H_2O and Eg showed the entropy generation decrease linearly proportional to the volume fraction. In mini channel nanofluids Al_2O_3-EG and Al_2O_3-H_2O have entropy generation ratios value more than one and approaching one with the addition nano particles. While nanofluids Cu-Eg and Cu-H_2O entropy generation ratios value start from one and by increased volume fraction become uniform less than one. Addition of copper in the base fluid H_2O decrease the entropy generation ratio in nanofluid by 24% to 41%. Addition of alumina in the base fluid H_2O decrease the entropy generation ratio in nanofluid by 12% to 18% . Addition of copper in the base fluid Eg decrease the entropy generation ratio in nanofluid by 22% to 38%. Addition of alumina in the base fluid Eg decrease the entropy generation ratio in nanofluid by 11% to 16%.

Difference entropy generation ratio between Cu-H_2O and Cu-Eg with addition of copper is 4%,7% and 9%. Nano particle copper in base fluid Eg have higher value than in base fluid H_2O. Difference entropy generation ratio between Al_2O_3-H_2O and

Al_2O_3-Eg with addition of alumina is 4%,5% and 7 %. Nano particle alumina in base fluid Eg have higher value than in base fluid H_2O.

Difference entropy generation ratio between Cu-H_2O and Al_2O_3-H_2O with different type of nano particle is 32%,53% and 83%. Nano particle alumina in base fluid H_2O have higher value than nano particle copper in base fluid H_2O. Difference entropy generation ratio between Cu-Eg and Al_2O_3-Eg with different type of nano particle is 32%,40% and 80%. Nano particle alumina in base fluid Eg have higher value than nano particle copper in base fluid Eg. Entropy generation ratio is in circular mini channel diameter varies 200µm,400µm and 600µm of constant cross section is higher use nano particle alumina compare to copper is due to higher thermo physical property density in copper compare to alumina.

4.4 DISCUSSION ENTROPY GENERATION RATIO

Entropy generation ratio of nanofluids decrease with addition nano particles in circular micro-mini channel.

Entropy generation ratio value is less than one in circular micro channel with addition of copper and alumina in both base fluids water and ethylene glycol. Selection of copper with higher density reduce the entropy generation ratio higher compare to alumina in both base fluids. Nano particles copper and alumina both effective in micro channel in water and ethylene glycol in circular micro channel with constant cross section.

Entropy generation ratio value is more than one in circular mini channel with addition of alumina in both base fluids water and ethylene glycol. While entropy generation ratio value is less than one in circular mini channel with constant cross section with addition of copper in both base fluids water and ethylene glycol. Selection of copper with higher density reduce the entropy generation ratio compare to alumina in both base fluids. Adding copper in the base fluids water and ethylene glycol was effective in the mini channel compare to the alumina in the circular mini channel.

4.5 ENTROPY GENERATION RATE BY HEAT TRANSFER

4.5.1 Entropy generation by heat transfer in micro-mini channel for turbulent flow influences of volume fraction.

Entropy generation rate by heat transfer in micro channel turbulent flow is calculated according to the input data required with varies volume fraction nano particles use equation (13). Figure 4.7 show results entropy generation rate by heat transfer of nanofluids in micro channel.

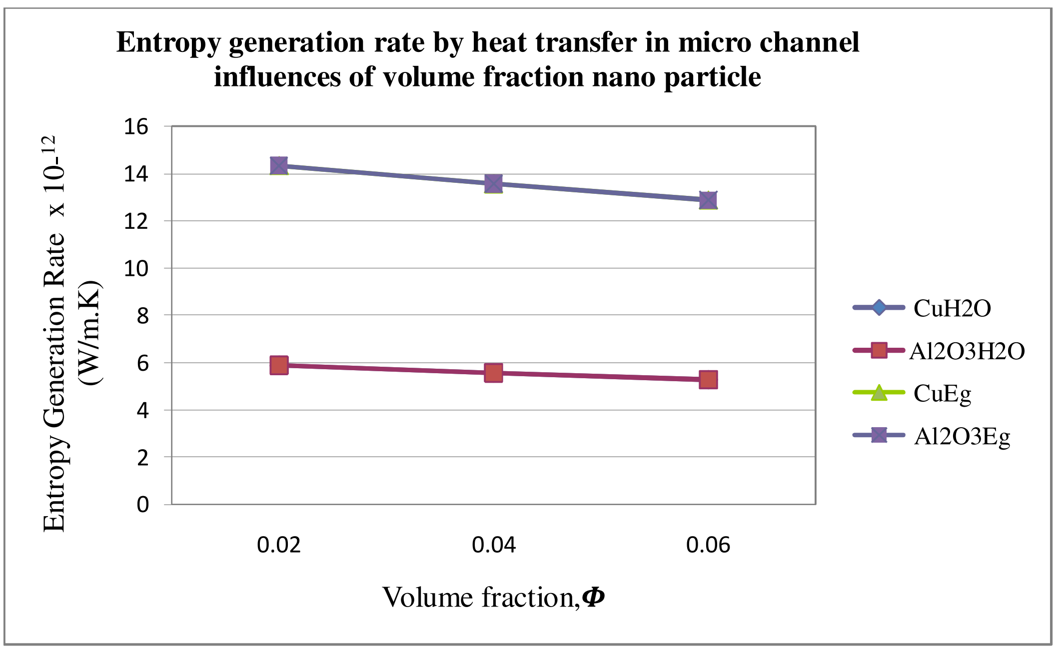

Figure 4.7 - Entropy generation rate by heat transfer in micro channel influences of volume fraction nano particle.

Entropy generation rate by heat transfer by nanofluid was analyzed in micro channel with diameter size 20µm. Entropy generation decrease linearly with the addition of nano particle. Addition nano particle copper and alumina in the base fluid H_2O decrease the entropy generation in nanofluid by 5.4%% to 10 %. Addition nano particle copper and alumina in the base fluid Eg decrease the entropy generation in nanofluid by 5.4 % to 10%.

Difference entropy generation rate between Cu-H_2O and Cu-Eg is 58% . The same value for Al_2O_3-H_2O and Al_2O_3-Eg. Nano particle copper in base fluid Eg have higher value than in base fluid H_2O. Nanoparticle alumina in base fluid Eg have higher value than in base fluid H_2O.

Difference entropy generation rate between Cu-H_2O and Al_2O_3-H_2O is 0%. The same value for Cu-Eg and Al_2O_3-Eg. Nano particle alumina in base fluid H_2O have same value as nano particle copper in base fluid H_2O.Nano particle alumina in base fluid Eg have same value as nano particle copper in base fluid Eg.

Entropy generation rate by heat transfer in mini channel turbulent flow is calculated according to the input data required with varies volume fraction use equation (13). Figure 4.8 show results entropy generation rate by heat transfer of entropy generation rate by heat transfer of nanofluids in mini channel.

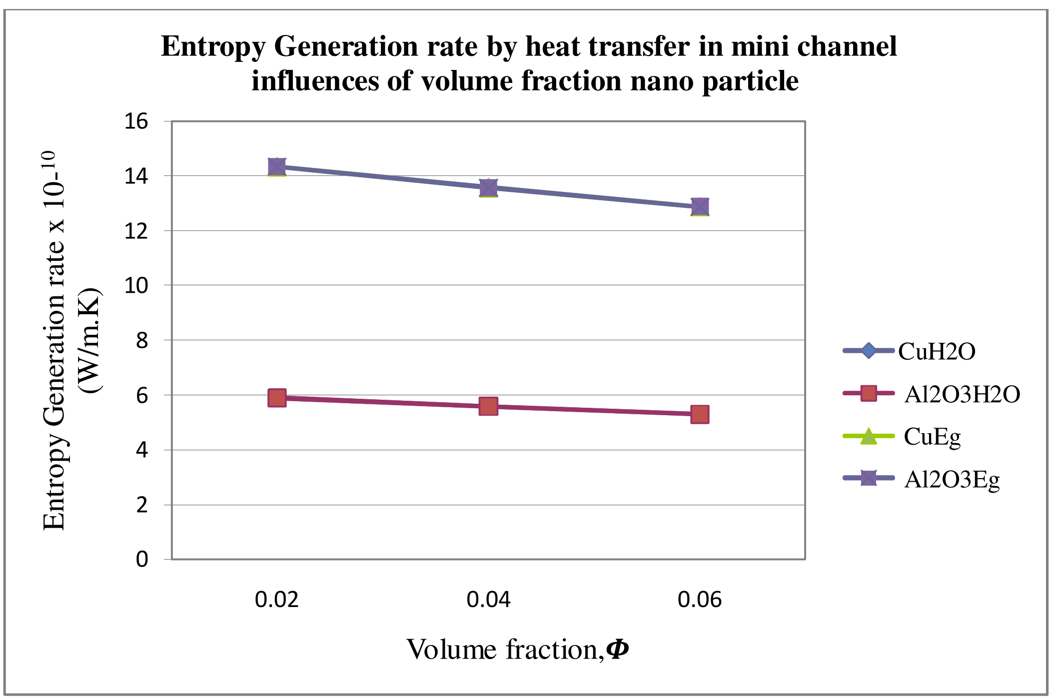

Figure 4.8 - Entropy generation rate by heat transfer in mini channel influences of volume fraction nano particle

Entropy generation rate by heat transfer by nanofluid was analyzed in mini channel with diameter size 200µm. Entropy generation decrease linearly with the addition of nano particle. Addition nano particle copper and alumina in the base fluid H_2O decrease the entropy generation in nanofluid by 5.4%% to 10 %.

Difference entropy generation rate between Cu-H_2O and Cu-Eg is 58% . The same value for Al_2O_3-H_2O and Al_2O_3-Eg. Nano particle copper in base fluid Eg have higher value than in base fluid H_2O. Nanoparticle alumina in base fluid Eg have higher value than in base fluid H_2O.

Difference entropy generation rate between Cu-H_2O and Al_2O_3-H_2O is 0%. The same value for Cu-Eg and Al_2O_3-Eg. Nano particle alumina in base fluid H_2O have same value as nano particle copper in base fluid H_2O.Nano particle alumina in base fluid Eg have same value as nano particle copper in base fluid EG.

4.5.2 Entropy generation by heat transfer in micro-mini channel for turbulent flow influences of size diameter circular tube.

Entropy generation rate by heat transfer was analyzed in micro channel with constant volume fraction of 2%. Entropy generation rate in micro channel turbulent flow is calculated according to the input data required with different circular micro channel diameter constant cross section 20µm,40µm and 60µm use equation (14). Figure 4.9 show results of entropy generation rate by heat transfer of nanofluids in micro channel .

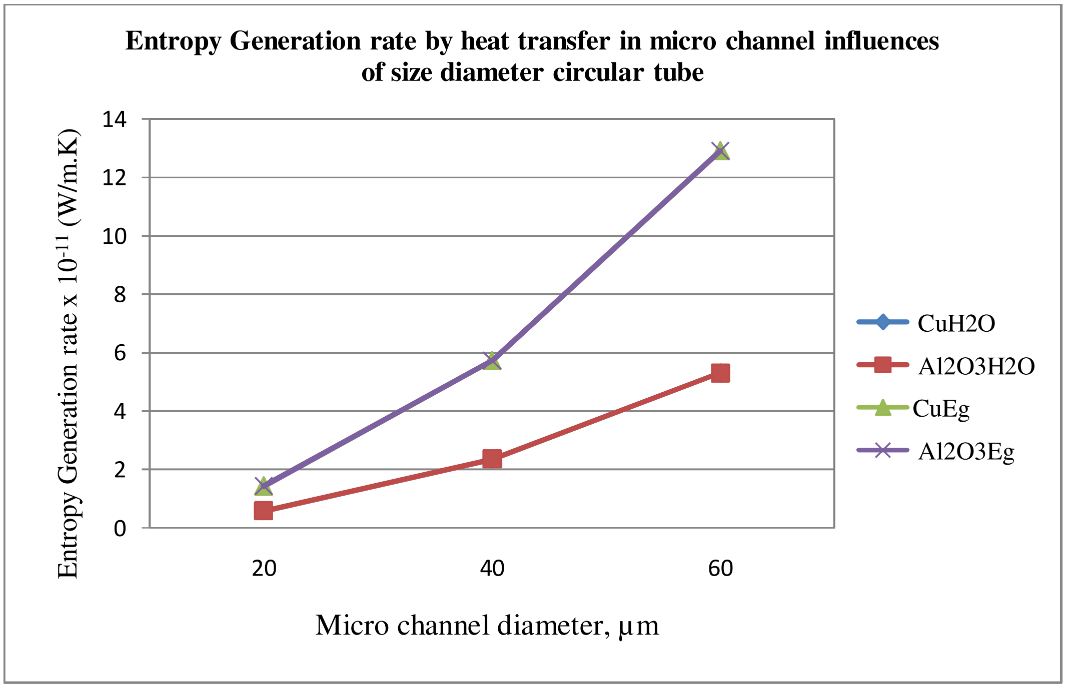

Figure 4.9 - Entropy generation rate by heat transfer in micro channel influences of size diameter circular tube

Entropy generation rate by heat transfer increase nonlinear with the increasing size diameter of micro channel diameter. Addition nano particle copper and alumina in the base fluid H_2O increase the entropy generation in nanofluid by 55% to 75% .

Difference entropy generation rate between Cu-H_2O and Cu-Eg is 58 % . The same value for Al_2O_3-H_2O and Al_2O_3-Eg. Nano particle copper in base fluid EG have higher value than in base fluid H_2O. Nanoparticle alumina in base fluid EG have higher value than in base fluid H_2O.

Difference thermal entropy generation rate between Cu-H_2O and Al_2O_3-H_2O is 0%. The same value for Cu-Eg and Al_2O_3-Eg. Nano particle alumina in base fluid H_2O have same value as nano particle copper in base fluid H_2O.Nano particle alumina in base fluid Eg have same value as nano particle copper in base fluid EG.

Entropy generation rate by heat transfer was analyzed in mini channel with constant volume fraction of 2%. Entropy generation rate in mini channel turbulent flow is calculated according to the input data required with different circular mini channel diameter constant cross section 200µm, 400µm and 600µm use equation (14).

Figure 4.10 show results of entropy generation rate by heat transfer of nanofluids in mini channel.

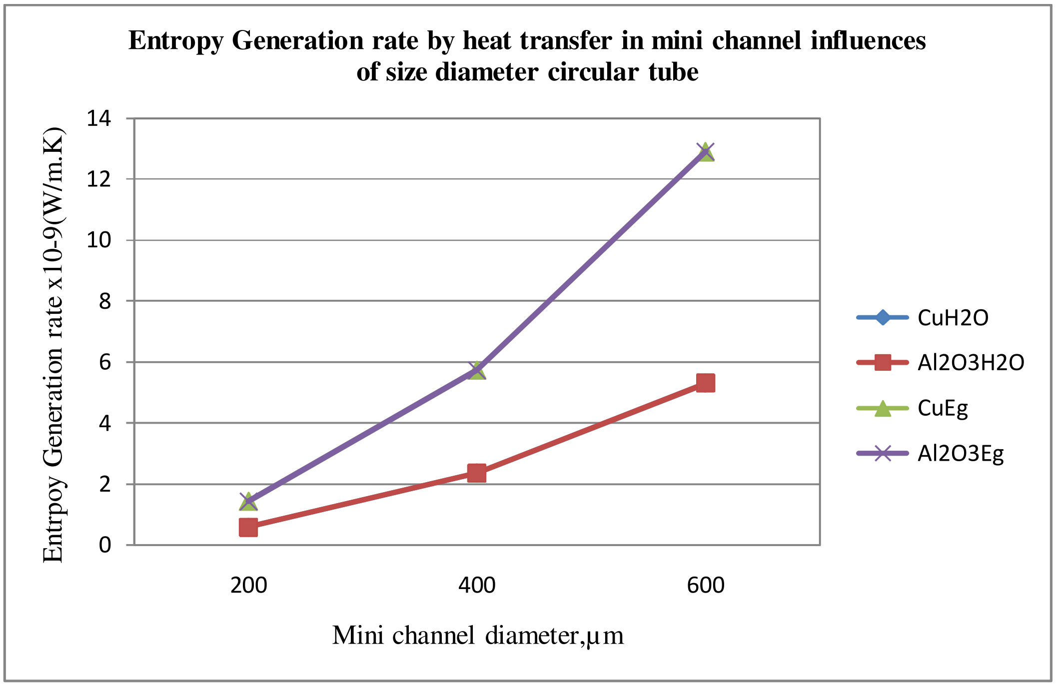

Figure 4.10 - Entropy generation rate by heat transfer in mini channel influences of size diameter circular tube

Entropy generation rate by heat transfer increase nonlinear with the increasing size diameter of mini channel diameter. Addition nano particle copper and alumina in the base fluid H_2O increase the thermal entropy generation in nanofluid by 55% to 75%.

Difference thermal entropy generation rate between Cu-H_2O and Cu-Eg is 58 %. The same value for Al_2O_3-H_2O and Al_2O_3-Eg. Nano particle copper in base fluid EG have higher value than in base fluid H_2O. Nanoparticle alumina in base fluid EG have higher value than in base fluid H_2O.

Difference thermal entropy generation rate between Cu-H_2O and Al_2O_3-H_2O is 0%. The same value for Cu-Eg and Al_2O_3-Eg. Nano particle alumina in base fluid H_2O have same value as nano particle copper in base fluid H_2O.Nano particle alumina in base fluid Eg have same value as nano particle copper in base fluid Eg.

4.6 DISCUSSION ENTROPY GENERATION RATE BY HEAT TRANSFER

Entropy generation rate by heat transfer of nanofluids decrease with addition nano particles and increase with influences of size diameter circular tube in circular micro-mini channel for turbulent flow.

Entropy generated depleted exergetic effectiveness of nanofluid in micro-mini channel. Entropy generation rate decrease with nanofluids thermal conductivity increase as the volume fraction nano particles increase in both micro-mini channel. Entropy is generated higher in ethylene glycol base fluid compared to water disregard what selection of nano particles they have. Selection of base fluid water with higher thermal conductivity reduce the thermal entropy generation rate compare to ethylene glycol. Entropy generated by heat transfer is lower in micro channel compare to minichannel under the influence of volume fraction nano particles.

Entropy generation rate by heat transfer increase with increasing both micro-mini channel diameter in circular constant cross section. Higher diameter provide higher volume rate of fluid through the circular cross section and allow more thermal entropy generated. Entropy generation rate by heat transfer is generated higher in ethylene glycol base fluid compared to water disregard what selection of nano particles they have. Selection of base fluid water with higher thermal conductivity reduce the thermal entropy generation rate compare to ethylene glycol. Entropy generation rate by heat transfer is lower in micro channel compare to mini channel under the influence of volume fraction nano particles.

4.7 ENTROPY GENERATION RATE BY FLUID FRICTION

4.7.1 Entropy generation by fluid friction in micro-mini channel for turbulent flow influences of volume fraction.

Entropy generation by fluid friction in micro channel turbulent flow is calculated according to the input data required with varies volume fraction nano particles use equation (15). Figure 4.11 show results of entropy generation rate by fluid friction in micro channel of nanofluids.

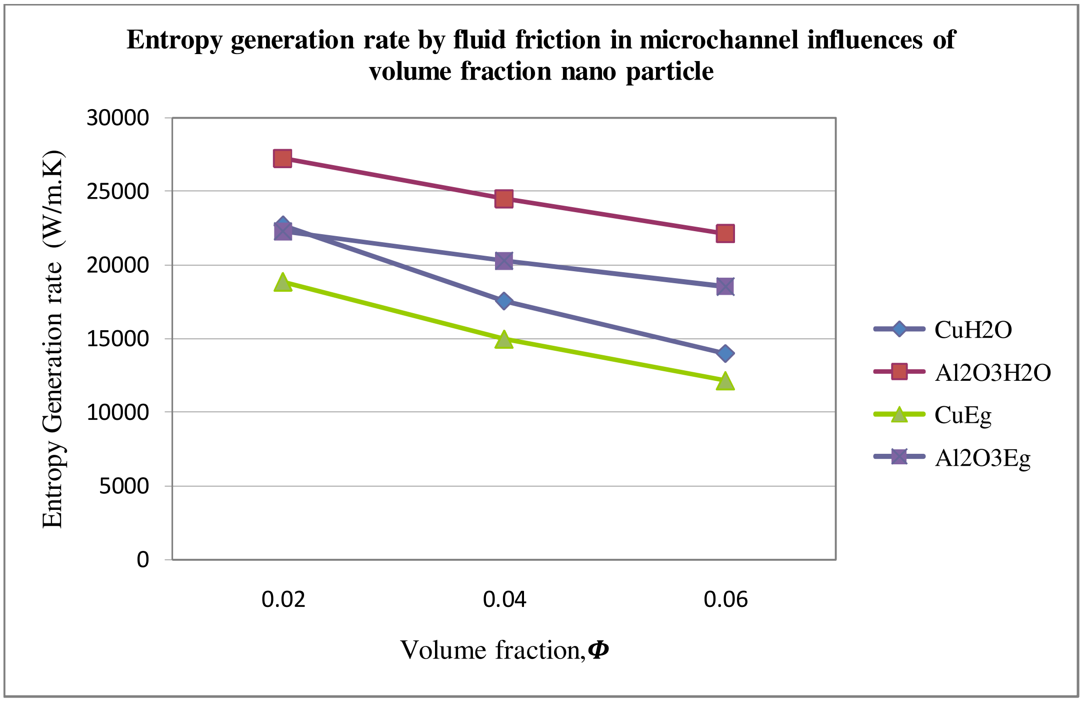

Figure 4.11 - Entropy generation rate by fluid friction in micro channel influences of volume fraction nano particle

Entropy generation rate by fluid friction was analyzed in micro channel with diameter size 20µm. Entropy generate decrease linearly with the addition of nano particle. Addition nano particle copper in the base fluid H_2O decrease the entropy generation in nanofluid by 23%% to 38 %. Addition nano particle alumina in the base fluid H_2O decrease the entropy generation ratio in nanofluid by 10% to 18%. Addition nano particle copper in the base fluid Eg decrease the entropy generation in nanofluid by 21%% to 35 %. Addition nano particle alumina in the base fluid Eg decrease the entropy generation in nanofluid by 8% to 16%.

Difference entropy generation rate by fluid friction between Cu-H_2O and Cu-Eg is 16%,15% and 13% . Nano particle copper in base fluid H_2O have higher value than in base fluid Eg. Difference entropy generation rate by fluid friction between Al_2O_3-H_2O and Al_2O_3-Eg is 18%,17% and 16%. Nano particle alumina in base fluid H_2O have higher value than in base fluid Eg.

Difference thermal entropy generation rate between Cu-H_2O and Al_2O_3 -H_2O is 17%,28% and 37%. Nano particle alumina in base fluid H_2O have higher value than copper in base fluid H_2O. Difference thermal entropy generation rate between Cu-Eg and Al_2O_3-Eg is 16%,26% and 34%. Nano particle alumina in base fluid Eg have higher value than copper in base fluid Eg.

Entropy generation rate by fluid friction in micro channel turbulent flow is calculated according to the input data required with varies volume fraction nano particles use equation (15). Figure 4.12 show results of entropy generation rate by fluid friction of nanofluids in micro channel .

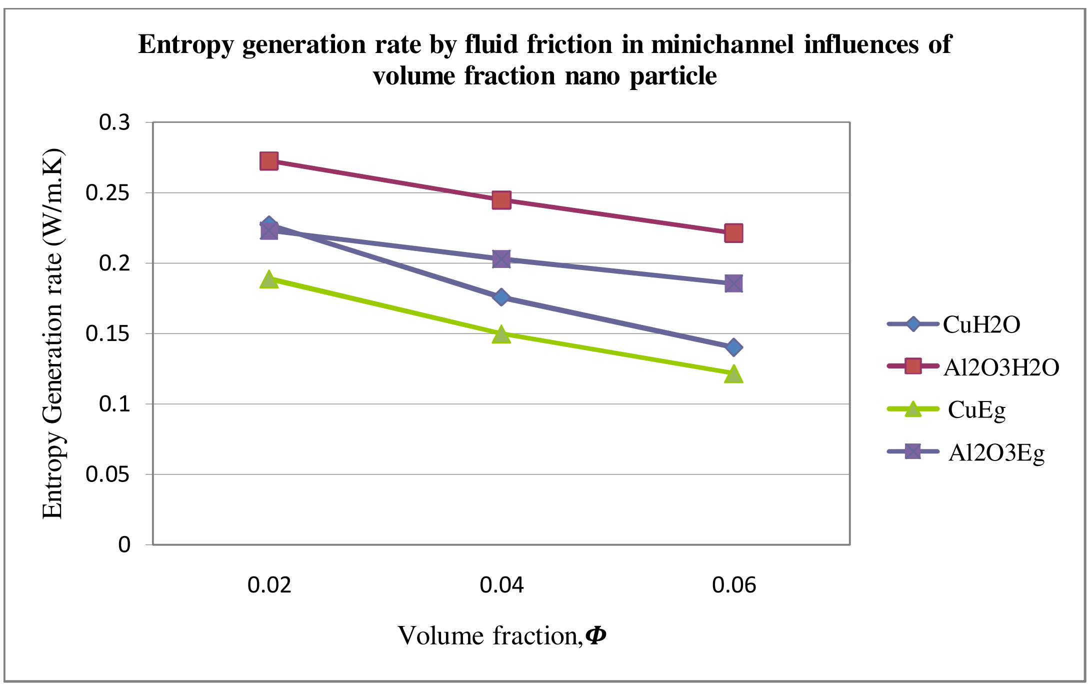

Figure 4.12 - Entropy generation rate by fluid friction in mini channel influences of volume fraction nano particle

Entropy generation rate by fluid friction was analyzed in mini channel with diameter size 200μm. Entropy generate decrease linearly with the addition of nano particle. Addition nano particle copper in the base fluid H_2O decrease the entropy generation by fluid friction in nanofluid by 23% to 38%. Addition nano particle alumina in the base fluid H_2O decrease the entropy generation rate in nanofluid by 10% to 18%.

Addition nano particle copper in the base fluid Eg decrease the fluid friction generation in nanofluid by 21%% to 35 %. Addition nano particle alumina in the base fluid Eg decrease the entropy generation rate in nanofluid by 9% to 16%.

Difference entropy generation rate by fluid friction between Cu-H_2O and Cu-Eg is 17%,28% and 13% . Nano particle copper in base fluid H_2O have higher value than in base fluid Eg. Difference entropy generation rate by fluid friction between Al_2O_3-H_2O and Al_2O_3-Eg is 18%,17% and 16%. Nano particle alumina in base fluid H_2O have higher value than in base fluid Eg.

Difference entropy generation rate by fluid friction between Cu-H_2O and Al_2O_3-H_2O is 17%,28% and 37%. Nano particle alumina in base fluid H_2O have higher value than copper in base fluid H_2O. Difference entropy generation rate between Cu-Eg and Al_2O_3-Eg is 16%,26% and 34%. Nano particle alumina in base fluid Eg have higher value than copper in base fluid Eg.

4.7.2 Entropy generation rate by fluid friction in micro-mini channel for turbulent flow influences of size diameter circular tube.

Entropy generation rate by fluid friction by nanofluid was analyzed in micro channel with constant volume fraction of 2%. Entropy generation rate in micro channel turbulent flow is calculated according to the input data required with different circular micro channel diameter constant cross section 20µm,40µm and 60µm use equation (16). Figure 4.13 show results entropy generation rate by fluid friction in micro channel .

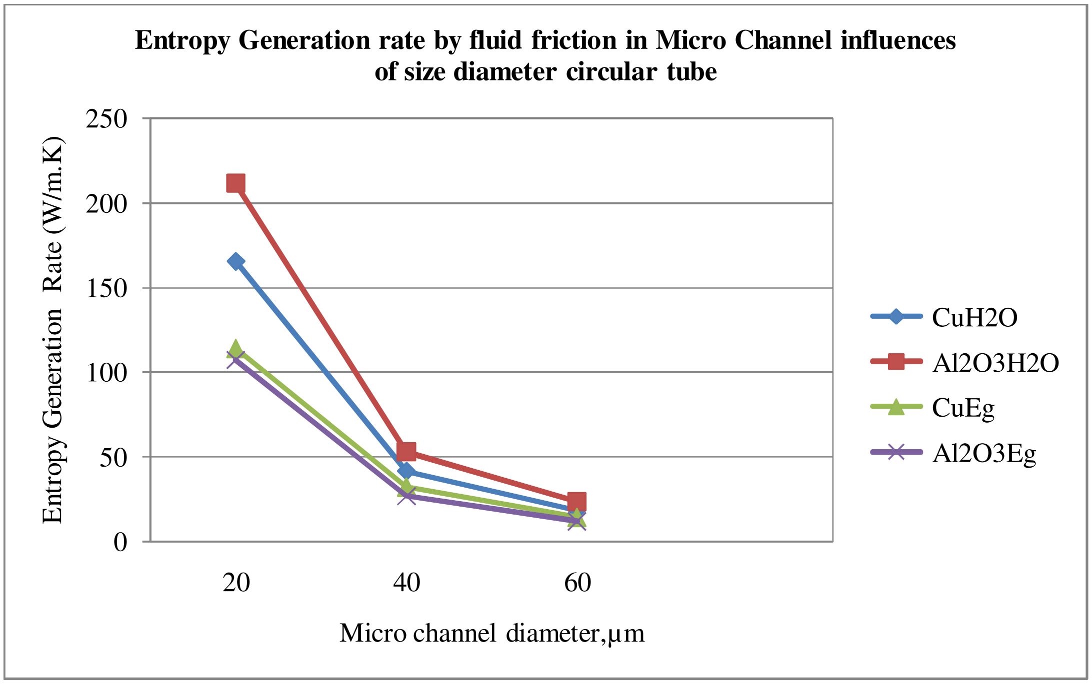

Figure 4.13- Entropy generation rate by fluid friction in micro channel influences of size diameter circular tube

Entropy generation rate by fluid friction rate decrease nonlinear with the increasing size diameter of micro channel diameter. Addition nano particle copper and alumina in the base fluid H_2O increase the entropy generation in nanofluid by 75% to 88% . Similar also for addition nano particle copper and alumina in the base fluid Eg.

Difference entropy generation rate between Cu-H_2O and Cu-Eg is 31%,23% and 33% . Nano particle copper in base fluid H_2O have higher value than in base fluid EG. Difference entropy generation rate between Al_2O_3.H_2O and Al_2O_3-Eg is 49%. Nano particle alumina in base fluid H_2O have higher value than in base fluid EG. Difference entropy generation rate by fluid friction between Cu-H_2O and Al_2O_3-H_2O is 21%. Nano particle alumina in base fluid Eg have higher value than alumina in base fluid Eg.

Entropy generation rate by fluid friction was analyzed in micro channel with constant volume fraction of 2%. Entropy generation rate in micro channel turbulent flow is calculated according to the input data required with different circular micro channel diameter constant cross section 200µm,400µm and 600µm use equation (16).

Figure 4.14 show results of entropy generation rate by fluid friction in mini channel of nanofluids.

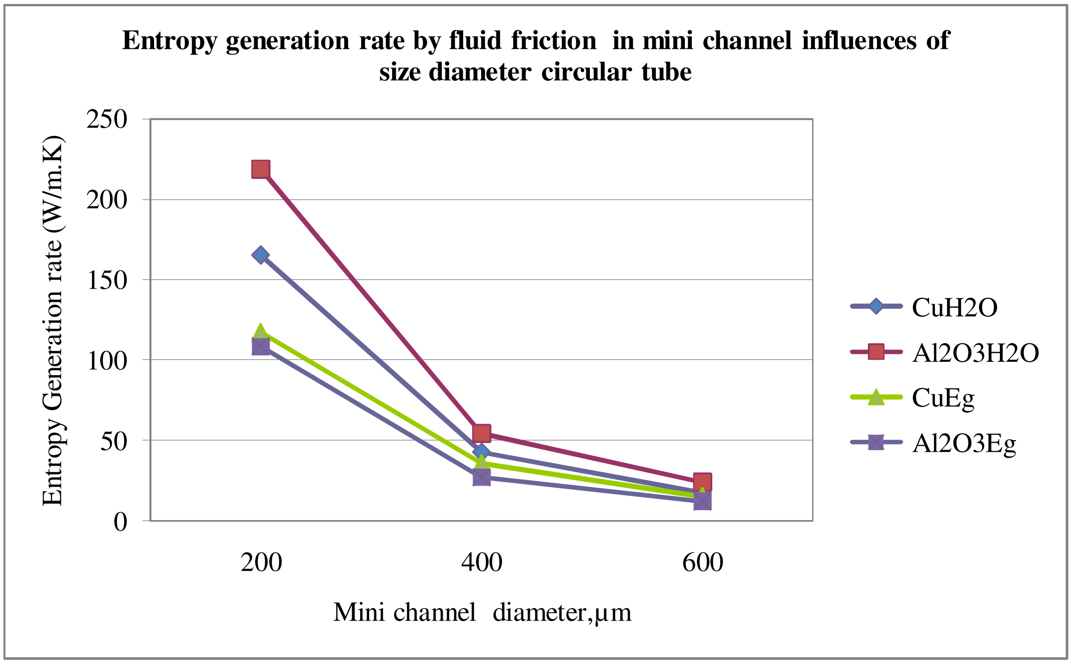

Figure 4.14 - Entropy generation rate by fluid friction in mini channel influences of size diameter circular tube

Entropy generation rate by fluid friction decrease nonlinear with the increasing size diameter of mini channel diameter. Addition nano particle copper and alumina in the base fluid H_2O increase the entropy generation in nanofluid by 75% to 88% . Similar also for addition nano particle copper and alumina in the base fluid Eg.

Difference entropy generation rate by fluid friction between Cu-H_2O and Cu-Eg is 29%,17% and 13% . Nano particle copper in base fluid H_2O have higher value than in base fluid Eg. Difference entropy generation rate between Al_2O_3-H_2O and Al_2O_{3}-Eg is 49%,50% and 48%. Nano particle alumina in base fluid H_2O have higher value than in base fluid Eg.

Difference thermal entropy generation rate between Cu-H_2O and Al_2O_3.-H_2O is 24%,22% and 21%. Nano particle alumina in base fluid H_2O have higher value than copper in base fluid H_2O. Difference thermal entropy generation rate between CuEg and

Al_2O_3-Eg is 7%,24% and 18%. Nano particle copper in base fluid Eg have higher value than alumina in base fluid Eg.

4.8 DISCUSSION FLUID FRICTION ENTROPY GENERATION RATE

Result showed entropy generation rate by fluid friction of nanofluids decrease as the volume fraction nano particles in the base fluids increase and as the circular micro-mini channel diameter increase.

Entropy generated by fluid friction depleted exergetic effectiveness of nanofluid in micro-mini channel. Entropy generation rate by fluid friction decrease with nanofluids increase as the volume fraction nano particles increase the density properties in nanofluids in both micro-mini channel. Entropy is generated highest in alumina in both base fluids with first ethylene glycol and second water compare to copper. Copper ethylene glycol and copper water will effective to reduce more the entropy generation rate by fluid friction .Selection of copper water with higher density reduce the entropy generation rate compare to alumina in both micro-mini channel. Entropy generated by fluid friction is lower in micro channel compare to mini channel under the influence of volume fraction nano particles.

Entropy generated by fluid friction decrease with increasing both micro-mini channel diameter in circular constant cross section. According to mathematical equation fraction of higher diameter reduce the entropy generation rate . Entropy is generated higher in base fluid water with first alumina and second copper compare to ethylene glycol . Copper ethylene glycol and alumina ethylene glycol will effective to reduce more the entropy generation rate. Selection of ethylene glycol with higher density and viscosity compare to water in both micro-mini channel. Entropy generation rate by fluid friction generated is lower in micro channel compare to mini channel under the influence of volume fraction nano particles.

CHAPTER 5.0-CONCLUSION AND RECOMMENDATION.

The analysis of entropy generation ratio and entropy generated by nanofluids caused by heat transfer and fluid friction flow in turbulent flow regime in constant diameter of circular tube channel. The analysis conducted under the influences of volume fraction nanoparticles inside the nanofluids Cu-H_2O, Al_2O_3-H_2O, Cu-EG and Al_2O_3-EG. Also the analysis conducted under the influences of diameter size of circular tube channel. The objectives are to determine and analyze the minimum entropy generation ratio and minimum entropy generation generated caused by heat transfer and fluid friction.

First objective, the conclusion is entropy generation ratio decrease with increasing volume fraction nano particles in base fluids. Entropy generation ratio is decrease due to thermo-physical properties of nanofluids such as thermal conductivity, viscosity and density increase as volume fraction nano particles increase in base fluids. Nano particles copper and alumina both effective in micro channel in water and ethylene glycol in circular micro channel with constant cross section. While nano particles copper in water and ethylene glycol is effective in mini channel compare to alumina in circular mini channel with constant cross section. Selection of ethylene glycol with higher density and viscosity compare to water in both micro-mini channel as the circular micro-mini channel diameter increase.

Second objective, the conclusion is entropy generation rate by heat transfer and fluid friction of nanofluids decrease as the volume fraction nano particles in the base fluids increase and decrease as the circular micro-mini channel diameter increase. Entropy generated by heat transfer is generated higher in ethylene glycol base fluid compared to water disregard what selection of nano particles they have. Selection of base fluid water with higher thermal conductivity reduce the entropy generation rate by heat transfer compare to ethylene glycol as the volume fraction nano particles in the base fluids increase and size tube diameter micro-mini channel increase. Selection of copper water with higher density reduce the entropy generation rate by fluid friction compare to alumina in both micro-mini channel as the volume fraction nano particles in the base fluids increase. Selection of ethylene glycol with higher density and viscosity compare to water in both micro-mini channel as the circular micro-mini channel diameter increase.

Journal on the entropy generation due to heat transfer and flow have findings which supported this thesis results and discussion. The findings are similar with the thesis findings wich alumina water with high viscosity is not advisable to use in minichannels and conventional channels with turbulent flow. Alumina water observed that at lower tube diameter, flow friction irreversibility is more significant and at higher tube diameter thermal irreversibility is more.

Present work only focused on the characterization and the convection of various nanofluids. However further research is required for better understanding of nanofluids. The thermo physical properties of nanofluids can be a function of parameters such as particle shape, particle agglomeration and particle polydispersity. In order to clarify these variables, a number of experiments will be necessary to be conducted. Due to the limitations of production preparation of nanofluids is a challenge to enhance the knowledge about nanofluids. Entropy analysis should be conducted on the various geometry shape.

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