IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 6, Issue 10, October 2017

Micro-Channel Heat Exchanger

Ujwal Chalse[1], Prof. A.A.Parlkar[2], Prof. V.S.Patil[3], Tejas Mawale[4]

Department of Mechanical Engineering, STC, SPRT, Khamgaon[1,2,3,4].

Abstract: A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. The goal of enhancing heat transfer while minimizing pressure drops and reducing the size and volume of energy conversion/thermal management systems has been the subject of intensive research for more than four decades. But growing energy demands, the need for increased energy efficiency and materials savings, space limitations for device packaging, and increased functionality and ease of unit handling have created revolutionary challenges for the development of high performance, next-generation heat and mass exchangers. Current heat exchanger designs rely heavily on fin-and tube or plate heat exchanger designs, often constructed using copper and aluminum. The strive for heat exchangers that are more compact and highly efficient has led to the development of micro-channel heat exchangers. The innovative micro-channel heat and mass exchangers appear to be the most promising way to meet these challenges in thermal management. When properly designed and utilized, micro-channels can distribute the flow precisely among the channels, reduce flow travel length, and establish laminar flow in the channels while achieving high heat transfer coefficients, high surface area-to-volume ratios, and reduced overall pressure drops. These are among the major advantages of micro-channels for use in a diverse range of industries.

Keywords: Heat Exchanger, Nano-fluid.

I. INTRODUCTION

A. Heat Exchanger

Heat exchanger is process equipment designed for the effective transfer of heat energy between two fluids. For the heat transfer to occur two fluids must be at different temperatures and they must come thermal contact. Heat exchanger involve convection in each fluid and conduction through the separating wall. Heat can flow only from hotter to cooler fluids, as per the second law of thermodynamics.

B. Micro-channel Heat Exchangers

In the last two decades, thermodynamic systems, either motors or thermal converters (cooling systems and heat pumps) have achieved better performances. This can be explained on one hand by the better knowledge of the processes that occur in these systems, thus allowing their design and functional optimization. On the other hand, their improvement comes from using new materials, especially for new types of compact heat exchangers which lead to enhanced heat transfer per unit volume and a higher heat transfer coefficient. In recent years, a very important contribution on increasing the performance of these systems, sometimes to levels once inconceivable, was obtained by using nano-technologies which have allowed the production of a new generation of compact heat exchangers with micro-channels.

Micro-channel Heat Exchangers (MCHEX) have, according to the classification proposed by Kandlikar and Grande, a hydraulic diameter h =0.2….0.01mm involving the advantage of a large heat exchange surface in a very small volume. Also, at very small sizes, the processes of heat and mass transfer occurring in the dynamic and thermal boundary layers are very effective. These new types of heat exchangers provide high heat transfer coefficients and thus they are up to 45% more compact than the classic ones, at the same thermal performances. Due to high thermal performance, MCHEX are used increasingly in both single-phase (liquid or gas) and two-phase heat exchange (condensation - evaporation); while the disadvantage of higher pumping power is compensated by the lower scale and cost obtained in the case of improved series production based on nano-technologies series production improvement. Using the MCHEX in vapor compression refrigeration systems, microchannel tubes having a lower internal volume will reduce the amount of refrigerant charged in the plant.

C. Ceramic Micro-channel Heat Exchangers

Materials used in heat exchangers can be divided into four categories polymers, metals, ceramics and carbonaceous materials. Doubtlessly the most widely adopted material is metal due to its high thermal conductivity. Instead of

depending upon monolithic materials composite materials can also be employed. Composite materials offer engineers an ability to. Create a limitless number of new material systems having unique properties that cannot be obtained using a single monolithic material. This approach to construction holds tremendous promise for future heat exchanger designs rather than selecting a single material, multiple materials may be selected and then tailored to meet the specific requirements of the application. The two main advantages for using ceramic materials in heat exchanger construction over more traditional metallic materials are their temperature resistance and corrosion resistance.
First, ceramic materials can withstand operating temperatures (i.e.14000C) that far exceed those of conventional metallic alloys. For example, the bulk material temperature of a heat exchanger made of carbon steel should not exceed 4250C. Similarly, the bulk material temperature of a heat exchanger manufactured from stainless steel typically should not exceed 6500C. The second major advantage of ceramic-based heat exchangers is their resistance to corrosion and chemical erosion. Corrosion which occurs under normal conditions is exacerbated by elevated operating temperatures. Although the impetus behind the use of ceramics in the manufacturing and design of heat exchangers arises from their excellent corrosive properties, their ability to withstand extremely high operating temperatures, and the economics of their use in heat recovery systems, radiant heating applications, and micro-reactors, major obstacles facing the incorporation and use of ceramics in these systems remain. These obstacles include ceramic metallic mechanical sealing, manufacturing costs and methods, and their brittleness in tension. Therefore, to help meet the specific requirements of the application, ceramic matrix composites (CMCs) were developed to overcome the intrinsic brittleness and lack of reliability of monolithic ceramics.

D. Nano- Fluids

Nano fluids are dilute liquid suspended nano particles which have only one critical dimension smaller than ~100nm. Much research work has been made in the past decade to this new type of material because of its high rated properties and behavior associated with heat transfer (Masuda1993; Choi 1995), mass transfer (Krishnamurthy 2006, Olle 2006). The thermal behavior of nano fluids could provide a basis for an huge innovation for heat transfer, which is a major importance to number of industrial sectors including transportation, power generation, micro-manufacturing, thermal therapy for cancer treatment, chemical and metallurgical sectors, as well as heating, cooling, ventilation and air-conditioning. Nano fluids are also important for the production of nano structured materials (Kinloch 2002), for the engineering of complex fluids (Tohver 2001), as well as for cleaning oil from surfaces due to their excellent wetting and spreading behavior (Wasan & Nikolov 2003).

E. History Of Nano-fluids

The twenty-first century is an era of technological development and has already seen many changes in almost every industry. The introduction of nano science and technology is based on the famous phrase "There's Plenty of Room at the Bottom" by the Nobel Prize-winning physicist Richard Feynman in 1959. Feynman proposed this concept using a set of conventional-sized robot arms to construct a replica of themselves but one tenth the original size then using that new set of arms to manufacture a even smaller set until the molecular scale is reached.

F. Preparation Of Nanofluid

The preparation of nano fluid is the first important step in using nano phase particles to change the heat transfer rate of conventional fluids. Nano fluids are mainly made up of metals, oxides, carbides and carbon nano tubes that can easily be dispensed in heat transferring fluids, such as water, ethylene glycol, hydrocarbons and fluorocarbons by addition of stabilizing agents. Nano particles can also be produced from several processes namely gas condensation, mechanical attribution or chemical precipitation. These nanoparticles can also be produced under cleaner conditions and their surface can be protected from unexpected coatings which may occur during the gas condensation process. The main limitation of such method is that the all particles made by this method occur with some incapability to produce pure metallic nano powders. The formation of such a problem can be reduced by using a direct evaporation condensation method. This method helps in controlling particle size and produces particles for stable nano fluids without surfactants or any electrostatic stabilizers, but has the disadvantage of oxidation of pure metals and low vapor pressure fluids. There are mainly four steps in the process of the direct evaporation condensation method also known as one step method.

1. A cylinder containing a heat transferring fluid such as water or ethylene glycol is rotated inside so that a thin film of the fluid is constantly ejected out through the top of the chamber.
2. A piece of metallic material is evaporated by heating on a crucible as the source of the nano particles.

IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319 5940
International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 6, Issue 10, October 2017

3. The fluid is allowed to cool at the bottom of the chamber to prevent any sort of unwanted evaporation.
Another method for synthesis of nano fluid is the laser ablation method, which is used to produce alumina nano fluids. Pure chemical synthesis is also an alternative method which has been used by Patel to prepare gold and silver nanofluids. Zhu also used one-step pure chemical synthesis method for preparing nanofluids using copper nano particles dispensed in ethylene glycol. There are basically four properties for the synthesis of nano fluids or important factors. They are basically,
1. Dispensing ability of nano particles
2. Stability factor of nano particles
3. Chemical compatibility associated to nano particles
4. Thermal stability of nano fluids.

II METHODOLOGY AND DESIGN PROCESS

A. Construction And Working

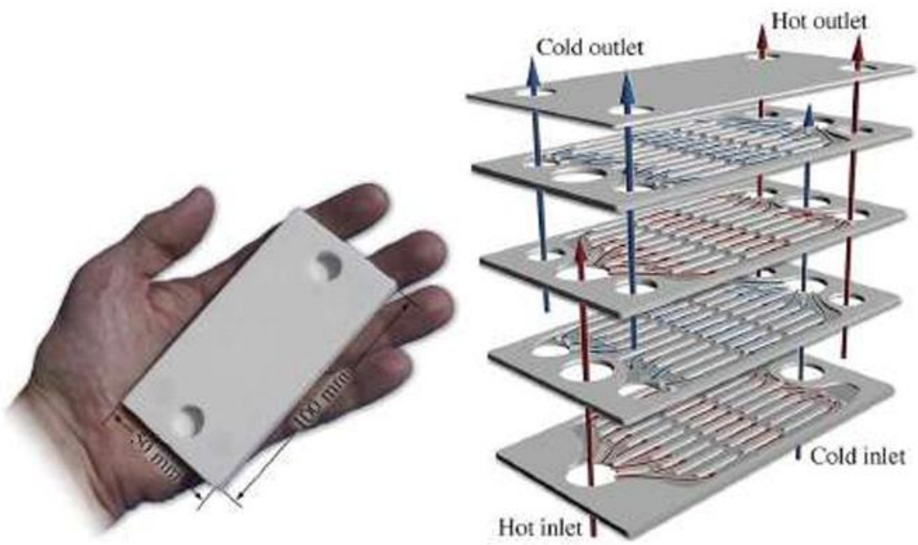

Fig. 1. Typical Counter-Flow MCHX

The design has an overall footprint of 50 mm by 100 mm. Each flow layer contains 10 microchannels that are approximately 550 microns high and 2.8mmwide. The channel floors that separate the hot and cold streams are approximately 600 microns thick. The axial gaps in channel ribs serve three purposes. The first is to enable pressure equalization between channels. The axial pressure drop is approximately inversely proportional to the cube of the channel height, which means that small fabrication variations have a large impact upon flow distribution between channels. Thus, the gaps tend to improve flow distribution. The gaps serve a secondary purpose by tending to reduce potentially deleterious longitudinal wall conduction. Conduction along the channel floors and ribs (i.e., parallel to the flow direction) is known to degrade counter-flow performance toward the lower performance of co-flow heat exchangers, especially for high-effectiveness designs A third beneficial effect of the rib gaps is to cause local entry-length boundary-layer behaviour as the flow enters the micro-channel sections, which serves to increase local heat-transfer coefficients. As illustrated in Fig.2.1, the hot and cold fluids enter through central holes from the bottom and exit via outboard holes at the top. Each of the internal layers is identical, but with alternating layers rotated 1800 relative to the underlying layer. The feed and exhaust manifolds at the ends of the layers are designed such that there is exact alignment upon layer rotation. Using identical layers reduces the manufacturing cost. One of flow directions can be reversed (i.e., inlet flow through the outboard holes), producing a co flow configuration. The heat exchangers to date have been fabricated with four flow layers (two hot and two cold), but are designed to accommodate more flow layers. The relatively large diameters of the central inlets and the outboard exhausts enable the use of many heat-exchanger layers. The large diameters also enable the staging of several heat exchangers without significant pressure drops in the connecting tubing.

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 6, Issue 10, October 2017

B. Design and Fabrication

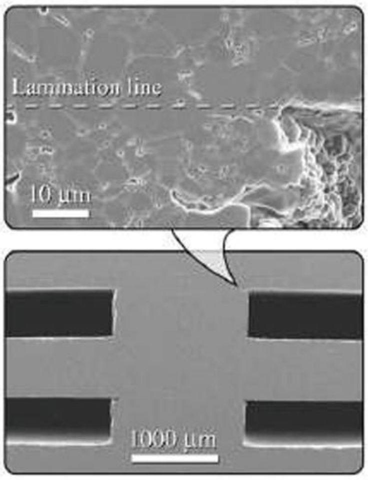

Fig. 2. Scanning electron microscope images showing channel structures.

Various methods used for the fabrication of micro-channels include Micro Machining, Diffusion Bonding, Chemical Etching, Stereo lithography, LIGA and PLIS. Researchers have found the best method for fabrication of ceramic micro-channels as PLIS. The Pressure Laminated Integrated Structures (PLIS) fabrication begins by mixing ceramic powders with appropriate binders. In production, the green (i.e., unfired) layers that incorporate manifold and channel geometry are formed using custom dies and high-pressure hydraulic presses. However, to avoid the expense of fabricating production dies, prototype designs are machined from pressed green state blocks. In preparation for laminating together in a hydraulic press, green layers are oriented and assembled. After laminating the layers in a press, the assembled part is fired. As illustrated by the scanning electron microscope (SEM) images shown aside the fired part becomes a single polycrystalline ceramic piece with essentially no evidence of the bond lines between initially laminated layers. The PLIS manufacturing process depends upon relatively complex interactions among ceramic powders and binders, layer formation pressures, and layer lamination pressures. For example, excessive pressures during lamination can damage or crush channel ribs, while insufficient pressure can cause poor bonding between layers. During development, a careful design of experiments process was used to determine best material combinations and processing conditions. The above fig. is microscopic image that shows essentially perfect polycrystalline joining between layers. In fact, the layers are not “bonded” together. Rather, after sintering the resulting part is a single polycrystalline ceramic. Prior to heat-exchanger testing, the finished parts are leak tested to an internal pressure of 3 atm, assuring no external leaks between layers or to the outside.

III OBSERVATION

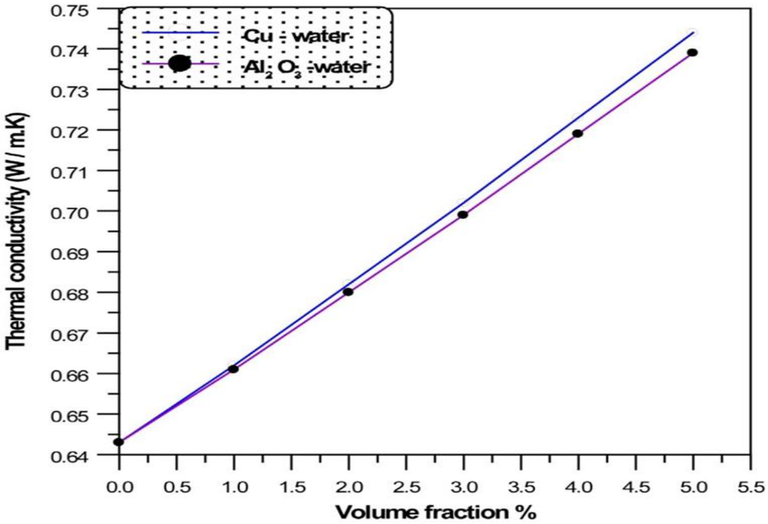

Fig. 3. Variation of thermal conductivity with volume fraction for two types of nanofluids.

Copyright to IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 6, Issue 10, October 2017

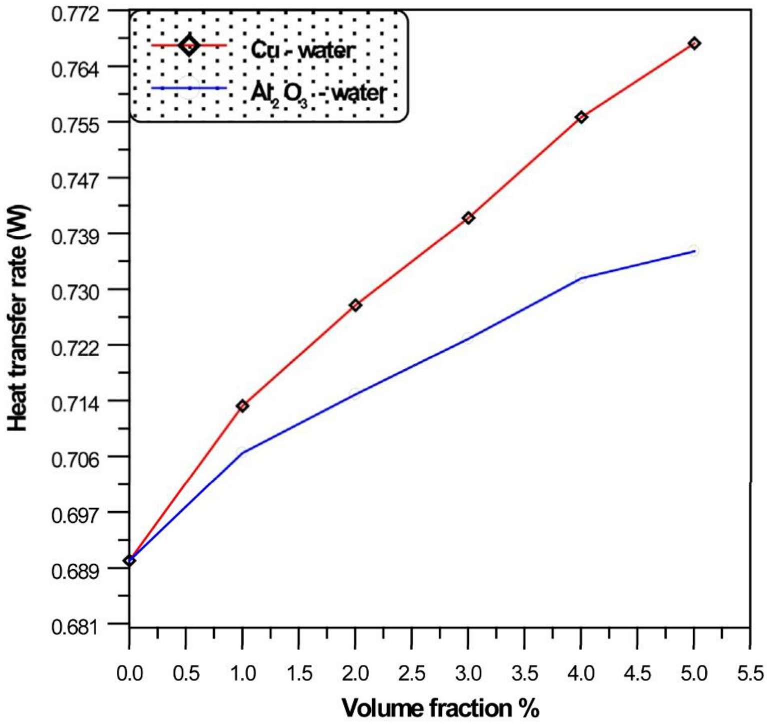

Fig. 4. Variation of heat transfer rate with volume fraction for two types of nanofluids

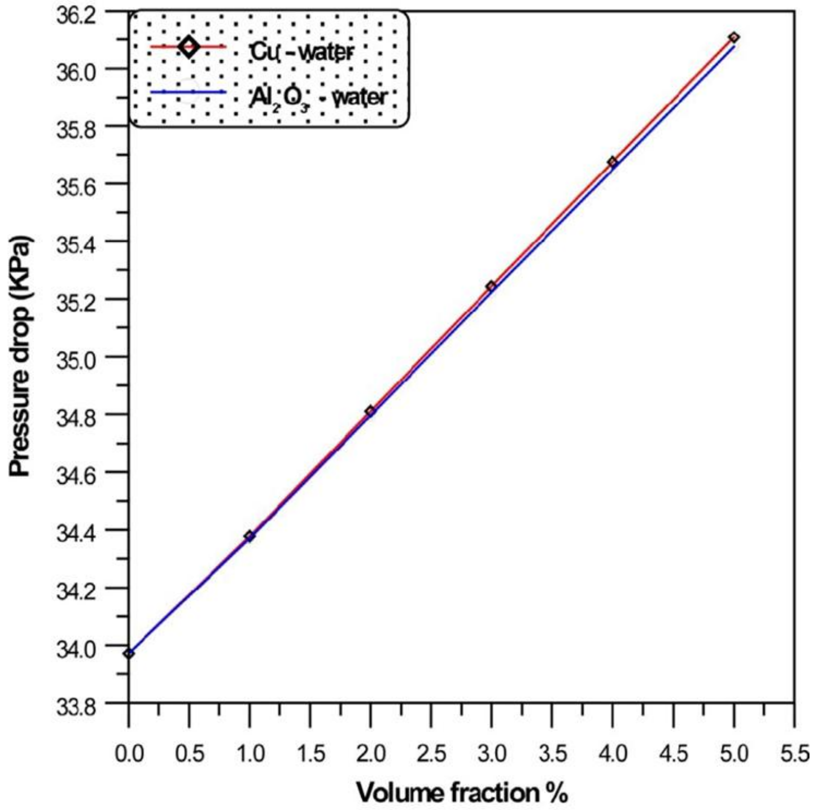

Fig.5. Variation of pressure drop with volume fraction for two types of nanofluids.

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 6, Issue 10, October 2017

IV ADVANTAGES & DISADVANTAGES

A. Advantages

- As 0.01mm-0.2mm small diameter tubes leading to high heat transfer area per operational volume unit High heat transfer coefficients.
- Machine tools involved lead to point by point processing; reduction of energy consumption and material.
- More than the conventional fin tube evaporator heat exchangers.
- More compact if MCHX used as evaporator than conventional fin tube heat exchangers.
- Aluminum construction yields high durability and is easy to recycle.

B. Disadvantages

- High pressure losses due to small size; requires use of high pressure.
- High price resulting in limited use.
- Limited knowledge involving engineering methods at this scale.

V APPLICATIONS

- Residential air conditioning (indoor units)
- Commercial cooling applications (rooftop units)
- Refrigeration applications, including retail food storage and bottle cooling
- Transportation (e.g., refrigerator trucks)

VI CONCLUSION

Rapid advancements in micro-machining and micro-deformation techniques are reducing the cost of fabrication while improving the reliability of micro-channel systems, thus minimizing one of the main limitations of micro-channels. Micro-channel heat exchangers provide enhanced heat transfer rate with minimized pressure drop along with the other advantages of compact size, precise distribution of flow and efficient energy conservation. Ceramic materials enable applications at high temperature and in harsh chemical environments that may be difficult to achieve with metal heat exchangers. Micro-channel heat exchangers are becoming an important area of interest in many fields of developing technology that require compact high heat energy removal solutions. Use of nano-fluids lead to increase the effectiveness and cooling performance of a CFMCHE . In general, it can be said that the MCHEX are only at the beginning of their development. Further research is necessary for greater and better use of MCHX.

REFERENCES

[1] A. Sommers, Q. Wang, X. Han , T.Joen, Y.Park, A. Jacobi "CERAMICS AND CERAMIC MATRIX COMPOSITES FOR HEAT EXCHANGERS IN ADVANCED THERMAL SYSYTEMS A REVIEW" Applied Thermal Engineering xxx (2010).

[2] Mushtaq I. Hasan, Abdul Muhsin A. Rageb, Mahmmod Yaghoubi "Investigation of a Counter Flow Microchannel Heat Exchanger Performance with Using Nanofluid as a Coolant", Journal of Electronics Cooling and Thermal Control, Published Online September 2012, PP 35-43.

[3] Detlef Westphalen, Kurt W. Roth, James Brodrick, "Microchannel Heat Exchangers", ASHRAE Journal, American Society of Heating, Refrigerating and Air- Conditioning, December 2003. PP 107-109.

[4] Charles Lewinsohn, "High Efficiency, Ceramic Microchannel Heat Exchangers", American Ceramic Society Bulletin, Vol. 94, No. 5, PP 26-31.

[5] Traian Popescu, Mircea Marinescu, Horaţiu Pop, Gheorghe Popescu, Michel Feidt, " MICROCHANNEL HEAT EXCHANGERS – PRESENT AND PERSPECTIVES", U.P.B. Sci. Bull., Series D, Vol. 74, Iss. 3, 2012 ,PP 56-69.

[6] Alpesh Mehta, Dinesh K Tantia, Nilesh M Jha, Nimit M Patel, " HEAT EXCHANGER USING NANO FLUID", Mehta et al., International Journal of Advanced Engineering Technology IJAET/Vol.III/ Issue IV, Oct.-Dec., 2012, PP 49-54.