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Fabrication and Experimental Analysis of a Novel Micro Heat Exchanger Circuit Printed Using Wooden Charcoal

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ABSTRACT

Modern cooling and heating systems rely heavily on the efficiency of heat exchangers to achieve their desired cooling and heating results. Researchers have a growing obligation to reduce energy loss and improve heat exchanger performance. It's a goal of heat exchanger designers and researchers alike to find ways to speed up the heat transfer from the heat exchanger surface to the heat transfer fluid. The most common way to improve heat transmission is to add longer external surfaces/fins to the airside. Although this strategy increases the system's weight and pressure drop, it also blocks airflow and reduces the pump's ability to move water through the system. Heat transfer enhancement methods now in use are quite complicated in terms of their design, size, long-term performance and economics. Nanofluids, on the other hand, may be used to improve heat transmission. Nanofluid heat transfer techniques, however, are still limited by the wide range and complexity of nanofluids organization. Recent advances in coating technology may help reduce this problem by improving heat transmission via the use of high thermal conductivity coatings on the heat exchanger's outer surface. Two types of carbon will be extracted for our work, one is to etch on the shell outer layer for heat rejection and the second adhesive is to etch on the outer surface of the tube for heat absorption by adding nano copper sulphate in the activated carbon. The chemical like sodium poly acrylate, sulphuric acid, nano copper sulphate, chloroform, xylene will be used to make the activated carbon adhesive in my project. Eventually the performance of the heat exchanger will be analyzed by taking temperature reading of the inlet and outlet of both shell and tube fluids. The rate of heat transfer will evaluate using these results.

I. INTRODUCTION

Heat exchangers are extensively used in industries, and improvement of their performances will improve energy utilization. Commonly, to enhance the thermal performance of heat exchangers, increasing the heat transfer coefficient is largely based on simple geometry configurations, and is referred to as technologies for improving heat transfer. The technology of improved heat transfer attained rapid development and the figure of published papers in this field increases every year. In the 1990s, though the progress in enhanced heat transfer technology has been reduced because a number of people assumed that the technology had been called "repetitive", and the energy price was constant. Then the next generation of enhanced heat transfer technology is claimed, such as 3 D (three dimensions) rib and compound improvement technology.

As far as construction design is concerned, it is classified into two types, (i) the tubular or shell & tube type and (ii) the finned type or extended surface heat exchangers are universally in use. Normally, fluid flows inside the tube whereas the air is directed crosswise between the fins. Since the air has poor thermal conductivity and heat transfer coefficient, it is compulsory to enhance the heat transfer without losing the heat exchanger compactness, hence extended surfaces are added. A cross-sectional view of circular finned– tube cross–flow geometry as exposed in Figure 1.

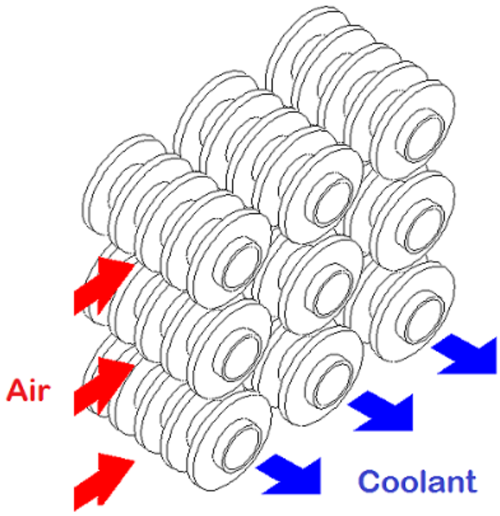

Fig 1 Cross-sectional view of circular finned–tube cross–flow

II. MATERIALS AND METHODS

2.1 Micro/Nano-coating

In general, coating procedures can be broadly classified into three groups; Vapor, fluid and strong phase coatings. The various coating approaches are glow discharge, gas phase chemical processes, evaporation methods and chemical techniques on liquid phase. Environmental conditions strongly affect the chemical composition, residual stress, and microstructure of the coating. A significant number of novel techniques that make use of combining different processes have been established to enhance the coatings in a controlled manner depending on the required applications. Coatings are applied to protect components in a system against corrosion and improve surface properties. These advantages favor coating of thermally sensitive substrates like plastic, large complex shapes and small components to a significant volume that draws the attention of semiconductor, optical, electronics, and several other high–technology fields. Moreover, the environmentally friendly processes guarantee high–quality coatings over other conventional surface treatment methods. Extensive use of the coating is greatly helpful in reducing production cost and improving productivity. The future of these particular coating markets will further expand in various industries such as marine, building, and defense. Revolutionary advancements in nanotechnology promise to unleash a vast potential in the field of coatings and is expected to play a significant role in the shield of the infrastructure and human health. The coating can be done via Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Electroless and electroplating deposition, Sol-gel coating method, dip coating method. The solvent-based coating can be applied to metals by a spin coating technique, spray coating method, and electrospinning technique.

2.2 Physical Vapor Deposition

Physical vapor deposition (PVD) is used to bond thin layers of material, normally in the range of few nanometers to micrometers. It is the preferred method to deposit metals and alloys because no chemical reaction will take place. PVD procedures are environment-friendly. Vacuum deposition methods comprise three fundamental steps as shown in Figure 2.

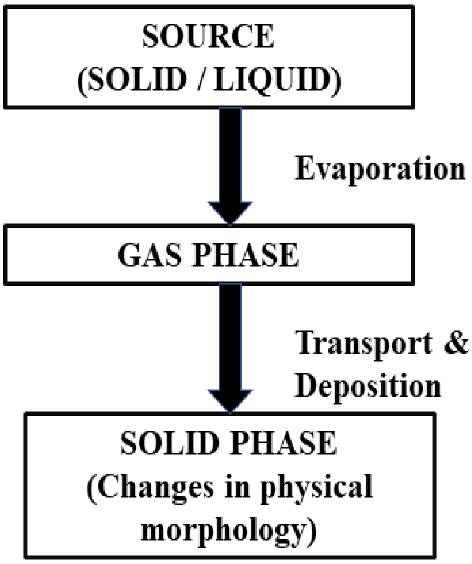

Fig 2 Illustration of a PVD process

2.3 Chemical Vapor Deposition

Chemical vapor deposition (CVD) is a technique used to deposit thin films on wafers or other substrates and this method is frequently used in the semiconductor industry to produce films (Creighton & Ho 2001). Figure 3 shows the process of CVD.

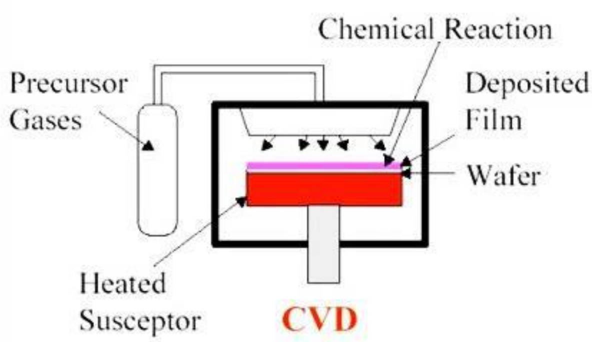

Fig 3 Illustration of a CVD process (Dow Corning Corporation)

2.4Spray Coating

Spray coating is a simple yet extremely scalable method for thin film coating sprayed onto a surface. Thermal spraying can deliver coating in levels of nano/micro thickness. Figure 4 displays spray coating technique.

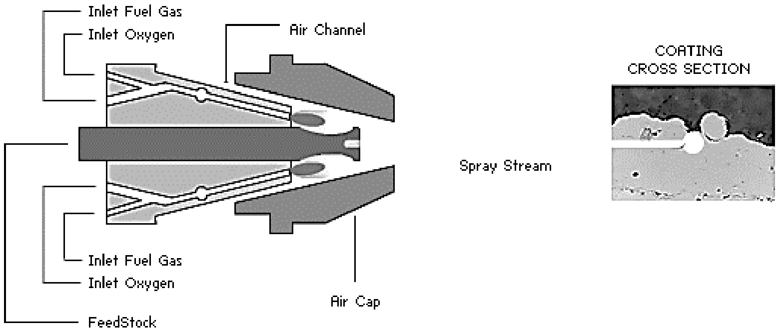

Fig 4 Illustration of a spray coating technique

2.5 Evolution of the carbon etched heat exchanger

A heat exchanger is a device in which heat energy is transferred from one fluidto another across a solid surface. Two important problems in heat exchanger analysis are(1):Ratingexistingheatexchangersand(2):Sizingheatexchangersforaparticular application. Rating involves determination of the rate of heat transfer, the change intemperature ofthe two fluids and the pressure drop across the heat exchanger. Sizinginvolvesselectionofaspecificheatexchangerfromthosecurrentlyavailableordetermining the design of a new heat exchanger forthe industrial application. A Primaryobjective in the Heat exchanger design is the estimation of the minimum heat transfer arearequired for a given heat duty, as it governs the overall cost of heat exchanger. So, thedesign of a heat exchanger usually involves a trial-and-error procedure where for a certaincombination of the design variables the heat transfer area is calculated and then anothercombinationistriedtocheckifthereisanypossibilityofreducingtheheattransferareaand also by withstanding the heat transfer rate/coefficient and temperature change in hotand cold fluid. Conventionally shell and tube heat exchanger is used in all chemical andallied industries for carrying out the heat transfer operations. Increase in the contact timebetweenhotandcoldfluidwillenhancetheheattransfer.Finally,thisaboveconcept (increasing the residence time distribution of fluids) is incorporated in thedesign ofheat exchanger to achieve the minimum heat transfer area and better heattransfer rate. Thisattempt has been made with the help of Pro-E software and the final design from Pro-E isnamedas MeshTypeHeatExchanger.Due to their design, carbon etched heat exchangers offer a less heat transfer area andhighcontacttimebetweenthefluidsandprovidethehighheattransferefficiency incomparisonwith others.

Fig 5 Model of heat exchanger

Steps involved in carbon nano material etching process.

1. **First coating (high thermal bonding material)**

High thermal bonding material is a silica-based material that gives better coupling of carbon nano material with the heat exchanger surface.

2. **Second coating (nano carbon material)**

Carbon nano materials are having high thermal insulating property. The carbon nano materials where coated the surface of the heat exchanger which is already coated with silica-based coating material.

3. **Third coating (curing process)**

This is process for protect the carbon layer and gives long lasting life.in this process hydro carbon solvents where used.

Fig 6 Model of carbon etched heat exchanger

III. RESULT AND DISCUSSION

In the current energy sectors, the performance expected from the heat exchangers plays a vital role in the development of cooling/heating systems for various applications. There is a tremendous need to decrease the energy loss and to increase the efficiency of heat exchangers have created a progressively significant responsibility for the researchers. The researchers, as well as the designers of heat transfer, are devoting their interest towards increasing the heat transfer rate between the heat exchanger surface and the heat transfer fluid (HTF) through several methods. Conventionally adopted enhancement for heat transfer technique is incorporation of prolonged exterior surface/fins to airside. However, this approach increases the overall weight of the system and pressure drop, obstructs airflow and the pumping power. In addition, the challenges in the existing enhancement method of heat transfer are very complex in design, size, long-term performance and economic considerations. On the other hand, heat transfer can be augmented using nanofluids. Nevertheless, due to the extensive range and the difficulty of the nanofluids arrangement, heat transfer mechanisms using nanofluids are still quite restricted. This could be minimized with the support of recent advancements in the arena of coating technology, which provides an opportunity to enhance the heat transfer when the heat exchanger exterior surface is coated with high thermal conductivity materials.

The present research work is aimed to investigate the heat transfer performance of the heat exchanger through recent advancement in coating technologies. Spray coating technique are used in this study to deposit the coatings on copper (Cu) substrate for cooling/heating applications. In addition, the same procedure was adopted to coat the heat exchanger to account for the subsequent enhancement achieved in the heat transfer rate.

In the present work, spray coating technique is used to coat the extracted charcoal from the wooden powder or coconut shell. The extracted charcoal from the material contain carbon and it will modify as activated carbon by using various chemicals. This activated carbon then converted as adhesive and used to paste in the outer layer of the shell and the outer layer of the tubes. Two types of carbon will be extracted for our work, one is to etch on the shell outer layer for heat rejection and the second adhesive is to etch on the outer surface of the tube for heat absorption by adding nano copper sulphate in the activated carbon. The chemical like sodium poly acrylate, sulphuric acid, nano copper sulphate, chloroform, xylene will be used to make the activated carbon adhesive in my project. Eventually the performance of the heat exchanger will be analyzed by taking temperature reading of the inlet and outlet of both shell and tube fluids. The rate of heat transfer will evaluate using these results.

IV. CONCLUSION

- The heat transfer rate is important in the heat–exchange device, as it has become a tough task for engineers in industry. The global demand for efficient, reliable and inexpensive heat exchange apparatus is accelerating rapidly, especially in large–scale industries, air conditioning and refrigeration systems. For improved airside heat transfer enactments, great developments in energy management and the defense of the surroundings are feasible. In recent years, coating technology has evolved globally into a most significant investigation area. The significance of coatings and fabrication of novel materials for manufacturing industry have led to in an amazing improvement of revolutionary coating and thin film technologies. At present, this advancement drives hand–in–hand by the rapid upsurge of technical and technological advances in optics, microelectronics, and nanotechnology.
- Another main field comprises process equipment for coatings with thinness fluctuating from one of few micron levels. These coatings are essentials for a group of manufacturing areas, for instance, thermal barrier and wear protection coatings, improving the service life of tools and protect materials against full of atmosphere and thermal impacts. Presently, rapidly changing requirements for coating material and procedures are generating new barriers for the progress of novel procedures, materials, and technologies. Hence, intense research actions will be essential in the upcoming, progressive predictive abilities for connecting the fundamental chemical and physical properties to the microstructure than the performance of coatings in many applications.
- In the present work, the heat exchanger is coated with a high thermal conductivity activated carbon material to increase the heat transfer performance of the heat exchanger for cooling/heating applications.
- The investigation will successfully evaluate the performance of the micro-coated heat exchanger.

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