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TITLE: A REVIEW ON HEAT TRANSFER ENHANCEMENT BY USING HIGH THERMAL CONDUCTIVITY MATERIAL (NANOGRAPHENE)

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Abstract

Heat transfer enhancement is the process of increasing effectiveness of heat exchanger, this can be achieved when heat transfer power of given device increase or when pressure losses generated by device are reduce. In any object heat transfer take place by conduction, convection & radiation. Consider fin which are often use to enhance heat transfer rate from the base surface, heat transfer take place in fins depend upon material use to make fin, thermal conductivity of material, size of fin etc. Overall heat transfer increase by coating of high thermal conductivity material like nanofluid, nanographene, diamond, gold, silver, yetrium oxide, copper, aluminium, brass etc. Graphene is allotrope of carbon, which is light in weight, thin, durable & low cost. For more heat transfer from fin or any other object with help of grapheme coating on it thermal conductivity of the object are improve. The use of nanofluid on surface of any object can enhance heat transfer rate without increasing pressure drop take place.

***Key words** : Fins, coating , nanographene ,allotropes of carbon, heat transfer enhancement.*

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1.INTRODUCTION

Heat always moves from a warmer place to a cooler place. Hot objects in cooler room will cool to room temperature. Cold objects in a warmer room will heat up to room temperature. Heat is form of energy which passes from a body at higher temperature to a body at a lower temperature. We need heat transfer, to come body in equilibrium. A thermodynamics tells us how much amount of heat transfer from one equillibrium state to another state. If two bodies at same temperature are in contact there is no net heat flow from one body to another. There are three modes of heat transfer as conduction, convection, radiation. In conduction and convection a material required while in radiation, heat travels through a vaccum. For better heat transfer in any object & for more efficient work of engine, there is required of more heat transfer rate in engine to enhance efficiency of engine. Thermal conductivity of any material depends on temperature difference, cross sectional area etc. Heat transfer enhancement has been always a significantly interesting topic in order to develop high efficient, low cost, light weight, and small heat exchanger. The energy cost and environmental issue are also encouraging researchers to achieve better performance than the existing design. Two of the most effective ways to achieve higher heat transfer rate in any body are using different kinds of inserts and modified the object. There are different kinds of inserts employed such as helical/twisted pipes & tapes coiled wire and ribs/fin/baffles, and winglets. From this insert improvement in performance of thermal systems takes place. Consider a objects there is increase heattransfer efficiency by using fins. A fin is surface that extends from an objects to increase heat transfer rate to or from the environment by increasing convection. Aluminium, Copper , Brass, Diamond use to make fin because of its high thermal conductivity property. Heat from the heated wall is conducted through the fin and its convected from the sides of the fin to the surroundings. Utility of fins in dissipating a given quantity of heat is generally assessed on the basis of following parameters like efficiency of fin and effectiveness of fin. Appropriate material for fin is Aluminium to high transmission of heat from the object. It is light in weight, cheap, easily available. Aluminium fins can in time degrade to such an extent that they can not provide required potential. In such condition, special coating material are used to extends the useful life of object.

2. LITERATURE REVIEW

Suspension of nanoparticles like Al, Zn, Si etc. in base fluids are called nanofluids. Nanofluid is the new challenge for thermal science provided by nanotechnology. These nanofluids have unique features different from conventional solid liquid mixtures. They contain mm or micrometer sized particles of metals and non-metals. Due to their excellent physical and chemical characteristics they find wide applications in enhancing heat transfer.

A.K.Singh[1] Defence Institute of Advanced Technology, Pune presented a paper on "Thermal Conductivity of Nanofluids". This study provides a review of nanotechnology with focus on thermal conductivity studies of nanofluids. They concluded that nanofluids have great potential for thermal management and control involved in a variety of applications such as electronic cooling, microelectro mechanical systems (MEMS) and spacecraft thermal management.

C.Choi, H.S.Yoo and J.M.Oh[2]presented a paper on "Preparation and heat transfer properties of nanoparticles – intransformer oil dispersions as advanced energy efficient coolants". They investigated three kinds of nanofluids prepared by dispersing Al2O3 and AIN nanoparticles-in-transformer oil. They found that the thermal conductivity of the nanoparticle oil mixtures increases with particle volume fraction and thermal conductivity of itself.

Elena V. Timofeeva, Wenhua Yu et. al. [3]presented a paper on " Nanofluids for Heat Transfer: An Engineering Approach". In this paper the factors contributing to the fluid cooling efficiency were discussed first, followed by a review of nanofluid engineering parameters and a brief analysis of their contributions to basic thermo-physical properties.

IndranilManna[4] in his paper "Synthesis, Characterization and Application of Nanofluid—An Overview" reviewed an update on the historical evolution of nanofluid concept, possible synthesis routes, level of improvements reported, theoretical understanding of the possible mechanism of heat conduction by nanofluid and scopes of application.

J. A. Eastman, S. U. S. Choi,W. Yu and L. J. Thompson[5] presented paper on "Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles". They experimentally found that a ''nanofluid'' consisting of copper nanometer-sized particles dispersed in ethylene glycol has a much higher effective thermal conductivity than either pure ethylene glycol or ethylene glycol containing the same volume fraction of dispersed oxide nanoparticles.

Ji-Hwan Lee, Seung-Hyun Lee, ChulJin Choi, Seok Pil Jang and Stephen U. S. Choi[6] in their paper "A Review of Thermal Conductivity Data, Mechanisms and Models for Nanofluids" presented a critical review of the classical and new models used to predict the thermal conductivity behavior of nanofluids. They discussed some controversial issues such as data inconsistencies, the sufficiency and suitability of classical and new mechanisms, and the discrepancies between experimental data and model predictions.

L.Xue, P. Keblinski, S.R.Phillot et. al.[7] presented a paper on " Effect of liquid layering at the liquid-solid interface on thermal transport". In this paper they showed how the ordering of the liquid at the liquid-solid interface affects the interfacial resistance. Their simulation of a simple monoatomic liquid shwed no effect on the thermal transport either normal to the surface or parralel to the surface. Also their findings suggest that the experimentally observed large enhancement of thermal conductivity in suspension of solid nanosized particles can not be explained by altered thermal transport proprties of the liquid layer.

M.T. Naik and L. SyamSundar[8] published a paper "Investigation into Thermophysical Properties of Glycol based CuO Nanofluids for Heat Transfer Applications". They presented experimental work on thermal conductivity and viscosity of water-propylene glycol based CuO nanofluids at different temperatures for five different concentrations. They showed that thermal conductivity of CuO nanofluids increases with increase in the CuO nanoparticle concentration in the base fluid.

Pawel Keblinski, Jeffrey A. Eastman and David G. Cahill [9]presented a paper on "Nanofluids for Thermal Transport". In this paper a brief discussion was given about synthesis of nanofluids, thermal transport in stationary fluids, and thermal conductivity of nanofluids.

P. Keblinski, S.R. Phillpot, S.U.S. Choi &J.A.Eastman[10]presented a paper on "Mechanism of Heat Flow in Suspensions of Nano-sized Particles (nanofluids)". In this paper they explained different mechanisms of heat flow in nanofluids.They explained Brownian motion of the particles, molecular level layering of the liquid at the liquid/particle interface, the nature of heat transport in the nanoparticles, and the effects of nanoparticle clustering.

SandipkumarSonawane, Kaustubh Patankar, Ankit Foglaet.al.[11] published a paper on "An Experimental Investigation of Thermophysical Properties and heat transfer performance of Al2O3-Aviation Turbine Fuel Nanofluids". They investigated aviation turbine fuel - Al2O3 for better heat transfer performance in a potential application of

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regeneratively cooled semi-cryogenic rocket engine thrust chambers. They experimentally measured the thermophysical properties of aviation turbine fuel - Al2O3 nanofluid. They varied volume concentration of Al2O3 nanoparticle between 0 to 1%. They found that at 1% particle volume concentration the enhancement in the thermal conductivity was 40% and the increase in the viscosity was found to be 38%.

Sarit Kumar Das, Stephen U.S. Choi & Hrishikesh E. Patel [12]presented a paper on "Heat Transfer in Nanofluids-A Review". In this paper they presented an exhaustive review of nanotechnology study and suggest a direction for future developments in nanotechnology. The conclusion drawn in this paper is that nanofluids show great promise for use in cooling and related technologies. They observed maximum enhancement (~160%) with 1% volume fraction with multi-walled carbon nanotubes dispersed in engine oil.

Seok Pil Jang and S.U.S.Choi[13]presented a paper on "Role of Brownian Motion in the Enhanced Thermal Conductivity of Nanofluids". In this paper they devised a theoretical model that accounts for the fundamental role of dynamic nanoparticles in nanofluids. The model not only captures the concentration and temperature dependent conductivity but also predicts strongly size-dependent conductivity.

S.U.S.Choi and J.A.Eastman[14] presented a paper on "Enhancing Thermal Conductivity of Fluids with Nanoparticles".
They provided information related to technology for production of nanoparticles and suspensions and theoretical study of thermal conductivity of nanofluids.They estimated potential benefits of nanofluids with copper nanophase materials.

Yulong Ding, Haisheng Chen et. al. [15]presented a paper on " Heat Transfer Intensification Using Nanofluids". This paper summarized some recent work on the heat transfer of nanofluids. It covered heat conduction, convective heat transfer under both natural and forced flow conditions, and boiling heat transfer in the nucleate regime.

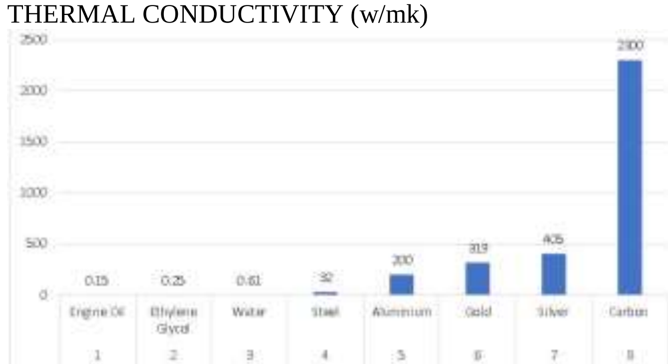
Kulwant Dhankar, Krishna Diwvedi, Hemant More, SmitaGanjare, Rohit Hankare.[16]Nanofluids consist of a base fluid enriched with nano size particles (less than 100 nm). The base fluids which we use for enrichment of nanoparticles like Water, Ethylene Glycol or oil with nanoparticles like metals, oxides, carbides, carbon. Mostly common examples of nanofluids are TiO2 in water, Al2O3 in water, CuO in water, ZnO in Ethylene glycol.
The heat transfer rates was lacking because low values of thermal conductivities of conventional cooling fluids. As a result there was a need to increase heat transfer rates with significantly increase in value of thermal conductivities. However, the micro sized particles are recline to sedimentation and clogging in micro channels. In contrast to that nanofluid is stable colloidal suspension of a low volume fraction of solid particles of nano size, dispersed in traditional heat transfer fluid, which is offering us enhancement of fluid thermal conductivity without sedimentation and clogging problems.

NEED OF NANOFLUIDS:
 Due to size of nano particles, pressure drop is minimum.
 Higher thermal conductivity of nano particles will increase the heat transfer rates.
 Successful employment of nanofluid can lead to shorter and smaller heat exchanger.
 Drastic change in the properties of base fluids.
 Nanofluids are most suitable for rapid heating and cooling systems.
 Increase in the rate of heat transfer due to large surface area of nanoparticles in base fluids.

Nowadays nanofluids have attracted much attention. The reason for this is their potential as high performance heat transfer fluids in electronic cooling and automotive. Effectiveness and high compactness of heat exchangers are obstructed the lower heat transfer properties of fluids as compared to solid. So it is more obvious that solid particles have high thermal conductivity (100times higher than fluids). In such case slurries have better thermal conductivities than fluid but it is not practical.

There are 2 primary preparation methods for nanofluids:
a) Two step method:
 In which nanoparticles are 1st produced as dry powder
 This dry powder is then dispersed into fluids
b) Single step method:
 Using methods like direct evaporation, condensation, chemical vapour condensation and single step chemical synthesis
 There are other novel methods like micro fluidic microreactor to synthesize **copper** nanofluids

THERMAL CONDUCTIVITY (w/mk)



Graph 1- (Thermal conductivities of various material)

Solids have thermal conductivities that are orders of magnitude larger than those of conventional heat transfer fluids

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Sr. No.	Material	Tthermal Conductivity (w/mk)
1	Engine Oil	0.15
2	Ethylene Glycol	0.25
3	Water	0.61
4	Steel	32
5	Aluminium	200
6	Gold	319
7	Silver	405
8	Carbon	2300

Table -1

Notations

C – heat capacity, [J/kgK] D – diameter, [m]
k – thermal conductivity, [W/mK] Nu – Nusselt number
Pr – Prandtl number ℜ – Reynold's number
α – convective coefficient, [W/m2K]

3. HEAT TRANSFER ENHANCEMENT BY NANOFLUIDS

A Nanofluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspension of nanoparticle in base fluid. Nanofluids are solid liquid composite materials has the ability to transfer heat across a small temperature difference enhances the efficiency of energy conversion and improves the design of automobile engine and improves the heat transfer rate.

1)**Types Of Nanofluid**

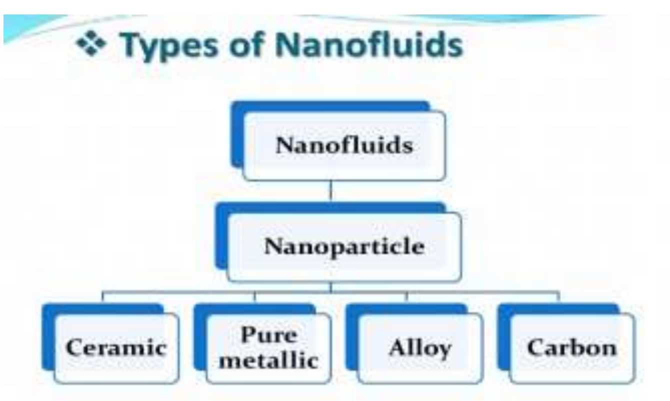

Fig.1: Types of Nanofluids

i) Effect of some parametrs on Thermal conductivity of nanofluid

1. Particle volume Fraction
2. Particle size
3. Particle shape
4. Particle material
5. Base fluid
6. Temperature
7. Effect of Acidity(pH)

ii) Mechanism of Heat Transfer Enhancement

a) Clustering of Nano Particles

It results in fast heat transfer along relatively long distance. Since heat can be conducted much faster by solid particles compare to liquid.

b) Effect of Brownian Motion (BM)

BM intensifies increase in temperature as per the kinetic theory of particle to enhance the heat transfer.

Fig.2: nanographene in black powder form

4. NANOGRAPHENE

To enhance the properties of metals such as Aluminium, Copper, Magnesium and polymer such as PDMS, epoxy, Polyethylene which are extensively use, by reinforcing them with graphene which is a material having high tensile strength, thermal conductivity,opticaltranmittance and various other mechanical and physical properties. Graphene is an ultra-thin layer of carbon atoms arranged in hexagonal pattern like chicken wire.

i) Reason to use Nanographene for Enhancement of Heat Transfer

a) Thermal Conductivity

Graphene has very high thermal comductivity (upto~5,300W/(mK)) allows for heat to be quickly spread away from a heat source. In a sheet form graphene can be use as a thermal spreader in mobile electronics.

b) Electrical Conductivity

Graphene has amazing electrical conductivity due to its excellent electron mobility.

c) Mechanical Enhancement

Graphene has the highest intrinsic strength of all material(upto~130 GPa).

It has very high specific surface area.

d) Process Enhancement

Because of Graphene exceptional thermal conductivity properties, the time that of takes for materials to be processed can be reduce. Due to this enhancement can lead to saving in production cost for various operation.

e) Barrier Properties

Graphene addition to a coating formulation dramatically improve the coating barriers.

f) Clarity in Thin Film

Even though Graphene in powder form appears black, a thin film of graphene blocks only 3% of light and is transparent and conductive.

ii) Structure of Nanographene

1. It is the one-atom thick planar sheet of carbon atoms(Graphite), which makes it the thinnest material ever discovered.
2. 2-dimensional crystalline allotrope of carbon.
3. C-C bond length is 0.142 nm.
4. It is almost completely transparent, yet so dense that not even Helium can pass through it.

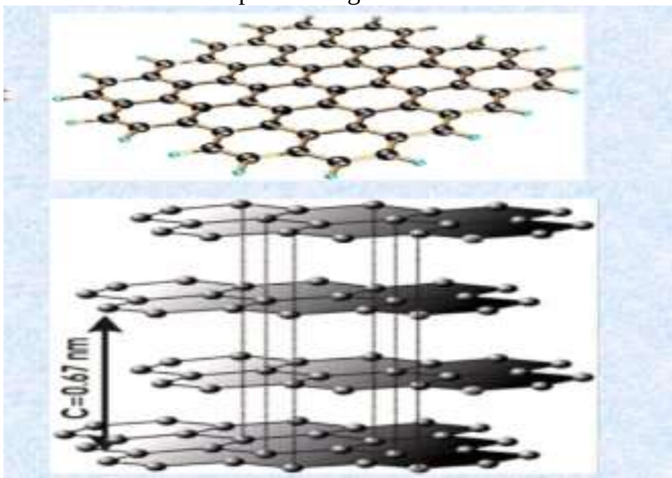

Fig.4.(ii): Structure of Nanographene

iii) Properties of Nanographene

1. A graphene sheet is thermodynamically most stable only for molecules larger than 24,000 atoms and size greater than 20 nm.
2. Thermal conductivity is measure to be between (4.84+-0.44)* 1000 to (5.30+-0.48)*1000 W/mK.
3. Thermal conductivity (~5000W/mK)
4. High intrinsic mobility.
5. Optical transmittance.

5.COATING OF FIN TO ENHANCE HEAT TRANSFER RATE

In coating materials are used to extend the useful life of the exchanger.consideration of performance and cost-friendliness,the most appropriate fin material for fin for heat transfer is Aluminium. Aluminium is more advantageous for its high transmission, resistance and lightness also cheap and easily available. However, in highly corrosive environments that are acidic, salty or with water, Aluminum fins can in time degrade to such an extent that they can not provide the required potential. In such severe conditions, specially The most commonly used coating material for protecting metal surfaces from salty or acidic environments is nanographene. The resistance of graphene coated Aluminum to corrosion delivers satisfying results in many industrial applications commonly encountered in practical applications. The graphene coating method is used as the most economical and effective method particularly in protecting metal surfaces exposed to the corrosive influence of the humid and salty air in regions with marine climates. In cases where the corrosive effect of liquid water is a more important factor than that of acid and salt, the need arises for a coating on which the water can be removed without staying on the fin for long. These coatings are classified under the general term of hydrophilic. This term is used to represent materials that are not easily wetted and they enable the fluid to flow easily off the surface. Hydrophilic coatings are particularly effective in environments of excessive condensation, to protect the exchanger from the corrosive effect of water. Water collects on the uncoated surface of the metal in large droplets. This leads to corrosion of the metals by the droplets, with the aid of the air flowing over the fins.

Coatings applied on Aluminum finned heat exchangers, the corrosive resistance of metals that are costly and difficult to process can be attained in a more economical way. The important point in this is to determine the need accurately and to apply the coating that will deliver the required resistance properties. It must be kept in mind that the application of coating in places where it is not needed will lead to unnecessary costs and that exchangers to which that coating which is required by the operating conditions has not been applied will not be long lived.

6. FUTURE SCOPE

1. They are also use in bulk and other microelectronics.
2. Effect of nanofluid like agglomeration, cogulation should be avoided.
3. The chaotic movement of nano particles increases fluctuation and turbulence of fluids, which increase the heat exchange process.
4. There is always a chance of development of some new experimental or numerical methods which can give the new hight in the field.
5. Growth of wafer scale.
6. Challenges in making stronger composite material use in aircraft parts.

7. Improves the heat transfer rate.
8. Fin thickness of fin.
9. Orientation of fin.
10. Different other fluid can be used as working medium for the future work.

7. CONCLUSION

We can conclude that nanofluids, thermal conductivity increases with increment in particles volume fraction and temperature. It enhances heat transfer efficiency by coating nanographene. The efficiency of annular composite fins with rectangular profile, when coated with nanographeneunder two dimensional steady state conditions. The efficiency of fin increases with core thickness increase. Nanographene coating have high thermal conductivity which enhance heat transfer efficiency.

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