Enhancement of Heat Transfer by Nanofluids in Solar Collectors

Santhisree Nerella
Department of MECHANICAL Engineering
Institute Of Aeronautical Engineering, Hyderabad, India

Dr.N.V.V.S.Sudheer
Department of MECHANICAL Engineering
R.V.R. & J.C.College Of Engineering, Guntur, Andhrapradesh, India

Dr. P. Bhramara
Department of MECHANICAL Engineering
Jntuh .College Of Engineering, Hyderabad, India

Abstract- Research and development activities are carried out to improve the heat transfer process to reduce the energy loss, which is an important task in this era of the great demand for energy. The heat transfer process can be improved by means of active and passive techniques .The Heat transfer rates can be enhanced in solar collectors with dispersion of Nanoparticles in to it The advanced research in nanotechnology emerging heat transfer fluids called nano fluids which are *colloidal mixtures of nanometric metallic or ceramic particles in abase fluid, such as water, ethylene glycol or oil. Nanofluids possess immense potential to enhance the heat transfer character of the original fluid due to improved thermal transport properties*. By using these nanofluids instead of conventional fluids, the heat transfer rate can be increased. Enhancement can be done in heat transfer by conduction, convective heat transfer under both natural and forced flow conditions, and boiling heat transfer in the nucleate regime.
Keywords – nanofluids, heat transfer enhancement techniques, solar energy, and solar collector

I. INTRODUCTON

Solar Energy: A worldwide research and development in the field of renewable energy resources and systems is carried out during the last two decades. As known fossil fuels are expensive, require for a stockroom, combustion of them makes pollution of the atmosphere and resources of fossil fuels in the nearest future will run away .Like an alternative energy sources it is possible to use: biomass, biogas, waterpower, wind energy, geothermal heat and solar radiation. Energy conversion systems that are based on renewable energy technologies appeared to be cost effective compared to the projected high cost of oil. Solar thermal systems are non-polluting and offer significant protection of the environment. The reduction of greenhouse gasses pollution is the main advantage of utilizing solar energy. Therefore, solar thermal systems should be employed whenever possible in order to achieve a sustainable future. Converting the suns' radiant energy to heat is the most common and well-developed solar conversion technology today. The temperature level and amount of this converted energy are the key parameters that must be known to match a conversion scheme to a specific task effectively. Conversion of solar radiation to other energy forms

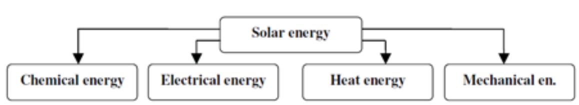

Fig: 1 Conversion of solar energy

Most solar water heating systems have two main parts: solar collector and a storage tank. Solar thermal collector essentially forms the first unit in a solar thermal heat transport fluid. The heat transport fluid delivers this heat to thermal storage tank/boiler/heat exchanger etc system. It absorbs solar energy, converts into heat and then transfers it to be utilized in the subsequent stages of the system.

Classification of solar collectors according to concentration degree

Category	Example	Temperature range, °C	Efficiency, %
No concentration	Flat-plate Evacuated tube	up to 75 up to 200	30 – 50
Medium concentration	Parabolic cylinder	150 - 500	50 – 70
High concentration	Parabodial	1500 and more	60 - 75

Table 1: Classification of solar collectors

II. DIFFERENT METHODS OF HEAT TRANSFER ENHANCEMENT

- **Active method**: This method involves some external power input for the enhancement of heat transfer; Techniques like mechanical agitating, rotating, vibration and the use of electrostatic or magnetic fields are used successfully for heat transfer improvement. However, the requirement of an external energy input viscosity and it is inconvenient under critical operations
- **Passive method**: These methods generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. Passive techniques include methods to modify the fluids' property, surface shape, roughness or external attachment to increase the surface area, and make the flow turbulent. However, a novel concept of dispersing solid particles (**NANOFLIDS**) in base fluids to break the fundamental limit of heat transfer having low thermal conductivities is introduced. These methods found more inexpensive compared to other two.
- **Compound method** Combination of above two methods. This involves complex design and hence limited applications.

.III. NANOFLUIDS

Cooling capabilities of heat transfer equipments have been constrained because of the low thermal conductivity of conventional heat transfer fluids. However, it is well known that, metals in solid form heavy orders-of-magnitude higher thermal conductivities than those of fluids. For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil. Therefore, the thermal conductivities of fluids that contain suspended solid metallic particles could be expected to be significantly higher than those of conventional heat transfer fluids .Applying nano technology to thermal engineering, the novel concept of "nanofluids". This new class of heat transfer fluids is engineered by dispersing nanometer-sized solid particles in traditional heat transfer fluids such as water, ethylene glycol or engine oil. The goal of nano fluids is to achieve the highest possible thermal properties at the smallest possible concentrations by uniform dispersion and stable suspension of nano particles (preferably <10 nm) in host fluids. Nanotechnology provides new area of research to process and produce materials with average crystallite sizes below 100 nm called nano materials. The term "nano materials" encompasses a wide range of materials including nano crystalline materials, nano composites, carbon nano tubes .

The Nano layer works as a thermal bridge between the liquid base fluid and the solid Nano particles and a nano fluid consists of the liquid base fluid, the solid Nano particles and the Nano layers

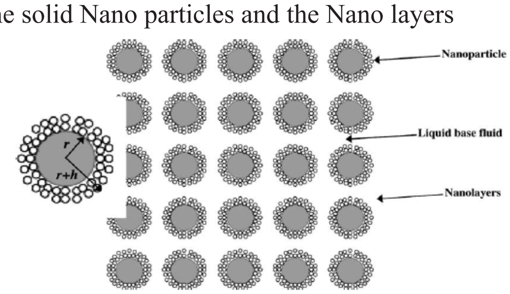

Fig: 2 Structure of Nanofluids

Nanofluids clearly exhibit improved thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficient. The property change of nanofluids depends on the volumetric fraction of Nano particles, shape and size of the Nano material's.

Different materials with thermal conductivity values:

	Materials	Thermal conductivity (W/mk)
Metallic Materials	Copper	401
	Silver	429
Nonmetallic Materials	Silicon	148
	Alumina (Al_2O_3)	40
Carbon	Carbon Nano Tubes (CNT)	2000
Base fluids	Water	0.613
	Ethylene glycol (EG)	0.253
	Engine oil (EO)	0.145
Nanofluids	Water/Al_2O_3 (1.50)	0.629
	EG/ Al_2O_3 (3.00)	0.278
(Nanoparticle concentration %)	EG-Water/Al_2O_3 (3.00)	0.382
	Water/TiO_2 (0.75)	0.682
	Water/ CuO (1.00)	0.619

Table2: THERMAL CONDUCTIVITY OF MATERIALS

Preparation of nanofluids

To prepare nanofluids by suspending nanoparticles into base fluids, some special requirements are necessary such as even suspension, durable and stable suspension, low agglomeration of particles and no chemical change of fluid.

Scientists developed some methods for producing nanofluids for heat transfer applications

- Two -step method
- One step method
- Phase transfer method (for preparing stable kerosene based nanofluids)
- Chemical precipitation method (for synthesizing Fe_3O_4 Nano particles)

TWO STEP METHOD

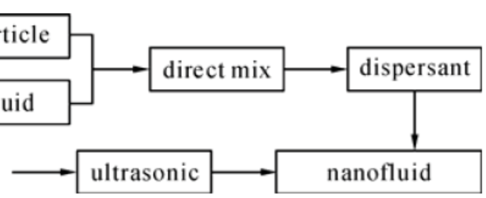

FIG 3 : TWO STEP METHOD OF PREPARATION OF NANOFLUIDS

Reasons for Heat transfer Enhancement by nanofluids in solar collectors

- Absorption of solar energy will be maximized with change of the size, shape, material, and volume fraction of the Nano particles.
- The main reason of heat transfer enhancement of nanofluids may be from intensification of turbulent or eddy, suppression or interruption of the boundary layer as well as dispersion or back mixing of the suspended Nano particles, besides substantial augmentation of thermal conductivity and heat capacity of fluid.
- Therefore the convective heat transfer coefficient of nanofluids is a function of properties, dimension and volume fraction of suspended Nano particles as well as flow velocity .Heat transfer enhancement in solar devices is one of the key issues of energy saving and compact designs .

IV. HEAT TRANSFER MECHANISMS IN NANOFLUIDS

The discrepancy in nano fluid thermal conductivity data can be enhanced by using several mechanisms such as

Brownian motion of Nano particles: Dynamic models assume that nanoparticles are in constant, random motion in the base fluid In the dynamic models, it is believed that this random motion may be the main cause of the increased thermal properties associated with nanofluids.Convection in the liquid induced by Brownian motion of nano particles was mainly responsible for the anomalous thermal conductivity enhancement of nanofluids.

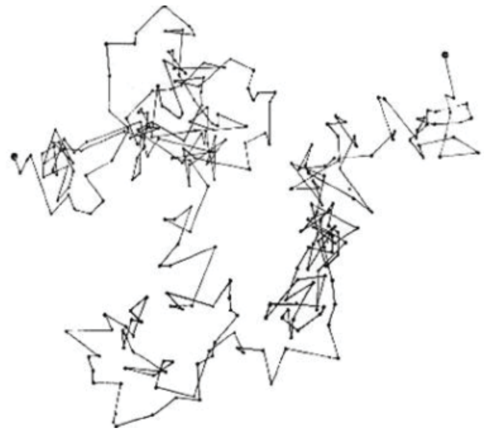

FIG 4: BROWNIAN MOTION OF NANO PARTICLES

- **Clustering of Nano particles**

Clustering is the formation of larger particles through aggregation of Nano particles. Clustering effect is always present in nanofluids and it is an effective parameter in thermal conductivity. Nano particles are known to form clusters these clusters can result in fast transport of heat along relatively large distances since heat can be conducted much faster by solid particles when compared to liquid matrix. It was stated that this behaviors due to the fact that Nano particles in the nanofluids with high volume fractions formed clusters at a higher rate.

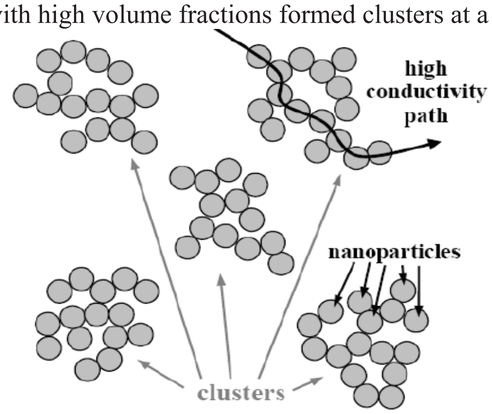

FIG 5: CLUSTERING OF NANOPARTICLES

- **Liquid layering around Nano particles**: At the solid-liquid interface, liquid molecules could be significantly more ordered than those in the bulk liquid. By analogy to the thermal behavior of crystalline solids, the ordered structure could be a mechanism of thermal conductivity Enhancement.

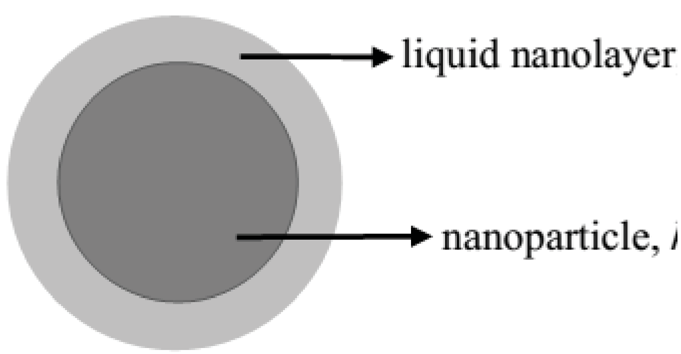

FIG 6: LIQUID LAYERING OF NANOPARTICLES

Nano fluids in solar collectors:

Solar collectors have been proposed for a variety of applications such as water heating; small solar power plants etc however the efficiency of these collectors is limited by the absorption properties of the working fluid. The improvements of efficiency in solar thermal collectors by utilizing nanofluids with base fluid are highly comparable with the efficiency of solar collector when only base fluid is used. The experimental and numerical results demonstrate an initial rapid increase in efficiency with volume fraction, followed by a leveling off in efficiency as volume fraction continues to increase.

V. OBSERVATIONS FROM LITERATURE SURVEY

The thermal conductivity enhancement is found to depend on the particle concentration, method of preparation and base fluid.
There are different nanofluids, namely Cu–water, Al2O3–water, Fe_3O_4–water and TiO2–water etc.
Fe_3O_4 Nano particles are synthesized using different synthesis methods and are suspended in various oils. Up to 28% increase in the thermal conductivity is obtained with 2.5 wt% magnetic particles in hexane.
Water based Ag Nano fluid and water based CuO Nano fluids are also used as the working fluids inside the solar collector. The Ag/water Nano fluid with the highest volume concentration are established to be more effective in enhancing performance of heat transfer rate than that of CuO/water Nano fluid.
The experiments demonstrated an increase in the collector efficiency of 28.3% at 0.2 w. % Nano particle concentration and 0.4 wt % water-multi wall carbon nano tube nano fluids improved the flat-plate collector efficiency.
It is found that there is a maximum increase of 28% in the value of convective heat transfer coefficient compared to the base fluid, with TiO_2-water Nano fluid of small particle volume fraction of 0.2%.
Enhancement of heat transfer in solar collectors can also be done by changing its requirement of application, type of heating, series or parallel arrangements of tubes i.e. tubes arrangements and type of material used for tubes etc .Flat plate collectors configuration can be modified in to different types as

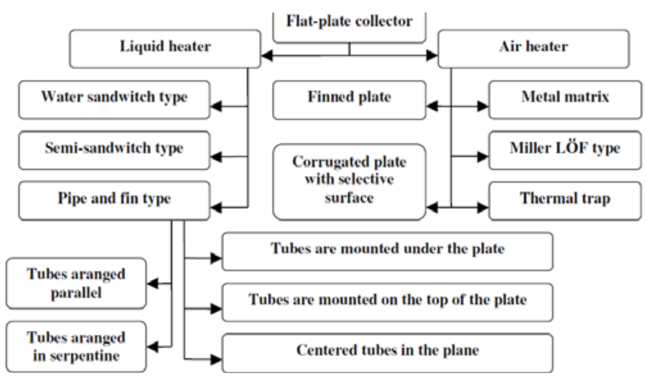

TABLE:4 MODIFIED FLATPATE COLLECTORS

VI .LIMITATIONS OF NANO FLUIDS

- **Stability of nanofluids for higher concentrations for long working hours**

Long-term physical and chemical stability of nanofluids is an important practical issue because of aggregation of Nano particles due to very strong Vander walls interactions so the suspension is not homogeneous. Physical or chemical methods have been applied to get stable nanofluids such as i) an addition of surfactant; (ii) surface modification of the suspended particles; (iii) applying strong force on the clusters of the suspended particles. Lee and Choi (1996) found that Al_2O_3 nanofluids kept after 30days exhibit some settlement compared to fresh nanofluids. Particles settling must be examined carefully since it may lead to clogging of coolant passages.

- **Increased pressure drop and pumping power**

Pressure drop development and required pumping power during the flow of coolant determines the efficiency of Nano fluid application. It is known that higher density and viscosity leads to higher pressure drop and pumping power. There are many studies showing significant increase of nanofluids pressure drop compared to base fluid. One of the experimental study by Choi (2009) calculated 40% increase of pumping power compared to water for a given flow rate.

- **High cost of nanofluids**

Nanofluids are prepared by either one step or two step methods. Both methods require advanced and sophisticated equipments. This leads to higher production cost of nanofluids. Therefore high cost of nanofluids is drawback of Nano fluid applications

VII.CONCLUSIONS

- As far as for better understanding of nanofluids, further research is needed. An important focus for future research should be determining the key energy transport mechanism in nanofluids.
- Mostly heat transfer depends on Thermal conductivity of Nano fluid. The thermal conductivity of nanofluids can be a function of parameters such as particle shape; particle agglomeration etc. therefore future research should be focused on finding out the main parameters affecting the thermal conductivity of nanofluids.
- Theoretical predictions should be evaluated in terms of agreement with experiments regarding concentration, particle size and temperature dependence. Currently, the available Nano particles are limited and their specifications are not accurate.
- The challenging point is to obtain the desirable Nano particle product. The development of the Nano particle production technique will be very helpful for the Nano fluid research.
- Production of stable green nanofluids is one of the most challenging directions for future applied research and Solar thermal systems are non-polluting and offer significant protection of the environment. The reduction of greenhouse gasses pollution is the main advantage of utilizing solar energy.
- Therefore, solar thermal systems should be employed whenever possible in order to achieve a sustainable future.

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