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# A Review on Corrugated Plate Heat Exchanger Performance with the Use of Nanofluid.

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**A B S T R A C T**

Heat exchanger is an essential tool that is often utilized in the processing, heating, and manufacturing, energy, refrigeration, and air conditioning sectors. Such equipment is crucial for the cooling of electronics and for addressing environmental problems like waste disposal and thermal pollution. as well as sustainable growth. There are many different types of heat exchangers, including fluid heat exchangers, waste heat recovery units, adiabatic wheel heat exchangers, plate fin heat exchangers, pillow plate heat exchangers, shell and tube heat exchangers, and plate heat exchangers. When surface area grows, heat transfer rate improves dramatically, giving plate heat exchangers an edge over standard shell and tube heat exchangers. Instead of using flat plates, corrugated plates are used to maximize heat transfer. Nano fluids are basically colloidal solution of nano particle in the base fluid prepared mainly to increase the thermal conductivity of the base fluid. Corrugation on plate increases the rate but besides it also increases pressure drop and which led in increase in pumping losses and hence more power requirement. Similarly in case of Nanofluids, Nano particle not necessarily always increases thermal conductivity, optimum concentration have maximum heat transfer. There is need to do more research on this domain. This review paper presents various resercher's work on plate heat exchangers with using nanofluids.

**Keywords: Plate heat exchanger, nanofluids, corrugation**

## 1. INTRODUCTION

Dr. Richard Seligman invented the plate heat exchanger device in 1923 as a means of indirectly heating and cooling fluids. It is a type of heat exchanger that uses series of plates which is thin and corrugated which is pressed together using gaskets between to form a rigid frame that allows hot and cold fluid to pass in between alternate plates without intermixing. Larger heat exchanger uses gasket but smaller one out for brazing usually. The plate heat exchanger has more heat transfer that conventional methods of heat exchanger as it involves more heat transfer area due to its waviness. Plates usually places at right angle to the direction of flow and are arrange in U or Z arrangements and clockwise or counter clockwise arrangement. Fluid uses in this heat exchanger can be any fluid without intermixing them. We can use nano fluid or mixture of nano fluid and water to enhance heat transfer.

***Working***

The basic structure of plate heat exchange consist of multiple plates usually made of stainless steel places in parallel seated by gasket so that hot fluid and cold fluid do not intermix in between. Hot fluid and cold fluid passed through plates alternatively. The plates provides more surface area so to increase heat transfer.

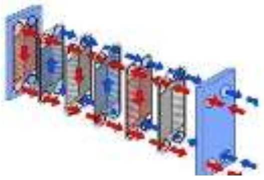


Fig : Working of plate heat exchanger

Here, cold fluid (blue) is entering from bottom and heating up by hot fluid and going up and have exit from top as shown in fig. Similarly hot fluid entering from top and going down while cooling and having exit from bottom.

## 2. LITERATURE REVIEW

**1 gururaj lalagi 2023**

• The results demonstrated that heat transmission increased significantly for all nanofluids (nf) at a particle concentration of 0.05 by weight %.

• Furthermore, at a particle size of 0.05 by weight percent, the heat transmission of the CNT-based nf rose by 37%, but the Al2O3- and CuO-based nf increased by 24.01% and 6.23%,

respectively.

**2 dan zheng 2020**

• Compared to DI-water, the plate heat exchanger's heat transfer capacities are significantly

improved by four nanofluids. The Fe3O4-water nanofluid performs better than other nanofluids at mass fractions higher than 0.05 weight percent. The heat transfer coefficient increases by 30.8% at 8 L/min when 1.0 weight percent Fe3O4-water nanofluid is utilized as the working fluid, as opposed to DI-water.

•We examined the pressure drops for four nanofluids between the input and output of the plate heat exchanger at the optimal particle concentration. In comparison to the other 0.5 weight percent nanofluids, the 1.0 weight percent Al2O3-water and Fe3O4-water nanofluids show more pressure decrease for a given pumping power, especially at large volume flow rates..

**3 ayatollah Khanlari (2018)**

• In this experimental inquiry, chevron angles (30°/60° and 60°/60°) that are symmetric and nonsymmetric were used.

• It was discovered that the ideal particle concentrations for CeO2/water, Al2O3/water, TiO2/water, and SiO2 were 0.75, 1.75, and 0.75 percent, respectively. PHE performed best with a 60°/60° chevron angle.

• The study also showed that the best results and an increased heat transfer coefficient of 35.5% are obtained with CeO2/water nano fluid at a particle concentration of 0.75 percent.

**4 Springer-Verlag GmbH Germany 2018**

• For a 0.5% volume percentage concentration compared to the base fluid, the highest total heat transfer coefficient increase is determined to be 7.8%. about a 30° chevron angle.

**5 Azher mush muhson abed 2015**

• When compared to other base fluids, the SiO2-glycerin Nano fluid has the greatest Nusselt number.

• Research shows that 4% SiO2, Al2O3, ZnO, and CuO nanoparticles added to the base fluid

improve exchange by 14%, 7.5%, 5.7%, and 4%, respectively.

**6 Patrice estelle- 2013**

• Alumina (cAl2O3) scattered in aqueous suspensions and CuO diffused in water

• The heat rate increases to almost 94% when 10% Al2O3 Nano fluid is added, and to approximately 89% when 6% CuO Nano fluid is added.

**7 D V Sai Teja (2017)**

• Heat exchanger using homogeneous mixes of nanofluids (CeO2 and Al 2O 3) with a single pass counterflow chevron corrugated plates.

• CeO2/water is simulated using CFD at the optimal concentration of 0.75 vol.%.

• The corrugation pattern of the plate, as determined by CFD simulation, produces turbulence and fluid vortices that speed up the heating of CeO2/water.

• The Nano fluid is suitable for practical use since it enhances heat transmission up to the optimal volume concentration without needing any pump power loss.

**8 Dongsheng Wen (2004)**

• C-Al2O3 nanoparticles in deionized water

• Less than 4 weight percent of very stable nanoparticles were found.

• The augmentation of the local heat transfer coefficient is noticeably more dramatic than the improvement in effective thermal conductivity.

• Using Al2O3 nanoparticles as the dispersed phase in water may significantly boost convective heat transfer in the laminar flow regime; under these conditions, the augmentation increases with both Reynolds number and particle concentration.

• Compared to the departure, the improvement is particularly more apparent at the entering.

**9 lazarus Godson (2010)**

• The most notable finding from the literature study is that nanofluids represent a novel class of heat transfer fluids with increased potential for use in the fields of cooling and associated technologies.

• It is evident from the obtained results that nanofluids have a higher potential for enhancing heat transfer and are highly suitable for use in practical

## 3. DESIGN OF PLATE HEAT EXCHANGER

The particular design of the plate heat exchanger (PHE) is ideal for transporting heat between fluids at medium and low pressures. Heat exchangers that are brazed, semi-welded, or welded are utilized when a more compact product is needed or for heat exchange between high-pressure fluids. Instead of a pipe going through a chamber, there are two alternating chambers, which are often narrow in depth and have a corrugated metal plate separating them at the greatest surface. One piece of metal plate pressing is used to create the plates used in a plate and frame heat exchanger. Because of its strength, resilience to corrosion, and capacity to tolerate high temperatures, stainless steel is a metal that is frequently used for plates. Rubber sealing gaskets that are cemented into a region surrounding the edge of the plates are frequently used to distance the plates apart. The heat exchanger's channels allow liquid to flow through them at right angles to the plates, which are pressed into the shape of troughs. The arrangement of the plate troughs creates a channel with 1.3–1.5 mm gaps between the plates as they join with the other plates. The largest possible surface area is produced by the plates, enabling the quickest possible transmission. By keeping each chamber narrow, the bulk of the liquid's volume in contact with the plate is ensured, which promotes exchange once more. The total rate of heat transfer between the hot and cold fluids passing through a plate heat exchanger may be expressed as:

$Q = UA\Delta Tm$

Where, U is the overall heat transfer coefficient, A is the total plate area, and ΔTm is the temperature difference. U is dependent upon the heat transfer coefficients in the hot and cold streams

**<u>Plate heat exchanger application</u>**

1) Power plant
2) High duty diesel engine
3) Food processing unit
4) Air conditioning units
5) Cooling towers
6) Oil refineries etc,

**<u>Advantage of heat exchanger</u>**

1) Compact in size
2) More heat transfer capacity
3) Higher in efficiency
4) Easy to clean
5) Easy dismentaling
6) Easy maintenance

**<u>Disadvantages of heat exchanger</u>**

1) High initial cost
2) Leakage finding is difficult
3) More pressure drop than conventional tube type of heat exchanger
4) Sensitive at joint

There are two types of plate heat exchanger designs: hot and cold. Every side is separated into a distinct channel. The diagram below illustrates several flow configurations.

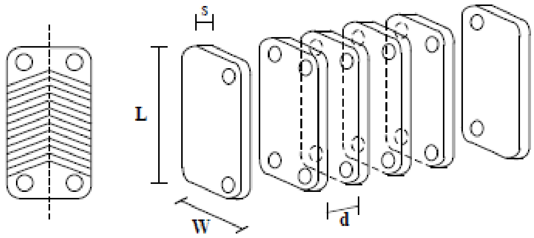



Fig : plate arrangement of PHE

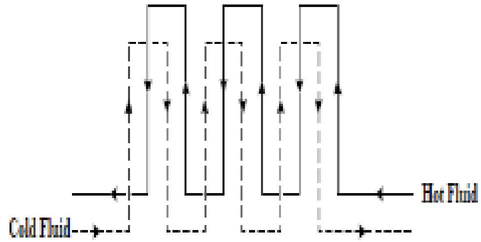



Fig : counter flow arrangement

Total Heat transfer rate at cold side $Q_{COLD} = m_{c\ Cp}(T_{C2}-T_{C1})$ Total Heat transfer rate at hot side $Q_{HOT} = m_{hCp}(T_{H1} - T_{H2})$

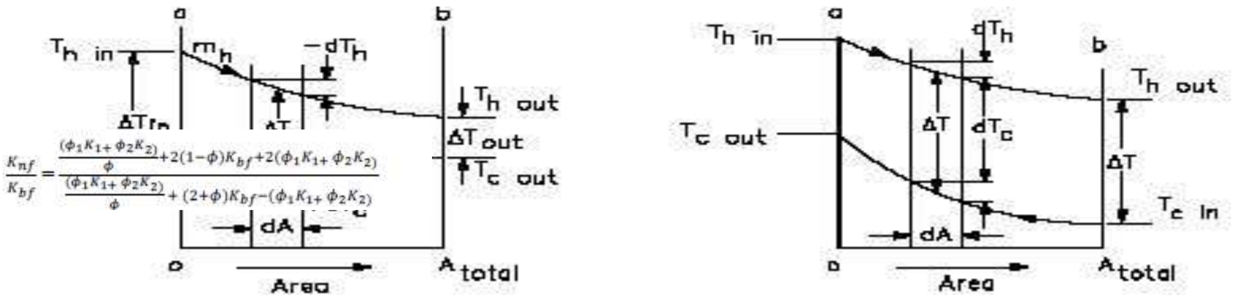



Fig : Temperature profile

**Equations used to design plate heat exchanger**

Logarithm Temperature Difference ΔTLM = (ΔT1-ΔT2)/ln(ΔT1/ΔT2)

Logarithm Temperature Difference for cross flow ΔTM = Ft ΔTLM

Overall area of heat exchanger A= Q/(UΔT1M)

Area of plate A1P =LW

No of channel Nc= (NP-1)/2

Area of channel AF =Wd

Velocity of channel Uc =mc/pAfNc

Equivalent diameter De = 2d

Reynolds number Re = pUDe/$\mu$

**Nano fluids equations used:**

Density of Nano fluids pnf = ϕ1p1 + ϕ2p2 +(1 – ϕ)pbf

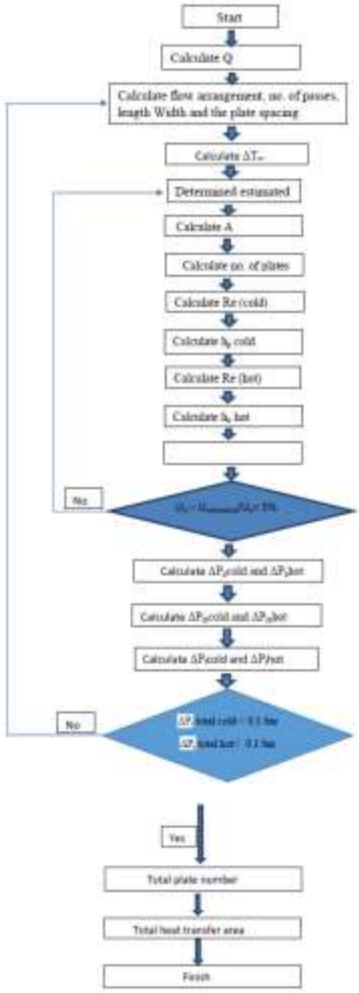
Where ϕ = ϕ1 + ϕ2

ϕ1, ϕ2 andiϕ are volumeiconcentration ofiparticle 1, particleu2 and total respectively. thermal conductivity

$$\frac{K_{nf}}{K_{bf}} = \frac{\frac{(\phi_1 K_1 + \phi_2 K_2)}{\phi} + 2(1-\phi)K_{bf} + 2(\phi_1 K_1 + \phi_2 K_2)}{\frac{(\phi_1 K_1 + \phi_2 K_2)}{\phi} + (2+\phi)K_{bf} - (\phi_1 K_1 + \phi_2 K_2)}$$

Where K1 & K2 are thermaliconductivity ofhparticlep1 and particle 2. Kbf &Knf are0thermal conductivity of baseifluid and Nano fluidorespectively.

Design method flow chart of plate heat exchanger is given below




## 4. CONCLUSION

Going through various research papers and literature surveys we find out that very less work done on corrugated plate and also on hybrid type of nanofluids. With using nanofluids and corrugation on plat, pressure drop increases hence power requirement also increase. Optimum concentration of nanofluid is needed to achieve maximum amount of heat transfer. In this review on plate heat exchanger, we study plate heat exchanger and its conventional design methodology. Plate heat exchanger design, simulation and analysis can be done by various softwares like ansys. There is need to is to develop a suitable model of wavy plate heat exchanger which can be use for rapid and high amount of heat transfer with using nano fluids at optimum concentration and corrugation on plate.

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**Nomenclature**

$k$ Thermal conductivity Nu Nusselt number

Pr Prandtl number

$P$ pressure

$q''$ wall heat flux

$T$ temperature

$T_w$ temperature at the vertical plate

$T_\infty$ ambient temperature attained as $y$ tends to infinity

$\alpha$ thermal diffusivity

$\beta$ volumetric expansion coefficient of the fluid

$\mu$ dynamic viscosity of the fluid

ν kinematic viscosity

$\rho_p$ nanoparticle mass density

$\Phi$ nanoparticle volume fraction

$\psi$ stream function