# Review on Experimental, Thermal Design and CFD Analysis of Corrugated Tube Heat Exchanger Using $Al_2O_3$ Nano-Fluid

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**Abstract:-In this paper double pipe heat exchanger is discussed . Heat Exchanger is a very important device in every modern industry and in the time when resources are limited and there is tough competition in the market of heat exchanger and it marks special importance. Experimental results like heat transfer rates, overall heat transfer coefficient, and effectiveness of heat exchanger have been calculated to assess the performance of heat exchanger. According to the results obtained by adding of nanoparticles in the base fluid (Distilled water) will cause significant enhancement of heat transfer characteristics. It shows the increase in heat transfer rate by use of corrugated tube and additional heat transfer is obtained by using nanofluids.**

***Keywords*— Corrugated tubes, Nanofluid, $Al_2O_3$, CFD, Heat Exchanger**

## I. INTRODUCTION

The importance of heat exchangers has increased with the view point of energy conservation and environmental conditions. Heat exchanger plays a vital role in the operation of many systems such as process industries , power plants, and various heat recovery units. A heat exchanger is a device which transfers thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different thermal conditions. In heat exchanger, there is usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream consists of condensation or evaporation of single or multi-component fluid streams. A fluid which contains nanometer-sized particles (nanoparticles) is called nanofluid. These fluids are colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metaloxides, metalcarbides, and carbon nanotubes. Common base fluids include water, oil and ethylene glycol . Nanofluids have properties that make them potentially useable in many applications of heat transfer, including pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, heat exchanger, domestic refrigerator, chiller, in boiler flue gas temperature reduction and in grinding machining process.Different publications on characteristics of a single corrugated tube and double pipe heat exchangers made of corrugated tubes are summarized chronologically as follows. Hamed Sadighi Dizaji, Samad Jafarmadar, Farokh Mobadersani [1] have studied that depending on Reynolds number and arrangement type the use of corrugated tube as the inner tube of the double pipe heat exchanger increased the Nusselt number about 10-52% and friction factor about 150-190% . When both of the inner and outer tubes were corrugated, the Nusselt number increased about 23-117% and friction factor increased about 200-254%. Feng Xin, Zhichun Liu, Nianben Zheng, Peng Liu, Wei Liu [2] studied that the flow characteristics of oscillatory flow and heat transfer enhancement by spirally corrugated tubes were numerically studied and results indicated that longitudinal swirl vortexes were generated with the guidance of a spirally corrugated channel in a two-start spirally corrugated tube in which the fluid flowed in spirally forward direction. The heat absorption (Q) of a two-start spirally corrugated tube was more than that of a smooth tube (Q0). The difference in the average heat absorption and the average of Q/Q0 was 561W and 1.36 respectively. At the same inlet temperature was 575 K and wall temperatures of 1000 K, the outlet temperature of the smooth tube increased by 205 K and spirally corrugated tube increased by 365 K. Thus, heat transfer enhancement can be obtained by using spirally corrugated tubes in a heater under an oscillatory flow. Mehdi Bahiraeia,, Reza Rahmania, Ali Yaghoobia, Erfan Khodabandehb, Ramin Mashayekhic,Mohammad Amanid [3] have studied use of nanofluids in heat exchangers including those carried out on plate heat exchangers, shell and tube heat exchangers, double-pipe heat exchangers, and compact heat exchangers. On the other side , some fascinating aspects about combination of nanofluids with heat exchangers are introduced. Use of nanofluids is very useful technique for heat transfer in heat exchangers. A.A. Rabienataj Darzi, Mousa Farhadi , Kurosh Sedighj[4] carried out different test at different Reynolds numbers ranging from 5000 to 20,000, approximately, and various nanoparticles concentration up to 1% by volume. Results show that there is a good potential in promoting the thermal performance of heatexchanger by adding nanoparticles in the tested ranges where not having a severe pressure drop penalty . In addition, Wang et al.[5] proved that special constructions of enhanced heat transfer tubes, such as spirally grooved tubes, corrugated tubes ,transverse groove tubes and so on, have noticeable effects on disturbing boundary layer. Hence, the heat transfer can be done efficiently in some degree and studied the flow and heat transfer performance of nanofluids in enhanced heat transfer tubes by numerical methods and experimentaly.

## II. EXPERIMENTAL APPARATUS AND PROCEDURE

### A. *Experimental setup*

The diagram shows experimental setup of tube in tube type heat exchanger. The length of test section was 220 cm. Copper tube with inner diameter of 8.1 mm (outer diameter of 9.57 mm) and steel tube with diameter of 150 mm were chosen as inner and outer tubes of test section. The outer surface of test section was isolated thermally from the surrounding with thick layer of glass wool[4]

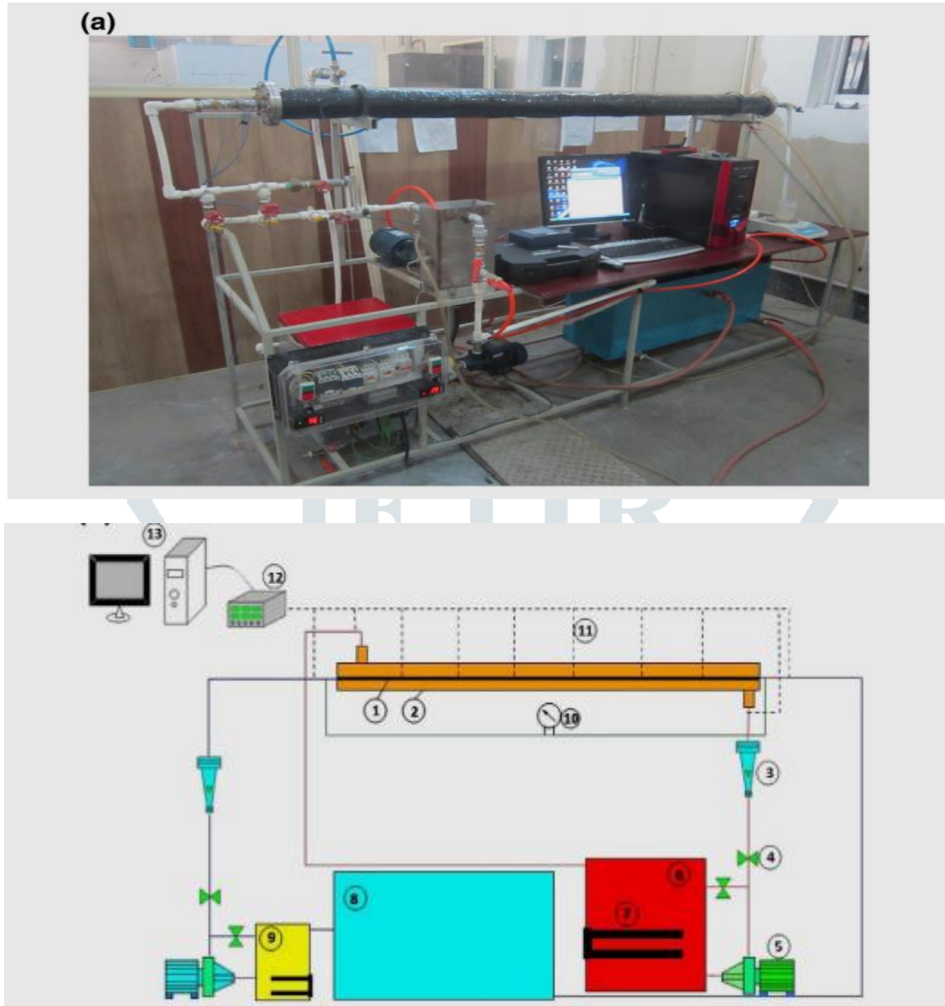


Fig 3.1 (a)Experimental apparatus and (b) schematics of setup: 1—inner tube, 2—outer tube, 3—Rotameter, 4—control valve, 5—water pump, 6—hot tank, 7—electrical heater, 8— cooling unit, 9—cold tank, 10—differential pressure gauge, 11—thermocouples, 12—data logger, 13—PC [4].

### B. *Tube geometry*

Fig shows type of tube used ie. Smooth tube , convex corrugated tube and concave corrugated tube. As corrugations are made on smooth tube the surface area of corrugated tube is more as compared to smooth tube. The length of smooth tube and corrugated tube is taken same finally so as to compare the results. So it can be concluded that, in the same length of the tubes, the surface area of the corrugated tubes is more than the surface area of the smooth tubes, and this is one of the corrugated tubes advantages when they are produced by said method[1] During the test various parameters were recorded .

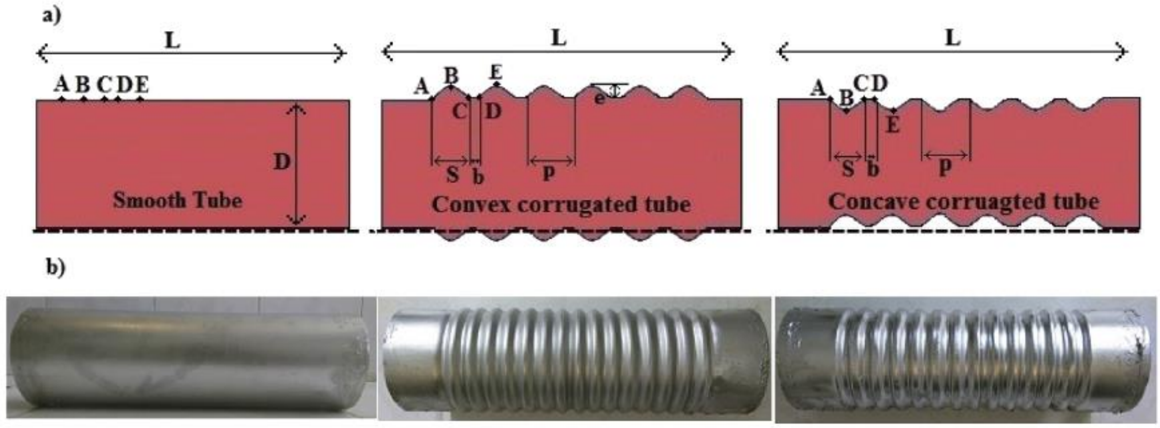


Fig 3.2 Types of geometry of tubes[1]

C. *Nanofluids*


Fig 3.3 Samples of prepared nanofluids[4]

1. *Preparation of nanofluids :*

This is the key step to the experimental studies of nanofluids. Two types of methods have been employed in producing nanofluids. One is a single-step and two-step method.

a. *Single step method:*

In this method, stable nanofluids are produced by the direct evaporation and condensation of the nanoparticulate materials in the base liquid.

b. *Two step method:*

In this method, first the nanoparticles are obtained by different methods and then are dispersed into the base liquid with or without surfactant. $Al_2O_3$ nanoparticles can be synthesized using the aqueous precipitation method. In this method, $Al_2O_3$ acetate is used as a precursor and sodium hydroxide as a stabilizing agent.

Single phase monoclinic structure of the $Al_2O_3$ nanoparticles is revealed using X-ray diffraction.The rectangular morphology of the $Al_2O_3$ nanoparticles is revealed using the scanning electron microscopy. Using different cross sectional and/or different dimensions like pitch, spiral angle for comparing results and to choose better heat exchanger in particular conditions. The CFD analysis of Corrugated Tube Heat Exchanger for the ease in calculations.

D. *Procedure*

(1) Tanks filled with cold and hot water.
(2) Switch on immersion type heater provided in the hot water tank and heat the water to the desired temperature.
(3) Switch "ON" the pump provided in hot water tank with bypass line valve fully open and supply valve fully closed to ensure complete mixing of water in the tank to ensure uniform temperature.
(4) Operate valves out of two valves provided on the panel in such a manner that the heat exchanger operates in parallel flow mode.
(5) Allow the hot water to flow through inner side of pipe. Adjust the flow rate as per desired value using the Rota meter.
(6) Start the cold water supply on the outer side of pipe. Adjust the flow rate to required value using rotameter.
(7) Observe the inlet temperature and outlet temperature of both cold water and hot water streams and record them after they achieve steady state condition.
(8) Record the flow rates of cold water and hot water with the help of rotameters.
(9) Repeat the procedure step number 6 to 9 for different flow rates of cold and hot water for Avg results.
(10) Alter the opening of valves out of two valves provided on the panel in such a manner that now, the heat exchanger operates in parallel flow mode.
(11) Repeat the procedure step number 6 to 10 for counter flow arrangement of double pipe heat exchanger.
(12) Drain out the water from both the tanks after completion of experiments.

## IV. RESULTS

The NTU effectiveness charts can be of great practical utility in design problems. More elaborate design procedures, requiring analytical expression for these curves Changes of the 3= 3 s with NTU are shown in Fig 4.1. . By determiningthe results of heat exchanger made of smooth inner tube and smooth outer tube as the references, if just the inner tube is corrugated, the effectiveness increases about 5-19% while if in addition to the inner tube, outer tube is corrugated too, the effectiveness increases about 28-55%. Maximum effectiveness was obtained for heat exchanger made of corrugated outer and inner tubes.[1]

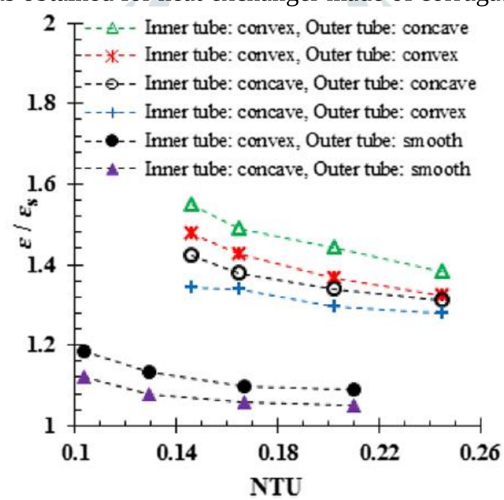


Fig 4.1 Relationship between enhanced effectiveness to non-enhanced effectiveness ratio and NTU.[1]

Table4.1 Comparison of CFD simulated results of cooling mediums[4]

| **Physical Properties** | **Distilled water as a cooling medium** | **Al2O3- Water nano fluid as a cooling medium at Pe=60000, 2% volume fraction** | **% Enhancement Or % Reduction** |
|---|---|---|---|
| Over heat transfer coefficient Ui (W/m2K) | 347 | 356.2 | 2.65% enhancement |
| Nusselt number | 71.6 | 77 | 7.54% enhancement |

## CONCLUSIONS

1. Nusselt number and performance of heat exchanger due to corrugations also enhancees heat transfer.
2. The spirally corrugated tube shows Increased heat absorption when compared to that in the smooth tube thus heat transfer enhancement is feasible by using spirally corrugated tubes in a heater under an oscillatory flow.
3. Proper quantity of nanofluids present causes increase in heat transfer an enhanced heat transfer rate in comparison with conventional fluids, and it agrees significantly by increasing concentration and Reynolds number.
4. Results indicate that by increasing the concentration of nanofluid,the heat transfer and the pressure drop simultaneously increase adding the nanoparticles to the base fluid has better result at higher Reynolds number.

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