IJIS: Vol.1, Issue 5, June 2025, Page:1-5 ISSN: 3049-3277

International Journal of Integrative Studies

Journal homepage:www.ijis.co.in

Amplifying the Heat Transfer is Double Pipe Heat Exchanger with Various Inserts and Nanofluids – Review

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Abstract

Techniques to enhance heat transfer rates while at the same time reducing heat exchanger size-and-cost. Passive heat-transfer strategies among them have been found to be extremely effective, and the technique of using inserts has gained considerable importance in terms of enhancing flow turbulence. Comprehensive review on experiments and numerical investigations and different insert designs, and tube geometries, are presented in the current work. These technologies have targeted improving critical performance parameters of heat exchangers. After reading about past methods designed to increase turmoil and system effectiveness, tape inserts are presented up as according to a highly effective description. They have attracted considerable attention and are used extensively to enhance the performance of heat exchangers, particularly with Nanofluids. Studies also show that inserts are very efficient both in laminar-and-turbulent flow regimes and are thus suited for application with Nanofluids to further improve heat transfer.

Keywords: *Inserts, Nanofluids, Efficiency, Double pipe Heat Exchanger*

DOI: https://doi.org/10.63856/fmm0my62

1. Introduction

Improvement in the rate of heat transfer despite the fact concurrently tumbling the size, weight, and charges of heat exchangers has been a long-standing goal in thermal system design. Attaining high thermal efficiency is paramount in a diverse range of applications, power peers, refrigeration, air conditioning, automobile cooling systems, and process industry. Of the innumerable systems of heat-transfer augmentation available, reflexive techniques have drawn significant attention owed to their easiness, low cost, and ease of incorporation into current systems.

Passive heat-transfer augmentation systems entail geometrical or external alterations to the stream path that entice turbulence or suboptimal flow without need for external power input. Such techniques are in opposition to active enhancement methodologies, which rely upon outside energy sources like pumps, magnetic fields, or vibration to enhance thermal performance. In passive techniques, inserts like tapes coiled, helical or coiled wire inserts, tapering rings, and others turbulators are placed inside the flow passages in heat exchangers to dislocate the thermal-boundary film and support fluid socializing, thus enhancing the convective heat-transfer coefficient.

Twisted tape-inserts are one of the most extensively researched and discarded passive devices. They achieve this by creating a swirl flow that increases fluid layer mixing, thereby decreasing temperature gradients as well as the Nusselt number. Helical coil inserts also generate centrifugal forces that enhance fluid mixing and heat-transfer, with high efficiency in compressed heat exchangers and coiled tubes. Conical ring inserts and conical strip turbulators achieve this by generating flow separations and reattachments, which break the laminar sublayer and strengthen turbulence. These systems have shown great promise in both laminar-and-irregular flow regimes.

Recent developments in nanotechnology have also broadened the application of passive enhancement methods using nanofluids. Nanofluids are inducing colloidal retainments of nano-particles probable to be TiO_2, Al_2O_3, or CuO—in typical fluids like water, and other additive oils. These fluids boast superior thermal-conductivity and enhanced heat transfer properties compared with base fluids alone. When used in conjunction with passive inserts, nanofluids provide a synergistic enhancement effect. The inserts enhance the fluid dynamics by disrupting the flow, while the nanofluids help with higher thermal conductivity, both resulting in dramatic increases in overall heat transfer rates.

There have been many investigations into the combined effect of inserts and nano-fluids on different heat exchanger configurations. For example, in experimental studies, incorporation of twisted tapes with nanofluids has been reported to give significantly larger heat transfer rates compared to the application of either method independently. In the same vein, application of conical strip inserts with TiO_2–water nanofluids has also been reported to provide substantial development in Nusselt-number and thermal-efficiency. Such enhancement is usually accompanied by an increase in gravity drop of moderate nature, which is a compromise that should be made in design cautiously.

2. Literature Review

The impression of helical tape additions in a DPHE and found a 129% rise in heat-transfer rate. This was owed to the increased turbulence triggered by the helical inserts, which raised the Reynolds-number and enhanced mixing of the fluid. Their work stresses the significance of turbulence for enhancement in heat transfer, particularly when dealing with compact heat exchangers. Twisted tape inserts have also been very promising [1]. There has been a report [2] that indicates that Nusselt(Nu)-number, an imperative portion of convective rate of heat-transfer, can be boosted by as much as 143% with twisted tapes. This improvement is further associated thru the rise in Reynolds (Re)number, which indicates more intense drift conditions enhancing the apparatus of convective heat -transfer.

In nanofluid context, the physical appearance of rate of heat -transfer of alumina (Al) /water nano-fluid within a shell-and-tube (ST) heat exchanger with twist inserts. The research took into account nanofluid volumes of 0.5%, 1%, and 1.5% and analyzed the effect of Peclet number on both the mutually impelling power and heat-transfer. Findings showed a respective growth of 12.6%, 20%, and 25% in the global heat-transfer factor related to distilled water at a Peclet number of 3000. While a 13% increase in propelling control resulted from the coil insert, the thermal performance gain overrode the extra energy expense [3]. Heat-transfer and abrasion factor physical look experimental investigation for spherical tubes equipped with twisted-tapes having jagged surfaces. Experiments ranged across a Reynolds (Re)-number choice of 5000 to 16000. Their marks exhibit the Nusselt number augmented by 44%, 82%, and 154% for twist ratios of 5.2, 4.2, and 3.2 respectively, indicating the consequence of more tightening twisting on heat-transfer. Consequently, the friction factor also rose to 12%, 27%, and 51%, respectively. This indicates that while the friction losses are greater with more vigorous twisting, the improvements in heat transfer effectiveness merit the compromise under certain operating conditions [4].

Considered the application of narrowed inserts as turbulators in heat exchangers. Three varieties of conical rings—converging, diverging, and converging-diverging—were tested for various diameter ratios compared to the tube. The experiment employed ambient air over the Reynolds numbers 6000 to 26000 [5]. Conical ring inserts recorded higher heat-transfer performances associated with plain-tubes, with the diverging-ring (DR) design showing the highest improvement. The experiment also initiate that the heat-transfer rate amplified with decreasing diameter ratio and Reynolds number, though such gains were accompanied by a sizable intensification in the friction-factor. Other augmentation features, including triangular fins, have also been explored [6]. These shapes enhance greater turbulence and enhance flow characteristics, hence enhancing Nusselt(Nu)-number and friction -factor in heat-exchangers. Such fins break the thermal-boundary film and provide additional effective heat-transfer.

Incorporated helical rotor blades within the heat-exchanger configuration and enhanced the heat-transfer rate by 123%. Improvement was accredited to the rise in swirl flow and turbulence brought by the spinning blades [7]. The helical rotors efficiently destroyed the laminar sublayer, leading to convective heat exchange and mixing. Investigated the use of conical ring inserts, focusing specifically on laminar flow conditions. Their findings indicated that tapered rings provide recovering performance under laminar flow as opposed to turbulent conditions. The research further elaborated on other passive enhancement techniques, such as ribs and conical nozzles, highlighting the adaptability and flexibility of conical ring inserts in different regimes of flow [8].

Figure 1: Triangular stripped and Conical type Inserts [6,7]

Detailed untried information for the friction -factor (FF) and Nusselt (Nu)-number for laminar drift of gelatinous oil along curved ducts with spiralling attach tape-inserts and basic helical-rib coarseness. Their results emphasized the combined effect of swirl generation and surface roughness in majorly improving thermal performance, even in laminar conditions [9]. Analyzed heat-transfer and airflow friction physical appearance in spherical hoses furnished thru deuce counter -rotating tappered disk inserts thru different twist -ratios, especially in turbulent flow environments. Their research found that double counter-rotating conical inserts resulted in significant heat transfer improvement through enhanced pressure drop and created secondary flows. Notwithstanding the increased-pressure losses, the heat transfer enhancement made their use worthwhile in systems where performance is given more emphasis compared to pumping power [10].

The literature emphatically illustrates that passive improvement of heat transfer via supplements like twisted-tapes, helical-coils, conical-rings, and fins places the stage for a crucial protagonist in illuminating the recital of heat exchangers. These inserts shatter the flow pattern, increase turbulence, and increase the effective outer extent for heat-exchange, all of which lead to enhanced thermal efficiency. Coupled with sophisticated fluids like nanofluids, the efficacy of these passive methods is even further increased. Although pressure drop and friction are significant issues, the compromises are usually tolerable in those applications where thermal performance takes precedence. Further research is crucial to maximize insert geometry, material, and arrangement to stability heat-transfer advantages per pressure losses for various thermal system uses.

Heat-exchangers are instrumental equipment in countless work claims, in which thermal performance enhancement is an ongoing research interest. Techniques of passive heat-transfer enrichment, particularly those involving internal inserts like conical and fusiform turbulators, have been prominently under the spotlight because they are simple and effective. This review condenses the results of three prominent studies which examined the contribution of different insert geometries and materials towards enhancing heat -transfer efficiency in DPHE configurations [11].

In addition, the implementation of these passive methods concurs with larger sustainability objectives through the minimized demand for mechanical pumps or fans commonly linked to active enhancement strategies. As energy efficiency remains an engineering design imperative, continued research and development in this field are timely and essential.

3. Nanofluid Preparation Methodology for Enhanced Heat Transfer Applications: A Review of Current Practices

Advanced heat -transfer research, the application of nano-fluids is particularly pronounced based on their enhanced thermal -conductivity and enhanced convective heat -transfer properties. Precise preparation of nano~fluids is a fundamental requirement for guaranteeing credible and reproducible experimental data. Of the numerous nanofluids, TiO_2 nanoparticles suspended in water-based nanofluids have shown significant potential due to their chemical stability, non-toxicity, and beneficial thermal properties.

In recent experimental techniques, nanofluids are typically prepared by suspending a certain amount of nanoparticles in a base fluid. For heat transfer studies, volume concentrations are usually varied between 0.1% to 0.5%, enabling one to training the impact of particle loading on thermal recital. One such widely chosen concentration range is 0.1, 0.3 and 0.5 vol%. At these concentrations, nano-fluids show significant variations in thermophysical behavior without bringing about appreciable viscosity penalties or flow resistance.

For the purpose of starting the process of preparation, a pre-determined amount of TiO_2 nanoparticles—typically having an average size of around 20 nanometers—is weighed and added to de-ionized (DI) water. The use of DI aquatic as the base-fluid is compulsory to remove impurities that might otherwise hamper the stability and heat behavior of the nanofluid [12].

One of the most basic challenges of producing nanofluids is to keep nanoparticles in a stable and uniform suspension. Aggregation and sedimentation are usual issues that can transform the thermophysical properties and decrease the consistency of experimental findings. To counteract this, an ultrasonication process is commonly utilized. Under ultrasonication, the nanofluid mixture is exposed to high-frequency sound waves—tend to be for 4 to 5 hours. This processing breaks apart agglomerated particles and provides an unchanging dispersion of nano-particles thru the liquid.

After ultrasonication, the nanofluids are usually exposed to regular mechanical stirring. This process, which runs for approximately 2 hours, is designed to reinforce the dispersion further and avoid preliminary sedimentation. Stirring keeps the kinetic energy in the fluid system and minimizes opportunities for nanoparticle settling during subsequent handling and testing.

To evaluate the stability of the prepared nanofluid, the suspension is retained undisturbed under stationary conditions for several days. Under controlled experimental observation, good-quality nanofluids have exhibited outstanding suspension stability, with no detectable sedimentation or settling of the nanoparticles even after 48 hours of stationary conditions. The lack of sedimentation validates the efficacy of the method of preparation and supports the presence of an effective colloidal system. This stability is important since it makes the fluid maintain uniform thermal characteristics over the testing period.

The described preparation method is a best-practice process that incorporates ultrasonication, mechanical stirring, and visual stability monitoring. The above steps collectively guarantee homogeneity in the nanofluid as well as its applicability for experimental analysis of heat -transfer performance, particularly in heat~exchangers where thermal conductivity and flow uniformity are the key requirements.

4. Conclusion

Improvement in heat transfer efficiency is still a critical goal in thermal system design, and the same may be suitably completed by usefully locating hot-and cold waters in the interior and exterior tubes of double-pipe heat-exchangers. With this method, it is possible to critically analyze the behavior of heat flux under different fluid arrangements and make the analysis of diverse thermal conditions easy with precise boundary specifications.

Meeting the demand for effective thermal energy addition or extraction is critical in systems with large temperature differentials between the working fluids. Double-pipe heat exchangers provide a real-world solution to handling heat gain-loss, and modifications to their use parameters further aid in obtaining desired thermal management.

To further enhance the performance and operational feasibility of such systems, experimental verification as well as theoretical analysis must focus on the influence of insert geometry and material choice. Specifically, adjusting the geometry of DPHE using conical-tape additions has proved to be beneficial in commotion improvement as well as heat-transfer rate enhancement.

The dispersion and diffusion behavior of nano-particles is of vital character in providing optimum heat-transfer enhancement uniformly. Nonetheless, the instability of nanoparticles under different operational conditions, including high flow rates or high Reynolds numbers, represents an issue that needs to be addressed in order to ensure long-term performance.

It has been detected that raising the Reynolds-number (Re) and friction-factor (FF) tends to speed up the rate of nanoparticle degradation. Hence, instead of studying the time-dependent decrease in particle size, focus should be given to measures for sustaining nanoparticle stability and maintaining consistent performance over a period of time.

Results of other investigations have attested that the incorporation of conical tape inserts is greatly beneficial for the thermal-effectiveness and heat -transfer rate in DPHE. Among the various nanoparticle types considered, silicon dioxide (SiO_2) has proven to be an especially good additive. It exhibits consistently better performance for Nusselt (Nu) number enhancement besides overall heat ~transfer than any other available nanoparticle choice.

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