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Enhancing Heat Exchangers with Graphene as Al2O3 Nanofluid Coatings - A Review Study

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ABSTRACT

A well-designed heat exchanger improves the effectiveness of the heat exchanger. A hairpin heat exchanger resembles a hairpin when a single-pass shell-and-tube heat exchanger unit is folded in half, which can be used where space is a constraint. Design, CFD analysis and evaluation of various parameters of hairpin heat exchanger with graphene layer and its comparison with hairpin heat exchanger without graphene layer is the main aim of this paper. The heat exchanger is modified with the addition of a graphene layer on both the side (inside and outside) of the tube of the heat exchanger. Graphene is an allotropic form of carbon having a single layer of atoms distributed in a 2-D honeycomb lattice. The thermal conductivity of graphene is very high as compared to other materials. In addition to it, nanofluid Al2O3 is introduced as cold fluid. Nanofluids are colloidal suspensions made out of nanoparticles in some base fluid. ANSYS FLUENT 2020 has been used to model the geometry and to perform numerical simulation. Turbulent flow conditions were used to analyse the heat exchanger. CFD analysis has been done on hairpin heat exchangers using graphene layer. The results indicate that the high thermal conductivity of graphene increases heat transfer and the numerical value of convective heat transfer coefficient is also high.

Keywords - Hair Pin Heat Exchanger, Graphene, Nanofluid, Thermal Analysis.

I. INTRODUCTION

The conversion, utilization and recovery of energy in every industrial, commercial and domestic application involve a heat exchange process i.e., need of a heat exchanger. Heat exchanger are devices that work with the exchange of heat between two liquids that are at different temperatures while holding them back from blending in with one another.

Types of Heat Exchanger

1) **On the basis of Flow Arrangement**
   1. Parallel Flow
   2. Counter Flow
   3. Cross Flow

2) **On the basis of construction**
   1. Double pipe heat exchanger
   2. Shell and tube heat exchanger
   3. Plate and frame heat exchanger

3) **As per the arrangement of fluid flow**

   [1] Parallel flow heat exchanger- Both the hot and cold fluids enter the heat exchanger at the same end and move in the same direction.

   [2] Counter flow heat exchanger- The hot and cold fluids enter the heat exchanger at opposite ends and flow in opposite directions.

   [3] Cross flow heat exchanger-In compact heat exchangers, the two fluids usually move perpendicular to each other, and such flow configuration is called cross- flow.

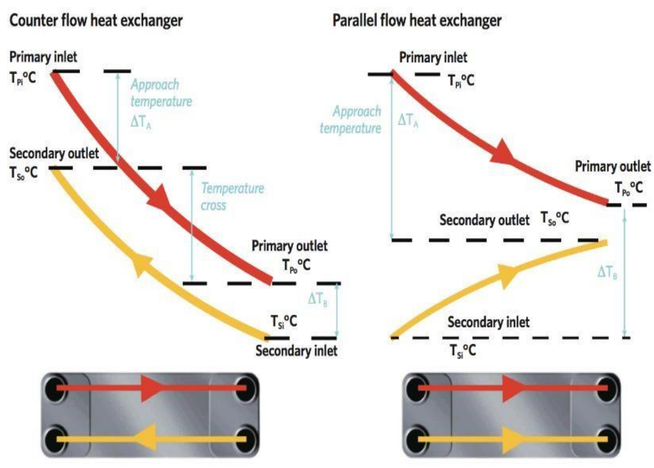

Fig.1.1(a) Parallel and Counter Flow exchanger

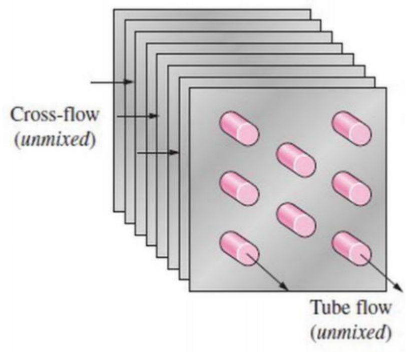

Fig.1.1(b) Cross Flow Heat Heat exchanger

Methods to improve heat transfer

The overall heat transfer coefficient depends on some parameters like orientation of heat transfer, pure mathematics of heat transfer, properties of fluid flow, nature offluid flow like laminar or turbulent, and material of the tube, etc. Heat transfer rate may be inflated by manufacturing turbulence result in fluid flow.

4) **Active Methods**

These techniques need some external power input for the required flow modification and an increase in the rate of heat transfer. It's restricted application owing to the need for external power in several sensible applications. Compared with passivetechniques, this method has not shown a lot of potential because it is tough to relinquish external power input in improvement cases.

In these days, external power is used to help the required flow modification and therefore the associated improvement within the rate of heat transfer.

5) **Passive Methods**

These techniques ordinarily use surface or geometrical changes to the flow channel byincorporating inserts or extra devices. They endorse higher heat transfer coefficients by varying or dynamically prevailing the flow nature (except for extended surfaces), that conjointly tends to extend within the pressure drop. Passive techniques hold the advantage over the active techniques as these techniques don't need any direct input of external power; rather they may use it from the system itself.

For example – Passive methodology doesn't need any external power for improving the heat transfer rate. Here the rate of heat transfer is improved by modifying the pure mathematics of heat exchangers, by modifying the surface texture or nature or by modifying the flow channel by inserting the extra channel.

6) **Compound Methods**

A compound technique consists of the combination of more than one heat transfer enhancement method (active and/or passive) to increase the thermohydraulic performance of heat exchangers. It can be employed simultaneously to generate an augmentation that promotes the performance of the system either of the techniques operating independently. Preliminary studies on compound passive augmentation technique of this kind are quite encouraging.

7) **Advantages of Hairpin Heat Exchanger**

- Offers smaller footprint for compliance with overall length restrictions.
- Able to be stacked via special supports.
- Accommodates differential thermal expansion without the need for an integrated expansion joint.
- Withstands high terminal temperature gradients, preventing potential failure due to thermal stresses.
- Able to handle a temperature cross between the cold- and hot-side fluids because of the pure counter current flow design.
- Offers a more thermally efficient design with a smaller shell than traditional shell-and-tube heat exchangers.

Applications

- Oil and Gas Industries
- Process Industries
- Chemical Industries
- Petrochemical Industries
- ANSYS

ANSYS is considered to be a FEA software package. It consists of a pre-processor portion which is used to develop the geometry, apply the material, create a co-ordinate system, maintain contacts between the parts as and when required and to develop the mesh according to the need. After this it consists of a solution program also known as a solver of ANSYS to employ the loads on the meshed model. At last, after solving the problem through its solver it provides the outputs in form of the results desired. These results obtained are then analyzed to evaluate the behavioral changes in the component. FEA is employed almost across all designs related to engineering.

Hence the sequence of operations to be performed by ANSYS consists of-

- Pre-Processing
- Solver
- Post-Processing

Pre-processing

It's the first step of ANSYS workbench in analysis of double strap double riveted butt joint. A user can use whichever software He/She wants to in order to develop the model of the component. After the creation of model in modelling softwares, this model needs to be imported to ANSYS & for this purpose, the model is converted into. igs or .stp format.

After importing the geometry, one needs to finalize the materials which will be used in the analysis and for that there is a large engineering material database provided by the ANSYS. So, the need now is to choose the suitable material. After applying the material there is need to place a coordinate system into the component although ANSYS provides a default coordinate system. So, if one needs to place another coordinate system, he or she is completely free to do so. After this contact conditions among different contacting surfaces is placed. Now one looks for the meshing of the component. Basically, to create mesh means to divide the component in several small blocks which may be one dimensional, two dimensional or three dimensional. These blocks have two components-nodes & elements. Elements are the outlines of the components & nodes are the points at which various elements meet each other. The process of mesh generation is also called grid generation.

• **Solver**

In the previous phase one needs to toil hard whereas this step is now the headache of the system in order to perform this task at hand. One just needs to click the solve button. The software performs the necessary work internally and gives its output in form of the result desired by the user.

• **Post-processing**

Last phase in **ANSYS** is called as post-processing. In this phase One needs to analyze the results obtained. ANSYS only helps the user to obtain accurate results & all the analysis work is done by the user keeping in mind the values obtained by the ANSYS analysis.

II. LITERATURE REVIEW

The increase of convective heat transfer coefficient is one of the foremost vitaltechnical aims for industrial appliances used in heat transfer applications. A hairpin heat exchanger resembles a hairpin when a single-pass shell-and-tube heat exchanger unit is folded in half. Unlike, multi-pass heat exchangers (multiple passes on the tube side), hairpin heat exchangers have the peculiarity that the shell side stream circulates countercurrent to the tube side flow, in all passes. Conventional fluids, like water, engine oil, and glycol are usually used as heat transfer fluids. Numerous techniquesare applied to boost the heat transfer, the low heat transfer coefficient of these typical fluids obstructs the performance enhancement and the compactness of heatexchangers. The mixing of solid particles in the base fluid is a technique to increase heat transfer. As metal has higher thermal conductivity than fluids, suspending solid particles into the base fluid is predicted to enhance the thermal conductivity of that fluid. The enhancement of thermal conductivity of typical fluids by the suspension of solid particles, like millimeter- or micrometer-sized particles, has been well- known for several years.

Experiments to increase the heat transfer in laminar and turbulent flow of various compositions of glycol mixed with water in a double tube hair-pin heat exchanger were conducted. Obtained results indicated that the heat transfer coefficient of the combination of ethylene glycol and water increase with Reynolds number and ethylene glycol concentration [6].

Several studies show that nanofluids will enhance heat conduction performance due totheir higher thermal conductivity than base fluids [15, 4, 3, 9].

Many researchers focused to increase the convection characteristics by considering nanoparticles, pipe cross-sectional area, materials, the concentration of nanofluid, and flow conditions [10, 16, 13, 8, 14,5].

A study was conducted on the specific heat of Al_2O_3, ethylene glycol, and water (EG/W) nanofluid and its results on the cogeneration efficiency of a 45-kW diesel electrical generator (DEG). The efficiency of waste heat recovery within the device was augmented because of the higher convective heat transfer coefficient of thenanofluid [2].

The experiments were done to analyse the feasibility of Al_2O_3/water nanofluid in an air-cooled heat exchanger. Results show that Al_2O_3/water nanofluid offers a betterheat transfer rate than water [11].

CFD analysis on hairpin heat exchanger using Al_2O_3 and TiC nanofluids mixed with base fluid individually at 0.6 and 0.7 percent volume fractions was carried out and it was found that TiC is the suitable fluid at 0.6 percent volume fraction inside the hairpin heat exchanger for a better heat transfer rate [7].

Aluminium graphene nanoplatelet composites were fabricated by the stir casting method to increase the mechanical properties of aluminium [12].

Heat transfer in condenser tank using Al_2O_3- DI water Nanofluids was analysed inthis experiment and it was observed that nanofluid enhances the heat transfer and the convective heat transfer coefficient [1].

III. CONCLUSIONS

On the basis of literature review regarding the conclusion

Enhanced Convective Heat Transfer: The review emphasizes the critical importance of increasing convective heat transfer coefficients, particularly in industrial applications like hairpin heat exchangers.

Solid Particle Incorporation: Techniques such as mixing solid particles into base fluids have been explored to improve thermal conductivity and thus enhance heat transfer. This approach aims to overcome the limitations posed by the relatively low heat transfer coefficients of conventional fluids like water and glycol.

Nanofluid Advancements: Nanofluids, comprising nanoparticles dispersed in base fluids, have emerged as a promising avenue for enhancing heat transfer. Studies have consistently shown that nanofluids exhibit higher thermal conductivity compared to base fluids, leading to improved heat transfer performance.

Experimental Findings: Experiments with nanofluids, including combinations like Al2O3/water and ethylene glycol/water, have demonstrated increased heat transfer coefficients, particularly under laminar and turbulent flow conditions. These findings highlight the potential of nanofluids to enhance heat transfer efficiency in practical applications.

Computational Insights: Computational fluid dynamics (CFD) analyses have provided valuable insights into optimizing heat transfer enhancement. Factors such as nanoparticle concentration and type have been studied to determine their effects on heat transfer rates within heat exchangers.

Diverse Applications: Nanofluids have shown promise in various applications, including cogeneration systems and air-cooled heat exchangers, where they offer improved heat transfer rates compared to traditional fluids. Additionally, composite materials like aluminum-graphene nanoplatelet composites have been explored to enhance both mechanical properties and heat transfer capabilities.

Future Directions: The literature review underscores the ongoing need for research aimed at advancing convective heat transfer technologies. By leveraging advancements in nanotechnology and composite materials, significant improvements in heat transfer efficiency can be achieved, leading to more efficient and compact industrial heat exchangers and thermal management systems.

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