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REVIEW ARTICLE

NANOFLUIDS HEAT TRANSFER INTENSIFICATION IN DOUBLE PIPE HEAT EXCHANGERS: REVIEW ARTICLE

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ABSTRACT

In current years, the warmth switch enhancement developed with the aid of the usage of nanofluid. A nanofluid is a kind of fluid that organized by means of dispraised of nanoparticles of metal, oxides or carbides with 100 nm size that depressed in water, ethylene glycol or oil. The enhancement of warmness transfer overall performance through expending nanofluid primarily relies upon on the type of nanoparticles, kind of base fluid, form of nanoparticles, size of nanoparticles and nanoparticles attention in the base fluid. In this paper, several newly massive numbers of studied have been being provided to discover the nanofluid enhancement the warmth switch charge in several heat exchangers kinds such as double-pipe warmth exchangers, plate heat exchangers, cross-flow warmth exchangers and shell and tube warmth exchangers. In existing review article, it presents quite a few experimental and numerical research studies that investigated the impact of using nanoparticles in the single and hybrid nanofluids to acquire greater overall performance of enhancement of warmness switch in the double pipe warmness exchangers conferring to relative route of movement of fluids (Parallel flow and Counter flow) and the nature of warmth trade process. The current study showed that there is a wide use of nanofluids in double pipe heat exchangers in all dimensions. Where the comparison showed that the use of nanofluids, whether inside the inner tube or in the annular tube of the heat exchanger, will effectively lead to heat transfer, reduce the size of the heat exchanger and reduce the cost of manufacturing and materials

KEYWORDS

Nanofluids; Nanoparticles; Hybrid Nanofluids; Double-Pipe Heat Exchangers

1. INTRODUCTION

The most regular gadget for transferring thermal energy between two bloodless and hot fluids between two surfaces of metallic is a heat exchanger. Direct or indirect contact between bloodless and hot fluids can be used for heat transfer. Heat exchangers with indirect counter-current flows transmit the most energy between the warmness exchanger two sides. Fluids waft velocities, structure of the warmness exchanger, and cloth utilized for fluid and stable flows thru it is some of the parameters that have an effect on strength transfer in warmness exchangers. We focused on improving the fee of warmness transfer in a double pipe warmness exchanger by means of changing the substances of the fluid that used to transmit heat, such as water, in us evaluate work. We are searching for different types of fluids with high thermal conductivity due to the small thermal conductivity of water.

1.1 Experimental Studies

An investigated the heat transfer coefficients of alumina nanofluids of transformer oil flowing thru a double pipe warmness exchanger system (Chun et al., 2008). They presented an experimental correlation for nanofluid gadget to apprehend the warmness switch improvement. From studied the heat switch via the compelled convection of a nanofluid containing 0.2 vol. of TiO2 nanoparticles that flows in a double-tube warmness exchanger under turbulent drift conditions (Duangthongsuk et al., 2009). The results displayed that the warmth switch coefficient of nanofluid is 6–11 percent higher than that of the base liquid. The warmness transfer coefficient of the nanofluid will increase with an amplify in the mass glide fee of the warm water and nanofluid, decreases with an increase in the nanofluid temperature, and has no effect on the warmth switch coefficient of the heating fluid. The Gnielinski equation also failed to predict the heat transfer coefficient of the nanofluid. Finally, the use of nanofluid has a minor influence on pressure drop. Based on investigated the outcomes of CuO and Al2O3 NF on HTC within a double-pipe heat exchanger (Zamzamian et al., 2011). They found that the presence of the NF elevated the CHT coefficient by up to 49.33 percent. They also determined that as NF awareness and temperature rise, so does the CHT coefficient. The performance of a water-based Mn–Zn nanofluid in a double-pipe heat exchanger beneath quadrupole magnetic subject by means of the use of the two-phase Euler–Lagrange method (Bahiraei and Hangi, 2013). They investigated consequences of various parameters such as particle concentration, particle size, magnetic discipline magnitude, and Reynolds number. The warmth switch of Al2O3 water nanofluid in a concentric double tube heat exchanger at 2% and 3% extent fraction concentrations (Sonawane et al., 2013). It was once discovered that the average warmness switch fees of nanofluids as a cooling fluid are greater than those of water. The effect of an alumina nanofluid on thermal overall performance of a double pipes heat exchanger (Darzi et al., 2013). The consequences exhibit that there is a exact viable for enhancing warmness exchanger thermal performance via including nanoparticles in the investigated tiers where there is no extreme stress drop penalty. The convection warmness transfer characteristics of a entirely developed turbulent glide of TiO2–water nanofluid in a horizontal double tube counter-flow warmth exchanger (Arani and Amani, 2013). The consequences confirmed that all nanofluids had a higher Nusselt number

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when compared to the base fluid. It used to be additionally observed that decreasing the diameter of nanoparticles normally does not make bigger the Nusselt number. As a result, a new definition for thermal performance issue used to be proposed. The impact of different concentrations of Al2O3 nanoparticles dispersed in water on the traits of warmth switch of for counter glide and parallel go with the flow preparations of the double pipe heat exchanger (Chavda et al., 2014). Their consequences confirmed that the heat transfer coefficient growths with growing the Al2O3 nanoparticles quantity concentration in contrast to water up to 0.008 percent and then decreases. From an examined the coefficients of the heat transfer enhancement of using AL2O3 nanofluid with volume fractions of 0.1-0.3 percent (V/V) (Aghayari et al., 2014). They investigated the consequences of nanoparticle attention and temperature on Nusselt variety changes in a counter turbulent waft double pipe warmness exchanger. The experimental results exhibit a big extend in heat transfer coefficient and Nusselt number, with values ranging from 19% to 24%. Furthermore, the heat transfer coefficient has been found to expand with operating temperature and nanoparticle concentration.

The friction factor and heat transfer coefficient of TiO2 nanofluid in 40 percent ethylene glycol and 60 percentage distilled water with quantity concentrations ranging from 0.0004 percentage to 0.02 percent that flows in a double pipe warmth exchanger (Reddy and Rao, 2014). When a 0.02 percentage quantity concentration of nanofluid is added to a tube of base fluid, the friction component and coefficients of the warmth switch extend with the aid of 10.73 percentage and 8.73 percent, respectively, investigated the effect of the usage of Al2O3 nanofluid that flows in a horizontal double pipe heat exchanger with twisted tapes (Maddah, et al., 2014). According to the experimental data, the use of RGPR twists in conjunction with nanofluids tends to enlarge heat transfer coefficient by way of 12 percentage to 52 percent and 5 percentage to 28 percent, respectively. Detected the effect of using Titana/water NFs that flows in concentric tube HEX on the warmness switch properties (Khedkar et al., 2014). The NFs have been created through combining water and Titana NPs. The HTC is increased when NPs are used in the double pipe HEX, in accordance to the results. A 14 percent improvement used to be observed. There was once no records supplied about the system's FPD. The investigated the pressured convective warmth switch coefficient of biologically produced nanofluid extent fractions of 0.1, 0.5, and 1% nanoparticles in ethylene–glycol/water (50:50 by means of volume) flowing in a round tube internal a heat exchanger (Sarafraz and Hormozi, 2015). The effects published a amazing expand in warmness transfer coefficient of up to sixty seven percent at vol. percentage = 1. Based on recent study, warmness transfer and friction thing coefficients homes of carbon nanotube water-based nanofluids with mass concentrations of 0.1–0.3 percent that drift interior a double pipe heat exchanger (Sarafraz et al., 2016). The have an impact on of a variety of operational parameters on the warmth transfer coefficient and stress drop was investigated, together with drift rate, nanofluid mass concentration, and nanofluid inlet temperature. The effects showed that the presence of carbon nanotubes can make bigger warmth conductivity by 56% at wt% = 0.3. Similarly, nanofluids of CNT/water have a larger coefficients of heat transfer than water due to CNT inside thermal conduction. It was once also located that carbon nanotube nanofluids can extensively enhance warmth exchanger thermal overall performance when in contrast to water through up to 44 percentage at most mass awareness (wt. percentage = 0.3). Summarized experimentally the compelled convective warmth switch and flow traits of a nanofluid consisting of water and 1% Al2O3 50 nm diameter (volume concentration) nanoparticle flowing in a parallel flow, counter go with the flow and shell and tube heat exchanger (Dharmalingam et al., 2015). The usual warmth transfer coefficient and dimensionless Nusselt wide variety of the nanofluid are marginally greater than these of the base liquid. It was also observed that as mass glide fee increases, the LMTD cost drops regardless of go with the flow direction.

The impact of utilizing CuO nanofluid as a substitute of water on the heat switch improvement. The bought information used to be assimilated from a quarter of turbulent flow same tube warmness exchanger (Zarringhalam M. et al., 2016). The experimental consequences displayed that the warmness switch coefficient extended by using 57% when using quantity fraction of 2%. The turbulent drift of graphen-water nanofluids in rectangular pipe. The outcomes shoed that the heat switch coefficient and friction thing rose by way of 19.68% and 9.22% for 0.1 vol.%, respectively (Armand H. et al., 2016).

Investigated fluid go with the flow and warmth transfer traits in a double-pipe heat exchanger the usage of 4 fluid types by the use of working fluids of ethylene glycol (Karamallah et al., 2016). The consequences exposed that the best possible Nusselt range (41) at flow rate (1.5 L/min). The Nusselt quantity for nanofluid grows with growing concentration, accomplishing (26.5) at ([phi] = three percent, T=70 oC, flow price 1.5 L/min. The performance of a horizontal double tube counter-flow heat exchanger utilising Cu-water nanofluids with 1% to 3% volume fraction that injected to the cold water in the annulus of the warmness exchanger, but the inner tube containing the warm water was once rotated (El-Maghlany et al., 2016). The addition of nanoparticles, as well as the rotation of the internal tube, resulted an growing in the rate of heat transfer. As a result, the warmth exchanger's efficacy and switch range gadgets (NTU) are increased. Based on research before used Nitrogen-doped graphene (NDG) nanofluids with aqueous answer of 0.025 wt.% Triton X-100 as a surfactant with a range of nanosheets at various concentrations (0.01, 0.02, 0.04, 0.06wt.%) (Goodarzi, et al., 2016). They investigated the total warmth switch coefficient, convective warmth transfer coefficient, percentage of wall temperature reduction, strain drop, and pumping electricity in a counter-flow double-pipe warmth exchanger the use of numerous water-based nanofluids as coolants. The results showed that using 0.06 wt. percentage nanomaterial in the base fluid extended the convective warmness switch coefficient by way of 15.86% as compared to water. An scan to explore the influence of nanofluid brought about convection heat transfer and fluid glide characteristics (Karamallah, A. A., and Jehhef, 2017). Three kinds of nanofluids, Al2O3, CuO, and ZrO2-DIW, waft in the internal pipe underneath laminar or turbulent conditions. Non-Newtonian Blood Mimic Fluids BMF more effectively simulate the shear thinning characteristic of blood. The outcomes show that all nanofluid kinds outperformed the base fluid DIW in phrases of heat transmission. It was once also located that Al2O3 reveals larger enhancement than the other by means of 82.4 percentage at (Renf =12670) and (=1 vol. percent). Comparisons current experimental results with formerly stated data and exhibit a excessive stage of agreement. A studies carried out research with a hybrid nanofluid that passes thru a double pipe warmness exchanger (Hussein, 2017). They employed combinations of Aluminum Nitride nanoparticles in ethylene glycol (EG) nanofluids with 1% to 4% volume fractions The hydrodynamic and thermal properties of AlN nanoparticles dispersed in EG are investigated. The outcomes expose that as the extent fractions of nanofluid grows, so does the friction factor, and as the quantity attention of nanofluid decreases, so does the Nusselt number. Meanwhile, as compared to ordinary fluids, the use of hybrid nanofluids with low quantity fract ions can expand warmth transfer effectivity by using up to 160 percent. Examined the warmth transfer extend of MWCNT-H2O nanofluid in double pipe heat exchanger due to vibrating partitions utilizing a bendy double pipe warmth exchanger composed of PVDF for various mass fractions (Hosseinian et al., 2017). The results show that imposing vibrations significantly boosts the warmth transfer coefficient whilst lowering nanoparticle deposition. The biggest make bigger in warmness transfer coefficient is a hundred percent, bought in the experiment range's take a look at of the lowest mass fraction (0.04 percent) with the best possible vibration depth (9 m/s2). The warmth transfer overall performance of CNT-water nanofluid that flows in twin pipe warmth exchanger with float charges ranging from two LPM to 4 LPM and nanoparticle concentrations ranging from 0.1 percentage to 0.3 percent by way of vol (Rajput et al., 2017). The expand in coefficients of warmness transfer was calculated and compared for each scenarios. The warmth transfer characteristics of (Al2O3) and (TiC) micro fluids at assorted of (0.1, 0.2, and 0.25 vol.%) quantity fractions and compared them to ethylene glycol (C2H6O2) (Sumathi and Vijay, 2017). The turbulent convective warmness transfer and waft characteristics of γ- Al2O3/water nanofluid in a double tube warmth exchanger (Raei et al., 2017). Their outcomes confirmed that nanofluids had a greater Nusselt variety in comparison with pure water. They also mentioned that the biggest extend of the friction thing and the warmness transfer coefficient have been 23 and 25% respectively, which have been located when the nanoparticle concentration was 0.15 vol%. The enhancement of warmness switch through the use of ZnO-water nanofluid with a diameter of 20 nm at different volume fraction of 0.3, 1.2, and 2.1 vol (Hussien, 2018). that flows in a double pipe warmness exchanger with and besides the addition of a nanofluid of Zinc Oxide. According to the findings of the experimental study, a nanofluid containing 2.1 percentage ZnO was once chosen as the best. The experimental effects exhibit that raising the particle quantity concentration, warmness flow, and Nusslet Number will increase the warmness transfer coefficient. Have an impact on of different nanofluids on warmness transmission via taking three exclusive nanoparticles into account: (Al2O3), (Fe2O3), and (CuO) (Dew and Shrivastava, 2018). They analyzed the effect of various percentages of nanoparticles in nanofluids and viewed two wonderful volume percentages of nanoparticles of 0.25 and 0.5 percent. According to the consequences of the investigation, CuO nanofluid well-knownshows the greatest warmth switch when in contrast to other nanofluids. CuO nanofluid has eight percent greater warmness transmission than Al2O3, and CuO has 39.90 percentage greater warmth switch than Fe2O3.

The heat transfer, effectiveness, friction factor, and (NTU) of Fe3O4/H2O nanofluids with particle volume concentrations range from 0.005% to 0.06% in a double tube U-bend warmness exchanger and with twisted tape inserts (Kumar, et al., 2018). The Nu of nanofluids rises when particle quantity concentrations and Reynolds numbers rise, and it rises even more as the twist ratio of twisted tape inserts falls. When compared to water data, the Nusselt quantity is improved to 14.76 percent (no insert) and to 38.75 percent (with twisted tape inserts of H/D=10) at 0.06 percentage volume awareness and 30,000 Reynolds number. A two pipe warmness exchanger loaded with Al2O3-TiO2 hybrid (Maddah et al., 2018). Exergy analysis was used to decide nanofluid concentrations in turbulent go with the flow regimes ranging from 0.2 to 1.5. To decide the most giant parameters on exergy efficiency, statistical evaluation such as the Student's test, variance analysis, F-test, and lack of in shape are used. It is concluded that the usage of nanocomposites and twisted tapes improves exergy efficiency as in contrast to the usage of typical water as a heat switch fluid. The average warmness transfer in a double pipe warmth exchanger furnished with twisted-tape elements and hybrid nanofluid. They made hybrid nanoparticles with a diameter of 20 nm and a attention of 1% (w/w) (Barzegar and Mohamad, 2018). The outcomes showed that the warmth switch coefficient used to be approximately 40% greater than when both twisted tape and nanofluid have been employed. The experimental consequences also published that 1% Al2O3/CuO nanofluid with twisted tape had relatively greater warmth switch than 1% hybrid nanofluid except twisted tape. The variants in CHTC, the stress drop of the nanofluid (multi-walled carbon nanotubes (MWCNT-Solar glycol) with exceptional volume concentrations (0.2%, 0.4%, and 0.6%) (Poongavanam, 2019). The outcomes confirmed that the CHTC of the nanofluid containing 0.6% of MWCNT nanomaterials is accelerated to a most of ~115% at a mass flow rate of 0.04 kg/sec. Also, the stress drop increased with an expand the quantity concentrations of MWCNT nanoparticles. The augmentation in strain drop for 0.6% volume awareness of MWCNT– photo voltaic glycol nanofluid is 1.56 times in the mass go with the flow rate of 0.08. Fe3O4/H2O nanofluid float in double pipe warmness exchanger with magnate field (Malekana et al., 2019). The findings confirmed that elevating the rate of mass float reduces temperature of cavern. In addition, as extent percentage of nanoparticles and magnetic subject increase. Experimentally the performance of friction factor, warmness transfer, and effectiveness Fe3O4 nanofluid with specific quantity fraction flow in double pipe warmth exchanger (Apparao, and Srinivasa, 2019). The warm Nanofluids flows an internal tube, while the bloodless water flows in an annular tube. The numerical find out about is finished in Ansys Fluent 15.0, and quite a few nanofluids are employed to decide which nanofluids have the excellent warmth transfer charge primarily based on the results. During this process, a range of nanofluids (Al2O3, CuO, and Fe3O4) are chosen, and the houses of these nanofluids are taken into account with the aid of a range of groundwork papers.

The thermal efficiency and warmness switch coefficient of -Al2O3/water nanofluids flowing thru a twin tube heat exchanger experimentally. At 0.05–0.15% vol., the nanoparticles were well diffused in water (Raei and Peyghambarzadeh, 2019). The effects confirmed that including pretty modest concentrations of nanoparticles to the base fluid elevated heat transmission via up to 16% underneath ideal conditions. It was once additionally confirmed that the thermal performance thing of this nanofluid might also reach 1.11. The impact of Al2O3-water in warmness exchanger of double pipe experimentally. They described that the warmness transfer performance in the heat exchanger of double pipe rose with the aid of 26%, the biggest enlarge among the three examples (Mansoury et al., 2019). The warmness transfer overall performance and strain drop of TiO2-water nanofluids that flows in warmness exchangers with double-tube configuration (Qi, et al., 2019). They regarded the impacts of water of rate vary (qv=1–5 L/min), (0.0, 0.1, 0.3, and 0.5%) nanoparticle mass frictions and nanofluid Reynolds numbers ranged through (Re=3000–12000). The effects confirmed that nanofluids with nanoparticle mass frictions of 0.1, 0.3, and 0.5 percent can improve heat transfer prices with the aid of 10.8, 13.4, and 14.8%, respectively. The impact of MgO-H2O-EG nanofluid that flows in a warmth exchanger of double-pipe experimentally. The fouling of nanoparticles within the warmness exchanger was also investigated and modeled (Arya et al., 2019). The introduction of MgO nanoparticles extended the heat transfer coefficient through 39% in the turbulent regime at Re Z 10500 and wt. percentage Z 0.3. The addition of MgO nanoparticles similarly extended the friction component and pressure drop values. At wt. percent Z 0.3 and Reynolds quantity Z 10500, the former was once elevated by means of 33.8 percent, while the latter was once extended with the aid of 37 percent. Carried out a sequence of assessments to look at the potential use of MgO/water-EG (ethylene glycol) nanofluids (NF) in a double-pipe warmth exchanger (HEX) Fig.1. The effects printed that MgO NPs can improve the HTC by using 39% at ReZ10,500 and wt.% Z 0.3 in the turbulent regime (Arya et al., 2020). Furthermore, the addition of MgO NPs expanded the FF and FPD values. At wt. percent Z 0.3 and Reynolds wide variety Z 10,500, the former was once increased by means of 33.8 percent, while the latter used to be accelerated by means of 37 percent.

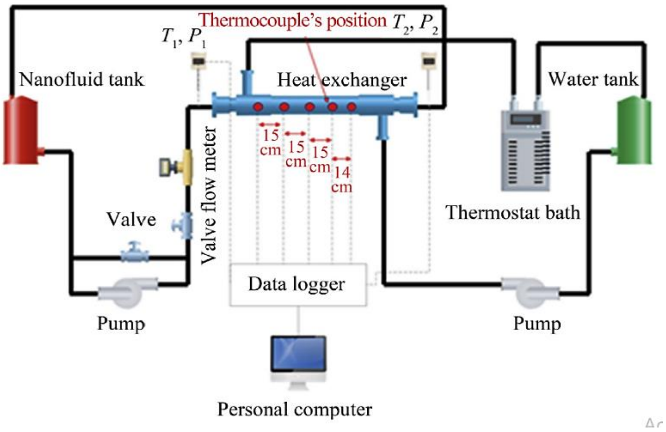

Figure 1: Experimental test rig used in the present work

Have an impact on of nanofluid glide in the counter cutting-edge waft of a twin pipe warmness exchanger. SiO2 nanoparticles are distributed in water at a variety of fractions of (0.2-2) percentage and sizes of particle (50-25) nm (Majeed et al., 2020). The consequences showed that the friction issue improved as the concentration of SiO2 nanoparticles grew and dropped as the dimension of the nanoparticles decreased. The warmness transfer coefficient rose as the awareness of nanoparticles increased and particle size decreased. An experimental investigation that used porous media as well as nanofluid to improve warmness transmission in a twin pipe warmness exchanger Fig.2 (Jasim et al., 2020). The inner pipe has been filled with porous media made of metal balls with sizes of 3 mm. The experiments were carried out with two volume concentrations of alumina nanofluid (Al2O3-water): 0.5 percent and 1 percent. It was carried out with a constant 28 oC bloodless fluid-flow inlet temperature interior the inner pipe and a regular 50 oC warm fluid-flow inlet temperature interior the outer pipe. The outcomes showed that when nanofluid volume concentrations and volume drift fees increased, so did heat transfer. It was once located that when drift fee and nanofluid concentrations increased, so did effectiveness.

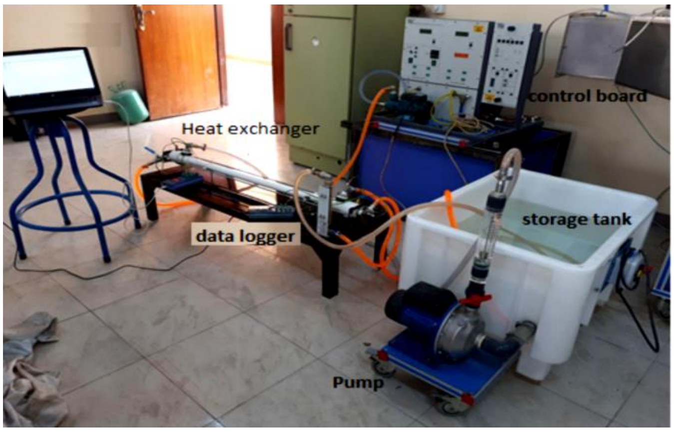

Figure 2: Picture of the experimental system

The transformer-oil based totally nanofluid suspensions via including 0.05 to 0.80 wt.% multi-wall carbon nanotubes (MWCNTs) that was once used as a coolant in a double pipe warmth exchanger operated beneath co- and counter-current waft configuration (Porgar, et al., 2021). The effects exhibited that the maximum coefficients of warmness switch enchancment had been determined to be 86.7% at a MWCNT mass fraction of 0.8 wt.%. Meanwhile, average increments of the coefficients of warmth switch and thermal conductivity of the organized nanofluid used to be printed about 37.2% and 138%, respectively in contrast with that of the base fluid. Examined and described current implementations of nanofluids in various warmth exchangers types, such as plate warmth exchangers, double-pipe, shell and tube, and cross-flow warmness exchangers (Maghrabie et al., 2021). The findings printed that nanofluids improved the performance of various warmness exchanger types. As a result, a performance comparison criterion that combines thermal enhancement and will increase pumping strength for any type of heat exchanger is required to correctly consider average performance. Studied the effect of graphite-water nanofluids with a variety of extent fractions of (0.01, 0.02, and 0.03% vol.) on enhancement of warmness transfer (Auswirkung, et al., 2021). The nanofluid flows in double tube warmth exchanger with each straight and rotational inner tube. The scan states that the nice heat transfer when using nanofluid with 0.02% vol. and 500 RPM speed. The overall performance of a water-based CuO nanofluid (with distinctive CuO quantity fractions) with quantity fractions ranging from 0% to 0.10% in a laboratory-sized double pipe warmness exchanger (DPHE) (Musediq et al., 2021). The temperature distribution, efficacy, and heat transmission in the DPHE have been discovered to rise linearly as the nanoparticle extent fraction increased.Used a hybrid nanofluid of silver and alumina that circulates in a double pipe warmness exchanger (DPHE) (Manjunath, 2021).

1.2 Numerical studies

The heat transfer enhancement by using $Al2O3$ and $TiO2$- water nanofluids that flow in a horizontal tube (Demir et al., 2011). A CFD program with a single-phase model and two-dimensional equations is used to model and solve the horizontal test section. The results reveal that the inclusion of nanoparticles in the fluid improves heat transport, which is consistent with the results of the experimental investigation utilized for the numerical model validation procedure. Studied numerically the effect of using louvered strip inserts placed in a circular double pipe heat exchanger on the thermal utilizing with $Al2O3$, CuO, $SiO2$, and ZnO with different volume fractions in the range of 1% to 4% in water (Mohammed, et al., 2012). The numerical findings show that the forward louvered strip arrangement can increase heat transmission by 367 to 411 percent at the highest slant angle of =30° and the lowest pitch of S=30 mm. The results showed that the Nusselt number increases with decreasing nanoparticle diameter and somewhat increases with increasing nanoparticle volume fraction. Single and two phase (volume of fluid) models to explore the forced convection flow and heat transmission of an $Al2O3$/Water nanofluid at 2% and 3% volume concentrations as shown in Fig. 3 (Mahrooghi and Moghiman, 2015). The results demonstrated that the overall heat transfer coefficient increases as the volume concentration of nanoparticles in the heat exchangers increases and the maximum heat transfer coefficient enhancement is 220 percent.

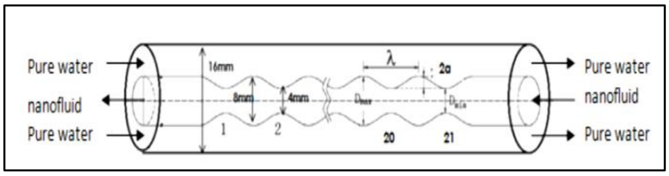

Figure 3: Schematic of considering configuration of circular double tube heat exchanger.

The impact of magnetic field on the $Fe3O4$/wate ferrofluid flowing in a counter go with the flow double pipe warmness exchanger. A non-uniform magnetic field generated through a cutting-edge carrying wire used to be imposed to the ferrofluid at exceptional intensities (Shakiba and Vahedi, 2016). Their numerical outcomes confirmed that the magnetic subject changes the axial pace profile and creates a pair of vortices which leads to an expand of Nusselt number, friction issue and pressure drop. Numerical CFD evaluation for nanofluids that flows in double pipe warmth exchanger (Meganathan et al., 2018). The study the variation between water and copper oxide nanofluids and is evident that as the concentrations of the nanofluids will increase the thermal conductivity also increases simultaneously. They regarded the properties of CuO/Water primarily based nanofluid in conjunction with the thermal conductivity enhancement, to enhance the performance of the warmness exchanger. The result shows that sizeable enhancement in thermal conductivity is attainable. Examined computationally the turbulent drift of $Al2O3$ nanofluid flows in double tube heat exchanger (Bahmani et al., 2018). The effects confirmed that the efficiency of the warmth exchanger amplified through 30% when the usage of nanofluids. Quantitatively investigated Titanium dioxide ($TiO2$) with 0-3vol.% in coolant for warmness transfer enhancement (Salman and Prakash, 2018). Using 3-Dimensional simulations, the thermal evaluation of double pipe warmness exchanger is explored. Investigated performance of warmness switch such as heat flow rate, coefficients of warmness transfer, LMTD, and effectiveness of nanofluid that flows in a parallel and counter go with the flow directions heat exchanger (Emeema et al., 2018). The experiment's results were graphically depicted for evaluation and conclusion. The Alumina/water nanofluid that flows in a double tube warmth exchanger with twisted tape. For nanofluid float modeling, a two-phase combination mannequin was used (Karimi et al., 2019). The impact of the usage of twisted tape with nanofluid drift on the thermal performance and hydrodynamic of the warmth exchanger used to be investigated. The results showed that the use of twisted tape increased the Nu with the aid of up to 22%. 3D numerical simulation to look at the overall performance of double pipe mini warmness exchanger at specific concentrations and drift charges of the magnetic nanofluid, and magnetic field intensities (Bezaatpour, and Goharkhah, 2019). Results exhibit that software of the exterior magnetic field augments the warmness transfer enhancement up to 320% with solely a moderate enlarge of the pressure drop. The induced swirling go with the flow improves the warmth transfer price through disrupting the thermal boundary layer and growing the float mixing in the warmness exchanger. Quantitatively modelled the warmness switch properties of a new category of mango bark nanofluids at some stage in turbulent flow via a double pipe heat exchanger Fig. four For a particle size of 100 nm, a variety of volume fractions were considered (Onyiriuka et al., 2019). The mixture model was used to consider a two-phase flow. The warmth switch coefficient of the nanofluid used to be found to be approximately double that of the base fluid. Furthermore, the Nusselt range decreased through an common of 0.76 with a 1% enlarge in extent fraction.

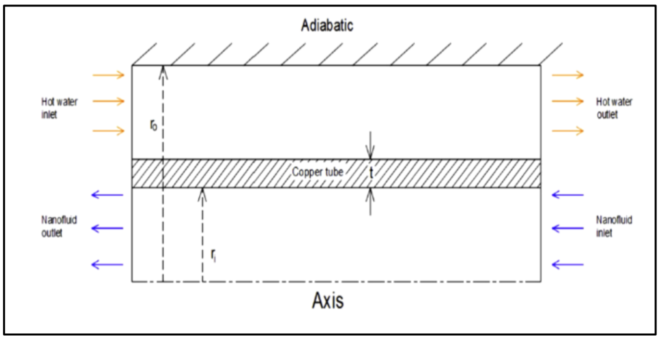

Figure 4: Domain of Geometrical configuration for the study of.

The have an impact on of choice inner and outer tube floor geometries on warmness transmission in a twin pipe warmness exchanger numerically. In the outer tube, a water-CuO nanofluid flows (Bayareh and Nourbakhsh, 2019). The turbulent drift is modeled using a two-equation trendy -turbulence model. The consequences demonstrate that the convex-concave case has the absolute best warmness transmission when in contrast to the smooth-smooth example. The results are also carried out of two exceptional nanofluids, water-ZnO and $SiO2$- water with 3% vol. In assessment to the different nanofluids, water-CuO nanofluid float effects in a higher heat switch fee in a double pipe heat exchanger. Numerically the pressured convection flows in horizontal concentric double tube heat exchanger counter float by using using $Al2O3$-water and Cu-water nanofluids with specific volume attention 1%, 2% and 3% (Mohamed, et al., 2020). The warmth exchanger as shown in Fig. 5 is simulated and solved in a 2D axisymmetric CFD mannequin with ANSYS-FLUENT software program under transitional regime. The nanofluid as bloodless fluid flows thru an annulus tube and the hot water flows via an internal tube. The effects indicate that the fee of warmness transfer of nanofluids will increase with increasing the volume awareness (ϕ). The rate of heat switch of Cu-water and $Al2O3$ –water nanofluids are more advantageous by way of 13% and 7.5%, respectively compared to base fluid at Reynolds wide variety of 4946 and 3% quantity concentration, however it additionally will increase the strain drop of Cu-water nanofluid and $Al2O3$ –water nanofluid through 37% and 27% respectively.

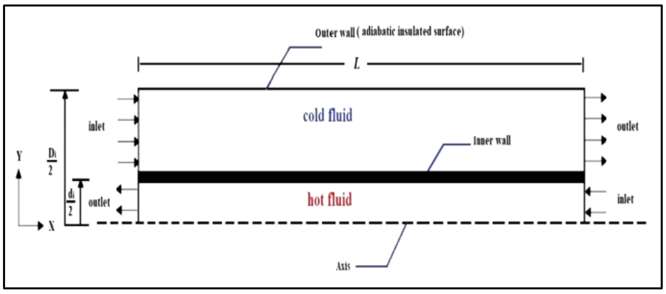

Figure 5: Schematic of the 2D axisymmetric concentric double tube geometry

Numerically investigated the turbulent float traits of CuO-water nanofluid with volume fraction (ϕ) that assorted from 0 to 2 p.c thru warmness exchanger pipe stronger with louvered strips (Nakhchi and Esfahani, 2020). The results showed that the essential reason of turbulent kinetic strength amplify is a high flow disruption between the wall and the louvered strip. Furthermore, the nanoparticles amplify the thermophysical characteristics of the working fluid, resulting in extended heat transmission. CFD to explore the utilization of $MnFe2O4$-(EG) and water nanofluids to discover the warmness switch houses of a warmth exchanger with double pipe the usage of MnFe2O4-EG/Water nanofluid (Permanasari, et al., 2021). The outcomes printed that MnFe2O4 nanofluid improved with MnFe2O4 nanoparticle addition and increased water flow. In contrast, the addition of ethylene glycol has a disastrous effect on this research. Numerically the possessions of the use of Al2O3/water nanofluids that flows in double pipe warmth exchanger with six gear disc turbulators; the nanoparticle was once brought to the hot fluid at concentrations of 1%, 4%, and 6% (Bashtania et al. 2021). The findings exhibit that the using nanofluid with turbulators raises the enhancement of warmth exchanger through 1.21, 1.19, and 1.20 times, respectively. Numerically simulated the warmth switch and glide characteristics of TiO2-H2O nanofluids with mass fractions of 0.0, 0.1, 0.3, and 0.5 wt.% in corrugated and smooth double-pipe warmth exchangers (Ding, et al., 2021). The consequences validated that TiO2-H2O nanofluids successfully superior the heat switch in contrast to deionized water, and that the warmth exchange capacity regularly improved with the TiO2 mass fraction. The corrugated pipe heat exchanger disturbed the fluid go with the flow on both the shell facet and pipe side, breaking the boundary layer and developing vortices in the corrugated zone.

2. Conclusions

From above extended review of experimental and numerical studies that was published on the influence of using nanofluids in the heat transfer enhancement in the double pipe heat exchanger as presented in Table (1). It is possible to infer that the heat transfer performance of a double pipe heat exchanger may be successfully improved by using nanofluids instead of base fluid water for different volume fractions of nanoparticles. One of the finest heat transfer augmentation methods is to take use of the high thermal characteristics of Nanofluids. Changing the geometry of a twin pipe is another approach for improving thermal presentation. Some heat exchangers with double pipe configuration with discontinuous helical fins, turbulaters, strips, ribs, gear diskes, and other modifications will also result in a higher heat transfer rate than a normal double pipe heat exchanger.

Table 1: Summary of previous works parameters.

No.	References	Heat Exchanger Dimensions	Nanoparticle Type	Volume Fraction
1.	Duangthongsuk and Wongwises, 2009	inner tube copper outer diameter 9.53 mm inner diameter, 8.13 mm outer tube PVC outer diameter 33.9 mm inner diameter 27.8 mm Length 1.5 m	TiO_2	0.2 vol.%
2.	Meganathan, et al., 2018	Di= 0.020m Do =0.027m Annulus Shell: di= 0.06m Do=-0.062m Length - 2.37 m	CuO/Water	
3.	Aghayari, et al., 2014	The inside pipe inner diameter of 6 mm, outer diameter of 8 mm, and thickness of 2mm while the outside pipe with the inner diameter of 14 mm, outer diameter of 16 mm, and thickness of 2 mm.	(γ-AL2O3)-water	0.1%–0.3% (V/V).
4.	Sumathi, and K.Vijay, 2017	Do=22.36 Di=9.5 L=500 mm	(Al2O3) and (TiC)	(0.1, 0.2 & 0.25)
5.	Chavda, et al., 2014	The outer pipe: outer diameter 36 mm inner diameter 32 mm length 3 m The inner pipe: outer diameter 18 mm inner diameter 15 mm length 3 m	Al2O3 nanofluid	0.001 % to 0.01 %.
6.	Mahrooghi1and Moghiman, 2015	length of 1000 mm inner diameter 6 mm outer diameters 16 mm	Al2O3/water	2% and 3%
7.	Rajput, et al., 2017	do = 18mm, di = 15mm Di = 132mm, Do = 36mm The length 1.5 m	CNT (Carbon Nano Tube) Water based Nanofluid	0.1% to 0.3%
8.	Onyiriuka , et al., 2019	1.5 m long, Inner pipe inner diameter of 8.13 mm outer diameter of 9.53 mm outer pipe internal diameter of 27.8 mm.	TiO2-water anofluid	0:2 %
9.	Bashtania, et al. 2021	ri= 8.5mm, ro=9.5mm Ri= 17.5mm length L = 750 mm	aluminum oxide to water	1%, 4%, and 6%
10.	Mohamed, et al., 2020	diameter of annulus Di= 0.0762 m, inner tube diameter di=0.0254 m thickness of 2 mm length L= 1.2 m	Al2O3-water and Cu-water	1%, 2% and 3%.
11.	Aryaa, et al., 2020	length 90 cm inner diameter of 6 mm outer diameter 12 mm	MgO NPs	wt.% Z 0.1%, 0.2% and 0.3%
12.	Hussien, 2018	outer pipe outside diameter 50.8 mm	Zinc Oxide ZnO	(0.3,1.2and 2.1).

		inner diameter 42.9 mm inner tube outer diameter 12.7 mm inner diameter 10.2 mm length of 82 cm		
13.	Dew and Shrivastava, 2018	Di 38 mm Do 100 mm L 2100 mm t 2 mm	(Al2O3) (Fe2O3) (CuO).	0.25 % and 0.5 %
14.	Malekana, et al., 2019	Length (m) 3 external diameter of the outer tube (inches) 3/4 external diameter of the inner tube (inches) 1/2 pipe thickness (mm) 1	Fe3O4/water	2% and 4%
15.	M. Bezaatpour, M. Goharkhah, 2019	inner diameters 10 mm outer diameters 14.5 mm wall thickness is 0.25 mm.	Fe3O4) nanoparticles dispersed in water	1, 2, 3 %
16.	Qi, et al., 2019	Dmax=15.8 mm Dmin=11.2 mm, the wall thickness is δ=0.25 mm, outer shell outer diameter 32 mm inner diameter 28 mm length 1200 mm.	TiO2-H2O nanofluids	(ω=0.0%, 0.1%, 0.3% and 0.5%),
17.	Sarafraz and Hormozi 2015	inner diameter 6.35 outer diameter 12.7 mm Length 2400 mm	Ag/water–ethylene glycol (50:50 by volume) or AG/WEG50 nanofluid	0.1%, 0.5% and 1%
18.	Sarafraz, et al., 2016	inner diameter 6.35 outer diameter 12.7 mm Length 2400 mm	COOH-CNT/water nanofluids	0.1–0.3%
19.	El-Maghlany, et al., 2016	inner tube outer diameter 25.4 mm thickness 2 mm outer tube outer diameter 76.2 mm thickness 5 mm	Cu-water nanofluid	1% to 3%
20.	Hosseinian, et al., 2017	Inner tube Copper outer diameter 19 mm thickness 2 mm Outer tubes PVDF outer diameter 84 mm Length 4 cm	MWCNT-water nanofluid	0.04%, 0.17%, 0.25%
21.	Mohammed, et al., 2012	inner diameter D=19.6 mm Length L=500 mm	Al2O3, CuO, SiO2, and ZnO	1% to 4%
22.	Reddy and Rao, 2014	inner tube copper outer diameter of 0.00953 m inner diameter of 0.00813 m, outer tube PVC outer diameter of 0.0339 m inner diameter of 0.0278 m. length 1.5 m	TiO2 nanofluid	0.0004% to 0.02%.
23.	Kumar, 2018	inner tube stainless steel inner diameter ID is 0.019 m outer diameter OD is 0.025 m, annulus tube cast iron inner diameter ID is 0.05 m outer diameter OD is 0.056 m,	Fe3O4/water	0.005% to 0.06%
24.	Maddah, 2014	The inner tube smooth copper inner diameter 50 mm outer diameter 60.2 mm annulus was stainless steel inner diameter of 74.2 mm wall tube thickness of 6 mm.	Al2O3 nanofluid	0.1-1.6 %

REFERENCES

Aghayari R., Heydar M., Fatemeh A., Afshin H., and Mehdi A., 2014. Effect of Nanoparticles on Heat Transfer in Mini Double-Pipe Heat Exchangers in Turbulent Flow. Heat and Mass Transfer. 51(3), 301–306. doi:10.1007/s00231-014-1415-0.

Apparao, G. V., Srinivasa K. 2019. CFD Analysis of a Double Pipe Heat Exchange by using Fluid Based Nanomaterials, International Journal of Trend in Scientific Research and Development (IJTSRD). 3(2); 209

Arani, A.A., and J. Amani, 2013. Experimental investigation of diameter effect on heat transfer performance and pressure drop of TiO2–water nanofluid, Exp. Thermal Fluid Sci. 44, 520–533.

Armand, H., Gharehkhani, S., Shirazi, S.F.S., Amiri, A., Alehashem, M.S., Dahari, M., Kazi, S.N., 2016, Experimental investigation of thermo-physical properties, convective heat transfers and pressure drop of functionalized graphene nanoplatelets aqueous nanofluid in a square heated pipe, Energy Conversion and Management, 114, 38.

Arya, H., Sarafraz M.M., Pourmehran O., M. Arjomandi, 2019. Improved efficiency of a double-pipe heat exchanger with MgO/water-ethylene glycol Q1Q7 (50:50) nano-fluid.

Aryaa H., M.M. Sarafrazb, O. Pourmehranb, M. Arjomandi, Performance Index Improvement Of A Doublepipe Cooler With Mgo/Water-Ethylene Glycol (50:50) nano-suspension, Propulsion and Power Research 2020; 9(1); 75e86.

Bahiraei, M., and M. Hangi, 2013. Investigating the efficacy of magnetic nanofluid as a coolant in double-pipe heat exchanger in the presence of magnetic field, Energy Conver. Manage. 76, 1125–1133.

Bahmani MH, et al. 2018. Investigation of turbulent heat transfer and nanofluid flow in a double pipe heat exchanger. Adv Powder Technol; 29(2); 273–82.

Barzegar, M.H., Mohamad F., 2018. Increasing the Thermal Efficiency of Double Tube Heat Exchangers by Using Nano Hybrid, Emerging Science Journal, 2(1).

Bashtania, I., Javad A.E., Kyung C.K., 2021. Effects of water-aluminum oxide nanofluid on double pipe heat exchanger with gear disc turbulators: A numerical investigation, Journal of the Taiwan Institute of Chemical Engineers. 000, 1-12.

Bayareh, M., A. Nourbakhsh, 2019. Numerical Simulation And Analysis Of Heat Transfer For Different Geometries Of Corrugated Tubes In A Double Pipe Heat Exchanger**,** Journal of Thermal Engineering, 5 (4), 293-301, July, Yildiz Technical University Press, Istanbul, Turkey.

Bezaatpour, M. and Goharkhah M., 2019. Convective heat transfer enhancement in a double pipe mini heat exchanger by magnetic field induced swirling flow, Applied Thermal Engineering, doi: https://doi.org/10.1016/j.applthermaleng.2019.114801.

Chavda, N. K., Jay R. Patel2, Hardik H. Patel3, Atul P. Parmar, 2014. Effect Of Nanofluid On Heat Transfer Characteristics Of Double Pipe Heat Exchanger: Part-I: Effect Of Aluminum Oxide Nanofluid, IJRET: International Journal of Research in Engineering and Technology, 3(12), Available @ http://www.ijret.org.

Chun, B., Hyun U.K. and Sung H.K, 2008, Effect of alumina nanoparticles in the fluid on heat transfer in double pipe heat exchanger system, Korean Journal of Chemical Engineering, 25(5), 966-971.

Darzi, A.A.R., M. Farhadi, K. Sedighi, 2013. Heat transfer and flow characteristics of Al2O3–water nanofluid in a double tube heat exchanger, Int. Commun. Heat Mass Trans. 47, 105–112.

Demir, H., Dalkilic A.S., Kürekci N.A., Duangthongsuk W., Wongwises S., 2011. Numerical investigation on the single phase forced convection heat transfer characteristics of TiO2 nanofluids in a double-tube counter flow heat exchanger, International Communications in Heat and Mass Transfer 38; 218–228.

Dew, K. K. and Shrivastava P., 2018. CFD Analysis Of Double Tube Heat Exchanger Using Different Nanofluid, International Journal for Research Trends and Innovation, 2018 IJRTI . 3(7).

Dharmalingam, R. & Sivagnanaprabhu, K.K. & Jeyaraj, Yogaraja & Gunasekaran, S. & Mohan, R.. 2015. Experimental Investigation Of Heat Transfer Characteristics Of Nanofluid Using Parallel Flow, Counter Flow And Shell And Tube Heat Exchanger. Archive of Mechanical Engineering. 62. 10.1515/meceng-2015-0028.

Ding, Z., Cong Q, Tao L, Yuxing W, Jianglin T, Chengchao W., 2021. Numerical simulation of nanofluids forced convection in a corrugated double-pipe heat exchanger, Can J Chem Eng; 1–11.

Duangthongsuk, W., and Wongwises, S., 2009, Heat Transfer Enhancement and Pressure Drop Characteristics of TiO2-Water Nanofluid in a Double-Tube Counter Flow Heat Exchanger," Int. J. Heat Mass Transfer, 52(7–8), 2059–2067.

El-Maghlany, W.M., Hanafy A.A., Hassan A.A., El-Magid M.A., 2016. Experimental Study of Cu-Water Nanofluid Heat Transfer and Pressure Drop in a Horizontal Double-Tube Heat Exchanger, Experimental Thermal and Fluid Science, doi: http://dx.doi.org/10.1016/j.expthermflusci.2016.05.015.

Emeema, J., C. Lakshmi Sindhuja, K. Laxman, 2018. Experimentation on Double Pipe Heat Exchanger Using Water and Nanofluid", International Journal of Science and Research (IJSR), https://www.ijsr.net/get_abstract.php?paper_id=ART2018284, 7(2), 1179 – 1182.

Goodarzi, M, A. Sh. Kherbeet, Masoud A., Emad S., Mohammad M., Peyman Z., Somchai Wongwises, M. Dahari, 2016. Investigation of heat transfer performance and friction factor of a counter-flow double-pipe heat exchanger using nitrogen-doped, graphene-based nanofluids, International Communications in Heat and Mass Transfer. 76, 16–23.

Hosseinian, A., Isfahani, A. M., and Shirani, E., 2018, Experimental Investigation of SurfaceVibration Effects on Increasing the Stability and Heat Transfer Coeffcient of MWCNTs-Water Nanofluid in a Flexible Double Pipe Heat Exchanger, Experimental Thermal and Fluid Science, 90, 275–285. doi:10.1016/j.expthermflusci.2017.09.018.

Hussein, A.M., 2017. Thermal performance and thermal properties of hybrid nanofluid laminar flow in a double pipe heat exchanger, Experimental Thermal and Fluid Science, doi: http://dx.doi.org/10.1016/j.expthermflusci.2017.05.015.

Hussien, I. A., 2018, Using The Nanofluid To Improve The Heat Transfer In The Double Pipe Heat Exchanger, International Journal of Civil Engineering and Technology (IJCIET), 9(12), 580–591.

Jasim, Q. K., Noah M.S., and Adnan M.H., 2020. Improving Thermal Performance Using Al**2**o**3**-Water Nanofluid In A Double Pipe Heat Exchanger Filling With Porous Medium**,** THERMAL SCIENCE, 24(6B), 4267-4275

Karamallah A. A., Laith J.H and Nisreen M.R, 2016, Investigation of flow and heat transfer in a double pipe heat exchanger with nano fluid, Advances in Natural and Applied Sciences. 10(12).

Karamallah, A. A. and Jehhef, K. A. 2017. Application of Nanofluids for Cooling Newtonian and Non-newtonian Blood Mimicking Fluids Flow in Annular Space, Engineering and Applied Sciences, 2(1), 1-16.

Karimi, A., Abdullah A.A.A., Masoud A., Omid M. , Somchai W., Amin S., 2019. The effects of tape insert material on the ßow and heat transfer in a nanoßuid-based double tube heat exchanger: two-phase mixture model, International Journal of Mechanical Sciences.

Khedkar, R.S., Sonawane S.S., Wasewar K.L., 2014. Heat transfer study on concentric tube heat exchanger using TiO_2 water based nanofluid, Int. Commun. Heat Mass Tran. 57, 163e169.

Koca, T. 2021, Effect of using graphene/water based nanofluid on heat transfer in heat exchangers with rotating straight inner tube. Kerntechnik, 86(1), 50-63. https://doi.org/10.1515/KERN-2020-0039

Kumar, N.T. Ravi, Bhramaraa P., Kirubeilb A., Syam L.S, Manoj K.S, Antonio C.M. Sousac, 2018. Effect of twisted tape inserts on heat transfer, friction factor of Fe3O4 nanofluids flow in a double pipe U-bend heat exchanger, International Communications in Heat and Mass Transfer. 95; 53–62.

Maddah, H., Mostafa A., Nahid G., Sharifah RWA, 2014. Experimental study of Al2O3/water nanofluid turbulent heat transfer enhancement in the horizontal double pipes fitted with modified twisted tapes, International Journal of Heat and Mass Transfer 78, 1042–1054.

Maddah, H., Reza A, Mojtaba M, Mohammad H.A, Milad S, Ali J. C, 2018. Factorial experimental design for the thermal performance of a double pipe heat exchanger using Al2O3-TiO2 hybrid nanofluid, International Communications in Heat and Mass Transfer 97; 92–102.

Maghrabiea, H. M., Khaled E., Enas T.S, Mohammad A.A, Tabbi W., Mohamad R., Olabie A.G., 2021. Intensification of heat exchanger performance utilizing nanofluids International Journal of Thermofluids. 10 100071.

Mahrooghi, A., and Mohammad M, 2015. Effect of nano particles on heat transfer in heat exchangers, Ciência eNatura, Santa Maria, 37, 199–206.

Majeed, N.S., Shaymaa M.S., Hussam N.A.L, Basma A.A, Paul C.A., Gheorghe N., 2020, Study the Effect of SiO2 Nanofluids on Heat Transfer in Double Pipe Heat Exchanger, Rev. Chim., 71 (5), 117-124.

Malekana, M., Ali K, Xiaowei Z, 2019. The influence of magnetic field on heat transfer of magnetic nanofluid in a double pipe heat exchanger proposed in a small-scale CAES system, Applied Thermal Engineering 146; 146–159.

Manjunath, K, 2021. Hybrid Nanofluid Laminar Flow Analysis in Double Pipe Heat Exchanger. Proceedings of the International Conference on Systems, Energy & Environment (ICSEE) 2021, Available at SSRN: https://ssrn.com/abstract=3794702 or http://dx.doi.org/10.2139/ssrn.3794702

Mansoury D, Ilami Doshmanziari F, Rezaie S, Rashidi MM. 2019. Effect of Al2O3 /water nanofluid on performance of parallel flow heat exchangers: An experimental approach. J Therm Anal Calorim; 135(1): 625–43.

Meganathan, B., Sanjeevkumar M., Santhakumar S.T., 2018. Comparsion And Cfd Analysis Of Heatexchanger With Nanofluid For Increasing Effectiveness With And With Out Baffles, International Journal of Pure and Applied Mathematics, 118, 24.

Mohamed M.A. E., Antonio J. G.T, Eduardo B.M., 2020. Numerical Investigation of Heat Transfer with Nanofluids in Concentric Tube Heat Exchanger under Transitional Flow, Energy Perspectives. 1(1).

Mohammed, H.A., Husam A. H, Wahid M.A., 2012. Heat transfer enhancement of nanofluids in a double pipe heat exchanger with louvered strip inserts, International Communications in Heat and Mass Transfer.

Musediq A., S., Yahaya, A., Olanrewaju B., O., Babatunde O., A., & Solomon O., G. 2021. Computational analysis of water-based copper oxide nanofluid properties and performance in a double-pipe small-scale heat exchanger. Engineering and Applied Science Research, 48(2), 161-170.

Nakhchi M.E., Esfahani J.A., 2020. CFD approach for two-phase CuO nanofluid flow through heat exchangers enhanced by double perforated louvered strip insert, Powder Technology. 367. 877–888.

Onyiriuka, E.J., Ighodaro O.O., Adelaja A.O., Ewim D.R.E., Bhattacharyya S., 2019. A numerical investigation of the heat transfer characteristics of water-based mango bark nanofluid flowing in a double-pipe heat exchanger, Heliyon 5. e02416.

Permanasari, A., Avita, H.R, Muhammad, Puspitasari, Poppy, Sukarni, Abdillah, Mirza, 2021. Computational fluid dynamics heat transfer analysis of double pipe heat exchanger using nanofluid MnFe2O4 with ethylene glycol/water, IOP Conference Series: Materials Science and Engineering, 1034(1), 012065.

Poongavanam, G.K., K. Panchabikesan, R. Murugesan, et al., 2019. Experimental investigation on heat transfer and pressure drop of MWCNT - solar glycol based nanofluids in shot peened double pipe heat exchanger, Powder Technology.

Porgar, S., Leila V, Nader N, and Gholamreza V.N, 2021. Physiochemical studies of functionalized MWCNT/transformer oil nanofluid utilized in a double pipe heat exchanger, Canadian Journal of Chemistry.

Qi, C., Tao Luoa, Maoni L, Fan F, Yuying Y, 2019. Experimental study on the flow and heat transfer characteristics of nanofluids in double-tube heat exchangers based on thermal efficiency assessment, Energy Conversion and Management 197, 111877.

Raei B, Shahraki F, Jamialahmadi M, Peyghambarzadeh SM. 2017. Experimental study on the heat transfer and flow properties of γ-Al2O3/water nanofluid in a double-tube heat exchanger. Journal of Thermal Analysis and Calorimetry. 127(3), 2561-75.

Raei, B. and Peyghambarzadeh S. M., 2019. Measurement of Local Convective Heat Transfer Coefficient of Alumina-Water Nanofluids in a Double Tube Heat Exchanger, Journal of Chemical and Petroleum engineering, 53(1); 25-36.

Rajput, N.S., Rishika S, Lav I, Abhishek J, and Shiv K.S, 2017, Comparison of Heat Transfer Performance of Shell & Tube Heat Exchanger and Double Pipe Heat Exchanger for CNT/Water Nanofluid, International Journal of Mechanical Engineering and Robotics Research 6(4).

Reddy, M. C. S., Veeredhi V.R, 2014. Experimental investigation of heat transfer coefficient and friction factor of ethylene glycol water based TiO2 nanofluid in double pipe heat exchanger with and without helical coil inserts, International Communications in Heat and Mass Transfer 50, 68–76.

Salman K, Prasidh E P, 2018. CFD analysis of TiO2/water nanofluid flow in a double pipe heat exchanger, International Journal of Advanced Information in Engineering Technology (IJAIET) 5(5).

Sarafraz, M.M., F. Hormozi, 2015. Intensification of forced convection heat transfer using biological nanofluid in a double-pipe heat exchanger, Experimental Thermal and Fluid Science 66, 279–289.

Sarafraz, M.M., Hormozi, F. and Nikkhah, V. 2016, Thermal performance of a counter-current double pipe heat exchanger working with COOH-CNT/water nanofluids, Experimental Thermal and Fluid Science, 78, 41-49, doi: 10.1016/j.expthermflusci.2016.05.014.

Shakiba, A., and K. Vahedi, 2016. Numerical analysis of magnetic field effects on hydro-thermal behavior of a magnetic nanofluid in a double pipe heat exchanger, J. Magn. Magn. Mater. 402. 131-142.

Sonawane, S. S., Khedkar, R.S., Wasewar, K. L., 2013. Study on concentric tube heat exchanger heat transfer performance using Al2O3 – water based nanofluids. International Communications in Heat and Mass Transfer. 49, 60–68.

Sumathi, B.A.L and Vijay K., 2017, CFD Analysis On Double Pipe Hair-Pin Heat Exchanger With Different Nano Fluids, (IJITR) International Journal Of Innovative Technology And Research, 5(3), 6471-6476.

Zamzamian, A., Oskouie, S. N., Doosthoseini, A., Joneidi, A., and Pazouki, M., 2011, "Experimental Investigation of Forced Convective Heat Transfer Coefficient in Nanofluids of Al2O3⁄EG and CuO⁄EG in a Double Pipe and Plate Heat Exchangers Under Turbulent Flow, Experimental Thermal and Fluid Science, 35(3), 495– 502.

Zarringhalam, M., Karimipour, A., Toghraie, D., 2016, Experimental study of the effect of solid volume fraction and Reynolds number on heat transfer coefficient and pressure drop of CuO–Water Nanofluid, Experimental Thermal and Fluid Science, 76, 342.