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ADVANCES IN HEAT EXCHANGER DESIGN AND DEVELOPMENT: A COLLABORATIVE STUDY1832

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ABSTRACT

Heat exchangers are devices that transmit heat from one medium to another without causing them to combine. A substantial amount of research being done to improve heat transfer with heat exchangers. The study done by several researchers to improve the effectualness of heat exchangers is discussed in the papers. Corrugated plate heat exchangers were discovered to have the highest rate of heat transmission after a thorough investigation.

1. INTRODUCTION

Heat exchangers are devices that transfer heat between two fluids that are the same or different without mixing them. Convection transfers heat from a hot fluid to cold fluid. The rate at which heat is transferred from one fluid to another and the metal should be as high as possible to achieve high efficiency. One method is to increase the heat exchanger's surface area. Recuperators and Regenerators are two types of heat exchangers. Surface generators are another name for recuperators. Another major type of heat exchanger is the recuperator, which extracts and transmits heat on both sides of a partition wall (often in the form of tubes and pipes). Recuperators include automobile radiators, oil coolers, condensers, superheaters, and economizers. Regenerators are further divided into heat exchangers with direct and indirect contact. The three forms of indirect contact heat exchangers are tubular, extended surface, and plate heat exchangers. Plate type heat exchangers are frequently utilized in industries such as automotive, dairy, chemical, power processing, and pharmaceutical. The plate could be perfectly flat or contain minor aberrations. The term "corrugated plate heat exchanger" refers to a heat exchanger that produces consistent undulations. The crest and trough of a corrugated plate heat exchanger give it a sinusoidal shape, which enhances the heat exchanger's rate. When compared to plane plate heat exchangers, the performance, efficacy, and Corrugated plate heat exchangers provide a much greater heat transfer rate.

2. LITERATURE REVIEW

CFD ANALYSIS OF HEAT EXCHANGER

Hwang Seong Won et.al. studied the rate of heat transfer in tubular heat exchangers by changing the shape of the fins from a plain fin to a slit and louvre type. Experiments with Delta winglet vortex generators show that adding fin tubes to a heat exchanger reduces pressure loss while maintaining heat transfer capability approximately identical. Delta winglet vortex generators have varying degrees of efficiency based on their shape and size, as well as where they are deployed. This research investigates the Delta winglet vortex generator and uses a CFD programme to calculate the rate of heat transfer. The pressure loss of delta winglet vortex generators decreases with the addition of fins, according to CFD research. Heat transfer performance improved at high Reynold's number and high velocity, as well as at low Reynold's number and low velocity [1].

Hoettiba et.al. conducted a statistical analysis to improve the penalty for lowering the pressure and heat transfer inside corrugated ribbed passages. When Reynold's number fluctuated between 5000 and 35000, the investigation was evaluated for dimensionless corrugation rib height related to passage heights of 0.05, 0.10, and 0.15, as well as dimensionless corrugation pitch height related to passage heights of 1.5, 2.0, and 3.0. The governing equations were solved using a discretization technique based on the finite volume method, and the flow and thermal fields were predicted using the k model. According to the projected findings analysis, the average Nusselt number within corrugated ribbed passage values ranged from 2.0 to 7.0 times greater than the matching flat passage. Nusselt number increased as the height of the corrugation ribs increased, and it also increased as the rib pitch decreased in corrugated ribbed passages. The boundary layer has broken down as a result of the collapse, downstream flow recirculation, and flow reattachment, the pressure drop ratio increased. The friction factor of flat passages was found to be 2.0 to 6.0 times lower than that of corrugated ribbed passages in the study. The friction factor rose as the height of the corrugated ribs grew and reduced as the pitch of the corrugated ribs decreased in a corrugated ribbed route. In corrugated ribbed passageways, the thermo hydraulic performance factor was likewise determined to range between 0.85 to 1.32.[2]

Nagrani et.al. demonstrated experimentally the total heat transfer rate using Elliptical Annular Fin (EAF) and Circular Annular Fin (CAF) validated by CFD, and used Genetic Algorithm for experimental analysis and EAF optimization (GA). According to the experimental results, the temperature of the annular fin surface declines continuously with the projected surface area in the direction of the main axis. When the SF value is smaller than 0.5, the

GA result shows that EAF is more effective than circular fin for the same area of cross section, regardless of efficiency. When the radius of the circular tube is lower, the form factor is low, and the minor axis hits the circumference of the circular tube, the greatest fin efficacy is achieved.[3]

Mohamed et.al. looked into the performance of V-corrugated channels in terms of heat transfer and flow development. In this study, he used a 290 W/m2 wall heat flux and the operating fluid is air. In addition channel heights (S = 12.5, 15.0, 17.5, and 20 mm) to change phase shifts. The thermal performance of wider channels was found to be superior to narrow channels based on the simulation results. As the phase shift and channel height increase, the pressure drop decreases and the heat transfer rate increases in V- corrugated channels. As a result, it was discovered that augmentation of turbulence and rotational flow produces drag forces on the flow field.[4]

Kapse and Arakerimath et.al. investigated heat transfer coefficient in rectangular plates with various shapes such as bare plate, tubular, and spherical wing, as well as different materials such as Copper, Brass, and Mild Steel plates, and used computational fluid dynamics to simulate the results. The results have also been mathematically modelled. According to the results, a bare copper plate's heat transfer coefficient is higher than other samples, and Reynolds number of tubular M.S plate is higher than Nusselt number of spherical M.S plate.[5]

Yasuyuki and colleagues investigated a heat exchanger that can utilise the difference in temperature between the source and sink of an ocean thermal energy system (OTEC). OTEC's plate heat exchanger has a low efficiency. Herringbone heat exchangers were utilized for experimental and numerical simulation to identify which heat exchanger can deliver better efficiency while using OTEC. As a consequence, the heat transfer rate of a herringbone heat exchanger was discovered to be superior than that of a plate heat exchanger.[6]

Johnson et.al. investigated the heat exchanger's analytical design, which was also numerically analysed. CFD study has been performed using standard k-modeling. When the ideal conditions of flow rate, outer diameter of pipe, and inner diameter of pipe are employed at an effective length for a twin pipe heat exchanger, the problem is solved. The stream was treated for a specific intake to exit temperature when it processed at specified flow rates. According to the findings, the design and study of a double pipe heat exchanger would be a huge success.[7]

Abdur and Jameel et.al. had created a heat exchanger with a baffle shell and tubes. The inclination angle of the baffle plate used in this simulation was 0℃, 10℃, and 20℃. The flow field and temperature were determined using the commercial software package STAR CCM+ v6.06. According to the results of CFD simulations, a shell-and-tube heat exchanger inclined at 20° baffle has superior performance than those inclined at 10℃ and 0℃. The maximum baffle inclination angle is 20 degrees; if the angle is greater than 20 degrees, the middle row of tubes is not supported.[8]

Melvinraj et.al. studied a parallel flow heat exchanger with a ribbed tube heat exchanger that was also modelled and computationally analysed. Pro-e and ANSYS 14.5 were used for designing and analysis, respectively. CFD was used to compare the efficiency of two heat exchangers. The efficiency of a ribbed heat exchanger is superior to that of a plain heat exchanger. Because of the ribbed helical tube's design, fluid flow is not parallel but swirls, generating turbulence and thus enhancing efficacy.[9]

Giurgiua et.al. studied two distinct plate heat exchanger models numerically. The plate's dimensions has an impact on the rate of heat transfer. Tiny channels at 30° are found on one plate heat exchanger, whereas mini channels at 60° are found on the other plate heat exchanger. According to CFD and numerical research, plate heat exchangers with 60° mini channels provide a higher rate of heat transfer than heat exchangers with 30° mini channels.[10].

Dnyaneshwar et.al. was the focus Modeling a copper plate heat exchanger for milk pasteurization in a food sector employing high temperature for a short time. For evaluating the energy required for circulating fluid, this work gives an analytical and CFD analysis of pressure drop of counter flow for milk and water across copper and steel plate type heat exchangers. The challenge of knowing all operating parameters was initially theoretically answered by LMTD. Then there was a comparison between the CFD and analytical results. When comparing the energy necessary for the circulation of water and milk in copper plate heat exchangers to steel plate heat exchangers, it was discovered that the energy required for the circulation of water and milk is very low.[11]

Kumar et.al. ANSYS CFD tool was used to analysis the performance of a baffle shell and tube heat exchanger. By varying the inclination of baffles in shell and tube heat exchangers, the performance of the heat exchanger was determined. Three distinct baffle inclination angles, 0°, 45°, and -45°, were utilized in CFD modelling to determine the impact of baffle inclination angle on heat transfer and fluid flow parameters. As a result of the CFD, it was discovered that the steady state heat flow is higher in the case of +45 degree baffles than in the case of -45 degree baffles. In the case of 0 degree baffles, the heat flux is halfway between 45 and -45 degrees.[12]

EXPERIMENTAL STUDIES ON CORRUGATED PLATE HEAT EXCHANGER

Mohammed and Abed et al studied Heat transfer and fluid flow properties of laminar forced convection in a corrugated channel were quantitatively. The temperature of the channel walls was maintained at a higher level than that of the fluid. The impact of wavy angle and Reynolds number on fluid flow and heat transfer was studied. The Prandtl number was 0.7, and the range of Reynold's numbers utilised for the solution was 500 to 2500. The range of wavy angles was 0° to 60°. The optimal values of heat transfer enhancement and pressure drop were determined to be 3.6 and 1.11 times greater, respectively, than the planar channel, at a wavy angle of 40°.[13]

Khan and Kumar et al studied the performance and efficiency of corrugated plate heat exchangers in parallel and counterflow design. The plate has a sinusoidal wavy surface with a corrugation angle of 45℃. There were three channels in the heat exchanger. The hot fluid in the centre channel started loosing heat because water was flowing through the exterior channels. The hot water was heated to a temperature of 40℃ to 60℃. Both hot and cold fluids have Reynolds numbers in the range of 900 Re > 1300.The performance or efficacy of a corrugated plate heat exchanger for counter flow was found to be 44.5 percent higher when compared to a parallel flow setup. Furthermore, when compared to parallel flow, counter flow has a 7.2 percent lower exergy loss.[14]

Rao et al. employed a corrugated plate heat exchanger with corrugation angles of 30°, 40°, and 50° in their research. Water was employed as the heating medium and glycerol was used as the test fluid. Four thermocouples were used at the input and output to monitor the temperature of the hot fluid and test fluid. According to the findings of the trial, a 50° corrugation angle boosted heat transmission. 60 percent glycerol demonstrated a significant rate of heat transmission when compared to 50 percent, 60 percent, and water. As a consequence of the experiment, it was revealed that the heat transfer rate rises as the corrugation angle and viscosity of the fluid increase.[15]

The performance and efficacy of a corrugated plate heat exchanger were studied by Kumar and colleagues et al. With one pass each, the experiment was carried out on three channels of a corrugated plate heat exchanger. In a counter and parallel flow, hot fluid flowed in the centre channel, while cold fluid flowed in the top and bottom channels. The plate has a sinusoidal form at a 30° corrugation angle. The hot fluid had a temperature of 50 to 70 degrees Celsius, whereas the cold fluid had a temperature of 30 to 40 degrees Celsius at the intake. A counterflow heat exchanger's efficiency was determined to be 48 percent greater than a parallel flow heat exchangers.[16].

Rao and colleagues used water as the test fluid in studies on a sinusoidal corrugated plate heat exchanger. Two stainless steel sheets with a thickness of 1 mm were used to make the plate heat exchanger for executing test channels. It was 30 cm long and had a 5 mm clearance. Three heat exchangers with corrugation angles of 30°, 40°, and 50° were made with these plates. According to the findings of the experiment, the corrugation angle influenced both the heat transfer rate and the pressure decrease. During the experiment, it was revealed that when the plate's corrugation angle increases, the fluid's pressure drop increases and the friction factor decreases.[17]

Kumar et al. investigated the energetic performance and heat transfer parameters of corrugated plates in an exploration through experimentation of plate heat exchangers. In connection to various operating factors, pressure drop, energetic performance, friction factor, exergy loss, effectiveness, and dimension less exergy loss are all investigated. As the number of transfer units (NTU) grows, the efficiency of the Plate heat exchanger improves. By raising the intake temperature of hot water and reducing the input temperature of cold water. The energy loss of corrugated type PHE rises as Reynold's number of cold and hot fluid sides grows. Exergy loss with no dimensions rose as the friction factor and the number of transfer units grew, according to the study (NTU).18]

Faizal and Ahmed put a corrugated plate heat exchanger to the test in circumstances where temperature variations are small. It had a total heat transfer area of 1.16298 m2 and was made up of 20 parallel corrugated plates. 6 mm, 9 mm, and 12 mm intervals were used to space the plates. The lowest rate of heat transmission was attained when the gap between plates was 6 mm. Water was employed as a hot and cold fluid that flowed back and forth. In this experiment, the impact on heat transfer rate was measured by changing the hot water flow rate while maintaining the cold side flow rate and the hot and cold water input temperatures constant. When a result, it was observed that as the mass flow rate of hot fluid increased, the corrugated plate became more turbulent and moved at a faster speed, increasing the rate of heat transfer. When the hot fluid flow rate and heat transfer rate of a heat exchanger with a 6 mm heat exchanger are compared to other values, the complete heat transfer coefficient U, pressure losses, and average thermal length all rise. Due to its effective high thermal length and heat transfer, the plate heat exchanger with 6 mm is judged to be adequate when the pressure loss is significant.[19]

3. CONCLUSION

Heat exchangers have been the issue of numerous investigations. Traditional methods have proven to be both expensive and time-consuming. For researchers, CFD has shown to be beneficial. CFD can be apply to swiftly evaluate a system's effectiveness and heat transfer rate. Corrugated heat exchangers transmit heat at the fastest rate of any type of heat exchanger.

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