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Design and Analysis of Condensing Heat Exchanger

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Abstract:

With the effective recovery of flue gas heat, we can save up to 15 % on fuel and, at the same time, reduce emissions. Also a large amount of water is present in vapour form in the flue gas of a coal power plant. In this study concentration is made on recovering water from flue condensation. Flue gas condensation is a process, where flue gas is cooled below its dew point and the heat released by resulting condensation of water is recovered as low temperature heat. Cooling of the flue gas can be performed either directly with a heat exchanger.or indirectly via a condensing scrubber. A more effective means of this exhaust heat transfer is a condensing heat exchanger. The objective is to identify the various parameters involved in the process of heat transfer which occurs in a condensing heat exchanger and further evaluating the same in view of optimized design. Finally, the result will be validated either using numerical or CFD simulation.

Keywords – : Flue gas, Condensing heat exchanger, Optimization, Dew point temperature.

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I. INTRODUCTION

In this study, analysis of condensing flue gas heat exchanger will be carried out. Condensing flue gas heat exchanger works as similar to that of a water tube boiler in which suitable number of tubes carrying water is heated up using flue gas around the periphery of tubes. It is shell and tube type of heat exchanger with flue gas passing into shell and water flowing through tubes. Thus, the indirect heat exchange takes place between the two fluids. When flue gas and water exchanges heat the temperature of flue gas falls which may go below its dew point temperature. As soon as the temperature of flue gas go below its dew point temperature the water vapour present in the flue gas begins to condensate. Consequently, its latent heat and sensible heat both alters. This is the principle of operation of condensing flue gas heat exchanger.

II. LITERATURE REVIEW:

Solidification mechanism of segment trade substances interior a triplex-tube warmth exchanger used to be investigated **Ammar M Abdulateef[1]** with the assist of experimental as properly as numerical simulations.

The authors had chosen RT82 Paraffin as the segment trade fabric in their studies. In their study, quite a number fin configurations – inside longitudinal fins, exterior longitudinal fins, internal-external longitudinal fins, interior triangular fins, exterior triangular fins and internal-external triangular fins – had been analysed. These analyses have been performed for three waft quotes of Heat Transfer Fluids (HTF). The authors had found an expand in solidification charge with the extend in HTF' mass gowith the flow rate.

Saied Seddegh[2] had studied the have an effect on the geometry orientation over the thermal performance–in phrases of melting (charging process) and solidification (discharging process) – of the PCM with the assist of Computational Fluid Dynamics simulations. The authors had chosen ANSYS FLUENT for these transient CFD simulations as the Enthalpy-Porosity method was once available. They had utilized Coupled algorithm for the indispensable pressure-velocity coupling. For fixing the Momentum and Energy equations, the authors had chosen Second-order Upwind scheme for higher accuracy.

The segment exchange substances that are used for thermal power storage structures go through from low thermal conductivity. Various researches had been carried out to sketch fin configurations to enhance the thermal overall performance of these systems.

GnanaduraiRavikumar Solomon [3] had investigated the have an effect on of fin heights over the solidification rate. This experimental learn about used to be performed on vertically oriented cylindrical latent warmness electricity storage unit with fins. The authors had additionally studied the fin' influence on the smart cooling and sub-cooling mechanisms on PCM.

Abduljalil A Al-Abidi[4] had concluded that the warmness switch fluid (HTF) inlet temperature had a greater have an effect on on the melting of segment exchange fabric than the HTF' mass glide rate. The authors had carried out experimental research on a triplex tube warmth exchanger with the internal-external kind fin arrangement. In this study, RT82 Paraffin used to be chosen as the PCM whilst warm water (90° C) acted as HTF.

Kunal Bhagat[5] had developed a numerical mannequin to analyse the multi-tube thermal electricity storage machine with fins. Their machine had a central tube for the warmth switch apart. These seven tubes had been enclosed with the segment alternate material. The authors had utilized periodic method for performing the CFD simulations for their study. This helped in decreasing the simulation time in their studies. The PCM temperature predictions between CFD simulations and the experimental from their investigations have been in exact agreement. The authors had concluded that the skinny fins helped in improving warmness switch fee whilst growing the fin thickness would end result in discount of PCM volume, consequently the usual thermal ability of the system.

Martin Longeon[6] had studied the affect of the warmness switch fluid's injection path for the charging and discharging cycle in a compact latent thermal electricity storage system. Their lookup work had covered each experimental and CFD simulations. While validating the facts between these strategies in phrases of Paraffin wax temperature predictions, the authors had recommended that the PCM's particular warmness fee performs vital position in discharging cycle results. Based on the outcomes obtained, the authors had concluded the path of warmth switch fluid' injection had much less affect on discharging cycle as in contrast to the charging cycle. They had encouraged pinnacle injection for the warmth switch fluid for the charging cycle whilst a backside injection for the discharging cycle. The authors had performed CFD simulations the use of ANSYS FLUENT. And, the consequences have been discovered to be in exact settlement with the experimental records in phrases of PCM temperature.

In order to have environment friendly warmness switch between the section trade cloth (PCM) and the warmness switch fluid (HTF) in the latent thermal strength storage device (LHTES), the fins are generally positioned on the pipe carrying the HTF. Multiple lookup had been undertaken to pick out fantastic fin design.

A Sciacovelli[7] had studied two modern fin sketch – single bifurcation and double bifurcation fins. These fins have been of Y-shaped as in contrast to the usual fin designs such as longitudinal fins. These bifurcation formed fins ensures the attain of fins prolong to the most distance in to the section alternate fabric subsequently ensuing in higher warmness switch rate. The authors had performed the find out about fluid additionally a tube at an perspective of 60°with the CFD simulations and the Response

Surface Method. Based on their results, they have found 24% enlarge in discharge cycle effectivity with the assist of double bifurcation fin design. **Shengxiang Deng** [8] had performed a comparable learn about on figuring out the have an effect on of fins over the overall performance of the latent warmth thermal strength storage system. The authors had undertaken a 2- dimensional CFD simulations with Lauric acid as section alternate fabric in this research. The perspective between the twin fins in their learn about used to be assorted via 30°, 60°, 90°, 120°, 150° and 180° to examine the consequences in opposition to base mannequin configuration. They had additionally prolonged the learn about by using various the fin size as well. From their results, they had determined an amplify melting time of 66.7% for the most fulfilling fin perspective of 30°. A finite-volume technique based, wholly implicit, numerical mannequin for the melting technique internal the enclosure of Octadecane, a segment exchange material, used to be developed by using **NourouddinSharifi**[9] for non- uniform grids. The enclosure consisted of cavity for the PCM and horizontally oriented fins for the warmness switch enhancement. The authors had investigated the have an effect on of fins such as quantity of fins, fin thickness and the fin size over the PCM melting mechanisms. For these transient process, they had concluded that the time-step of 0.01 seconds to be enough for the simulationsMultiple shell-and-tube warmth exchanger configurations for the Latent Heat Thermal Energy Storage (LHTES) gadget used to be studied the usage of ANSYS FLUENT with the aid of **SoheilaRiahi**[10]. The configurations in their learn about had been Fin Plate Vertical (FPV), Parallel Flow Horizontal (PFH), Counter Flow Horizontal (CFH), Parallel Flow Vertical (PFV) and Parallel Flow Horizontal (PFH). The section exchange fabric (PCM) in their find out about used to be Sodium Nitrate whilst air was once circulated as warmth switch fluid (HTF). In their simulations, air-flow used to be modelled as laminar stipulations whilst the density variants on each fluid and solids due to the warmth switch have been regarded to be negligible. Also, symmetry model strategy was once utilized by way of the authors to mannequin the LHTES system.

Zakir Khan[11] had researched tentatively the inert heat stockpiling framework in a longitudinaland tube warmness exchanger mannequin with paraffin as the segment trade material. The authors had focussed on the LHTES system's transient thermal overall performance and the wonderful warmth switch mode underneath these devices. They had recognized the conduction mode of warmness switch as dominant amongst different modes in LHTESS. Also, low warmness switch at the backside section of the LHTESS was once found as in contrast to the central and the pinnacle portion. The affect of HTF inlet temperature and the go with the flow price over the melting technique of a finned- LHTESS used to be experimentally studied by means of **Moe Kabbara**[12]. In their study, the authors had chosen Dodecanoic Acid as the segment exchange cloth due to its melting temperature (43 ± 0.5°C) and has low hysteresis alongside with decrease cost. Based on their lookup work, the authors had found that HTF inlet temperature to have sizable have an effect on on the PCM melting time as in contrast to the HTF float rate. When the HTF inlet temperature used to be multiplied from 60°C to 70°C, the PCM melting time decreased via 3.5 hours. However, for an HTF go with the flow price make bigger of 0.7 liters/min to 1.5 liters/min, the authors hadn't located any great enchancment in thermal overall performance of LHTESS though they had been capable to decrease the melting time by way of 1 hour by using growing the HTF glide price from 1.5 litres/min to 2.5 litres/min.

Francis Agyenim[13] have studied the sub-cooling procedure in the PCM melting on a Tube-In-Tube LHTESS. In their study, Erythritol with a melting temperature of 117.7 °C used to be chosen as PCM whilst air at one hundred forty °C was once chosen as HTF. The authors had studied three geometrical configurations – Control PCM device (no fins), Circular Finned PCM device and Longitudinal Finned PCM system. Based on the Cycle Time vs. PCM Temperature curve from their experimental studies, it was once found that the longitudinal finned LHTESS had excessive temperature gradient for the duration of the charging procedure observed with the aid of the Control device and then Circular finned system. At the Cycle Time of one hundred minutes, the temperature on the longitudinal finned machine used to be almost 105°C whilst the round finned gadget used to be at 78°C.This shows the low thermal

overall performance at some stage in good warmth addition on the charging cycle of the LHTESS with round fins. A numerical simulation primarily based investigation on thermal overall performance enchancment on a triplex tube warmth exchanger with PCM charging cycle used to be studied by using **Abduljalil A Al-Abidi**[14]. The authors had studied two fin geometrical meeting – interior and exterior – alongside with fin parameters such as wide variety of

fins, fin thickness and fin length. The principal mechanism of warmth conduction, melting and the herbal convection in the PCM was once modelled in ANSYS FLUENT with Boussinesq approximation. The PCM melting was once observed to be decreased with the make bigger in fin size however, for the extend in fin thickness resulted in negligible discount in the melting time.

Conventional LHTESS are oriented either in vertical or in horizontal direction. **N Kousha**[15] had studied the influence of LHTESS unit' inclination perspective over the PCM melting on a Tube-In-Tube warmth exchanger LHTESS. The authors had studied 4 perspective of inclinations - 0° [horizontal orientation], 30°, 60° and 90° [vertical orientation]. The authors had located an preliminary excessive warmth switch on the horizontal orientation as in contrast to the vertical orientation. This used to be attributed the gravitational outcomes of herbal convection of melting. However, after this preliminary stage, melting charge on the vertical orientation had expanded relatively. They had concluded that inclination attitude had a tremendous have an effect on on the solidification system alternatively than on the melting process. Thermal storage ability of the LHTESS suffers due to the low thermal conductivity of the segment trade substances (PCMs) such as Paraffin. Hence, a number of researchers had focussed on improving the warmth switch traits of the LHTESS. The most frequent strategy has been the inclusion of fins on the HTF pipe. **Manish Rathod**[16] had investigated the have an impact on of longitudinal fins on the thermal overall performance – in phrases of PCM's solidification time – with the assist of scan studies. In their take a look at model, three longitudinal fins that had been made of brass have been connected at an attitude of 120°. The general solidification time had been decreased by using 43.6% with the addition of these fins.

Conventional format of LHTESS are of cylindrical in shape.**SaeidSeddegh**[17] had in contrast the thermal overall performance of conical and cylindrical fashioned LHTESS with the assist of experimental studies. The gain of conical structure – with the large radius at the backside – ensured the enchancment in the herbal convection mechanism at some stage in the charging manner of LHTESS. However, the authors had discovered minimal have an effect on on the discharging technique in their find out about on conical fashioned LHTESS.

Most lookup on LHTESS are focussed on the thermal overall performance such as melting/solidification time. The price related in constructing a LHTESS frequently overlooked. **Ralf Raud**[18] had developed mathematical optimization approach for the LHTESS to estimate the thermo-economic cost. In their optimization study, the authors had investigated the connection between LHTESS geometry that consists of fins and their thermo-physical residences and fee for two exceptional PCMs with the melting time as the constraint. Based on their lookup work, the authors had recognized that the choice of fins with excessive thermal conductivity leads to considerable discount of LHTESS cost.

Saied Seddegh[19] had carried out experiments on shell and tube latent warmth storage structures in which the PCM used to be saved on the shell-side. The authors had investigated the overall performance of this shell-and- tube-latent-heat-storage gadget for 4 cylinder diameter primarily based on the shell-to-tube radius ratio and 4 working prerequisites primarily based on the warmth switch fluid inlet temperature. Based on the outcomes received from this experimental study, they had concluded that the HTF inlet temperature had more advantageous affect on the LHTESS overall performance whilst the HTF go with the flow charge had insignificant have an impact on on the performance. Also, they had discovered a discount in charging time almost 38% when the shell-to-tube-radius ratio used to be decreased from 8.1 to 2.7.

M. J. Hosseini[20] had performed a find out about the thermal overall performance of double pipe, longitudinal orientation, warmness exchanger for quite a number fin heights as nicely as Stephan Number for the charging process. RT50 used to be chosen by means of the authors as the PCM in their find out about due to its melting temperature (45 - 51°C) used to be located to be appropriate for photo voltaic strength storage systems. In this study, each experimental and numerical (CFD) strategy had been applied. For the numerical simulation, the enthalpy-porosity approach that are handy in frequent CFD softwares such as ANSYS FLUENT had been utilized for modelling the PCM melting. Based on their study, the authors had concluded that the extend in fin peak resulted higher thermal penetration in the

PCM, main to decreased melting time. The notion of LHTESS was once utilized for enhancing the cooling coefficient of overall performance (COP) of the air- conditioner machine by using **DongliangZhao** [21] with numerical simulations. In their LHTES system, water (for charging process) and air (for discharging process) have been used as warmth switch fluid. The authors had described PCM warmth storage device effectiveness as a ratio of actual-to- theoretical warmth switch in the device and is commonly greater than 0.5. As the fin top used to be regarded to have tremendous have an effect on on the thermal overall performance of LHTESS, the authors had advocated the numerical (CFD) method to discover the most appropriate fin height. With the help of 3-dimensional CFD simulations, **Mushtaq I Hasan** [22] had utilized LHTESS for enhancing the warmness switch traits of micro-channels. In this study, air was once flowing over the micro-channels whilst the PCMs have been positioned at the base of the micro- channel warmness sink. The authors had in contrast
4 exceptional PCMs (Paraffin wax, RT41, n-eicosane, P116) in this study. The software of PCM for the micro-channel warmness sink enabled to preserve general decreased surface temperature. **Sohif Mat** [23] had carried out numerical and experimental research for a triplex-tube LHTESS with a a number of fin configurations. Their 2-dimensional numerical simulations (CFD) had been carried out in ANSYS FLUENT with enthalpy-porosity method with transient solver. The authors had utilized 0.5 seconds as time step for their simulations. For these CFD solver settings, the PCM common temperature anticipated from the simulations have been in precise settlement with the experimental approach. The authors had

investigated the thermal overall performance of the LHTESS beneath three warmth load stipulations – heating from internal the tube, heating from outdoor the tube and heating from each sides. Of these there heating method, the authors had envisioned that the inside heating resulted in most melting time whilst both-side heating approach resulted in minimal melting time. The PCM solidification inner the co- axial cylinder used to be studied by way of **ImenJmal**[24] the usage of numerical simulations (CFD). In this study, Paraffin wax was once chosen as the PCM whilst air used to be furnished as warmness switch fluid in two-passages. The authors had in contrast the solidification manner with and barring the herbal convection on the PCM. Based on their results, they had concluded that the contribution from the herbal convection used to be large and have to be covered in numerical simulations. A transient, laminar, three-dimensional numerical simulation based totally method was once carried out by using **M. Esapour**[25] to look at the LHTESS geometrical parameters as properly as operational stipulations – HTF inlet temperature and float fee - over the PCM melting time. For the geometrical parameters, the authors had assorted the wide variety of HTF tubes as properly as the positioning of the HTF tubes, ensuing in 12 geometrical configurations. With the accelerated range of HTF tubes, the universal warmth switch floor location additionally increases. This resulted in quicker melting time (10%) in their study. The HTF inlet

III. OBSERVATIONS:

The major observations from this literature review has been listed below.

- 2-dimensional CFD simulations with time-steps of 0.5 seconds in the enthalpy-porosity strategy on business CFD softwares had expected the thermal overall performance of LHTESS similar to experimental approach.
- HTF inlet temperature has massive affect on the LHTESS overall performance

while the impact of HTF flow rate was minimum[19].

- The section alternate procedure of the PCMin the LHTESS have been modelled the useof the Enthalpy- porosity method in the CFD software program as a substitute than the multi-phase approach.

IV. CONCLUSION

With the present flue gas composition and available data, the different parameters have been analyzed. These parameters include sensible heat recovery, condensed and uncondensed heat recovery, total heat recovery and mass of condensate.Sensible heat covered is found to be approximately 3300 kg/hr, Latent heat covered is found to be approximately 1700 kg/hr and the total heat covered is found to be approximately 5000 kg/hr. Mass

of water recovered in24 hours is about 17-18 kg.

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