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Improvement The Heat Transfer Rate Of Ac Evaporator By Optimizing Materials- Review

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Abstract- The enhancement of heat transfer in air conditioning (AC) evaporators is essential for improving system efficiency, reducing energy consumption, and meeting modern environmental standards. This review focuses on the role of material optimization in improving the heat transfer performance of AC evaporators. Various materials such as copper, aluminum, and composite structures are evaluated based on their thermal conductivity, corrosion resistance, weight, and cost-effectiveness. Advanced approaches, including nano-coatings, porous structures, and hybrid materials, are also discussed for their potential to enhance heat exchange rates. Furthermore, the use of computational techniques like Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), and optimization algorithms such as Genetic Algorithms (GA) plays a significant role in simulating and selecting optimal materials and designs. This review concludes that material optimization, combined with innovative surface treatments and smart design techniques, holds significant promise for the next generation of high-efficiency AC systems.

Keywords – Finite element analysis, AC condenser CFD analysis, thermal analysis.

I. INTRODUCTION

Air conditioning (AC) systems play a vital role in indoor thermal comfort, particularly in residential, commercial, and automotive applications. The evaporator is a critical component in the refrigeration cycle where the actual cooling of air occurs through heat exchange between the refrigerant and air. Improving the heat transfer rate of the evaporator not only enhances cooling performance but also improves energy efficiency and reduces environmental impact.

II. EVAPORATOR

It is in the evaporators where the actual cooling effect takes place in the refrigeration and the air conditioning systems. For many people the evaporator is the main part of the refrigeration system and they consider other parts as less useful. The evaporators are heat exchanger surfaces that transfer the heat from the substance to be cooled to the refrigerant, thus removing the heat from the substance. The evaporators are used for wide variety of diverse applications in refrigeration and air conditioning processes and hence they are available in wide variety of shapes, sizes and designs. They are also classified in different manner depending on the method of feeding the refrigerant, construction of the evaporator, direction of air circulation around the evaporator, application and also the refrigerant control. In the domestic refrigerators the evaporators are commonly known as the freezers since the ice is made in these compartments. In case of the window and split air conditioners and other air conditioning systems where the evaporator is directly used for cooling the room air, it is called as the cooling coil.In case of large refrigeration plants and central air conditioning plants the evaporator is also known as the chiller since these systems are first used to chill the water, which then produces the cooling effect. In the evaporator the refrigerant enters at very low pressure and temperature after passing through the expansion valve. This refrigerant absorbs the heat from the substance that is to be cooled so the

III. HISTORY

In 1935, Otto Happel in co- operation meet with the engineer Dr. Kurt Lang, for start developing air cooled condenser for stationary steam turbines. The earliest laboratory condenser, a “Gegenstrom Kuhelar” was invented in 1771 by the Swedish-Germen chemist Christian Weigel. At mid 19th century Germen chemist Justeen Von Liebig would provide his own improvements on the preceding design of Weigel and Johann Freidrich and August Gottling with the device becoming known as the Liebig condenser.

Problem Statement: Now a days the A.C. used the material for condenser tube is copper or alluminium, mostly the copper is used as a tube material but the copper used is having low thermal conductivity. So, to increase the heat transfer rate the copper material must have higher thermal conductivity. To overcome this problem we have selected a copper material

C11000 which is having highest thermal conductivity in the entire copper alloy. So, the heat transfer rate can be increase.

IV. LITERATURE REVIEW

Ali Sohani Cellulose pad direct contact evaporative coolers (CPDECs) were modeled and optimized. In this regard, a detailed method for evaluation of the initial cost was introduced. This model as well as thermodynamic, hydraulic and other economic ones were employed to minimize the life-cycle cost (LCC) and the annual water consumption (AWC) and maximize the annual average coefficient of performance (AACOP). It was assumed that the CPDEC was employed as the cooling system for a middle flat of a five-story residential building with floor area of 97.1 m2. Multi-objective optimization (MOO) imposing proper constraints including thermal comfort was done in two scenarios: design optimization process (DOP, applicable before production) and retrofit optimization process (ROP, for currently manufactured systems).

From the different groups within the Koppen-Geiger climate classification system, the ones in which the CPDEC had the potential of usage were identified; a sample city from each group was selected, and the features of the optimized systems for that condition were obtained. It was found that for all applicable climates in ROP as well as classes 'B' and 'C' in DOP, the optimum specific contact area was 540 m2 m−3. Moreover, the features of the optimized system in ROP were affected by both climatic and economic parameters while in DOP the effect of climatic condition was much more than economic criteria. The results also showed that in comparison to the base case conditions, MOOs improved, in average, LCC, AWC, and AACOP 52.8%, 74.3% and 146.9% in the case of DOP and 20.9%, 64.6% and 70.1% in the case of ROP. These mean significant improvements were achieved by MOOs in the both scenarios.

Towhid Gholizadeh An innovative bi-evaporator electricity/cooling cogeneration system fueled by biogas is introduced. The plausibility of the introduced integrated power plant is examined from thermodynamic and economic vantage points. Later, single- and multi-objective optimization of the reckoned system are achieved by selecting appropriate parameters as decision variables and thermal and exergy efficiencies and total unit product cost (TUPC) of the system as objective functions. Four optimum modes of thermal efficiency optimum design (TEOD), exergy efficiency optimum design (EEOD), cost optimum design (COD), and multi-objective optimum design (MOOD) are selected for optimization and the attained results are compared with each other. In MOOD mode, it was found that the recommended system could generate optimum overall cooling load and net electricity of 641.7 kW and 1137 kW, respectively, achieving thermal efficiency of 62.69%, exergy efficiency of 38.75%, and TUPC of 7.75 $/GJ. It was substantiated that integrating the introduced cogeneration system with biogas-fueled gas turbine (GT) cycle could improve the thermal and exergy efficiencies up to 67.33% and 19.15% in the base mode and 77.84% and 15.94% in the optimum mode (MOOD mode), respectively. In MOOD mode, the TUPC of the integrated system is around 32.69% lower than that value in the GT cycle. The outcomes of the 2nd law evaluation portrayed that among all components, the combustion chamber attributes as the utmost destructive part of the system, followed by the vapor generator. Also, to examine how the introduced set-up reacts to any external fluctuations, a thoroughgoing sensitivity examination based upon given parameters was fulfilled.

Jian-hua XIANG A theoretical model of phase change heat sink was established in terms of thermal resistance network. The influence of different parameters on the thermal resistance was analyzed and the crucial impact factors were determined. Subsequently, the forming methods including ploughing–extrusion and stamping method of boiling enhancement structure at evaporation surface were investigated, upon which three-dimensional microgroove structure was fabricated to improve the efficiency of evaporation. Moreover, the crucial parameters related to the fabrication of miniaturized phase change heat sink were optimized. The heat transfer performance of the heat sink was tested. Results show that the developed phase change heat sink has excellent heat transfer performance and is suitable for high power LED applications.

S. Spiering Compound In2S3 powder was evaporated on Cu(In,Ga)Se2 substrates from the ZSW inline multi-stage co-evaporation process. Laboratory devices with the complete layer structure Mo/CIGS/In2Sx/i-ZnO/ZnO:Al/Ni–Al grid on 0.5 cm2 total cell area were prepared and analysed for their J–V characteristics. A post-annealing step in air after completing the device is essential to enhance the cell performance. In this work the influence of window process conditions like process temperature, layer thickness and sputtering gas composition on the cell characteristics was investigated. Electrical characterisation by temperature-dependent current voltage and admittance spectroscopy were performed to better understand the impact of buffer parameters on electrical transport. By optimization of the buffer layer thickness in combination with window layer variations, cell efficiencies >16% could be achieved. A record cell efficiency of 18.2% with anti-reflective coating was obtained.

D. Zöller The Vacuum Thermal Evaporation (VTE) process is a technique for the production and deposition of thin films, which are used in various industrial applications. Here, the coating process is performed by evaporating a raw material in a high vacuum (HV) environment. The major goal is to produce a thin layer through a well-defined deposition rate. Due to high demands on the layer thickness, the tolerance for the temperature within the vacuum chamber is less than 0.2 K. This requieres the design of very well tuned controllers. In this paper, a Model-based Predictive Control (MPC) approach is presented for controlling the temperatures in the VTE process that explicitly takes into account the limitations arising from the requirements.

First, the heat transfers within the heater and the source are investigated and described by physically motivated equations. As the heat transfer in the HV is dominated by radiation, this approach leads to a nonlinear system. Reliable measurement data are used to parameterize the previously derived dynamic model of the temperature behavior. An advantage of this physically motivated model is, in contrast to a linear operating point model, to allow an extrapolation and therefore to adequately depict the system behavior in a large operating range. Based on this approach, a MPC is developed and implemented on a pilot plant. It is shown that the high requirement on the temperature accuracy is met by the use of the proposed MPC. Experimental results show the potential of the introduced control scheme.

Yan-Ke Lin Flash spray cooling has been subject to increased attention because of its high heat dissipation capacity at low surface temperature in the application of high power technologies. In this study, experiment was conducted to study the effects of spray distance and nozzle diameter on heat transfer performance in a closed-loop R410A flash spray cooling system for the first time. Five spray distance from 10 mm to 30 mm and three nozzles with same internal structure but different diameters of 0.51, 0.56 and 0.69 mm were employed. The experiment results indicated the critical heat flux (CHF) value firstly increased and then deceased with the increase of spray distance, which is consistent with previous research of spray cooling with FC-72 and FC-87. The highest CHF value reached 264 W/cm2 while maintaining surface temperature below 30 °C and heat transfer coefficient (HTC) was about 210 kW/(m2·K) at 25 mm, which were 60% higher than those at 10 mm spray distance. The nozzle with medium orifice diameter of 0.56 mm showed a superior cooling performance, instead of larger nozzle with higher refrigerant flow rate. Therefore, there existed a counterbalance between the mass flow and outlet velocity in determining the optimum nozzle orifice diameter.

Mohit Barthwal Thermal energy storage can be employed for air conditioning system load management, i.e., load shifting and leveling, to serve the peak electricity demand for the air-conditioning system with high capacity utilization. Ice and phase change material-based thermal energy storage systems were modeled and optimized for air-conditioning applications. The mathematical modeling involved energy, exergy, environmental and economic analysis of both the systems at full and partial operating modes. The system is then optimized for a commercial building to give maximized exergy efficiency and minimized total annual investment and operating cost over five different system temperatures as decision variables. The full operating mode strategy resulted in a higher exergy efficiency for both systems, whereas partial operating mode proved to be a more economical operating strategy. The multi-objective genetic algorithm-based optimization is carried out with two different refrigerants (R134a and R717) in the vapor compression refrigeration cycle of the systems. A single system design point is then selected using a multi-criteria decision-making technique. The electricity consumption while utilizing the thermal energy storage based system was lower as compared to the conventional system for air-conditioning applications. The two modeled systems are compared based on storage media, operating strategies, and the refrigerant used.

Abdurrahman Muhammad Fahmy Voriconazole (VRC) is a broad spectrum, second generation triazole antifungal. The main use of VRC is via the oral and intravenous route. The study aimed to formulate VRC into ternary micellar systems (TMSs) for the topical treatment of ocular mycosis. TMSs were successfully prepared by water addition/solvent evaporation method, applying a 3-factor D-optimal design. The numerical optimization process suggested an optimal formula (OTMS) composed of total Pluronics to drug weight ratio of 22.89: 1, 1:1 weight ratio of Pluronic® P123 and F68, and 2% w/v of Labrasol. OTMS had high solubilization efficiency of 98.0%, small micellar size of 21.8 nm and suitable zeta potential and polydispersity index values of -9.0 mV and 0.261, respectively. OTMS exhibited acceptable stability for 3 months. Transmission electron microscopy demonstrated the spherical morphology of micelles. OTMS was expected to cause no ocular irritation or blurring in vision as reflected by pH and refractive index measurements. The histopathological study revealed the safety of OTMS for ocular use. The fungal susceptibility testing using Candida albicans demonstrated the superiority of OTMS to VRC suspension, with greater and more durable growth inhibition. Therefore, ocular application of optimized VRC-loaded TMSs can be a promising treatment for ocular mycosis.

Zepeng Han Solar-driven trigeneration systems do not consume any fossil fuels and can output cooling, heating, and electricity independently, which effectively reduces environmental pollution and improves solar energy utilization. However, the traditional solar-driven trigeneration system only utilizes part of the solar spectrum, resulting in significant heat losses. Therefore, a new full-spectrum solar-driven trigeneration system integrated with an organic Rankine cycle is proposed to improve solar energy utilization efficiency. Applied the Engineering Equation Solver, the thermodynamic models of the trigeneration system are established, and the effects of some key parameters on thermodynamic performance are discussed. Additionally, the thermal allocation ratio is optimized to maximize the environmental benefits of the system. The simulation results indicate that solar to electric efficiency, energy efficiency, and exergy efficiency are positively

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correlated with the cut-off wavelength of norbornadiene. When the thermal allocation ratio is 0.3, the system has the most significant environmental benefit. The annual solar to electric efficiency, annual energy and exergy efficiencies reach 3.80%, 66.97%, and 8.27%, respectively. Compared with the reference system, both the carbon dioxide emission and primary energy consumption are reduced by 41.75%, demonstrating that the proposed system effectively improves the utilization of solar energy.

Hadi Ghaebi In the present work, a novel combined power and ejector refrigeration cycle is proposed by an appropriate combination of a Kalina cycle (KC) and an ejector refrigeration cycle (ERC) to produce power output and cooling output, simultaneously. The exhaust of the turbine is fed to the ejector as a primary flow to draw the secondary flow into the ejector. Energy, exergy, and exergoeconomic analysis of the proposed cycle are carried out using Engineering Equation Solver (EES) software. In addition, considering the thermal efficiency, exergy efficiency, and sum unit cost of the product (SUCP) of the system as objective functions, single- and multi-objective optimizations are carried out by genetic algorithm (GA) leading to determination the optimum design variables including the vapor generator pressure, evaporator temperature, condenser pinch point temperature, heat source temperature, ammonia concentration, and expander ratio.

The results of the optimization demonstrated that the proposed cycle performs in an optimum state based on the selected objective functions when vapor generator pressure, evaporator temperature, condenser pinch point temperature, heat source temperature, ammonia concentration, and expander ratio work at 17.5 bar, 285 K, 8 K, 473 K, 15%, and 2.5, respectively. In this case, the optimum thermal efficiency, exergy efficiency, SUCP of the system are calculated 20.4%, 16.69%, and 2466.36 $/MWh, respectively. Moreover, it is demonstrated that the thermal efficiency can be maximized for the proposed cycle with respect to the vapor generator pressure, vapor generator temperature, and heat source temperature. Furthermore, it is shown that ejector has the main contribution in the exergy losses which is followed by the condenser. At the end, the effect of some key parameters on the main thermodynamic performance criteria are examined. It is shown that one can obtain a higher thermal and exergy efficiencies at lower ammonia concentration and condenser pinch point temperature as well as at higher evaporator temperature.

V. IMPORTANCE OF MATERIAL OPTIMIZATION

The material used in the construction of an evaporator has a direct impact on:

- Thermal conductivity
- Corrosion resistance
- Mechanical strength
- Weight and cost

Optimizing the material can significantly enhance the performance of the heat exchanger without increasing the size or cost substantially.

Methods for Improvement

Several techniques can be adopted to improve heat transfer by optimizing materials:

- Material selection using multi-criteria decision-making (e.g., thermal conductivity, cost, manufacturability).
- Surface treatment such as nano-coating, fin design enhancement.
- Use of composite materials like aluminum foam, or metal matrix composites (MMCs).
- Bio-inspired fin geometry and advanced fabrication methods like 3D printing.

Role of Computational and Optimization Techniques

The improvement process is often aided by computational tools like:

- Finite Element Analysis (FEA)
- Computational Fluid Dynamics (CFD)
- Optimization algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), or Multi-Objective Optimization for material and design selection.

These techniques allow simulation-based evaluation before physical prototyping, saving cost and time.

Research Trends and Experimental Findings

Recent studies have shown:

- Use of nano-coated surfaces can increase heat transfer by up to 30%.
- Optimization with genetic algorithms leads to 10-15% better performance in simulated environments.
- Aluminum foams or porous structures help increase the surface area, improving overall heat exchange.

Limitations and Challenges

- High-performance materials often come at a high cost.
- Long-term reliability and corrosion behavior in humid environments.
- Difficulty in large-scale manufacturing of nanomaterials or advanced composites.
- Need for balancing performance with affordability in commercial applications.

VI. CONCLUSION AND FUTURE SCOPE

Conclusion

Optimizing the materials used in AC evaporators is a promising approach to significantly enhance the heat transfer rate, reduce energy consumption, and contribute to the development of more efficient and sustainable cooling systems. With continued research and development, especially in the field of nanotechnology and AI-based optimization, the future of heat exchanger design looks more efficient, compact, and environmentally friendly.

Future Scope

- Research on green materials and recyclable composites.
- Integration with smart systems for adaptive heat transfer based on environmental load.
- Hybrid materials combining graphene, aluminum, and phase change materials (PCMs).
- AI-based predictive material selection and optimization.

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