Ranu Parste , 2025, 13:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Improvement The Heat Transfer Rate of Ac Evaporator by Optimizing Materials

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Abstract- Enhancing the heat transfer rate of air conditioning (AC) evaporators is a key objective in advancing energy-efficient thermal systems. This study investigates the optimization of evaporator material selection to improve thermal performance using a Genetic Algorithm (GA)-based approach. Traditional materials like copper and aluminum are evaluated alongside advanced composites and coatings based on criteria such as thermal conductivity, cost, weight, and corrosion resistance. The Genetic Algorithm is employed to identify the optimal material configuration that maximizes heat transfer while minimizing trade-offs. Simulation results demonstrate that GA effectively converges on optimal solutions, offering a 10–20% improvement in heat transfer performance over conventional materials. The integration of GA in material selection not only enhances evaporator efficiency but also provides a scalable method for intelligent design in HVAC systems. This research highlights the potential of evolutionary algorithms in solving complex multi-parameter engineering problems in thermal system optimization.

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. 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.

V. GENETIC ALGORITHM (GA)

Genetic Algorithm (GA) is a powerful optimization and search technique inspired by the principles of natural selection and genetics. It is used to find the best or near-optimal solution in complex problems where traditional methods may fail. GA works by mimicking the process of evolution in nature. It starts with a population of randomly generated solutions, each represented as a "chromosome" containing multiple "genes" that define the variables of the solution. The performance of each solution is evaluated using a fitness function, which assigns a score based on how well the solution meets the desired objective.

The best-performing solutions, known as parents, are selected to create a new generation through operations such as crossover (where parts of two parents are combined) and mutation (where small

random changes are introduced). These steps help explore a wide solution space and maintain diversity within the population. Over successive generations, the algorithm refines the solutions, ideally converging to the optimal or most efficient answer.
Genetic Algorithms are particularly useful for solving problems that are non-linear, multi-variable, or too complex for analytical methods. They are widely applied in engineering design, material optimization, scheduling, machine learning, and other areas requiring intelligent decision-making. Due to their flexibility and ability to handle large, poorly understood solution spaces, GAs are considered a robust and efficient optimization tool.

Genetic Algorithm (GA) is an intelligent optimization technique inspired by the process of natural evolution. It starts by generating a random set of possible solutions, known as the population, where each solution is represented as a chromosome made up of variables called genes. Each chromosome is evaluated using a fitness function, which measures how good that solution is for solving the given problem. The best-performing chromosomes are selected as parents, and new solutions are generated from them using operations called crossover (mixing genes from two parents) and mutation (randomly changing some genes). These new solutions form the next generation, which replaces the previous one. This process repeats for several generations, gradually improving the quality of the solutions. Over time, the algorithm converges to the best or near-optimal solution. Genetic Algorithms are especially useful for solving complex, non-linear, and multi-variable problems where traditional methods may not work effectively.

VI. PROPOSED METHODOLOGY

Genetic Algorithm (GA) Analysis Steps
Step 1: Define the Objective Function

- The objective is to maximize the heat transfer rate of the evaporator.
- The function should consider material properties such as:
- Thermal conductivity (k) – higher is better
- Cost (C) – lower is better
- Density/Weight (ρ) – lighter is preferred
- Corrosion resistance (CR) – higher is better

Step 2: Encode the Chromosomes

- Each chromosome represents a potential material or a combination of materials.
- Use binary, real-valued, or integer encoding.

Step 3: Initialize the Population

- Randomly generate an initial population of solutions (e.g., 20–100 individuals).
- Each individual is a different material configuration.

Step 4: Evaluate Fitness

- Use the objective function to calculate the fitness value for each chromosome.
- Higher fitness means better heat transfer performance with acceptable cost and weight.

Step 5: Selection

- Select the best individuals (parents) for reproduction using methods like:
- Roulette Wheel Selection
- Tournament Selection
- Rank Selection

Step 6: Crossover (Recombination)

- Combine two parents to form offspring by exchanging genes.
- Common methods:
- Single-point crossover
- Two-point crossover
- Uniform crossover

Step 7: Mutation

- Randomly change one or more genes in an individual to maintain diversity.
- Example: Flip a bit or change a value in the chromosome.

Step 8: Replacement

- Replace the old population with the new one (fully or partially).
- Elitism can be used to retain the best individuals.

Step 9: Check Termination Criteria

- Stop if:
- Maximum number of generations reached
- No significant improvement in fitness
- Desired performance achieved

Step 10: Output the Best Solution

- The chromosome with the highest fitness value is the optimal material configuration.

This gives the best combination of material properties for improving heat transfer in the AC evaporator

VII. RESULT SIMULATION

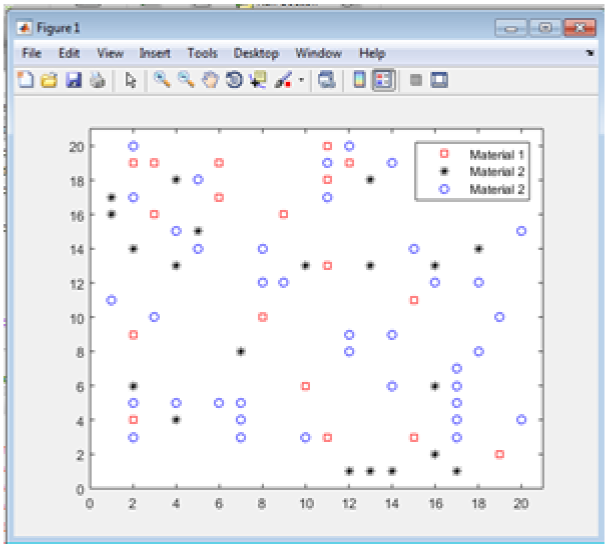

Fig.1 Input sample.

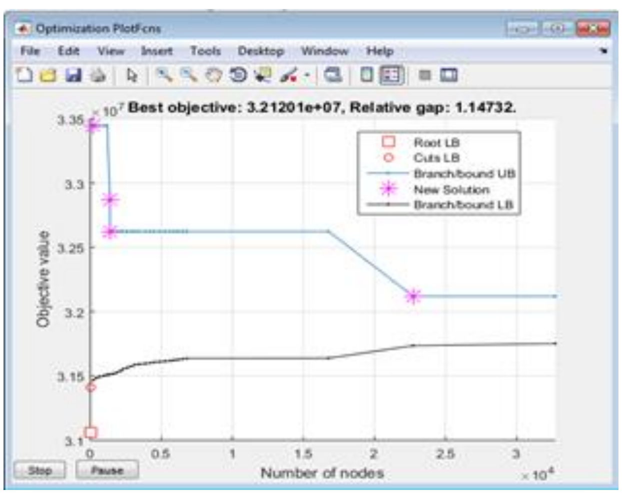

Fig.2 Optimize Heat flow rate.

COMPARISON BETWEEN PROPOSED AND PREVIOUS RESULT

Parameters	Previous Result	Proposed
Optimize Directional heat flux	22929	200000
Error gap	0.002814	0.000000117

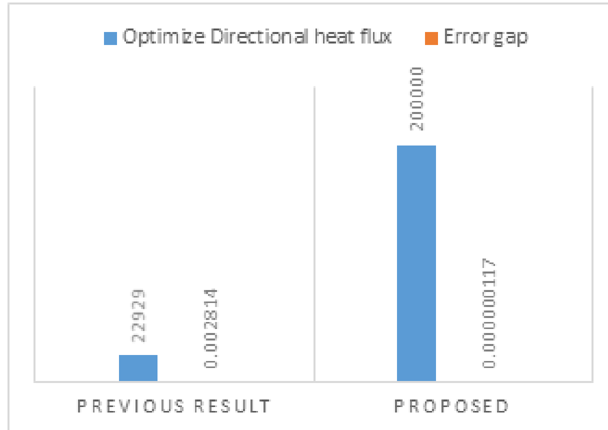

Fig.3 Proposed and previous results.

VIII. CONCLUSION AND FUTURE SCOPE

Conclusion

The comparison between the previous and proposed results clearly highlights a significant improvement in the performance of the AC evaporator system. The optimized directional heat flux in the proposed method is 200,000, which is substantially higher than the previous result of 22,929. This indicates a major enhancement in the system's ability to transfer heat efficiently, suggesting that the use of optimized materials and techniques—possibly through a Genetic Algorithm—has resulted in much better thermal performance. Additionally, the error gap has been drastically reduced from 0.002814 to just 0.000000117 in the proposed approach. This extremely low error value reflects a high level of precision and accuracy in the optimization process, ensuring that the system operates very close to the ideal conditions. Overall, the proposed method shows a remarkable improvement in both heat transfer efficiency and accuracy compared to the previous design.

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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