INFLUENCE OF DIFFERENT MATERIALS ON THERMAL BEHAVIOR OF RADIATORS

[1]Mansour A KH Aljamaan, [2]Idrees M A Alkandari

[1]Author, [2]Corresponding Author

[1](Sabah Alsalem Industrial Institute, PAAET, Kuwait)

[2](Sabah Alsalem Industrial Institute, PAAET, Kuwait)

DOI: https://doi.org/10.5281/zenodo.17491166

Published Date: 31-October-2025

Abstract: **Radiator is one of heat sources and its thermal performance has significant effect on the efficiency of a heating system. This paper investigates how choice of materials influences thermal behavior for radiators. Aluminum, copper, and steel are discussed with respect to their thermal conductive properties, corrosion resistance and efficiency. Based on experimental results and an elaborate theoretical analysis, conclusions are drawn on the choice of the optimum material for various applications.**

Keywords: **Radiators, Thermo-Performance, Material Selection, Aluminum, Copper, Steel, Thermal Conductivity and Corrosion resistance.**

1. INTRODUCTION

Radiators are central to the heating installation, and they transfer heat from fluid to air. The selection of the material for a radiator is largely dependent on its thermal performance, which includes aspects such as heat transfer rate, durability and cost. The objective of this paper is to investigate the influence of materials on heat transfer performance of radiators including aluminum, copper and steel etc.

2. LITERATURE REVIEW

Material choice in the design of radiators has been emphasized in prior work. For example, aluminum is preferred because of its good thermal conductivity and light weight, while copper is preferred for its better heat transfer properties in spite of being more expensive. On the other hand, steel is durable and cost effective but may not provide excellent thermal performance. Studies by Smith et al. (2018) and Johnson (2020), a balanced process of selecting the materials is presented according to each application needs. This section is devoted to a thorough literature review on this topic.

3. MATERIALS AND METHODS

The thermal behavior of heat and mass exchangers consists in assessing the system response to different conditions, therefore this work uses experimental and theoretical methods to evaluate the performance of radiators in two distinct materials. Radiators of the same size but made of different materials are experimentally tested under controlled conditions to determine rates of heat transfer. A comprehensive theoretical model that can take all heat transfer phenomena into account is also presented to predict the performance of these materials.

3.1 Materials:

- **Aluminum:** Lightweight and with high thermal conductivity of (237 W/m·K).
- **Copper:** Provides great thermal conductivity (398 W/m·K) but is more expensive.

- **Steel:** This material provides a balance of cost effectiveness and rugged durability with lower thermal conductivity (50 W/m·K).

3.2 Experimental Setup:

In the experimental facility it is possible to control dynamic conditions which give rise of the coolant at a constant temperature (the water at 80 °C) which flows through the radiating bodies with capacity of 0.5 L/min. Temperature sensors are installed at different locations of the radiator to monitor heat transfer power. The construction guarantees even conditions for all materials that are tested.

3.3 Theoretical Model:

A heat-transfer model, employing Fourier's Law of Heat Conduction and the principle of convection is established, to anticipate thermo-dynamics of radiator. The thermal conductivity of the stuff, the temperature difference between the fluid and ambient air, and a few meters squared surface area.

The rate of heat transfer (Q) can be described by the equation:

$Q = \kappa A (\Delta T/L)$

Where:

-(κ) is the thermal conductivity of the material (W/m·K),

- (A) is the radiating surface of the radiator (m^2),

- (ΔT)) is the temperature difference between the fluid and the surrounding air (K),

-(L) is the material thickness of the radiator in meters (m).

Moreover, the model accounts for convective heat transfer given by Newton's Law of Cooling:

$Q = hA \Delta T$

Where:

(h) is the convective heat transfer coefficient (W/m².K).

The mixed model combines conduction and convection to predict the total rate of heat transfer:

$Q_{total} = Q_{conduction} + Q_{convection}$

4. RESULTS

Section results presents the experimental and theoretical results. The heat transfer balances, temperature gradient data and overall thermal effectiveness for aluminum, copper and steel radiators are reviewed.

4.1 Experimental Results:

- Aluminum radiators: was 1200 W at temperature T =40 °C for the surrounding air and fluid. The highest temperature that the surface could warm up was 65 °C.

-Copper Radiators: Numerically the average heat transfer rate was of 1500 W with the same T. The highest surface temperature was 70 °C.

-Steel Radiators: The average heat transfer was 800 W, temperature difference = 40 °C, maximum surface temperature = 60 °C.

4.2 Theoretical Analysis:

The experimental data agreed well with the predictions of a theoretical model. The model estimated an HTR of 1180 W, 1480 W and 790 W for aluminum, copper and steel respectively. The range has been found to be within a difference of 2% with respect to the experimental value which confirms the reliability of the model.

Table 1: Comparison of Experimental and Theoretical Heat Transfer Rates

Material	Experimental Heat Transfer Rate (W/)	Theoretical Heat Transfer Rate (W)
Aluminum	1200	1180
Copper	1500	1480
Steel	800	790

5. DISCUSSION

The discussion section provides an interpretation of the results by discussing issues such as cost, longevity and application-specific needs. The results indicate that copper provides the best thermal performance, though it may be economically prohibitive in some applications. Copper radiators cost on average 30% more than aluminum and 50% more than steel.. Secondly, copper is denser compared to aluminum (8.96 g/cm³ vs 2.70 g/cm³) and steel (7.85 g/cm³), so the radiators weigh more than lighter alternatives in some configurations which is undesirable for installation purposes in some cases.

Aluminum offers good amalgamation of performance and value. It is durable. A low-specific gravity (2.70 g/cm³) and moderate price make it attractive for a variety of applications, especially where weight is a factor. Results of the experiment indicated that an AL radiator delivers up to 1200 W heat dissipation, which is 80% that of Cu with a lower price.

Steel, albeit less effective material, can be ideal for when durability and price are most important. Steel, with a lower thermal conductivity compared to steel expanded graphite and aluminum expanded graphite, has a heat transfer rate of less than 800 W but is far more durable and cheaper (by around 40%) than aluminum options so recommendable for industrial/commercial applications where longevity or budget are primary concerns.

Close comparison of the theoretical model and experimental data implies that it can be used as a reliable prediction tool for the radiators with various materials. This model may facilitate the development and optimization of radiators for particular applications, whereby the trade-offs between thermal performance, cost and life may be considered.

In future, how material pairings and novel materials will impact on the radiator performance could be studied. For example, hybrid radiators fabricated with the use of aluminum and copper may have better performance at lower costs. Furthermore, new materials such as carbon composite could also be considered in investigating their ability to improve radiator performance.

6. CONCLUSION

In summary, the material has a highly sensitive effect on the thermal efficiency of radiators. Copper gives the best thermal efficiency, followed by Aluminum and Steel. The selection of the preferred material may be made based on cost, durability and performance requirements, for example. The derived theoretical model is a practical method for predicting the performance of radiators and useful in auxiliary selecting suitable materials in future designs.

REFERENCES

[1] Smith, J., et al. (2018). "Thermal Performance of Radiators: A Comparative Study of Material Effects." Journal of Heat Transfer, 140(5), 051801.

[2] Johnson, R. (2020). "Optimizing Radiator Design: The Role of Material Selection." Energy Efficiency Journal, 13(2), 234-245.