Thermal Performance Enhancement of High-Temperature Flue-Gas Channels with Radiation-Enhancing Inserts

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Abstract

This study expands the analysis of radiation-enhanced heat transfer within high-temperature flue-gas channels by investigating the axial variation of heat flux components, the thermal response of a radiation-enhancing plate, and the localized heat transfer augmentation along the pipe channel.

An analytical–numerical model implemented in MATLAB discretizes the channel into successive axial segments and resolves convective heat transfer from the flue gas, radiative heat transfer from the gas, and radiative heat exchange from the heated plate to the wall. The results demonstrate that all heat flux components reach their maxima in the inlet region (l ≈ 0–0.2 m) and diminish rapidly downstream due to progressive cooling of the flue gas and a reduction in radiative contribution. Radiative heat transfer from the flue gas is considerable near the inlet but decreases more swiftly than convective heat transfer, whereas the heat flux radiated by the plate toward the wall exceeds the direct gas radiation in the entrance zone, thereby illustrating that the plate functions as an intermediary radiator.

The predicted plate temperature profile shows a sharp rise at the inlet (≈900 K), followed by a rapid drop to 630–650 K within the first 0.5 m and a gradual decrease to ~410 K further downstream, indicating a transition toward a quasi-steady heat exchange regime.

Local heat-transfer enhancement resulting from the plate is approximately 37–38% at the inlet, diminishing to 12–13% at l ≈ 3 m. A notable inflection point in the enhancement curve at l ≈ 0.3–0.4 m signifies the transition from laminar to transitional flow, indicating alterations in the local Nusselt number and heat-transfer characteristics.

These findings clarify the coupled radiative–convective behavior in insert-equipped channels and help optimize the design of radiation-intensifying elements in high-temperature heat exchangers.

Index Terms

Radiation-Intensifying Element, Insert, Heat Transfer