ABSTRACT

The survivability of defence platforms is strongly influenced by their infrared (IR) signature characteristics, particularly in naval warships where hot exhaust plumes from marine gas turbines generate a pronounced thermal contrast against the cold sea background, increasing vulnerability to infrared-guided threats. Although complete elimination of IR emissions is nearly impossible, exhaust plume signatures can be significantly reduced by lowering plume temperatures through passive air entrainment using infrared suppression (IRS) systems. Depending on vessel operating conditions, the exhaust flow through IRS devices may occur under forced, natural, or mixed convection regimes, with partial-load operation introducing significant buoyancy effects that lead to mixed convection. While the performance of IRS devices has been extensively investigated under forced and natural convection conditions, their behavior under mixed convection remains inadequately understood. This thesis addresses this through a systematic numerical investigation of IRS devices operating in the mixed convection regime. Numerical simulations are conducted to analyse the flow and thermal characteristics of IRS devices, focusing on entrainment ratio (*ER*), exit temperature, pressure recovery coefficient (C_{PR}), and cooling efficiency (η), with temperature-dependent fluid properties being incorporated. The study first examines a conventional IRS device under turbulent mixed convection conditions for Richardson numbers in the range $0.1 \leq Ri \leq 10$, considering variations in non-dimensional nozzle exit temperature and key geometric parameters, and demonstrates that increasing Richardson number enhances entrainment through buoyancy-assisted suction of ambient air, resulting in improved thermal suppression, with an optimal Richardson number of $Ri = 0.75$ identified based on maximum cooling efficiency and an empirical correlation for entrainment ratio proposed. Building on these findings, the performance of IRS devices with modified diffuser geometries, including converging, diverging, and perforated-diverging configurations, is investigated, revealing that diverging diffuser designs provide superior entrainment and thermal suppression compared to converging designs, while the perforated-diverging configuration consistently delivers the best overall performance across the investigated mixed convection conditions. Overall, this work provides new insights into the influence of mixed convection on IRS device performance and offers practical design guidelines for effective infrared signature suppression in naval and related industrial applications.

Keywords: Infrared suppression device; Mixed convection; Richardson number; Air entrainment