Abstract

An experimental study was conducted on a laboratory-scale infrared suppression (IRS) device comprising conical frustum shaped funnels to assess the mass entrainment of ambient air into it for various operating conditions. A numerical analysis was also undertaken to assess the mass entrainment rate against pertinent input parameters independently. The numerical results were validated against the experimental data to ensure the reliability of the numerical analysis of the proposed IRS device at real scales. The numerical method solves the three dimensional, incompressible Navier-Stokes equations, the mass continuity equation and the eddy viscosity based two-equation k-epsilon turbulence model in the flow field. Numerical assessment of air entrainment was also performed for the conventional as well as for the proposed IRS device. It was observed that the conventional IRS device performs better than the proposed IRS device up to a geometric ratio of 1.4. However, beyond this value of geometric ratio, the proposed IRS device outperforms the conventional one significantly. In the proposed IRS device, the maximum mass entrainment was observed with four funnels while the nozzle was flush with the lower opening of the bottom-most funnel. The mass entrainment increases with increasing funnel overlap and attains its peak when the non-dimensional funnel overlap height is kept at 8 in the proposed IRS device. Further increase in the funnel overlap height reduces the mass entrainment. The nozzle protrusion adversely affects the mass entrainment, and therefore for getting the highest entrainment, the nozzle was flush with the lower opening of the bottom most funnel. Mass entrainment also increases with the nozzle-exit Reynolds number for the range of values considered in the study.

Another experimental and numerical analysis was performed on the conical frustum shaped funnels in which the funnels were provided with a certain number of circumferential louvers around their periphery. These louvers are circular in cross section and allow additional air suction that causes entrainment ratio to increase considerably in the louvered-conical IRS device. A comparison between the louvered-conical, conical and the cylindrical IRS device based on the air entrainment shows that the louvered-conical IRS device outperforms the other two IRS devices significantly when the geometric ratio exceeds a value of 1.4. The effect of different parameters like number of funnels, nozzle protrusion, funnels overlap and nozzle-exit

Reynolds number were also studied in context to the laboratory-scale louvered-conical infrared suppression device.

A numerical analysis was also carried out on a real-scale infrared suppression device to estimate the mass entrainment of air and corresponding temperature drop of the exhaust gases flowing through it. The analysis of this practical-scale IRS device was performed for the exhaust of a gas turbine plant installed on a typical naval warship. The operational data used in the analysis were taken from LM2500 series gas turbine from GE. The effect of using a different number of nozzles at the gas turbine exit on the air entrainment and the exit plume temperature was discussed. The results show that the maximum air entrainment and minimum plume temperature can be achieved by using four to six numbers of nozzles depending on the inlet plume temperature. The air entrainment and the exit plume temperature are also affected by the pitch circle diameter of the nozzle placement. The maximum air entrainment and minimum exit plume temperature was achieved at a pitch circle diameter of 1.6m. In addition to this, the effect of various parameters such as the nozzle-exit Reynolds number, funnel overlap and nozzle protrusion were also studied on the entities like mass entrainment and exit plume temperature in the real-scale IRS device.

***Keywords*:** air entrainment; infrared suppression device; stealth; k-epsilon turbulence model; louvers; plume cooling; LM2500 series gas turbine; ship