ABSTRACT

Experiments on a laboratory-scale Infrared Suppression (IRS) device have been carried out to measure the entrainment of ambient air into it at different operating conditions. The entrainment rate is measured by varying various operating parameters, such as nozzle exit Reynolds number, distance of nozzle from bottom funnel, funnel overlap height, nozzle protruding length and the temperature of the nozzle fluid. For the laboratory scale IRS device, numerical simulations have been performed by solving the conservation equations of mass, momentum and energy with a surrounding computational domain so as to facilitate the entrainment through the peripheral openings of the IRS device. The discretized equations have been solved numerically using finite volume technique of Fluent 6.3. Turbulence in the flow and temperature field have been modeled by many different turbulent models, such as; k-e, k-omega, RNG k –e and realizable k –e. It was found out from the numerical simulation that k-e model produces the closest result to the experimental observation. So the results from this model were used to develop numerical correlation for mass entrainment as a function of pertinent input parameters. Results from the present computational model are also validated with some of the results from existing literature (Chassaing, 1979; Wygnanski and Fiedler, 1969; Ricou and Spalding, 1961). The computed results for entrainment rate, axial and radial velocity profiles match well with the above experimental results for turbulent free jets. It has been observed from the experiments and also from the CFD computations that the entrainment rate is enhanced with the nozzle exit Reynolds number and the temperature of the nozzle fluid. However, the entrainment rate is reduced with the nozzle distance from the bottom funnel. It is also observed that the funnel overlap height plays a significant role in the entrainment process. For this small scale IRS device, optimum funnel overlap height and nozzle protruding-length have been obtained, for maximum air entrainment.

Air entrainment in to a full scale IRS device has been studied extensively by employing the CFD technique. The Reynolds number, funnel diameter, funnel overlap height, and the temperature of the nozzle fluid have been varied over a wide range to collect a large number of data from CFD simulations. Non-linear regression analysis has been used to develop empirical correlations (entrainment rate as a function of different input parameters) from the above data by writing a computer code in Engineering Equation Solver (EES).

The general correlation equations thus developed, have been tested to predict the mass suction rate and the funnel outlet temperature very well with the CFD results.

Finally, numerical simulations for a three dimensional computational domain has been carried out to investigate the entrainment rate of air into a full-scale IRS device by employing several circular and noncircular nozzles. An enhancement in entrainment rate has been observed when several nozzles are used compared to the use of a single nozzle. Moreover, the shape of the nozzle (circular, triangular or rectangular cross section) plays a significant role in the entrainment rate. The isosceles triangular nozzle can entrain more air than the rectangular and the circular nozzle having the same cross sectional area. The axis switching phenomenon and its effect on entrainment rate has been discussed, when several nozzles participate in the entrainment process. The effect of wind velocity on entrainment rate has also been discussed.

Key Words: IRS device, entrainment rate, turbulent jet, ship, $k-\varepsilon$ turbulence model, ship, noncircular nozzles, pitch circle, axis switching