A CFD analysis of the effective plume-chimney Height of lazy plumes and its implications to clear Air turbulence

ABSTRACT

Plume chimney is a plume that has chimney characteristics due to stack effects of plumes. In this study, CFD simulation was carried out for three different heights of chimney, three different diameters of chimney at various heat loads to cover a range of source Richardson number from 0.034 to 0.33, and Plume Function from 1.01 to 7.16. Reynold's average Navier-Stokes's conservation equations were solved in modelling the plume. A zero-gravity forced convection plume model was applied to obtain the overall total pressure drop. Effective Plume-Chimney Height (EPCH) was correlated with several parameters to obtain an empirical correlation. It was found that EPCH was related to the square root diameter of the chimney, as predicted by dimensional analysis in a pioneering plume rise study and concurred with all existing prediction methods. Through this finding a scaling formula for plume characteristic height is proposed. The power indices of volumetric coefficient of expansion, temperature differences, mean density of plume source density difference of air between ambient and plume source were 0.45, 0,80, 1.09 and -0.97 respectively; and correlation with the air velocity was negligible. The EPCH predicted by the correlation derived using the current method was found to be very close to previous correlations at the same Richardson number and plume function. For improved applicability, the range of parameters should be sufficiently broad and evenly distributed in future analysis. The theory of effective plume-chimney height is strongly supported by this CFD analysis, in addition to experimental data from industrial tests. Implications of the phenomenon of effective plume-chimney height, where a lazy plume has invisible walls causing a stack effect, generates a sizeable up thrust that is recommended to be investigated as it may be one of several factors contributing to mesoscale Clear Air Turbulence phenomenon experienced by aircrafts.