Computational Fluid Dynamic Investigation of Wind Interference Effects and Structural Adequacy of Tall Chimney Structures

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Wind forces represent a critical loading condition for tall industrial chimneys, necessitating precise pressure distribution and interference assessments for structural integrity and economic optimization. This study evaluates wind-induced effects on tall chimney structures by employing a design wind profile developed in accordance with EN 1991-1-4, based on long-term reference wind velocity data at the standard 10 m reference height and representative terrain roughness parameters. This profile serves as the basis for validated Computational Fluid Dynamics (CFD) simulations used to examine wind pressures, interference phenomena, and the overall structural adequacy of tall chimneys. The main objectives were to establish the design wind profile, perform comprehensive CFD simulations to map pressure distributions on isolated and grouped chimneys, and evaluate interference-induced base moments across multiple wind incidence angles to quantify structural safety margins against design moment capacities. Numerical simulations were conducted in *OpenFOAM* using the Reynolds-Averaged Navier–Stokes (RANS) method with the *k-ω SST* turbulence model. Numerical model was validated against the CAARC standard tall building benchmark, where comparison with experimental wind tunnel data yielded a Mean Absolute Percentage Error (MAPE) of 7.39%, confirming the model's accuracy. Following validation, the 150 m cylindrical chimney was analyzed in both isolated and triple-unit linear configurations, incorporating varied center-to-center spacing to evaluate the resulting aerodynamic and structural interaction effects. Wind incidence angles of 0°, 30°, 60°, and 90° were examined. Surface pressure distributions were mapped to calculate base moments for comparison against the chimneys' structural moment capacity. The results showed clear wind interference effects in the grouped arrangement. The windward chimney consistently experienced the highest wind forces, while shielding from upstream structures reduced the loads on leeward chimneys. Pressure patterns varied noticeably with wind angle, and base moment evaluations indicated that the chimneys remained structurally adequate under the studied conditions, although interference significantly increased demands on the leading chimney. Overall, the validated CFD methodology, combined with the EN 1991-1-4 based wind profile, provides enhanced insight into aerodynamic interference for grouped tall chimneys. The findings support more accurate wind loading assessments and contribute to refined design practices for tall industrial chimneys, emphasizing the need to account for aerodynamic interactions in multi-structure layouts.

Keywords: base moment, CFD simulation, interference effect, tall chimney, wind loading