Numerical Study of Reduction of Ceiling Heat Load by Forced Convection

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Abstract

The peak surface temperature of ceiling surface of a house in the hot and humid climate reaches 36-38 °C in the afternoon that causes uncomfortable condition and leads to high cooling energy consumption. Therefore, driving hot air off the attic by ventilation is a technique to reduce air and surface temperatures simultaneously. Using computational models in ANSYS Fluent and the average measured surface and air temperatures as the boundary conditions, this study investigated airflow and temperature reduction by forced convection produced by small exhaust fans and winglets. The three dimensional simulation model comprised of a vertical air gap connecting with a horizontal 10-cm air gap with dimensions of 3.0 m x 3.8 m x 0.13 m above the ceiling. Two fans of 680 m^3/hour (100 Watts) placed at the two outlets at the soffit induced cool air of 25 °C from the ground floor flowing through the air channels and conveying heat out of the house. The validation of the simulation results was conducted by comparing with the previous experiments on horizontal air duct with hot surface facing down. The simulation results of exhaust fans turning on for 10 seconds showed the average air velocity in the horizontal channel increased to 1.0-1.5 m/s and air temperature reduced by 6.5-11.7 °C from 38.0 °C. The Installation of 2 rows of rectangular winglets with half air gap height, length of 30 cm and angle of attack of 45° increased the Nusselt number by 3 times of air gap without winglets. The vortices rotation enhanced convection heat transfer process near the winglets and decreased air temperature near surfaces by 2°C for 40 cm downstream from the rear tip of the winglets. Therefore, adopting of the system that consists of air gap formed by ceiling plates, the exhaust fans at the house soffits and two rows of winglets are preferable to reduce the effect of heat transfer in the attic.

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