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Modelling and simulation of the near-wall velocity of a turbulent ceiling attached plane jet after its impingement with the corner

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ABSTRACT

At present, ceiling-mounted diffusers are very popular for indoor air distribution, particularly in offices, owing to greater efficiency in the distribution of the air supply and a more comfortable indoor environment. The objective of this study is to construct an effective model to design the indoor airflow of an attached plane jet after its impingement with the corner in a room. In this study, a full-scale test facility was set up to obtain detailed experimental data. One commercial CFD tool, CFX 11.0, was used to simulate the air velocity distribution of an attached plane air jet bounded by the ceiling and an insulated wall. One semi-empirical model was also constructed to predict the impingement jet velocity. The results show that bout the semi-empirical model and CFX 11.0 were able to predict the maximum velocity of an impinging jet at low Reynolds numbers, 1000 and 2000, with an inaccuracy of ±11%. However, the semi-empirical model could be more conveniently used to predict the maximum jet velocity decay after its impingement the corner in a room than CFD simulation in terms of accuracy and the time required to design the indoor airflow pattern.

1. Introduction

1.1. The application of an attached plane jet

Attached plane jets are used for air distribution in rooms owing to the advantages they offer in terms of their good energy performance, excellent thermal comfort, and silent operation [1–6]. However, the improper design of the airflow configuration with an attached plane jet can cause draught problems in rooms [7–9]. In earlier studies, a design chart of an air distribution system was developed to specify the relationships between draughts and the supply airflow rate in a room [10]. Besides the supply airflow rate, the supply air velocity will be also determined by the selection of air diffusers. The application of a linear slot diffuser is presented in Fig. 1 and shows the probable airflow patterns of an attached plane jet in rooms. As shown in Fig. 1, the airflow pattern of an attached plane jet with the presence of a ceiling-wall corner completely differs from that of directly downward air jets in a room. Earlier studies have shown that the most critical zone regarding draught sensations is located near the floor region [7]. To avoid a high air velocity in the occupied zone, the maximum air velocity, V_1, of the attached plane jet should be predictable and designed accurately before the air enters the occupied zone in room conditions. In room conditions, prior to the attached plane jet impinging the ceiling-wall corner, the jet is bounded by the ceiling surface on its upper side, but it is separated prior to the impingement (see Fig. 1). After impinging and turning at the corner, the jet flow will reattach to the wall surface and flow parallel to the vertical wall, with its thickness growing downwards. Earlier studies revealed that the air velocity distribution in the corner is nearly symmetric [5,6]. This means that the maximum jet velocity at the separation point in the ceiling zone is approximately equal to the jet velocity at the reattachment point after its impingement the ceiling-wall corner in the near-wall region. The direction of the flow may be reversed without any change in the pattern with a low Reynolds number, $Re<3000$ [11].

Impinging jets have been extensively studied from theoretical perspectives, such as impinging shear stress, eddy viscosity, and pressure gradients [12–14]. However, in the experimental studies, it was reported that from a more stringent scientific point of view one cannot say whether there is a linear relationship between the maximum velocity, the standard deviation, and the mean velocity [15]. Later, by weighing the jet kinematics momentum, it was found

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