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A comparison of three turbulence models for the prediction of parallel lobed jets in perforated panel optimization

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ABSTRACT

The general context of the present study is the design of high induction HVAC air diffusers by means of passive jet control. When the diffuser is a perforated panel with lobed orifices (Meslem et al. 2010), the optimization of jet induction consists in improving the orifice's geometry, the spacing between orifices and their arrangement on the panel. In this study, the flow field of a turbulent twin cross-shaped jet is investigated numerically using the standard k-ϵ model, the Shear Stress Transport (SST) k-ω model and the Reynolds Stress Model (RSM). The results are compared with PIV measurements. The objective is to assess their capability and limitations to predict the significant features of twin jet flow when the flow is numerically resolved through a lobed diffuser. It is shown that the k-ϵ and RSM models are more appropriate for predicting potential jet core length, the change in jet centreline streamwise velocity, and flow expansion in the symmetry plane of the twin jet flow. However, these models overestimate the overall flow expansion and the jet volumetric flow rate. The SST k-ω model seems more appropriate for the prediction of such dynamic integral quantities. A high level of turbulent kinetic energy predicted by the k-ϵ and RSM models in the near field of jets is probably the reason for this overestimation of jet induction. The SST k-ω model would appear to be the most appropriate tool for optimizing orifice design, orifice to orifice spacing and relative orifice orientation on a perforated panel diffuser.

1. Introduction

An innovative concept for optimized air diffusion in buildings using passive control of air jets through lobed diffusers was proposed in previous studies [1,2]. Lobed geometry can be defined either by lobed ailerons integrated into a rectangular grille diffuser [2] or by lobed orifices integrated into a perforated panel diffuser [1]. The concept reposes on the idea of relatively costless and simple modifications of the exit boundary geometry of conventional diffusers. It was shown that jet flows from innovative rectangular air diffusion grilles with lobed ailerons ensure higher mixing in a room than baseline jets from standard rectangular air diffusion grilles with straight ailerons [2]. The estimated entrainment in the case of the jet from a grille with lobed ailerons was found to be greater than in the case of a standard grille with straight ailerons. Furthermore, the special geometry of the lobed grille was not found to generate supplementary noise. Pressure losses were found to have similar values for innovative and standard grilles.

It was also shown that a jet flow from a perforated panel with lobed orifices, chosen to be cross-shaped, on average induced twice as much ambient air as a circular perforated panel when the orifice spacing was $S = 3.5D_e$ (D_e is the equivalent diameter based on the exit area of the elementary orifice). Despite the consequent gain in air induction for the lobed perforated panel flow, the streamwise maximum velocities display comparable values in the far field, which signifies comparable throws for the two flows [1]. Within the troughs of each elementary cross-shaped orifice, large scale streamwise structures develop and generate a complex three-dimensional distortion that results in an axis-switching, i.e. a 45°-like rotation of the initial cross-shaped transverse field (see Fig. 1c). These phenomena control air induction in the near field of lobed jets [3]. An experimental study of jet flows from cross-shaped orifices at different scales, i.e. an isolated jet, a twin jet, a row of 53 jets and a perforated panel flow composed of 53 × 53 jets, was conducted [1]. A row of orifices or a perforated panel generated a number of jets that coalesce and mix together. The particular

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