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Investigation of the Cooling System Condenser Fans Performance at Different Speeds of Subway Train

R. Nazeri Boori Abadi, N. Rezazadeh, M. Deymi-Dashtebayaz*

Department of Mechanical Engineering, Hakim Sabzevari University, Sabzevar, Iran

ABSTRACT: In the present work to evaluate the cross wind flow effects due to the subway train motion on efficiency of condenser fans in air conditioning system, the behavior of fluid have been studied. Velocity profiles in output fan, temperature variations at near fan were studied at different velocity of train. In numerical analysis, for the turbulent and incompressible flow, Navier-Stokes and energy equations and k-ε turbulence model has been used for modeling of turbulent flow. Variations of temperature and velocity of outflow of the fan at horizontal and vertical directions and the effective length as outflow guidance of the fan in opposite direction of train at difference velocity of train have been reported. At high velocity of train, negative output velocity of the fan and high effective length have been observed. Dimensionless effective length in high velocity of train at height of 10 and 20 cm were obtained 0.528 and 0.951 respectively. Finally, a parameter that is heat transfer rate to maximum heat transfer rate at height of 10 cm is defined which maximum amount is 5.88 percent. Due to the prevailing crosswind flow on the outflow of the fan, this parameter reduces.

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1- Introduction

Axial flow fans are applied in air conditioning system and industrial process applications. Fans accelerate the transfer of heat and cold in the environment so that vertical velocity of the fan increases the amount of heat transfer [1]. Crosswind flow is one of the most important factors that influences fan performance. The impact of crosswind flow is similar to a barrier for the outflow of the fan. Stafford et al. [2], placed heated thin foil on top of the axial fan. They concluded that distance from the fan to foil and radial velocity of the fan were important parameters for heat transfer between foil and the outflow of the fan. So, each factor that effects on outflow of the fan influences the heat transfer.

In the present work, the effect of crosswind flow on the fan performance of subway train has been investigated. For numerical analysis, Navier-Stokes and energy equation for turbulent and incompressible flow are solved. Velocity and temperature variations are investigated for different velocities of the subway train. Finite element based commercial software COMSOL 5.1 Multiphysics is used to calculate the heat transfer and fluid flow parameters and k-ε turbulence model is used to predict the fluid flow and heat transfer performances.

2- Methodology

Fig. 1 shows a view of air conditioning system of the subway train including fan, compressor, condenser tubes and evaporator. The area of (B) in Fig. 1 shows condenser tubes so that air passes perpendicular on series of the tubes. Section of A-A in Fig. 1 has been considered. This section cuts condenser fan and tunnel so the walls are roof of the tunnel and train. All of the walls are insulation and no-slip. A view of the tunnel and fan is shown in Fig. 2. The length and height of the channel are assumed 4 and 1.5 m respectively, at air temperature of 35°C.

3- Governing Equations

The following assumes that the flowing fluid is incompressible and steady state in which case the Navier-Stokes equations take the form:

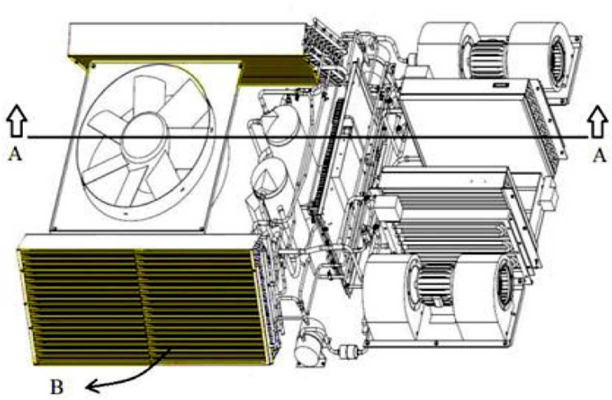

Fig. 1. View of air conditioning system in subway train

Corresponding author, E-mail: mahdi.deymi@gmail.com

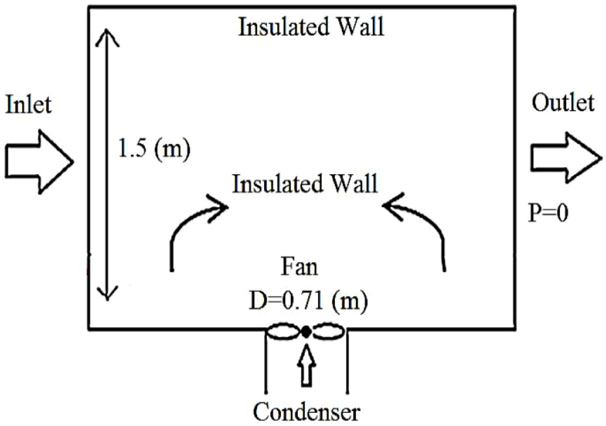

Fig. 2. View of the tunnel

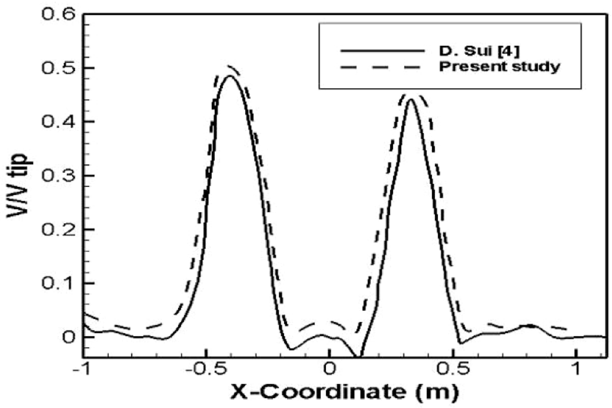

Fig. 3. Comparison the experimental data [4] and present simulation results

- Continuity equation:

$$\rho \nabla \boldsymbol{u} = 0 \tag{1}$$

- Momentum equation:

$$\rho(\boldsymbol{u}.\nabla)\boldsymbol{u} = \nabla.[-p\boldsymbol{I} + \mu(\nabla\boldsymbol{u} + (\nabla\boldsymbol{u})^T]] \tag{2}$$

- Energy equation:

$$\rho C_p \boldsymbol{u}.\nabla T = -\nabla.q \tag{3}$$

$$q = -k\nabla T \tag{4}$$

Zargar et al. [3], to optimize the chamber's airflow design and the distribution of aerosolized bacteria inside it used fan and k-ε realizable turbulence model for turbulence modeling in which the turbulence kinetic energy, k, and its rate of dissipation, ε. The turbulent viscosity is computed as follows:

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon} \tag{5}$$

$$\rho\boldsymbol{u}.\nabla k = \nabla.\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\nabla k\right] + G_k + G_b - \rho\varepsilon + S_k \tag{6}$$

$$\rho(\boldsymbol{u}.\nabla)\varepsilon = \nabla.\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\nabla\varepsilon\right] + \rho C_1 S_\varepsilon - \rho C_2 \frac{\varepsilon^2}{k + \sqrt{\upsilon\varepsilon}} + C_{1\varepsilon}\frac{\varepsilon}{k}C_{3\varepsilon}G_b + S_\varepsilon \tag{7}$$

where, μ_t is turbulent viscosity. G_k and G_b represent the generation of k due to the mean velocity gradients and buoyancy, respectively; σ_k and σ_ε are the turbulent Prandtl numbers for k and ε, respectively; and S_k and S_ε are user-defined source terms for k and ε, respectively. The model constants have the following value:

$$C_{1\varepsilon} = 1.44, C_{2\varepsilon} = 1.92, C_\mu = 0.09, \sigma_k = 1, \sigma_\varepsilon = 1.3$$

4- Validation

The crosswind flow as a barrier in the output of the fan can change velocity profile on outflow of the fan. Sui et al. [4], investigated the influence of presence flat impingement plate on exit flow behavior of axial fan while surrounding fluid was at rest. They used a fan with a diameter of 67 mm and a rotating speed of 9 m/s. A plate was placed at a distance of 2 times of the fan diameter relative to the center of the fan and then investigated the profile velocity for outflow of the fan at different length distances relative to the center of the fan. Fig. 3 compares the velocity profile obtained in the simulation process and experimental work for a distance of 0.25 times of the fan diameter. Numerical and experimental results compared with each other. This comparison validates the present numerical model for simulating of the fan.

5- Results and Discussion

In this paper, the effect of crosswind flow on outflow of the fan has been investigated. Fig. 4 shows variation of outflow velocity profile of the fan at horizontal direction for crosswind flow velocities of 0, 1, 7, 13 and 19 m/s. When subway train velocity increases, negative velocity can be observed in the outflow of the fan because crosswind flow prevailed over it. Also, increasing velocity of crosswind flow reduces the outflow average velocity.

6- Conclusions

In present work, the effect of the crosswind flow on the

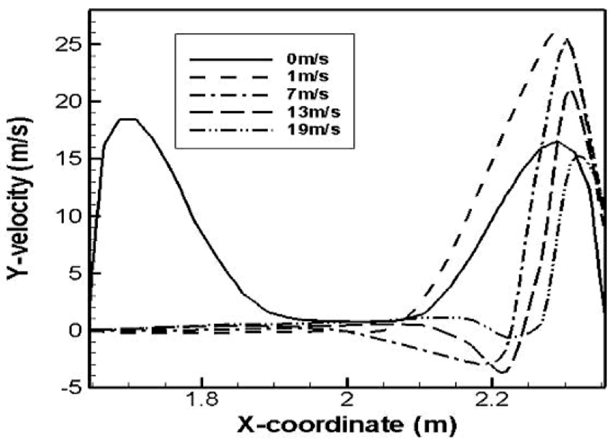

Fig. 4. Variation of vertical velocity over the subway train roof for different train speeds

performance of the subway train condenser fan in the air-conditioning system was investigated. Temperature and velocity variation for outflow of the fan in vertical and horizontal directions at different velocities of crosswind flow and effective length have been investigated. The formed vortex behind the outflow of the fan at low subway train speed is larger than the vortex at the high subway train speed. Due to the prevailing crosswind flow at a high speed of the subway train, negative velocity on outflow of the fan has been observed.

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