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Review of One Dimensional Model Algorithm for the Computational Simulation of Ventilation System in Deeply Network Double Deck Road Tunnel

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Abstract
In this study, the computational algorithms of 1D model are investigated for ventilation system in deeply network double deck road tunnel.

Keywords:*One Dimensional Model (1D model), Deeply Network Double Deck Road Tunnel, Ventilation System .*

1. Introduction

70 % of Korea is mountainous. Consequently, road tunnels are being constructed to straighten roads for highway in Korea. Recently, population concentration into the capital region causes to be short space for construct roads and compensate a high cost to land owners. It has been suggested as an alternative to be constructed the network double deck road tunnel below 40m underground. However, there are a lot of design factors to be considered for ventilation systems of the deeply network double deck tunnel than the conventional road tunnels.
Therefore, It is not easy with the existing S/W to simulate and assessment for these deeply network double deck road tunnel. In this paper, the algorithm of 1D model for the design of ventilation system in deeply network double deck road tunnel are reviewed.

2. 1D model (One dimensional model)

2.1 1D model

One dimensional model(1D Model) means the formula program with one spatially dimension CFD (Computational Fluids Dynamics) code.The formula used governing equation for 1D model is assumed as the fact that the flow in each cross section is homogeneous and each parameter like velocity and pressure gradient has the changing according to longitudinal direction.The 1D model ,therefore, used in high aspect ratio (length/width or diameter) are applied to tunnel ventilation system, pipe system, duct system etc. The main advantage of using 1D models for analysis of tunnels is that it allows for a complete and compact description of the system and conducts with a less using resources for computing than 3D CFD that.

2.2Overview the Existing 1D models

The first studying for the computational calculation were investigated to develop to design mine ventilation in the late1950s. A first significant attempt at including the effect of fire in a network system calculation wasmade in the late 1970s, when Greueret aldeveloped a tool that could be used forthe steady-state calculation for temperature, velocity and pollutant of complex ventilation system (Greuer, 1977). The solution being computed using aHardy-Cross-like method (Tullis, 1989).
In the 1990s and 2000s several national institutions proposed contributions to the subject. Modelssuch as MFIRE (US Bureau of Mines, 1995), ROADTUN (Dai and Vardy, 1994; West et al.,1994), RABIT and SPRINT (Riess and Bettelini, 1999; Riess et al., 2000), Express’ AIR andSES (NTIS, 1980; Parsons Brinckerhoff Quade& Douglas, 1980; Schabacker et al., 2002) are nowcommonly used to perform complete studies of tunnel ventilation systems.
MFIRE, developed by the US Bureau of Mines, performs steady-state fluid-dynamic simulationsof

underground network systems. The same theoretical approach has been used by Ferro and co-workers (Ferro et al., 1991; Borchielliniet al., 1994) and Jacques (1991). The former presented a 1D computer model for tunnelventilation. The model was designed to deal with a complex tunnel network, including phenomenasuch as the piston effect from moving vehicles and the distribution of pollutant concentration.The model can be used to perform steady-state calculations. A similar approach was used byBorchiellini et al. (1994), who presented numerical simulations of an urban tunnel 2.5 km long.The Subway Environmental Simulation code (SES), developed by Parsons Brinckerhoff Quade&Douglas Inc. (1980), is a 1D simulation tool capable of predicting steady-state ventilationscenarios in railway tunnel system.).Chang Woo Lee et al (Korea, 1997) developed the simulation model (NETVEN) of the vehicle tunnel ventilation system as a decision-making tool taking into account distinctive local conditions for various type ventilationsystem.

H. J. Shin et al(Korea, 1999) developed the 1D computer code for optimal design of road tunnel ventilation system based on 1D analysis of the air flow . The control volume was used to calculate the air velocity and the concentration distribution of pollutions(CO, Nox, Particulate) for various tunnel ventilation system.

3. Algorithm for 1D model for deeply network double deck road tunnel

3.1Network matrix

Francesco Collea et al (2010) described using two concepts node and branch ofmatrix representation and graph theory for complex network tunnel system. A node is a section wherestate properties such as temperatures, pressures, mass or molar fractions, are defined. A uniquevalue of these properties is defined at a node. A branch is an element bounded by two nodesand characterized by geometrical properties, such as length and cross-section, together withflow and thermal properties, such as roughness and wall temperature. Branches are associatedwith mass flow rates, velocities and heat fluxes.And the flow network is described through the interconnections between nodes and branches. Multiplebranches can join at the same node, which plays the role of ‘flow splitter’ or junction. In graphtheory, incidence matrix A is used to express the interconnections. This matrix is characterizedby a number of rows equal to the total number of nodes, and a number of columns equal tothe number of branches

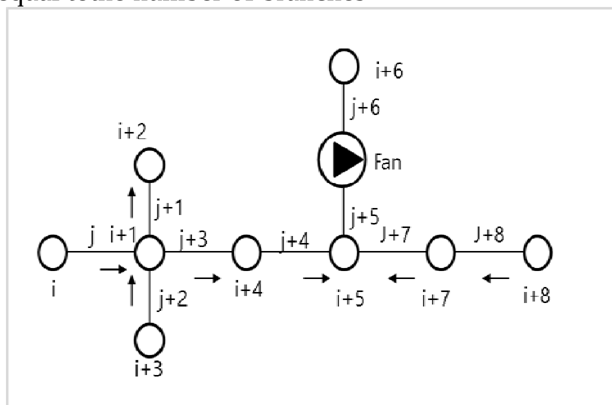

Fig 1 Example of the network representation of a tunnel

.The corresponding incidencematrix A is:

	j	j+1	j+2	j+3	j+4	j+5	j+6	j+7	j+8
i	+1	0	0	0	0	0	0	0	0
i+1	-1	+1	-1	+1	0	0	0	0	0
i+2	0	-1	0	0	0	0	0	0	0
i+3	0	0	+1	0	0	0	0	0	0
i+4	0	0	0	-1	+1	0	0	0	0
i+5	0	0	0	0	-1	+1	0	-1	0
i+6	0	0	0	0	0	-1	0	0	0
i+7	0	0	0	0	0	0	0	+1	-1
i+8	0	0	0	0	0	0	0	0	+1

Fig 2 incidence matrix for network tunnel

3.2Governing Equation

The Navier-Stokes and energy equations, as eliminated the y and z spatial dependences, and neglected the viscous stress term become

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} = 0 \qquad (1)$$

$$\rho \frac{\partial u}{\partial t} + \rho u \frac{\partial u}{\partial x} = -\frac{\partial P}{\partial x} + \sum S_{Mx} \qquad (2)$$

$$\rho c\frac{\partial T}{\partial t} + \rho c u\frac{\partial T}{\partial x} = k\frac{\partial^2 T}{\partial x^2} - q_l + q_v \qquad (3)$$

The tunnel domain is first discretized in branches and nodes indicated as i and j in Fig 3.

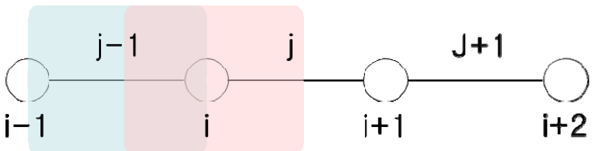

Fig 3 Schematic of the control volume

The variables,which pressures, temperatures are calculated in each node and velocities in each branch, are allocated in a staggered arrangement. Therefore, continuity, momentum and energy equations are applied on different control volumes. One control volume(a light blue box) between two nodes is applied to discretized for the momentum equations. the other control volume(a light red box) include a node is used for the integration of continuity and energy equation. After performing the double integration and after some rearrangements equations, equations are rewritten in final form.

$$\left(\sum_j \frac{A_j L_j}{2\Delta t}\right)\left(\rho_i^t - \rho_i^{t-\Delta t}\right) + \sum_j A_j\, \rho_j^t u_j^t = 0 \qquad (4)$$

$$\rho_j L_j \frac{u^t{}_j - u_j^{t-\Delta t}}{\Delta t} + P_i^t - P_{i-1}^t - \frac{1}{2}\left(\left(f_j\frac{L_j}{D_{h,j}} + \beta_j\right)\rho_j u_j^2\right) + \Delta P_{fan,j}^t + \Delta P_{Pist,j}^t = 0 \qquad (5)$$

$$\rho_i c_i\left(\frac{T_i^t - T_i^{t-\Delta t}}{\Delta t}\right) + \sum_j A_j\, \rho_j^t c_j^t u_j^t T_j^t = -Q_{L,i}^t + Q_i^t \qquad (6)$$

3.3SIMPLE Algorithm

SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) method, which based on 'guess and correct'procedure' can be used to solve the final equations.

The main steps of the solution for the 1D model are described as follows (Fig 4)

1. Guess a pressure field P*

2. Solve the momentum equations to obtani u*

3. Solve the pressure correction equations to calculate P'

$$\{u'\} = \{u\} - \{u^*\}$$
$$\{P'\} = \{P\} - \{P^*\} \qquad (7)$$

4. Update pressures and velocities

5.Solve energy equations and update temperature and densities

6. Iterate from step 2 to step 5 until convergence is reached.

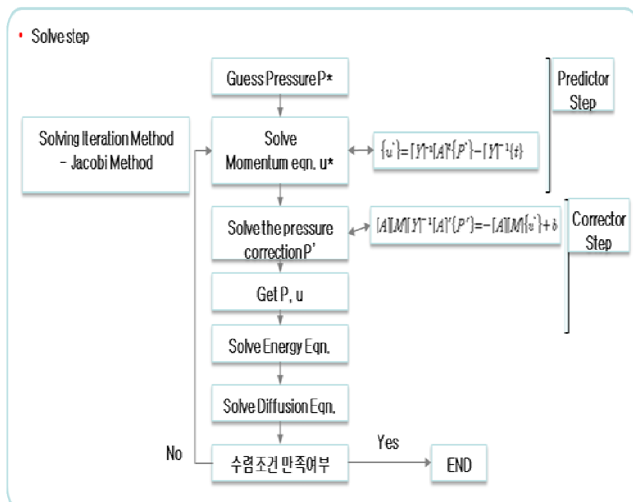

Fig 4Simple Flow Charts

4. Conclusions

In this paper, 1D model algorithms for ventilation system of deeply network double deck road tunnel weredriven to a conclusion as follows

- Conventional 1D model was approached a quasi-steady state problem but this wasimproper to simulate complextype of network road tunnels

- It was used a branch and node in order to represent the network.
-Simple algorithm was applied to solve the continuity, momentum,energy and diffusion equations.
- JACOBI method wereappliedfor solving each a matrix equation.

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