Numerical Simulations of Fires in Long Vehicle Tunnels

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Key words**：** fire, tunnel, numerical simulation.

ABSTRACT

The study of tunnel fires is important in the design of long vehicle tunnels in terms of fire management system, emergency exit, and ventilation system. The physical behavior of tunnel fires can be investigated experimentally or numerically. The difficulty of experimental study is that a reduced-scale test cannot imitate the characteristics of a full-scale fire due to their different turbulent scales. Therefore, most fire tests have been conducted in full-scale tunnels. This is costly and time consuming. Numerical simulation aided by full-scale test is the pragmatic approach in the investigation of this problem.

However, a real fire in long tunnels resulting from the burning of a car or a truck is extremely complex and very difficult to simulate. This is because a vehicle consists of many different materials and the burning process involves many complex chemical reactions. In order to reduce considerably the complexities of simulations, the fire is treated as a predetermined heat source in the present study. A finite difference method, which solves the unsteady, compressible, three-dimensional Navier-Stokes equations and the energy equation, is employed to simulate this physical problem. The comparison of numerical results with experimental data demonstrates that the proposed method can be an effective engineering tool when dealing with fires in the design of long vehicle tunnels.

Ⅰ. INTRODUCTION

Owing to the economic development and social evolvement, the construction of long vehicle tunnels is becoming a new demand and trend. For example, the Channel Tunnel is 49.2 kilometers long and the Ping-Lin Tunnel under construction in Taiwan is 12.9 kilometers long. Due to their extraordinary length, long tunnels constitute severe engineering challenges in areas such as construction, ventilation, fire management, operational management, etc. The occurrence of a tunnel fire is rare, about once for every 10 million kilometer-cars [11]. But due to its peculiar configuration, once a tunnel fire does occur, the damages quite often are disastrous. For example, the subway tunnel fire (October, 1995) in Azerbaijan took away the lives of 600 people.

The study of tunnel fires is important in the design process of fire management system, emergency exit, and ventilation system. The physical behavior of tunnel fires can be investigated experimentally or numerically. The difficulty of experimental study is that a reduced-scale test cannot imitate the characteristics of a full-scale fire due to their different turbulent scales. Therefore, most fire tests have been conducted in full-scale tunnels. This is costly and time consuming. Numerical simulation aided by full-scale test is the pragmatic approach in the investigation of this problem.

Full-scale fire tests began quite early [14], and new tests have been conducted to meet or verify specific requirements of new tunnels [6,10]. Numerical simulations started in a much later time. Kumar and Cox [5] employed a finite-volume method plus a simple one-step combustion model to simulate tunnel fires. The comparison of predicted results with experimental data demonstrated that it is a promising tool in the prediction of tunnel fires. Kawabata et al.[4] applied two-dimensional simulations to predict the three-dimensional physical phenomena with additional assumptions and modifications to the numerical