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Assessing the influence of fuel geometrical shape on fire dynamics simulator (FDS) predictions for a large-scale heavy goods vehicle tunnel fire experiment

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ABSTRACT

This paper uses four different simple geometrical shapes to simulate a large-scale heavy goods vehicle (HGV) tunnel fire experiment using Fire Dynamics Simulator, version 6 (FDS6) in order to investigate the influence of using different fuel package shapes. Simulations also investigate the influence on temperature profiles when a large target is placed downstream of the fuel package. Predictions of flame extension, temperature profiles and gas species concentrations are compared with the experimental data. The use of the geometrical shapes causes significant differences in flame extension lengths during the fully developed fire phase. The variation in temperature predictions caused by using the different fuel shapes are insignificant when a large target is present behind the fire, however this is not the case if the target is omitted especially during the fully developed phase.

1. Introduction

Fires in tunnels are often caused by vehicle accidents that occur inside them. The characteristics of the fire depend on the various types of vehicles involved and for road tunnels these could include passenger cars, utility vehicles, buses and/or heavy goods vehicles (HGVs). HGVs usually have much larger dimensions and carry goods that can cause more severe fires than normal passenger cars. Therefore HGV fires can pose a greater risk to life safety and property protection than fires caused by other types of vehicles.

Fire Dynamics Simulator version 6.2.0 (FDS6) [1] is a commonly used tool in fire engineering to simulate fires. In FDS, a typical way to simulate a given heat release rate (HRR) fire is to represent it as the ejection of gaseous fuel from a solid surface by a 2D 'gas burner'. In previous work Li et al. [2] used a simple 2D gas burner with a dimension of 3 m × 10 m to represent the HGV to simulate the Runehamar tunnel fire experiment using FDS. This 2D gas burner representation of a fire is also specified in the New Zealand Verification Method: Framework for Fire Safety Design [3]. The results in the study of Li et al. showed that the simplified 2D gas burner of HGV could give reliable predictions of ceiling temperatures along the tunnel length however, Li et al. did not predict temperature profiles at different tunnel cross section locations. In the work of Cheong et al. [4] a more complex fuel representation was used to simulate the Runehamar HGV fire experiment where the fuel package surface area in the simulation was equivalent to the fuel surface area in the experiment and the inputted HRR curves were based on cone

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calorimeter experimental results. The approach used in their work was mainly for the prediction of HRR of tunnel fires using FDS and the influence on temperature distributions due to the geometrical shape of the HGV was not investigated in their work.

For an HGV fire that occurs under a forced ventilation condition, the burning behaviour will be affected by the airflow [5,6]. The physical dimensions of the HGV will also interact with the airflow so that the behaviour of the fire and the downstream temperature distribution in the tunnel will likely be further affected. Any changes in the shape of the fuel package due to material burning away or the collapse of the fuel package will result in additional effects on the fire and hence the temperature distributions. Therefore, it is important to take into account the large geometrical vehicle shape in the simulations of HGV fires.

In this case study, a series of simulations are carried out to model a large-scale HGV tunnel fire experiment by using different simple geometrical shapes to represent the HGV in order to investigate the influence of the shape of fuel package on flame extensions, the distributions of temperature and gas concentrations. Several simplifications have been made in order to carry out the simulations in a practical manner.

2. The LTA tunnel fire experiment

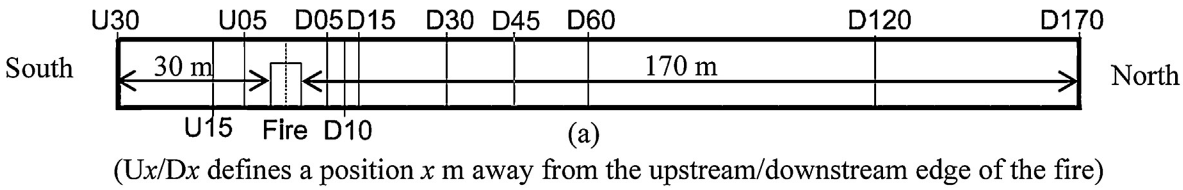
A series of large-scale HGV tunnel fire experiments [7] were conducted on behalf of the Land Transport Authority (LTA) of Singapore in a tunnel test facility in Spain. A rectangular shape test section was used for all the experiments, which had a minimum cross section of 7.3 m (W) × 5.2 m (H) and 1% longitudinal gradient. The length of the test tunnel was 600 m and the fire was located 350 m away from the south portal. Measurement points in the tunnel were installed from 30 m away from the upstream edge of the fire to 170 m away from the downstream edge of the fire.

The tunnel section in which the measurements were made is shown in Fig. 1 together with the instrumentation locations. Temperatures were measured using thermocouples at the different cross sections shown in Fig. 1(a) and gas concentrations of O_2, CO_2 and CO were measured at location D170. The cross sections with the thermocouple locations at D10, D15 and D30 are illustrated in Fig. 1(b).

The fuel source consisted of 228 pallets with 48 plastic pallets (20% by volume) and 180 wood pallets (80% by volume) [8], in a configuration representative of a fully loaded HGV (7.5 m (L) × 2 m (W) × 3 m (H)). According to the averaged densities of the plastic (1376 kg/m^3) and wood (566 kg/m^3) from the LTA, the estimated mass fractions of plastic and wood pallets are ∼38% and 62%, respectively. The fuel source was elevated 1 m above floor and in addition, the top side, the front side and the back side of the fuel source were covered by steel plates to represent a typical HGV configuration. During the experiment the fuel source collapsed as the pallets burned away.

In addition to the fuel source, a target consisting of a stack of pallets with dimension of 1.2 m (L) × 2 m (W) × 3 m (H) was used in the experiments that was located 5 m from the downstream edge of the fuel source.

Jet fans at the southern end of the tunnel were used to generate longitudinal air flow with a desired velocity of 3 m/s in all of the experiments. According to the measurements [7] at the upstream side of the fire, an average of 3 m/s was maintained in the upper cross section of the tunnel, while lower velocities were obtained in the lower cross section. A total of seven experiments were conducted, six with a water suppression system in the vicinity of the HGV and one without. In this study,



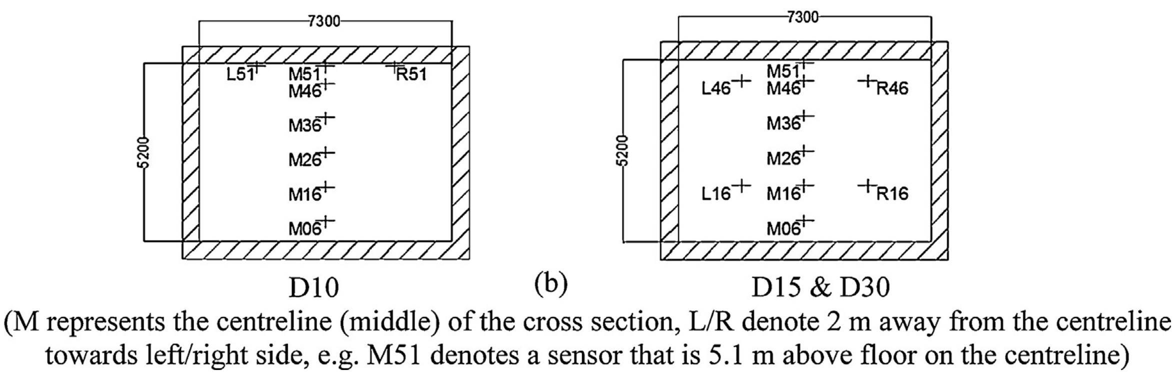


Fig. 1. (a) Tunnel with the measurement locations, (b) tunnel cross sections.