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Fire and explosion hazards of alternative fuel vehicles in tunnels

Environmental issues such as climate change and scarcity of resources have forced the development of alternative fuel vehicles. Many incidents involving alternative fuel vehicles have occurred especially in the past decade, most of which referred to compressed natural gas (CNG), liquefied petroleum gases (LPG) and electric battery vehicles. In comparison to traditional vehicles, the fire and explosion hazards for some alternative fuel vehicles are much higher, especially in confined spaces such as tunnels and underground garages. For example, in Salerno, Italy in 2007, a LPG vehicle exploded resulting in a three-story building completely destroyed and 5 other buildings affected. In 2016, at least three CNG explosion incidents occurred in Sweden. The most known could be the bus explosion in Gothenburg, resulting in two firefighters injured. During 2015-2016, at least three CNG bus incidents occurred in the Klaratunneln tunnel in Stockholm, causing major traffic interruptions.

According to the different fuels used, they could be divided into four types: liquid fuels, liquefied fuels, compressed gases, and electricity. The liquid fuels mainly consist of ethanol, methanol and biodiesel. The liquefied fuels mainly consist of LPG and liquefied natural gas (LNG). The compressed gases mainly consist of compressed natural gas (CNG) and compressed hydrogen (CGH2) stored at very high pressures. The electric vehicles could be driven either by rechargeable batteries, or fuel cells such as renewable hydrogen fuel cells.

Aims and objectives

The aim is to investigate the fire and explosion hazards of alternative fuel vehicles in tunnels. Specifically, it is to obtain detailed parameters for each type of alternative fuel vehicles, to identify the potential hazards for each type of alternative fuel vehicles in tunnels, and to quantify the consequences based on state-of-the-art knowledge.

Methods and implementation

The project is divided into the following parts:

- Obtain detailed parameters for each type of alternative fuel vehicles by a literature review and contact with the manu facturers.
- Analyze the possible risks and consequences for each type of alternative fuel vehicles in tunnels.
- Develop a simple numerical model for explosion flows in tunnels.
- Quantification of consequences based on existing knowledge and the numerical model developed.
- Considerations for practical use of different types of alternative fuel vehicles from the safety perspectives, based on comparisons to the scenarios with traditional vehicles.

Results

Fire hazards

For liquid biofuels, the behaviors are similar to the traditional liquid fuels, and the spillage and burning behaviors are two key issues for any related fire safety design.

For liquefied fuel and compressed gas vehicles, pressure relief devices (PRDs) are equipped to reduce the tank pressure and prevent tank rupture in case of an incident. But after a PRD opens, a high-speed fuel jet forms, resulting in a long jet flame if ignited. This long jet fames normally correspond to very high temperatures and heat fluxes, thus easily causing fire spread to other objects.

Explosion hazards

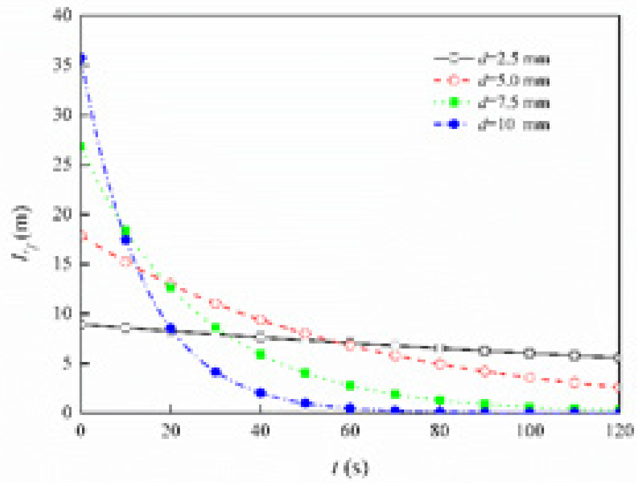
Liquefied fuel vehicles, compressed gas vehicles and battery electric vehicles also pose explosion hazards. The fuel tanks may rupture if the PRDs do not operate properly or the tank is heated up too quickly. The released gases may also form a vapor cloud and cause an explosion if ignited.

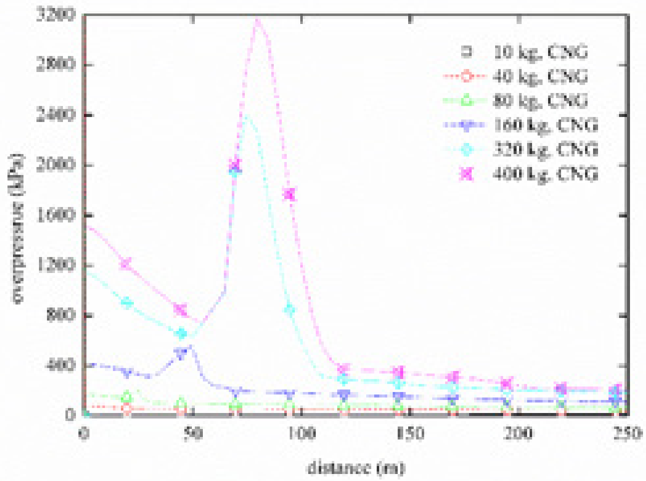
Fires in battery electric vehicles may not be more severe than traditional vehicles in terms of fire size. However, batteries may experience a thermal runaway with a large amount of gases vented out, which are not only toxic but also explosive.

Conclusions

These fire and explosion hazards need to be carefully considered in safety design of tunnels and underground spaces. Further researches on these hazards, especially large scale experiments, are in urgent need.

Information presented here can be used for hazard analysis of alternative fuel vehicles running both in tunnels and in the open areas. It could help authorities make decisions on the use of different alternative fuel vehicles, and help tunnel users including fire fighters realize the risk and make fast response to such accidents. It could also be helpful in design of alternative fuel v ehicles and serve as materials for training of alternative fuel vehicle drivers.





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