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Uncertainties associated with tunnel design fire scenarios

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Abstract

Computer fire modelling and design fire scenarios are traditionally used in the tunnel design process to challenge tunnel systems, e.g. smoke ventilation, evacuation routes and strategy, and the exposure of structural members. In general, any such fire scenario should be reasonably severe, however, not unrealistically, which may lead to unnecessary over-designing and cost increase. This approach is commonly referred to as the worst-case design fire approach. The objective of the paper is to analyze the impact of uncertainties associated with input data and design fire selection on the representativeness of the design fire scenario. Firstly, the design fire scenario specifications are mapped and uncertainties relating to input data identified and quantified. Subsequently, a risk-based design fire selection approach is introduced taking into account the objective of the analysis: life safety or property protection. The paper is concluded with recommendations regarding the significance of selected input parameters, given analysis objectives, and the possibilities of their uncertainty treatment.

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Keywords: Tunnel fire; uncertainty; CFD modeling, FDS + Evac; heat release rate (HRR); smoke movement; ventilation

1. Introduction

Tunnel fires differ in many ways from enclosure and open fires. To understand what is happening inside of a tunnel is a very difficult task and to collect data in order to specify uncertainty in tunnels is also very limited. Large scale testing in tunnels is due to time and logistical issues costly. This is one of the main reasons why we decided to use computational fluid dynamics (CFD) modeling as a powerful tool for gathering data from tunnel fire. To better understand uncertainty related to fires in tunnels, we must analyze them from the point of view of fire dynamics

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with the interaction between tunnel – vehicles – humans. The following chapters give you through practical example – tunnel "Šibenik" an insight into uncertainty associated with tunnel design fire.

2. Uncertainty in tunnel fire design

Uncertainty is often described as a variety of concepts which can arise from variability, lack of knowledge, randomness, judgement, approximation, error, linguistic imprecision. Uncertainty is often incorrectly replaced by term indeterminacy, defined as the inability to know what will happen in the future. Therefore, it's important to distinguish between these different terms [1].

Understanding the level and significance of uncertainty is important to make good decisions in fire safety and therefore uncertainty is divide into two major categories:

- *Aleatory uncertainty* – which is embedded in the structure of the model and deals with randomness which is an essential element of a fire model of the system under analysis.
- *Epistemic uncertainty* – is on the other hand associated with incompleteness in the analyst's state of knowledge. Therefore, in fire modelling, there is a need to make simplifications and approximations which make significant influence on results [2].

2.1. Sources of uncertainty associated with tunnel design fire scenarios

In these paper, we are dealing with both aleatory and epistemic uncertainty. Lack of accurate predictions by model could lead to faulty conclusions. To treat uncertainty, we must identify possible sources of doubt related to input parameters, calculation procedure, etc., which causes potential risk or danger in our model scenarios (Table 1).

Table 1. Sources of uncertainty associated with tunnel design fire.

Group	Sources of uncertainty
Input Parameters	Simplification due to geometry; duration of simulation; number type and position of vehicles, number and structure of passengers (gender, age, mobility), ambient conditions (wind), type of flammable fuel
Calculation procedure	Number and size of cells in computational meshes; correlation among input parameters
Distribution of fire curves	Variations in fire curves (appearance / influence of extreme values in fire curves); differences between standardized and modelled curves
Number of scenarios	Narrow range of fire scenarios; considering only worst-case scenario or very similar scenarios

3. Tunnel fire and evacuation model

Fire dynamics simulator (FDS) with Evac extension was selected for modelling tunnel fire and evacuation scenarios. For our modeling purposes was used road tunnel Šiberník located on the D1 motorway near Levoča, Slovak Republic.

3.1. Fire dynamics simulator

FDS is a powerful computational fire dynamics simulator developed at the National Institute of Standards and Technology (NIST). FDS simulates fire scenarios by solving of navier-stokes equations optimized for low-speed flow with an emphasis on smoke and heat transport from fire area [3]. The results from these simulations are used to ensure and evaluate fire safety of structures, reconstruct fires, help firefighter training. Smoke and other attributes of the fire generated by FDS as numerical outputs are visualized by program tool "Smokeview" which is also part of FDS package.