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Assessment of the validity of the use of CFD with FDS in the analysis of the Railway accident on 28/02/2023 in Tempi (Greece) by HARSIA

As determined by the Greek accident investigation body HARSIA, the scenario under review is the railway accident that took place in Tempi, Greece, on 28 February 2023. The accident involved the collision of two trains (i.e., a passenger train and a freight train) and resulted in a huge fire ball with severe number of casualties and damage. Based on the available information, one of the involved investigators (Mr. Costas Lakafossis) has made an attempt to evaluate the fire ball created in this accident with Computational Fluid Dynamics (CFD) using the Fire Dynamics Simulator (FDS) code.

FDS (https://pages.nist.gov/fds-smv/) is a CFD code developed by the National Institute of Standards and Technology (NIST) in the USA. FDS has been developed to simulate fire-related scenarios involving low-speed flows (Mach < 0.3), with an emphasis on smoke and heat transport from fires and is currently the state-of-the-art CFD code when it comes to fire modelling and research in the context of fire safety engineering. The FDS documentation states[*]: "*FDS is designed for use solely by individuals with expertise in fluid dynamics, thermodynamics, heat transfer, combustion, and fire science, and is intended only to supplement the informed judgment of the qualified user. As a computer model, FDS may or may not accurately predict outcomes in a given situation. Inaccurate predictions could lead to incorrect conclusions about fire safety. Therefore, it is suggested that all CFD results should be evaluated by an informed user.*"

In the past, FDS has been validated[**] by NIST for a wide range of fire scenarios including, e.g., heat and smoke transport, fire plumes, liquid pool fires, compartment fires, tunnel fires, fire

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extinction, fire suppression, water sprays, flame spread and atmospheric dispersion among others. The FDS validation guide in particular also contains cases with a fire ball and with spray combustion (albeit at much smaller scale than the Tempi accident)***. Because FDS is only suited for flows with Mach below 0.3, it is not suited for simulating explosions.

The UGent team (i.e., Dr. Georgios Maragkos and Prof. Bart Merci) has reviewed the available information, as provided by Mr. Costas Lakafossis, concerning CFD simulations as performed for the Tempi accident. The findings of the analysis as performed by the UGent team are:

1. There is an 'initiating' event, preceding the creation of the fire ball, visible as a flash in the video footage. This initiating event is not known with sufficient detail for the UGent team to be able to confirm that the use of FDS is suitable to model it.

2. Notwithstanding finding 1, the resulting observed fire ball, fire plume and pool fires are all physical process for which CFD modelling with FDS is deemed suitable. The observed fire ball, fire plume and pool fires also involve velocities that are well within the range of validated applicability of FDS. If the fire ball was the result of the combustion of a spray of liquid fuel droplets, FDS contains in principle all the necessary sub-models to simulate such scenarios.

3. Given the many unknowns involved in the scenario (i.e., lack of clear video evidence, lack of precise information about the available load on the freight train, and lack of information on the exact atmospheric conditions (in particular wind), to name a few), using FDS for reverse engineering of the Tempi accident in order to try and determine the type and minimum required amount of fuel involved in the incident that led to the observed fire ball, will inevitably involve a high degree of uncertainty. It is indeed very likely that multiple different choices for the input data in the CFD simulations can lead to a fire ball that resembles the video footage with a reasonable level of accuracy.

The analysis as presented above is the technical opinion of the UGent team, based on their professional experience and expertise in the context of fire simulations with CFD, and based on the available information as provided at the date of writing this report. The findings of the analysis are the result of careful consideration of the available information and are subject to change if new information on the accident were to be disclosed.

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*K. McGrattan, S. Hostikka, J. Floyd, R. McDermott, M. Vanella, E. Muller, Fire Dynamics Simulator Technical Reference Guide Volume 3: Validation, NIST Special Publication 1018-3 Sixth Edition (2024).

**Taken from FDS documentation: "Validation is a process to determine the appropriateness of the governing equations as a mathematical model of the physical phenomena of interest and typically involves comparing model results with experimental measurement."

***Fire Dynamics Simulator (FDS) validation guide (accessed 15 January 2025): https://github.com/firemodels/fds/releases/download/FDS-6.9.1/FDS_Validation_Guide.pdf