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# COMPARAȚIE ÎNTRE DATE MĂSURATE ȘI CALCULATE CU PRIVIRE LA INCENDIEREA TRENURILOR

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# COMPARISON BETWEEN MEASURED AND CALCULATED DATA REGARDING A TRAIN FIRE

The objective of this work is to compare the results of a model application with the measurements of visibility and temperature in case of fire in a train carriage. The aim is to find out the criticalities and to organize an adequate evacuation plan.

Keywords: evacuation, fire, train, temperature trend
Cuvinte cheie: evacuare, incendiu, tren, dinamica temperaturii

## 1. Introduction

Some fires occurred in the context of rail transport, have led the industry to conduct studies to increase security [1-3]. This research consisted in making real measurements of physical and chemical parameters of combustion that takes place in a railway carriage, specially provoked. The next step consisted in comparing the modelling results and the measured data during the real test, in order to highlight the criticality of the system of calculation and propose changes for improvement. The test pattern includes a burner fuelled by propane, that can issue a power of 75 kW for 2 minutes and then an output of 150 kW for a further 8 minutes, all on a train compartment with 2 floors.

The modelling was done using the software CPIwinFSE–FDS 2011 (BM Sistemi), based on the equations of state of gases, conservation of mass, energy and momentum, describing the following variables:

- RHR [kW];
- temperature [°C];
- visibility [m];
- stratification of smoke [m].

The simulation has also investigated about the modes of passenger's evacuation likely in such a situation.

In the following the specification of the analysis conducted shows only one part over all the tests developed.

## 2. Material and methods

The dimensions of the compartment are:

- carriage length: = 24.00 [m];
- carriage width = 2.84 [m];
- carriage height = 3.95 [m].

The vehicle consists of:

- no. 39 windows;
- no. 4 external doors;
- no. 2 doors catwalk;
- no. 60 seats in the lower deck;
- no. 60 seats in the upper floor;
- no. 12 seats in the atria.

The burner has sides of 30 cm (surface area of 0.09 $m^2$) with a maximum height of 30 cm and the distance from the wall is 20 cm. The performance of the thermal power of the burner is 75 kW (833 $kW/m^2$) for the first two minutes of simulation; for the next 8 minutes, the power is 150 kW (1667 $kW/m^2$) and then become extinct. The detection of the probes applied within the carriage is made by a computer system located in another carriage. The train car has two floors in which they are positioned 56 thermocouples. In the upper level several thermocouples were placed on both seats on the backs of the seats. They are also placed three stakes (trees) along the corridor, with 3 thermocouples each. Downstairs several thermocouples were placed over the burner at 30 cm from the wall at different heights (from 1 but 1.9 m) and other thermocouples were placed, on the seats and on trees, located in the middle of the hallway to the end, at the stairs leading to the upper floor and outputs.

The simulation is performed with the doors of the walkway and exterior doors closed for the first 270 seconds, after which the two external doors placed on the same side where the burner is located, are opened. The domain of calculation is performed with cells having dimensions of 10 cm for a total of 450,000 cells. This domain is open on all sides except the one of the plane at an altitude of 0 (ground) in such a way as to allow natural ventilation. The parameters of the simulation and materials used are shown in the following table.

Table 1

| Parameter | | Value |
|---|---|---|
| Test conditions | | |
| Duration of the simulation | | 900 [s] |
| Initial ambient temperature | | 20 [°C] |
| Ambient pressure | | 101,325 [Pa] |
| Relative moisture | | 40 [%] |
| Materials characteristics | | |
| F1A-1-2 - Seat (Cover) | Specific heat | 11.65 [kJ/kgK] |
| | Conductivity | 0.1610 [W/mK] |
| | Density | 239.00 [kg/m$^3$] |
| | Thickness | 4.00e$^{-3}$ [m] |
| F1A-1-2 - Seat (polyurethane) | Specific heat | 1.50 [kJ/kgK] |
| | Conductivity | 0.0280 [W/mK] |
| | Density | 76.00 [kg/m$^3$] |
| | Thickness | 0.0240 [m] |
| IN 1.5 - Walls | Specific heat | 1.46 [kJ/kgK] |
| | Conductivity | 0.59 [W/mK] |
| | Density | 1.857 e$^3$ [kg/m$^3$] |
| | Thickness | 4.00 e$^{-3}$ [m] |
| IN 1.7 - Partitions | Specific heat | 0.1700[kJ/kgK] |
| | Conductivity | 0.1500 [W/mK] |
| | Density | 700.00 [kg/m$^3$] |
| | Thickness | 0.0130 [m] |
| IN 3.1 - Ceiling strips | Specific heat | 1.20 [kJ/kgK] |
| | Conductivity | 0.2400 [W/mK] |
| | Density | 1.200 e$^3$ [kg/m$^3$] |
| | Thickness | 2.00 e$^{-3}$ [m] |

### 3. Results and discussions

As an example, the following is a chart that shows the trend of temperature (°C) measured by a thermocouple compared to the value calculated by the software. The vertical lines refer to the time at which the change of the thermal power of the burner 75 to 150 kW (blue), the opening of doors (purple) and at the end of the fire (green, after 600 seconds). In the example (figure 1) the graph shows the temperature trend relative to a thermocouple positioned above the burner at a height of 1 meter).

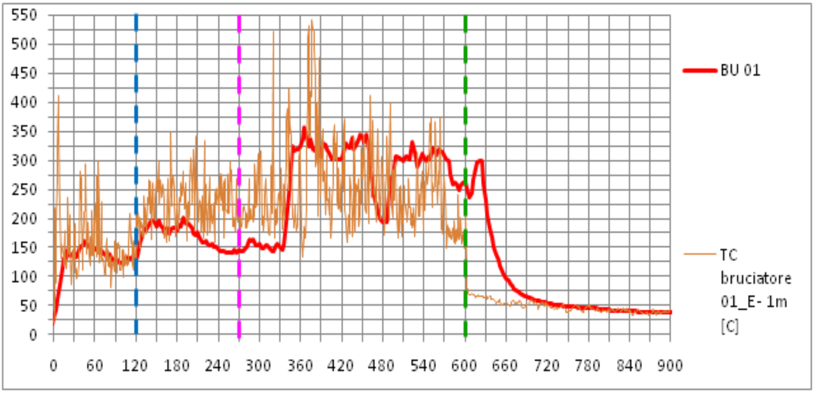


Fig. 1 Example result of temperature (thermocouple 1,
h = 1 m altitude above the burner)

The results obtained by the thermocouples to 1.9 meters in height are not significant because the temperatures detected by the software are much lower compared to the real case. It is a significant finding only for thermocouples positioned at a height of 1.8 meters above the ground and for those positioned on the seats, especially those close to the burner.

Referring to the last case, figure 2 shows the graphs relating to the thermocouples positioned on a seat and backrest of the chair 01 in the vicinity of the burner.

The temperature curves obtained from the simulation differ from the actual case from about 480 seconds; thermocouples detect an actual case temperature peak, probably due to the fact that the seat caught fire, or that the flame has grown more strongly from this side. The differences in the temperatures measured by the tests appear to be minimal for all seats, with the exception of those located close to the burner; generally the temperature detected by the simulation is higher than in the real case. The curves obtained from the simulation tend to rise during the first 270 seconds (time period in which the carriage doors are closed), and then realign. This behaviour is presumably due to an influx of fresh air in the area is not on fire while in the case of the burnt areas it denotes an increase in temperature.

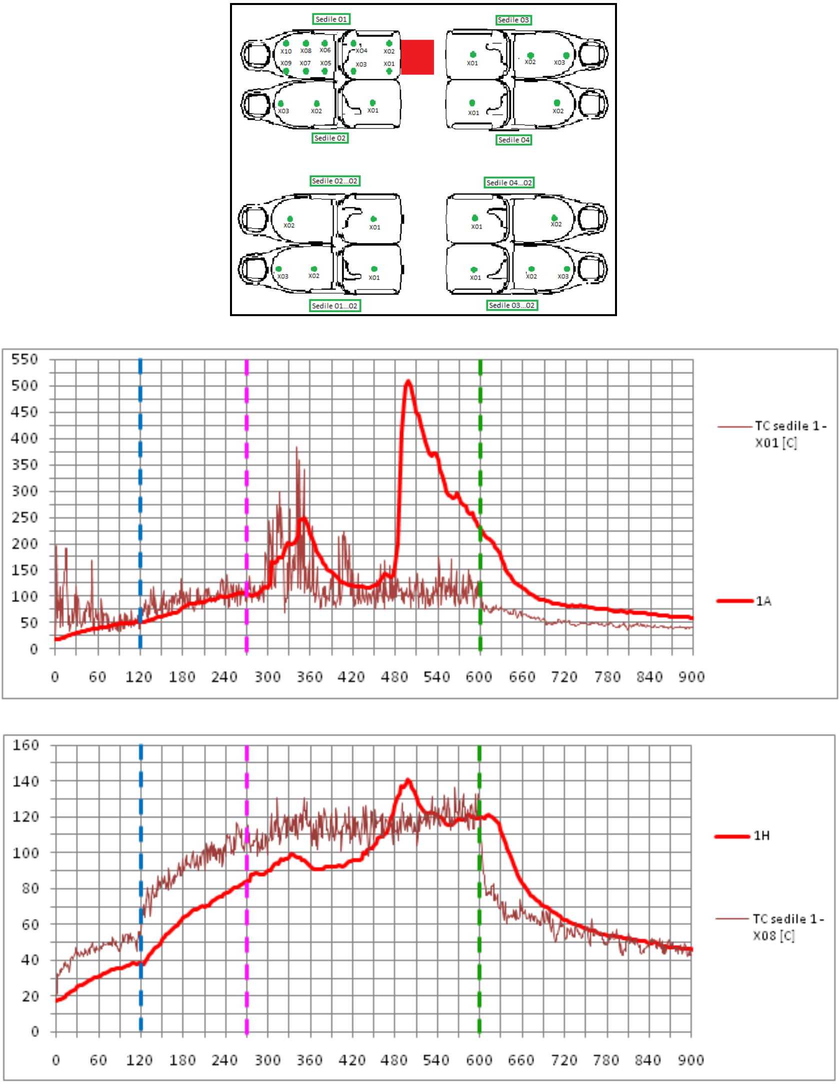


Fig. 2 Example result of temperature (chair 01, seat and back)

On the ground floor, including thermocouples applied to the trees showed a good correspondence between the measured data and those calculated for a height of over 1.7 m. At the bottom of this portion the results are not good with an obvious underestimation of the calculated value from the measured values (figure 3). The difference is even more pronounced on the first floor, where the difference is probably due to two windows that are always open (10 cm) to allow the passage of instruments.

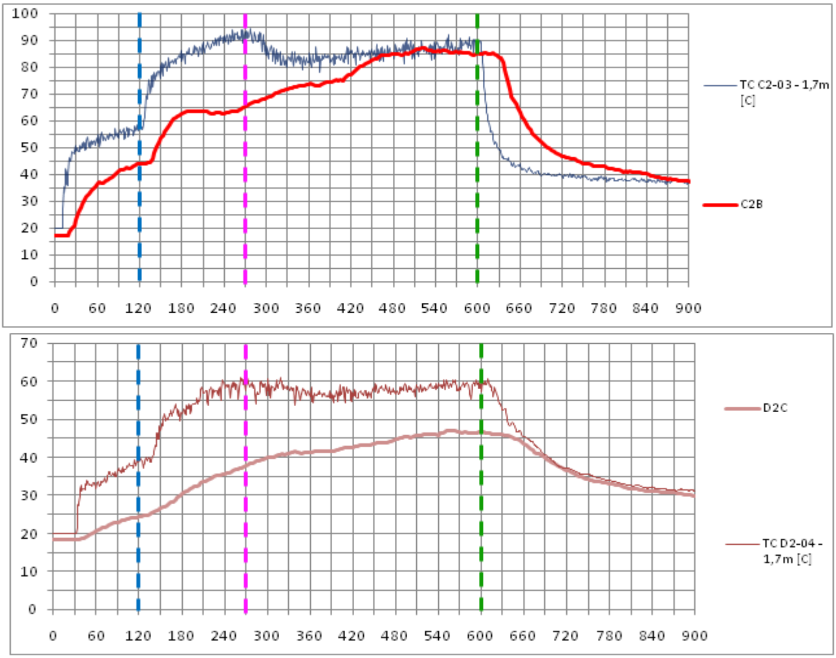


Fig. 3 Example of result of temperature (tree on the ground floor, up, and first floor, second graph, at a height of 1.7 m)

Finally, whereas the thermocouples are positioned in the atrium, is also found in this case an average temperature higher than that calculated, especially until the opening of the doors (figure 4).

The stratification of the fumes inside the carriage can be divided into five phases:

I. initial stage of the fire;

II. propagation of smoke in the lower part of the carriage;

III. propagation of smoke in the carriage, before the opening of the ports to 270 seconds from the start of the fire;

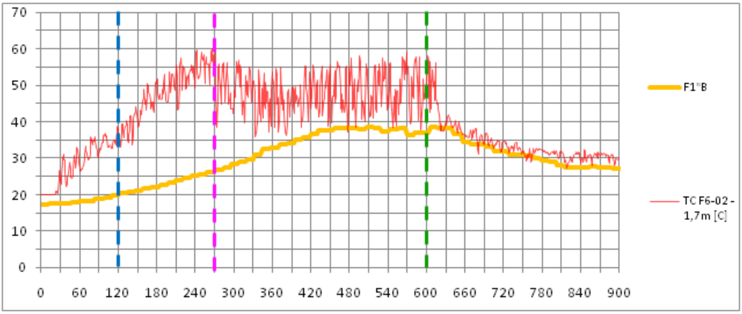


Fig. 4 Example of result of temperature (atrium)

IV. stratification of the smoke after the door is opened;
V. reduction in the thickness of the fumes to fire off.

In the initial stage of the fire, fumes develop vertically above the burner until you hit the ceiling of the lower deck. Then the smoke runs horizontally with a thickness of 15-20 cm to the height of the stairs that connect the low-floor atrium of the carriage. In the latter area the fumes reach the ceiling of the cab and also propagate in the upper floor.

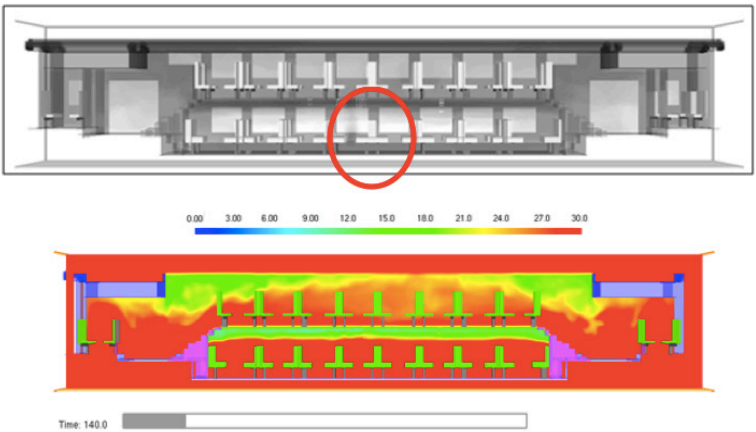


Fig. 5 Distribution of the smoke (second phase)

In the second phase, the fire continues to give off fumes which layer while maintaining a thin layer, and then begin to invade the upper floor, creating a layer more and more often starting from the intrados of the ceiling of the upper floor the same. The stratification beginning from the upper floor despite the fire starts from the lower level (figure 5). The black and white image depicts the amount of smoke present in the cab at a certain time (time 0.0 s). Instead the color image shows the visibility through the section of red color placed in the center of the corridor in a certain instant (time 0.0 s).

In the third phase the thickness of the smoke continues to rise up to invade the whole carriage (there is no longer a double layering of the fumes but the whole compartment is flooded). When the doors open after 270 seconds from the start of the fire, the smoke starting to come out of the carriage, releasing part of the low floor despite the continued presence of the fire. The layer of smoke that is formed after about 80 seconds of entering air, occupies the entire first floor of the cab and the floor below. This is due to the fact that the opening of the ports determines a change of air, letting fresh air in the lower part of the carriage (the fresh air has a higher density than the hot gas and promotes the flotation of the fumes in the upper part of the carriage) and by venting from the top of the fumes. It is to form a constant layering of the fumes inside the carriage and the separation line which divides the layer of fresh air from the flue gas; the so-called neutral plane, is positioned approximately at mid-height of the door. In this situation, you create a zone (upstairs) completely invaded by smoke and a lower zone (almost the entire downstairs) free from fumes.

When the doors open, the fumes are extracted with a higher speed compared to their production, in fact, in addition to obtaining a stratification of the smoke in the upper part of the carriage, it is also known to increase the visibility in the layer of smoke.

The last phase occurs after 600 seconds, where the fire is no longer spent so the development of the fumes. The carriage gradually Iberian fumes.

In the graph below (figure 6) an example of a reproduction of the visibility detected with suitable sensors positioned at 1.7 m from the tread surface and the centreline of the carriage (positions 5 , 6 and 7) is proposed.

On the basis of the above, it can be estimated the time required for the evacuation of the wagon. The time required to evacuate the upper floor of the carriage is about 4 minutes from the start of the fire. At this moment at an altitude of 1.7 meters from the tread surface of the upper floor, visibility is about 10 m. The time required to evacuate the ground floor of the carriage is instead of about 3 minutes from the start of the fire.

The above presented results can be a part of a more comprehensive approach for studying the risk from fire events [4].

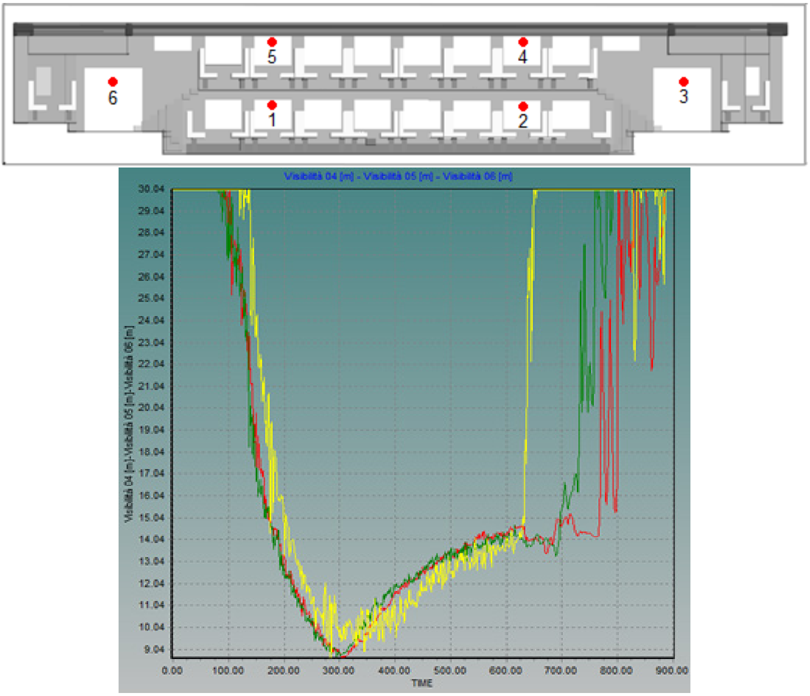


Fig. 6 Detection of visibility

## 4. Conclusions

■ The modelling normally used is fairly reliable as regards the distribution of temperatures, especially near the point from which it originated the fire. However, the results are little face precautionary, in the sense that the data measured in the field are greater than those calculated.

■ Regarding the visibility and thus the production of smoke, a weak point of the modelling is represented by a lack of available data, in real cases, the actual molecular composition of fuels. The different fuels that can come into play in practice will have articulated compositions and often differences between them. But above all too often not known.

■ This leads to an uncertainty in the qualitative and quantitative determination of the products of combustion. Alternatively the composition may have molecular laboratory data that allow inserting an accurate model. The analysed model includes a propane burner while in real cases other fuels are simultaneously present.

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