CHECKING JET-FAN'S FIRE PERFORMANCE FROM CLOSED CAR PARKS USING PYROSIM PROGRAM

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Abstract. *This paper presents a solution for the checking of the jet-fun's fire performance providing in closed car parks. We propose for this to use the Pyrosim program. The main goal of the simulation is to reveal the temperatures recording in three points under ceiling of closed car park, where the jet – funs are placed.*

Keywords: *Pyrosim, smoke, temperature, car park.*

1. INTRODUCTION

Pyrosim program provides a platform for using Fire Dynamic Simulator, a useful tool for fire security specialists, giving to them mathematical supported data regarding the quality and quantity of fire usually associated parameters: temperatures (of the air, on the surfaces), concentration (oxygen, burning gases, smoke), visibility, in connection with smoke quantity, pressures (on different spaces, applied by fans etc.), temperature, pressure and other gradients [1].

1.1. Pyrosim simulation program

As mentioned above, Pyrosim program offers the possibility to implement, in the drawing structure and in the calculation, different types of actors accustomed with fire security analysis: heat detectors, thermocouples, pressure and temperature sensors, ventilation systems with incorporated fans, smoke control dampers etc.
The benefits for the users who know how to work at full capacity with this soft are enormous, inclusively for scientists who study fires in underground parking facilities: it can obtain correct results using only calculations without destructive and non repetitive full scale tests. Pyrosim represents a platform for easier use of the FDS program, which is a difficult to use as such.
Thermal calculation is made using the same network finite volume technique. Lagrange's study method is used to simulate smoke movement and sprinkler discharge [2].
FDS is a dynamic simulation of fluids software, respectively heat flux of the fire. Models resolve numerical a new form of Navier-Stokes' equations for slow speed, heat flux and smoke evolution. Partial derivatives of mass preservation equations, moment and energy are approximated as finite differences and the solution is developed in time on a tridimensional, rectilinear network [2, 3]. The software uses an algorithm based on the following equations [2]:
- Mass preservation,

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \boldsymbol{u} = \dot{m}_b''' \tag{5.1}$$

- Moment preservation (second Newton's law),

$$\frac{\partial}{\partial t}(\rho \mathbf{u}) + \nabla \cdot \rho \mathbf{u}\mathbf{u} + \nabla p = \rho \boldsymbol{g} + \boldsymbol{f_b} + \nabla \cdot \tau_{ij}\ ; \tag{5.2}$$

- Energy preservation (first law of thermodynamic),

$$\frac{\partial}{\partial t}(\rho h) + \nabla \cdot \rho h \mathbf{u} = \frac{Dp}{Dt} + \dot{q}''' - \dot{q}_b''' - \nabla \cdot \dot{q}'' + \varepsilon\ ; \tag{5.3}$$

- Perfect gaseous stain equation,

$$p = \frac{\rho \Re T}{M} \quad . \tag{5.4}$$

Above equations represent a set of nonlinear differential equations with partial derivatives which consists in six equations with six unknown, all functions of three dimensions in space and time: density ρ, the three components of speed **u**, temperature T and pressure p.
Enthalpy h is a function of temperature,

$$h = \int_{T^0}^{T} \mathrm{c_p}(T')\,\mathrm{d}T' . \tag{5.5}$$

In the following is a brief of terms used in the equation above:

$\boldsymbol{c_p}$ – specific heat at constant pressure, in [J/kg·K];
$\boldsymbol{f_b}$ – external forces vector on unit volume (without gravitational forces), the scalar in [N/m^3];
$\boldsymbol{g}$ – gravitational acceleration vector (0, 0, $-g$), the scalar in [m/s^2] ;
$\dot{m}_b'''$ – burning gases producing rate b on unit volume, in [kg/m^3·s];
$\dot{q}''$ – heat flux, in [W/m^2];
$\dot{q}'''$ – heat release rate on unit volume, in [W/m^3];
$\dot{q}_b'''$ – heat flux used by burning gases for ignition and continuous burning, in [W/m^3];
$\Re$ – ideal gas constant, in [J/kg·K];
t – time, [s];
M – molecular mass of gas mixture, in [kg/kmol];
ε – dissipation rate, in [W/m^3];
τ_{ij} – viscosity tensor.

Thermal radiation is calculated using finite volume technique on the same network. Lagrange's study method is used to simulate smoke movement and

sprinkler discharge [2].
Using numerical modeling of fire, in reality it can be calculated temperature, density, pressure, speed and chemical composition in each cell for small time steps. Usually there are hundreds of thousands to million of cells and it is performed thousands to hundreds of thousands of iterations.

1.2. Implementing and running Pyrosim for fire simulation in a canton of an underground parking facility

After completion of smoke extraction system described in figure 1 the results show that this system cannot clear two zones, influencing negatively user's evacuation.

Table 1. Input data

Category	Parameters	Value
Calculation domain	Canton 6	Canton 6 belongs to an underground parking facility afferent to a big commercial centre in Bucharest
	Dimension of the canton in which simulation is carried out	80 m × 50 m × 3,5 m (in order on the axis (*Ox*, *Oy* and *Oz*)
Numerical information	Dimension of calculated network	240 × 150 × 12 calculation cell
	Dimension of calculated cell	0,33 m × 0,33 m × 0,29 m
	Total number of cells	432 000
	Boundary conditions for walls	The walls from all plans were considered inert
	Boundary conditions for floor	The floor (*xOy* minimum plan) was considered closed inert
	Boundary conditions for ceiling	The ceiling (*xOy* maximum plan) was considered closed inert
Other information	Fire source	Surface with 0.8 m × 1.2 m dimensions on 0.6 m height, representing a part of front side of a car, with heat flux release of 4000 kW/m^2 placed near a wall, on the floor.
	Measuring instruments simulated	It was simulated introduction of seven speed and temperature measuring points on three heights 0.5 m, 1.5 m and 2.5 m.
	Atmospheric values	Default values of the software: 20 °C, relative humidity 40%, atmospheric pressure 101 325 Pa, initial speed of air current 0 m/s.

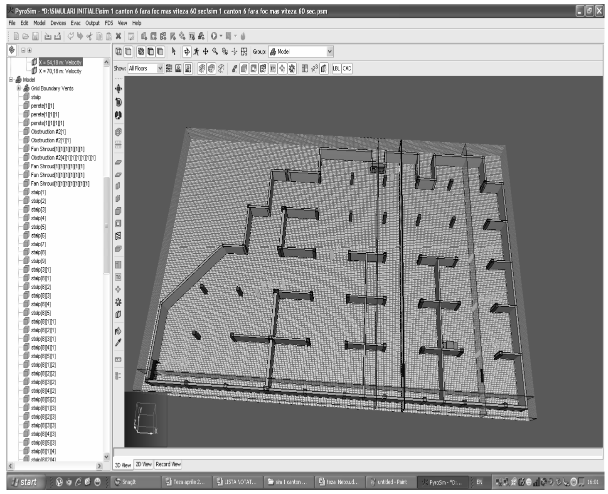


Fig. 1. Design of a canton from a parking facility, using Pyrosim

Chosen solution is proposed to be verified for smoke extraction in canton, regarding geometrical configuration.
By this it is to be determined that the two jet-fans are correctly dimensioned regarding fire performance. In the following there will be presented all the input information, so that by running the program to obtain realistic results. Normally, input data introduced in program mainly refers to elements described in table 1.
After the introduction of all data from table 1, it was initiated running of program. The simulation space contained a number of 432,000 cells.

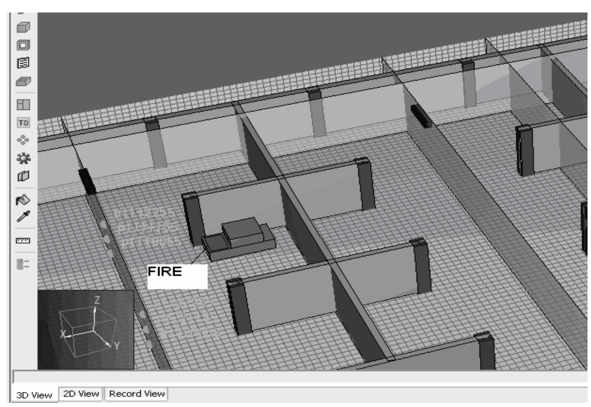


Fig. 2 Visualization in Pyrosim of fire source used in simulation

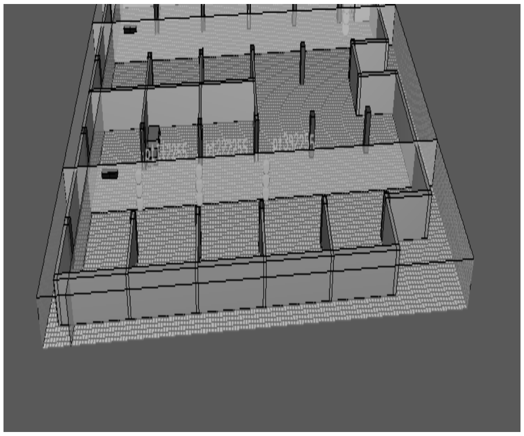


Fig. 3. Visualization of points for measuring the temperatures

Figure 2 presents fire source based on construction elements and in figure 3 are indicated measuring points of temperature.
For viewing the results it was used Smokeview, which is freeware part of FDS [4].

1.3. Acquisition and interpretation results obtain after the simulation

It was ordered to simulate a fire using Pyrosim, for determination of temperature at 2.5 m height in three relevant points shown in figure 4, as follow:
- Point 1 placed at 3.30 m in front of the jet-fan, in circulation axis;
- Point 2 placed at 11.30 m in front of the jet-fan, in circulation axis;
- Point 3 placed at 20.20 m in front of the jet-fan, in circulation axis;

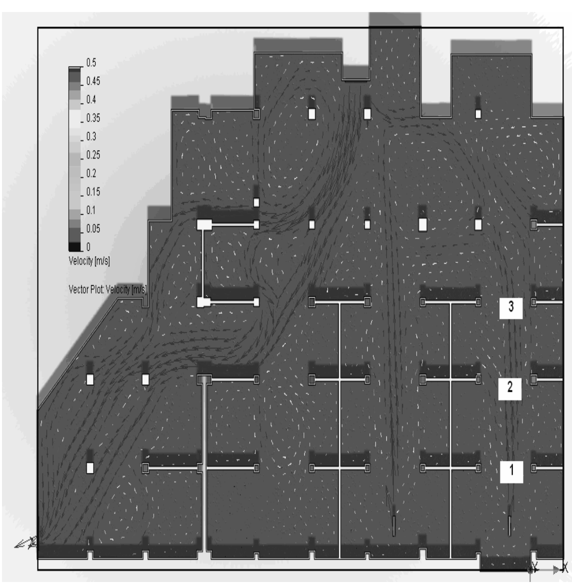


Fig. 4. Points in which was measured temperatures and speeds

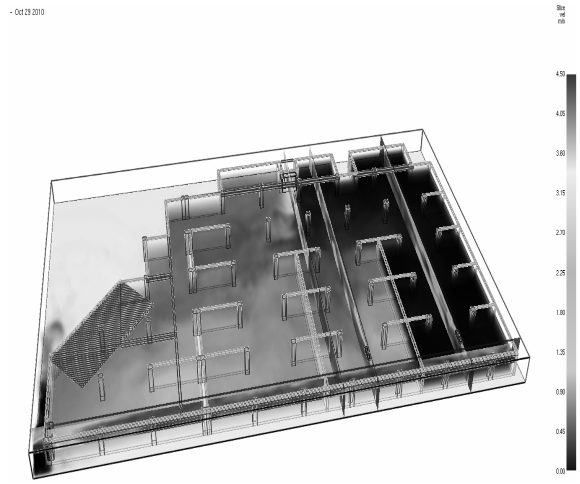
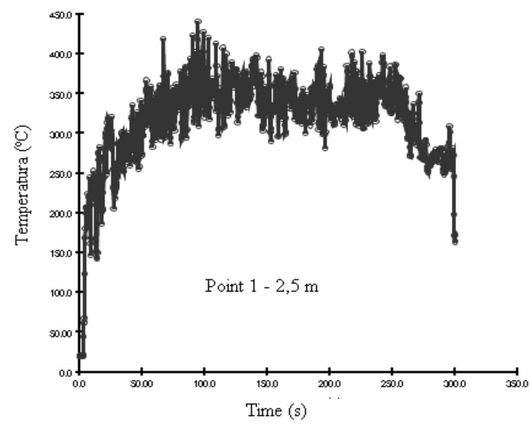
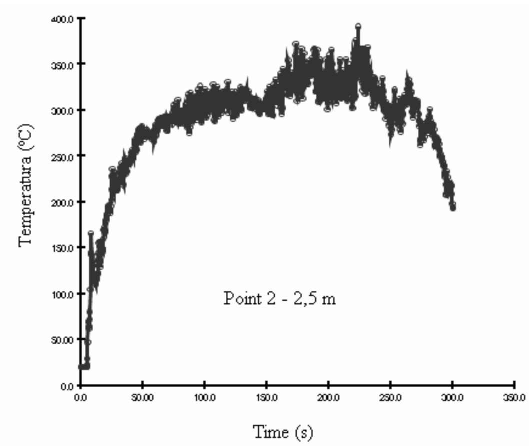


Fig. 5. Smoke circulations inside the canton

From figure 5 result that following the fire with source placed as above, it can be observed that the most part of smoke and hot gas is in the zone propose for analysis. Therefore verification of recorded temperatures at 2.5m height is justified.





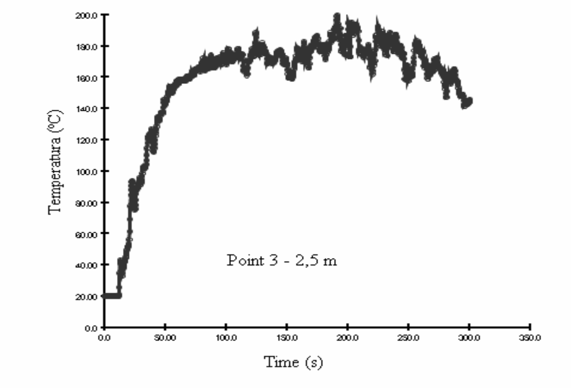


Fig. 6. Graphics with recorded temperatures recorded at 2.5 m height in those 3 relevant points

From graphical analysis of temperature variation in time, figure 6, it appears that fans were correctly chosen as 400 ºC temperature was not exceeded and fire performance criteria of these fans is F_{400} 120, meaning that they are fire resistant 2 hours at a 400 °C temperature[5, 6].

1.4. Conclusions

The simulation was performed for 5 minutes as this represents maximum response time of a fire security crew of a underground parking facility.
The obtained results confirmed viability of chosen solution for smoke extraction regarding jet-fan's fire performance.

2. ACKNOWLEDGMENTS

Thank you from all my heart to Prof. phd. eng. em. Valeriu PANAITESCU and eng. Robert STRUGARIU for the help accorded in realizing this article.

3. REFERENCES

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