Raspored požarnih detektora u posebnim slučajevima – primjer hodnika

Arrangement of fire detectors in special cases – hallway example

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SUMMARY

Fire protection systems present one of the most important systems of the object protection systems. Fire protection system consists of many different parts connecting in one unique system. One of those parts is fire detector. Detector presents one of the main elements of all real time systems that collecting data by measuring material and energetic changes of supervised occurrence. One of the most important tasks in projection of fire system is the type and disposition of detectors in object. These tasks were regulated by proper standards. But, there are special cases where deviations are necessary and possible. This paper presents simulation check of heat and smoke detectors positioned in hallway.

Key words: fire, detectors, arrangement, heat, smoke, simulation

Sažetak

Vatrogasni sustavi za zaštitu predstavljaju jedan od najvažnijih sustava zaštite objekata. Sustav zaštite od požara sastoji se od više različitih dijelova povezanih u jedan jedinstveni sustav, a jedan od tih dijelova je detektor požara. Detektor predstavlja jedan od glavnih elemenata svih u realnom vremenu sustava koji prikupljaju podatke mjerenjem materijalnih i energetskih promjena nadzirane pojave. Jedan od najvažnijih zadataka u projekciji požarnih sustava je tip i raspored detektora u objektu, a ti zadaci su regulirani odgovarajućim standardima. No, tu su i posebni slučajevi u kojima su potrebne i moguće devijacije. Ovaj rad predstavlja simulaciju provjere topline i dima smještenu u hodniku.

Ključne riječi: vatra, detektori, raspored, toplina, dim, simulacija

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INTRODUCTION

Uvod

The most important purpose of fire protection systems is to provide information to the user about fire genesis in order to avoid human victims and material damage. Fire protection system is very complex system that has many different parts connecting in one unique system. Precision and correct work of every part of fire protection system has great importance. The projecting of fire protection systems purports cognition of huge numbers of facts according to the object and possible development of fire. The most important results of the projection process are the right choice of fire detector and it's positioning into an object.

The fire is occurrence that presents uncontrolled and unpredictable process of heat propagation. One of the most important fire parameter is combustion. It presents the series of the chemical reactions between the fire material and oxygen, where the releasing of the heat, smoke and heat is presented. Many of the combustion products could be toxic and present great danger for humans and material properties. Because of that, it is very important that fire should be detected at early stage. Many of these products have used for fire detection. To reach the combustion process, the presence of the all components of the fire triangle is required: fire material, heat source and oxygen, which means that the lack of any of noted components stops the combustion process. If the combustion process comes without influence of the external source, it could be defined as self trigger process. The combustion process consequence is the heat transfer. Considering the fire detection, it is very important fact that the heat, as the measure of the warming, presents the only parameter that could produce the signal which is not need to amplify. There were three basic mechanisms of the heat transfer: conduction, convection and radiation. The most frequently used products used for fire detection are smoke, heat and flame (Furness and Mucket, 2007).

One of the most important parts of the fire protection system is detector. This term is often equalled with term sensor, but, many literatures, for example Anglo-Saxon, consider that detector presents wider concept than sensor and it comprises three parts: sensor part, converter part and part for signal conditioning (setting the amplification, filtering and normalization of the signal). The detector or sensor term doesn't mean the presence of the energy source for its work. Fire sensors could be divided on different ways and in dependence of different criteria. One of those divisions is presented on Figure 1.

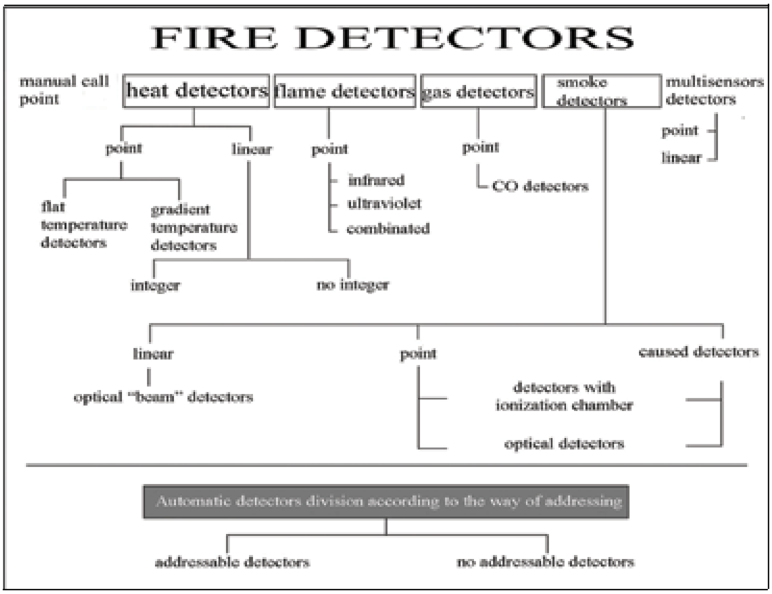


Figure 1. Fire detectors division (Figure source: Alarmni sistemi, M. Blagojević, 2011.)

Slika 1. Podjela požarnih detektora (Izvor: Alarmni sistemi, M. Blagojević, 2011.)

The arrangement of fire detectors in object presents one of the most important tasks in fire detection at early stage. There are several standards that deal with this problem: BS (British Standard), NFPA (National Fire Protection Association), НПБ 88-2001 (Нормы пожарной безопасности) and other.

The general rule for needed number of fire detectors and its positioning is to divide the supervised area with detector supervised area. There are lots of other factors that should be considered, such as shape and slope of the roof, barriers, girt, walls positioning, installation positioning, wholes into the walls positions, room height etc. The position of the detectors should be easy accessible, because of its testing and repairing. The reduction of the range between detectors leads that the system sensibility becomes higher. It is important to note that increment of fire detector numbers over the optimal limit brings small gain according to the price of the system. Because of that, it is important to find an optimal relation between performance increment and price needed for that.

For example, according to the Russian standard NPB 88-2001 (Нормы пожарной безопасност НПБ 88-2001), the arrangement of heat detectors in object are presented in Table 1.

Table 1. Rules for point heat detectors positioning

Tablica 1. Pravila za pozicioniranje točkastih detektora topline

Room height [m]	Detector supervised area [m²]	Maximal range [m]	
		between detectors	detector from wall
up to 3.5	up to 25	5.0	2.5
3.5-6.0	up to 20	4.5	2.0
6.0-9.0	up to 15	4.0	2.0

American standard NFPA 72 is one of the most detailed and the largest standards that regulate fire detection. For example, the distance between detectors, marked as S, is formed by references presented on Figure 2.

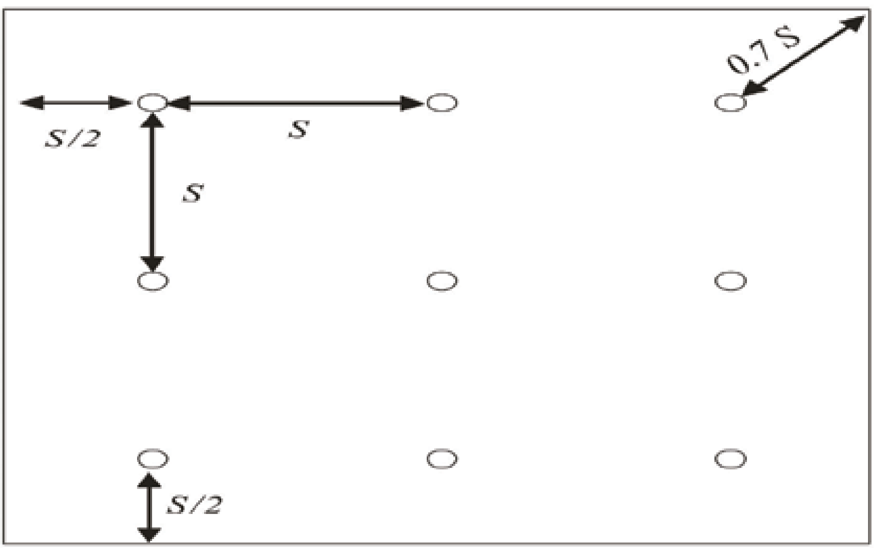


Figure 2. The references for detectors arrangement according to NFPA 72

Slika 2. Reference za raspored detektora prema NFPA 72

The limits of this paper, of course, do not allow the presentation of every rule and regulative for detectors disposition in object. Although the noted standards provide detail and analytic approach to fire problematic, there are possible deviation related to some tasks, but that demands of many different factors and special cases (NFPA 72, 1999; НПБ 88-2001, 2001; ISO 7240, 2006).

THE ARRANGEMENT OF FIRE DETECTORS IN SPECIAL CASES - *Raspored požarnih detektora u posebnim slučajevima*

Stairs present special case for fire detectors arrangement and deviate from basic regulates according to room's surface and height. It is general rule that at least one fire detector is positioned on stairs, right on the roof of the last floor. This rule is valid only if there are no separations by doors between floors. If so, then the detectors are positioned on the floor in front of those doors. In addition, if the stairs height was bigger than 12 m and if there were no obstacles, detectors are positioned one on each three floors.

The distance of detectors from walls, furniture, stored stuff and similar obstacles also shouldn't be less than 0.5 m, except in the case of hallways or object's parts with width less than 1 m. If the furniture, stored stuff and similar have height which is smaller than 30 cm from the ceiling, then they should be treated as compartment walls because they stopping smoke spreading.

Girt, galleries and similar structures that can hinder smoke transition through the room are treated on similar way as stored stuff. If singular ceiling part are equal or bigger from 0.6 A (A presents supervised surface of detector), then the detector should be placed in every panel. If the panel's surfaces are bigger from allowed covering surface of detector, then they are treated as separated spaces. If the girt`s height above then 800 mm, one detector must be predicted for every ceiling's panel. Girts on roofs with length less than 150 mm can be ignored.

In the hallways, passages and similar spaces (spaces with the width less than 3 m) distances between detectors could be 10 m, for heat detectors and 5 m, for smoke detectors. Also, one very important thing is, in the case with hallways crosses, one detector must be positioned at the cross place, taking care that its maximal covering surfaces don't be outreached. In the hallways, passages and similar spaces, the smoke spreading was canalized which enables bigger distance between detectors, but, the dimension of supervised surface must be the same. It implies that in the rooms with the width less or equal with the half of the distance (0.5 S), distance between detectors could be increased up to relation of $S_{max}=1.6\sqrt{A_m}$, what is presented as curve on Figure 3.

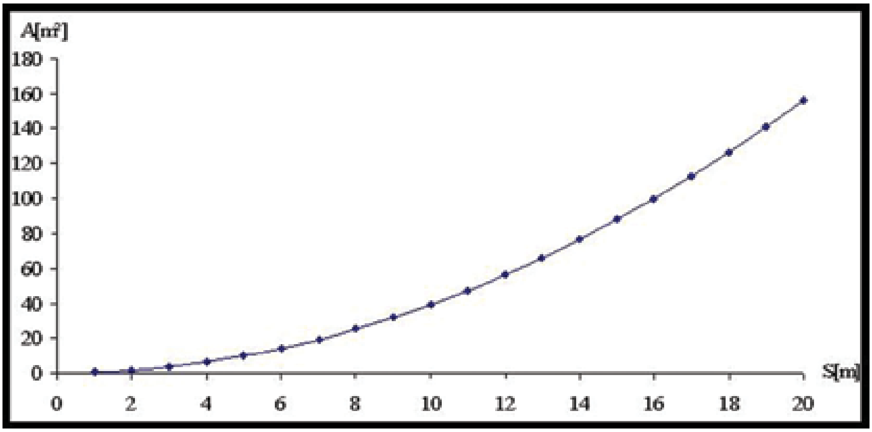


Figure 3. Maximal distance between detectors in hallway

Slika 3. Maksimalni razmak između detektora u hodniku

In some standards from western countries, (for example, in British) the hallway term (narrow room) is related for width of 5 m, so the rule in this case is different. For hallways and corridors with length less than 5 m, where all other neighbour rooms were protected with detectors, the half of difference from 5 m and real hallway width is added on maximal allowed distance. Maximal distances between detectors in hallway according to the British standard are presented in Table 2.

Table 2. Maximal distance between detectors in hallway

Tablica 2. Maksimalni razmak između detektora u hodniku

Hallway width [m]	Maximal distance between detectors [m]	
	Smoke detectors	Heat detectors
1.2	18.8	14.4
1.6	18.3	14.0
2.0	17.9	13.5
2.4	17.4	13.0
2.8	17.0	12.5
3.2	16.5	12.0
3.6	16.0	11.5
4.0	15.5	10.9
4.4	15.0	10.3
4.8	14.4	9.7

Air flow doesn't have the influence on heat and flame detectors functioning. For projecting of fire detection systems in the rooms where the presence of ventilation is, it should be taking care that smoke detectors don't be positioned in the fresh air current from ventilation or ventilation device. Smoke detectors can be positioned in the space where air flow is not bigger than 5 m/s, except if the characteristics for particular detector enable appliance for bigger air flow speeds than 5 m/s (Blagojević, 2011; Blagojević and Petković, 2001; Jevtić, 2015).

SIMULATION MODEL – *Simulacijski model*

Simulation model was created in PyroSim software, version 2012. PyroSim presents a graphical user interface for the Fire Dynamics Simulator (FDS). FDS models can predict smoke, temperature, carbon monoxide (CO), and other substances during fires. The results of these simulations have been used to ensure the safety of buildings before construction, evaluate safety options of existing buildings, reconstruct fires for post-accident investigation, and assist in firefighter training. FDS is a powerful fire simulator which was developed at the National Institute of Standards and Technology (NIST). FDS simulates fire scenarios using computational fluid dynamics (CFD) optimized for low-speed, thermally-driven flow. This approach is very flexible and can be applied to fires ranging from stove-tops to oil storage tanks. It can also model situations that do not include a fire, such as ventilation in buildings. FDS and the Smokeview visualization program are both closely integrated into PyroSim. The PyroSim interface provides immediate input feedback and ensures the correct format for the FDS input file. In addition, PyroSim offers high-level 2D and 3D geometry creation features, such as diagonal walls, background images for sketching, object grouping, flexible display options, as well as copying and replication of obstructions. It is possible to import DXF files that include either 3D faces or 2D lines that can be extruded to create 3D objects in PyroSim (PyroSim, 2012).
Simulation model used in this paper implied storage space with dimensions 55 m x 18 m x 2,75 m. Storage space has two halls with length of 2 m and one hall with length of 4 m. The fire source was modelled as burner (1 m x 1 m dimensions) with HRR (Heat release rate per area) of 100 and 250 kW/m^2. The burner's positions were in the mid-

dle of the whole object and in the last room of the object. The whole object was build from concrete. Doors from all rooms were opened. Smoke and heat detectors were positioned in object according to noted rules. Simulation model in PyroSim with its dimensions, in 2D view and smoke detectors arrangement and burner position is presented on Figure 4 (a) while the simulation model in PyroSim in 3D view with arrangement of heat detectors and burner position is presented on Figure 4 (b).

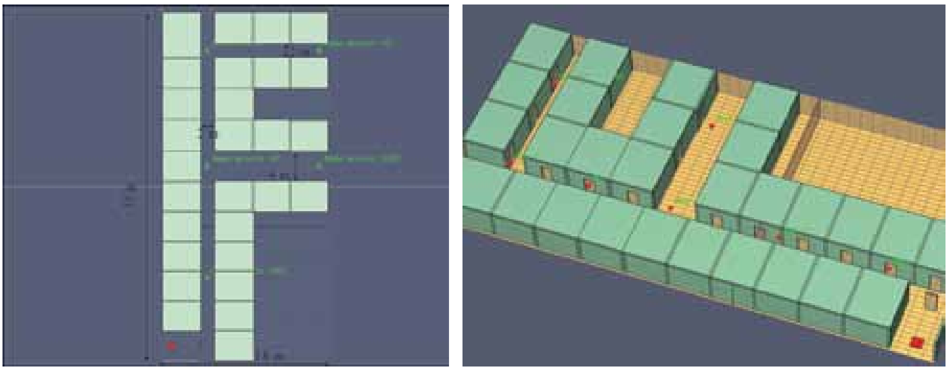


Figure 4. Simulation model with its dimensions in 2D PyroSim presentation and positions of smoke detectors (a) and 3D PyroSim presentation with heat detectors positions (b)

Slika 4. Simulacijski model sa svojim dimenzijama u 2D PyroSim prezentaciji i položaj detektora dima (a) i 3D PyroSim prezentacija s pozicijama detektora topline (b)

SIMULATION AND SIMULATION RESULTS – *Simulacija i simulacijski rezultati*

The simulations were realized on laptop Fujitsu Siemens Esprimo Mobile V5535, with Intel Celeron 1733 MHz (13x133), 2GB of RAM and SiS Mirge 3 Graphics (256 MB). The simulation time was set on 200 seconds for every simulation. PyroSim simulation software and similar simulation software demand very strong hardware configuration because the duration of simulations could be from several hours to several days, even weeks, in dependence of the simulation's model complexity. It is also important was the file created in PyroSim or was it imported from some other program. For objects created in some other program, such as, for example, some version of AutoCad, it is often necessary to reformat some object's parts, material properties, positions and similar elements. Creation disability of some complex objects, for example, creation of curved edges or curved elements in PyroSim are the most common cases for importing from some other program.

Realized simulations provided the smoke and heat propagation in object and time diagrams of every positioned detector. In order to limited size of paper, only some scenes from the first and second scenario are presented on pictures 5 and 6 (Jevtić and Ničković, 2014)

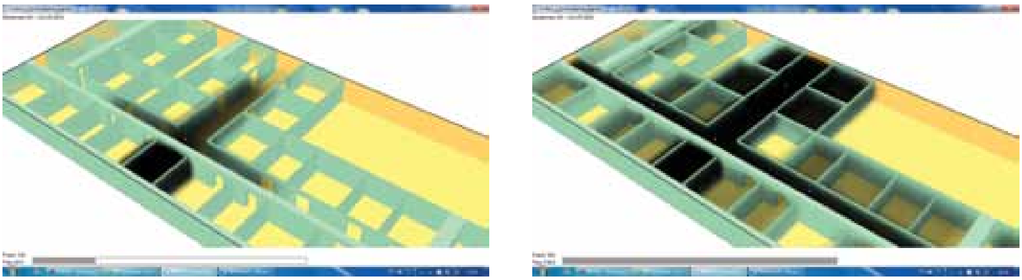


Figure 5. Simulation moments at 48,6 seconds after simulation start (a) and at 199,8 seconds after simulation start for burner position at the middle of the object and burner HRR of 100 kW/m^2

Slika 5. Trenutak simulacije na 48,6 sekundi nakon početka simulacije (a) i na 199,8 sekundi nakon početka simulacije pri poziciji plamenika na sredini objekta i plamenika HRR od 100 kW/m^2

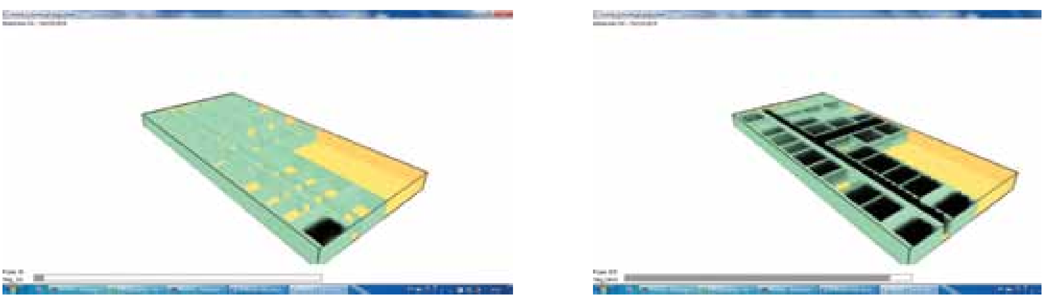


Figure 6. Simulation moments at 8,6 seconds after simulation start (a) and at 184,8 seconds after simulation start for burner position at the end of the hall and burner HRR of 250 kW/m^2

Slika 6. Trenutak simulacije na 8,6 sekundi nakon početka simulacije (a) i na 184,8 sekundi nakon početka simulacije pri poziciji plamenika na kraju hodnika i plamenika HRR od 250 kW/m^2

The reaction temperature for heat detectors was 75°C and the response time index (RTI) was 100 $m^{½}s^{½}$, while the activation threshold for smoke detectors was 3,25 % of obscuration. Simulation results for the nearest and for the farthest heat detectors in the scenario where the burner was in the middle of the object and the burner HRR was 100 kW/m^2 are presented on figure 7 (a, b), while the simulation results for the nearest and for the farthest smoke detectors in the scenario where the burner was in the middle of the object and the burner HRR was 100 kW/m^2 are presented on figure 8 (a, b). Simulation results for the nearest and for the farthest heat detectors in the scenario where the burner was in at the end of the hall and the burner HRR was 100 kW/m^2 are presented on figure 9 (a, b), while the simulation results for the nearest and for the farthest smoke detectors in the scenario where the burner was at the end of the hall and the burner HRR was 100 kW/m^2 are presented on figure 10 (a, b) (Jovanović and Tomanović, 2002; Jevtić 2014).

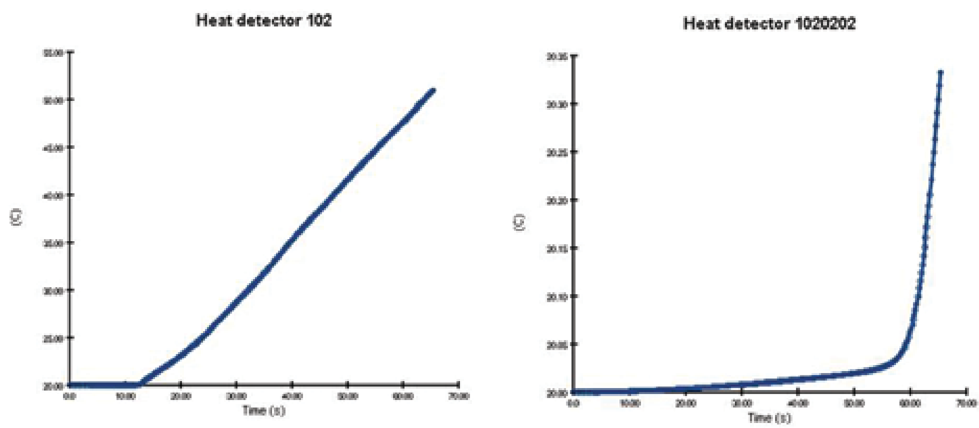


Figure 7. Simulation results for the nearest (a) and for the farthest (b) heat detectors for burner positioned in the middle of the object and HRR of 100 kW/m^2

Slika 7. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor topline za plamenik smješten u sredini objekta i HRR 100 kW/m^2

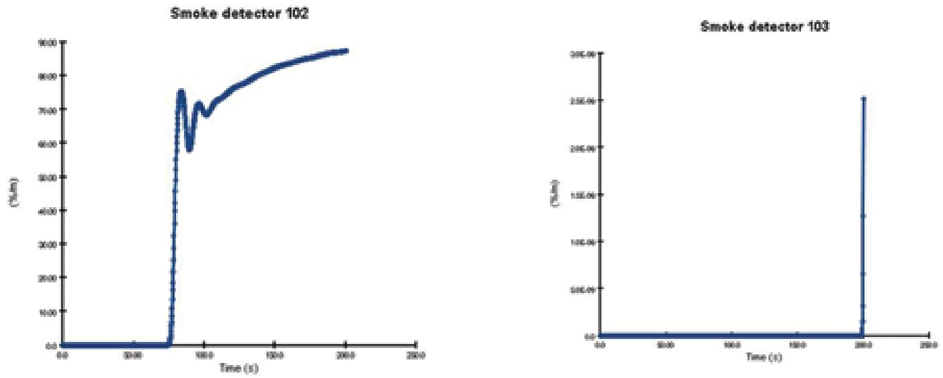


Figure 8. Simulation results for the nearest (a) and for the farthest (b) smoke detectors for burner positioned in the middle of the object and HRR of 100 kW/m^2

Slika 8. Simulacijski rezultati za najbliži (a) i za najudaljeniji (b) detektor dima za plamenik smješten u sredini objekta i HRR 100 kW / m^2

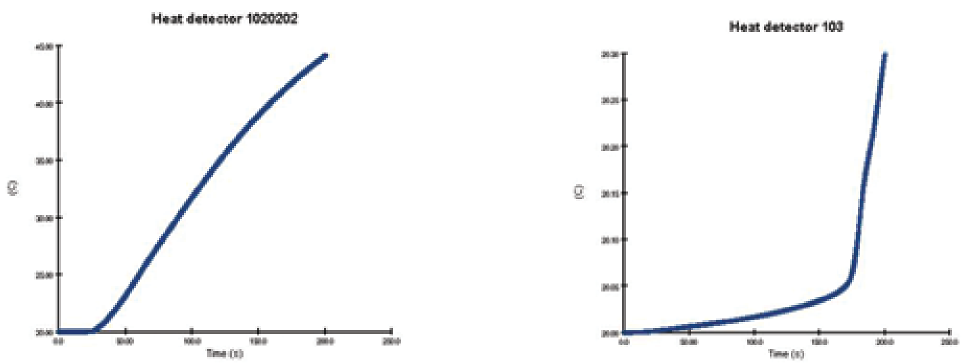
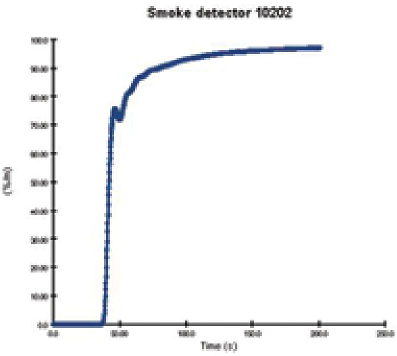


Figure 9. Simulation results for the nearest (a) and for the farthest (b) heat detectors for burner positioned at the and of the hall and HRR of 100 kW/m^2

Slika 9. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor topline za plamenik postavljen na kraju hodnika i HRR 100 kW/m^2



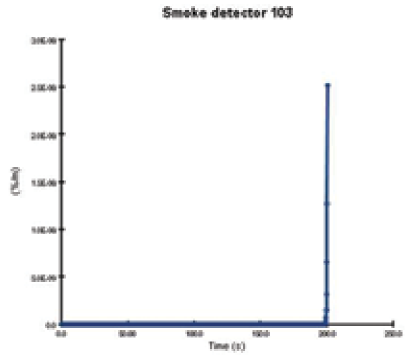


Figure 10. Simulation results for the nearest (a) and for the farthest (b) smoke detectors for burner positioned at the and of the hall and HRR of 100 kW/m^2

Slika 10. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor dima za plamenik postavljen na kraju hodnika i HRR 100 kW/m^2

Simulation results for the nearest and for the farthest heat detectors in the scenario where the burner was in the middle of the object and the burner HRR was 250 kW/m^2 are presented on figure 11 (a, b), while the simulation results for the nearest and for the farthest smoke detectors in the scenario where the burner was in the middle of the object and the burner HRR was 250 kW/m^2 are presented on figure 12 (a, b). Simulation results for the nearest and for the farthest heat detectors in the scenario where the burner was in at the end of the hall and the burner HRR was 250 kW/m^2 are presented on figure 13 (a, b), while the simulation results for the nearest and for the farthest smoke detectors in the scenario where the burner was at the end of the hall and the burner HRR was 250 kW/m^2 are presented on figure 14 (a, b).

It was obvious that, as it can be seen on figures 5 and 6, the heat and smoke transfer would be greater and faster in the second case, what realized results showed. It is important to note that, generally, fire with greater burner's HRR doesn't imply faster heat and smoke transfer and it could depend from many different reasons, factors and conditions. For example, the object used in this paper implied all inner doors opened, while in some other situations it doesn't have to be a case. Also, the existence of some kind of gap or hole can significantly increase in heat and smoke transfer and, according to that, to right timed fire detection.

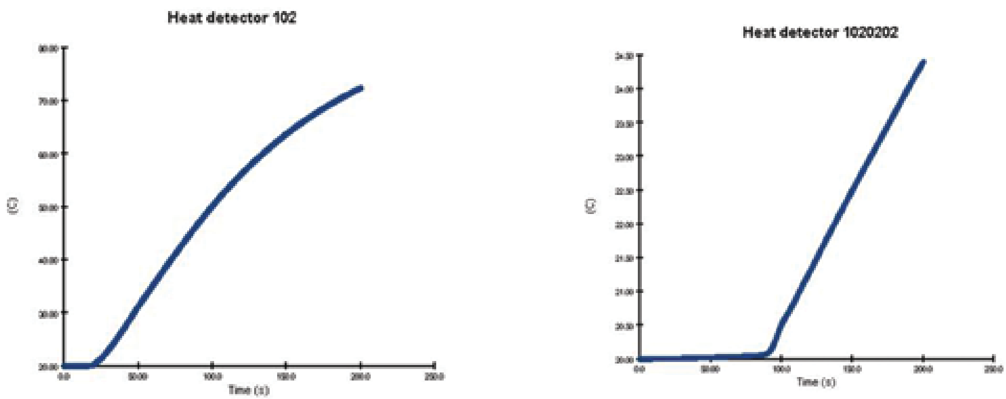


Figure 11. Simulation results for the nearest (a) and for the farthest (b) heat detectors for burner positioned in the middle of the object and HRR of 250 kW/m^2

Slika 11. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor topline za plamenik smješten u sredini objekta i HRR 250 kW/m^2

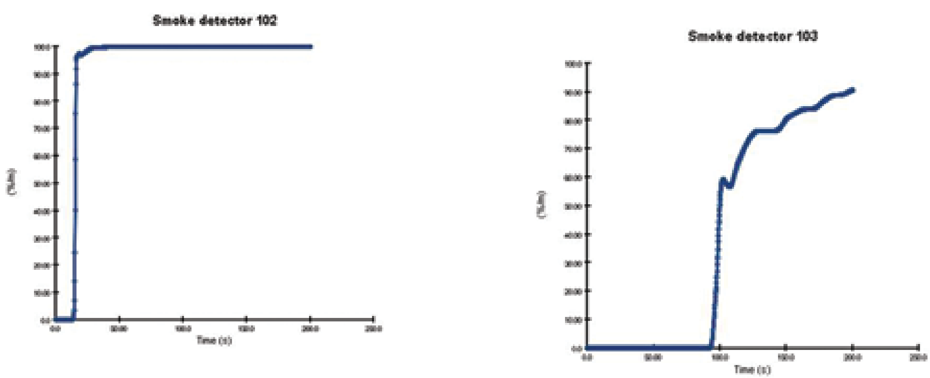


Figure 12. Simulation results for the nearest (a) and for the farthest (b) smoke detectors for burner positioned in the middle of the object and HRR of 250 kW/m^2

Slika 12. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor dima za plamenik smješten u sredini objekta i HRR 250 kW/m^2

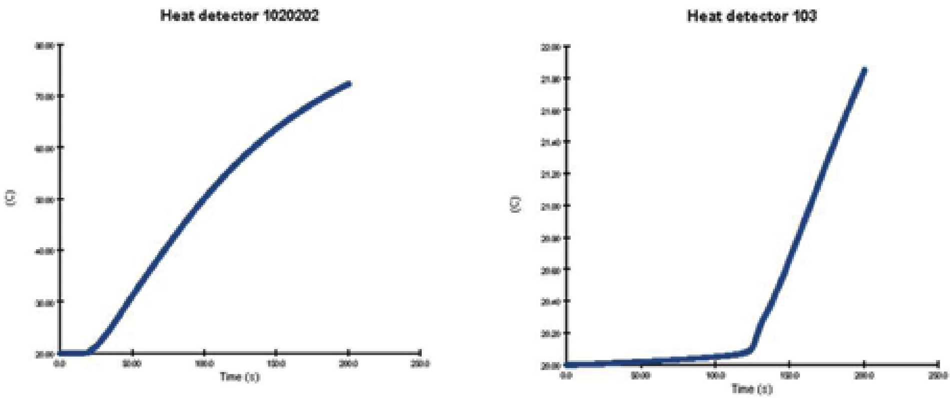


Figure 13. Simulation results for the nearest (a) and for the farthest (b) heat detectors for burner positioned at the and of the hall and HRR of 250 kW/m^2

Slika 13. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor topline za plamenik smješten na kraju hodnika i HRR 250 kW/m^2

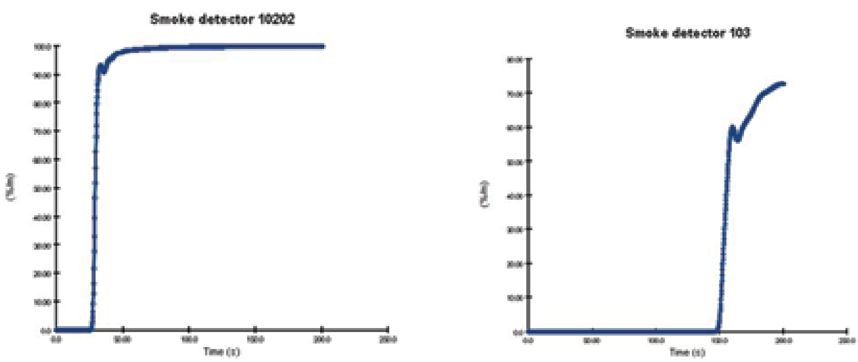


Figure 14. Simulation results for the nearest (a) and for the farthest (b) smoke detectors for burner positioned at the and of the hall and HRR of 250 kW/m^2

Slika 14. Rezultati simulacije za najbliži (a) i za najudaljeniji (b) detektor dima za plamenik smješten na kraju hodnika i HRR 250 kW/m^2

DISCUSSION
Rasprava

Realized simulation results showed that, for the first case where the HRR of burner was 100 kW/m^2, reaction for heat detectors was absent, while the reaction for smoke detectors was at 75 seconds after simulation start. During the simulation time of 200 seconds none of heat detectors reacted. On the other side, the most of smoke detectors reacted. For the second case, where the where the HRR of burner was 250 kW/m^2, also none of heat detector reacted, while all of smoke detectors reacted. In this case, the temperature for the nearest heat detector was almost attained (73 ^{o}C after the simulation time of 200 seconds). It was obvious that, for this kind of detectors arrangement, the grater burner's HRR will provide faster reaction of detectors. It is also important to note that bigger number of fire detectors and their thicker arrangement often give small benefit in sense of detection time's reduction.

CONCLUSION
Zaključak

Prediction of fire and its potential spreading all around is very important and complex task for every object. The detection of fire at early stage is very important; but also the detection in other fire phases, such as burning phase or heat development phase, otherwise fire can cause much damage and endanger human lives or destructs material properties. Simulation of fire spreading could show the potential fire spreading for different objects and different scenarios of fire sources power. The simulation of fire spreading and prediction of possible fire scenarios are very important for determination of potential evacuation scenarios.

Simulation results showed the potential heat and smoke detectors arrangement and reaction times in special case, such as hallway. Detectors were positioned according to noted rules. Simulation results for every simulated object could show the optimal positions for fire detectors, smoke detectors, carbon monoxide detectors, flame detectors and other fire installations in order to safe human lives, material properties and stopping of fire (Jevtić, 2014; Jevtić and Blagojević, 2014).

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