COMBUSTION AS FIRE CONSEQUENCE – GREAT DANGER FOR HUMANS HEALTH

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САГОРЕВАЊЕ КАО ПОСЛЕДИЦА ПОЖАРА – ВЕЛИКА ОПАСНОСТ ПО ЗДРАВЉЕ ЉУДИ

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Summary

Fire presents very real and very often occurrence in nowadays human's life. Its influence on human's health and material properties could be devastating. Big number of fires finished with death epilogue. Fire could have great influence on human's health. Combustion with its products is one of them. One of the most common is poisoning by gases, at the first place by carbon monoxide. The speed of destruction effects on human health and its difficult detection present big problem in the projecting of gases and smoke detection devices and its potential position in object. One of good ways for positioning of this detection devices and detection of its reaction time is the fire simulation in proper software. This paper was written to show the influence of smoke and carbon monoxide on endanger of human health and possible protection in the form of detectors.

Key words: smoke, CO, fire, human's health, simulation.

Сажетак

Пожар представља врло реалну и веома честу појаву у савременом животу. Последице на здравље људи и материјална добра могу бити разорне. Велики број пожара завршава се смртним исходом. Пожар може бити значајан фактор ризика по здравље људи. Продукти сагоревања су, такође, фактор ризика. Тровања гасовима, пре свега угљен-диоксидом, врло су честа код пожара. Брзина појаве штетних ефеката на људско здравље и тежина њиховог откривања разлог су за пројектовање ефикасних уређаја за детекцију гасова и дима и њихово адекватно распоређивање у објектима. Један од добрих начина за позиционирање ових уређаја и мерење времена њихове реакције је симулација пожара коришћењем одговарајућег софтвера. Овај рад је написан да покаже утицај дима и угљен-моноксида на угроженост здравља људи и могућу заштиту путем детектора.

Кључне речи: дим, CO, пожар, здравље људи, симулација.

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INTRODUCTION

One of the simplest ways for fire explanation is that it presents uncontrollable combustion process that causes the material disaster and endangers human health and lives. Every fire has its own products of combustion which could be different by its intensity, range and duration time. According to this, the proper fire dimension appropriate for detection could be selected. The phase of the fire development, from the detection and information aspects, could be presented through four phases: the start phase, the smoldering phase, burning phase and heat development phase. The fire speed through noted phases depends of burning material. The duration of time for all of four phases could be from split of seconds (in the case of the explosion) to several days. Regardless on development time, the combustion products that were made in noted phases present the base for fire detection and information. The combustion products, from detection aspects, could be presented as on figure 1.

Figure 1. Combustion products from detection aspects.

Fire presents very complex process of uncontrollable combustion which depends of lot different parameters. These are parameters that characterize burning zone, heat effect zone and smoke zone. But, from detection aspect, material and energetic converts are very important because its products present fire dimensions that could be used for success, precise and forehand fire detection.

Material and energetic conversion during the combustion process are presented on figure 2.

Figure 2. Material and energetic conversion during the combustion process.

Although these parameters could be used for successful fire detection, they could be very danger for human health.⁽¹⁾

SMOKE

Smoke presents suspension of solid and liquid particles in gas environment. Smoke presents very often parameter for fire detection because almost every fire follows proper combustion products. The structure and dimension of particle products depends on burning material, burning conditions etc. From the detection aspect, dispersion and absorption occurrences of smoke are very important for the smoke detection. Except smoke and smut, the combustion product, generally, could be divided into three basic groups: poisons (carbon monoxide, cyan hydrogen, sulfur hydrogen...), acids (chlorine hydrogen, sulfur oxide, nitrogen oxide...) and materials that could defect séances (form aldehyde, acroline...).

The construction of the smoke detectors was based on two principles of the smoke detection: radioactive and optical. According to this, there are two groups of the smoke detectors:

- Ionizations smoke detectors and
- Optical smoke detectors.

The smoke particles just after its generating are very small and have size from 0.01 μm

to 0.4 μm . By its movements, particles are connecting each other and become bigger. The smoke that could be seen consists of particles with size of 0.4 μm and bigger. The smoke concentration could be presented in mass (mg/l or mg/m^3) or as optical density ($\%/m$). Noted dimensions are interdependent. The most of the famous manufactures note, for ionization detectors sense range, the dimension sense

from 0.01-1 μm to 0.5-10 μm for optical smoke detectors.

The minimal alarm limits for alarm reaction for ionization and optical smoke detectors according to the density percentages, optical density per meter (OD/m) and percentage of obscurity per meter (Obs/m) are presented in table 1. Optical density is defined as $\text{OD} = -\log(I/I_0)$.

Table 1. Density percentages, optical density per meter (OD/m) and percentage of obscurity per meter (Obs/m) minimal alarm borders.

Minimal alarm limit	Ionization detector		Optical detector	
	OD/m	Obs	OD/m	Obs
20%	0.007 ± 0.004	1.6%/m	0.031 ± 0.016	7.2%/m
50%	0.021 ± 0.005	4.9 %/m	0.063 ± 0.029	14%/m
80%	0.072 ± 0.027	16.0%/m	0.106 ± 0.039	23.6%/m

The smoke detector manufactures propose alarm limits based on UL (Underwriters Laboratories) laboratories research, apropos, UL 268 standard, Standard for Safety Smoke detectors for Fire Protective Signaling Systems. In table 2, criteria for acceptable reaction ranges of smoke detectors in order with this laboratory research are presented.

Table 2. Criteria for acceptable reaction range of smoke detectors consistent UL 268, for gray and black smoke.

The colour of smoke	Reaction range	
	%/m	%/ft
Gray	1.6 - 12.5	0.5 - 4.0
Black	1.6 - 29.2	0.5 - 10.0

As a special type of smoke detectors, the aspirating smoke detection system could be used.^(2, 5)

CARBON MONOXIDE

One of the most danger products of fire incomplete combustion is carbon monoxide (CO). This gas presents colorless, odorless,

tasteless and high toxic gas that is less dense than air. It consists of one carbon atom and one oxygen atom, connected by a triple bond that consists of two covalent bonds as well as one dative covalent bond.

Its source was connected for old Greek. In the year of 1800, the gas was identified as a compound containing carbon and oxygen by the Scottish chemist William Cumberland Cruikshank. Its toxic properties on dogs were thoroughly investigated by Claude Bernard around 1846. This is gas which was generated as a consequence of incomplete combustion in industry, car motors and many different processes. The influence of this gas on humans depends of many different factors: gender, age, physical condition, the presence of some other diseases etc. The most common symptoms of carbon monoxide poisoning could be resemble to other types of poisonings and infections, including different symptoms such as headache, nausea, vomiting, dizziness, fatigue, and a feeling of weakness. Neurological signs could include also different symptoms, such as confusion, syncope, disorientation, visual

disturbance and seizures. This highly toxic gas is very difficult for detection. Some of symptoms according to the concentration and time are presented in table 3.⁽⁶⁾

Table 3. *Symptoms Associated With a Given Concentration of CO Over Time.*

PPM CO	Time	Symptoms
35	8 hours	Maximum exposure allowed by OSHA in the workplace over an eight hour period.
200	2-3 hours	Mild headache, fatigue, nausea and dizziness.
400	1-2 hours	Serious headache-other symptoms intensify. Life threatening after 3 hours.
800	45 minutes	Dizziness, nausea and convulsions. Unconscious within 2 hours. Death within 2-3 hours.
1600	20 minutes	Headache, dizziness and nausea. Death within 1 hour.
3200	5-10 minutes	Headache, dizziness and nausea. Death within 1 hour.
6400	1-2 minutes	Headache, dizziness and nausea. Death within 25-30 minutes.
12800	1-3 minutes	Death

The mechanism of CO poisoning is very complex. Carbon monoxide can have severe effects on the fetus of a pregnant woman. Chronic exposure to low levels of carbon monoxide can lead to depression, confusion, and memory loss. Carbon monoxide mainly causes adverse effects in humans by combining in contact with hemoglobin to form compound (HbCO) in the blood, which is known as carboxyhemoglobin. This prevents hemoglobin from releasing oxygen in tissues, effectively reducing the oxygen-carrying capacity of the blood, leading to hypoxia. Based on realized research in United States, in period from 2004 to 2006, two the most frequent sources of carbon monoxide were house stoves and cars. According to all noted facts, it is very understandable the need and importance for carbon monoxide detectors.⁽⁷⁾

These detectors are generally more recent date. Its basic purpose is to signalize the exceeded concentration of carbon monoxide during some time period.

Depending on technology which was used for sensor realization, there are four types of carbon monoxide detectors:

- Opto-chemical CO detectors,
- Biomimetic CO detectors,
- Metal oxide semiconductor CO detectors and
- Electrochemical CO detectors.

It is very important to note the usage of these detectors. They do not present substitute for smoke detectors and its installation is not recommended for next cases:

- If the protected area presents evacuation route,
- If exist possibilities of machine or devices overheating,
- If exist possibility that area should be exposed to fumes or alcohol steams,
- If exist recommendation for fire flammable liquids detection.

At the other side, CO detectors should be installed as additional protection with smoke detectors for next cases:

- If there exist risk from smolder fire,
- If there exist risk from arising of fire in closed area.

The alarm limit for CO detectors was differently defined in some states standards. For example, the Russian standards demands were that CO detector must react in range from 20 to 80 ppm. The characteristics of some CO detectors manufactures are presented in table 4.

Table 4. Responses and alarm limits for some CO detectors

Working mode	Alarm limit (ppm)	Detection time (s)	Application
1	30	60	Sleeping rooms without CO presence
2	45	30	Additional protection at lobbies
3	45	60	Sleeping rooms with low CO presence
4	60	30	Rooms with piled materials
5	75	30	Additional protection at kitchens and steam rooms

For the right time warning and alarm reaction, it is very important the type, position and number of detectors. Detectors could be used as individual or multipurpose. According to the fire type, the different detectors would have different reaction time. If the most or all of the combustion products (energetic and material) are detected, then the fire will be detected at the earliest possible stage.^(8, 10)

SIMULATION

The simulation implied the usage of heat detectors and smoke detectors in the second floor of the laboratory part of Electro technical school “Nikola Tesla” in Niš. The complete simulation model of this school was constructed and used in some earlier papers. The complete simulation model of school with its complete inventory is presented on figure 3.^(11, 12)

Figure 3. Electro technical school “Nikola Tesla” simulation model in PyroSim software.

The fire source was realized in laboratory 112 as burner of 500 kW. In every laboratory of the second part and hall, the smoke and heat detectors were positioned. The fire simulation duration was 120 seconds. The reaction temperature for heat detectors was 74 °C, while the response time index was 100 m^{1/2}s^{1/2}. According to the smoke detectors, the ionization smoke detectors were used, where the alarm limit for reaction was obscuration of 3.28 %/m.

Figure 4. Second floor of the laboratory part of the of Electro technical school “Nikola Tesla” simulation model in PyroSim software with positioned smoke and heat detectors.

Examples of fire at early stage and at heat release phase are presented on figures 5 and 6.

Figure 5. An example of fire at the second floor of the school at the start of fire.

Figure 6. An example of fire at the second floor of the school at the heat release phase of fire.

Results of alarm reaction of sensors are presented in figures from 7 to 10.

Figure 7. Simulation results of heat detector positioned at the hall.

Figure 8. Simulation results of heat detector positioned at the laboratory 112.

Figure 9. Simulation results of smoke detector positioned at hall.

Figure 10. Simulation results of heat detector positioned at laboratory 112.

DISCUSSION AND CONCLUSION

Simulation results showed that right time alarm reaction would be realized for proper time. Simulation results aren't shown for all of marked detectors, but, that was not too important. The presented results showed that, according to the smoke, fire could be detected at early stage even if the fire in space that was separated from the detector. According to the heat, results showed that detectors in the laboratory 112, where the fire source was, and eventually in the laboratory 113 and 101 could detect fire. Detectors at the hall and laboratories 108, 110 and 106, which were positioned opposite to the laboratory 112, could not detect heat increase or smoke increase.

According to the materials that was used in simulation school object construction (plywood, pine tree, concrete, glass, aluminum, oak tree, cardboard and similar), it could be seen that smoke as combustion product consisted lot of different products.

For example, as one of the most frequent products of incomplete combustion, carbon monoxide presents one of the most dangerous fire consequences. The detection of this fire consequence is from crucial importance for human life protection. There were many cases that, in the fire situations, occupants and rescuers were suppressed by this poison gas.

The choice of the detectors type is very important and it depends from many different factors (fire type, room height, ambient conditions, obstruction factors etc). The positions of detectors, their internecine reach, area covered with detectors, number, in dependence of object structure and other factors, were defined with proper standards. After that, the next very important thing is the activation time of detector. For noted factor, it is important to know the basic technical characteristics and place of positioning of some fire protection components, the properties of fire development in rooms and detector positioning data.

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