THE INFLUENCES OF FIRE CONSEQUENCES ON HUMANS HEALTH AND ITS POSSIBLE ELIMINATION

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УТИЦАЈ ПОСЛЕДИЦА ПОЖАРА НА ЗДРАВЉЕ ЉУДИ И МОГУЋНОСТИ ЊИХОВЕ ЕЛИМИНАЦИЈЕ

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Summary

The appearance of fire in human's environment presents very possible real situation that could be very danger and could cause destructive consequences on human health, human lives and material properties. There are several ways of the fire influence on human's health. The most common are burns and poisoning by gases, at the first place by carbon monoxide and carbon dioxide. The prediction of these influences, possible avoidance of these influences and first aid after consequences effects present very important tasks in human health protection. One of the very important factors in the decreasing or eliminating of the fire influences is evacuation.

Key words: fire, propagation, burn, CO, CO₂, evacuation, simulation

Сажетак

Појава пожара у човековој околини представља врло могућу стварну ситуацију, која би могла бити врло опасна и узроковати деструктивне последице на животе и здравље људи и материјална добра. Постоји неколико начина утицаја пожара на здравље људи. То су најчешће опекотине и тровања гасовима, на првом месту угљен-моноксидом и угљен-диоксидом. Превидижање ових утицаја, могућа избегавања тих утицаја и прва помоћ после испољавања последица представљају врло важан задатак у заштити здравља људи. Један од веома важних фактора у смањењу или елиминацији утицаја пожара је евакуација.

Кључне речи: пожар, пропагирање, опекотине, CO, CO₂, евакуација, симулација.

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Introduction

The fire presents uncontrollable combustion process that causes the material disaster and endangers human health and lives. The one of the most important factors according to the fire is combustion. Combustion means the series of chemical reactions between oxygen and combustible material, followed by the production of heat, smoke and flame. The heat presents one of the most important consequences of the combustion process. There are three ways of heat transfer: convection, conduction and radiation. The smoke presents suspension of the liquid, solid and gasses parts. Depending of the combustion material, every fire is followed by different combustion products. The flame presents the gas environment where the physical-chemical reaction is happening. The flame comprises wide range of light-from ultraviolet to infrared area.

According to the material properties, the fire following the April 18, 1906, San Francisco earthquake in the USA cost an estimated 350 million dollars at the time, equivalent to 6.862 billion dollars (£4.749 billion) in today's terms. One of the fires with lot of human victims was the fire that destroyed the World Trade Center at 11.09.2001. The Twin Towers completely collapsed 56 and 103 minutes after the plane's impact. There were 2.974 people died in the attacks and lot of them with injuries.

The appearance of fire causes the appearance of several fire consequences on human's health, such as burns, poisoning with carbon monoxide (CO) and carbon dioxide (CO₂). The influence of these fire consequences could cause huge damages on human's health, including the death. Because of that, it is very important to have a basic knowledge about these types of injuries in order to provide the first aid to the affected victims and, if it is possible, save theirs life. Also, it is important, if it is possible, to avoid this injuries with some effective way, such as opportune and safe evacuation.^(1, 2)

BURNS

Burn presents a special type of injury on flesh or skin. It could be caused by several different factors, such as heat, electricity, variety chemicals, friction or radiation. The most common division of burns is on the first, second, third and fourth degree.

The first degree burns affect only the superficial skin. This is the weakest type of burns and usually retreats after several days. The usual symptoms are redness of the skin without blisters or possible appearance of blisters. They are painful. This type of burns is presented on figure 1.

Figure 1. An example of the first degree burn.

The second degree burns implies damage of some of the under skin layers. They can overtake superficial partial thickness or deep partial thickness. The usual symptoms are redness with clear blisters, blanches with pressure, yellow or white color at the damage location etc. They are very painful. Mortality level of this type of burns could be high. They complicate the complete healthy state of victim. The duration could be from two or three weeks up to eight weeks or longer. This type of burns is presented on figure 2.

Figure 2. An example of the second degree burn.

The third degree burns are the injuries that extend to all layers of the skin. They could have a great mortality level. Usual appearance is as stiff and white or brown color of skin. They take very competent medical personal, competent medical treatment and the duration of the recovery could be by months. They are painless. The consequences of these types of burns could be amputation of burned parts of body. This type of burns is presented on figure 3.

Figure 3. An example of the third degree burn.

The fourth-degree burns are burns which take over skin, tissue, bones and muscles. The main characteristic is black color of skin and death tissue. The consequences are significant functional damage, amputation of burned parts and very high mortality level. This type of burns is presented on figure 4.^(3, 4)

Figure 4. An example of the fourth degree burn

CO₂ AND CO POISONING

The possibility of CO₂ poisoning is everywhere where this gas arises: vine cellar, ships tanks, ferment industry etc. This gas can cause damage on nerve system, muscle paralyze and suppression. The best therapy is an exposition to fresh air and oxygen.

CO is gas which is 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. CO is a toxic gas, but, being colorless, odorless, tasteless, and initially non-irritating, it is very difficult for people to detect. 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. The effects of CO exposition for different time of exposition are presented on figure 5, while the influence symptoms of CO on organism are presented in table 1.^(5, 6)

Figure 5. The CO influence on humans after specific time.

Table 1. Influence symptoms of CO on organism.

Conc. (ppm)	Symptoms
50	No effects for exposition up to 8 hours.
200	Weak headache after 2-3 hours.
400	Headache, qualm after 1-2 hours.
800	Dizziness after 45 min., faint after 2 hours.
1000	Faint after 1 hour.
1600	Headache, qualm after 20 min.
3200	Qualm 5-10 min., faint after 30 min.
6400	Qualm after 1-2 min., faint after 10-15 min.
12800 (1.28 %)	Momentary faint, death after 1-3 min.

EVACUATION AS A WAY OF PROTECTION

The influence of the most common fire consequences, flame and gases (CO_2 and CO) could have a disaster effects on humans in some object. One of the safest ways for human's protection is opportune evacuation. Because of that, one of the most important tasks in object projecting is prediction and projection of evacuations routes. The evacuation term, generally, presents the safest, shortest and fastest way of moving for people, animals and material properties from endanger object or location to the secure place. At the other side, this ways should provide possibilities for safe and fast approach for fire and medical services. The causes of evacuation, beside fire, could be different: gas, bomb threat, earthquake, overflow, civil disorders etc. According to the

cause of evacuation, the proper strategy of projecting would be realized. The explorations on the field of evacuation in case of fire started in the late seventies of the XX century and that explorations were caused by several catastrophic fires, where the one of the worst was in workshop in Brussels with 300 people killed. Especially case in the evacuation problematic is evacuation of object with lot of humans inside in case of fire. These object consist buildings, schools, hospitals and similar object, very often with huge dimensions, for example big object height of big object surface. These are facts that significantly can complicate projecting and design of evacuation routes and, if they don't realize correctly, directly harm safety of humans inside them.

Evacuation routes were projected as primary and secondary. Primary evacuation route is the most frequently, route for normal communication in object. For example, these routes could be stairs, hallways, corridors and other surfaces used for communication in object or in separate floor. They are with the different dimensions for every type of object. These routes are the routes that fire services used for, in case of fire. The secondary routes depend on objects purpose. These routes could involve windows, roofs etc. Both types of evacuation routes must satisfied many standard and no standard demands, according to the number of people, type and purpose of object, speed of people moving, necessary time of evacuation etc.⁽⁷⁾

SIMULATION MODEL AND SIMULATION OF EVACUATION

Very good way for projecting of evacuation routes is using of the simulation programs for evacuation. These programs are very good way for safe, economic and easy calculation of minimal time need for object evacuation and the easiest and the fastest routes for object evacuation.

One of the often used simulation program for evacuation is Pathfinder. Pathfinder is an agent based egress and human movement simulator. This program provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis. The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. This movement mesh can be entered manually or automatically based on imported data (e.g. FDS geometry). Walls and other impassable areas are represented as gaps in the navigation mesh. These objects are not actually passed along to the simulator, but are represented implicitly because occupants cannot move in places where no navigation mesh has been created. Doors are represented as special navigation mesh edges. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow. Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway. Also, this speed could be set to the desire value in order to simulate different situations. Each stairway implicitly defines two doors. These doors function just like any other door in the simulator but are controlled via the stairway editor in the user interface to ensure that no geometric errors result from a mismatch between stairways and the connecting doors.⁽⁸⁾

Occupants that present humans are modeled as upright cylinders on the movement mesh and travel using an agent-based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters (maximum speed, exit choice, 3D model, etc).

In this paper, the simulation model of the residential building was used. The residential building in Bulevar Nemanjića 70 street in Niš presents two residential objects with separate

exits (entrances), connected one beside other. Every object has ten floors, 2 elevators, vault rooms, loft, ground floor and four flats on every floor started from ground floor, which means forty flats per separate object, eighty flats altogether. On every floor from ground floor up to ninth floor, there are four flats, two with approximate surface of 66m² and two with approximate surface of 50m². The maximal width of stairs is about 1,3m. Every object has two elevators: one with totally capacity of four persons and one of totally capacity of six persons. The speed of smaller elevator was 1,1m/s and the speed of bigger elevator was 0,9m/s. The maximum range between floors is 2,5m and the totally height of the building was about 34m (measured from the ground to the elevator house on the last floor). The residential building in Bulevar Nemanjića street is presented on figure 6.

Figure 6. The residential building in Bulevar Nemanjića 70 street in Niš.

According to the real model of named building, the simulation model in program Pathfinder was constructed. The upper and the front view of the building are presented in figures 7 and 8 .

Figure 7. Simulation model of building in B. Nemanjića 70 – upper view.

Figure 8. Simulation model of building in B. Nemanjića 70 – front view.

The simulation model consists of floors, exits, stairs and occupants. The complete number of occupants was 294, according to the resident lists from both objects. The occupants were placed per floors and per flats also according to the residential lists.

After the simulation model was constructed, it was decided to simulate three possible scenarios for three different occupants' speeds. It is known that the occupant moving speed in calm state is about 1,2-1,5m/s. In panic state, occupants move faster or even run. According to that, it was decided that occupants speeds were 1,4m/s, 2m/s, 3m/s, and 4m/s. For every occupant speed, the three scenarios were constructed and calculated. The first scenario included both elevators per object available and both exits per object opened. The second scenario included elevators available, one exit available and one exit blocked. The third

scenario included both exits opened but both elevators unavailable. These scenarios were chosen because they present possible real situations which could be happened, especially in the buildings that don't have particular fire stairs, but have common passage on the top floor with determinate occupants flow, such as noted building. The time required for object evacuation in different situations could be crucial factor in human lives safety and it depends on many subjects, because fire factors, such as flame, smoke, panic and many others that could appreciably endanger human lives. Figures from 9 to 11 present time dependences for every of three noted possible cases.⁽⁹⁾

Figure 9. Number of occupants from time dependence for different occupant speed in both exits opened, both elevators available scenario.

Figure 10. Number of occupants from time dependence for different occupant speed in one exit opened, one exit blocked, both elevators available scenario.

Figure 11. Number of occupants from time dependence for different occupant speed in both exits opened, both elevators unavailable scenario.

DISCUSS AND CONCLUSION

According to the realized simulation results, it can be concluded that the most of the time needed for building evacuation was in the case with one exit opened, one exit blocked, both elevators available, occupants speed 4 m/s (517 seconds). That situation showed that at bigger occupants speeds, stuck and crush became very often scenario with hard predictable consequences. It was said that panic and stress situations could cause that

occupants run faster, but faster running also could cause stuck in the elevators and stairs. Very important fact is that in the simulation program, speed of every occupant was the same, which is a not always real situation. That implies more stuck and crush situations which significantly increase the time need for object evacuation. The shortest time needed for building evacuation was in case of both exits opened, both elevators unavailable scenario, where the occupant speed was 3m/s, which was particularly interest because elevators were unavailable.

According to all exposed, it can be seen the great importance of the opportune evacuation of humans from endanger object. This way of analyzing of evacuation times and evacuation routes is very appropriate because it gives good presentation how available evacuation routes could be used for different fire locations and conditions in some object. On that way, it can be possible to avoid flame and production of CO₂ or CO, or at least decrease its effects. All these factors could be tested for different occupants speed and behavior, which gives of good real presentation of potential fire situation and great advantages in projecting of complete fire protection system for some particular object, as it was realized in this paper.^(10, 11)

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