VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

Flóra Hajdu, Gabriella László, Zsuzsanna Kerekes, Nikoleta Csapaiová, Rajmund Kuti

EXAMINATION INITIAL PARAMETERS OF FIRES FOR FIRE SPREAD SIMULATIONS

Abstract

Due to the continuous development of building materials and technologies, the study of indoor fires and heat load on building structures are topical issues nowadays. Despite modern construction and the use of modern fire protection equipment, fires occur in buildings on a daily basis. Some of the fires occur in the premises of residential buildings, so we consider it important to study the spread of a fire in an average room and its effects on building structures with the help of a unit fire. In fire spread simulations the initial model of the fire is a key issue. In our research a model of unit fire was created and examined in simulation environment, which is presented in detail in this paper. It was examined how the initial parameters of the fire affects the simulation results. With our experience, we want to help the work of fire designers and to contribute to fire prevention.

Keywords: unit fire, fire load, numerical simulation, fire prevention

A TŰZ KIINDULÁSI PARAMÉTEREINEK VIZSGÁLATA TŰZTERJEDÉSI SZIMULÁCIÓHOZ

Absztrakt

Az építőanyagok, építési eljárások és technológiák folyamatos fejlődése miatt az épületekben keletkezett tüzek vizsgálata, a tűzterjedés és a hőterhelés épületszerkezetekre gyakorolt negatív hatásainak vizsgálata aktuális kérdések napjainkban. A korszerű kivitelezés és modern tűzvédelmi berendezések alkalmazása ellenére is naponta keletkeznek épületekben tüzek. A tűzek egy része lakóépületek helyiségeiben keletkezik, ezért fontosnak tartjuk írásunkban egységtűz segítségével vizsgálni egy átlagos helyiségben keletkezett tűz terjedését, valamint az épületszerkezetekre gyakorolt hatásait. Kutatásunk során először az egységtűz modelljét készítettük el, azután az adatok felhasználásával számítógépes szimulációt végeztünk, melyet részletesen bemutatunk. Tapasztalatainkkal a tűzvédelmi tervezők munkáját kívánjuk segíteni és a tüzek megelőzését elősegíteni.

Kulcsszavak: egységtűz, tűzterhelés, modellezés, számítógépes szimuláció, tűzmegelőzés

1. INTRODUCTION

IT developments have become increasingly important in the field of fire protection in recent years. Various computer programs also aid fire protection planning and fire investigation. Fires in different buildings have been investigated in several studies from different perspectives. The most commonly studied fields are fire propagation, the consequences of heat, the properties of combustion products generated during combustion, and the fire protection properties of building materials [1-3]. Other studies have examined the effects of smoke on people and the environment, the possibilities of reducing the heat load and the problem of firefighting [4-6]. It can be stated that it is an important task to study damage of fire spread on building structures and the effects of the generated heat. Due to the tightening of environmental standards 1:1 scale fire tests can only be carried out in exceptional cases. Therefore it is effective to use computer simulation before real tests, for which the experience of fire cases occurred can be used. The aim of the research is to study fire spread in the room of an average apartment using computer simulation. To create the initial model preliminary calculations were performed taking into account the amount of combustible materials in the room, then we using the data a computer simulation was created to study the effects more accurately. For simulations FDS (Fire Dynamic Simulator) was used [7].

2. EXAMINED ROOM

The simulation model was based on an average size room common in Hungary (Figure 1.). The inner height is 2.65 m. In the simulation model the opening were a standard size door and a double window.

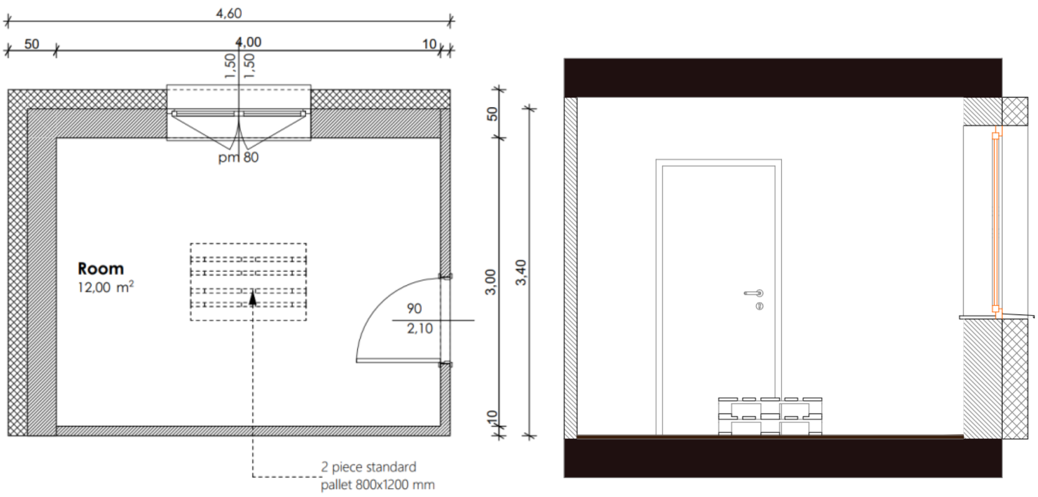

Figure 1.: Floor plan and overview of the examined room (by Authors)

Regarding the furnishing of the room a unit fire was modelled. 2 EUR pallets placed in the middle of the room were the combustible material. Fire load should be calculated to get a starting point for computer simulation.

The materials used for the experiment and their combustion characteristics are given in the following table:

Material	**Quantity (kg)**	**Ignition temperature (°C)**	**Heat of combustion (MJ/kg)**	**Density (kg/m^3)**
Pallet (pine)	40	260	16,75	600-900

Table 1. Combustion characteristics of furnishings and built-in combustible materials in the examined room. (by Authors based on [8])

Before starting the simulation the temporary fire load was calculated, for which the following formula was used:

$$\boldsymbol{p_n} = \frac{\sum_{j=1}^{n} \boldsymbol{M_i H_i}}{\boldsymbol{S}} \qquad (1)$$

where

p_n is the temporary fire load

M_i is the mass of the ith material (kg)

H_i is the calorific value of the ith combustible material (MJ/kg)

S is the floor area of building or part of building (m^2)

j is number of materials included in temporary fire load

Completing the calculation, the value of temporary fire load is:

$$\boldsymbol{p_n} = \frac{\sum_{j=1}^{n} \boldsymbol{M_i H_i}}{\boldsymbol{S}} = \frac{\mathbf{670}}{\mathbf{12}} = \mathbf{55.83}\ \text{MJ/m}^2 \qquad (2)$$

The temporary fire load has to be calculated in order to have information on the thermal effects damaging the building structures. Building structures do not contain combustible material, so a constant fire load does not need to be calculated. Adding the temporary and permanent fire loads, the calculated fire load can be obtained, which in our case is the same as the temporary fire load.

3. SIMULATION MODEL

The simulation model is shown in Figure 2. The fire can be defined in 2 ways: with specifying the HRRPUA (heat release per unit area) value of the fire of by giving the material properties and starting the fire with an ignition particle.

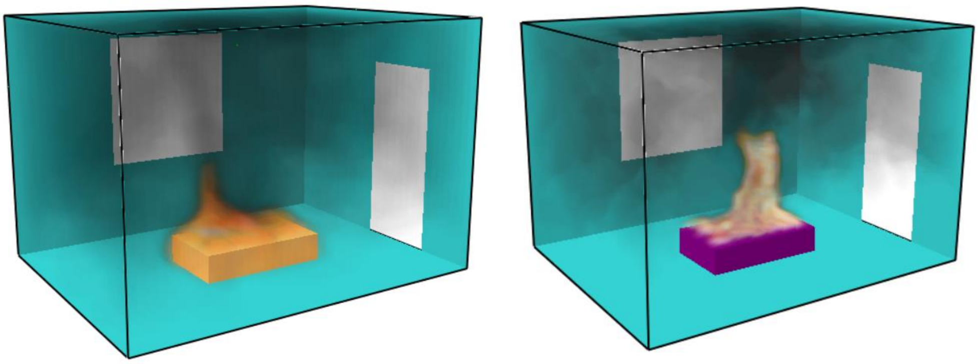

Figure 2.: Fire models (left: fire is given with its HRRPUA value, right: fire is is started with ignition particles)

In the first case the fire parameters can be easily adjusted. With a ramp function the start and the extinction of the fire can also be examined. The second setting gives a realistic material based fire. Burning of the object and the temperature change inside the object can also be simulated (Figure 3.).

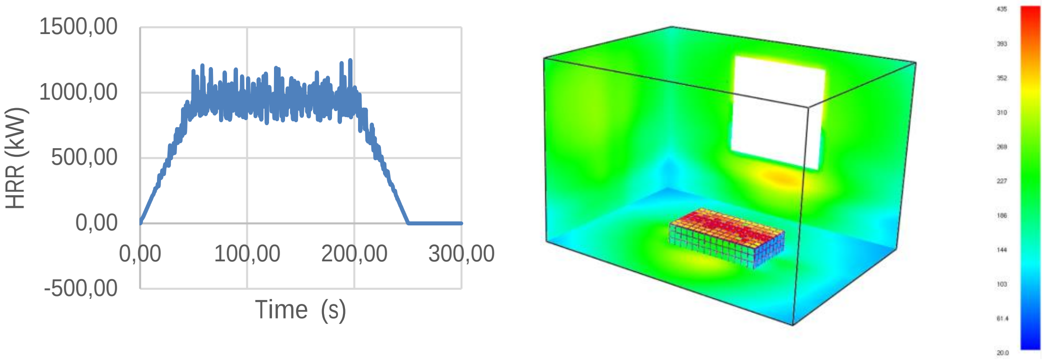

Figure 3.: Fire modelling with ramp function (left) and wall temperature in case of a fire started with igniton particles (right)

According to the literature the initial fire is usually given with its HRRPUA value [9]-[10], there is only few examples of starting a fire with ignition particles [7]. Therefore In this study the first simulation setting is studied in detail. The temperature, the CO concentration and the O_2 concentration are the output values. It was examined how the HRRPUA value of the fire and the CO yield of the reaction fuel affects the simulation. The reaction fuel was propane.

Before starting the simulation a short mesh sensitivity study was carried out. The results of the mesh sensitivity study is shown in Figure 4. and Table 2.

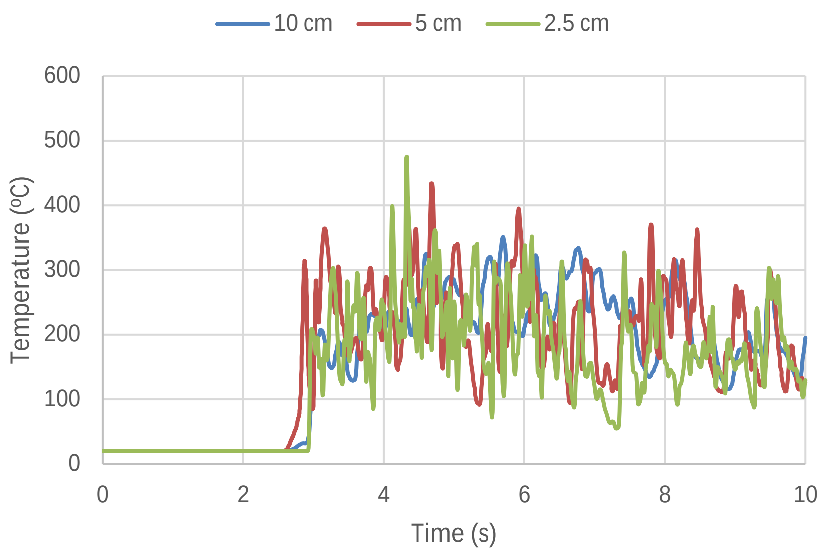

Figure 4.: Mesh sensitivity study

	10 cm	5 cm	2.5 cm
Calculation time (s)	152	1393	20300
Max. temperature (°C)	350.93	433.95	474.98
Average temperature (°C)	189.2144	169.1941	141.1186

Table 1.: Mesh sensitivity study results

It can be seen that there was no significant difference between the simulations with different mesh sizes. The average temperature was similar in all cases. There was larger difference in case of the maximum temperature. The calculation time was much less in case of larger mesh size. The aim of the study was to test the effect of the initial fire parameters, therefore in order to reduce the calculation time the largest mesh size (10 cm) was chosen. The sensors were placed in the middle of the room 30 cm from the ceiling.

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4. RESULTS

The effect change of HRRPUA value on the temperature, CO concentration and the O_2 concentration are shown in Figure 5.-Figure 7. The HRRPUA value of pine wood is around 150 kW/m2 [11], therefore the HRRPUA value of the fire was changed from 50 kW/m2 to 300 kW/m2.

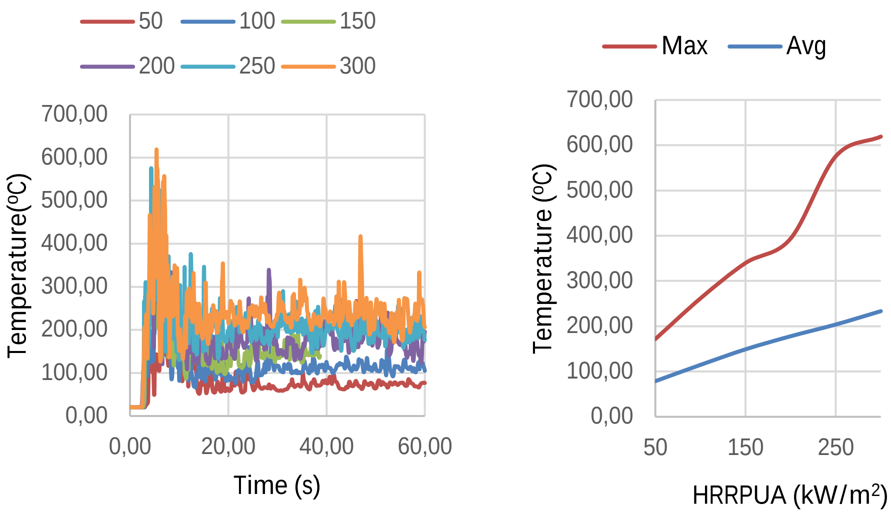

Figure 5.: The effect of changing the HRRPUA value of the fire ti the temeprature

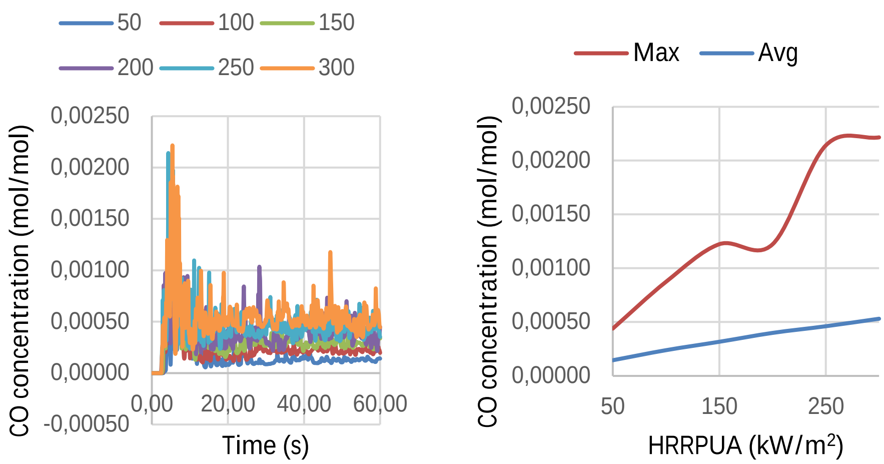

Figure 6.: The effect of changing the HRRPUA value of the fire to the temeprature

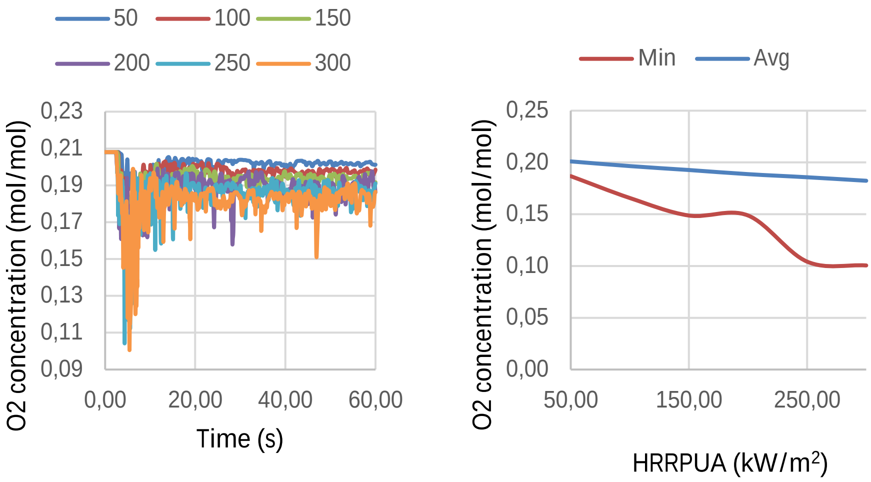

Figure 7.: The effect of changing the HRRPUA value of the fire to the O2 concentration

It can be seen that as HRRPUA was increased the temperature and the CO concentration increased and the O_2 concentration decreased. The average values changed linearly in all cases. The maximum value of the temperature increased first with a smaller slope, then with a larger slope and then again with a smaller slope. The CO concentration first increased, then decreased and then it increased again. The O_2 concentration decreased first and after it increased and it decreased and it became constant. At the time dependent diagrams it can be observed, that the largest values are reached at the beginning of the simulation. It is because the fire starts rapidly and after remains constant. Because there ventilation because of open door and window after a short time the values oscillate around an average value.

It was also observed how the CO yield of the reaction gas affects the simulation results. The HRRPUA value of was 150 kW/m^2. In case of the temperature and the O_2 concentration there was no significant change therefore only the CO concentration is presented (Figure 8.).

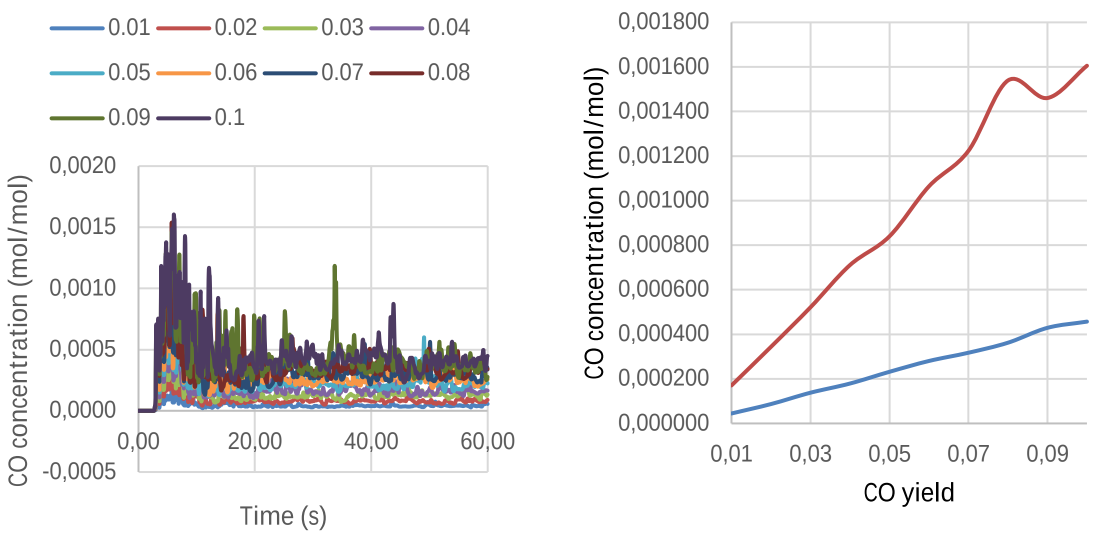

Figure 8.: The effect of changing the CO yield of the reaction fuel to the CO concentration

It can be observed that the CO concentration is increased as the CO yield of the reaction fuel is increased. The average value changes linearly. In case of the maximum value there is a linear increase till 0.08 and after that it remains constant.

5. SUMMARY

In this study the effects of changing the initial parameters of the fire was examined. An average size room common in Hungarian compartments was the basis of the simulations. It was observed that changing the heat release rate per unit area of the fire linearly increases the average temperature and the CO concentration and decreases the O_2 concentration. Increasing the CO yield of the reaction fuel increases the average CO concentration. In case of the maximum value of the examined output values there oscillations. It is the task of further research to find out the cause of it. It was also observed that the peak values occurred at the start of the simulation. The cause of it that the fire started rapidly and there was ventilation in the room it, therefore after the transients the examined output variables oscillated around an average value. It can be concluded that fire can be effectively modelled using its HRRPUA value, however this value should be chosen carefully. A further research task is to model the fire with material and ignition particles and compare it to the results presented in this paper.

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Dr. Flóra Hajdu

assistant professor, Széchenyi István University, Faculty of Mechanical Engineering, Informatics and Electrical Engineering,

E-mail: hajdfl@sze.hu

ORCID: 0000-0002-7252-0879

Gabriella László

PhD student, Széchenyi István University Doctoral School of Multidisciplinary Engineering Sciences,

E-mail: laszlo.gabriella@sze.hu

ORCID: 0000-0001-5932-4358

Kerekes Zsuzsanna

associate professor, University of Public Service

Email: kerekes.zsuzsanna@uni-nke.hu

ORCID: 0000-0002-2041-2622

Nikoleta Csapaiová,

PhD student, University of Zilina, Doctoral School of Security Engineering Sciences,

E-mail: nikoleta.csapaiova@gmail.com

ORCID: 0000-0001-9929-0877

Prof. Dr. Rajmund Kuti

full professor, Széchenyi István University, Faculty of Mechanical Engineering, Informatics, and Electrical Engineering,

E-mail: kuti.rajmund@sze.hu

ORCID: 0000-0001-7715-0814