Flame spread simulation of fire occurrence at motorcycle parking building

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Abstract. This research is motivated by the condition of the parking building in A Campus, State University of Jakarta that development that very compact and crowded with wide openings. This study aims to estimate the flame spread of motorcycle parking. This study used computer fire modeling by simulating flame starting point and direction of the wind, numbers of fuel source and forms. This research will discuss about the development of the fire where the fire development will be represented by HRR (Heat Release Rate), burning rate, and visualization of each simulation. This step is very advantageous because it can figure out how the spread of fire during a fire and how fire simulated. With the fire of this modeling can be a practical engineering approach to provide additional review of aspects of fire safety on campus parking building at Jakarta State Univeristy. From these results it can be concluded that the rapid spread of the fire affected by the starting point of fire, wind speed and direction. HRR where the greater the value the greater the value of burning rate obtained and the greater the level of occurrence of fire.

1. Introduction

The potential contributions of universities span all phases of the disaster cycle and can cover an extremely wide range of pre-/post-disaster activities. Through the mentioned examples of disasters that happened in some universities, it can clearly be concluded that a university plays multiple roles in the disaster response and recovery process, since it has comprehensive capabilities by nature. In addition, for that, there is a need for the government in general and the universities to increase awareness (students, staffs of the universities) towards preparedness in managing the disasters through education programs [1].

For universities, the protection of the life and safety of students, faculty and staff should be a top priority. It is important to ensure the sustained operation of the campus. As one of the region's largest job centers, and an important research and educational center for the nation, it is very important for the campus to continue business if a major quake strikes [2]. A car parking building is identified as one type of structure with the potential for travelling fires [3]. Currently there are applications that are used to determine the characteristics of the spread of flames when the fires of in space. This step is very advantageous because it can figure out how the spread of fire during a fire and how fire simulated. With fire modeling can provide additional review of aspects of fire safety, so we can prepare our students and scholars when fire hazard occurred at motorcycle parking building. We believe by knowing how the fire started and developing, we can prepare fire mitigation: how to evacuate people, stop the spread of flames and diminished the flames itself. Fire can be diminished by reducing its temperature, sometimes using water, or removing the oxygen by using gas. On solid fuel burning, cooling the surface with coarse
spray is better on open flames rather than gas fuel [4]. Fire The delayed extinction of the flame spreading over a paper sheet after the velocity change of an upward ambient air stream [5]. This means, opposite wind can make flames more difficult to diminished.

2. Methods

This study was conducted in a campus parking State University of Jakarta located on the street Front Rawamangun, East Jakarta. Researchers use Fire Simulator software to conduct a fire simulation with computer modeling. Steps that used in this research are:

1. Set time limits and determine the fire simulation domain as well as the size of the grid.
2. Modeling of the geometry of buildings and objects or motorcycle.
3. Defining the boundary conditions which include data related to the material properties.
4. Defining the starting point of the fire and air flow speed which will calculate the amount of the Heat Release Rate per Unit Area (HRRPUA).
5. Writing the process by using the command prompt.
6. Retrieved output of simulations, multiple output data used is the rate of heat release, as well as the maximum temperature.

This research used PC of Intel Core Duo Processor (2.20 GHz) with 4.0 GB of RAM memory, fire simulation software, text editor Notepad ++ for making the coordinates of drawing. We measured the wind situation at building surrounding using anemometer, and measure all the size of the openings of parking building. The wind speed that entering the opening was set 0.9m/s, based on the average measurement of the wind speed entering building’s opening. And we determined the fire start-up from the side of openings, in the middle, and the corner without openings. We draw the size of the building based on real size and determined there was no heat transfers from the walls. The fuels that burned are the motorcycle modeled as box of polyethylene sized 1.85m long, 0.5m wide and 1.1m tall. We choose polyethylene to represent the calorific value of total material contained by a motorcycle. Simulated room size is 24.75m x 24.75m, 3m high, and distance between motorcycle is 0.1m. All simulation is done in 30 minutes combustion, to see the first minute of flame development. Figure 1 is showing us where the flame started up, and then we will see how the flame was built and spread.

![Figure 1](image1.jpg)

**Figure 1.** Point 1.1 is first position of flame start up near openings, point 1.2 in the middle of parking bay, point 1.3 flame position near the wall.

3. Results and discussion

![Figure 2](image2.jpg)

**Figure 2.** Temperature built up fire started near opening.
Figure 2 shows us the temperature built up after the combustion started 1800 seconds after. The fire started from the bottom of the motorcycle, where the heat source came from (battery/overheated engine). The temperature ignition given was 440 Celsius deg as the yields temperature of polyethylene start releasing vapor fuel. As seen, the flame spread from the tip of the fuel form approaching the area where flown by the oxygen from building’s opening, from left to right. And these flames developed to the top of the motorcycle as the flame consume the fuel vapor where it is become very buoyant, that is why the temperature spread is going up when built by flame [6]. From Figure 2 we can see that there are some convections happened, since we found there are temperatures rise perpendicular to the flame source adjacent to wind direction. This proofed that flame spread concurrent the air flow.

![Figure 3. Heat Release Rate per unit volume at near opening.](image)

The Figure 3 and Figure 4 Shows us Heat Release Rate (HRR) in kW. The color difference in the curve indicates the difference in the starting point of the flame. Same as temperature spread, heat release work as the same when flames formed up. Fuel vapors will be consumed by flames, and the vapors formation is formed as it next to the flame front which is on the top of unburnt surface in this case. As seen on the Figure 3 the flames developed from bottom to the top then move to the right side concurrent with source of oxygen which came from the opening. Figure 4 showed us that the heat release rate went flat because used to do conduction and as the heat also transferred to neighboring through convection. The heat flux is not accumulated in one place, so it shows a sign of heat transfer.

![Figure 4. HRR rise per time unit.](image)

![Figure 5. Heat Transfer Amounts during combustion.](image)
Figure 5 shows that conduction occurred in quite number compared to convection and radiation. Conduction between the molecules happened so dominant in order to finish the pyrolysis [6]. Convection occurred in small amount, since the motorcycle body act as barrier of the flow, so only a few heats was transferred to neighboring. The heat was distributed along the body of the material to start its pyrolysis to continue the combustion, this is shown by the number of heats calculated on conduction process. Few convections happened because only one side that contact directly with the wind source. The rest rely on the radiation due to the close distance.

Figure 6. Temperature built up fire started in the middle of parking bay.

Figure 6 shows us that when fire started in the middle, there was less air flow but enough oxygen to start flame, so the head built up rapidly rise and the temperature reaching 1000 degree Celsius. The flame built up straight to the ceiling and spreading to the side. The fire spread caused by the close distance and the large number of radiations.

Figure 7. Heat Release Rate per unit volume at middle park bay.

What we see in Figure 7 is the fire spread of side by side motorcycle. In 30 minutes, if the fire started in the middle, it would consume at least 3 motorcycles in left and 3 motorcycles in the right. This is caused by the number of heat that been released in 30 minutes already numerous, around 1000kW/m². Even though this is middle point, it has perfect supply of oxygen and group of fuel, by 0.5m distance each other, allow the radiation heat to reach the pyrolysis temperature of 450 degrees Celsius in short time. When the material decomposed and volatile matter up in the air, it will soon be consumed with oxygen as fire [7].
Figure 8. Heat Transfer Amounts during combustion in the middle of parking bay.

Figure 8 is showing that the radiation and conduction are massive. After 15 minutes of start of flame, the radiation has been released above 1000kW and growing. This means that the combustion is continuous and causing the ignition in neighboring fuel.

Figure 9. Temperature built up fire started next to wall.

Figure 9 shows that temperature built up quickly, since there is no heat transfer to the wall, the temperature distributed to the neighboring fuel evenly in every direction by convection, since the ceiling and wall act as boundary. Temperature built very high because there is large amount of fuel that burnt in 30 minutes. In such a crowded stack of fuel, high temperature concentration will accelerate the decomposition and combustion [7].

Figure 10. Heat Release Rate per unit volume at fire source near wall.

Figure10 tells us how the rate accelerated quickly by the convection, and it caused conduction inside the fuel accelerated as well. The rate was 1000kW/m2 in every fuel burnt, and this is as predicted since the
distance between fuel so packed. High rate gained in short time could happen when the concentration of fuel and air is enough which will cause perfect combustion.

![Graph](image)

**Figure 11.** Heat transfer amounts during combustion near the wall.

In Figure 11 we see after 15 minutes, where the combustion escalade, high conduction inside the fuel happened and the convection is also high since the wall and the ceiling act as boundary. There is no heat transfer to the wall and ceiling, this make the heat concentrated. Concentration of heat will accelerate the formation of fuel vapors and flaming combustion [8].

4. **Conclusion**

Flame spread in which direction of wind from any direction is much higher than the wind direction only from one direction. Speed the spread of fire with fire locations starting point near the center of the room and the wall without any openings is higher than the location of the starting point of the fire located one corner of the room with the wind direction, this caused by cooling by the wind. Where there is no cooling effect, the heat will be accumulated and the amount of oxygen that available in such a big room, will provide enough condition for perfect process of combustion. That the wind direction and the location of the starting point of the fire affects the speed of the spread of fire, spread parallel in the direction of the wind, and then spread in all directions following the fuel material and the direction of the openings in search oxygen by the reaction process. The heat conduction and convection will vary with the form of fact, because of the motorcycles shape is uneven as modeled in the simulation, but the spread of the fire will not much different. The greater the value of the HRR, the greater the value of burning rate obtained and the greater the level of occurrence of fire. From this simulation we learned that fire would spread perfectly when they have heat, enough air and large number of fuels. The wall and ceiling that does not have any conduction properties, will make the parking bay act like a cone calorimeter, that creating adiabatic ambient. To prevent great fire in motorcycle parking bay, we should create enough cooling but low wind speed, so whenever fire occurred, the flame not built rapidly and spreading.

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