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Fire position effect on fire behaviour in industrial building

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Abstract

As a fact that the industrial buildings are under many possibilities of fire cases at any time, worldwide there were many actual cases of massive fires recorded as capital losses as well as human losses or injuries recorded.

The fire tests are under improvement every day to investigate and reveal the fire phenomena as well as its effect when spreading to analyze the possible ways of fighting it whenever happened by the effective time.

This paper illustrates the effect of fire position when occurred inside the industrial building and compares the fire thermal distribution all over the inner space for three different major positions.

The model of industrial building is scaled to one tenth for prober time modelling using PyroSim fire modelling program, the parameters of fire HRR, inner volume and initial parameters are kept fixed to investigate the change of fire position in thermal temperature distribution.

Keywords: Fire, model, HRR

INTRODUCTION

Fire tests are being conducted in two categories, either in full-scale or numerical simulation. Full scale tests are being operated in different laboratories around the world, Tran & Jansen [1,2] for example constructed a full scale test for industrial building fire and studied its growth over different wall lining materials, Motavalli, Marks [3] in another tests and Motavalli & Ricciuti [4] as well studied also the characteristics of ceiling jets occurred in fires occurred in confined and unconfined enclosures as well which ended with results of Q* as dimensionless number, it's used mainly in many tests to represent heat release rate, Cox & Chitty [5] tests are an example, other full scale experiments [6 and 7] are performed to investigate fire behavior.

On the other hand, and due to the difficulty and higher costs of conducting the full-scale tests, numerical simulation programs are used to investigate the fire after being validated against a full-scale test with the same parameters. Validation tests are being studied and detailed as well [8 and 9] this is in addition to many full scale and modelling tests [10, 11, 12, 13 and 14].

In this paper, a scaled one to ten of Industrial Building gypsum model is used in the simulations, its dimensions are 3 m x 1 m and a height of 1 m The ceiling is un-symmetric triangle shape while the whole inner space is covered with thermocouples to evaluate the change of inner space temperature along the fire interval duration of 20 minutes.

The burner is positioned in three different locations inside the model which are corner as it's positioned in the inner left corner of the model, side as placed in the opposite wall to the door at its center and center as it's placed in the model floor center position.

Among all FDS (fire dynamic simulators) programs, PyroSim is selected to simulate the fire cases as it's a powerful simulator and user-friendly interface.

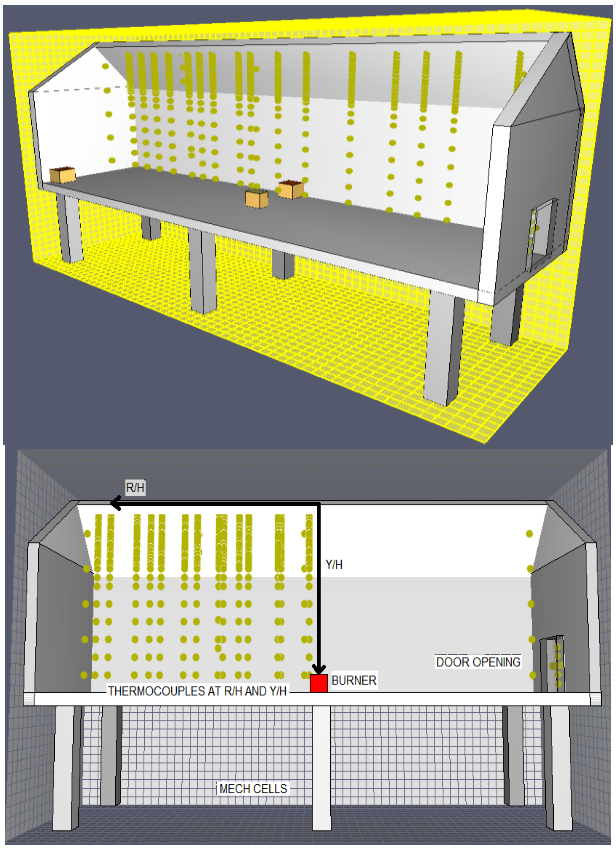
MODEL DESCRIPTION

The model material is gypsum plaster which is used by the program using full standard properties such as density, conductivity, specific heat and absorption coefficient. The model dimensions are as described above of 3 m x 1 m x 1 m. The model has a triangular un-symmetric ceiling shape which its vertical elevated length is at 0.78 m from the bottom of model. The model has one door only as an opening with dimensions 0.3 m in height and 0.25 m in width with a uniform wall thickness of 60 mm. The fire source top is elevated 10 cm from the floor with top surface area of 0.01 m^2 giving net HRR of 240 Kw/m^2 equivalent to 2.4 Kw. It was positioned in three different locations inside the model inner ground area, first burner position is at the inner left corner which is at the opposite side of the opening door wall and is indicated by corner position, and second position is at the other side of the center position which is called side position.

The third location is the model center point and is called center position.

Figure 1-a is showing the model of PyroSim. Temperature measurements were recorded via the indicated thermocouples positions shown starting from the ignition time till reaching the steady state condition of temperature reading, thermocouples temperatures recording interval is every minute during this time which is 20 minutes, and this is for each thermocouple. Consequently, these measurements are repeated for each burner position individually.

Figure 1-b is showing the horizontal and vertical axis of the measurements which is recorded in the curves in dimensionless values. Horizontal R/H values of the thermocouple position indicating the distance R from the burner position divided by H which is the model length. Vertical Y/H values indicating the vertical position Y divided by the H vertical length of the model.



Figures 1-a, b, Un-Symmetric ceiling model, three fire source positions and thermocouples are shown.

RESULTS

For different R/H positions of the thermocouples, Y/H is taken in the below curves against fire duration to show the temperature rise with time. So that, taking the whole row of R/H in variable vertical values against time is the first set of results while the second set of curves are showing the individual thermocouple at each R/H for the vertical positions Y/H with time.

Corner fire results

A. Results at y/h = 0

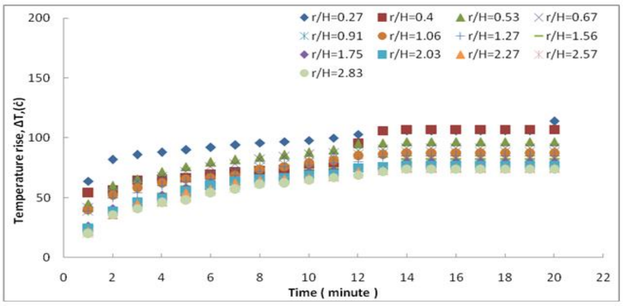


Figure 2, Temperature rise at y/H = 0

B. Results at y/h = 0.1

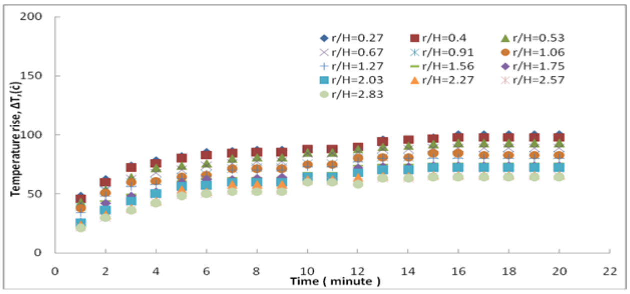


Figure 3, Temperature rise at y/H = 0.1

C. Results at y/h = 0.2

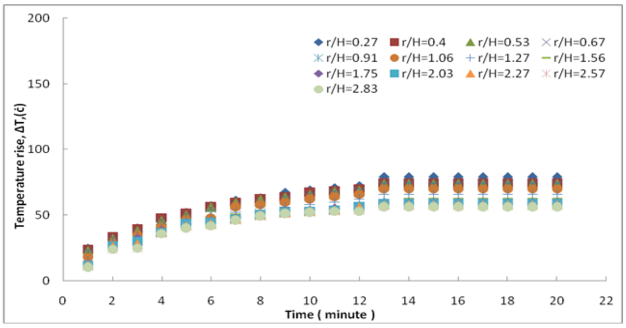


Figure 4, Temperature rise at y/H = 0.2

D. Results at y/h = 0.3

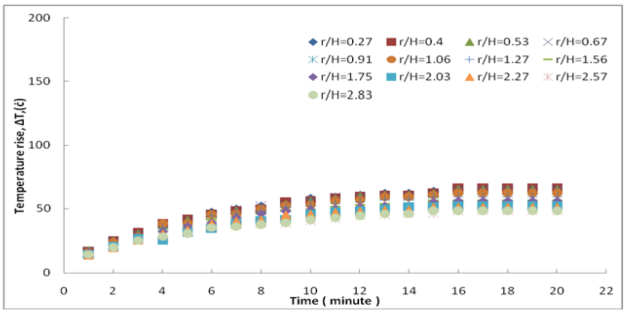


Figure 5, Temperature rise at y/H = 0.3

E. Results at y/h = 0.9

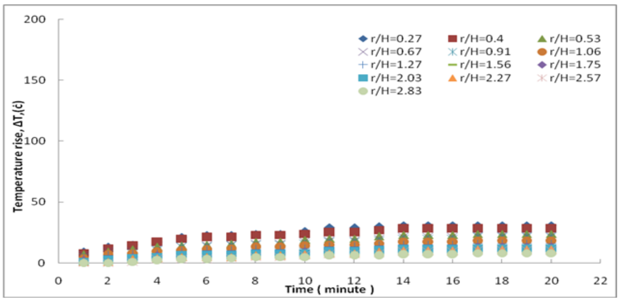


Figure 6, Temperature rise at y/H = 0.9

As we can see from the above curves that starting with the ignition time till steady of the temperature after 20 minutes, we have temperature rise from the ambient to around 100 degree Celsius. In addition, it's noticed that the hot gases are concentrated at the top level of the model which are the highest temperatures, as known the hottest gases with less density is going up and above the high density gases, and going down in temperature every step up in y/H.

A. Results at r/h = 0.27

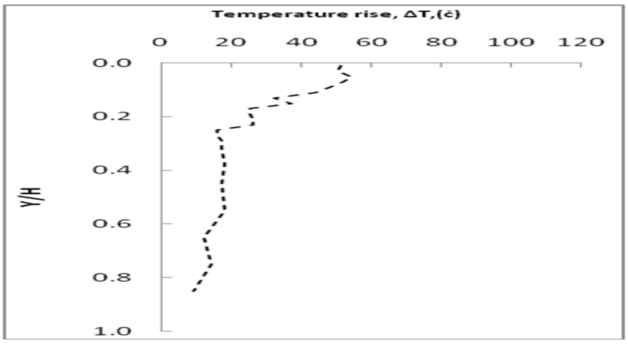


Figure 7, Temperature rise at r/H = 0.27 in the first minute of fire

B. Temperature Profile at r/h = 1.27

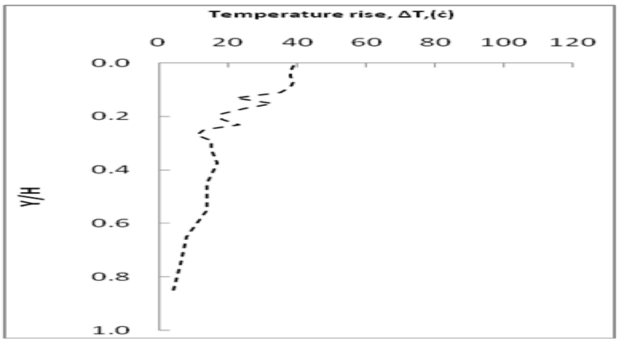


Figure 8, Temperature rise at r/H = 1.27 in the first minute of fire

C. Temperature Profile at r/h = 2.83

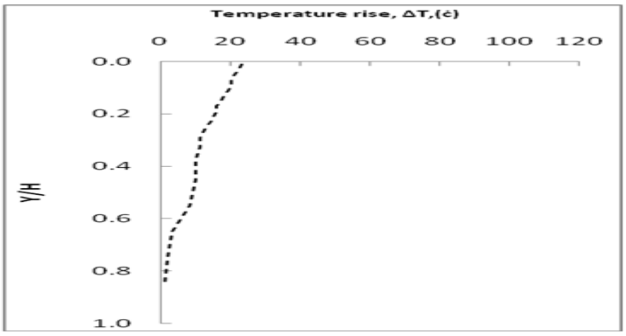


Figure 9, Temperature rise at r/H = 2.83 in the first minute of fire

As we can see from the three figures above that the highest temperature is beside the burner position and temperature reduced going away of the flame position. This is at the first minute of ignition so that the highest temperature is not that high as the first set of curves above. In the first curve, which is the nearest to the flame position t's clear that the highest temperature is not at y/h =o as expected but it's almost at y/h = 0.1 which gives us a useful observation point illustrated in the conclusion below. The same notices are obtained in the side and center position fire cases and related curves below.

Side fire case results

A. Measurements at y/h = 0

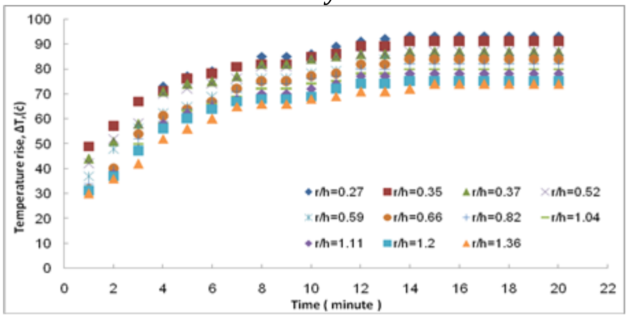


Figure 10, Temperature rise at y/H = 0

B. Measurements at y/h = 0.1

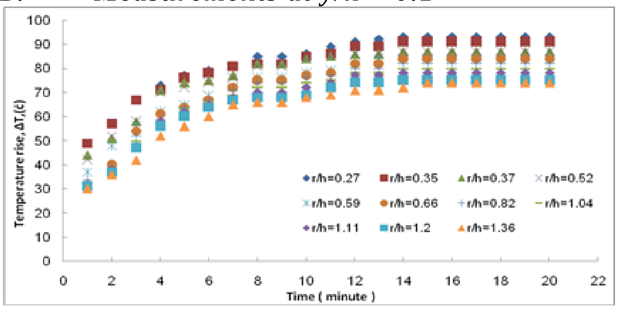


Figure 11, Temperature rise at y/H = 0.1

C. Measurements at y/h = 0.2

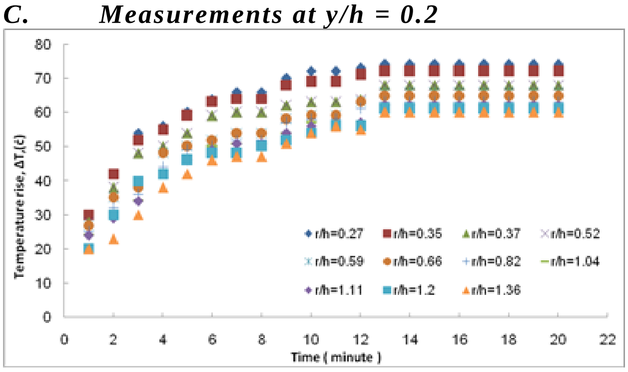


Figure 12, Temperature rise at y/H = 0.2

D. Measurements at y/h = 0.3

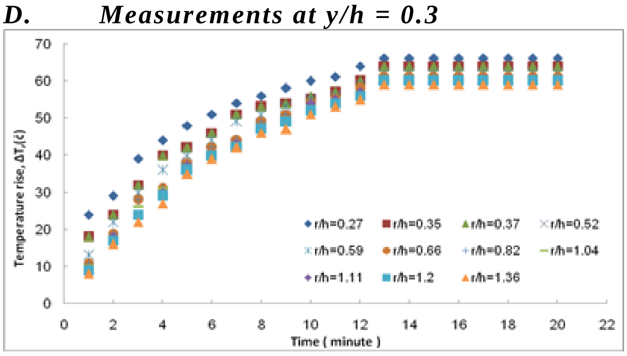


Figure 13, Temperature rise at y/H = 0.3

E. Measurements at y/h = 0.9

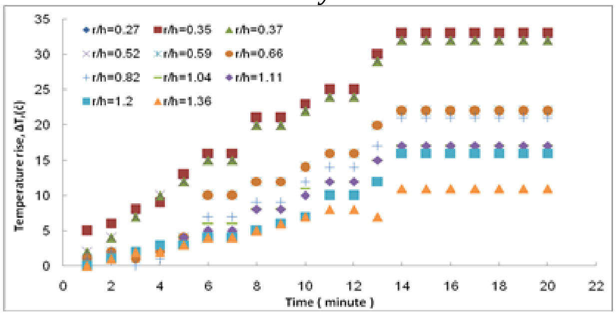


Figure 14, Temperature rise at y/H = 0.9

A. Temperature Profile at r/h = 0.27

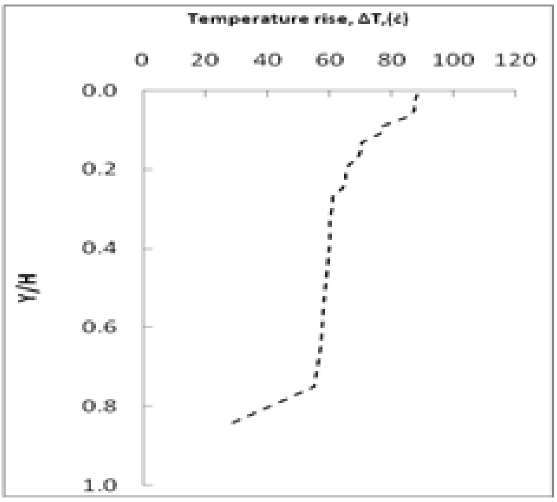


Figure 15, Temperature rise at r/H = 0.27 in the fifth minute of fire.

Center fire case results

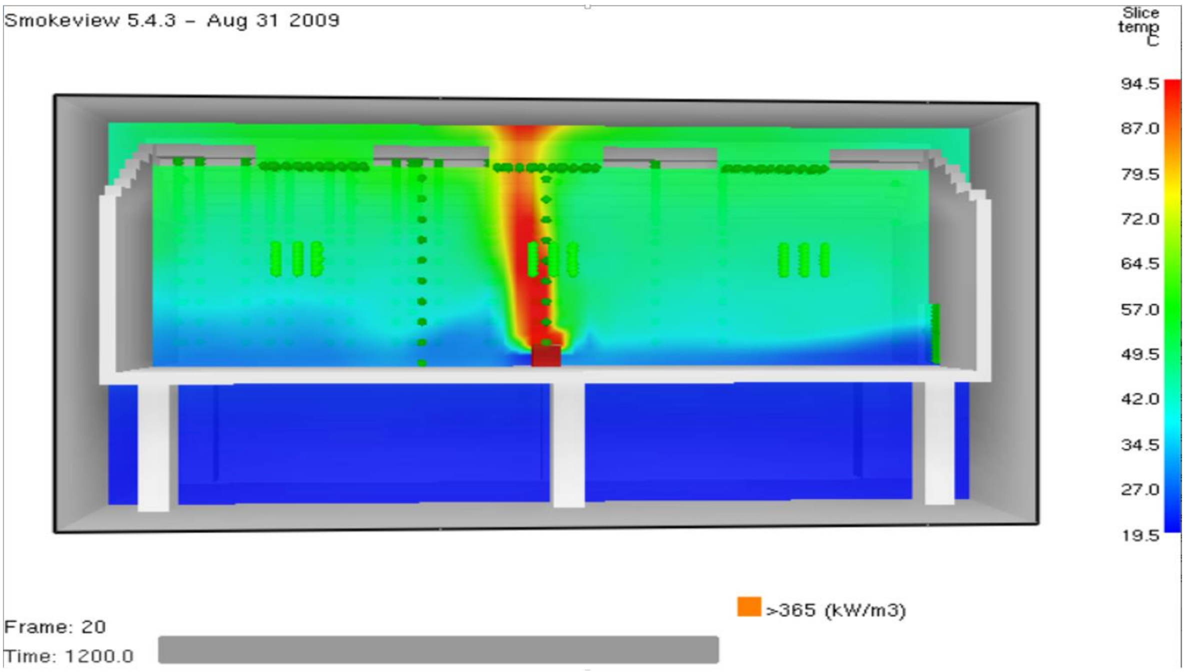


Figure 16, Temperature pattern of the center model at steady of fire.

CONCLUSIONS

This research introduces one of the applications of fire simulations by using PyroSim as an FDS model for fire spread simulations. The conclusion is illustrated below

1. For the results considering burner position effect, it's shown that the position is affecting on the plume and hot gases temperatures by the existence of fresh air surrounding the plume and its quantity. This fresh air is playing the role of cooling down the plume and hot gases temperature and consequently reduces the ability of fire spread. Therefore, the most severe condition results are in case of corner fire inside the industrial building due to less ability of fresh air entrainment to surround the fire and only two sides of the fire is exposed to fresh air and the other two sides are facing the corner walls.

2. In case of side fire position, the fresh air is surrounding three sides of the fire source while the center fire case is totally surrounded by the fresh air and consequently is having the lowest hot gases temperatures.

3. The results showed that the sprinklers and detectors can be placed below of ceiling at the distance of 10% from the ceiling [y/H=0.1] which the measurements are showing maximum temperatures we found that the maximum temperature occurred at 10 cm down of the model ceiling.

4. Finally, study showed that the temperature affected by fast growth after five minutes from the fire ignition which is a considerable time duration to fight the fire back within these five minutes and it makes it easy to be controlled and people can safely escape.

5.

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