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NUMERICAL INVESTIGATION OF FIRE SPREAD, EVACUATION AND HAZARD ASSESSMENT IN AN OFFSHORE PETROLEUM PLATFORM BY USING CFD SIMULATION

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ABSTRACT

In case of fire in an offshore oil platform the safe evacuation of people from the hazardous location is of great concern. This study investigates the safety evacuation path provided in petroleum offshore platform for occupant evacuation under fire conditions by using FDS – Evac CFD software. It was found that the evacuation time obtained from the CFD – evacuation simulation results is within the accuracy of around 97% as compared with the standard evacuation time used in an offshore platform. Results also showed that seventy one people at ground deck will be exposed to the high temperature of 300 °C, which can cause 3rd degree burn or death. Evacuation of occupants from the upper decks (2nd, 3rd and 4th) is found to be safe. Based on the results obtained, it is recommended to install a fire resistant wall at the evacuation egress route in order to prevent occupants from being exposed to high temperature during evacuation.

Keywords: FDS – evac, fire, offshore platform, evacuation.

INTRODUCTION

If fire occurs in an industry, it may cause loss of lives and property. The main challenge in an industrial fire protection is to control the impact from large and open hydrocarbon fires and to ensure the safe evacuation of the staff. In an event of fire, smoke and thermal radiation is considered as major hazards to the occupants [1]. However, in industrial fire, thermal radiation is considered as major threat to the occupants [2]. When any equipment in a facility (offshore platform) catches fire, thermal radiation from that fire may ignite the nearby fuel source, which results in propagation of fire (called domino effect) [3].

Thermal radiations can also cause severe injury to the occupants. The severity of the injury depends on duration and intensity of the incident thermal radiation on the occupants. The severity of the burn is classified as first, second and third degree burn.

There might be loss of life because of exposure to high thermal radiation which can cause heat stroke, body surface burns and respiratory tract burns [1]. In offshore platform, people work at different locations and floors (decks). In case of fire in an offshore platform, the evacuation of people is primary concern for fire safety team. Any negligence in evacuation plan or evacuation path (exit) may cause loss of precious lives. Recently, fire occurred in Pemex offshore platform of Mexico on 1st April 2015 which killed four workers and injured 45 workers.

Therefore, the objectives of this study are to investigate the evacuation process, evacuation time of occupants at the offshore platform and to assess the most risky location which presents the maximum hazard to the occupants by using Computational Fluid Dynamics (CFD) software called Fire Dynamics Simulator – Evacuation software (FDS+Evac). This research also highlights the deficiency in the offshore platform in term of evacuation route and proposes the recommendations to eliminate or overcome the hazard found during the evacuation from the offshore platform.

FDS-EVAC model

FDS-Evac is a combined agent-based egress calculation with a CFD model of fire-driven fluid flow, where the fire and egress parts are interacting. It can also be used just to calculate the egress problem without any fire-driven fluid flow calculation, for example; it can be used to simulate fire drills. FDS-Evac models the egress of the agents using continuous space and time, but the geometry of the facility is fitted to the underlying rectilinear mesh. The evacuation module of FDS was developed by the VTT Technical Research Centre – Finland which is incorporated with FDS which is developed by the Fire Research Division in the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) [4].

FDS+Evac is able to model the fire spread by using CFD techniques and simultaneously model the occupants' evacuation. FDS-EVAC model development is through providing the coordinates and commands in an input file by using Notepad. The software provides the solver once it reads the commands and run the simulation. The post processor of this software is known as Smoke view which shows the results. The results will also be presented in spreadsheet files. The software models only unsteady conditions.

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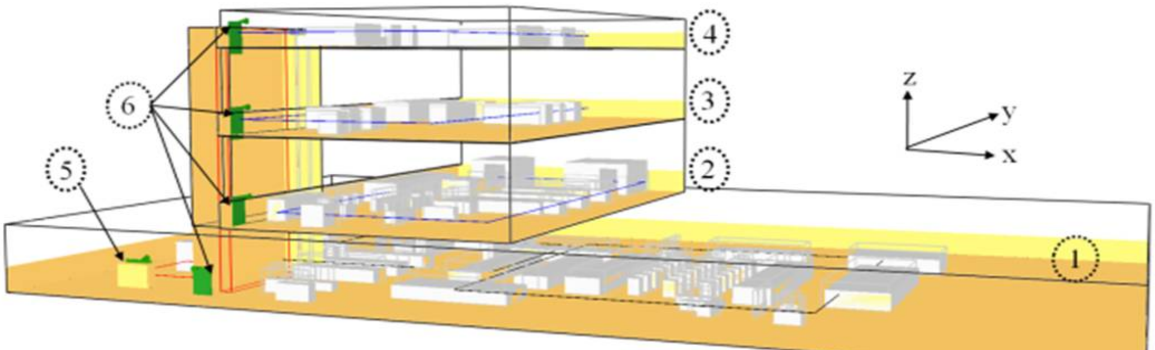

1	Ground Platform Deck	2	Second Deck
3	Third Deck	4	Fourth Deck
5	Main Assembly Area	6	Evacuation Exits

Figure-1. Full-scale model of the offshore facility layout.

MODEL DEVELOPMENT

In this study the full scale offshore platform which extracts crude oil is modelled by using FDS-Evac. Figure-1 and Figure-2 show the full scale offshore platform, which comprises of four main decks.

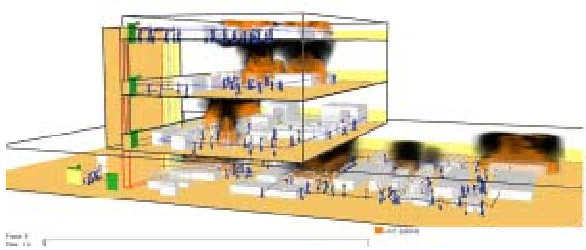

Figure-2. Fully-scaled CFD-FDS model of the facility.

The overall dimensions of the offshore platform is 61m x 36m x 23m (height). The ground platform deck is the largest operational area with different equipments. It has highest number of hazardous equipment which works under high pressure as compared to other decks. Moreover, it has largest number of occupants as compared to other decks. The remaining decks (2nd, 3rd and 4th) have smaller area and it contain less equipment as compared to the ground deck.

The total number of occupants on the platform is 220. There are 110 occupants present on the ground decks and the remaining are present on upper decks (2nd, 3rd and 4th). The orientation of the equipments and distribution of the occupants is defined according to the general design requirements for an oil and gas facility.

As mentioned that the platform is an offshore facility that extracts crude oil from subsea reservoirs for further processing and export purposes. Hence, for simplicity, same properties are applied for all resultant fire where all fuel tanks modelled within the FDS-Evac input file are assumed to be crude oil.

Fire from these hazardous equipments may cause adjacent equipments to burn as they reach their specific ignition temperature. The ignition temperature is defined in the input file of FDS-Evac and it represents the temperature at which the equipment ignites.

To model fire spread using this software, the inner and outer shell of the equipment must be modelled by defining the material properties. The outer shell for the equipment is made from stainless steel (Table-1).

Table-1. Stainless steel properties [5].

Properties	Values
Density	7750 kg/m3
Specific Heat Capacity	0.502 kJ/kg.K
Conductivity (k)	16.2 W/m.K
Thickness	5 cm

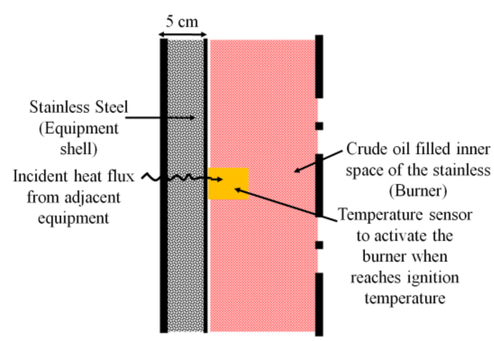

Figure-3. Cross section of facility equipment modeling.

Temperature sensors were placed inside all equipment in the facility to obtain the temperature at the locating of interest. When those sensors detect a temperate above the ignition temperature, the equipment will ignite directly.

Figure-3 illustrates the modelling of all equipment using FDS-Evac.

RESULTS AND DISCUSSION

Results are presented to assess the safety of occupants and respective evacuation time of the offshore platform. Firstly mesh sensitivity analysis and validation

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of the CFD model are performed in which evacuation time from two different mesh sizes are compared with the standard evacuation time. Then, risk determination of the offshore platform is studied by investigating the safety of occupants egress route and the hazard associated in the egress route.

Mesh sensitivity analysis and validation of CFD model

Mesh sensitivity analysis is performed to select the optimum mesh size which gives correct results. During mesh sensitivity two mesh sizes are used, which are coarse mesh with 182,992 cells, and fine mesh with 1,054,392 cells. For mesh sensitivity, total evacuation time from the facility is compared with evacuation time obtained from safety officer of an oil and gas organization which is around 4 minute (240 seconds). It can be seen in Figure-4 that the total evacuation time for coarse mesh is 191 seconds.

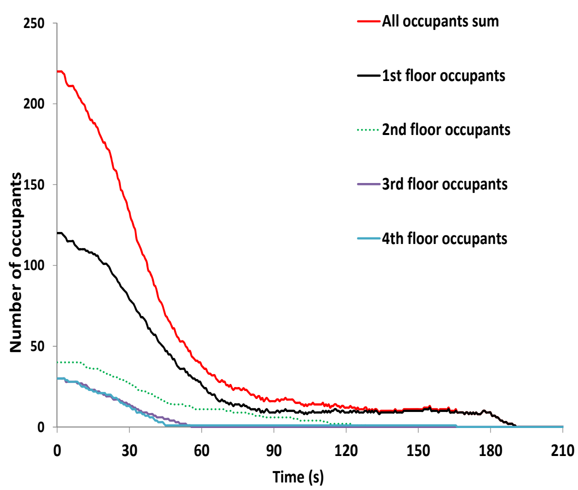

Figure-4. Evacuation time of people from offshore platform for coarse mesh.

However, the evacuation time obtained from the fine mesh simulation is 248 seconds (Figure-5). This represents the time at which all the people evacuated from the exit of main assembly area. It is clear from the evacuation time results obtained from fine mesh size simulation that good agreement were achieved with the standard time of evacuation used in oil and gas offshore platform as compared to the coarse mesh.

Table-2 lists the evacuation time from each mesh and percentage accuracy, which shows that the accuracy for fine and coarse mesh size were 96.7% and 79.6% respectively.

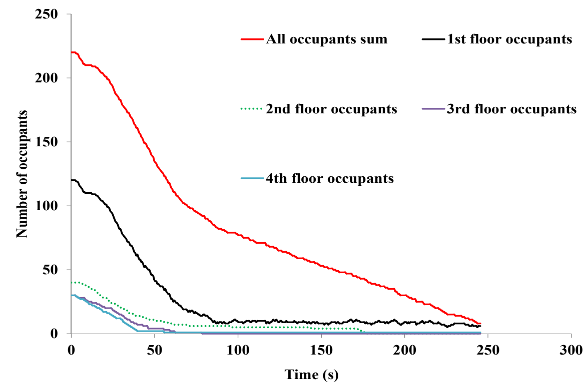

Figure-5. Evacuation time of people from offshore platform for fine mesh.

From Table-2 results, it can be seen that fine mesh should be used in the simulation of fire spread and evacuation modelling to determine the fire risk in the offshore platform.

Table-2. Comparison of evacuation time for different mesh sizes obtained from the simulations.

Comparison	Coarse mesh	Fine mesh
Evacuation time (Sec.)	191	248
Accuracy (%)	79.6	96.7

Risk determination of egress route

As mentioned that thermal radiations are the main hazard during fire in the offshore platform. Therefore, thermal sensors are placed on each deck along the evacuation route of the occupants till the main assembly area. In the simulation, the FDS will simulate the fire spread between tanks and provides the temperature of the sensors located at the egress rout at each time step.

The simultaneous simulation results of temperature and occupants evacuation are shown in Figure-6. The analysis of the results shows that the temperature in ground deck at one of the sensors located at is x=15m and y=15m which recorded high temperature. Location of the high temperature is shown in Figure-7. Where total of 71 occupants were exposed to very high temperature (around 300 °C) which may cause significant hazard to the occupants [6-8].

Figure-8 shows that all the occupants at upper decks (2nd, 3rd and 4th deck) are exposed to ambient temperature which means they are not exposed to hazard.

The finding of this research showed that 71 occupants (Figure-6) are exposed to the high temperature (300 °C), which can cause death in few minutes.

Therefore, it is recommended to install fire resistant wall on the location where high temperature is recorded and provide another exit for the evacuation of occupants.

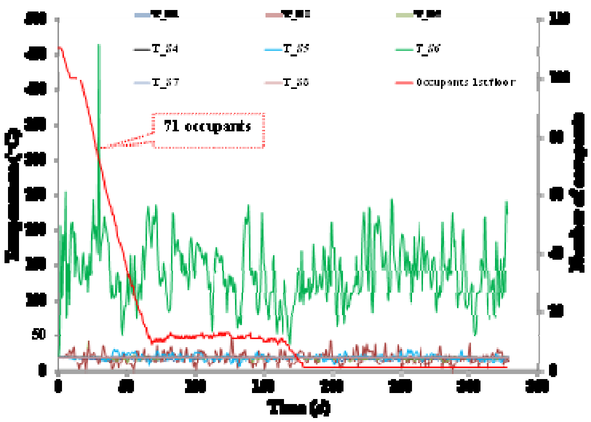

Figure-6. Evacuation route for ground deck people.

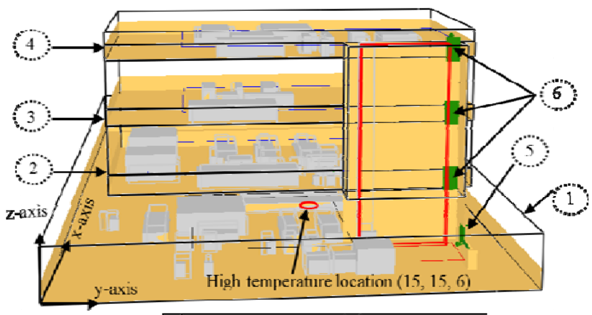

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Figure-7. Location of high temperature.

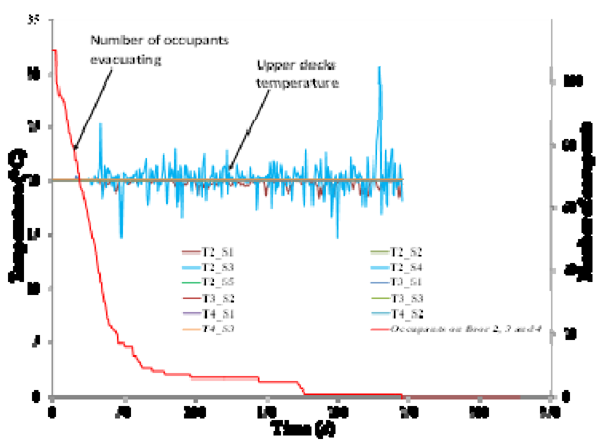

Figure-8. Evacuation route for 2nd, 3rd and 4th deck occupants.

CONCLUSIONS

In this paper, hazard determination of an offshore petroleum facility is performed by using FDS-Evac CFD evacuation software. The analysis of results shows that only ground deck is unsafe for people evacuation and it risks occupants' life. The most hazardous location found in the facility is at x=15m and y=15m. The total numbers of people which are in highly risky where they are exposed to high temperature of 300 °C are 71. The evacuation of people from other decks (2nd, 3rd and 4th deck) is found as safe without any risk. In order to minimize the risk on ground floors, two precautions measurements should be taken which are to increase exit point on the ground deck and toinstall thermal resistant wall on the first deck at the location where risk is maximum.

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