International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

Fire Impact Assessment of Flammable Fuel Storage in Heat Treatment Plant Using Fire Dynamic Simulator

[1]V.Kurinji, [2]R.Rajkumar, [3]S.Prabhakaran, [4]K.Umanath, [5]D.S.Balaji

Abstract--*Today we use highly durable materials in our day to day life. Some material used for manufacturing of mechanical components and infrastructure projects requires high strength and durability. To make a component highly durable heat treatment is done to fulfill the requirement of particular needs of a component. The Heat Treatment process increases the strength of the material by modifying their metallurgical properties. In Heat Treatment facility, the fire hazards are comparatively high and even a single fire accident may be catastrophic due to the congested and complex layout of the facility. This study proposes a novel methodology for modelling the impact of a fire event in a Heat Treatment facility. Hazard identification and accident credibility assessment have been used to discover the most credible fire accident scenarios. These scenarios have been simulated using Computational Fluid Dynamics (CFD) code, Fire Dynamics Simulator (FDS). The results have then been compared to identify the most severe impact of the fire on personnel and assets using thermal radiation and risk levels. It has been found that the fire event in scenarios has a high potential to cause damage to adjacent assets. From this comparison, it is evident that the scenario in the fuel storage and transmission pipe lines in the combustion process has the highest risk of fire to both personnel and assets. The proposed methodology may be adapted further for safety measure design to mitigate or avoid the impacts of a fire event in any complex processing facility.*

Key words--*Fire Impact Assessment, Flammable Fuel Storage, Heat Treatment, Fire Dynamics Simulator (FDS).*

I. INTRODUCTION

Process facilities are usually equipped with diverse equipment, control systems and operating procedures. Any process deviations from normal operating conditions, due to errors in the interaction of equipment, human factor, management and organizational issues make process plants susceptible to process failures and or accidents. Some major accidents such as The Piper Alpha disaster, The Bhopal accident, The Ocean Ranger accident, The Cleveland accident, The Skikda accident, The BP Texas City disaster and The BP Deep water Horizon explosion are examples of such accidents. Some lessons were learned from each accident and safety regulations and designs have been upgraded. Despite upgrading for designs, operating and emergency procedures, previous accidents demonstrate that the processing plants are still vulnerable. Accidents in processing facilities are mainly associated with fire, explosions and toxic product releases.

[1] *Department of Mechanical Engineering, Academy of Maritime Education and Training, Chennai.*
[2] *Department of Applied Science and Technology, Anna University, Chennai.*
[3] *Department of Marine Engineering, Academy of Maritime Education and Training, Chennai.*
[4] *Department of Mechanical Engineering, Academy of Maritime Education and Training, Chennai.*
[5] *Department of Mechanical Engineering, Academy of Maritime Education and Training, Chennai.*

Received: 12 Mar 2020 | Revised: 22 Apr 2020 | Accepted: 09 May 2020

Fire is the most frequent accident in process facilities and in the transportation of hazardous materials. Considering fire and explosion as the potential major accidents, fires account of these accidents in process industries. Because of the frequent occurrences of fire accidents in process facilities, there is always a need for an efficient means of combating potential fire accidents.

In recent years, many studies have been conducted considering the fire risk analysis and accident modeling. For modeling the impacts of fire, various models are available, namely semi-empirical models, integral models, zone models and CFD models. Analytical models cannot simulate obstacles and they do not represent the real condition of a system.

II. LITERATURE SURVEY

A small-scale fire test in-order to determine the consequences in case of fire accident in a building. They constructed a replica of a structure using wood, polymers and other common materials used in construction of buildings. They literally fired the replica of the building and studied the consequences. Modeling on a reduced scale can also make use of the forensic detection of fires or causes fire engineering. Fire test shows that the proposed method of reducing a confined space is useful for continuous fire tests [1]. The aspect of tank rupture and leakage by numerical simulation, which can be further applied to safe design and accident consequence analysis of oil storage tank. They developed a CFD based model to simulate the dike over topping after catastrophic rupture ofoil tank. As a result of their research they concluded that the rupture occurred at bottom of tank will cause quicker spill and more overtopping of oil than that in other positions [2]. A novel methodology for modelling the impact of fire in a Floating Liquified Natural Gas facility. Hazard identification and accident credibility assessment have been used to discover the fire scenarios, which have been simulated using Computational Fluid Dynamics and Fire Dynamics Simulator. The result has been compared to identify most severe impact of fire on personnel and assets by thermal radiation [3]. The modelling challenges that need to be overcome when performing probabilistic precursor analysis.

The events used to analyze are selected from the Organization for Economic Cooperation and Development (OECD) and Fire Incident Records Exchange (FIRE) and concludes that the Relative Risk Index (RRI) decrease when Bayesian model is used [4]. A simplified approach capturing major flame extinction mechanism has been formulated and calibrated against the measurement data for critical strain of laminar diffusion counter flow flames with fuel and (or) oxidizers stream diluted by nitrogen. This model correctly predicts the minimum extinguishing concentration of different inert diluents like argon, nitrogen, water vapor and carbon dioxide which is used for fire suppression. This proposed algorithm can be used for any practical fuel as the global kinetic model of fuel oxidation is calibrated using procedures developed in this project [5]. The details of a new fire safety engineering computer model that has been developed in New Zealand called B-Risk. It has three options for inputting Heat Release Rate (HRR) and provision for comparison of these data to HRR Directory contained in the newly published fire safety engineering compliance document. This can be used to calculate Available Safe Egress Time (ASET), Design Fire Generator (DFG), Parabolic Fire Growth Rate and Peak Heat Release Rate [6]. A ubiquitous source of uncertainty in fire modeling is specifying the proper Heat Release Rate (HRR). In this paper, they have proposed an Inverse Heat Release Rate (IHRR) calculation method to determine an inverse HRR solution that satisfies measured temperature data. From the literature review my objective is to assess the impact of fire accident by simulating it virtually and to make the industry realize that even a simple permissible violation may lead to severe loss, even though there is no such previous incident occurred [7]

III. METHODOLOGY

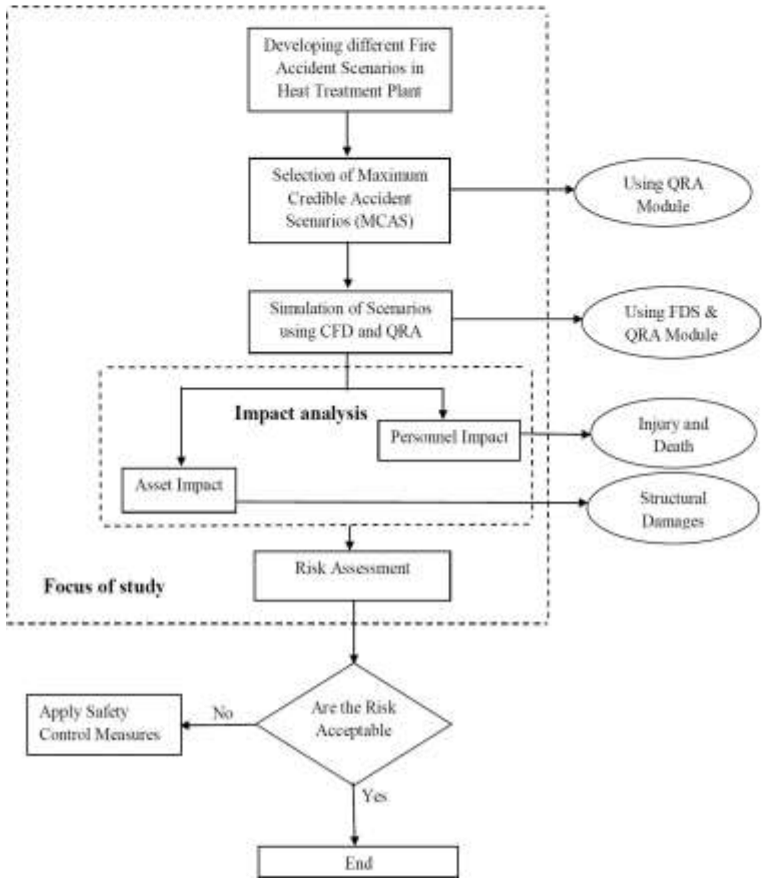

Fig.1 Overall framework of the developed methodology of fire impact assessment in HTP

Maximum Credible Accident Scenario for Fire

i. CLG/Methanol/HSD main pipe leak leads to free spread Pool Fire.

ii. Cryogenic liquid Pool Fire.

iii. Main pipe rupture leads to Jet Fire.

iv. Tank ruptures flash vaporization forming gas cloud puff immediate edge ignition lead to Fire Ball.

v. Main pipe leak flash puff immediate edge ignition lead to Fire Ball.

Maximum Credible Accident Scenario for Explosion

i. CLG/Methanol/HSD tank rupture at stored temperature flash vaporization forming gas cloud delayed internal ignition leads to BLEVE.

ii. Tank rupture free spread liquid pool on rapid vaporization of cryogenic delayed ignition leads to explosion.

iii. Mechanical explosion scenario.

iv. Main pipe rupture flash puff delayed internal ignition leading to explosion.

Fire Dynamics Simulation

It is software based virtual testing of fire scenarios without any prototype or model.

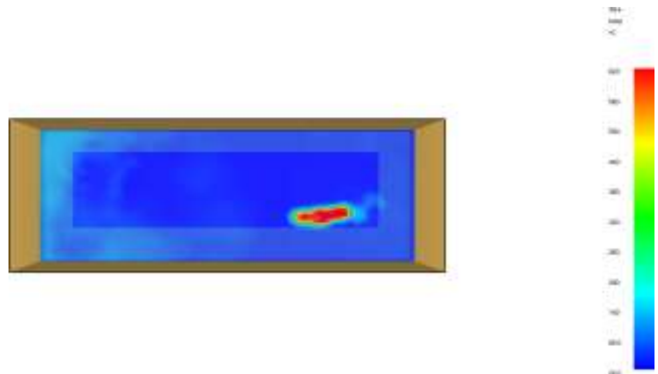

Fig.2. Simulation I for 10 Seconds of fire spread

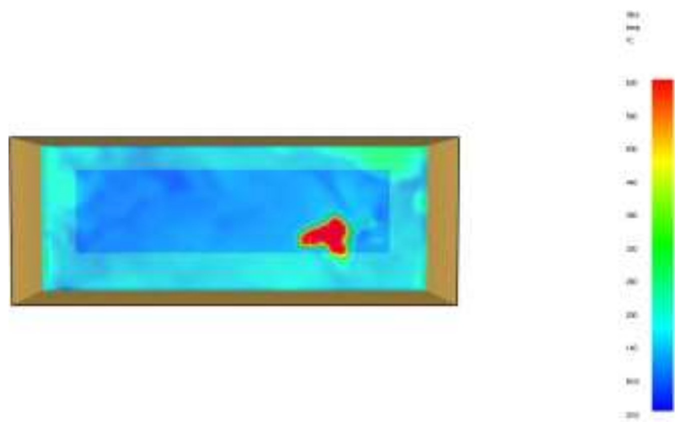

Fig.3. Simulation II 40 Seconds of fire spread

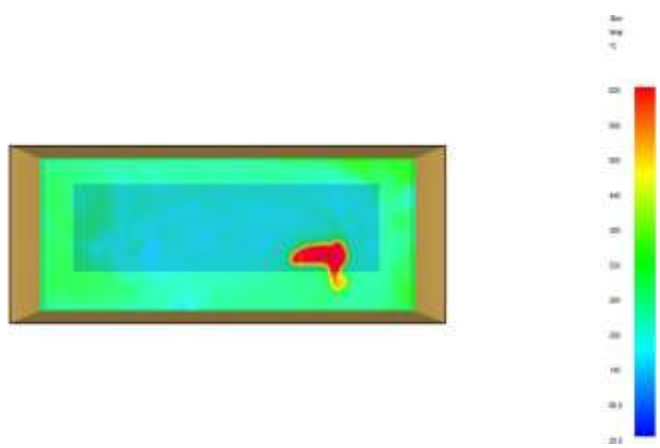

Fig.4. Simulation III for 80 Seconds of fire spread

IV. RESULT AND DISCUSSIONS

The simulation results are given below for different Flammable Fuel

Table.1. Impact of dispersion of lpg

MCAS	Dist. in (m)	Time in (Sec)	Dosage in (mg)	Fatality %	Injury %
SCENARIO 1	2.1	0.53	620117.581	100	0
	232.68	58.2	619.95	0	26.38
SCENARIO 2	2.1	0.53	569.6392	74.91	25.09
	66.7	16.53	0.6221	0	20.73
SCENARIO 3	2.1	0.53	9556.0219	100	0
	89.91	22.49	0.19	0	2.71
SCENARIO 4	2.1	0.53	3422.5532	100	0
	111.24	27.82	1.4007	0	40.64
SCENARIO 5	2.1	0.53	569.6352	74.91	25.09
	66.07	16.53	0.6221	0	20.73

Table.2. Impact of fire of lpg

MCAS	Dist.in (m)	IHR in (kW/m^2)	Dose in (kWh/m^2)	Fatality %	Injury %
SCENARIO 1	270.23	37.62	46.4	100	0
	1102.23	2.26	2.37	0	1.13
SCENARIO 2	17.21	39.23	56.23	100	0
	71.61	2.27	2.78	0	1.23
SCENARIO 3	128.29	35.22	43.18	94.86	5.18
	510.29	2.23	2.34	0	0.84
SCENARIO 4	184.62	37.56	46.55	100	0
	756.62	2.26	2.39	0	1.13
SCENARIO 5	74.87	37.81	47.76	100	0
	308.07	2.26	2.44	0	1.13

Received: 12 Mar 2020 | Revised: 22 Apr 2020 | Accepted: 09 May 2020

V. RECOMMENDATIONS

i. Storage of LPG in bullets instead of cylinders
ii. Installation of gas detectors
iii. Installation of automatic fire detection and suppression system
iv. Provision of dike for liquid fuel storage tank
v. Provision of spark arrestor in all electrical equipment's used in the storage yard
vi. Periodic maintenance of mechanical fittings used in fuel transfer system.

VI. CONCLUSION

The fire impact assessment is done for Flammable Fuel Storage in Heat Treatment Plant using Fire Dynamics Simulator in order to calculate Heat Release Rate (HRR) evolved during fire accident. The HRR obtained from Fire Dynamics Simulator is used as an input in Advanced Quantitative Risk Assessment Module (QRAM) to evaluate the Dispersion, Fire and Explosion Radius of the accident for the Maximum Credible Accident Scenario (MCAS). The recommendations are made to mitigate the accidents are proposed and cost comparison of losses incurred due to accident and implementation of mitigation system are done.

REFERENCE

1. *Maroš Krajčíra, Jana Müllerová* (2017) “3D small-scale fire modeling testing preparation”, Procedia Engineering 192 480-485.
2. *Qiang Liu, Zhili Chen, Hongtao Liu, Wenqi Yin, Yi Yang* (2017) “CFD simulation of fire dike overtopping from catastrophic ruptured tank at oil depot”, Journal of Loss Prevention in process Industries 1-10.
3. *Til Baalisampang, Rouzbeh Abbassi,Vikram Garaniya, Faisal Khan, Mohammad Dadashzadeh* (2017) “Fire impact assessment in FLNG processing facilities using Computational Fluid Dynamics (CFD)”, Fire Safety Journal 92 42-52.
4. *Dominik Hermann* (2017) “Identification of Fire Modelling Issues Based on an Analysis of Real Events from the OECD FIRE Database”, Nuclear Engineering and Technology 49 342-348.
5. *A.Yu. Snegirev, A.S. Tsoy* (2015) “Treatment of local extinction in CFD fire modelling”, Proceeding of the Combustion Institute 35 2519-2526.
6. *Greg Bakera, Colleen Wade, Michael Spearpoint, Charley Fleischmann* (2013) “Developing probabilistic design fires for performance-based fire safety engineering”, Procedia Engineering 62 639-647.
7. *Kristopher J. Overholt and Ofodike A. Ezekoye* (2012) “Characterizing Heat Release Rates Using an Inverse Fire Modelling Technique”, Fire Technology Vol.48, 893-909.
8. *Greg Bakera, Michael Spearpoint, Kevin Frank, Colleen Wade, Shahriar Sazegar* (2017) “The impact of user decision-making in the application of computational compartment fire models”, Fire Safety Journal 91 (2017) 964- 972.
9. *Dwi Arini, Fitri Pancawardani, Muhammad A. Santoso, Bambang Sugiarto,Yulianto S. Nugrohoa* (2017) “Froude modelling of fire phenomena: observation of fire-induced smoke movement in basement structure for firefighting purpose”, Procedia Engineering 170 182-188.

10. *Wolfram Jahn* (2010) “Inverse Modelling to Forecast Enclosure Fire Dynamics”, Phd.Thesis University of Edinburgh.
11. *A.R. Sivaram, R. RajaveL, K. Umanath, S. Ruban kumar & S. B. Narayana swamy*, A technical review on emulsion fuel with nano additives, International Journal of Mechanical and Production Engineering Research and Development, Vol. 8, Special Issue 7, Oct 2018, 1196-1200.
12. *K. Srividhya, R. Rajavel, K. Umanath, A.R. Sivaram, V. Srinivas, N. Jayakumar*, Effects of fuel injection timing, injection angle, ignition position on emission and spraycharacteristics - An overview, J. Adv. Res. Dyn. Control Syst. 9 (2017) 818–825.