# Blast Fragment Projection Effect of Feyzin Domino Accident

Muhammad Aiman Bin Jamel, Dr. Zulkifli Abd Rashid

*Faculty of Chemical Engineering, Universiti Teknologi Mara*

***Abstract*—This research is conducted in order to study the blast fragment projection effect of Feyzin domino accident and also to study the relationship between the probability for the domino accident to occur against the blast fragment projection distances. The method that is used for this research in order to achieved the objectives is the monte carlo simulation method. The result of the relationship between the probability for the domino accident to occur against the blast fragment projection is then tabulated into the graphically data. For the probabilistic analysis, both of the graph that has been made shown that the relationship between the probability of the domino accident to occur against the blast fragment projections distances were decrease monotonically. It can be justify that the longer the distances for the blast fragment projection effect to get the impact, the lower the probability for the domino accident to happened.**

## I. INTRODUCTION

### A. Problem Statements

There are several accident that had occurred in the oil and gas/refining and petrochemical industries since the last 50 years ago that involving the large quantity of liquified petroleum gas (LPG) and other highly flammable products. "A large number of dangerous chemicals are used or produced in chemical industries, where massive complexes of chemical process equipment are concentrated in a relatively small area." (Dongliang et al.,2017). When the Boiling Liquid Expending Vapor Explosion (BLEVE) occurred in a vessels containing liquefied petroleum gas (LPG), fragments produced during the fragmentations. According to Dongliang et al. (2017), these fragment are usually have high velocity, high kinetic energy and also large penetrating power. It can be projected over long distances that can damaging other equipment and also the facilities nearby which can causing the domino effect.

There are three considerations that need to be included in each cycle of the domino effect caused by fragments which are the source, fragment trajectory, and the impact. The source is referring to the fragment generation from the original position, while the fragment trajectory referring to the fragment projectile and the impact is the impact fragments on the target vessel that may lead to the secondary explosion or incident.

In order to determine the blast fragment projectile effects and how far does it take for the fragment to fly away and the probability to cause the domino accident to cause of the explosion, a simulation model will be used to determine the relationship between probability against blast fragment effect distance. The result is then being compared to see why does the model give an approximate result reading.

### B. Objectives

This research is conducted in order to study the blast fragment projection effect from Feyzin domino accident scenario and also to study the relationship of the probability for the domino accident to occur against the blast fragment projectile distances.

### C. Significance of research

This research is being conducted mainly to study the blast fragment projection effect of Feyzin domino accident. The blast fragment projection effect is one of the parameters to be considered for the Boiling Liquid Evaporating Vapour Explosion (BLEVE) besides the overpressure and also thermal load. By calculating the blast fragment projection effect from this research, it is actually thought us that this safety precaution is very important in the industrial plant as the explosion happened, it may lead to the other tragedy which is called as domino accident. We can take the safety precaution from learning the past tragedy of this Feyzin domino accident.

## II. METHODOLOGY

### A. Modul

Monte Carlo model

In multiple domino accident scenario, when a vessels explodes, there will be some fragments produces from the explosions, it can be projected in a very long distances, and damaging the nearby facilities. When the nearby facilities damaged, it will cause secondary explosions to occur because of the blast fragment projection. The probability for the domino accident to occur will be studied by using the formula as below. The relationship for the probability of the domino accident to occur against the blast fragment projection distances will be shown in the graphical:

$$\begin{cases} \ddot{x} + k\,\dot{x}^2 = 0 \\ \ddot{y}_A + k_A\,\dot{y}_A^2 + g = 0 \\ \ddot{y}_D - k_D\,\dot{y}_D^2 + g = 0 \end{cases}$$

The dot notation shows the time derivative while the x and y shows the horizontal and also the vertical components of the trajectory. As for the g, it is the gravitational constant.

$$\begin{cases} x(0) = 0 \\ \dot{x}(0) = u_o \cos q \\ y_A(0) = 0 \\ \dot{y}_A(0) = u_o \cos \\ y_D(t^*) = \max(y_A(t)) \\ \dot{y}_D(t^*) = 0 \end{cases}$$

$$k = \frac{r C_D A_D}{2m_i}$$

$$k_A = \frac{r\left(C_D A_D - C_L A_L\right)}{2m_i}$$

$$k_D = \frac{r\left(C_D A_D + C_L A_L\right)}{2m_i}$$

Where;
t* = time for the ascending of the trajectory in order to get the maximum height
$m_i$ = Fragment mass
$C_D$ = Drag coefficient
$C_L$ = coefficient of lift
$A_D$ = Drag area
$A_L$ = lift area
u = the initial velocity of the blast fragment projection
θ = angle of departure

### *B. Data Analysis*

For the data analysis, once all of the data has already been accumulated, the probability of the domino accident to occur against the blast fragment projection distances will be tabulated into graphically data by using the Microsoft excel. Then, the justification will be made.

## III. RESULTS AND DISCUSSION

### *A. Consequences of the incident*

As the result of the explosions of the two spheres which is T61 442 and T61 443, "a lot of fragments were projected within the area with a radius of 800 m" (Lisi. R.,2014). Some of the fragments were large and weighted for about more than 80 tons and being projected to about 270 m from the original locations of the sphere. Table 4.1 below shows the characteristics of the tanks and the other one, table 4.2 shows the characteristics of the main fragments whereas the figure 4.1 shows you the location of the projected fragments throughout the industrial area.

Table 4.1: Characteristic of the tanks (Source from ARIA Report by French Ministry of Environment, updated 2008)

| Tank | Type of steel | Volume ($m^3$) | Dimension (m) | Pressure (bar) | Thickness (mm) | Empty weight (t) |
|---|---|---|---|---|---|---|
| Sphere of propane | BH 36 KT (carbon steel) | 1218 | diameter: 13.27 | 18.7÷28.05 | 42 ÷ 43 | 220 |
| Sphere of butane | BH 36 K (carbon steel) | 2038 | diameter: 15.74 | 7.97÷11.95 | 24.5 ÷ 25.4 | 186 |
| Cylinders of propane / butane | BH 36 KT (carbon steel) | 161 | diameter: 3.04 length: 20.80 | 28.05 | mantle: 11 end-cup: 20 | not known |

Table 4.2: Characteristics of the main fragments (Source from ARIA Report by French Ministry of Environment, updated 2008)

| Tank | Fragment ID | Dimension (m x m) | Mass (t) | Fallout distance (m) |
|---|---|---|---|---|
| T61 442 | A1 | 19 x 21.5 | 88.2 | 138 |
| T61 442 | A2 | 10.5 x 18.3 | 47.7 | 325 |
| T61 442 | A3 | 12.6 x 14.5 | 53.1 | 222 |
| T61 443 | B1 | 10.5 x 15 | 48 | 85 |
| T61 443 | B2 | 4 x 3 | 2.8 | 82 |
| T61 443 | B3 | 4.2 x 11.5 | 18 | 228 |
| T61 443 | B4 | 16.8 x 18.2 | 79 | 248 |
| T61 443 | B5 | 10.5 x 17.5 | 37 | 270 |

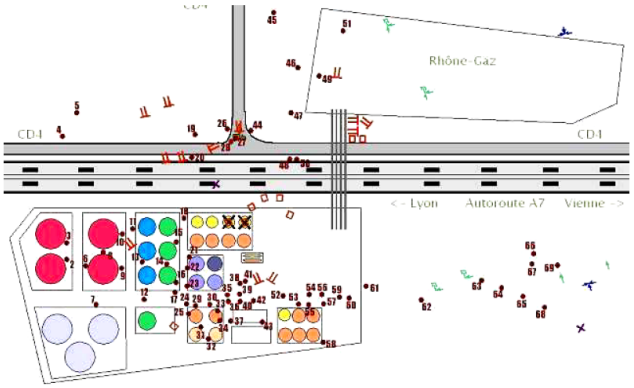


Figure 4.1: Location of the blast fragments projection (Source from ARIA Report by French Ministry of Environment, updated 2008)

### *B. Deterministic Analysis*

The initial velocity of the fragments has been calculated by using the Gurney equation that can be calculated automatically as the UN SaferGuard has provide the auto calculator to calculate the initial velocity of the blast fragment. Although it is not very suitable for BLEVE, but the result for the initial velocity of the fragments may be considerable as it is being compared to the case study itself where the vary of the initial velocity is between 140 m/s < θ < 200 m/s as stated in . According to Lisi. R., et. al., (2014) two quantities that are assumed to be vary randomly are the departure angle, θ and also the initial velocity of the fragments.

For the departures angles of the fragments, θ all values for each of the main fragments can be taken for consideration as tabulated by Lisi. R. (2014) as shown in the figure 4.2 below.

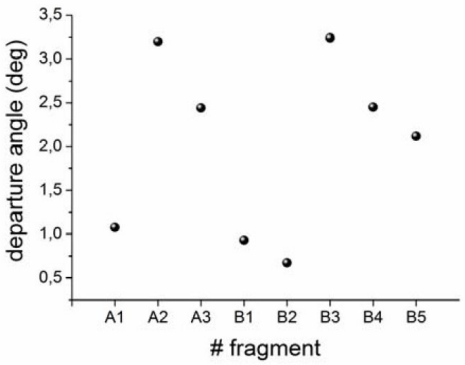


Figure 4.2: departure angle of the fragments (Source from Lisi. R. et. al.,2014)

### C. *Probabilistic Analysis*

In order to determine whether the objective of the research is achieved or not, the relationship of the blast fragment projection and the probability for the domino accident to happened is tabulated in a graphical data where it is easier to see the relationship between those two. These data is what the monte carlo simulation looks like. The data is shown in the figure below.

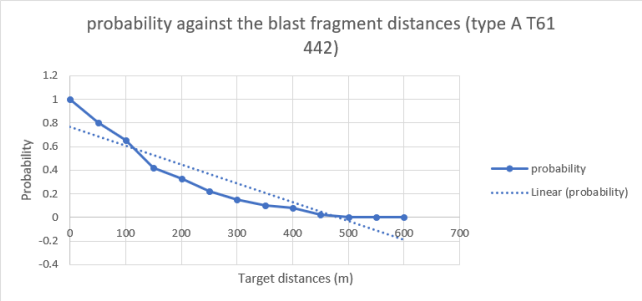


Figure 4.3: Probability for the blast fragment projection of type A (T61 442)

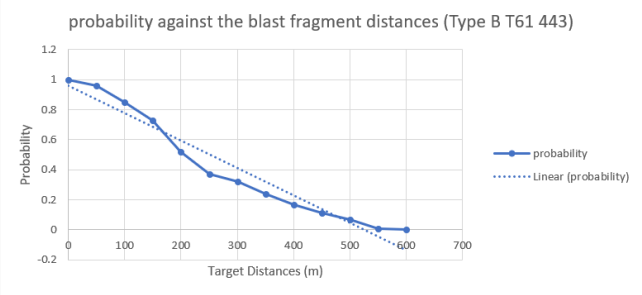


Figure 4.4: Probability for the blast fragment projection of type B (T61 443)

Based on the graph shown above, as you can see the relationship between the blast fragment projection effect and the probability for the domino accident to occur is that the longer the blast fragment projection impact distances, the lower the probability for the domino accident to occur. As stated in the earlier chapter of this research, the BLEVE caused the explosion of this Feyzin accident and the domino accident also occurred where the first explosion caused another explosion to happened. The domino happened is because of the domino accident where the blast fragment projection of the first explosion hit or crashed into another sphere tank. The impact from the crashed itself caused the other nearby tank to exploded. Therefore, it is proven from this simulation that when the blast fragment distance is short, it is most likely to hit at the other tank nearby and the domino accident will occurred. The trend for both of these graph can be stated as decrease monotonically for the probability of the domino accident to occur against the blast fragment projection distances.

## IV. Conclusion

For this research, the methodology for studying the blast fragment projection effect of Feyzin domino accident is originated by the explosion of the spehirical tank by BLEVE and has been extended to see the probability for the domino accident to occur. The probabilistic analysis has been made for the estimation of the probability for the domino accident to occur against the blast fragment projection distances by applying the monte carlo simulation. The trend for this graph decrease monotonically. Therefore, we can state that the longer the distances for the blast fragment projection effect to landed for the impact, the lower the probability for the domino accident to occur.

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