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Research paper

Risk Assessment of Dropped Objects on Topside Facilities and Subsea Pipelines

M.F. Irfan Ahmad Fuad[1]*, M.A Zakwan Hamidi[2], M. Ammar Abidin[3] , Z. Abdul Rashid[4], K. Abdul Razak[5]

[1]*Faculty of Chemical Engineering, Universiti Teknologi MARA, Selangor, Malaysia*
[2]*Faculty of Chemical Engineering, Universiti Teknologi MARA, Selangor, Malaysia*
[3]*Independent Consultant, Kuala Lumpur, Malaysia*
[4]*Faculty of Chemical Engineering, Universiti Teknologi MARA, Selangor, Malaysia*
[5]*Faculty of Chemical Engineering, Universiti Teknologi MARA, Selangor, Malaysia*
**Corresponding author E-mail:fazrilirfan@salam.uitm.edu.my*

Abstract

Falling object and swinging load impacts due to mechanical handling failures can occur in industrial facilities both onshore and offshore. The risk of accidental dropped object is considered as one of major risk categories predominantly in offshore production platform. As part of the offshore platform engineering design development, there is a need to consider the potential risk arising from falling object and swinging load impacts during routine and non-routine lifting activities utilizing platform pedestal crane. Dropped Object Risk Study as part of formal safety assessment is predominantly used to support the design of an offshore platform. The interest is focused on impacts to platform designated laydown area, structures, process equipment and subsea pipelines. The consequences from such events may include injuries or fatalities among personnel underneath, damage to equipment containing hydrocarbons onboard and subsea pipelines (overboard) resulting to leaks and hydrocarbon fires in extreme cases and damage to the platform structure either localized or as a whole. The results and findings from dropped object risk study will be used to specify requirements for engineered and operational safeguards to mitigate the risks. These include requirement of adequate integrity of deck/laydown or restriction on lifting pathways.

Keywords: *Risk Assessment; Dropped Object; Frequency; Impact Energy; Consequences Analysis*

1. Introduction

A dropped object is defined as any object that fall from its previous static position under its own weight or with a force with that have potential to cause serious consequences such as injury or fatalities and damages towards the equipments and environment [3]. Even a small object that falls from a height can cause a serious impact. Dropped objects have a threat and add up towards the great majority of potential and actual facilities in the offshore operations. During the operation, impact damage towards the facilities and subsea pipeline networks can be caused by the transverse loading from the heavy object dropped towards the facilities and to the seawater. The fracture of subsea pipelines from the impact of dropped objects could cause containment breakdown and leak of hydrocarbon into the sea [4]. In order to control and minimize the possibilities of these accidents from occur, safety measurements need to be considered especially in the safety issues and the different extent of risk. Therefore, risk assessment is proposed as one of the methods to control these accidents from occurring.

Risk assessment consists of two aspects which are probability or frequency analysis and consequences analysis [5]. When the frequency analysis and consequences analysis are high, mitigation would be required as the possibilities for accident to occur is high [6]. For the research, the risk assessment would be focused on reducing the possible accidents caused by the dropped objects towards the topside facilities and subsea pipelines. Load handling activities including the lifting operations by the crane and through hatches need to be reviewed for the risk assessment of the dropped objects and swinging objects whether it is during the operations, maintenance and simultaneous of both major maintenance and operation. Therefore, the objectives for this research are to review load handling activities inclusive of all lifting operations by crane, determine the dropped object impact energy by combination of qualitative and quantitative assessment, determine the frequency and recommend the dropped object protection. This analysis could be used as an input to the structural engineer to assess structural response and performance against the design impact energy.

2. Methodology

In this study, the dropped object analysis is divided into several steps including:

2.1 Identification of Critical Area of the Platforms Based on Location and Mechanical Handling Type Such as Frequency and Nature of Lifts.

The possible lifts have been categorised per potential drop area in order to evaluate the impact energy they are to be designed against. With reference to the equipment layout drawings, the areas of interest are main deck, mezzanine deck, cellar deck, wellhead deck, shutdown valve deck and sump pump deck.

2.2 Dropped Object Causes

The causes of dropped objects / swinging loads including the Mechanical failure of lifting components, boom lines or slings, failure of crane systems (e.g. diesel, hydraulic, pneumatic, braking system etc.), Structural failures (e.g. padeyes, crane pedestal), Overload protection failure or by-pass, use of non-certified equipment, poor inspection of critical mechanical components, inappropriate/ Inadequate procedures, inadequate communication with crane operator during operations, high winds and / or supply vessel motions increasing the likelihood of accidents during supply boat offload and loading operations; and human error.

2.3 Dropped Object Probability

The dropped object probability obtained based on the industry guidelines or standard. For the purpose of this research, the dropped object probability is taken from the DNV-RP-F107 which is 2.2 x 10-5 per lift for below 20 tonnes. The lifts above 20 tonnes are estimated to be 3.0 x 10-5 per lift. The probability of dropped object is then split into two categories which are between fall onto the deck (~70%) and into the sea (~30%) [7].

2.4 Drop Frequency

The drop frequency is needed to determine the crane activities. For the drop frequency, the parameter needed are number of lift per year, drop probability and the probability of drop whether onto the deck or into the sea. The formula of drop frequency is obtained from DNV-RP-F107 as shown below:

Drop freq = No. of lift per year x Drop prob. x Prob. of drop (1)

2.5 Energy Calculation (Impact towards the Deck)

The gravitational potential energy is converted into kinetic energy when an object or a load dropped from a certain height. Therefore, the impact energy of an object is directly proportional to the height from which it is dropped, until the object reaches its terminal velocity. The impact energy can be obtained by using below equation[7].

K.E.=mgh (2)

Where,
K.E. : kinetic energy (J)
m : mass of object (kg)
g : acceleration due to gravity (9.81 m/s2)
h : height from release point to the point of impact (m)

For this study, air friction is assumed to be negligible. Therefore, the object dropped from an installation tends to accelerate rapidly as it falls through the air. Other than that, for this research, a drop height of 4 m will be assumed. This is because 3 – 4 m can be considered as typical drop height for general lifts over main deck.

2.6 Energy Calculation (Impact towards the Subsea Pipeline)

If an object falls into the water, the drag forces acting on the falling object come into equilibrium with the force of gravity which came with outcome of decelerations. The impact energy of the dropped object is assumed to be equal to the kinetic energy at the point of impact plus the kinetic energy of added mass. The kinetic energy of the dropped object is depending on the mass and the velocity of the object. Besides that, the velocity through the water depends upon the shape of the object and the mass in water. The terminal velocity can be reached when the drag forces balance the gravitational force. This can be expressed by the following equations [7].

$$E = \frac{1}{2}(m + m_a)v_T^2 \quad (3)$$

where,

ma : ρw.Ca.V ,
Ca : added mass coefficients (assumed to be 1.0)

2.7 Projected Area

For the long-shaped object, the projected area in the flow direction is assumed to equal the projected area of the objects tilted at a certain angle. The objects are presumed to drop angle of 45 degrees vertically. Therefore, for long shaped objects, the projected area in the flow direction is given:

$$A = L.D.sin\theta \quad (4)$$

where,
A = projected area (m2)
L = length of the object (m)
D = diameter of the object (m)
θ = the angle of object from vertical (degrees)

3. Results and Discussion

3.1 Dropped Object Frequency

The dropped object probability is obtained from the DNV-RP-F107 which is 2.2 x 10-5 per lift. This dropped object probability is based on the accident data issued by the UK Department of Energy covering the period from 1980 – 1986. There are 81 incidents with the dropped objects and 825 cranes are reported during this period of time. Other than that, from the dropped object probability, it is further split between fall onto the deck (~70%) or into the sea (~30%) [7]. These data from DNV-RP-F107 is assumed to be applied into the lifting operations in this study. Based on the number of lifts per year and the dropped object probability per lift, the dropped object frequencies are obtained and calculated based on equation 1-4. The dropped frequencies for each deck are presented in the Figure 1 below.

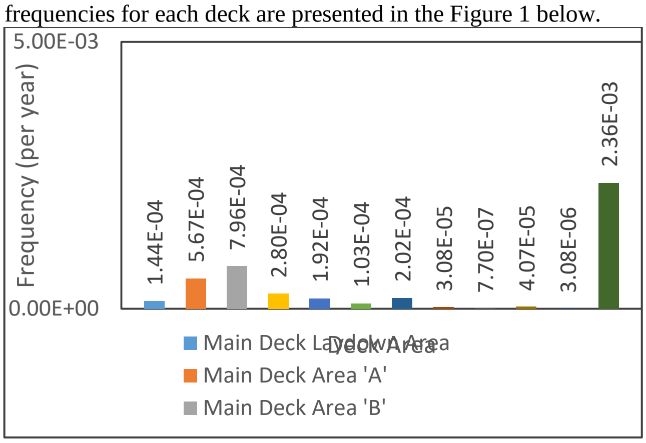

Fig. 1: Dropped Object Frequency for each Platform's Decks

Based on Figure 1, Main Deck Area 'B' has the highest frequency per year which is 7.96 x 10-4 per year and the main factors for the dropped object frequency are the number of lift per year, quantity of the object and lift factor. If the number of lift per year increases, the dropped object frequency increases as well. Furthermore, the quantity of the object also would affect the probability of the dropped object. When the quantity of the object is large, the probability of the object to be dropped also would be large compared to the smaller amount of quantity of the object.

3.2 Hazard Identification

The resulting impacts of objects dropped during lifting operations using the pedestal crane on platform have been qualitatively assessed. The area where an object is dropped on the installation is limited to the crane radius. On the platform, the pedestal crane is restricted to slewing through 360O because of the helideck and vent boom. This means that all of the Main Deck area falls within the operating arc of the crane boom where approximately only half of it is covered by the crane arc.

There is no hydrocarbon processing equipment on the Main Deck. However, if a dropped object with impact energy exceeding the deck rating were to fall through the Main Deck, then it could impact the process areas below the Main Deck and cause a hydrocarbon release. In addition, personnel located below the Main Deck in the path of the dropped object could cause fatalities. Objects dropped into the sea during lifting activities between supply vessels and the platform could impact the sub-sea pipelines, resulting in the release of hydrocarbons.

3.3. Impact Energies Due to Dropped Objects onto Platform Decks

The impact energy is calculated by the potential energy of the dropped object which then converted into the kinetic energy. The maximum impact force is depending on the object itself. The dropped object study evaluated the impact energy due to the dropped object for each deck.

The impact energy for each type of equipment has been calculated and presented in Table 1 for Main Deck. By considering the mass of the object, the acceleration due to gravity and the drop height, the impact energy is calculated. Each equipment being lifted to and from the deck or laydown area is considered. The result of the impact energy is rounded to the nearest 10 kJ. Table 1 shows the example of impact energy of dropped object at the Main Deck areas.

Table 1: Impact Energies for Dropped Object on Main Deck

Equipment	Mass (Kg)	Drop Locations	Lift Frequency (/Year)	Impact Energy (Kj)
Flush Water Pump	200	MDB	4	10
Sand Pot	13000	MDB	4	510
Condensate Pot	12000	MDB	24	470
1 3/4 " Coiled Tubing Unit	35000	MDB	2	1370
Control Cabin	7000	MDB	2	270
Power Pack	7000	MDB	2	270
CT Injector & BOP Skid	9000	MDB	2	350
Hydraulic Jacking Frame	5000	MDB	2	200
Stainless Steel Acid Blending Tanks, Twin 35 bbl	7000	MDB	2	270

3.4. Impact Energies Due to Dropped Object into the Sea

The impact energy of the dropped object into the sea is considered due to the dropped object would have an impact towards the risers and pipelines. Therefore, dropped object into the sea is included in this research. For the purpose of this study, it is assumed that the angle of the falling object to be 45° vertically when the object is dropped into the sea. Table 2 shows the calculated impact energies for the dropped object into the sea.

Table 2: Impact Energies for Dropped Object into the Sea

Equipment	Mass (kg)	Terminal Velocity (m/s)	Impact Energy (kJ)	Impact Frequency(/year)
Sand Pot	13000	9.70	690	6.26E-04
Condensate Pot	12000	6.66	300	1.88E-03
12" Launcher	500	2.90	10	4.70E-05
20" Launcher	1000	2.93	10	5.25E-05
Diesel Transfer Pump	200	5.85	10	1.57E-04
100' Burner Boom	12000	3.93	50	1.57E-04
Drill Casing 30" OD	5625	3.73	40	1.57E-04
Drill Casing 7" OD	480	2.25	10	3.13E-04
Drill Pipe 5 1/2" OD	310	2.34	10	6.26E-04
Drill Collar 4 3/4" OD	3120	5.66	60	3.13E-04

The highest impact energy of an object dropped onto the Main Deck is 1370 kJ, which comes from the 1 ¾" Coiled Tubing Unit (CTU) based on a drop height of 4 m. However, the CTU is only lifted on and off the platform twice per year compared to Condensate Pots are lifted 24 times per year with an impact energy of 470 kJ and Sand Pots whereby each is lifted on and off the platform 4 times per year with impact energy of 510 kJ and. Even though Flush Water Pump is lifted 4 times per year, the impact energy is not as high as others which is 10kJ.

Parameters of the dropped object need to be determined so that the impact energy can be obtained. For example, parameters that affect the impact energy such as mass of the object and the size of the object need to be taken into consideration. Based on the size of the dropped object, larger object with bigger masses would create greater impact energy compared to smaller object [10]. This is because larger object would create a higher velocity and trajectory and gives a greater damage to the topside facilities and subsea pipelines. Heavier loads tend to be lifted less often than the smaller loads with lower impact energy.

4. Conclusion

In order for the operation to operate efficiently and smoothly, there should be no disturbance from anything especially from dropped objects. Therefore, the entire disturbance on the deck and platform should be avoided. Based on the results of the dropped object performed in the case study, there are certain decks that can't withstand the highest load in the deck. The dropped object frequency results presented in the research need to be used with caution. From the result, it can be concluded that the dropped object frequency is largely dependent on the lift frequency. Therefore, it can be said that the objective of the research is achieved. The risks caused by the dropped object need to be reduced or eliminated in order to avoid the occurrence of unwanted event. This can be done by reducing the frequency of the event, reducing the consequences of the event or a combination of both frequency and consequences.

It is recommended that the risk can be avoided by implementing safety management. Platform safety management system can ensure the following controls are in place for the operation and maintenance of cranes, the control and issuance of certified portable lifting appliances and equipment and the control and erection of scaffolding so that the risk associated with load lifting operations are as low as reasonably practicable (ALARP). For example, by creating a dropped object work group specific to the site, introducing working at height procedures, using inventory to develop an inspection program, ensuring user checks of hoisting and lifting equipment prior to use, engaging competent scaffolders operating an integrated scaffold control system which include design, tagging, registration and regular inspection of all and operating best practice policy for working with tools at height.

For subsea pipelines, the structures can be protected in many ways either through coating or adding a protection structure like roof plate and protection frame. Roof plate is sufficient to provide a protection from the dropped object. For protection frame, it is able to resist the impact load and provides support to the roof plate. To achieve an accurate or optimal design of protection system, the interactions between the fluid and structure, and between structure and foundations are important to be observed

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