

Risk Assessment Caused By Dropped Objects On Topside Facilities And Subsea Pipelines

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Abstract— In the oil and gas industry, offshore operations continue to develop and increase as the oil and gas becoming one of the high demand year by year. This rapid increment of offshore operations has lead towards the expansion of the subsea facilities and offshore structures. From the offshore operations, there are many possibilities of unexpected accidents that can be happen especially that caused by the dropped object. Dropped object are one of the top that can cause a serious impact in the oil and gas industry. The impact load from the dropped objects can cause dangers towards the subsea equipment as it vulnerable and difficult to repair plus need much cost to repair it. The consequences of the dropped object are including the human fatalities, offshore damages, pollution and economic impact. Safety measures need to be consider in order to mitigate and reduce this dropped object events. Therefore, to avoid these undesirables events, this research presents an assessment and analysis of risk that caused by dropped objects towards the topside facilities and subsea pipelines which including the qualitative and quantitative risk assessment. The aim of this research is to review the lifting operation that can cause risk from the dropped objects and determine the impact energy towards the facilities by using both qualitative and quantitative risk assessment. Other than that, the frequency of dropped object need to be determined and protection measurement and proper procedure can be recommended as the steps to overcome this dropped object accidents. To achieve this aim, methodology includes the qualitative and quantitative risk assessment. The quantitative risk assessment is divided into two which are frequency analysis to analyse the frequency of dropped object within a certain parameters and consequences analysis by accessing data in terms of human injuries, assets damages and business impact.

Keywords— Risk assessment, dropped object, frequency, impact energy, consequences

I. INTRODUCTION

Over the past a few decades, we can see that the energy consumption has increased and the energy demand is estimated to continue to be rise. From the situation, the high demand of oil and gas will lead towards the increment of the offshore operations and rapid development of offshore and subsea facilities system [1]. The oil and gas industry continue to develop with more subsea fields been discovered which have significantly increase the number of subsea facilities installed. This industry involves risks of major and minor accidents. It can be proved through few famous disasters that happened in the past such as oil spill incident of the Deepwater Horizon and the explosion of Piper Alpha oil rig [2]. Offshore exploration is a risky operation and major part of

accidents are caused by accidental collision and third-party activities especially dropped objects.

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 equipment and environment [3]. Even a small object that fall 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 consider especially in the safety issues and the different extent of risk. Therefore, risk assessment is proposed as one of the method to control these accidents from occurring.

Risk assessment is consists of two aspects which are probability or frequency analysis and consequences analysis [5]. When the frequency analysis and consequences analysis is 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 the reducing the possible accidents that caused by the dropped objects towards the topside facilities and subsea pipelines. The load handling activities including the lifting operations by the crane and through hatches need to be review 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 objective 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, determination of frequency and recommendation of dropped object protection.

II. METHODOLOGY

In oil and gas industry, dropped objects can be said as one of the common accidents that causes high potential threat towards the industry. To mitigate and reduce these possible dropped object events, risk assessment is required. The Quantitative Risk Assessment (QRA) consists of two analysis which is frequency analysis and consequences analysis.

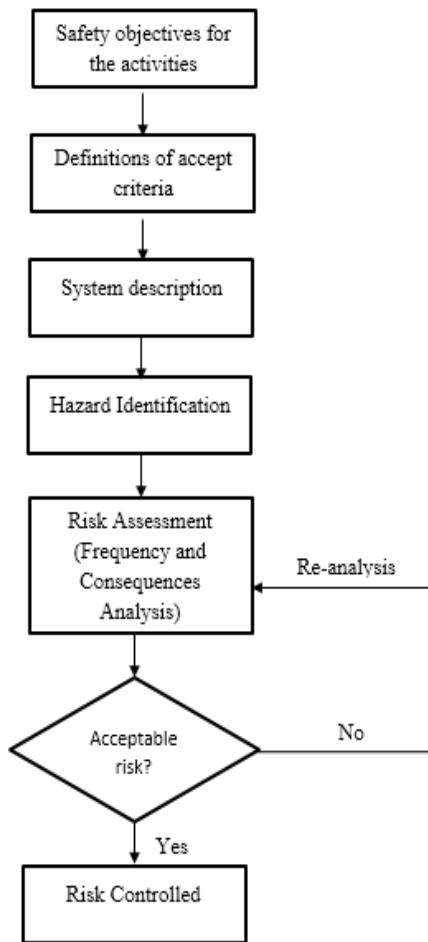


Fig. 1: Flowchart of Risk Assessment

The dropped object will be analysed by assessing the dropped load mass, dropped load height, lift frequency and dropped load potential for every lift which generate dropped object frequency for platform decks and dropped object impact energy band. The potential impact area will at the Main Deck Area (divided into four which are areas of A, B, C and D), Laydown Area on Main Deck, Mezzanine Deck, Cellar Deck, Sump Pump Deck, Sand Pot Access Platform and SDV Service Platform. For this analysis, there are steps that required to be completed which are:

- Identification of the critical area based on the location and also mechanical handling type.
- For each area of interest, the lifted loads will be identified which consists of the mass of objects lifted, the frequency and typical lifting height
- Lift frequencies will take account of both routine and non-routine lifts, making justifiable assumptions on the frequency of non-routine lifts
- The dropped object probability will be taken from DNV-RP-F107
- For each item lifted, dropped object frequency and impact energy can be generated.
- Dropped object impact energy bands can be generated

A. Dropped Object Probability

The dropped object probability obtained based on the industry guidelines or standard. For this research, the dropped object probability is taken from the DNV-RP-F107 which have is 2.2×10^{-5} per lift for below 20 tonnes. For the lifts above 20 tonnes are estimated to be 3.0×10^{-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].

B. Drop Frequency

The drop frequency is needed to be determined for the crane activities. For the drop frequency, the parameter needed is such as 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 in below:

$$\text{Drop freq} = \text{No. of lift per year} \times \text{Drop prob.} \times \text{Prob. of drop} \quad (1)$$

C. 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].

$$\text{K.E.} = mgh \quad (2)$$

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 are 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.

D. Energy Calculation (Impact Towards The Subsea)

The 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. Based on the mass and the velocity of the object, the kinetic energy of the dropped object is depending on. 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].

$$(m - V \cdot \rho_w)g = \frac{1}{2} \rho_w \cdot C_D \cdot A \cdot v_T^2 \quad (3)$$

Where:

m = mass of dropped object (kg)

V = volume of the object (m³)

ρ_w = water density (1025 kg/m³)

g = acceleration due to gravity (9.81 m/s²)

C_D = drag-coefficient of the object (assumed to be 1.0)

A = projected area of the object in the flow direction (m²)

v_T = velocity of dropped object prior to impact (m/s)

The kinetic energy of the object, E_T at the terminal velocity is:

$$E_T = \frac{1}{2} m v_T^2 \quad (4)$$

Combining these E_T to the equations would give the following

expression for the terminal velocity:

$$E_T = \frac{mg}{C_D A} \cdot \left(\frac{m}{\rho_w} - V \right) \quad (5)$$

When the object is dropped from a certain height, the probability of falling objects hitting the deck can be obtained by determine the parameter that effect the probability of the dropped object. The dropped object load is characterized by a kinetic energy, which affected by the mass of the object, the velocity of an object and including the hydrodynamic added mass. The equation of kinetic energy is as shown in below.

$$E = \frac{1}{2} (m + m_a) v_f^2 \quad (6)$$

where,

$$m_a = \rho_w C_a V,$$

$$C_a = \text{added mass coefficients (assumed to be 1.0)}$$

m is a mass of an object when at air which means the greater the mass, the greater the impact of the object towards the topside facilities and subsea pipelines. Other than that, v is a velocity of the dropped object which consists of drag force and buoyancy force that balance the gravity force. Plus, m_a is hydrodynamic added mass for the considered motion [8].

E. 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 from the vertical. Therefore, for long shaped objects the projected area in the flow direction is given by:

$$A = L \cdot D \cdot \sin\theta \quad (7)$$

where,

A = projected area (m^2)

L = length of the object (m)

D = diameter of the object (m)

θ = the angle of object from vertical (degrees)

III. RESULTS AND DISCUSSION

Hazard can occur at anywhere and anytime in the industry. Risk is a combination of probability of failure and consequences. The purpose of this research is to assess and evaluate the risk of a dropped object towards the topside facilities and subsea pipelines. It is an important thing to evaluate the risk based on quantitative and qualitative analysis. Therefore, for this study, it has been qualitative assessed and are presented in following section.

A. Dropped Object Frequency

The dropped object probability is obtained from the DNV-RP-F107 which is 2.2×10^{-5} per lift. This dropped object probability is based on the accident data issued by the UK Department of Energy which 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.

The data for the number of lifts per year for this study is provided and can be referred in the appendix section. Based on the number of lifts per year and the dropped object probability per lift, the dropped object frequencies can be obtained and calculated. The

equation for the dropped object frequencies can be refer in the methodology section. The dropped object frequencies are considered these parameters which are quantity of the object and the lift factor of the object. Lift factor is a multiplying factor based on lifts over different areas of the platform. It is assumed there is an equal probability that dropped objects will occur over the different areas the equipment is being lifted. The dropped frequencies are presented in the Fig. 2 below.

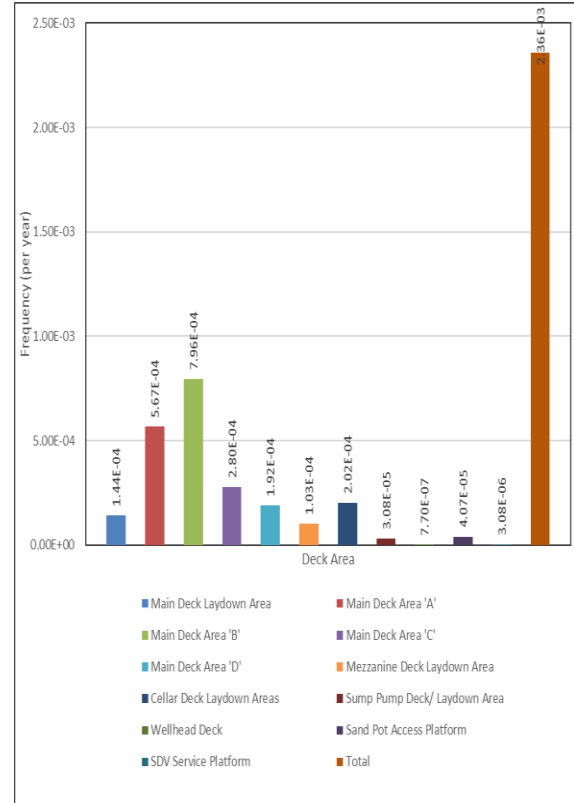


Fig. 2: Dropped Object Frequency for Platform Decks

Table 1: Dropped Object Frequency

Deck Area	Frequency (per year)
Main Deck Laydown Area	1.44×10^{-4}
Main Deck Area 'A'	5.67×10^{-4}
Main Deck Area 'B'	7.96×10^{-4}
Main Deck Area 'C'	2.80×10^{-4}
Main Deck Area 'D'	1.92×10^{-4}
Mezzanine Deck Laydown Area	1.03×10^{-4}
Cellar Deck Laydown Area	2.02×10^{-4}
Sump Pump Deck/Laydown Area	3.08×10^{-5}
Wellhead Deck	7.70×10^{-7}
Sand Pot Access Platform	4.07×10^{-5}
SDV Service Platform	3.08×10^{-6}
Total	2.36×10^{-3}

Based on the Fig. 2 and Table 1 above, at the Main Deck Area 'B', it has the highest frequency per year which is 7.96×10^{-4} per year. From the data, it can be said that the main factor for the dropped object frequency is the number of lift per year, quantity of the object and lift factor. When the number of lift per year is greater, the higher the dropped object frequency. This can be explained when the increment the number of lift per year can be affect the increment of probability of object to be dropped.

Furthermore, the quantity of the object also would affect the probability of the dropped object. When the quantity of the object is large, thus the probability of the object to be dropped also would be large compare to the smaller amount of quantity of the object.

B. Impact Energies Due To Dropped Objects Onto Platform Decks

The impact energy is calculated by the potential energy of the drop object which converts into the kinetic energy. The maximum impact force is depending on the object itself. The dropped object study will evaluate the impact energy due to the dropped object for each deck.

The impact energy for each type of equipment have been calculated and presented for each deck which are Main, Mezzanine, Cellar, and Sump Pump Decks respectively. By considering the mass of the object, the acceleration due to gravity and the drop height, the impact energy can be calculated for each deck. For each table, every equipment being lifted to and from the deck or laydown area are being considered. The drop location of each equipment can be referred in the appendices section. The result of the impact energy is rounded to the nearest 10 kJ. Below is an example of impact energy of dropped object at the Main Deck Area (Table 2).

Table 2: Impact Energies for Dropped Object at Main Deck

Equipment	Mass (Kg)	Lift Frequency (Per Year)	Impact Energy (KJ)
Flush Water Pump	200	4	10
Sand Pot	13000	4	510
Condensate Pot	12000	24	470
1 3/4 " Coiled Tubing Unit	35000	2	1370
Control Cabin	7000	2	270
Power Pack	7000	2	270
CT Injector & BOP Skid	9000	2	350
Hydraulic Jacking Frame	5000	2	200
Stainless Steel Acid Blending Tanks, Twin 35 bbl	7000	2	270
Laydown Area 001	3000	-	120

Parameter of the dropped object need to be determined so that the impact energy can be obtained. For example, parameter that affect the impact energy are such as mass of the object and the size of the object. Based on the size of the dropped object, larger object with bigger masses would create greater impact energy compare to the smaller object [9]. 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 a lower impact energy.

In the Main Deck, the deck area has been split into four area which are Main Deck 'A', Main Deck 'B', Main Deck 'C', and Main Deck 'D'. The impact energies are evaluated by assuming the height of the dropped equipment is 4 m. Based on the table of the impact energies for dropped object on the Main Deck and excluding the drilling heavy lifts, 1 3/4 " Coiled Tubing Unit has the highest impact energy which is 1370 kJ based on the drop of 4 m. However, compare to the other equipment, 1 3/4 " Coiled Tubing Unit only lifted twice per year. For the equipment that have high lift frequency per year such as Condensate Pot have an impact energy of 470 kJ.

The platform laydown areas are generally designed based on the maximum loads that lifted onto the laydown area from the supply

boat by crane from a drop height of 4 m. For this research, the Main Deck are currently design to handle loads up to 3000 kg. Thus, the Main Deck laydown are can hold up impact energy of 120 kJ. However, based on the equipment dropped onto the Main Deck laydown area, the Welding sets/Air compressor/ Scaffolding materials have an estimated impact energy of 140 kJ with a weight of 3500 kg and the same drop height of 4 m. Since the laydown area is built and designed to an impact 120 kJ, it cannot withstand the impact from the scaffolding and welding materials due to higher impact energy. The laydown area only can handle the impact if the object is dropped from the elevation of 3.4 m only.

C. Impact Energies Due To Dropped Object Into The Sea

The impact energy of the dropped object into the sea need to be considered because the dropped object can give an impact towards the risers and pipelines. Therefore, dropped object into the sea need to be included in this research. For this study, when the object is fall into the sea, it is assumed that the angle of the falling object to be 45° from the vertical. The terminal velocities have been calculated based on the information given and the data is presented in the appendices section. Below are the calculated impact energies for the dropped object into the sea.

Table 3: Impact Energies for Dropped Object into the Sea

Equipment	Mass (kg)	Impact Energy (kJ)
Sand Pot	13000	690
Condensate Pot	12000	300
12" Launcher to F13W	500	10
20" Launcher to F13W	1000	10
Diesel Transfer Pump	200	10
100' Burner Boom	12000	50
Drill Casing 30" OD	5625	40
Drill Casing 7" OD	480	10
Drill Pipe 5 1/2" OD	310	10
Drill Collar 4 3/4" OD	3120	60
Drill Collar 9 1/2" OD	623	10

The highest impact energy when the object dropped into the sea is Sand Pot with 690 kJ compare to the other equipment since it has the highest mass.

D. Impact Frequency Of Dropped Object

For every object, have their own specific masses and size. In fact, an object of equipment with the heavier masses would create a higher and massive impact compare to the lighter ones. This is because mass of an object would affect the momentum of an object to gives an impact. However, eventhough heavier object gives and greater impact, doesn't mean that it gives high frequency. The number of lift per year of an object is the ones that largely affect the frequency of a dropped object.

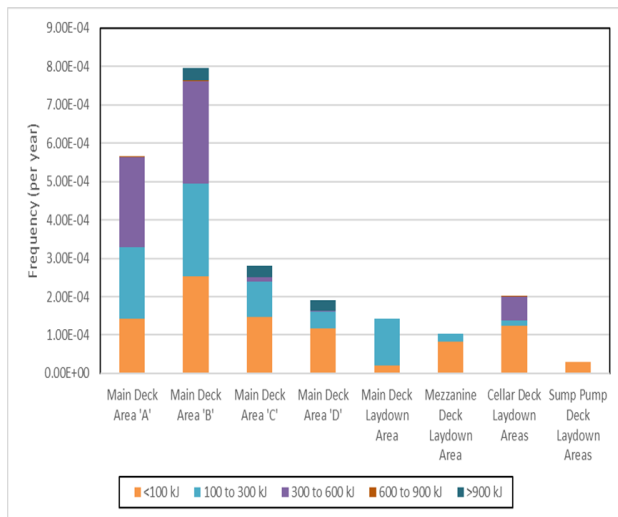


Fig. 3 : Dropped Object Frequency per Energy Band

Table 4 : Data Dropped Object per Energy Band for Main Deck B

Frequency of Dropped Object Impact (Per Year)	Main Deck Area 'B'
<100 kJ	2.53E-04
100 to 300 kJ	2.42E-04
300 to 600 kJ	2.66E-04
600 to 900 kJ	3.05E-06
>900 kJ	3.08E-05
Total	7.96E-04

Based on the Fig. 3 and Table 4 the data in the, the Main Deck 'B' has the highest frequency of dropped object. From that, it can be observed that the impact energy of 300 kJ to 600 kJ has the highest frequency compare to than the other range of impact energy. Other than that, the figure also shows that the heavier loads with higher impact energy does not have high frequency. The loads lifted with the impact energies between 600 kJ to 900 kJ are infrequent and for the loads greater than 900 kJ only have a small percentage of lifts. Therefore, it can be said that the heavier loads do not lift regularly. For that reason, heavier loads with impact that greater than 900 kJ will not have high frequency compare to the other impact energy.

IV. CONCLUSION

In order for the operation to operate efficiently and smoothly, there should be no any disturbance from anything especially from the dropped object. Therefore, all the disturbance at the deck and platform should be avoided. Based on the results of the dropped object that performed in the case study, there are certain deck 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 risk that caused from the dropped object need to be reduced in order to avoid unwanted event to be happen. The risk can be reduced 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 issue 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,

- Create a dropped object work group specific to the site.
- Introduce working at height procedures.
- Use the inventory to develop an inspection program.
- ensuring user checks of hoisting and lifting equipment prior to use.
- engagement as necessary of competent scaffolders operating an integrated scaffold control system which includes design, tagging, registration and regular inspection of all.
- operate a best practice policy for working with tools at height

For the subsea pipelines, the structures can be protected in many ways either through coating or add 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 provide support to the roof plate. To achieve an accurate or optimal design of protection system, the interaction between the fluid and structure, and between structure and foundations is important to be observed.

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