Ship Collision Risk Assessment of an Offshore Platform Process Facilities

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Abstract
Successful continuation of production of South Pars Gas Field is of utmost importance, because it directly affects numerous domestic and industrial natural gas users throughout the country. The present paper summarizes a part of offshore safety assessment of South Pars Platforms phases 15 and 16 by identifying ship collision hazards and their potential for immediate injury or loss of life or the potential for escalation, resulting in hydrocarbon release. The current design safeguards were evaluated for being sufficient to protect personnel and installation. Three collision scenarios, namely powered impact of a passing vessel, and powered and drifting impacts of an attendant vessel, were studied in order to cover all possible impacts and ascertain survivability of the platforms in any collision case. According to the frequency and severity of each collision case a risk matrix was formed. None of the aforementioned scenarios found to pose a high risk hazard to the platforms. In addition, the boat landing and platform structure were designed to absorb this impact energy in working stress condition.

Keywords: Offshore platforms, ship collision, risk assessment.

Introduction
South Pars Gas Field is one of the most extensive gas reserves of Iran, supplying a large portion of the total natural gas consumption of the country through offshore (wellhead/production) platforms, subsea pipelines, and onshore facilities. Therefore protecting the related offshore facilities from risk of collisions is of utmost importance. Several serious accidents in the past two decades such as the Piper Alpha tragedy that led to 165 fatalities have attracted public concerns to offshore safety and reliability. In particular, several accident scenarios caused by ship collisions, attracted considerable interest. Since 1980, there had been 6 cases of total loss of a platform due to collision or contact. [1] The studies on how similar accidents may be prevented in the future have been actively carried out at both the national and international levels.
This paper tries to identify ship collision hazards and their potential for immediate injury/loss of life or the potential for escalation in an offshore installation in South Pars Gas Field, resulting in hydrocarbon release and also to evaluate if current design safeguards were sufficient to protect personnel/installation. Eventually an evaluation was performed to conclude if further design measures should be recommended to reduce the possible loss of lives based on qualitative analysis.

Ship Traffic and Collision Types
In any collision, a fraction of the incident kinetic energy of the ship will be absorbed in plastic deformation of the installation's structure. The severity of the collision on the installation depends on its structural integrity. Also, the potential of escalation depends on the hydrocarbon equipment on the installation. For example, a wellhead platform would have risers and well conductors but living quarters would not. Thus, the potential of escalation for a wellhead platform would be far greater than living quarters.
Marine collisions/impacts maybe from:
Figure 1 shows a diagram of different vessels categories having the potential to collide with an offshore installation. Ship traffic for this study was divided into 2 groups:

- **Passing Vessels:** Ship traffic, which is not related to the installation being considered, including merchant vessels, fishing vessels, naval vessels etc. Less than 4% of the collisions reported in the Vessel/Installation Collision Risk Database [2] were caused by passing vessels.

- **Attendant Vessels:** Offshore traffic, which is there to serve the installation being considered, e.g. supply vessels, oil tankers, work vessels, etc. According to the collision database, over 96% of vessel/installation collisions involve vessels with legitimate business there.
Traffic density near the installation is of great importance in a collision study. According to UKOOA [3] the traffic density is defined as:

- Low: <1,000 passing vessels per year
- Low to Medium: 1,000 to 5,000 vessels per year
- Medium to High: 5,000 to 20,000 vessels per year
- High: >20,000 vessels per year

Collisions were divided into two categories:

- Powered collision
- Drifting collision

Powered collision will cover situations like navigation/ maneuvering errors (human/technical failures), watch keeping failure, bad visibility/ineffective radar use, etc.

A drifting vessel is a vessel that has lost its propulsion or has experienced a progressive failure of anchor lines or towline and is drifting only under the influence of the environmental forces such as the wind and the currents.

In addition, while analyzing collision consequences, collisions can be split into two types:

- Glancing blow
- Full-on collision

In a glancing blow the ship "brushes" against the platform and retains most of its incident kinetic energy. For most collisions of this type the platform will suffer negligible damage. Hence they were screened out from further analysis.

In a full-on collision the ship is stopped by the platform and the incident kinetic energy is dissipated in the collision.

**Scenario Definition**

From the above discussions four possible scenarios can be concluded including:

- Powered collision of an attendant vessel
- Drifting collision of an attendant vessel
- Powered collision of a passing vessel
- Drifting collision of a passing vessel

The last scenario is almost improbable as a passing vessel is not permitted to approach and stop near a platform.

**Collision Hazards**

The primary causes of collision of a passing vessel with an offshore installation include:

- Poor watch keeping onboard the approaching vessel
• Ignorance of the installation’s presence due to it being new, due to poor visibility and/or poor radar watch keeping
• Setting a course too close to the installation due to ignorance or irresponsibility

Secondary causes or contributory factors include:
• Vessel watch keeper failing to detect the installation due to inattention, distraction or simply not expecting a structure in that area
• Vessel control failure at a critical point
• Vessel drifting out of control
• ERRV failing to detect an approaching vessel due to overload, distraction, poor visibility, obstructed radar or visual view
• Unsuitability or inadequacy of ERRV equipment or manning
• ERRV failure or inability to contact an approaching vessel because it is not keeping a proper visual or radio watch
• Failure of approaching vessel to take avoiding action in sufficient time

Adverse weather can increase the probability of most of the above. A common theme is poor watch keeping, particularly on the approaching vessel.

Although attendant vessels caused about 10 times more moderate/severe collisions than passing vessels [2], the majority is low energy collisions. Among the more obvious and frequently reported causes of attendant vessel collisions are:
• Equipment failure
• Personnel misjudgement

Weather (which includes environmental factors such as wind, tide, current and wave drift) may also be considered to be ‘misjudgement’. The reported causes by vessel and operation at time of impact could be broken down to about 40% misjudgement, 30% equipment failure, 10% weather and 20% unspecified causes [4].

Collision Consequences

To assess the severity of consequences of a collision, different impact consequences and impact energies were considered.

Equipment may be affected by direct impact of a colliding vessel. Deck equipment located close to possible impact zones, Riser, Emergency Shutdown (ESD) valves and in rare cases, conductors are vulnerable to direct impact in fixed installations.

Indirect impact will affect equipment supported or shielded by a member damaged by vessel impact. For example risers supported or shielded by chords or braces can be affected by large deflection or failure of the latter.

The damage to the platform will be related to the colliding ship's energy. The incident kinetic energy of the ship is calculated as follows:

\[ K = \frac{1}{2} a M V^2 \]  

(1)

where \( M \) is the displacement in tons, \( a \) is added mass coefficient (1.1 for bow or stern impact and 1.4 for side impact) and \( V \) is velocity of impact in m/s.

In a full-on collision, the incident kinetic energy of the ship is split into the following:
• Residual energy of the ship
• Energy absorbed in plastic deformation of the ship's structure
• Energy absorbed in plastic deformation of the platform's structure

To provide an estimate of the energy absorbed by the platform in a collision, estimated data on the worst known supply vessel collision in the UK sector maybe used [5]. According to the data from an incident energy of 11 MJ, 3.5 MJ or 32% was absorbed by the platform. The proportion of the incident energy absorbed by the platform depends to a large extent on the size, construction and orientation of both the installation and the colliding vessel. Generally small vessels will tend to absorb a greater proportion of the energy than larger ones. For present study, it was assumed that about one third or 32% of the energy is absorbed by the platform for all moderate or severe collisions, as above.

The severity of a collision and the consequences are directly linked to the incident energy absorbed by the platform. For low energy collisions (< 0.5 MJ), the consequences should be insignificant, minor dents and scratches, and for high-energy collisions (> 50 MJ), total loss.

The mass of a support vessel and impact velocity while drifting toward the boat landing were considered to be 1500 tons and 0.5 m/s, respectively. Under these conditions and assuming added mass coefficient of 1.4, the total impact energy is 262.5 kJ. The boat landing was designed to absorb this impact energy in working stress condition. Moreover,
even if a vessel with greater energy collides with the platform, still the platform shock cells are in place to absorb the energy while they are in elastic mode.

Even if the size of the assumed vessel is larger than 1500 tons, it can be shown that the platform is still capable of absorbing its impact energy, provided that the above statistical percentage of absorbed energy (32%) is assumed. Different types of vessels may collide with the installation having different kinetic energies. Impact energies for typical vessel powered impacts and the resulting damage are listed in table 1.

According to these damage criteria, the kinetic energy of a fishing boat is insufficient to damage the jacket. Large passing vessels (over 50,000 tons displacement) will cause complete collapse of the platform. The damages are isolated to the platform involved in the collision.

Table (1) Impact energies for typical vessel powered impacts and consequent damages based on a typical transit speed of 12 knots

<table>
<thead>
<tr>
<th>Vessel Type</th>
<th>Vessel Mass (Tons)</th>
<th>Vessel Kinetic Energy (MJ)</th>
<th>Energy Absorbed by Platform (MJ)</th>
<th>Jacket Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing boat</td>
<td>25</td>
<td>0.52</td>
<td>0.17</td>
<td>-</td>
</tr>
<tr>
<td>Support Vessel</td>
<td>1,500</td>
<td>31</td>
<td>10</td>
<td>Extensive damage (loss of one leg)</td>
</tr>
<tr>
<td>Supply Boat</td>
<td>3,500</td>
<td>73</td>
<td>23</td>
<td>Total collapse</td>
</tr>
<tr>
<td>Container Ship</td>
<td>50,000</td>
<td>1048</td>
<td>335</td>
<td>Total collapse</td>
</tr>
<tr>
<td>Tanker</td>
<td>70,000</td>
<td>1467</td>
<td>470</td>
<td>Total collapse</td>
</tr>
<tr>
<td>Bulk carrier</td>
<td>80,000</td>
<td>1677</td>
<td>537</td>
<td>Total collapse</td>
</tr>
<tr>
<td>LPG Carrier</td>
<td>100,000</td>
<td>2096</td>
<td>671</td>
<td>Total collapse</td>
</tr>
</tbody>
</table>

Perhaps the most likely ship collision event is when a supply boat drifts into the platform, either whilst docking at the boat landing, manoeuvring (human error, mechanical failure), or by lurching and swinging in large wind and wave conditions. It is reported [5] that 70% of collisions with platforms are by supply vessels. Based upon a collision velocity of 0.5 m/s and added mass coefficient of 1.4 for broadside impacts, the impact to the boat landing (designed for a load of 262.5 kJ) from support and supply boats will cause no damage.

Collision Frequencies

The frequency of severe collisions for the period from 1970 through 1992 based on historical data from worldwide incidents is reported to be 3.8×10⁻⁴ per installation-year [5]. Hence, for this study, the frequency of a severe collision with installation in wellhead platform for all external vessel types is estimated at 3.8×10⁻⁴ per year. In the absence of historical data for the Persian Gulf, it is assumed that the frequency of worldwide incidents could be used to represent the shipping density in the Persian Gulf.

Factors which affect the probability of collision and which need to be assessed include:

- Traffic density close to the target location
- Proximity to ferry routes, traffic separation schemes, deep water routes and/or constricted navigation channels
- Other types of shipping passing nearby
- Size, speed and peculiarities of passing traffic
- Fishing activity, both en route to fishing grounds and fishing in the area
- Estimates of levels of competence among crews of regular traffic

Collision between attendant vessels and offshore installations are relatively frequent occurrences, since these vessels work in close proximity to the installation. According to OTO99052 [3], the basic collision incident rate for a fixed steel platform is 0.188 per installation-year (based on 2.5 supply vessels per week). However, since all storage vessels on the platform are designed to have 2 weeks supply, the attendance rate of these vessels to the platform is once per two weeks. Hence, the total incident rate is reduced to 0.038 per installation-year.

Most collisions from visiting vessels are low-energy (i.e. bumps against the installation), and cause little more than damaged paintwork and minor denting. However, there is a possibility of high-energy collisions occurring on approach. Table 2 shows a distribution of different collision accident severities based on historical data [2].
Table (2) Distribution of different collision accident consequences

<table>
<thead>
<tr>
<th>Severity</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fender damage</td>
<td>21</td>
</tr>
<tr>
<td>No damage</td>
<td>23</td>
</tr>
<tr>
<td>Minor damage</td>
<td>39</td>
</tr>
<tr>
<td>Moderate damage</td>
<td>13</td>
</tr>
<tr>
<td>Severe damage</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

In the above table, the definition of severe is taken to be impacts greater than 0.5 MJ. It is assumed that 10% of the severe damages will have the potential to cause jacket collapse or localized topside failure. Therefore, the frequency of severe incidents that could result in jacket collapse or localized topside failure is: $4\% \times 0.038 \times 10\% = 1.5 \times 10^{-4}$ per year.

90% of severe damages will not lead to a collapse, 39% of the collisions are described as minor and 13% of the collisions are described as moderate. Hence the frequency of mild incidents (which is taken to include both minor and moderate damages to the steel bracing of the jacket) can be estimated as: $55.6\% \times 0.038 = 0.021$ per year.

**Collision Risk Assessment**

A hazard identification was conducted, recording the causes, consequences and safeguards for each vessel/installation impact identified (see Table 3).

The risk matrix shown in figure 2 (adopted from [6]) was used to qualitatively assess the risk to personnel and installation from ship collision on the platform, based upon the frequency and consequences of an event.

Based on the risk assessment, the severity of a powered impact from a passing vessel or an attendant vessel is of category 4 that is equal to death or severe occupational illness for personnel, more than 6 months of production loss and more than 10 million dollars of damage to facility/equipment. However, likelihood of such collisions is of category 1 that indicates a frequency of less than 0.001 per year. For a drifting collision of an attendant vessel the severity has category 2 which is defined as minor injury or minor occupational illness to personnel between 1 week to 1 month of production loss and 0.1-1 million dollars damage to facility/equipment and the likelihood has category 3 that indicates frequency of 0.1-0.01 per year.

Hence, it is found that the risk of a severe collision from a passing vessel, the risk of a sever collision from an attendant vessel and the risk of a moderate collision from an attendant vessel are acceptable with controls (zone II on the risk matrix). Table 3 shows the details of hazard identification and risk assessment prepared by PHA Pro® software.

![Figure (2) Risk Matrix](image)
<table>
<thead>
<tr>
<th>Events</th>
<th>Consequences</th>
<th>Risk Matrix</th>
<th>Safeguards</th>
<th>Frequencies</th>
<th>Consequences on Personnel</th>
<th>Levels of Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Collision by passing vessels (Powered)</td>
<td>Ship impact affecting bridge structure integrity if platforms collapse. Ship impacts jacket, affecting jacket structural integrity; platform collapses, pipeline rupture with fire/explosion. Ship impacts risers, caissons, well conductors, causing hydrocarbon loss, with potential escalation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1</td>
<td>II</td>
<td>Riser, caissons, well conductors within jacket bracing, braces will absorb impact of collision. Exclusion zone and standby vessels are able to intervene to alert deviating vessel of the risk in time. Platform is unmanned. Personnel visit platform periodically for maintenance work. (E.g. 1 shift, once a wk/fortnight) Platform has 1 bridge to flare platform. There should be sufficient time for personnel to escape to neighboring platform. All platforms are equipped with sufficient escape routes, lifeboats and life rafts. Navigation light will be constantly switched on.</td>
<td>Unlikely</td>
</tr>
<tr>
<td>2. Collision by Attendant Vessels (Drifting)</td>
<td>Boat collides with the jacket at a low velocity (broadside), only localized structural damages would be incurred to the boat landing.</td>
<td>2</td>
<td>3</td>
<td>II</td>
<td>Due to the smaller displacement of the vessels at low velocity, the impact of collision is unlikely to cause boat landing to fail i.e. only localized structural damage to boat landing, no damages to jacket.</td>
<td>Likely</td>
</tr>
<tr>
<td>3. Collision by Attendant vessels (Powered)</td>
<td>Ship impacts on boat landing, energy exceeds landing's impact energy design, causes landing to fail and ship continues to collide into jacket. Ship impacts jacket, affecting jacket structural integrity; platform collapses, pipeline rupture with fire/explosion Ship impacts risers, caissons, causing hydrocarbon loss of containment, with potential escalation</td>
<td></td>
<td></td>
<td></td>
<td>Well conductors within bracing around jacket, brackets will absorb impact of collision; i.e. no direct impact on well conductors. There is a shock cell between boat landing and jacket. Impact on jacket would be further reduced Boat landing on the East of platform. Well conductors located away from the boat landing. Vessels visit the platform on regular basis; operators should be familiar with area. Visiting vessel approach procedures are specified. Visiting vessels will only be allowed to approach the platform in calm weather conditions.</td>
<td>Unlikely</td>
</tr>
</tbody>
</table>
Conclusion
Active detection of vessels approaching Normally Unattended Installations (NUI) is impractical unless within the radar coverage of a field support vessel or radar system. The hazards which passing vessel collisions pose to such installations are environmental and commercial. Any such collision also presents hazards to the vessel and to its crew.
The potential hazards to wellhead platform are identified as coming from:
- Collision by powered Passing vessels
- Collision by powered Attendant vessels
- Collision by drifting Attendant vessels
Based on the HAZID and risk assessment it was found that the risk of the aforementioned collisions is acceptable with controls. However, if the platform is normally unmanned, the risk to personnel from the above mentioned hazards is low. It was concluded that current design safeguards are sufficient to protect the personnel and to reduce possible loss of lives. No further design measures need to be recommended.

References