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Risk assessment of ship/platform collision

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1 Abstract

Although there have been few collisions between ships and offshore installations, the grave consequences of such a collision has provoked the study of the probability of collision worldwide. A theoretical study is undertaken on the assessment of risk of collision in this paper. The causes of collision and the models of evaluating the risk collision are reviewed, which are then followed by some discussions on modelling human error and mariners' behaviour of collision avoidance decision making briefly. Finally, some suggestions on reducing such a risk are proposed.

2 Introduction

In the past twenty years, experts and scholars in various major shipping and offshore oil and gas exploring states have studied widely the risk of collision between ships and offshore installations, including platforms. During 1980, a study was undertaken on behalf of the UK Department of Energy by the Marine Technology Support Unit (MATSU) at Harwell [1]. This review concluded that the level of risk from ship collision might be sufficiently high to be of concern, but that there were a number of important omissions and discrepancies in the existing data. Hence the confidence which could be placed in the risk figures was too low for firm conclusions to be drawn. A recommendation for a more rigorous review of the collision hazard was thus made. After that, several comprehensive pieces of research on ship collision risk with oil and gas offshore installations have been done [2] to [8], and at least three pieces of software, RABL, COLLIDE and CARASH, were developed [9] to [12]. These studies developed and the software have taken almost all aspects and relevant elements into account. The models are still in need of improvement. Therefore, the basis of this studies, attention is drawn to human error, especially not keeping proper look-out, and mariners' behaviour of collision avoidance decision making. Some simulating models are reviewed briefly.

3 Causes of Ship Collision with Platforms

It has been deduced from the results of studies that merchant vessels contribute the highest risk to the platforms [13]. Therefore, the following discussions will be focused purely on merchant vessels.

3.1 Unawareness of the Existence Platforms

At the beginning of the installation of a platform, many vessels are not fully aware of the existence of such a platform, so it was not taken into account when these vessels chart their routes. So that when they navigate along their routes, they maybe will pass too close to the platform. Therefore, the risk of collision is high. With the lapse of time, the vessels may be aware of the location of that platform and will consider it when they re-new their routes.

3.2 Position Fixing

Some navigators use platforms as navigational marks, checking their position by visually observing the platform. If they deviate from the straight course line in order to pass close to a platform, to ensure a positive observation of it, these are "position-fixing vessel" [14]. Besides that, similarly, some vessels approach the platform out of apparent curiosity; circling it or simply coming close enough for crew/passengers to take photographs [6].

3.3 Watch-keeping Failure

A collision maybe caused simply by the watch-keeper on the bridge not keeping a proper look-out, or even absent, so that it is too late to identify the platform. Such a ship is called as errant vessel (EV). [6]

3.4 Radar Failure

Effective watch-keeping is impossible when the radar is inoperable, or being incorrectly operated, in say conditions of poor visibility. Such a ship is called a blind vessel (BV) [6].

3.5 Equipment Failure

Ships lose their ability to avoid a collision due to failure of propulsion, or loss of power, or failure of rudder and/or steering engine. Alternatively, vessels under tow which have slipped their tow-line. Such ships are called as drifting vessel (DV) [6].

3.6 Erroneous Action

A collision can still happen even when action was taken, e.g.

- The anti-collision action is taken too late;
- The passing distance kept by the approaching vessel is too little (near miss);
- Is avoiding another vessel it collides with the platform.

All belong to human error, which are mainly related with mariners' behaviour of collision avoidance decision making.

4 Risk Assessment Models

The first one to draw the attention to the problem of ship/platform collision in the North Sea was T. MacDuff in 1974 [15]. The model he proposed could calculate the probability of collision per encounter between a ship and a platform:

$$P_{R_c} = P_p P_c \tag{1}$$

where P_p represents the geometrical probability of collision, i.e. the probability of collision if the vessel navigates randomly through an area where a platform is located. P_c is the "causation probability", or the probability that a vessel which is on a geometrical collision course takes no action to avoid the collision.

Using this basic principle, S. Haugen et al [14] modeled the probability of collision as follows:

$$P_{cpp} = \sum_{i=1}^{m}\sum_{j=1}^{6}\sum_{k=1}^{n} N_{ijk} \sum_{l=1}^{4} p_{cc,ijkl} P_{FSIR,jkl} P_{FPIR,jkl} \tag{2}$$

where: P_{cpp} = Annual number of powered passing vessel collisions.

N_{ijk} = Annual number of vessels category j, in size category k, travelling in "lane" i. The risk contribution from each relevant "lane" is calculated and added together to get the total risk to the platform.

$P_{cc,ijkl}$ = The probability that a vessel in vessels category j, in size category k, in traffic group l, travelling in lane i, is on a collision course at the point when the vessel can observe the platform visually or on radar. It is considered that there are six vessel categories: 1) Merchant vessels 2) Fishing vessels 3) Standby boats 4) Supply vessels 5) Shuttle tankers 6) Naval vessels (submarines).

$P_{FSIR,jkl}$ is the probability that the vessel itself does not initiate some action to avoid a collision with the platform (Failure of Ship Initiated Recovery).

$P_{FPIR,jkl}$ is the probability that the platform or the standby boat does not succeed in initiating recovery on the vessel, given that the vessel has not initiated such action itself (Failure of Platform Initiated Recovery).

On the other hand, the basis traffic flow, and considering each combination of a shipping lane and a platform, a model for errant and blind vessel collision risk was developed by the Technica Ltd [6]. The traffic using the lane is assumed to have a known distribution about the centre-line. Thus, if the centre-line to platform distance is known, the proportion of traffic on a course for the platform can be determined from the distribution. Of this traffic a certain proportion will be keeping an inefficient watch and could collide with the platform. Most of these vessels will effect a last-minute recovery, but a small proportion will fail to recover and will actually collide. The simplified model is expressed mathematically as follow:

$$P_1 = F_d N D P_2 P_3 \tag{3}$$

where: P_1 is Collision risk per year for a given platform which is distance d from the centre-line of the shipping lane.

F_d is Fraction of the total traffic in a strip 1/100 of one standard-deviation (σ) wide at a distance d from the centre-line of the shipping lane.

N is traffic in the whole lane (Vessel/year).

D is collision diameter of the platform/ship combination, expressed in terms of $\sigma/100$.

P_2 is proportion of errant and blind vessels among the traffic in the shipping lane.

P_3 is probability of failing to recover from an imminent collision.

The above calculation is repeated for each shipping lane near the platform and the results are summed to give the total errant and blind vessel collision risk for that platform.

The model for drifting vessel collisions is based on the same shipping lanes as used for the errant and blind vessel risk. Instead of a percentage of errant vessels being used, the expected frequency of major propulsive or steerage breakdown is applied. The chance of the vessel colliding with the platform is then calculated in terms of the wind direction.

From the above discussion we can see that, of the three models, it is assumed that if the approaching vessel keeps proper look-out, she will identify the platform and an action will be taken if necessary. From 3.6 above, we can see that this is not always true.

5 Mariners' Behaviour

In almost all ship/platform collision risk assessment models, it is assumed that an action can be expected, subject to the platform being identified and the original passing distance being regarded as unsafe. So that they can avoid taking a mariner' collision avoidance behaviour into account. However, in practice, even if the platform is observed, the approaching vessel may not take any action but just keep her course and speed only because the original distance to the closest point of approach (DCPAo) is regarded as acceptable, in fact it may be too small. Even if an action is taken, a collision still may occur merely because such an action is taken too late, or the new DCPA is still not big enough. All these events are important and have great influence on the assessment of ship/platform collision risk. A possible way to investigate a mariner' behaviour of collision avoidance is to use, computer simulation based on an investigation of mariners' behaviour of collision avoidance.

5.1 Questionnaires

Questionnaires maybe the cheapest way to obtain mariners' opinion on action to be taken to avoid collision. However, the precision of these data is low. The captains, deck officers and pilots, normally not do fill in the form according to their practices, instead of that, they tend to answer the questions in the light of the provisions in the Rules, guidelines and textbooks.

5.2 Simulator Investigation

It is quite economic to derive such data with a navigation simulator, as you can devise any encounter situation you like. For this reason, many studies have been undertaken in the past ten years, and the reality of these simulator experiments has been demonstrated.

5.3 Marine Investigation

Marine investigation is a major method of investigation used in marine traffic engineering, which normally take photographs from helicopter sor from radar on fixed ship or shorebased radar. Its purpose is mainly for traffic flow, but not the collision avoidance process. So that it is not quite suitable for the studies of collision avoidance.

5.4 On-board Investigation

The previous on-board investigations are mainly based on the data received by the course recorder. It is obvious that if we do need accurate data of mariners' behaviour of collision avoidance, we have to record each step of and every parameter in collision avoidance on board. Nevertheless, it will, be costly in time and money. Accordingly, not many of such investigations have been done.

The Collision Avoidance Studies Group in Dalian Maritime University has been working on mariners' behaviour of collision avoidance on-board investigation since 1985, and about two thousand collision avoidance data, each with more than thirty parameters, including some subjective parameters, have been obtained.

In the meantime, various mariners' behaviour of collision avoidance decision making simulating models have been developed, and all these models provide a possibility for such an assessment with simulation. Ref. [16] reviewed some models and analyzed their features briefly. It appears that fuzzy programming [17]-[18] maybe are used for such a simulation. The basic idea of these models is as follows:

- From the view of safety navigation at sea, DCPA the bigger, the better.
- From the economical aspect, the navigators try to reduce the loss of voyage, time and make the alteration of course and/or speed the smaller, the better.
- If the assessment of the alteration of DCPA is quite small, they tend to take no action.

For the sake of simulating the above, three fuzzy events, and three fuzzy sets have been introduced: fuzzy goal set (G, fig.1), fuzzy constant set (C, fig.1) and fuzzy concept "small" set (S, fig.2). In addition, the Rules for collision avoidance at sea provide in most situations, that ships should pass each other port to port. Hence, if they do pass each other on the starboard side, then navigators will be even more careful, and will feel unsafe. The contrary is equal true. In order to simulate this mariners' psychological event, a fuzzy set B is established (fig.1). Their membership functions are as follows:

$$\mu_G(x) = 1 - \exp(-\lambda_1 x^2) \tag{4}$$

$$\mu_C(x) = \exp(-\lambda_2 (x - x_0)^2) \tag{5}$$

$$\mu_B(x) = (1 - \exp(-\lambda_1 x^2))^{\lambda_3} \tag{6}$$

$$\mu_S(y) = \lambda_4 y^{\lambda_5}, y \le y_0 \tag{7}$$

$$\mu_S(y) = 1, y > y_0 \tag{8}$$

where x is the passing distance, and x_0 is DCPAo. The vector of $\lambda(\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5)$ represents mariner's behaviour, y and y_0 are as follows:

$$y = \|(1 - x_0/x)\| \tag{9}$$

$$y = \min(y, \mu_s(y) = 1) \tag{10}$$

The simplest decision making process is a single ship/fixed object encounter in open sea. If the S set is ignored, the result of decision making is the solution of the following equation.

$$1 - \exp(-\lambda_1 x^2) = \exp(-\lambda_2 (x - x_0)^2) \tag{11}$$

The use of fuzzy programming techniques has been reviewed in ref [19].

6 Risk Reducing Measures

Many studies are related with risk reducing suggestions (such as ref. [6], [14], [20] and [21]).

- Install collision risk auto warning system on platform.
- Use of RACON on platform.
- Improve the distribution of information about platforms.
- Calling vessels on VHF/radio, and other communication system.
- Use of light and sound signals on platform.
- Active use of standby boat.
- Active use of helicopter.
- Availability of tugs.
- Extend and stricter enforcement of safety zone.
- Improved design and operation of mooring and DP systems.
- Develop ship/platform collision treatment system and install on platform.
- Set up ship routeing systems if a platform is located in or quite close to high traffic density shipping lane.
- Install automatic collision avoidance system on board;
- Include ethe ship/platform collision avoidance knowledge and skill training into mariners training, education and examination.

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7 Conclusion

On the basis of a review of the current assessment models, attention has been drawn to modelling human errors, and a simulation model on mariners' behaviour of collision avoidance decision making is introduced briefly. Further work will be divided into three parts: Firstly, to introduce a simulation model on mariners look-out; Secondly, to study the risk assessment with computer simulations using mariners' collision avoidance decision making, including DCPA and TCPA, simulating models based on the statistical studies of mariners' behaviour of collision avoidance; Thirdly, on consequences of collision, including the risk reducing measures.

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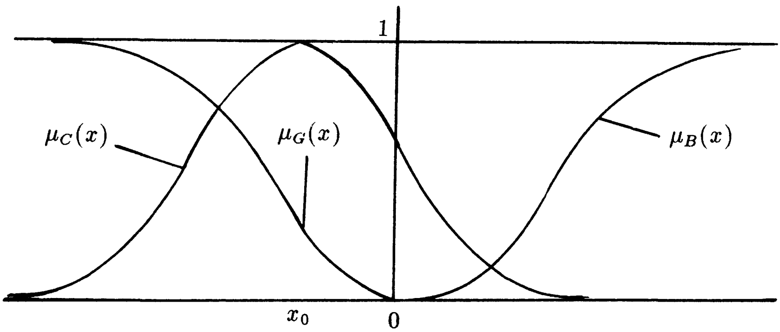

Fig 1. Membership Function of Fuzzy sets G, C and B

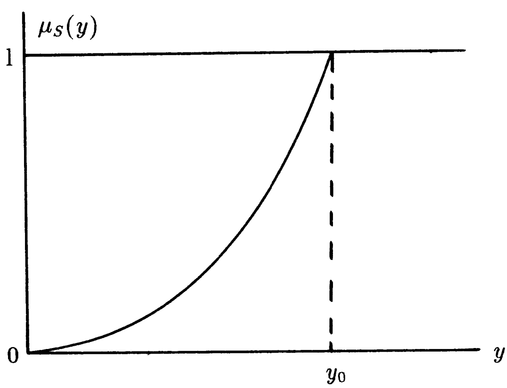

Fig 2. Membership Function of fuzzy set S