A Study on Evaluation of Collision Strength for FPSO

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Abstract

The analysis of ship collision has attracted attention in order to prevent a environment pollution. Some of the ship collision accidents in the past remain instructive records in losses of human lives and properties and environmental damages. The research activities of the ship collision have attended to large oil carrier, LNG carrier, FPSO and so on that may cause serious environmental pollution and in recent, some ship owners have requested the collision evaluation for design.

In this study, The FPSO vessel which contains the large amount of oil is evaluated for collision analysis. In the analysis, we assumed realistic collision scenarios and considered in structural design by the results of collision analysis. The collision mechanics of the ship structure is complicated and highly nonlinear phenomena. In order to simulation of collision analysis, we will use MSC/DYTRAN program for analyzing finite element method with explicit time integration algorithm for FPSO collision analysis.

Keywords: collision accident, FPSO, MSC/DYTRAN, explicit time integration algorithm

1 Introduction

The analysis of ship collision has attracted attention in order to prevent a environment pollution. Some of the ship collision accidents(EXXON VALDEZ, 1989, etc) in the past remain instructive records in losses of human lives and properties and environmental damages. The research activities of the ship collision have attended to large oil carrier, LNG carrier, FPSO and so on that may cause serious environmental pollution and in recent, some ship owners have requested the collision evaluation for design.

The collision mechanics of the ship structure is complicate and highly nonlinear phenomena. However it is important to establish a reliable analysis procedure of the hull structure collapse under collision accident. In the past years, much research activities have been focused on behavior of the structural component of ship structure. A number of simple expressions between the colliding obstacles and the collided structures have been derived analytically or empirically. A simplified method which describes the structural response under collision has contributed to a practical design up to present. On other hand, the finite element method with explicit time integration algorithm has been widely used in the analysis of the dynamic non-linear structural response of the industrial products with much success. The application of numerical simulations
are also tried to the analysis of the ship structure to investigate whether the cargo tank boundary can protect the polluting cargo from the colliding obstacles.

The numerical simulation allowed designers to investigate the structural behavior of a ship during collision process. The yielding, bucking, tearing of material and the share of the collision energy for each structural member can be observed and it provides useful information for safe operation of the ship and optimum design of the hull structure. Shipbuilding authorities and leading shipyards are also making their own studies on the numerical analysis of the ship collision.

In this study, The FPSO vessel which contains the large amount of oil is evaluated for collision analysis. In the analysis, we assumed realistic collision scenarios and considered in structural design by the results of collision analysis. In order to simulation of collision analysis, we will use MSC/DYTRAN[1] program for analyzing finite element method with explicit time integration algorithm for FPSO collision analysis.

2 Collision Scenario

Fig. 1 shows the configuration of FPSO environment on sea and subsea. In this figure, we can see the various systems around FPSO and also the various vessels (for example, supply boat, shuttle tanker and so on) can approach the FPSO. For the collision analysis, we need realistic collision scenario and firstly have to decide the striking vessel for collision scenarios considering various environmental systems.

In this study, supply boat impact to the FPSO hull and protecting structure for subsea umbilicals, jumpers and risers shall be considered and so we will consider the striking ship as supply boat.

Principal particulars of largest expected boat and its impact velocity for the riser or caisson protection are as follow.

► Boat mass : 6000 tons

► Impact velocity : 1.0 meter/second (Frame 24 to 29)
   0.5 meter/second (Frame 29 to 55)
   0.5 meter/second (bow impact)

Fig. 2 shows the configuration of FPSO for impact analysis and table 1 shows the FPSO principal dimension.
We will perform collision analysis of 3 scenarios.

- **Scenario 1**
  - striking boat velocity: 1 meter/second
  - impact contact point: between FPSO frame 24 and 29.

- **Scenario 2**
  - striking boat velocity: 0.5 meter/second
  - impact contact point: between FPSO frame 29 and 55.

- **Scenario 3**
  - striking boat velocity: 0.5 meter/second
  - impact contact point: FPSO bow part

Fig. 3 shows the configuration of 3 scenarios.

<table>
<thead>
<tr>
<th>Table 1 Characteristics of struck ship (FPSO)</th>
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<tr>
<td>Length O. A.</td>
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<tr>
<td>Length B. P.</td>
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<tr>
<td>Breadth MLD.</td>
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<tr>
<td>Depth MLD.</td>
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<td>Draught MLD.(Design)</td>
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<td>Draught MLD.(Scantling)</td>
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Fig. 2 Configuration of FPSO for impact analysis
3. Numerical Modeling

3.1 Description of finite element software for collision analysis

Several commercial softwares have been developed for the finite analysis of impact-contact and crash problems since the earlier version of DYNA-3D, developed at the Lawrence Livermore National laboratory, appeared in the early 1980s. Among the software, DYNA-3D, MSC/DYTRAN and PAM-CRASH have been widely used in the automobile industry and have been applied to the analysis of ship groundings, ship to ship and ship-bridge pile collisions.

In this project, we will use the explicit transient dynamic code, MSC/DYTRAN V4.

3.2 Numerical modeling outline

Extend of the model

To reduce computer time, only collision contact parts are modelled as a deformable structure and the remaining parts of the vessel is modelled as an undeformable rigid body for correction of mass center of gravity. And deformable body is modeled by half model. Fig. 4 shows the F.E. model about scenario 3 collision.
Material properties are taken as defined, as follows.

- Young’s modulus = 2.05E5 MPa  for all steel classes
- mild steel : yield stress = 235 MPa
tensile stress = 400 MPa
  failure strain = 22%
- HT32 steel : yield stress = 315 MPa
tensile stress = 440 MPa
  failure strain = 22%

Added mass of striking boat

The major component of striking boat motion during collision is surge. In the present analysis, added mass of 20% of the striking boat's mass will be considered.

\[ M_{total} = M + M \times 0.2 = 7,200 \text{ ton} \]
\[ M : \text{striking boat mass (}=6000 \text{ ton}) \]

Expected maximum impact energy of striking ship is calculated as follows.

\[ \text{Energy} = \frac{1}{2} \times M_{total} \times v^2 = 3.6 \text{ MJ} \]
\[ v : \text{striking boat velocity (}=1 \text{ meter/second}) \]

### 3.3 Design criteria of analysis

We have decided the design criteria for analysis and in these scenarios, striking vessel will impact side hull at the main tank. Therefore, not to spill the oil after impacting, we must check the strength of inner side shell. That is, we must check whether inner side shell is failed or not.

### 4. Results

Fig. 5, 6 and 7 show the deformed shape of the FPSO riser protector and tank structure at selected times during collision, with the effective plastic stress plotted. Fig. 8, 9 and 10 shows the striking ship kinetic energy and the energy absorbed in deformation of the FPSO side structure until the striking ship stops and rebound back.

![Fig. 5 Deformed shape and effective plastic stress and strain of the FPSO tank structure at 0.55 sec. after start of collision (collision scenario 1)](image-url)
Fig. 6 Deformed shape and effective plastic stress and strain of the FPSO riser protector at 0.37 sec. after start of collision (collision scenario 2)

Fig. 7 Deformed shape and effective plastic stress and strain of the FPSO riser protector at 0.3 sec. after start of collision (collision scenario 3)

Fig. 8 Striking ship kinetic energy and energy absorbed in deformation of the FPSO structure (collision scenario 1)
In case of scenario 1, as shown in Fig. 5, only local parts of outer shell, upper deck and frame have damaged after striking ship collision. All ship structures except collision contact local part have sufficient structural strength after collision. And there are no failure in any structures.

In case of scenario 2, as shown in Fig. 6, only local parts of riser protector and frames have damaged after striking ship collision. And also there are no failure at riser protector and other structures. Therefore, the riser structures are all safe during striking vessel impact because the riser protector may protect the riser structure against collision vessel.

In case of scenario 3, as shown in Fig. 7, only local parts of riser protector and elevation girders have damaged after striking ship collision. And also there are no failure at riser protector and other structures. Therefore, the riser structures are all safe during striking vessel impact because the riser protector may protect the riser structure against collision vessel.
5. Conclusion

In this study, The FPSO vessel is evaluated for collision analysis. In the analysis, we assumed realistic collision scenarios and considered in structural design by the results of collision analysis. As results, we can conclude that only local parts of structures of FPSO have damaged after striking ship collision. And also there are no failure at side structure, riser protector and other structures. Therefore, the structures of FPSO are all safe during striking vessel impact because the riser protector may protect the riser structure against collision vessel

References

1. McNeal Shwendler, "MSC/DYTRAN User Manual", ver.4.0, USA