# Simulation Analysis on Cable Breaking of Large Ships in a Port

## Jian Guo, Zhijun Chen, Haiqi Tang*

China Waterborne Transport Research Institute Beijing, China

[a]e-mail: guojian@wti.ac.cn [b]e-mail: tanghaiqi@wti.ac.cn

**Abstract.** Simulation analysis on drifting of an oil tanker of 300,000 tons deadweight (DWT) after cable breaking was done with a large ship maneuver simulator. Risks such as being stranded and colliding into other docks or ships are illustrated when cable breaking accident happens to a large ship under different wind and current directions. Specific emergency countermeasures are proposed to ensure safety operation.

**Keywords:** Cable breaking; ship maneuver simulation; oil tanker

## 1. Introduction

As heavy-duty docks have been built and developing, oil ports of 200,000 to 300,000 DWT can be found all over the world. If the cable of a large ship berthed in a port breaks, it is highly prone to loss of control. Under different wind and current directions, it may hit the dock and damages the ship itself and the dock, may also drift in the vicinity and becomes stranded, and may even hit other docks or ships [1]. On March 21st, 2022, a super tanker ARZOYI at berth 94 of Qingdao port, China was undocked due to cable breaking. The oil transfer arm was broken. The ship drifted and was stranded subsequently. This accident attacked much attention worldwide. In this study, simulation analysis on cable breaking of an oil tanker of 300,000 tons deadweight (DWT) in a port, to illustrate the developing and application of a ship cable breaking model. Specific emergency countermeasures are also suggested to ensure safety operation.

## 2. Simulation equipment and method

### 2.1 Simulation purpose

The simulation is intended to study the drifting trajectory of a ship after cable breaking with anchor movement, and to predict the potential damage to its dock and objects in its vicinity, so as to guide emergency responses after cable breaking and to inform involved parties to take early precautions.

### 2.2 Simulation equipment

A large ship maneuver simulator developed by Dalian Maritime University (Dalian, China) and certified by Det Norske Veritas (DNV) group and port and shipping authorities was used as the platform. The simulator meets the performance qualification of ship maneuver simulators in Standards of Training, Certification and Watchkeeping (STCW) 95 Convention, and is capable of simulating maneuver and movement of a ship under various conditions.

### 2.3 Method and process

1) Establishing virtual platform

The latest marine chart was selected and digitalized to develop digital chart of the port and its surrounding waters. And then data such as hydraulic structure of the dock, layout of the waters, etc. was imported to develop a simulation system showing pivotal data such as submerged reefs, obstructions, depth points, and isobaths of the whole area.

2) Developing ship model

A data model was developed based on ship data, and then adjusted to obtain an accurate ship model.

3) Setting up the virtual meteorological and hydrological environment

Local meteorological and hydrological data was collected and investigated to set up the virtual natural environment.

4) Developing and deploying the simulation plan

Specific simulations and repeating numbers were determined based on loading state of a docked ship (full load, half load, no load), environment (wind, current and tide), and direction of vulnerable

targets. Simulated maneuver was performed by well experienced ship pilot according to real ship maneuver and in the same operation time. The simulation recorded the operation data automatically.

5) Result analysis

The drifting trajectory and range of the ship as well as influence from external factors such as wind and current were analyzed to demonstrate that evaluating surrounding waters of the dock may help assessing the risk of ship drifting after cable breaks and support emergent evacuation of the ship.

## 2.4 Ensure accuracy

To make sure that the results from ship movement simulation accurately reflect real world ship movement safety, a ship movement simulation system should meet certain standards regarding the accuracy of the ship movement mathematic model, precision of the virtual environment, and accurateness of the simulation platform.

1) Accuracy of the ship movement mathematic model

According to Resolution A751 (18) of the International Maritime Organization (IMO)，sea ships with a length $\geqq$ 100 m should undergo three standard tests, i.e. turning cycle test, Z maneuver test and stopping test. The test results should meet corresponding criteria. Results from these standard tests are kept in the pilot card, wheelhouse poster and maneuvering booklet on board. The test data is the main evidence to prove the mathematic model accuracy of the ship maneuver simulation system.

2) Precision of the virtual environment

Since wind in real world is unsteady, it is difficult to ensure that the virtual environment is completely consistent with the real world. It is generally presumed that wind encountered by a ship in a certain water area is constant. Using average wind direction and speed from meteorological statistics ensures consistency with real world situation, although it still varies from natural wind.

Due to the influence from topography, tidal field is also constantly changing. However, since the size of a ship is relatively small as compared to navigable waters, it is assumed that the current direction and speed within the length of the ship in the water area is constant in a time span. Thus the virtual environment is fundamentally the same as the real world, although disparity still exists.

3) Accurateness of the simulation platform

Accurate ship position, heading and speed are pivotal to safe navigation. Accuracy of the digital marine chart and ship symbols adjusted to scale may directly affect the validity of the test result. When the marine chart is digitalized and displayed on a computer screen, the projected coordinates need to be converted into screen coordinates. Therefore, for chart work, geographic coordinates should be converted into screen coordinates to ensure high precision.

## 3. Simulation and analysis

### 3.1 Project description

A crude oil terminal of 300,000 DWT in a port is located to northwest of the Bohai Bay and is separated from the sea by breakwater. About 800 m to its north, there is approach bridge leading to the oil storage area. An ore dock of 250,000 DWT lies about 570 m to its east. Approximately 1,500 m to its east are a liquefied natural gas (LNG) dock and trestle. To the south is the Bohai Bay.

### 3.2 Simulation water area

Front of the dock and surrounding waters are described in Table 1.

Table 1. Dock's hydraulic structure and water area

| Item | Date |
|---|---|
| DWT | 300,000 |
| Berth length | 520 m |
| Working platform | 45 m × 35 m |
| Bottom elevation of dock front | -23.5m |
| Water depth of dock front | 20-30 m |
| Width of docking water area | 136 m |
| Designed bottom elevation of docking water area | -25.8 m |
| Dock structure | High pile cap |

## 3.3 Ship factors

Ship factors influencing safety during ship's entering and leaving port including ship type, load, loss of control (no propulsion), etc.

1) Ship type of the simulation

According to ships using the port of this project, an oil tanker of 300,000 DWT was selected as the simulation ship.

Table 2. Ship dimension

| DWT | Length (m) | Width (m) | Full load draft (m) | Ballast draft (m) |
|---|---|---|---|---|
| 300,000 | 336 | 58 | 208 | 10 |

2) Ship status

Considering emergent environmental condition and ship condition, the ship was mostly in ballast state in the simulation, and a few tests were done in full load state. According to actual maneuver during docking, the heading was unexceptionally pointing to the east.

## 3.4 Environmental factor for navigation

1) Choice of wind direction

Operational experience showed that strong wind direction of the port is east-northeast (ENE) and northeast (NE), and normal wind direction is south-southwest (SSW). Therefore, these wind directions were selected for the simulation, with wind force levels 7-8.

2) Choice of tidal current

This sea area has reciprocating tides. In the sea far from the shore and shoal where the dock is located, the tides reciprocates at the east-west direction, with an average current speed of 0.24-0.97 m/s, while the average current speed of the whole area is 0.56 m/s. The ebb current goes east with an average speed of 0.21-0.70 m/s, whereas the average current speed of the whole area is 0.42 m/s. The flow is faster than the ebb. In the sea area close to the shore and shoal, the current follows the shore or the direction of the isobaths.

An unfavorable test current speed of 2 kn was chosen based on whole tide hydrological observation data obtained by professional organizations and statistical data on the current near the dock of this project, and considering possible extreme tide under bad weather,.

## 3.5 Simulation plan

A typical simulation test was designed taking all the factors and principles described above together, based on specifics of the berths to be built, as well as considering the most unfavorable

situation for ship maneuver. One simulation was performed for each test in the simulation plan, and some tests were repeated according to dynamic change of the test conditions.

Simulation test parameters are described in Table 3.

## 4. Analysis on simulation results

Drifting after cable breaking was simulated with combinations of normal wind and current directions. The results showed that main risks after cable breaking are collision and being stranded. The level of risks is related to factors including ship load, port width, wind force and direction, human factor, etc.

Table 3. .Simulation test parameters

| Scenarios | Wind force (BF) | Wind direction (Deg) | Current speed (Kn) | Current direction (Deg) | Notes |
|---|---|---|---|---|---|
| Test1 | 8.0 | 45.0 | 2.0 | 225.0 | Ballast |
| Test 2 | 8.0 | 67.5 | 2.0 | 250.0 | Ballast |
| Test 3 | 8.0 | 90.0 | 2.0 | 225.0 | Ballast |
| Test 4 | 8.0 | 90.0 | 2.0 | 225.0-270.0 | Ballast |
| Test 5 | 8.0 | 200.0 | 2.0 | 120.0 | Ballast |
| Test 6 | 8.0 | 200.0 | 2.0 | 120.0-90.0 | Ballast |
| Test 7 | 8.0 | 202.5 | 2.0 | 45.0 | Ballast |
| Test 8 | 8.0 | 292.5 | 2.0 | 45.0 | Ballast |
| Test 9 | 8.0 | 67.5 | 2.0 | 250.0 | Full load |
| Test 10 | 8.0 | 200.0 | 2.0 | 120.0 | Full load |

1) With northeast or northwest wind and southerly current, the ship drifted to southern open water after cable broken. Since the shortest distance from the dock to the anchorage ground is about 1.6 nmi, the ship might drift to the anchorage ground on the east side of the port and collide with anchored ships (Figure 1-Test1).

2) In east wind and flow, the ship drifted southwest, and might run into the ore dock nearby or ships docked at the front of the dock in the process. Especially when the ship came across west flow during drifting, it had a very high chance to collide with ships docked at the front. The risk was extremely high under these environmental conditions. With an east wind of 8 and west or south by west current of 2 kn, after the cable broke, a ship in ballast state may drift into the ore dock or ships at the front of dock within 20 minutes (Figure1-Test4)

3) With south by west wind and south by east to east ebb, the ship drifted to the east side of the dock after the cable broke. It might get stranded in shallow water or run into the LNG dock, causing severe accident. With a wind force of 8 and a current of 2 kn, the ship might get stranded in shallow water within 20 minutes (Figure 1-Test5), or collided with LNG dock or docked ships in around 30 minutes (Figure 1-Test6).

4) With south wind and flow, the ship might collide with the dock and damage berthing mechanism of the dock or ship body. However, the risk of cable breaking is relatively low (Figure 1. -Test7 and Test8).

5) It is worth noticing that under the same wind and current condition, the drifting path may vary with ship's loading state, thus raising different crushing risk. For instance, with southwest wind of 8 and southeast current of 2 kn, a fully loaded ship will drift towards southeast side of the dock and may run into ships anchored in the east dock. On the contrary, with the same wind and current condition, a ship in ballast state will drift to the northeast side of the dock and becomes stranded because the influence from wind is more significant due to high freeboard (Figure 1-Test5 and Test10).

6) Under the simulation conditions, a ballasted ship moves faster than a fully loaded one. With a wind force of 8 and current of 2.0 kn, an ballasted oil tanker of 300,000 DWT drifts 1.5 times faster than a fully loaded one.
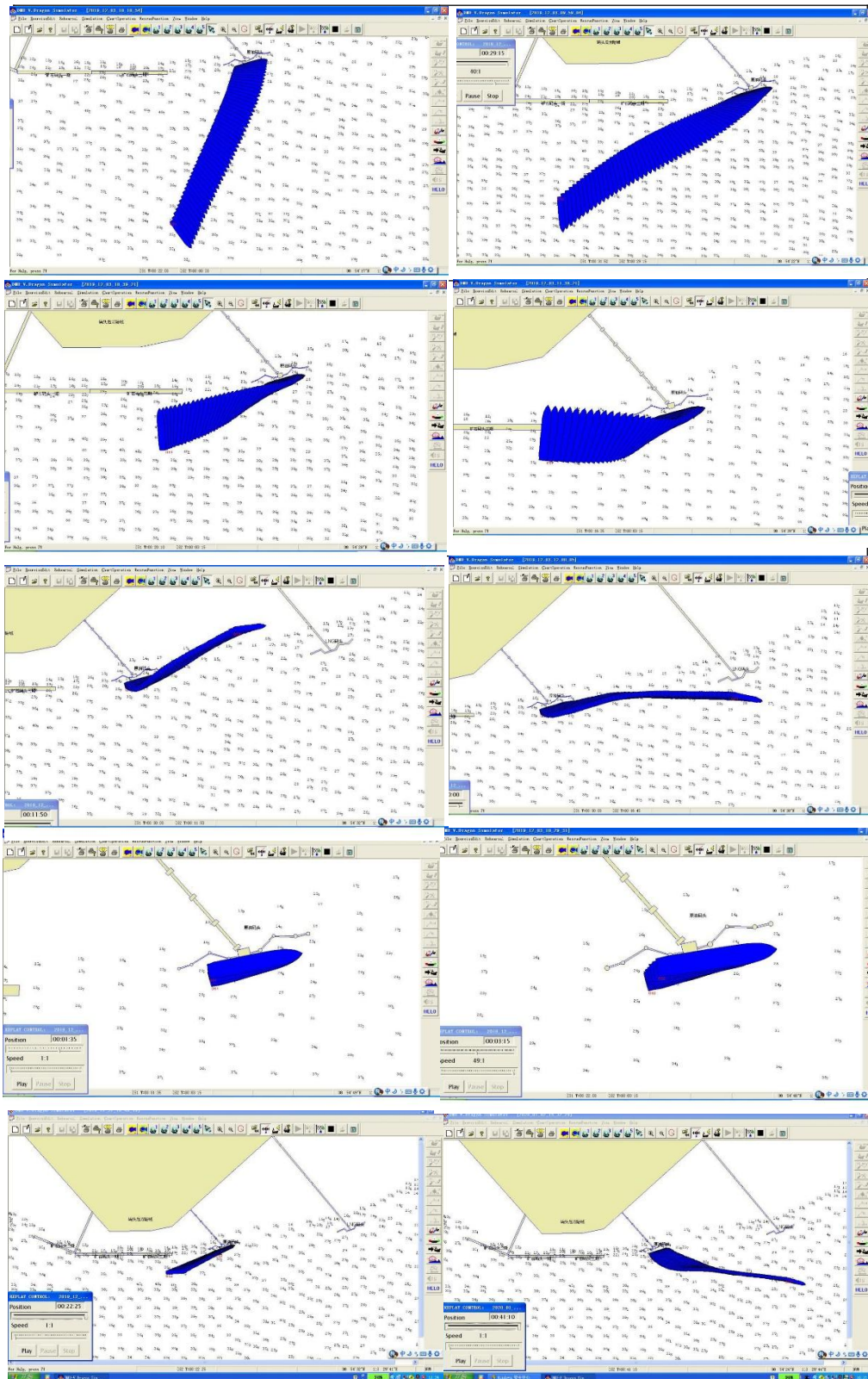
# 5. Emergency countermeasures



Figure1. Trajectory diagram of ballasted ships drifting after cable breaking in scenarios 1-10 from 0-30 min

1) Weather condition monitoring

In simulation scenarios, weather condition could directly impact ship drifting after cable broke. Therefore, dynamic monitoring of meteorological parameters and sea conditions in the dock area should be enhanced. When the weather condition approximates the threshold of docking and unberthing, the port and ships should be warned immediately [2].

2) Cable maintenance

The mooring force should be correctly calculated with safety margin[3]. When necessary, extra cable may be used to increase mooring stability. Additionally, cables made of the same material should be used with appropriate exiting angle, to avoid excessive cable friction [4].When the ship is docked, the cable tension should be monitored. For instance, if the current is coming from the head of the ship, causing tightened bow cable and loose stern cable, the stern cable should be tightened, and wise versa, to reduce collision between the ship and the dock [5].

3) Tugboat patrol

With tugboat patrolling in place, the tugboat may help pushing the ship away from vulnerable areas or assist the port reapplying cable when a ship drifts after cable breaking.

4) Notifying emergency avoidance

Simulation results of a ship's unpowered drifting revealed the drifting path under different wind direction and current. In real world, various scenarios of cable breakings may happen, and ships may be in different states after loss of control. Therefore, once cable breaking is noticed with risk of unpowered ship drifting, docks, maritime authorities and sailing ships should contacted immediately to inform them of the hazard. The risk level may be suggested with consideration of real-time wind direction and sea condition, so that all parties can take early precautions and prepare for evacuation.

## References

[1] Yingwei Zhao. Prevention and countermeasures of ship cable breaking accident [J]. Marine Equipment/Materials & Marketing,2020(8):101-102.

[2]  Yijun Yang. Pearl River Water Transport [J]. Pearl River Water Transport,2012(21):89-90

[3]  JTS144-1-2010, Load code for harbour engineering.

[4]  Weifeng Chen. Research on the stability and safety of large ships [J]. Marine Equipment/Materials & Marketing,2020(08):72-74.

[5] Hong Chen. Prevention and emergency measures for ship's cable breaking [J]. Tianjin of Navigation,2017(01):1-2.