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Determination of the Tankers' Drift During STS Operation - Simulation Study

K. Formela, M. Gil & P. Wilczyński
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: The safety of the tankers during the Ship-to-Ship operations carried out in shallow water close to port limit is influenced by many factors. Based on the experience of ship crew involved in STS operation it was found that area for such operation and weather analyses is the most important factors affecting the safety of the tankers. Wind speed and accompanying waves very often determine if such operation could be commenced.
For the article simulations were carried out with maximum allowable wind speed and waves for such operation to obtain the drift of both tankers and capacity of area for STS operation.
The results obtained from simulations allowed to assess the required space for tankers involved in STS operation.

1 INTRODUCTION

Nowadays tanker's STS operations consist an essential part of the oil supply chain, in many cases also security of the oil supply for example if the port infrastructure is damaged or still not existed. The STS operation is cost effective way of oil supply and greater trading flexibility to compare with the traditional way of the oil transfer between tanker and oil terminal. There are many solutions to perform such oil transfer between two tankers:
- at anchor,
- in adrift,
- and underway.

The most popular method to perform oil transfer between two tankers is STS operation when both tanker after mooring operations stay adrift. The STS in adrift to compare with others method always required more space around. This paper should give the answer, what is the speed and direction of the drift and drift pattern for both tankers perform STS operation.

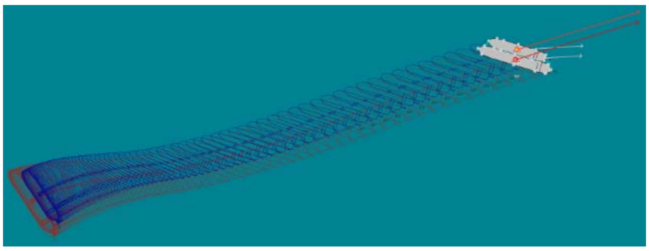


Figure 1. Example of simulation of the tankers involved in STS operation.

2 CHARACTERISTICS OF THE RESEARCH AREA

Transfer areas should be selected in safe sea areas. In coastal areas, these STS transfer areas will be agreed to by nearby coastal authorities and, as appropriate, in accordance with specific port or national regulations [1, 4, 5].

Various environmental conditions prevalent in the transfer location may impose restrictions on the STS operation. Some coastal state authorities may have regulations that would limit STS operations under adverse weather conditions [3].

On the grounds of the fact, that the research objective was to determinate total distance of the drift, for the both vessels, their loading conditions did not change during the simulation. Mother Vessel (MV) in the beginning of each scenario was in the position: $\varphi = 55°27.382'$ N, $\lambda = 018°10.796'$ E. For each of the analysed directions of the hydrometeorological conditions, receiving vessel position and orientation was changed. She was placed both on the lee side and on the windward side of the MV.

Comparison of all conducted scenarios of the simulation was presented in table 1.

Table 1. Detailed list of the conducted scenarios.

Scenario	True wind dir. [°]	Current dir. [°]	Position of Receiving Vessel (RV)
001	000	180	Starboard side of MV (windward side)
002	000	180	Port side of MV (lee side of MV)
003	238	058	Starboard side of MV (lee side)
004	238	058	Port side of MV (windward side)
005	058	238	Starboard side of MV (windward side)
006	058	238	Port side of MV (lee side)
007	328	148	Starboard side of MV
008	328	148	Port side of MV
009	148	328	Starboard side of MV
010	148	328	Port side of MV

According to the requirements [4], atmospheric condition during STS transfer operation reached maximum Beaufort force 4 [2]. This value represents wind speeds from 11 to 16 knots [8].

For that reason, as the speed limit of constant wind, average number was 13 knots. Changing hydrometeorological conditions followed regardless of the selected scenario. For each simulation, research was carried out based on the following procedure (table 2).

Wind wave direction consistent with the aggregated direction of the wind and current. Height of wind wave changed automatically for specified parameters of wind, according to *Phillips Spectrum*. Maximal recorded value of wind wave: height 1.1 m, length 20.4 m, period 3.6 s at medium-development stage.

Table 2. Detailed procedure of conducting simulations.

Simulation time [hh:mm]	Wind speed [kn]	Gusts [dir. deviation, speed, period]	Current speed [kn]	Action taken
00:00	0.0	n/a	0.0	Beginning of the simulation, sending and heaving up mooring lines.
00:20	1.0	±10°,	0.0	Linear increasing of wind speed (1 kn per 10 minutes). Increasing of wind speed in gusts.
00:30	2.0	0.5 kn,		
00:40	3.0	10 s		
00:50	4.0			
01:00	5.0	±10°,	0.0	
01:10	6.0	1.0 kn,		
01:20	7.0	10 s		
01:30	8.0			
01:40	9.0			
01:50	10.0			
02:00	11.0			
02:10	12.0			
02:20	13.0	±10°,		
02:30		1.5 kn,	0.1	Linear increasing of current speed (0.1 kn per 10 minutes).
02:40		10 s	0.2	
02:50			0.3	
03:00			0.4	
03:10			0.5	
03:30		±15°, 5.0 kn, 20 s		Increasing of gusts parameters.
08:00	End of the simulation.			

3 MODEL OF OIL TANKER INVOLVED IN STS OPERATION

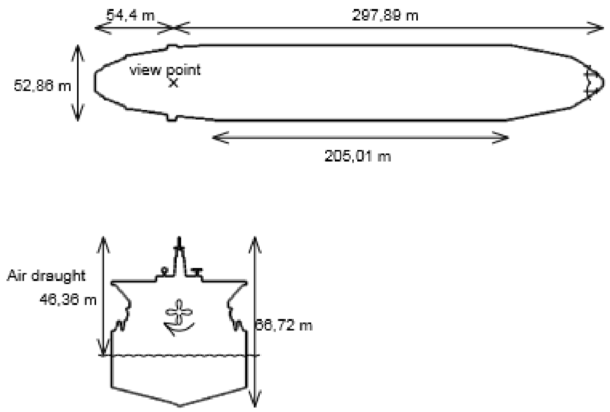
Conducted research contained ten simulations, realized according to project assumptions. Further scenarios differed from each other by the direction of the true wind, sea current and wind wave. Two tankers – represented as a Mother Vessel (MV) and Receiving Vessel (RV) – were used during all the simulations.

VLCC05L (MV) is powered by one diesel engine rating 19280 kW at 80 rpm and propelled by one fixed pitch propeller (FPP). Direction of propulsory revolution is right.

Model TANK16B (RV) is ballasted 115000 DWT tanker, based on *Americas Spirit* vessel. She is powered by one diesel engine rating 12711 kW at 105 rpm and propelled by one fixed pitch propeller. Direction of propulsor revolution is right.

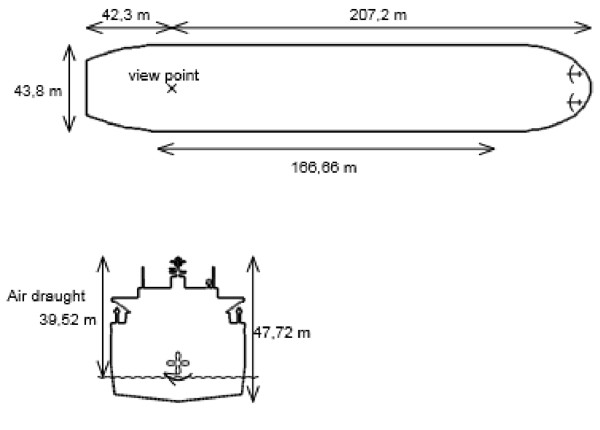
Characteristic and basic operating parameters of both models are presented in the table 3 and 4.

Table 3. Characteristic and the basic operating parameters of the model VLCC05L. *[9]*



Model	VLCC05L
Length overall [m]	315.0
Breadth [m]	47.2
Draft forward/aft [m]	18.45
Displacement [t]	226000
Type of Engine	Diesel 19280 kW
Propeller	FPP

Table 4. Characteristic and the basic operating parameters of the model TANK16B. *[10]*



Model	TANK16B
Length overall [m]	249.9
Breadth [m]	43.8
Draft forward/aft [m]	5.97/8.58
Displacement [t]	61320
Type of Engine	Diesel 12711 kW
Propeller	FPP

4 REQUIREMENTS & RECOMMENDATION

The oil transfer from one tanker to another is a subject to a strict regime of environmental and safety regulation, both though as international conventions MARPOL 73/78 and industry guidelines and requirements provided by the OCIMF (Oil Companies International Marine Forum). In the area where an STS operation is planned also the local regulation and requirements should be fulfilled.

The areas for STS transfer operations may be defined by the appropriate coastal State authorities. The size of transfer areas selected varies considerably and the space available for the transfer would have a direct relation to the type of manoeuvre that would be used for the STS operation. If both ships are intended to be underway, a relatively large transfer area would be required. Whereas if one ship is required to approach the other ship at anchor a much smaller overall area would be required [3].

In selecting the area for STS transfer, the following should be considered, in the absence of any applicable national legislation:

- the traffic density in the given area;
- the need for sufficient sea room and water depth required for manoeuvring during mooring and unmooring;
- the availability of safe anchorage with good holding ground;
- present and forecasted weather conditions;
- availability of weather reports for the areas;
- distance from shore logistical support;
- proximity to environmentally sensitive areas; and
- security threat [3].

Regulation 41 of the MARPOL convention required that any oil tanker involved in STS operations shall carry on board a Plan prescribing how to conduct STS operations. Each oil tanker's STS operations Plan shall be approved by the Administration [1].

The STS operations Plan shall be developed taking into account the information contained in the best practice guidelines for STS operations identified by the Organization. The STS operations Plan may be incorporated into an existing Safety Management System required by chapter IX of the International Convention for the Safety of Life at Sea, 1974, as amended [1].

And additional any oil tanker subject to this chapter and engaged in STS operations shall comply with its STS operations Plan [1].

The tankers compatibility is the essential factor to conduct an STS transfer operation. To ensure an STS transfer operation is conducted safely, reliably and efficiently, it is necessary to choose in proper way parameters of the tankers. All necessary ship's parameters, system, equipment with all limitations are presented in Q.88 form. This form is exchanged between tanker's operators on the first phase of planned operation.

Generally, tanker's operator for STS operation choice the ships with the different length, one large tanker called mother vessel or STBL ship to be lightered and the small tanker called receiving ship or daughter vessel. In many cases STS operation is performed by ships with the same or with almost the same length. These vessels of similar lengths involved in STS operations may require additional adjustment of the fore and aft positions of the ships for the purpose of offsetting the bridge wings.

To protect sides of the both vessel appropriate mooring equipment should be used, the most important is to use primary fenders, capable of absorbing the impact energy of berthing and wide enough to prevent contact between the ships should they roll while alongside one another. [2, 3, 4, 5]

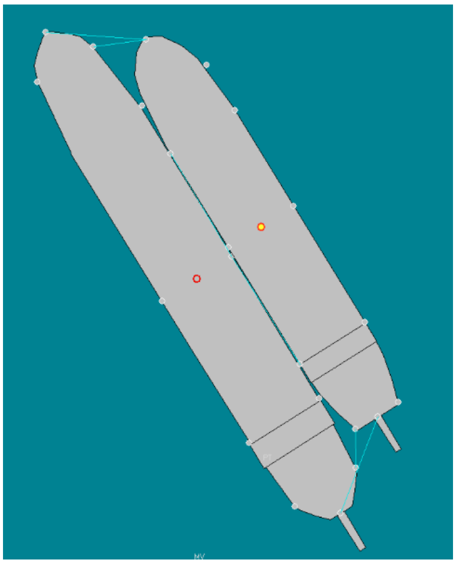


Figure 3. Typical mooring arrangement for the different size tankers in STS operation.

5 RESEARCH STUDIES

Main part of the conducted research depended on performing several simulations with the use of the representative vessel models, to determine distance of their drift during Ship-to-ship (STS) underway operation.

To carry out the research studies Kongsberg Navigational Manoeuvring Simulator Polaris was used. Devices selected to analyse apply complex mathematical models. As a result, it is possible to perform the detailed mapping of reaction and behaviour of the ship and its surroundings according to the phenomena observed in real conditions.

The Polaris simulator was repeatedly used in numerous scientific studies, research work and expertise. Besides the objectives of researches, the devices were used at regularly conducted specialized courses and didactic classes for future watch-keeping officers, senior merchant navy officers and Deep-Sea captains. The simulator is accredited by the classification society DNV (Det Norske Veritas) and has certificates confirming its ability to perform certified specialist courses in accordance with the requirements of the International Maritime Organization – IMO.

According to the research assumptions, each of the simulation in this study held with the use of equivalent tanker models. Sea area, on which research was conducted, was excluded of vessel's traffic, as well as free of any aids of navigation and hydrotechnical structures. Each of the simulation depended on the orientation of the vessels on the same initial course, sending and heaving up mooring lines, Afterwards, gradual deterioration of the hydrometeorological conditions as per simulation scheme. Each of the scenarios assumed equal research duration totalled 8 hours, which represents average STS cargo transfer operation [2, 4].

6 SIMULATION DATA PROCESSING

The data recorded by the simulator during executing research, was stored in intervals from 2 to 12 seconds, depending on the dynamic changes of ship's parameters. During simulation, following parameters for both vessels (RV and MV) and environment were recorded:
- Simulation time,
- Latitude,
- Longitude,
- Heading,
- Course thru water,
- Course,
- Speed,
- Rate of turn,
- Roll,
- Surge,
- Surge thru water,
- Sway,
- Sway thru water,
- Drift angle thru water.

To present drift distance for both vessels as two-dimensional chart, it was necessary to convert geographic coordinates into grid coordinates. To that end, Gauss–Krüger projection was used for the reference ellipsoid WGS-84, as per following formulas [6, 7]:

$$x = k \cdot R \cdot \left[\frac{S(B)}{R} + \frac{(\Delta L)^2}{2} \cdot \sin B \cdot \cos B + \frac{(\Delta L)^4}{24} \cdot \sin B \cdot \cos^3(B) \cdot \left(5 - t^2 + 9 \cdot \eta^2 + 4 \cdot \eta^4\right) \right. \quad (1)$$

$$\left. \cdot \frac{(\Delta L)^6}{720} \cdot \sin(B) \cdot \cos^5(B) \cdot \left(61 - 58 \cdot t^2 + t^4 + 270 \cdot \eta^2 - 330 \cdot \eta^2 \cdot t^2 + 445 \cdot \eta^4\right) \right]$$

$$y = R \cdot \left[\Delta L \cdot \cos(B) + \frac{(\Delta L)^3}{6} \cdot \cos^3(B) \cdot \left(1 - t^2 + \eta^2\right) + \eta^4) \cdot \frac{(\Delta L)^5}{120} \cdot \right. \quad (2)$$

$$\left. \cos^5(B) \cdot \left(5 - 18 \cdot t^2 + t^4 + 14 \cdot \eta^2 - 58 \cdot \eta^2 \cdot t^2 + 13 \cdot \eta\right) \right]$$

where:
B, L– measured ellipsoidal coordinates,
R – radius of curvate,
S(B) – distance from equator to the point at the specified coordinates [m],
L∆ – distance of point from central meridian [m],
k = 999923,0 – scale factor.

Calculations for the central meridian 018° was performed pursuant to the Polish National Geodetic Coordinate System 2000 (PL-2000). Total drift of vessels was calculated through determination distance between intermediate, following coordinates of ships. Remaining projection parameters for grid coordinates in PL-2000 system were [6, 7]:

$$t = tan(B), \quad (3)$$

$$\eta = \frac{e^2 \cdot cos^2(B)}{1 - e^2}, \quad (4)$$

where:
e – eccentricity of ellipsoid,
η – orientation angle of ellipse distortion.

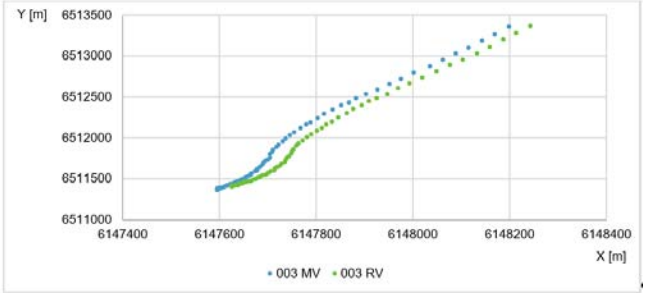


Figure 4. Presentation of MV and RV positions after 3.5 h of simulation.

7 SUMMARY

The simulation research allowed to assess parameters of tanker's drift during STS operation and required sea space to fulfil all the safety requirements.

Results of simulation show the tanker's drift pattern due to different weather condition are presented in table 5.

Table 5. Drift parameters of MV in relation to scenario number.

time [hh:mm] scenario no.	total drift [NM]	wind dir. [°]	position of RV	profit [m]	profit [NM]	profit [%]
001	7.87	000	windward	0.0	0.00	0.00
002	6.17		leeward	3143.5	1.70	21.58
003	5.90	238	leeward	3483.2	1.88	24.19
004	7.78		windward	0.0	0.00	0.00
005	7.46	058	windward	0.0	0.00	0.00
006	6.05		leeward	2619.1	1.41	18.95
007	6.65	328	from bow	0.0	0.00	0.00
008	6.22		from bow	798.6	0.43	6.49
009	5.76	148	from stern	0.0	0.00	0.00
010	5.49		from stern	499.1	0.27	4.68

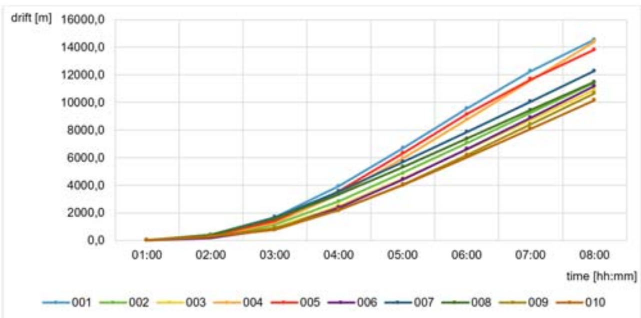


Figure 5. Total drift of MV in relation to scenario number.

Drift patterns (001, 004 and 005), where Receiving Vessel is on the windward side in real conditions is up to 25% greater than, when the RV is on the lee side. That is why, during STS operation, Mother Vessel (MV) should protect and give a shelter for RV – especially, on initial stage, when she has maximum freeboard. In simulations 001, 004 and 005 observed drift distances, were relevant (from 1.41 to 1.88 NM) greater than, when RV was on lee side.

Additional, it should be mentioned about the disadvantages of simulation research that tanker's models during all simulations didn't change loading condition. This fact caused that total drifts during real conditions will be greater than these during simulation's research. The dynamic changing (increased) freeboard from windward side of the Mother Vessel for sure increased drifting speed of both tankers and change the final pattern of the drift in real condition.

The simulation research may be used as a one of the tools for planning process of the STS operations in the defined sea area, taking in to account tanker's parameters.

In order to obtain full overview, it is necessary to carried out in the same hydrometeorological conditions additional simulations, taking into account another loading condition of Receiving Vessel.

REFERENCES

[1] IMO, MARPOL 73/78 Annex I, Chapter 8: "Prevention of Pollution during Transfer of Oil Cargo between Oil Tankers at Sea", Regulations 40, 41 and 42 , London 2014
[2] Wilczyński P., *STS transfer plan for m/t ICARUS III*, Gdansk 2014
[3] ABS, *STS Transfer operations Plan for compliance with MARPOL Annex I , Chapter 8 revision 3*.
[4] CDI, ICS, OCIMF & SIGTTO, *Ship to Ship Transfer Guide* first edition, Edinburgh: Whitersby Publishing Group Ltd., 2013.
[5] ICS, OCIMF and IAPH, I*nternational Safety Guide for Oil Tankers and Terminals*, ISGOTT 5th Edition., London: Withersby, 2006.
[6] Deakin R.E., Hunter M.N., Karney C.F.F., *The Gauss-Krüger Projection*, Proceedings of the 23rd Victorian Regional Survey Conference, Warrnambool 2010.
[7] Specht C., Szot T., i Specht M., *The Research of Accuracy of the Personal GPS Receivers in Dynamic Measurements*, Technika Transportu Szynowego, no. 10, p. 2547–2555, 2013 (in Polish).
[8] Cornish M., Ives E., Reeds Maritime Meteorology, 3rd Edition, Adlard Coles Nautical, London 2014.
[9] Kongsberg Maritime, Description of Ship Model TANK16B Version 3, Doc.No.TANK16B ver.3 / 24-Jul-2015, 2015.
[10] Kongsberg Maritime, Description of Ship Model VLCC05L Version 15, Doc.No.VLCC05L ver.15 / 24-Jul-2015, 2015.