Journal of the Korean Society of Marine Environment & Safety
Research Paper
Vol. 25, No. 3, pp. 313-319, May 31, 2019, ISSN 1229-3431(Print) / ISSN 2287-3341(Online) https://doi.org/10.7837/kosomes.2019.25.3.313

A Study on the Allowable Range of Overhanging Berthing at the Port of Ulsan

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Abstract : *As vessels become larger and competition between ports intensifies, there has been an increase in the number of cases where vessels that exceed the available berths are berthed at the pier. Therefore, there has been an increase in the number of cases in which the bow or stern of a ship is projected and moored. The risk of overhanging berthing is that mooring safety can be compromised because it is not possible to connect the bow and stern mooring line to the ship properly. In addition, collision accidents may occur between moving vessels if the view of a vessel moving in the port is obstructed. Therefore, in this study, the simulation of mooring safety was performed according to the overhanging range in Piers No. 6 and 7 in Ulsan's main port to propose the overhanging limit and operational standards according to each ship. As a result of the assessment, 30,000 DWT bulkers are able to overhang up to 0.75B, and 50,000 DWT bulkers can overhang up to 0.50B. The results of this study are expected to be used as basic data for setting the allowable overhang limit, as well as clear usage criteria for safe unloading operations.*

Key Words : *Overhanging berthing, Allowable range, Mooring safety assessment, Mooring system, Port of Ulsan*

1. Introduction

According to the International Trade Forum in 2015, ship sizes of major vessels are increasing, such as for container ships, bulk carriers, and oil tankers (International Transport Forum, 2015). Therefore, as ships become larger, mooring systems should also be prepared for this trend. However, the maintenance of the pier system is time-consuming and costly, so pier growth is not keeping pace with ship sizes.

As a result, the number of berthing vessels that are able to berth on a general berth is also growing, and there has been an increase in the number of cases in which a bow or stern of a ship is moored while overhanging. In addition, as the competition among ports is intensifying, there has been an increasing trend where ships larger than berthing vessels according to the basic plans of the port are docked at a small wharf.

If the vessel is moored in overhanging position at the wharf, mooring safety may be compromised due to failure to properly attach the bow and stern mooring ropes to the berth on the ship. Accordingly, when the weather deteriorates, a mooring line may be broken, and an unloading accident may occur due to an increase in sway of the ship. In addition, it is difficult to obtain visibility of a moving ship due to the ship projecting onto the berth. Thus, collision accidents between ships may occur.

The results of research into mooring safety are as follows. Cho et al. (2006) numerically calculated the motion of a ship due to a tsunami impact, and calculated the load acting on the ship and the mooring system due to the tsunami. Kwak et al. (2014) proposed a method to analyze the motion of a ship according to the wave period, and to calculate the loading limit wave height. R. Santos (2014) conducted mooring safety simulations in order to minimize vessel hull motion and improve terminal operations and security conditions at harbor terminals exposed to external waters. Cho (2017) analyzed the behavior of moored vessels on a training ship in a pier. In this way, studies are being conducted to estimate the level of mooring safety, ship's motion, and the loading limits of wave height according to various environmental externals such as wind, waves, long-period waves, and tsunamis both at home and abroad. Also, there are many studies that have been done to improve port operation rates by analyzing mooring reduction factors. However, little research has been done to evaluate the mooring safety of vessels that are overhanging from the quayside, or to derive operational plans.

This study investigated the current status of the vessels in Ulsan Harbor during the last five years. Ships for berthing and ships used excessively were selected. The simulated mooring safety assessment was performed according to the overhanging length of the ship

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when the ship was in overhanging position. Accordingly, the overhanging limit range and operating standards were proposed.

2. Selection of target pier for simulation

2.1 Selection of target pier

In order to simulate the mooring safety assessment according to the overhang, we selected the No. 6 and No. 7 piers of Ulsan port in Korea.

Fig. 1 is the paper chart of Pier No. 6 and No.7 in Ulsan Harbor. The No. 6 pier in Ulsan Port is made up of 4 berths, and wharf No. 4 at the end of the berth is designated for 30,000 DWT vessels, as shown in Table 1. The No. 7 berth consists of one berth, and 20,000 DWT bulker are designated for berthing there.

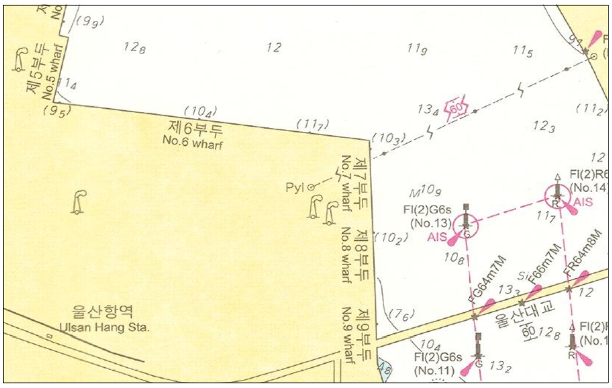

Fig. 1. Chart of pier No.6, No.7 at Ulsan's main port.

Table 1. Specifications of target pier

Category	Ship's type	Berth ability (DWT)	Length of berth (m)	Depth (m)
Pier No. 6 No. 4 wharf	Bulker	30,000	240.0	11.7
Pier No. 7 No. 1 wharf		20,000	210.0	10.2

2.2 Analysis of the port entrance of the target pier

In order to select the target vessels, we analyzed the arrival of vessels by size (GT) for five years (2013 to 2017).

Fig. 2 is the port entrance performance according to the gross tonnage of the vessels at pier No. 6, wharf No. 4 for 5 years. The results of the DWT survey of the ships in port are as follows. Of the vessels entering wharf No. 4 in Pier No. 6, 78 vessels exceed 30,000 DWT, the berth capacity, were analyzed at 33 % of the total.

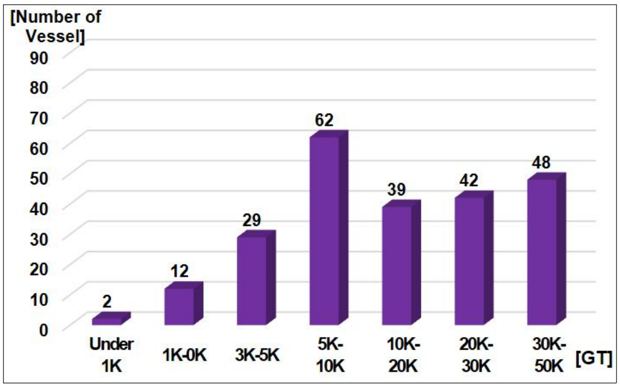

Fig. 2. Analysis of port entrance of pier No. 6, whart No. 4.

Fig. 3 is the port entrance performance according to the gross tonnage of the vessels at pier No. 7, wharf No. 1 for 5 years. The results of the DWT survey of the ships in port are as follows. Of the vessels entering pier No. 7, wharf No. 1, 96 vessels exceed 20,000 DWT, which is the berth capacity, and were analyzed at 32 % of the total.

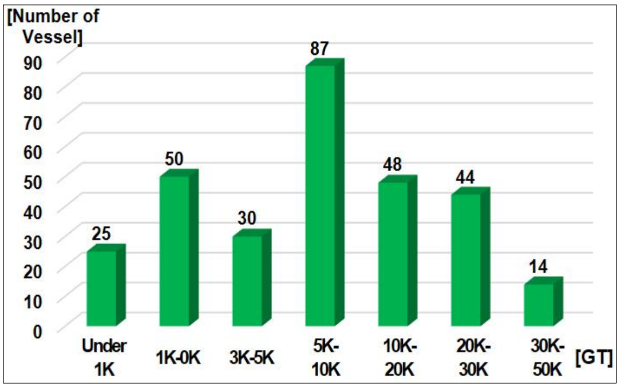

Fig. 3. Analysis of port entrance of pier No. 7, wharf No. 1.

As a result of the field visit survey, Fig. 4, there were often cases where the vessel was moored at the berth.

Fig. 4. Photo of overhanging vessel in pier No. 6, wharf No. 4.

3. Simulation for overhanging berthing

This simulation was performed using OPTI-MOOR SW (Ver. 6.4.1) of TTI (Tension Technology International). OPTI-MOOR is a linear analysis program, a simple and accurate modeling application compared to other mooring safety analysis programs. Therefore, it is an analytical program that is typically used in domestic maritime traffic safety diagnosis, as well as simulations of domestic and overseas mooring safety evaluations.

3.1 Target ship Selection

The cargoes of Ulsan Harbor No. 6 and No. 7 berth are the same as general cargoes, and the berthing capacities are 30,000 DWT and 20,000 DWT, respectively. The mooring safety simulation of was carried out by choosing Pier No. 6, which has bigger berths. In addition, the target vessels selected were the 30,000 DWT bulker, corresponding to the berthing capacity vessel in the port's basic plan of wharf No. 4., and the 50,000 DWT bulker, which is berthed frequently.

The major specifications of the 30,000 DWT and 50,000 DWT bulker, which are subject to mooring safety assessment at the target pier, are shown in Table. 2. The main specifications of the ship were selected considering the specifications of ships with history of actual arrivals. The mooring direction was set to the port side, which is the position when entering. The loading status of the cargo was set to ballast condition, considered the least efficient condition for ensuring mooring safety.

Table 2. Specifications of target vessel

Category		30,000 DWT	50,000 DWT
LOA (m)		192.9	213.4
LBP (m)		182.0	203.6
Breadth (m)		27.8	31.0
Depth (m)		15.5	19.0
Draft (m)	Fore	7.5	7.6
	Aft	8.5	8.8
Projected Windage Areas (m²)	Transverse	850	1,000
	Lateral	2,930	3,380

3.2 Modeling of mooring conditions

Table 3 shows the arrangement and capacity of the mooring system, including the dimensions of the target pier, bollards, and fenders. The model is based on actual pier drawings of the target pier.

There are 11 bollards installed on the target pier, and all of them are 70 tons in capacity. The spacing between each mooring line was analyzed as 20.9 to 23.2 m.

There are a total of 21 fenders installed on the target pier, being BP Type (800H × 2,000L). These were analyzed to be installed at intervals of about 9.3 to 11.6 m.

Fig. 5 is the specifications of a mooring arrangement when the stern of a 30,000 DWT, 50,000 DWT bulker is moored at the end of the pier.

Table 3. Specifications of mooring condition

Category			Pier No.6, wharf No.4
Length of Pier (m)			240
Line	Fore	Head	L1, L2, L3, L4
		Spring	L5, L6
	Aft	Spring	L7, L8
		Stern	L9, L10, L11, L12
	Type / Dia.(mm)		Nylon (New) / 52
	M.B.L (t) / S.W.L (t)		52.0 / 26.0
Bollard	Fore		B1, B2
	Aft		B3, B4
	Interval (m)		20.9 ~ 23.2
	Max. Load (t)		70
Fender	Type		BP 800H × 2000L
	Interval (m)		9.3 ~ 11.6
	Max. Load (t)		68

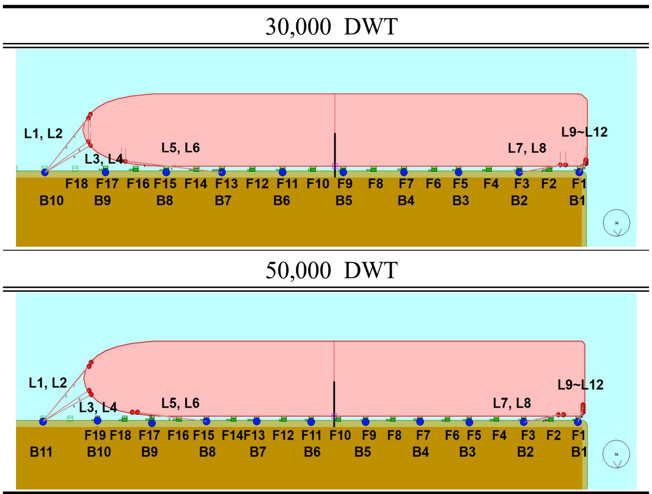

Fig. 5. Mooring Arrangement of each vessel.

In order to determine a ship's overhanging limit, the overhanging condition of the aft part of the ship was modeled to 0.25, 0.50, and 0.75 scale of breadth. Table 4 shows the overhanging length according to the size of the ship. Fig. 6 is in the arrangement of the 0.75B overhanging mooring of a 30,000 DWT bulker.

Table 4. Overhanging length according to the size of the ship

Size	Breadth (m)	0.25B	0.50B	0.75B
30,000 DWT	27.8	6.95	13.90	20.85
50,000 DWT	31.0	7.75	15.50	23.25

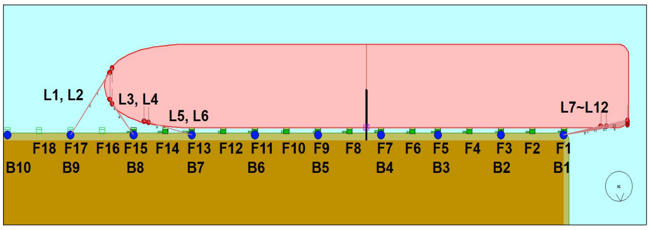

Fig. 6. 30,000 DWT bulker which is overhanging by 0.75B.

3.3 Modeling of environmental external force

For the sake of simulating mooring safety according to the overhanging state, the wind speed was set to 20 kts as the wind speed limit for safe unloading operation in the case of overhanging, not normal mooring situations, and the wind direction was set in all directions. The current of the target pier flows almost parallel to the direction of the pier.

Near the target pier, the strongest flood currents were surveyed at 0.1 to 0.2 kts in the NNE direction. The strongest ebb current was in the SSW direction, flowing at 0.1 to 0.2 kts. Therefore, the strongest flood currents, which were evaluated so as to influence the mooring safety of the target piers, were selected for the simulation.

The height of the wave was set to 0.5 m in consideration of the wave height for loading limits according to ship size for Harbor Design Criteria in Korea.

3.4 Evaluation factors for simulation

Ship motion occurs when external forces such as waves, wind, and current act on a vibration system composed of a hull and mooring system. The evaluation factors for this simulation are the tension acting on the mooring line, the load acting on the bollard, and the reaction force of the fender. In addition, safety evaluations during loading are carried out in order to evaluate whether or not 6-DOF in motion for cargo handling operations are possible by an external force. In general, the mooring system will derive the mooring limit of the ship considering the safety margin.

4. The results of evaluation on a 30,000 DWT bulker

4.1 Tension of the mooring line

As a result of the analysis of the max. tension of the mooring line according to overhang, the max. load was applied to the fore spring line when mooring at the end of the pier. However, all lines were evaluated at less than 50 % of M.B.L, which is the S.W.L of the mooring rope. It was concluded that tension on the mooring line under environmental conditions is safe.

Fig. 7 shows the tension on the mooring lines according to the overhanging length. When overhanging by 0.75B, the max. load was applied to the headlines, and the max. load was 21.2 tons, which was estimated to be about 40.8 % of the M.B.L and about 81.5 % of the S.W.L.

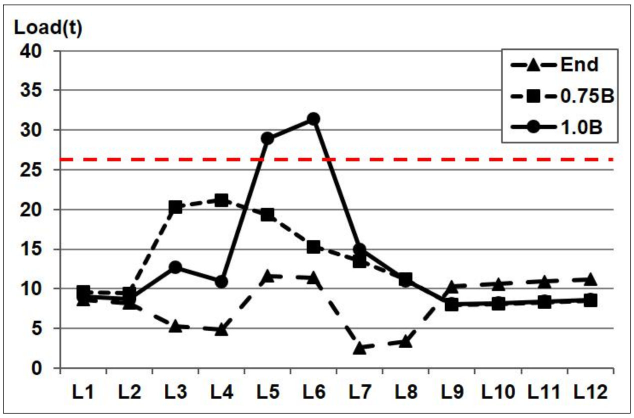

Fig. 7. Tension of mooring lines on a 30,000 DWT bulker.

4.2 Load of the bollard

Table 5 is the load on the bollard according to the overhanging length. The max. load when moored at the end of the pier is used in the stern line. At this time, it was analyzed that a max. load of about 42.9 tons (61.3 %) was applied. When overhanging by 0.75B, the max. load on the bollard was applied to the stern line, and the max. load was 54.1 tons (77.3 %).

Table 5. Load of bollards on a 30,000 DWT bulker

Cate-gory	Allowable Load (t)	End of pier		0.75B	
		Line	Load (t)	Line	Load (t)
B1	70	Stern	42.9	Stern	54.1
B2	70	Stern Spring	6.1	-	-
B7	70	Head Spring	22.6	-	-
B8	70	-	-	Head Spring	33.1
B9	70	-	-	Head Spring	41.4
B10	70	Head	26.7	Head	19.1

4.3 Reaction force of the fender

Fig. 8 shows the reaction force of fenders according to the overhanging length. The max. reaction force when moored at the end of the pier is used on the bow. At this time, it was analyzed that a max. load of about 29.0 tons (42.6 %) was applied. When overhanging by 0.75B, the max. load of the fender was applied to the bow, and the max. load was 47.0 tons (69.1 %).

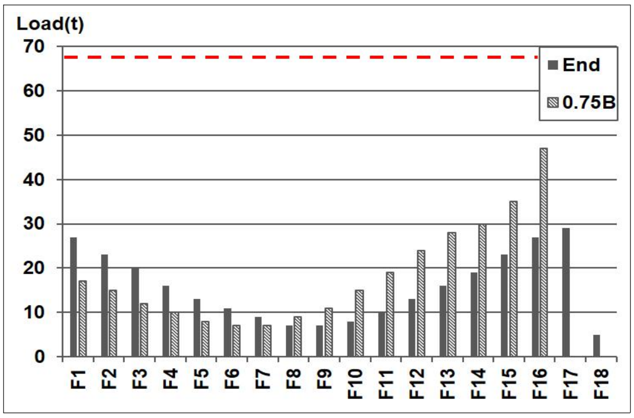

Fig. 8. Reaction force of fenders on a 30,000 DWT bulker.

4.4 Ship's motion in 6-DOF

As per the Harbor Design Criteria, the permissible motion for each 6-DOF is specified based on ship type, and the unloading of equipment. Table 6 shows the 6-DOF motion statistics of the hull and the motion amplitude for the relative motion of hull-specific parts in order to evaluate whether the loading and unloading work done on the ship is within the allowable range due to external fluctuations.

Since overhanging berthing differs from the normal method, they must be moored in various ways to reduce the amount of ship's motion. When the stern position is at the end of the pier, all of the motion fluctuations are evaluated to be safely within the allowable value. When the stern is overhanging by 0.75B, the fore spring line is divided into two mooring lines and is moored, decreasing the value of surge. When the stern is overhanging by 1.0B, it was analyzed that the value of sway exceeds the allowable fluctuation regardless of the mooring line arrangement.

Table 6. Motion for 6-DOF on a 30,000 DWT bulker

Ship Type	Loading Device	Surge (m)	Sway (m)	Heave (m)	Yaw (°)	Pitch (°)	Roll (°)
Bulk Carrier	Crane Elevator	2.0	1.0	1.0	6	2	2
End	Motion	1.79	0.13	0.04	0.1	0.1	0.0
	Safety	○	○	○	○	○	○
0.75B	Motion	1.44	0.95	0.04	0.6	0.1	0.0
	Safety	○	○	○	○	○	○
1.0B	Motion	1.94	1.32	0.04	0.9	0.1	0.0
	Safety	○	×	○	○	○	○

4.5 Overall results

Table 7 shows the results of the mooring safety assessment when mooring a 30,000 DWT bulker in pier No.6, wharf No.4. When the stern is overhanging by 0.75B, it is derived that the value of sway is 0.95 m, approaching the limit value of 1.0 m. However, it was analyzed that the mooring line and the unloading criteria exceeded the allowable limit when the stern was overhanging by 1.0B. Therefore, it is determined that overhanging mooring is possible up to 0.75B (20.8 m) under a wind speed of 20 kts.

Table 7. Result of mooring safety assessment on a 30,000 DWT bulker

Category	Line		Bollard		Fender		Motion
	Max. Load (t)	Rate (%)	Max. Load (t)	Rate (%)	Max. Load (t)	Rate (%)	Sway (m)
Allowable Value	26.0	50	70	100	68	100	1.0
End	11.6	22	42.9	61	29	42.6	0.13
0.75B	21.2	41	54.1	77	47	69.1	0.95
1.0B	31.4	61	60.3	86	47	69.1	1.32

5. The results of evaluation on a 50,000 DWT bulker

5.1 Tension of the mooring line

As a result of the analysis of the max. tension of the mooring lines according to degree of overhang, the max. load was applied to the stern line when mooring at the end of the pier. However, all lines were evaluated at less than 50 % of M.B.L, which is the S.W.L of the mooring rope. It was evaluated that the tension on the mooring lines under environmental conditions is safe.

Fig. 9 shows the tension of the mooring lines according to overhanging length. When overhanging by 0.50B, the max. load was applied to the stern spring lines, and the max. load was 21.5 tons, which was estimated to be about 41.3 % of the M.B.L and about 82.7 % of the S.W.L.

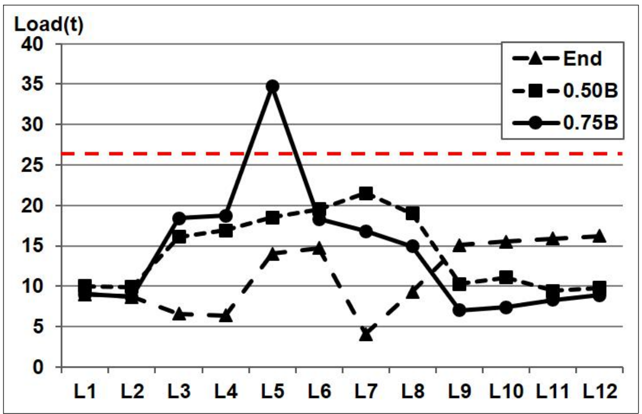

Fig. 9. Tension of mooring lines on a 50,000 DWT bulker.

5.2 Load of the bollard

Table 8 is the load of the bollard according to overhanging length. The max. load when moored at the end of the pier is used in the stern line. At this time, it was analyzed that a max. load of about 62.6 tons (89.4 %) was applied. When overhanging by 0.50B, the max. load of the bollard was applied to the stern line, being 56.6 tons (80.9 %).

Table 8. Load of bollards on a 50,000 DWT bulker

Cate-gory	Allowable Load (t)	End of pier		0.75B	
		Line	Load (t)	Line	Load (t)
B1	70	Stern	62.6	Stern	56.5
B2	70	Stern Spring	13.2	Stern	21.2
B8	70	Head Spring	28.7	Head Spring	38.0
B9	70	-	-	Head Spring	33.0
B10	70	-	-	Head	19.9
B11	70	Head	30.3	-	-

5.3 Reaction force of the fender

Fig. 10 shows the reaction force of fenders according to the overhanging length. The max. reaction force when moored at the end of the pier is used on the bow. At this time, it was analyzed that a max. load of about 30.0 tons (44.1 %) was applied. When overhanging by 0.50B, the max. load of the fender was applied to the bow, being 46.0 tons (67.6 %).

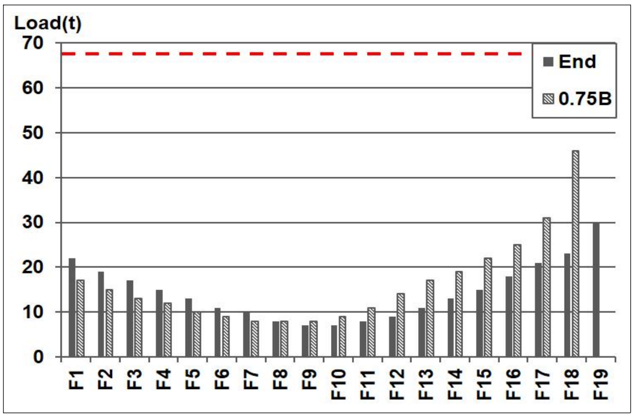

Fig. 10. Reaction force of fenders on a 50,000 DWT bulker.

5.4 Ship's motion in 6-DOF

Table 9 shows the 6-DOF motion statistics when the stern position is at the end of the pier. All of the motion fluctuations are evaluated safely within the allowable value. When the stern is overhanging by 0.50B, the fore spring line is divided into two mooring lines and the value of surge is decreased. When the stern overhangs by 0.75B, it was analyzed that the value of sway exceeds the allowable fluctuation regardless of the mooring line arrangement.

Table 9. Motion for 6-DOF on a 50,000 DWT bulker

Ship Type	Loading Device	Surge (m)	Sway (m)	Heave (m)	Yaw (°)	Pitch (°)	Roll (°)
Bulk Carrier	Crane Elevator	2.0	1.0	1.0	6	2	2
End	Motion	1.79	0.34	0.04	0.2	0.1	0.0
	Safety	○	○	○	○	○	○
0.50B	Motion	1.23	0.96	0.04	0.5	0.1	0.0
	Safety	○	○	○	○	○	○
0.75B	Motion	2.79	2.51	0.04	1.5	0.1	0.0
	Safety	×	×	○	○	○	○

5.5 Overall results

Table 10 shows the results of the mooring safety evaluation when mooring a 50,000 DWT bulker in pier No.6, wharf No.4. When the stern is overhanging by 0.50B, it is derived that the value of sway is 0.96 m, approaching the upper limit value of 1.0 m. However, it was analyzed that the mooring line and the unloading criteria exceeded the allowable limit when the stern was overhanging by 0.75B. Therefore, it is analyzed that overhanging mooring is possible up to 0.50B (15.5 m) under a wind speed 20 kts.

Table 10. Result of mooring safety assessment on a 50,000 DWT bulker

Category	Line		Bollard		Fender		Motion
	Max. Load (t)	Rate (%)	Max. Load (t)	Rate (%)	Max. Load (t)	Rate (%)	Sway (m)
Allowable Value	26.0	50	70	100	68	100	1.0
End	16.2	31	62.6	89	30	44.1	0.34
0.50B	21.5	42	56.5	81	46	67.6	0.96
0.75B	34.7	67	61.4	88	47	69.1	2.51

6. Conclusion

As vessels become larger and competition intensifies among ports, the number of vessels exceeding the number of berths capable of berthing is rising. Therefore, in this study, mooring safety simulations were carried out according to the overhanging range by selecting pier No. 6 at Ulsan Port, and the following conclusions were drawn.

(1) As per the results of the mooring safety assessment when mooring a 30,000 DWT bulker, when the stern is overhanging by 0.75B, it is derived that the value of sway is 0.95 m, approaching the upper limit value of 1.0 m.
(2) As per the results of the mooring safety assessment when mooring a 50,000 DWT bulker, when the stern is overhanging by 0.50B, it is derived that the value of sway is 0.96 m, approaching the upper limit value of 1.0 m.
(3) It is suggested that the allowable range of overhanging berths should be presented on the basis of the breadth, even if the same tonnage is available because of ship specification variance.

The results of this study can be used as a set of basic data to propose criteria for the allowable margin of overhang per port. In order to prevent accidents involving overhanging moored vessels, it is held that overhanging simulations should be performed in consideration of the characteristics of the target pier and ship.

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Received : 2019. 05. 11.
Revised : 2019. 05. 27.
Accepted : 2019. 05. 28.