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A Study on Determining the Priority of Supervising Mooring Line while 125K LNG Moss Type Discharging at Pyeong Taek Gas Terminal

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Abstract : *The Port of Pyeong Taek is located on the west coast, meaning that the difference between the rise and fall of tide is great (flood tide 1.8 to 2.9 knots, ebb tide 1.6 to 2.9 knots). Due to mainly N~NW'ly strong winds & high waves during winter, navigating as well as loading & discharging vessels must focus on cargo handling. The strong tidal and wind forces in the Port of Pyeong Taek can push an LNG carrier away from its berth, which will end up causing forced disconnection between the vessel's cargo line and shore-side loading arm. The primary consequence of this disconnection will be LNG leakage, which will lead to tremendous physical damage to the hull and shore-side equipment. In this study, the 125K LNG Moss Type ship docked at No. 1 Pier of the Pyeong Taek is observed, and the tension of the mooring line during cargo handling is calculated using a combination of wind and waves to determine effective mooring line and mooring line priority management. As a result if the wind direction is 90° to the left and right of the bow, it was found that line monitoring should be performed bearing special attention to the Fore Spring Line, Fore Breast Line, and Aft Spring Line.*

Key Words : *Tidal & Wind force, Cargo handling, Mooring line, LNG carrier, Line priority*

1. Introduction

The Port of Pyeong Taek is located on the west coast of Korea, causing a great difference between the rise and fall of the tide (flood tidal current 1.8 to 2.9 knots, ebb tidal current 1.6 to 2.9 knots) (West coast of Korea Pilot, 2012). Particularly in winter, strong wind blows from the north to northwest and causes high tides, causing difficulty for vessels underway. Not only underway vessels but also vessels in loading operations while making fast to shore are very cautions in these conditions. The Port of Pyeong Taek's wind, tide, and current are much stronger than that found in Southeast Asia and the middle east, which are the two main ports of loading for LNG (Liquefied Natural Gas). Thus, LNG vessels keep a 3 person interval watch on the mooring lines during discharging operations. For LNG vessels discharging at the Port of Pyeong Taek, the operation will be halted when the wind is 25 knots, and when it is 35 knots or more, the loading arm is separated and preparations will be made to take the ship off the pier (Pyeong Taek Port Information and Terminal Regulations, 2013).

Due to the wind and current, LNG vessels may suddenly fall away from the shore, which could cause cargo leakage. If so, the vessel or the shore connections and equipment are liable to sustain great damage (LNG Carriers, 2008). Thus, if the wind and tide is kept in consideration during watch keeping to prejudge which of the mooring lines are highly tensioned, extra supervision can be afforded those lines. In this way, accidents involving vessels coming off of the pier can be prevented.

Cho (2017)'s improved methods of using moorage systems derived via the movement analysis of a moored training ship is one of the precedents for researchers on the movement of moored vessels. In addition, Kubo et al. (1993; 1995) suggested a simplified equation that can calculate the unloading rate along with proof that wave height in consideration of the moored ship's movement and the long period wave is caused by extra vibration.

The purpose of this study is to determine effective methods of mooring line management and mooring line care priority for the 125K Moss Type LNG vessel docked and unloading at Pier no. 1 of Pyeong Taek Port, based on calculations of the tension on mooring lines using a combination of wind & wave.

2. Calculation conditions & methods

We can think of using motion observation data or calculation results through the motion simulation data in order to evaluate

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moored ship motion, but in the former case, it is difficult to apply in reality due to a general lack of data. Thus, in this study, the latter method was chosen. That is, to motion simulate under a variety of conditions (external force, ship body shape and mooring conditions) and carry out statistical analysis on ship motion, line tension, and time series analysis pertaining to fender deformation.

Also, based on these probability distributions and the correspondent on the limit value of unloading or mooring, we can calculate the movement amount limit, exceedable probability, load limitation of mooring, and the probability distribution of the fender's ultimate deformation, during unloading (Technical Note of the Port & Harbour Research Institute Ministry of Transport Japan No. 956, 2000). Also, this study is carried out based on the data of the Technical Note of the Port & Harbour Research Institute Ministry of Transport Japan.

During winter in the Port of Pyeong Taek, when the weather is rough, mainly northwesterly wind blows. However, at times, northern wind also blows (West Coast of Korea Pilot, 2012). In addition, the port is open toward the northwest, with the rest is surrounded by mountains or land, as shown in Fig. 1. This displays that the impact of wind and wave from any other direction but the northwest is relatively limited. The calculation conditions in this study were derived from the corresponding ship's GA (General Arrangement), displacement curve, mooring arrangement, fender specifications, and so on (HMM, Hyundai Utopia Finished plans, 1994). These were set as shown in Fig. 2, Table 1 & 2 (HMM, Hyundai Utopia Ship/Shore Compatibility, 1994). 18 mooring lines were set in total including the head line, spring line, and stern line.

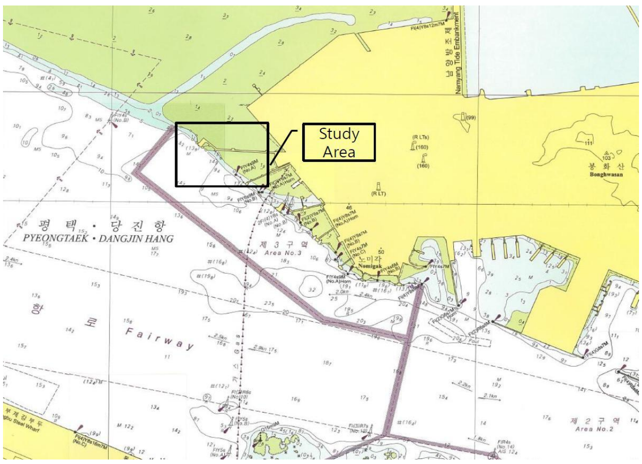


Fig. 1. Port of Pyeong Taek.

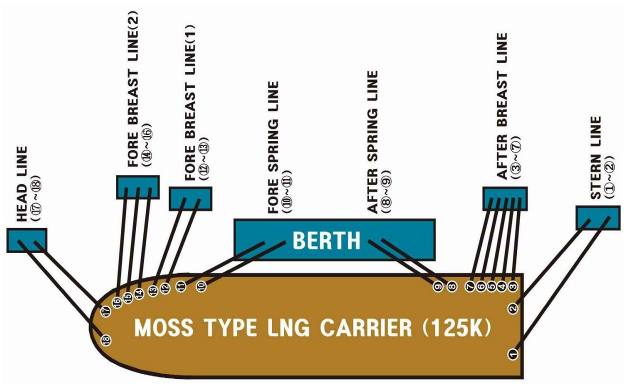


Fig. 2. Mooring Layout of No.1 Pyeong Taek berth.

Table 1. Conditions of calculation

Ship's particular	LBP: 260.0 m, Bmld: 47.20 m, Dmld: 26.50 m, draft: 9.80 m
Displacement & Cb	Displacement: 82022 ton, Cb: 0.67
Wind load area	front 1,670 m^2, side 7,486 m^2
Wire rope	42 Φ (6 × 37 IWRC) × 275 m × 22 sets, MBL: 124 ton with 65 Φ × 11 m length nylon tail rope × MBL 155 ton
Wave height wind direction wind velocity	Wave height 1m, wind velocity 10 m/s. Wave direction was set as 60° (30° interval) from bow to port. Wind direction was set in 30° interval in all bearings.

Table 2. Fender specifications

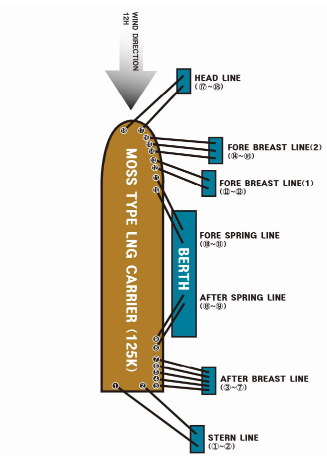
Type	Unit	CELL (2250H)
Number	pc	4
Size (L × H)	m	4.5 × 8.2
Energy absorption	ton.m	576
Reaction force	ton	524
Face pressure	t/m^2	13.67
Max. berthing speed	cm/sec	20
Operational berthing speed	cm/sec	10

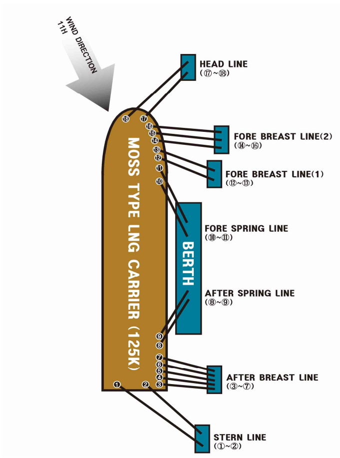
3. Results of calculation

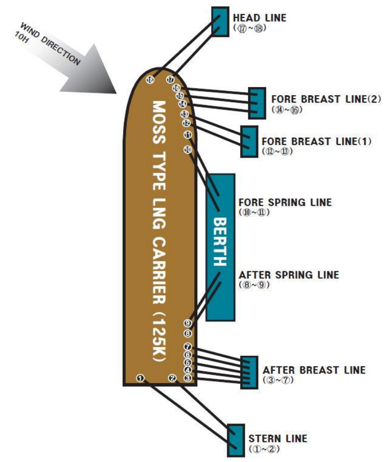
3.1 In cases when waves come from the direction of the bow, wave height: 1 m, wind velocity: 13 m/s

In this study, it has been shown that the influence of wind and waves coming in from the ship's 12 o'clock to 10 o'clock, such as

Table 3. Mooring calculation scenario case







Case 1	Case 2	Case 3

in Fig. 1, is the strongest when a 125K LNG vessel is unloading at the Port of Pyeong Taek. Relatively, it can be said that the influence of wind and wave from directions other than the former seem small.

Table 3 shows the case where wind blows from the ship's 12, 11, and 10 o'clock positions.

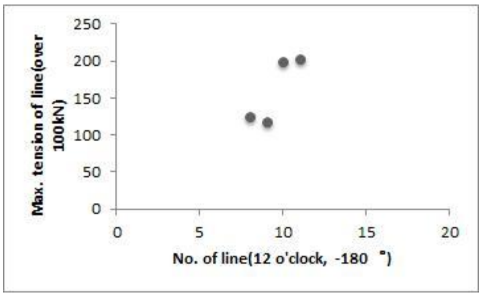


Fig. 3. Tension on mooring line (bow, -180°).

Typically, as for Fig. 3, if wind blows from directly ahead, mooring line nos. 8 and 9 would each endure approximately 13 tons and 12 tons of tension, respectively. Furthermore, nos. 10 and 11 will each endure approximately 20 tons and 21 tons of tension, respectively.

In the circumstances shown above (bow direction wave height: 1 m, wind velocity: 13 m/s), Figs. 4 & 5 show, that if wind blows from the 1 o'clock to the 2 o'clock direction starting from ahead, mooring nos. 11 & 10, which are fore spring lines, will endure approximately 33 to 38 tons of tension.

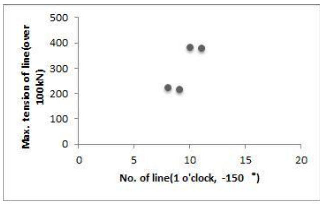


Fig. 4. -150° (1 o'clock).

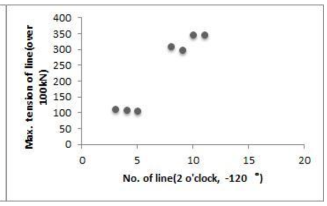


Fig. 5. -120° (2 o'clock).

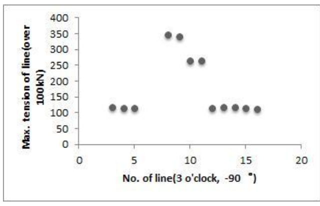


Fig. 6. -90° (3 o'clock).

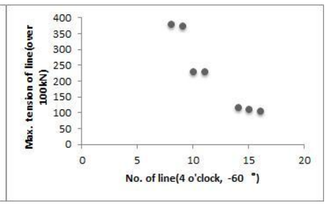


Fig. 7. -60° (4 o'clock).

If the wind blows to the side from the shore (3 o'clock, Fig. 6) while made fast to starboard, the aft spring lines will endure 35 tons of tension, the fore spring lines will feel 26 tons, and the aft breast lines, 12 tons. It has been found that under a wind direction of 4 o'clock (Fig. 7) to 8 o'clock (Fig. 11), strong tension occurs on the aft spring lines (approx. 37 to 38 tons). In particular, when the wind comes from the 5 o'clock direction, the aft spring line tension is about 45 tons, and on the fore spring line approximately 21 tons.

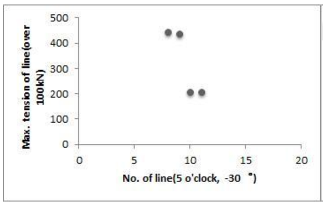


Fig. 8. -30° (5 o'clock).

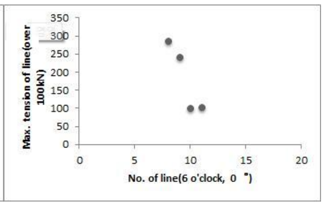


Fig. 9. 0° (6 o'clock).

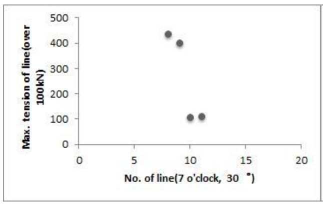


Fig. 10. 30° (7 o'clock).

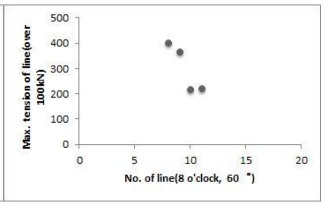


Fig. 11. 60° (8 o'clock).

In the 9 o'clock direction (Fig. 12), the aft spring line tension is 36 tons and the fore spring line 32 tons. Between the two spring lines of the same position, the one closer to shore endures more tension. If the wind comes from the 10 o'clock (Fig. 13), 11 o'clock (Fig. 14), and 12 o'clock directions (Fig. 15), the fore spring line tension is about estimated at 46 to 54 tons. When the wave height is 1m coming from ahead, and the wind velocity is 13 m/s, primarily the spring lines resist the most tension. Wind blowing from the 11 o'clock direction causes the greatest tension on the fore spring lines. Lastly, in the 3 o'clock direction, tension occurs on the majority of the mooring lines.

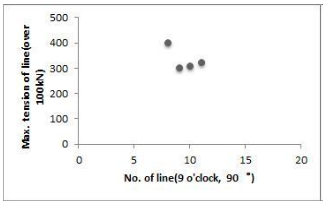


Fig. 12. 90° (9 o'clock).

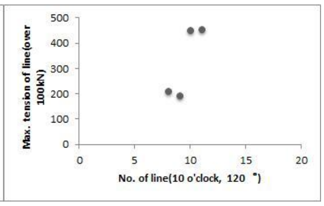


Fig. 13. 120° (10 o'clock).

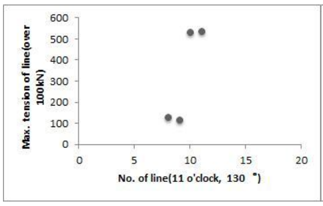


Fig. 14. 150° (11 o'clock).

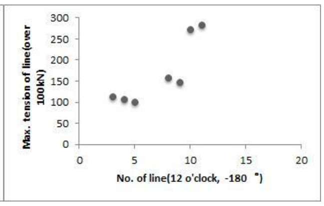
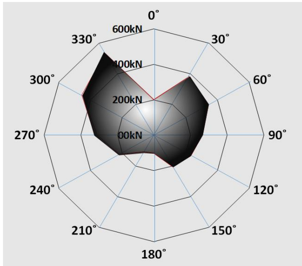
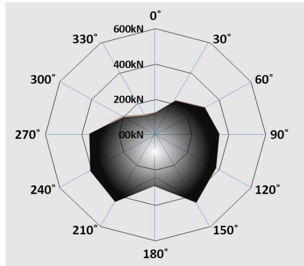
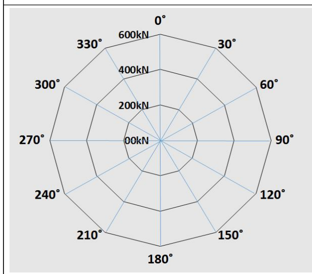
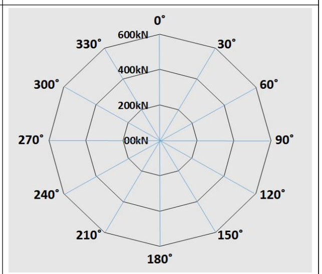
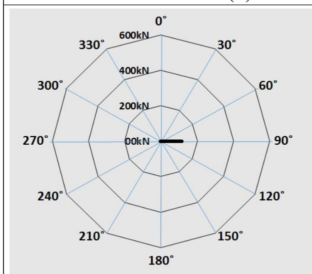
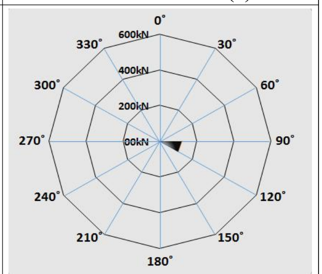
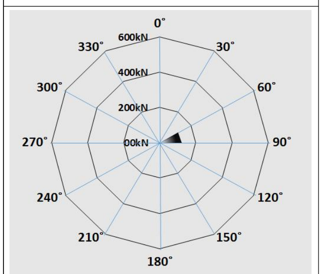


Fig. 15. 180° (12 o'clock).

Table 4 shows each mooring line's overall tension when the condition is case 1 (waves coming from the direction of the bow, wave height: 1 m, wind velocity: 13 m/s)

Table 4. Results of mooring line tension (in the direction of bow, 1 m wave, 13 m/s wind)

Fore spring line	Aft spring line
	
Head line	Stern line
	
Fore breast line (1)	Fore breast line (2)
	
After breast line	
	

3.2 In cases where waves come from 11 o' clock, wave height; 1 m and wind velocity: 13 m/s

In the circumstances shown above (wave direction: 11 o'clock, wave height: 1 m, wind velocity: 13 m/s), if the wind blows from ahead (Fig. 16), the fore spring line will endure approximately 28 tons of tension.

If the wind blows from the 1 o'clock direction (Fig. 17), the fore spring line will endure about 46 tons of tension. The aft spring line will endure 23 tons and the breast line, 10 to 20 tons.

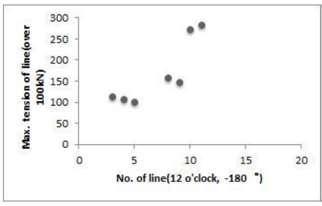


Fig. 16. -180° (12 o'clock).

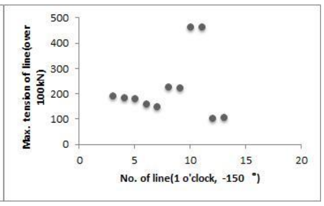


Fig. 17. -150° (1 o'clock).

When the wind blows from the 2 o'clock direction (Fig. 18), the fore and aft spring line will endure approximately 42 to 46 tons of tension, and the aft breast line more than 30 tons. Around 16 to 27 tons of tension will build at the fore breast line. It is shown that when the wind comes from 3 o'clock (Fig. 19), up to an estimated 47 to 50 tons of tension is formed on the fore and aft spring lines. 32 to 38 tons of tension is formed on the aft breast line. Also, on the fore breast line, 22 to 23 tons of tension forms. Out of these, 36 tons of tension forms on mooring line no. 16, making it the most stressed line.

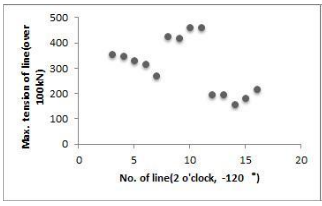


Fig. 18. -120° (2 o'clock).

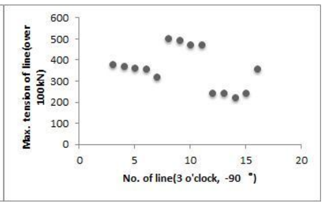


Fig. 19. -90° (3 o'clock).

In the 4 o'clock direction (Fig. 20), approximately 43 tons and 47 tons formed each at the aft spring and the fore spring lines, respectively. At the aft breast line (line nos. 3, 4, 5) about 23 tons of tension formed. Moreover, the fore breast line (line nos. 12, 13, 14) experiences 21 to 23 tons of tension. Out of these, 33 tons is formed on mooring line no. 16, making it the most stressed line compared to the breast line nearby (approximately 10 tons). In the 5 o'clock direction (Fig. 21), the aft and fore spring lines endure about 33 to 47 tons of tension, and the fore breast line about 18 to 23.

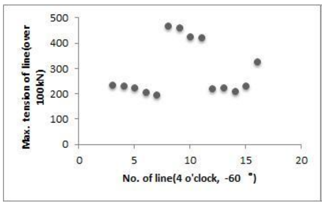


Fig. 20. -60° (4 o'clock).

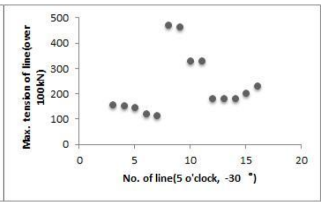


Fig. 21. -30° (5 o'clock).

Under wind moving from 6 o'clock (Fig. 22), 7 (Fig. 23) and 8 o'clock (Fig. 24), nearly 50 tons of tension is experienced by the aft spring line, which requires special caution due to its higher tension as compared to other spring lines.

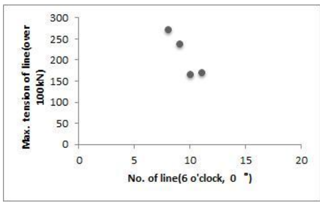


Fig. 22. 0° (6 o'clock).

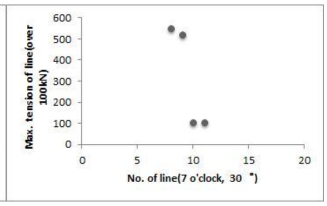


Fig. 23. 30° (7 o'clock).

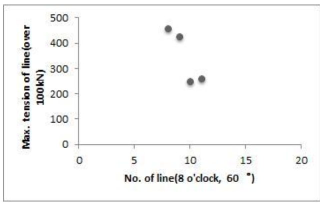


Fig. 24. 60° (8 o'clock).

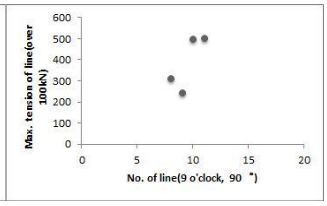


Fig. 25. 90° (9 o'clock).

Under wind moving from 9 (Fig. 25), 10 (Fig. 26) and 11 o'clock (Fig. 27), around 43 to 56 tons of tension builds up on the fore spring line, and about 20 tons of tension builds up on the aft spring line. On other mooring lines, no tension occurs, although the fenders are stressed.

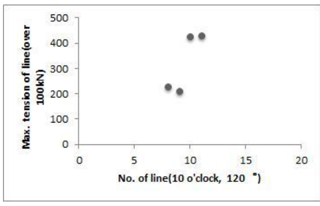


Fig. 26. 120° (10 o'clock).

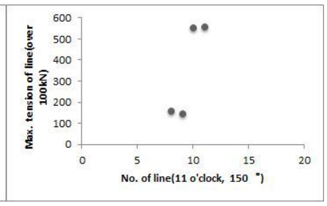


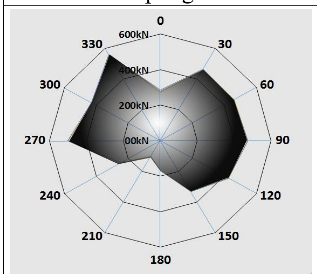
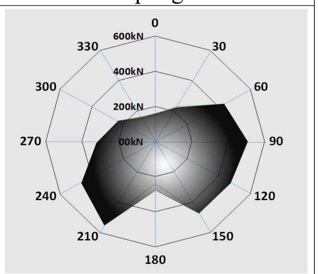
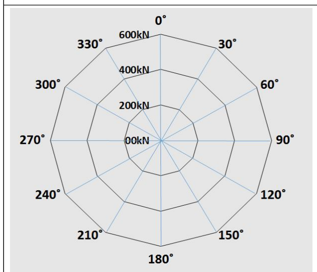
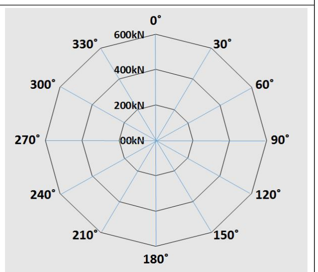
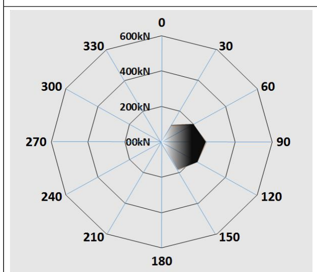
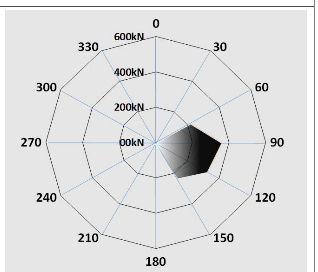
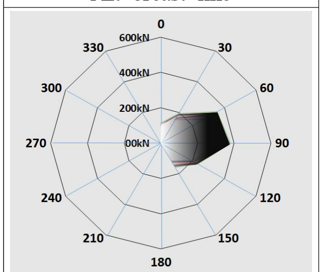
Fig. 27. 150° (11 o'clock).

When waves come from 11 o'clock (Fig. 27) at a height of 1 m and wind velocity: 13 m/s. from a wind direction of 3 o'clock to 8 o'clock, the aft spring line is highly tensioned. In particular, when the wind blows from the 7 o'clock direction, the highest tension is built up via the aft spring line. When the wind comes from 3 o'clock, strong tension is experienced by most of the mooring lines (except lines 17 & 18). This also applies to wind from 2, 4, and 5 o'clock. In other words, from the 2 o'clock to 5 o'clock directions, many of the mooring lines endure tension, with the exception of lines 17 and 18, which are headlines.

When the wind comes from the 7 o'clock and 8 o'clock directions, the aft spring line must be watched using extra caution (including the fore spring line). Finally, when the wind direction is from 9, 10 and 11 o'clock, it is desirable to watch the fore spring line using extra caution (including the aft spring line).

Table 5 shows each mooring line's overall tension when the condition is as described in case 2 (waves from 11 o'clock, wave height: 1 m, wind velocity: 13 m/s)

Table 5. Results of mooring line tension (in the 11 o'clock direction, 1 m wave, 13 m/s wind)

Fore spring line	Aft spring line
	
Head line	Stern line
	
Fore breast line 1	Fore breast line 2
	
Aft breast line	
	

3.3 In the case where waves come from 10 o' clock, wave height: 1 m and wind velocity: 13 m/s

In the circumstances shown above (wave direction: 10 o'clock, wave height: 1 m, wind velocity: 13 m/s), if the wind blows from ahead (Fig. 28), the fore spring line will experience approximately 89 tons of tension and the aft spring line will feel 73 to 76 tons of tension. In addition, the aft breast line (23 to 35 tons) and stern line (about 19 tons) both experience tension. Mooring line no. 14, one of the fore breast lines, endures about 35 tons of tension as well.

When the wind comes from 1 o'clock (Fig. 29), around 105 tons of tension occurs on the fore spring line. The aft spring line endures around 85 tons, and the fore breast line endures approximately 71 to 94 tons. On the aft breast line, 54 to 72 tons of tension endured. The stern line is also stressed.

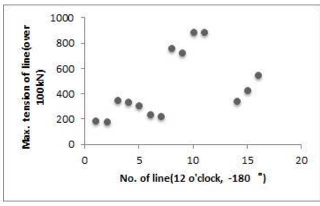


Fig. 28. -180° (12 o'clock).

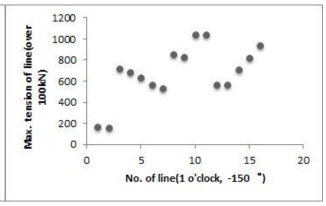


Fig. 29. -150° (1 o'clock).

When the wind blows from 2 o'clock (Fig. 30), around 93 to 107 tons of tension is experienced by the fore spring lines (line nos. 14 to 16). The fore spring line experiences 97 tons, the aft breast line experiences approximately 86 to 96 tons, and the aft spring line about 90 tons of tension. In these cases, it is shown that the mooring lines near the bow are much more stressed than the mooring lines near astern.

If the wind blows from 3 o'clock (Fig. 31), around 68 to 100 tons of tension is endured by the fore breast lines (line nos. 12 to 16). The fore spring line endures 66 tons and the aft breast line approximately 64 to 75 tons of tension. As with the results when the wind blows from 2 o'clock, the mooring lines near the bow are much more stressed than the mooring lines near astern.

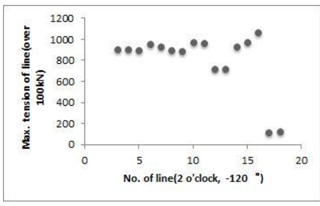


Fig. 30. -120° (2 o'clock).

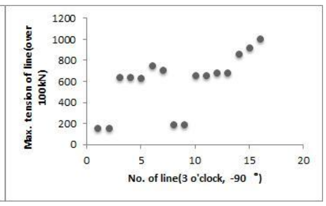


Fig. 31. -90° (3 o'clock).

When the wind comes from 4 o'clock (Fig. 32), the fore breast line experiences around 84 to 105 tons of tension (line nos. 14 to 16). The aft breast line endured 78 to 87 tons and about 59 tons of tension occurred on the aft spring line. The breast lines are more stressed than the spring lines.

When the wind blows from 5 o'clock (Fig. 33), the breast line and spring line endure around 39 to 68 tons of tension all-around.

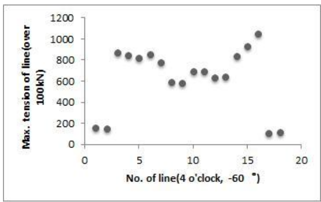


Fig. 32. -60° (4 o'clock).

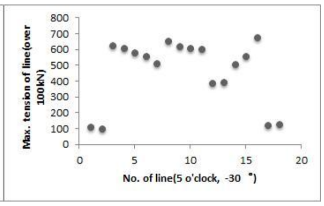


Fig. 33. -30° (5 o'clock).

If the wind blows from 6 o'clock (Fig. 34), the aft spring line experiences around 43 tons of tension and the fore spring line around 22 tons. The fore spring line endured about 22 tons of tension, and the fore and aft breast line around 12 to 22 tons of tension.

It has been shown that when the wind blows from 7 (Fig. 35) and 10 o'clock, a lot of tension is built up on the aft spring line (7 o'clock: 99 tons, 10 o'clock: 106 tons). Also, at the fore spring line, about 70 tons (7 o'clock) and 91 tons (10 o'clock) builds up.

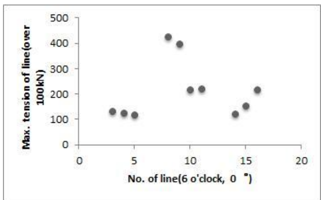


Fig. 34. 0° (6 o'clock).

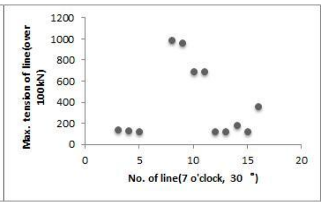


Fig. 35. 30° (7 o'clock).

When the wind blows from 8 o'clock (Fig. 36) direction, around 93 tons of tension occurs on the fore spring line, and on the aft spring line, around 65 tons of tension was endured. Additionally, on the aft breast line, about 40 to 62 tons of tension was endured. It has been found that the fore breast line experiences 31 to 70 tons of tension, resulting in the spring line seeming more stressed.

When the wind blows from 9 o'clock (Fig. 37), the fore spring line endures approximately 89 tons of tension, and the aft spring line 58 tons. The breast line also feels tension.

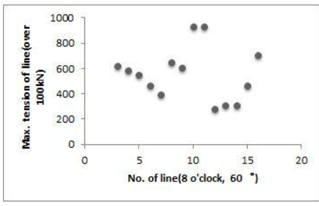


Fig. 36. 60° (8 o'clock).

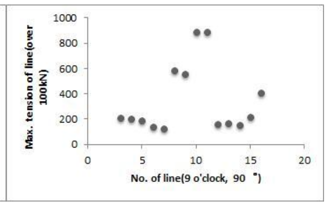


Fig. 37. 90° (9 o'clock).

In cases where the wind blows from 10 (Fig. 38), 11 o'clock (Fig. 39), around 85 tons, 53 tons, and 27 to 57 tons of tension was endured by the fore spring line, aft spring line, and the fore breast lines, respectively (mooring line nos. 14 to 16). The aft spring line experienced 11 to 19 tons of tension.

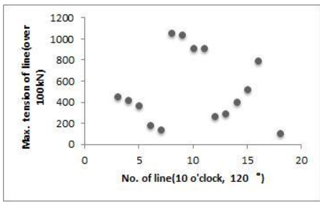


Fig. 38. 120° (10 o'clock).

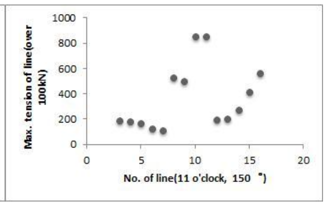


Fig. 39. 150° (11 o'clock).

Table 6 shows each mooring line's overall level of tension when the conditions match those of case 3 (waves from 10 o'clock, wave height: 1 m, wind velocity: 13 m/s)

Table 6. Results of mooring line tension (towards 10 o'clock, 1 m wave, 13 m/s wind)

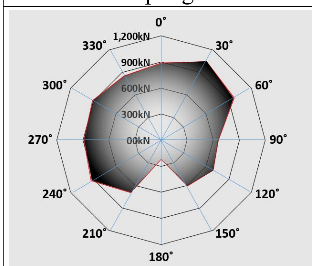
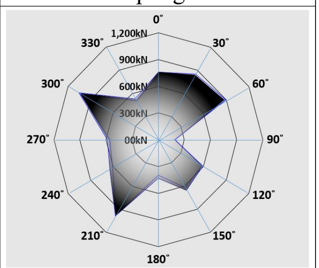
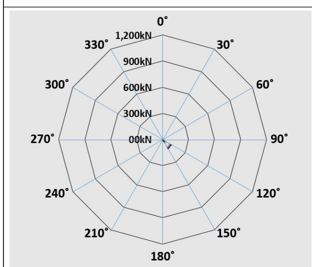
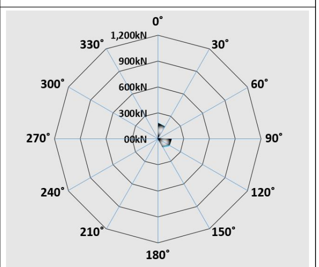
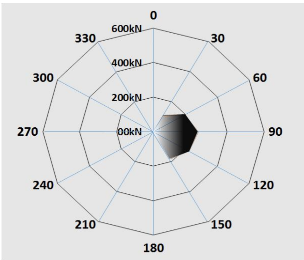
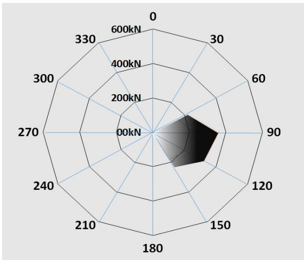
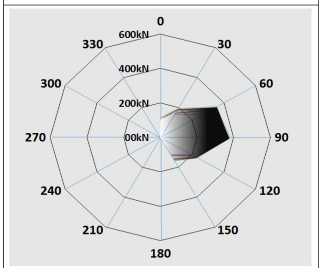
Fore spring line	Aft spring line
	
Head line	Stern line
	

Table 6. (continued)

Fore breast line 1	Fore breast line 2
	
Aft breast line	
	

If the waves come in from 10 o'clock with a height of 1 m when wind velocity is 13 m/s, in cases when the wind comes from 1, 2, 3, 7, and 8 o'clock, much tension is endured by the mooring lines.

When the wind comes directly from the bow, tension occurred in this order from strongest to weakest: fore spring line, aft spring line and aft breast line.

When the wind comes from 1 o'clock, tension occurred in this order from strongest to weakest: fore spring line, aft spring line, fore breast line and aft breast line.

When the wind comes from 2 and 3 o'clock, tension occurred in this order from strongest to weakest: fore breast line, fore spring line, aft breast line and aft spring line.

When the wind comes from 4 o'clock, tension occurred in this order from strongest to weakest: breast line, spring line. According to calculations, tension built up more on the springs near the bow than the stern.

When the wind comes from 5 o'clock, tension occurred evenly throughout each mooring line.

When the wind comes from 6 o'clock, tension occurred in this order from strongest to weakest: aft spring line, fore spring line, and breast line.

When the wind comes from 7 and 10 o'clock, tension occurred strongest on the aft spring line.

Finally, when the wind comes from 8, 9 and 11 o'clock, tension occurred in this order from strongest to weakest: fore spring line, aft spring line, fore & and aft breast line

4. Conclusion and Discussion

It has been found that even if wave height, wind direction and wind velocity are identical, the shift of wave direction influences the tension on the mooring lines. Likewise, the shift of wind direction affects the tension on mooring lines.

By analyzing the shift of tension that affects the mooring lines beforehand, the person of watch can acknowledge which of the mooring lines should be the priority, enabling effective notice regarding the mooring line tensions. The summary is shown below.

(1) When waves come directly from the bow at a height of 1 m with wind velocity of 13 m/s, mostly the spring lines are stressed. In particular, the strongest tension occurred at the fore spring line when the wind came from 11 o'clock. When the wind comes from 3 o'clock, many of the mooring lines were stressed.

It is desirable for persons of mooring line watch to exercise extra caution of the spring line when waves coming from the bow are 1m or greater, and when wind velocity is 13m/s or greater.

(2) When the wind comes from 11 o'clock at a velocity of 13 m/s, and for wind blowing from 3 to 8 o'clock, the aft spring is stressed. In particular, when the wind blows from 7 o'clock, the strongest tension occurs on the aft spring. When the wind comes from 3 o'clock it affects the tension of many mooring lines (except line nos. 17 & 18). Also, when the wind comes from 2, 4, and 5 o'clock, many mooring lines are tensioned.

(3) In such cases where waves come from 10 o'clock at heights over 1 m, with wind velocity of 13 m/s, if the wind blows from 1, 2, 3, 7, and 8 o'clock then, the highest tension occurs on the mooring lines.

The most tensioned mooring lines must be the watched preferentially with extra caution. When the wind blows to 90 degrees on either side starting from the bow, extra caution is required throughout the watch (including of the fore spring, fore breast, and aft spring lines).

References

[1] Bae, B. D., J. S. Kim and G. H. Yun(2008), LNG Carriers, Kyunganp, pp. 530-532.

[2] Cho, I. S.(2017), Behavior Analysis and Control of a Moored Training Ship in an Exclusive Wharf, Journal of the Korean Society of Marine Environment & Safety, Vol. 23, No. 2, pp. 139-145.

[3] HMM, Hyundai Utopia Finished plans(1994).
[4] HMM, Hyundai Utopia Ship/Shore Compatibility(1994).
[5] Kubo, M., K. Saito and T. Oki(1993), Approximate calculation of ship motions under the prevention system of ship separation from quay wall, Journal of Japan Institute of Navigation, Vol. 89, pp. 15-21.
[6] Kubo, M. and S. Sakakibara(1995), Effects of long period waves caused by wave groups and harbor oscillation in computation of wharf operation efficiency, Proceeding of Coastal Engineering, Japan Society of Civil Engineering, Vol. 42, pp. 931-935.
[7] Pyeong Taek Port Information and Terminal Regulations(2013), p. 106.
[8] Technical Note of The Port & Harbour Research Institute Ministry of Transport Japan(2000), No. 956, p. 18.
[9] West Coast of Korea Pilot(2012), Korea Hydrographic and Oceanographic Agency, pp. 274-276.

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