Influence of "Suezmax" Tankers Size Increase on Mooring Ropes at Existing Terminals

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ABSTRACT: Growth in maritime traffic results in larger vessels and larger main traffic channels. Due the latter reasons and in comparison with the cargo terminals, angle of mooring rope is not the same as when cargo terminals were built. The aim of the proposed research is to see how the increment of the "Suezmax" tankers affects mooring rope angles in such a way that the safety of the vessel is reduced. In order to analyse the mooring rope angles it was necessary to determine the average size of the "Suezmax" tanker. When the aver-age size was obtained, the level of safety at the berth was observed on tanker terminal which was built in 1980`s, when the size of "Suezmax" tankers was significantly different. The result showed that mooring ropes are reducing the safety of the vessel. Using OCIMF[2] calculation for mooring rope strength it was possible to calculate holding force of the ropes for lateral and longitudinal straining. Reduction of safety is noticeable, but it does not endanger the cargo operations. However, conducted research led to the conclusion that constant increase of "Suezmax" tankers will affect the angles of mooring ropes and will represent safety issue in the future. Further research will consist of continuous monitoring of "Suezmax" tanker size and recognising the moment when the size will impede the safety at the berth.

1 INTRODUCTION

Constant growth of maritime transportation over the years caused increment of vessels size. Crude oil tankers were the first type of the vessels which had recorded major increase in size and in deadweight. That increment was possible due to tanker fast cargo manipulation and large crude oil demand all over the world. However, that increment was limited with size of the world major canals and ports. One of the reasons was limited depth in ports and size of terminals. But increment of vessels size does not mean increment of terminal size. In Croatia the biggest crude oil terminal is located in Omisalj bay. The terminal started with cargo manipulation in 1980, with storage capacity of 760.000 m^3. From the point of view of maritime safety at the berth, beside depth, a very important factor is mooring rope arrangement. By analysing the size of "Suezmax" tankers from 2008 to 2012 it was possible to determine average dimensions of the vessels, like length over all, breadth and draught. After determination of average dimensions, mooring ropes arrangement was analysed in order to determine if increment of the vessels size caused change in mooring ropes angles. Results of the analysis results were compared with mooring arrangement of "Suezmax" tanker which has 140,000 tons of deadweight and represents typical "Suezmax" tanker from 1980 to 2001.

[2] OCIMF – Oil Companies International Marine Forum - Mooring equipment guidelines

2 "SUEZMAX" TANKERS DIMENSIONS ANALYSIS

„Suezmax" tanker represents the vessel with maximum dimensions for passage through the Suez Canal. That vessel is limited with length, draught and breadth. In 2007 *MAN Diesel A/S* analysed "Suezmax" tankers´ deadweight and dimensions, and average deadweight was 150.000 tons, length over all 274 m, breadth 48 m and draught 16.1 m.

From 2008 to 2012 draught of "Suezmax" tankers was between 12 and 17.99 m, breadth between 32.51 and 55 m and length over all from 200 to 350 m.

Table 1 shows the number of „Suezmax" tankers by draught, and in 2012 91% of "Suezmax" tankers had draught between 16 and 17.99 m.

Table 1. Number of „Suezmax“ tankers by draught from 2008 to 2012

Draught(m)	2008	2009	2010	2011	2012
12 – 13,99	3	2	2	1	0
14 – 15,99	45	41	38	40	36
16 – 17,99	321	319	355	373	405
18 – 19,99	6	5	4	4	4
Total	376	368	400	418	445

Breadth of "Suezmax" tankers from 2008 to 2012 was between 32.51 m and 55 m. In 2008 89.89% of the analysed vessels had breadth between 40 and 50 m and in 2012 86.07%. However, in the analysed time period the number of "Suezmax" tankers with breadth between 50 and 55 m was increased from 9.04% to 13.93%. According to data in Table 2, the number of "Suezmax" tankers with breadth between 40 and 50 m is lower due to the increment of the "Suezmax" tankers with breadth between 50 and 55 m. In the analysed time period "Suezmax" fleet increased for 45 new ships, which represents an increment of 15%.

Table 2. Number of „Suezmax“ tankers by breadth from 2008 to 2012

Breadth(m)	2008	2009	2010	2011	2012
32,51 - 40	4	4	4	2	0
40 - 50	338	326	353	360	383
50 - 55	34	38	43	56	62
Total	376	368	400	418	445

Length over all (LOA) of "Suezmax" tankers from 2008 to 2012 was between 200 m and 350 m. In 2012 the 99.33% of "Suezmax" tankers have LOA between 250 and 300 m. "Suezmax" tankers with LOA between 200 and 250 m and LOA between 300 and 350 m represent only 4% of analysed fleet in 2008 and by 2012 only 0.67%. The number of "Suezmax" tankers by LOA is presented in Table 3.

Table 3. Number of „Suezmax“ tankers by length over all from 2008 to 2012

LOA(m)	2008	2009	2010	2011	2012
200 -250	4	4	3	2	2
250–300	368	362	396	415	442
300–350	4	2	1	1	1
Total	376	368	400	418	445

From the analysed data it is noticeable that in the time period from 2008 and 2012 average "Suezmax" tanker dimensions were, for draught between 16 and 17.99 m, for breadth between 40 and 50 m and for length over all between 250 and 300 m. In 2012 "Suezmax" tankers with those dimensions represent 90% of the vessels in total tanker "Suezmax" fleet.

In 2008 "Suezmax" fleet had 376 vessels with 57 million tons of deadweight. Decrement of 1 million tons of deadweight was recorded in 2009, when total fleet was decreased by 8 vessels. From 2010 to 2012 total number of the vessels increased. In five analysed years number of "Suezmax" tankers, with draught between 12 and 13.99 m and draught between 18 and 19.99 m, was decreased. Also the number of "Suezmax tankers, with breadth between 23.51 and 40 m and with length over all between 200 and 250 and length over all between 300 and 350, also decreased. In 2012 average deadweight of "Suezmax" tanker was 155.000 tons. The trend of "Suezmax" tankers number and deadweight in the analysed time period is shown in Figure 1.

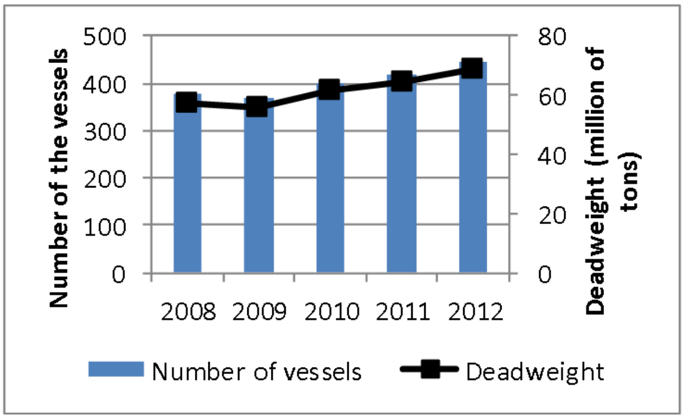

Figure 1. Number and deadweight of „Suezmax“ tankers from 2008 to 2012

The analysed data shows that "Suezmax" tankers´ dimensions are increasing. One of the reasons is constant increment of Suez Canal. The draught of the passing vessels was increased to 20.1 m by 2010. Canal length is 193.30 km and cross-section area is 5200 m^2. Further step is to increase vessels maximum allowed draught to 21.9 m. The increment of the Suez Canal through history is shown on Figure 2.

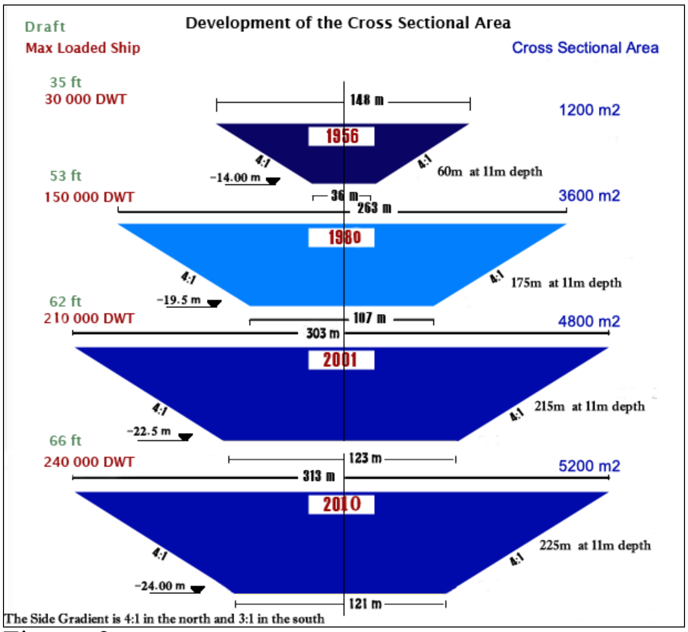

Figure 2. Cross-sectional area of the Suez Canal trough history, Suez Canal Authority ©

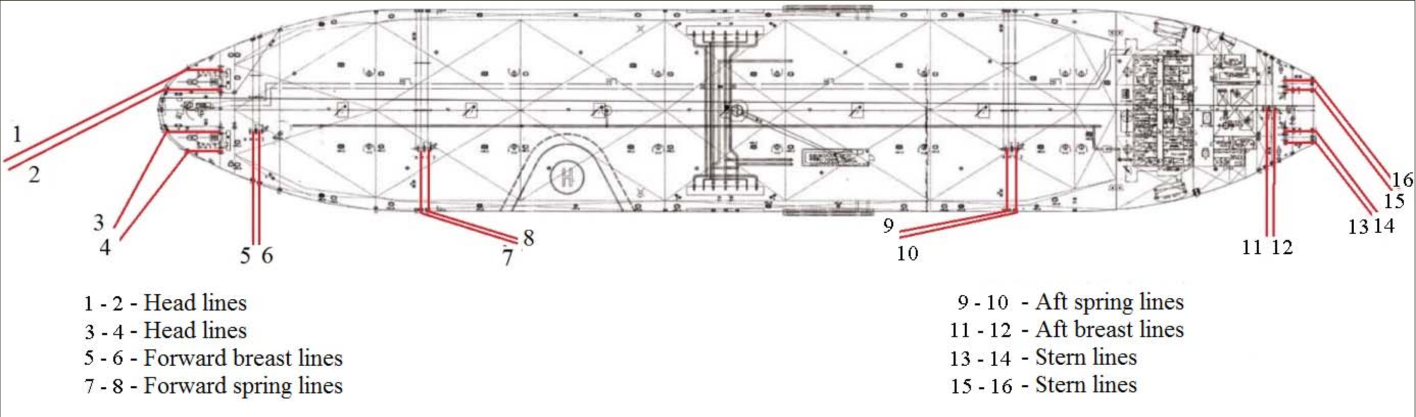

Figure 3. Vessel mooring ropes by location

3 VESSEL MOORING ROPES

Vessel mooring ropes are divided by location on: head lines, forward breast lines, forward spring lines, aft spring lines, aft breast lines and stern lines as shown in figure 3.

Mooring ropes should be positioned as much as possible symmetrically to the vessel centreline in order to ensure equal load on each mooring line. When planning vessel mooring arrangement, it is necessary to follow basic principles for every line. Head and stern lines should be on the vessel bow i.e. stern and horizontal angle should be close to 60°. Head and aft breast lines should be as much as possible perpendicular to the vessel centreline and positioned close to the vessel bow and stern. Horizontal angle of breast line should be around 90°. Forward and aft spring lines should be parallel to the vessel centreline and positioned on the ¼ of the vessel length from the bow and stern of the vessel. Horizontal angle of spring lines should not exceed 10°. Ideal vertical angle for all mooring lines is 0°, but should not exceed 25°, maximally 30°.

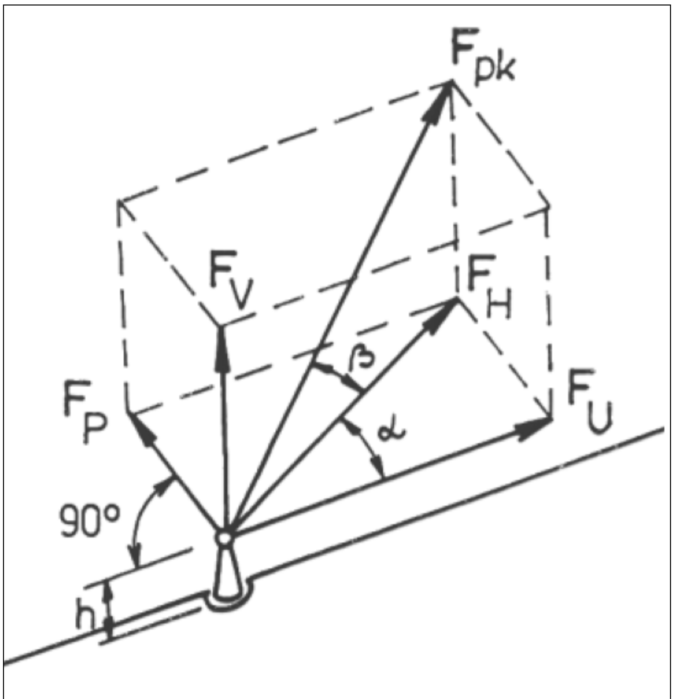

Figure 4. Components of mooring ropes angles

When analysing mooring ropes arrangements it is necessary to know the values of horizontal and vertical angle of mooring lines. Horizontal angle (α) is the angle which the mooring line makes with the longitudinal centreline of the vessel.

Horizontal component is divided on two components: lateral and longitudinal. Vertical angle (β) is the angle which the mooring line forms with the horizontal plain. Vertical angle can be used for calculating lateral and longitudinal mooring ropes holding force.

Tankers are moored by steel wires. Steel wire characteristics are small elasticity and large holding force. At the end of steel wire is the “tail”. “Tail” is synthetic rope, its approximate length is around 11 meters and breaking force is 125% of breaking force of the attached steel wire. All mooring lines should have the same characteristics, like elasticity and if more mooring ropes are given from the same position their length should be equal. Mooring rope optimal length is between 35 and 50 meters, but mooring rope length depends on shore mooring arrangements. It is also necessary to take into consideration the lack of homogeneity of mooring ropes, which means that not all mooring ropes are equally loaded at the same time. In practice it is impossible to achieve homogeneity of mooring ropes, so in calculation it is necessary to take into consideration the safety factor. Forces acting on the vessel should not be larger than 55% of breaking load of the mooring ropes, which is equal to safety factor of 1.82.

The load of external forces on the vessel is considered through two components: force acting perpendicular to the vessel centreline and force acting parallel to the vessel centreline. Force acting perpendicular to the vessel centreline, lateral force, has the greatest effect on the breast lines. Force acting parallel to the vessel centreline, longitudinal force, has the greatest effect on the forward and stern spring lines. When calculating lateral and longitudinal components it is necessary to take into consideration the wind force, which acts on the vessel surface above sea level and has the greatest effect when the vessel is empty. Also it is necessary to take into consideration the sea current force and sea wave's force.

4 TANKER TERMINAL OMISALJ

Tanker terminal "Omisalj"[3] is located in Omisalj bay, and has two berths for mooring vessels from 30.000 to 350.000 tons of deadweight. The terminal was built in 1980.

Terminal consists of central part on pilots, 120 m in length. Mooring hooks are located at height of 3 meters above sea level.

On the vessel every mooring rope is attached to mooring winch, and from every winch two mooring ropes are given. This means that vessels has in total 8 mooring ropes at forward end and 8 mooring ropes at aft end of the vessel.

The analysed vessels were: tanker "Donat" built in 2007, dimensions length over all 280 m, breadth 48 m, summer draught 17 m and deadweight 166.000 tons; tanker "Jahre Target" built in 1990, dimensions length over all 269 m, breadth 44.5 m, summer draught 16.2 m and deadweight 140.000 tons.

5 MOORING ARRANGEMENTS GEOMETRY FOR "SUEZMAX" TANKERS AT "OMISALJ" TERMINAL AND COMPARATIVE ANALYSIS OF CALCULATED MOORING ROPES HOLDING FORCES

At the "Omisalj" terminal "Suezmax" tankers are berthed with the bow turned to bay exit, and all mooring ropes are of steel wire. On both analysed vessels there were 16 mooring lines, marked by numbers from bow to stern. At the bow there were four headlines, two breast lines and two spring lines. At the stern there were four stern lines, two breast lines and two spring lines. Horizontal and vertical angles of mooring ropes on both analysed vessels are shown in Table 4.

When holding force of mooring ropes was analysed, it was concluded that beside rope breaking forces, rope elasticity, mooring rope arrangements, horizontal and vertical angles for the analysed case, restrictions for mooring arrangement can arise from shore mooring hooks breaking load. In this analysis all calculations were made taking into account the breaking load of mooring hooks, which is 1250 kN for tanker terminal "Omisalj".

Table 4. Horizontal and vertical angles of mooring ropes

Name of the rope	Mooring line	Tanker „Donat“		Tanker „Jahre Target“	
		Horizontal angle(°)	Vertical angle(°)	Horizontal angle(°)	Vertical angle(°)
Head line	1	40	8,8	42	6,8
Head line	2	40	8,8	44	6,8
Head line	3	55	10,4	55	8,4
Head line	4	53	10,4	54	8,4
Fwd. Brest line	5	85	14,6	87	12,6
Fwd. Brest line	6	84	14,6	88	12,6
Fwd. Spring line	7	12	23,5	9	21,5
Fwd. Spring line	8	11	23,5	9	21,5
Aft Spring line	9	10	21,8	8	19,8
Aft Spring line	10	9	21,8	9	19,8
Aft Brest line	11	54	12,8	60	10,8
Aft Brest line	12	52	12,8	59	10,8
Stern line	13	70	12,7	65	10,7
Stern line	14	59	12,7	67	10,7
Stern line	15	48	9,9	42	7,9
Stern line	16	45	9,9	44	7,9

For calculating lateral holding force expression (1)

$$Fp_{pk} = F_{pk} * \sin\alpha * \cos\beta \qquad (1)$$

was used, and for calculating longitudinal holding force expression (2) was used.

$$F_{U\,pk} = F_{pk} \cdot \cos\alpha \cdot \cos\beta \qquad (2)$$

In both expressions the following figures were used: Fp_{pk} - is the lateral component of mooring rope holding force, Fu_{pk} – is the longitudinal component of mooring rope holding force, F_{pk} – the holding force of mooring rope, α – the horizontal angle of mooring rope and β – the vertical angle of mooring rope.

After calculating true lateral and longitudinal holding force of the mooring rope, due to lack of homogeneity of mooring ropes, mooring ropes holing force was corrected using the safety factor. In this case the safety factor is 1.82.

Longitudinal holding force, unlike lateral holding force, was calculated for two directions of action, from the bow and from the stern. Considering the direction of acting of longitudinal force it is necessary to determine which ropes are loaded in each case. For both analysed cases values of lateral and longitudinal forces were calculated and result is shown in Table 5.

[3] http://www.janaf.hr/sustav-janafa/naftni-terminal-luka-omisalj/ (5.01.2013)

Table 5. Results of analysed lateral and longitudinal forces for „Suezmax“

Mooring rope	Tanker „Donat“			Tanker „Jahre Target“		
	Lateral force (kN)	Longitudinal force (kN)		Lateral force (kN)	Longitudinal force (kN)	
		Fwd	Aft		Fwd	Aft
1	397,0	473,1	-	415,3	461,2	-
2	397,0	473,1	-	431,1	446,4	-
3	503,6	352,6	-	506,5	354,6	-
4	490,9	370,0	-	500,2	363,4	-
5	602,5	-	-	609,1	-	-
6	601,5	-	-	609,6	-	-
7	-	-	560,6	-	-	574,4
8	-	-	562,6	-	-	574,4
9	-	571,5	-	-	582,3	-
10	-	573,2	-	-	580,8	-
11	493,1	358,2	-	531,7	307,0	-
12	480,3	375,2	-	526,2	316,2	-
13	572,9	-	208,5	556,6	-	259,5
14	522,6	-	314,0	565,3	-	240,0
15	457,5	-	412,0	414,2	-	460,1
16	435,4	-	435,4	430,0	-	445,3
Total	5954,4	3547	2493,2	6095,9	3412	2553,6

Vessels` length and height have the largest influence on mooring arrangement. Difference between two analysed ships is 11 meters in length and 2 meters in height. That is not a large increase in size and in new terminals this will not have any effect. However, on terminal which was built in 1980 calculation showed some changes, but that change is still minimal. Mooring rope lateral holding force is reduced for 3% or 141.5 kN. Moring rope longitudinal holding force acting from the bow of the vessel is increased for 4% or 135 kN and mooring ropes longitudinal holding force acting from aft of the vessel is reduced for 3% or 60.4 kN. This small reduction in mooring ropes lateral and longitudinal holding force will not affect vessel safety, but vessel length is changed for only 11 meters or 4% so further analysis should keep track of "Suezmax" tankers dimensions.

From the point of safety at berth, external forces acting on the vessel have to be compared with the holding force of the mooring ropes. External lateral force acting on the vessels` will not be increased due to vessel small increment in length and height. However, external longitudinal forces will be increased because of increment in vessels` breadth and draught.

6 CONCLUSION

Analysing "Suezmax" dimensions, due to Suez Canal increment in size, it is noticeable that "Suezmax" tankers dimensions are increasing. Between 1980 and 2001 Suez Canal dimension did not change and average deadweight for "Suezmax" tanker was 140.000 tons. After the increase of the canal depth between 2001 and 2010 "Suezmax" vessels` deadweight increased up to 240.000 tons. However, tankers did not follow that sudden increase in deadweight like container vessels, and increment of "Suezmax" tanker is noticeable but still very small. If we take "Suezmax" tanker which is berthed on "Omisalj" terminal, mooring arrangement can be analysed. Considering analysis and results, with current terminal limiting factors, the vessel safety at the berth is not significantly impaired. However, taking into consideration the trend of vessels` dimensions increment, current terminals at some point will not be able to ensure safe mooring arrangement. That means that ropes horizontal and vertical angles will be out of allowed limits and when external forces are taken into account, due to vessels` dimensions increase, vessels mooring ropes and terminal mooring hooks holding force will be questionable.

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