INVESTIGATION OF VARIOUS LONGITUDINAL FRAME SPACING EFFECTS ON SIDE SHELL PROFILES ON OIL TANKER

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ABSTRACT

In this study, one existing oil tanker side shell with longitudinal bulb flat profiles have been analyzed through Mars2000 software provided by the Bureau Veritas. This particular existing oil tanker construction is modeled. Main goal is to investigate the weight and shipyard manufacture cost which includes man-hour changes in parallel with the various longitudinal frame spacing applied to the calculation. The floors, deck and corrugated bulkheads of parallel midbody was assumed to be same as original construction plan of the existing oil tanker, then, side shell and the longitudinal profiles are being modified according to yielding criteria, minimum thickness and buckling criteria checked by the Bureau Veritas Mars2000 software. The longitudinal frame spacing of the existing vessel is 0.665 meters. Investigation is focused on starting from 0.55 meters ending at 0.85 meters with the step of 0.05 meters.

Key words: Longitudinal Frame Spacing, side shell profiles, oil tanker

1. Introduction

It is known fact that whenever a ship is being built, optimum longitudinal and transverse frame spacing needs to be designed in aspect of hull strength and minimum construction weight. Any extra undesired construction weight, indirectly means decrease of operational capability of the vessel in terms of speed during the journey and sea capability. Draft of the vessel mostly depends on the material take off for construction which means optimum structure needs to be calculated and to be built by yard.

In this short investigation for an oil tanker, side shell with longitudinal bulb flat profiles are modelled with the frame spacing starting from 0.55 meters tending at 0.85 meters in step of 0.05 meters. This oil tanker has Fatigue Limit State (FLS) notation. Considering FLS, ships specially intended to carry in bulk flammable liquid products other than those covered by the service notations oil tanker, chemical tanker or liquefied gas carrier. The service notation may be completed by the additional service feature flash point > 60°C, where the ship is proposed to carry only such type of products, under certain conditions.

This detail is important due to flammable cargo, any deficit in the construction strength may cause undesirable results. Due to this additional service notation, in the calculation section, actual and rule section modules criteria have some margin in between. The actual section modulus is always above the rule section modules.

This approach naturally brings additional safety margin however this margin is not significant. Regarding to the chosen bulb flat profiles, the most available profiles which are being used by the yard are taken into account. However, depending on yards and the ship types, bulb flat profile dimensions vary, this selection is made upon acceleration of the manufacturing process in the yard so that shipbuilding can continue without delay of any extra profile orders.

Considering the welding and cost, straight bead welding with the thickness of 3.5 mm for the 8mm shell plate and thickness of 5mm for the 15mm is foreseen. The craftmanship or man-hour is taken from most common shipyard prices and in the calculation section (see in Figure 1).

Figure 1 Straight bead weld considered between longitudinal bulb flat profiles and side shell

2. Calculations

In this study Mars2000 software has been used and will be described briefly. The ship midship construction was modeled by using the software. The model will be given by using screenshots to explain the design model.

Mars 2000 software allows to analyze the scantling of any transverse section or any transverse bulkhead along the ship length. Considering a transverse section, program calculates:

- The geometric properties (area, inertia and moduli, etc.),
- The hull girder strength criteria,
- The hull girder ultimate strength,
- The rule scantlings of strakes, longitudinal and transverse stiffeners considering the yielding criteria, minimum thickness criteria and buckling criteria. The fatigue check of structural details can be also calculated.

The software can also estimate the distribution of warping stresses by using a beam model with variable inertia (each hold should be modeled by a transverse section).

The moment and draught input of the existing oil tanker for the Mars2000 software is shown in Figure 2. Also 3D view of the tanker and construction elements are shown in Figure 4.

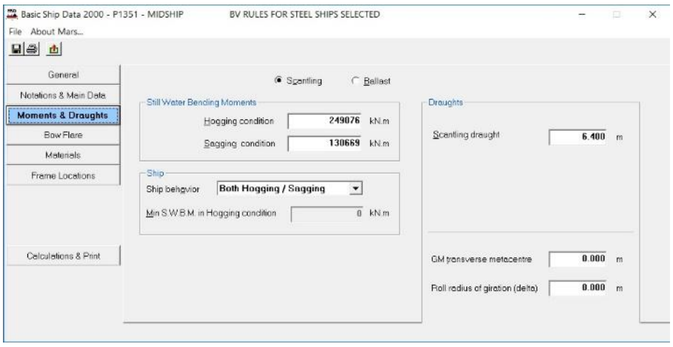

Figure 2 Hogging and sagging moments and draughts of the existing vessel

The additional data for the vessel design parameters are shown in Figure 3.

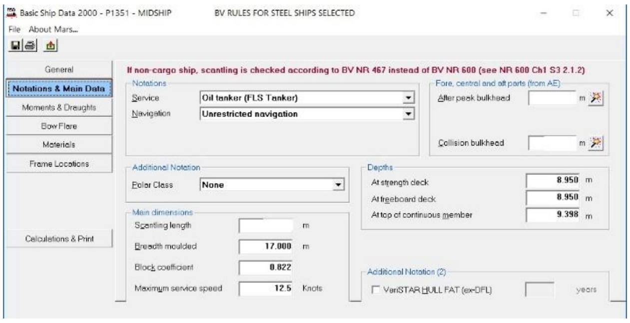

Figure 3 Notation and main data of the existing oil tanker

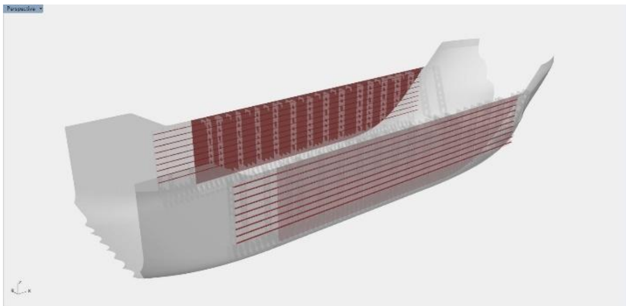

Figure 4 Perspective of the parallel midbody from aft-starboard side, red colored areas are longitudinal bulb flat profiles and side shell

In the next figure, the transversal section of the vessel will be shown. This cross section is modelled according to construction plans. The starboard of the cross section is modelled due to structural symmetry. The longitudinal bulb flat profiles can be seen in the figure. The vertical spacing of these profiles always kept same with the changing longitudinal frame spacing. Distance of vertical spacing is 0.730 meters. The height of the vertical side shell plate is 7.1 meters starting from the end of the bilge radius until the deck line.

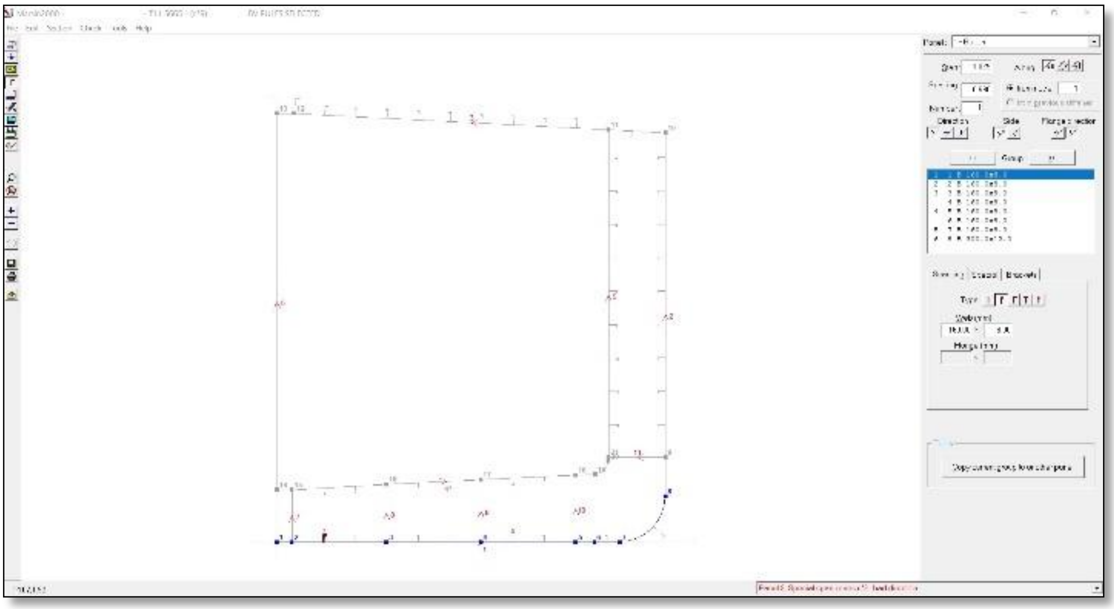

Figure 5 Transversal section of the existing vessel

The modelling is completed for each structural member in the transversal section. Also 3 different side shell thicknesses considered: 8mm, 11mm and 15mm.

In total, 21 different transversal model is created with the Mars2000 software for investigating the structural change with the different longitudinal frame spacing. Below, the checking criteria is shown with a screenshot taken from Mars2000. Basically, the actual section modulus must be greater than the rule section modulus.

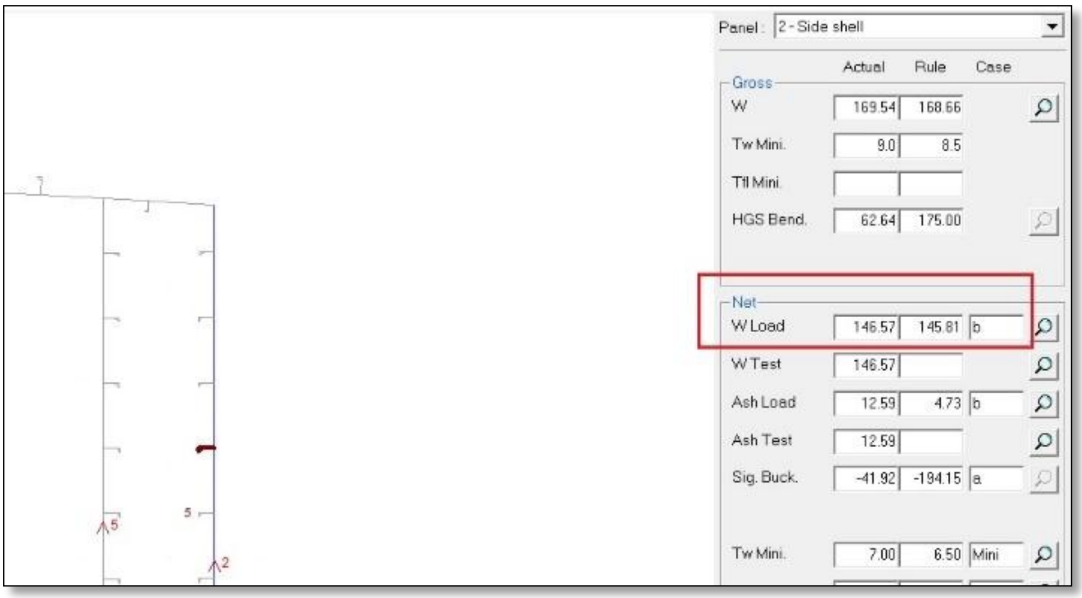

Figure 6 The analyses section of the software showing actual and rule section modulus, respectively.

In particular figure above, shows the actual and the rule section modulus criteria from the analyze section of the software. It should be mentioned that software automatically takes the net scantling of the structural members into account. Due to calculations done with the Bureau Veritas (BV), most of the time net scantlings are being used. The deduction percentage or thickness can be found from the BV online rules given in the resources section in the end of the paperwork.

Considering 21 different transversal sections modelled in software, each profile and plates must meet the checking criteria mentioned before.

In the charts below, the successful profiles and side shell combinations are given. First, the weight calculation for the successful bulb flat profiles are shown below.

Frame Spacing 0.55 meters	
Sıde Shell Stiffeners from top to bottom	Weight per 1
160x11.,5	17.3
160x8	12.7
160x8	12.7
160x9	14
160x9	14
160x9	14
160x8	12.7
160x9	14
160x11.,5	17.3
Total	**128.7**

Figure 7 Side shell gross thickness chosen as 8mm, chart showing the minimum required bulb flat profiles and their weight

Next charts are given from thinnest side shell to thickest side shell respectively. First column is for distance of the longitudinal frame spacing. The second column indicates the side shell gross thickness. Next column shows the stiffener weight calculated for 1 meter in kilograms. In 5th column total steel weight can be seen and welding weight will be added in next column. In the last columns, manufacture cost including man-hour for specific straight bead welding which is taken from Dutch yard is given. That is mostly used calculation value available in the market.

Longitudinal Frame Spacing	Side Shell Thicknes s	Stiffener Weight per 1 meter	Shell Plate ($\sum$h=7.1 meter) Weight per 1 meter	Total Steel Weight	Welding Weight	Total Weight	Build Cost per 1 Tonnes	Build Cost per spacing
meter	(mm)	(kg)	(kg)	(kg)	(kg)	(kg)	(Euro/Tonne)	(Euro)
0.55	8	128.7	445.9	574.6	11.5	586.1	5000	2930.4
0.6	8	147.4	445.9	593.3	11.9	605.1	5000	3025.7
0.665	8	156.2	445.9	602.1	12.0	614.1	5000	3070.6
0.7	8	164.8	445.9	610.7	12.2	622.9	5000	3114.5
0.75	8	176.3	445.9	622.2	12.4	634.6	5000	3173.1
0.8	8	194.6	445.9	640.5	12.8	653.3	5000	3266.4
0.85	8	203.5	445.9	649.4	13.0	662.4	5000	3311.8

Figure 8 Side shell gross thickness chosen as 8 mm

Longitudinal Frame Spacing	Side Shell Thickness	Stiffener Weight per 1 meter	Shell Plate ($\sum$h=7.1 meter) Weight per 1 meter	Total Steel Weight	Welding Weight	Total Weight	Build Cost per 1 Tonnes	Build Cost per spacing
meter	(mm)	(kg)	(kg)	(kg)	(kg)	(kg)	(Euro/Tonne)	(Euro)
0.55	11	113.0	613.1	726.1	20.0	746.1	5000	3730.3
0.6	11	149.9	613.1	763.0	21.0	784.0	5000	3919.8
0.665	11	152.0	613.1	765.1	21.0	786.1	5000	3930.6
0.7	11	164.2	613.1	777.3	21.4	798.7	5000	3993.3
0.75	11	172.3	613.1	785.4	21.6	807.0	5000	4034.9
0.8	11	193.7	613.1	806.8	22.2	829.0	5000	4144.9
0.85	11	198.3	613.1	811.4	22.3	833.7	5000	4168.5

Figure 1 Side shell gross thickness chosen as 11 mm

Longitudinal Frame Spacing	Side Shell Thickness	Stiffener Weight per 1 meter	Shell Plate ($\sum$h=7.1 meter) Weight per 1 meter	Total Steel Weight	Welding Weight	Total Weight	Build Cost per 1 Tonnes	Build Cost per spacing
meter	(mm)	(kg)	(kg)	(kg)	(kg)	(kg)	(Euro/Tonne)	(Euro)
0.55	15	113.7	836.3	949.9	33.2	983.2	5000	4915.8
0.6	15	139.9	836.3	976.2	34.2	1010.3	5000	5051.6
0.665	15	145.7	836.3	982.0	34.4	1016.3	5000	5081.6
0.7	15	158.5	836.3	994.8	34.8	1029.6	5000	5147.8
0.75	15	166.2	836.3	1002.5	35.1	1037.5	5000	5187.7
0.8	15	185.5	836.3	1021.8	35.8	1057.5	5000	5287.6
0.85	15	192.4	836.3	1028.7	36.0	1064.7	5000	5323.3

Figure 10 Side shell gross thickness chosen as 15 mm

3. Results

The charts for 3 different side shell thickness given above, will be given in next figure. In the left vertical axis, weight of side shell with longitudinal bulb flat profiles and welding is plotted. On the other side, right vertical axis of the figure has manufacture cost. Regarding to the bottom longitudinal frame spacing distances given. In 3 different blue tones, the data of minimum required bulb flat profiles is plotted.

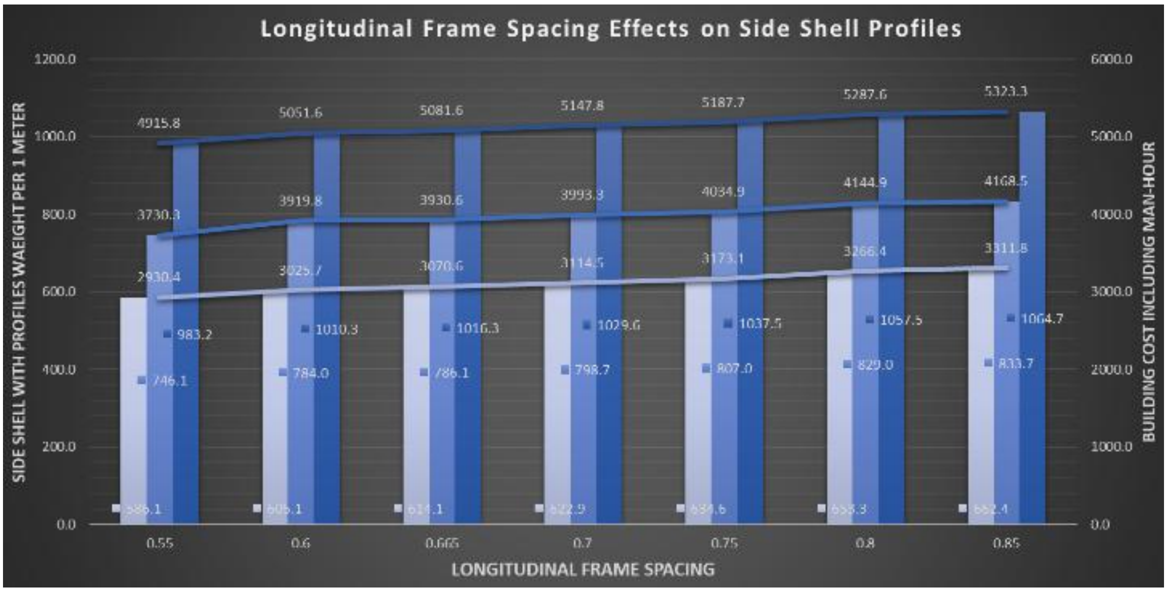

Figure 11 Combination of weight, longitudinal frame spacing and manufacture cost

4. Conclusion

Considering the weights of 21 different combination, shell thickness of 8mm with frame spacing 0.55 meter is the lightest and cheapest construction to be built. Moreover, according to the software results, it is valid, and it can be issued for classification. But, before this, midship structure to be checked with analyses softwares such as StaadPro or Ansys, in 2,5 or 3 dimensional, later on required Von-Misses law will be applied and weak points will be determined. Mars2000 is just the beginning of structural modifications and gives the initial results.

The reason behind it is that, according to still water or wave conditions, to find out critical stress points, it is always better to use finite element methods. Maybe this side thickness of 8mm is not enough, so that next thickness of 9mm or 10mm should be considered. It is not surprising that curvature of the 3 different thickness has kind of same slope on the Figure 11.

This comes from the increasing frame distance and required higher section modulus need of the structure. Regarding to increase in the frame spacing distance, profiles has to be stronger, thus section modulus increases, and weight of the combination becomes higher so that cost of manufacture does.

5. Future Work

Regarding to longitudinal frame spacing changes in the side shell, next investigation should be focused on change in the floor spacings. Then, deck primaries and secondary structural members can be re-modelled with various longitudinal spacings or if necessary vertical spacings. Nevertheless, all these modifications should be checked with structural analyse softwares such as StaadPro or Ansys, in 2,5 or 3 dimensional.

Considering the steel properties, S235 steel can be replaced with S335 or maybe S355 steel so that Mars2000 software calculation will be updated accordingly and possible new combinations can be found. This may effect the weight and cost, so it is an another future work.

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