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DIREZIONE NAVI MERCANTILI

INDEX

1 INTRODUCTION

This report contains the results of a series of verification (NAPA and CFD simulations) requested to verify the sloshing behaviour inside of the Oil Sump Tank on the VIKING series vessels. The main target is to verify the tanks design with respect to the prescription of the rule Lloyd's Register Reg. Part 5, Chapter 1, Section 3, par. 3.7 Inclination of ship (Table 1.3.2).

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the ship	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5 *see* Note 3	22,5 *see* Note 3	10	10

Note *1*. Athwartships and fore-and-aft inclinations may occur simultaneously.

Note *2*. Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$\frac{500}{L}$ degrees

where *L* = length of ship, in metres.

Note *3*. In ships for the carriage of liquefied gas and of liquid chemicals the emergency machinery and equipment fitted in accordance with Statutory Requirements is also to remain operable with the ship flooded to a final athwartships inclination to a maximum angle of 30°.

Figure 1: Table 1.3.2 of the rule Lloyd's Register Reg. Part 5, Chapter 1, Section 3, par. 3.7 Inclination of ship.

Due to the fact that the rules prescribe a double verification (Static and Dynamic), the analysis have been performed into two steps:

- **NAPA simulation to verify the static prescription of the rule**: the tank have been moved to the prescribed position (i.e. ±15 deg roll and ±2.5 deg of pitch) and tank has been filled to reach the required head on the suction point;

- **CFD simulation to verify the dynamic prescription of the rule**: the tank have been moved between the prescribed position (i.e. ±22.5 deg roll and 7.5 deg of pitch) with an harmonic motion of 10s of period.

2 STEADY NAPA VERIFICATION

To verify the static prescription of the rule, the tank have been moved to the prescribed position (i.e. ±15 deg roll and ±2.5 deg of pitch) and tank has been filled to reach the required head on the suction point. Considering that the ship length exceed 100m, the static limit for the “Fore-Aft” inclination has been computed as follow as prescribed by the rule Lloyd's Register Reg. Part 5, Chapter 1, Section 3, par. 3.7 Inclination of ship (Table 1.3.2):

$$\frac{500}{L_{ship}} = \frac{500}{196.643} = 2.54\ deg$$

The limit for the transversal inclination has been considered 15 deg follow as prescribed by the rule Lloyd's Register Reg. Part 5, Chapter 1, Section 3, par. 3.7 Inclination of ship (Table 1.3.2).

As results, the minimum filling volume to satisfy the rule is shown in the following table:

						Static Filling (Trim 500/L°, Heel 15 °)		
Free CCODE	ROOM NAPA	Description	Frame Min	Frame Max	Vol. Max	Vol. Requested by the Static Rule	Filling	Free air above oil level
					m3	m3	%	mm
LO05P	R0532	LUBE OIL SUMP N.05 PORT	69	81	9.10	4.92	54.1	303
LO05S	R0531	LUBE OIL SUMP N.05 STBD	69	81	7.40	4.61	62.3	230
LO06P	R0634	LUBE OIL SUMP N.06 PORT	83	95	7.40	4.60	62.2	305
LO06S	R0633	LUBE OIL SUMP N.06 STBD	83	95	9.00	4.77	53.0	308

In order to verify the dynamic condition, the worst tank (05STBD) in terms of filling requirements, has been selected and verified through CFD simulations.

3 SIMULATIONS

3.1 NUMERICAL SET UP

In this analysis a series of RANSE full scale transient simulations with a multi-phase flow have been performed. The Turbulence model consist of the 2 equation model k-omega SST (as per Menter formulations). The behaviour of the free surface has been reproduced with the Volume of Fluid (VOF) method.

For all the simulation the commercial code STAR-CCM+ v14.02 has been used.
The physical property of the oil has been imposed as follow:

- Density: 880 kg/m^3;
- Dynamic Viscosity: 0.02816 $Pa\ s$

3.2 FLUID DOMAIN

The fluid domain is confined by the Oil sump tank, without inlet or outlet (pump suction)

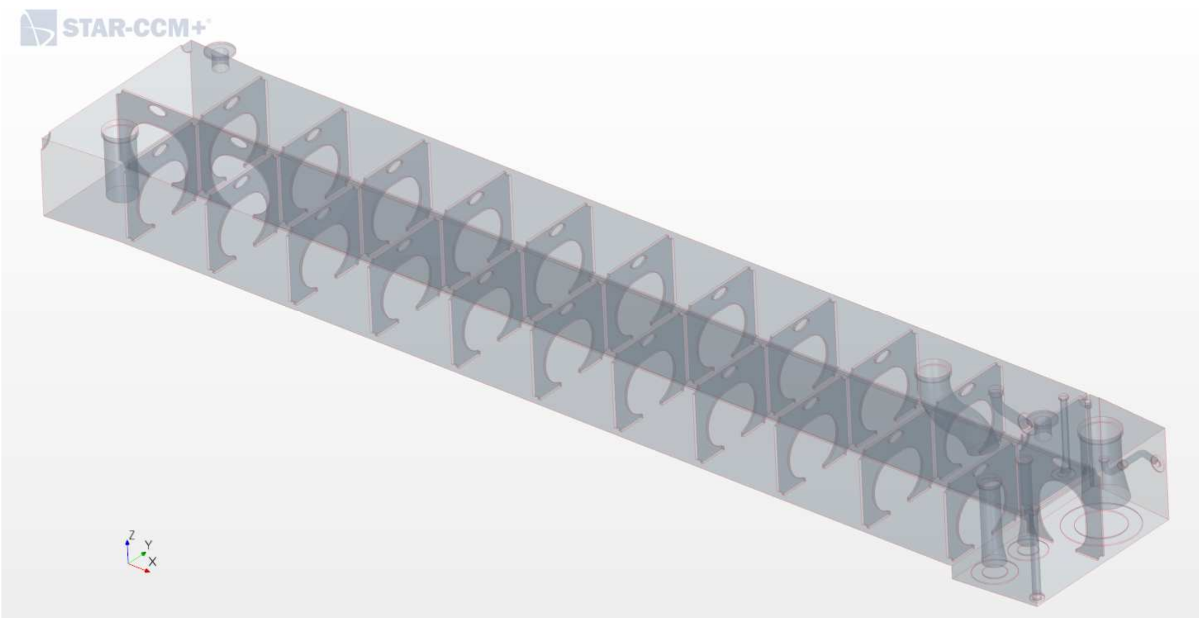

Figure 2: Model of the analysed geometry.

3.3 MESH

The discretization of the domain consist of abt 3.5M cell.

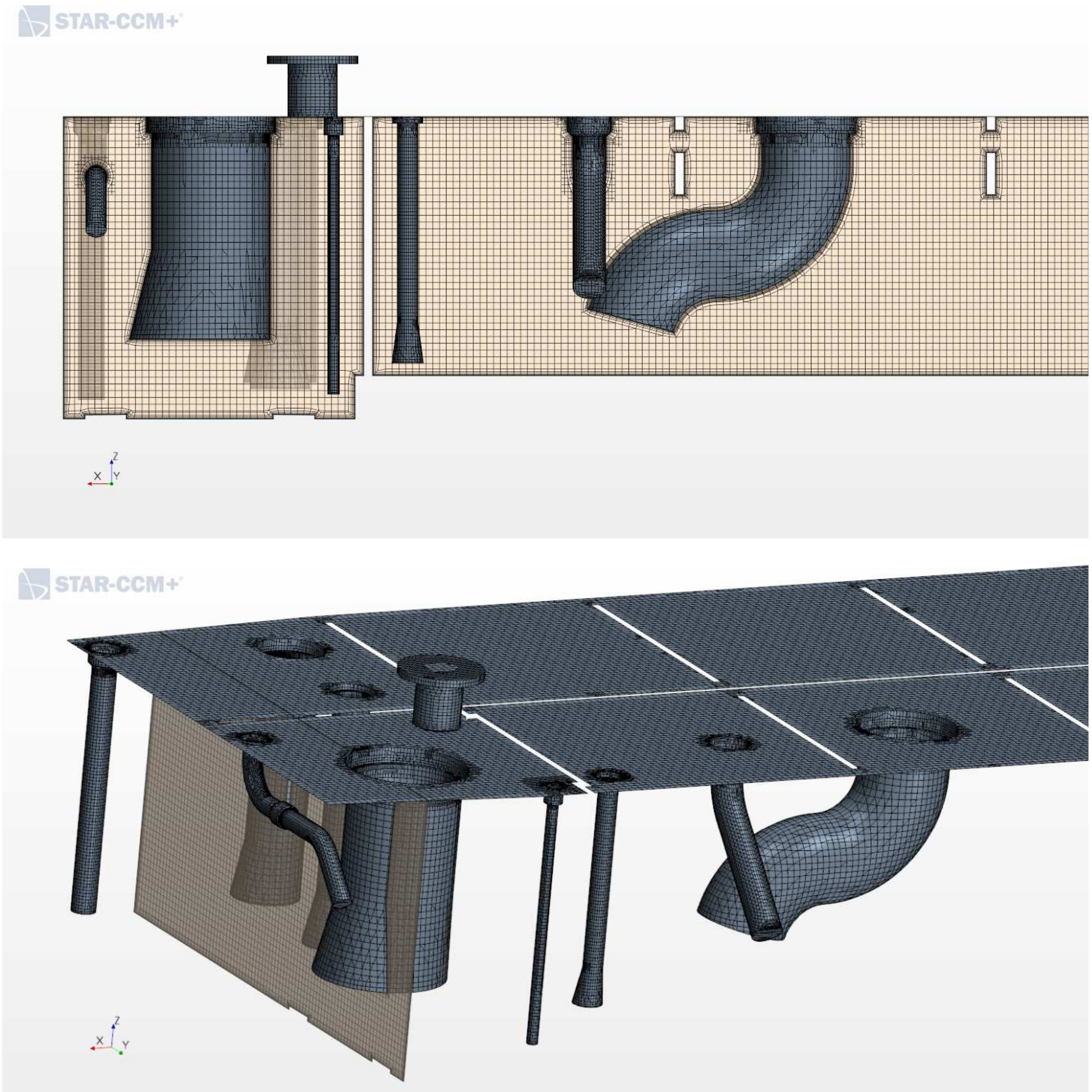

Figure 3: Views of the meshed domain

4 CFD VERIFICATION

To verify the dynamic behaviour of the oil contained into the tank, the pitch and roll motions have been simulated as harmonic motions. To evaluate the worst combination, it has been considered that the maximum Roll and Pitch can be achieved at the same moment and at the same moment but with opposite direction or phase (so two simulations have been performed). The applied conditions are the following:

1. Filling volume 5.4 m^3 (Recommended level as indicated in Lube Oil Service System Functional Diagram - A5 D360 273), Roll ±22.5 deg, Pitch ±7.5 deg (“Design Scenario” derived from Table 1.3.2 of the rule Lloyd's Register Reg. Part 5, Chapter 1, Section 3, par. 3.7 Inclination of ship), period 10s.

The simulations take into account a time window covering 4 full oscillations the first two of which do not represent the real physical phenomenon as simulation start abruptly from a static condition (blue highlighted portion of the graphics)

The results of this simulations consist in verification of the average volume fluid on the suction section in order to evaluate the wetted portion of the suction surface (VOF)

4.1 DESIGN SCENARIO

To verify the dynamic prescription of the rule: the tank have been moved between the prescribed position (±22.5 deg roll and ±7.5 deg of pitch) with an harmonic motion of 10s of period and 5.4 m^3 filling volume.

The suction pipe remain partially uncovered (VOF < 90%) for less than 1 sec at +22.5 deg of Roll and -7.5 deg of Pitch.The MAN pressure sensor activating the Engines shutdown intervenes when the low oil pressure in the suction line persist at least for 4 seconds.

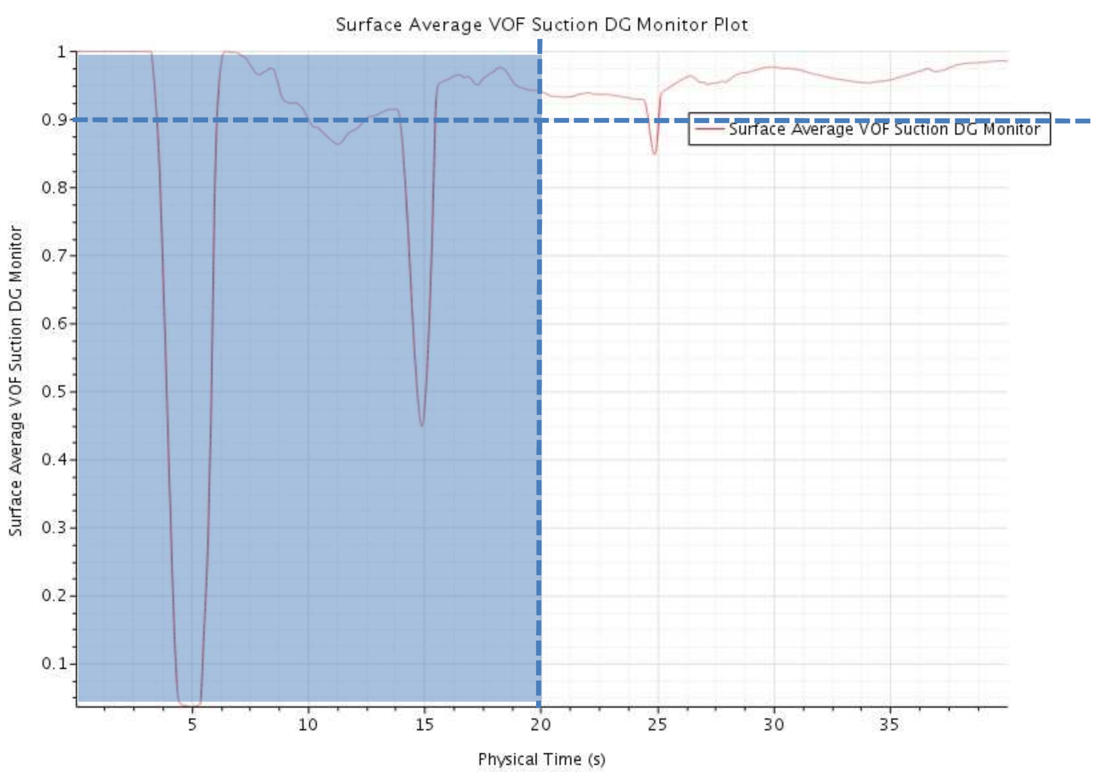

Figure 4: time dependent behaviour of the VOF on the suction pipe in the “Design Scenario” with motions with opposite phase.

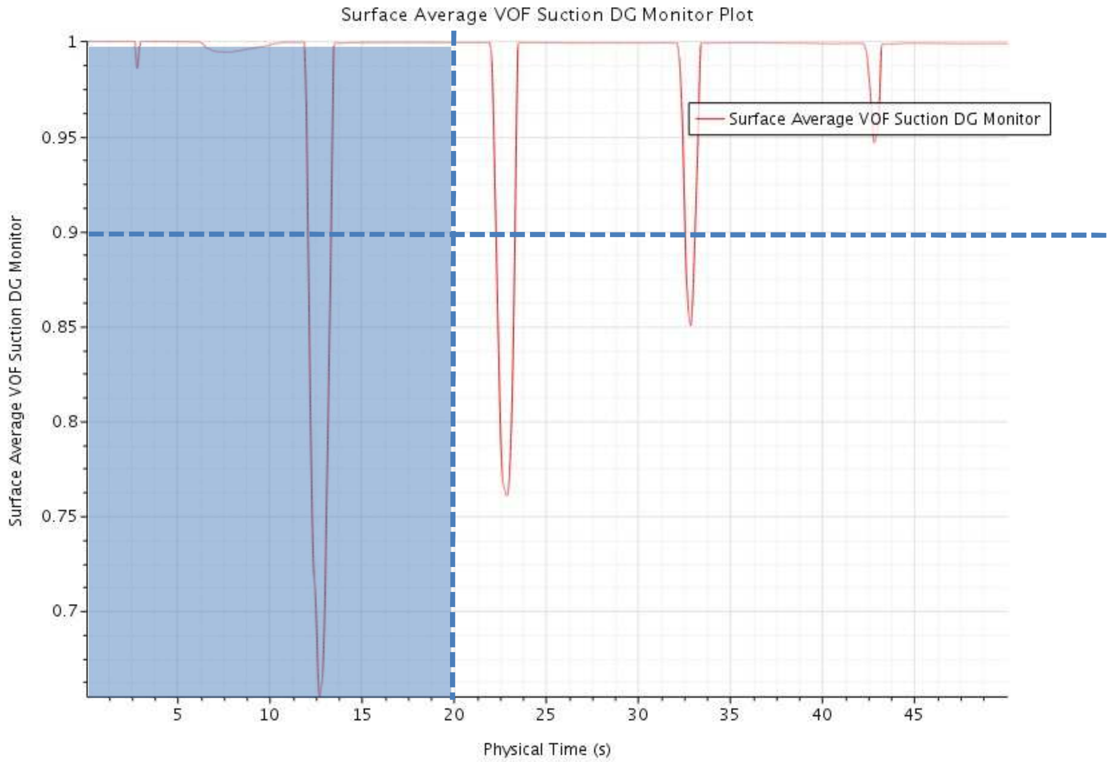

Figure 5: time dependent behaviour of the VOF on the suction pipe in the “Design Scenario” with motions in phase.

4.2 SUMMARY OF THE CFD SIMULATIONS

Both simulations show that the suction, also in such extreme theoretical condition, remains always covered (e.g.: VOF ≥ 90%) unless for some instant which duration is always lower that the 1 sec which tends already to disappear after the third oscillation.

The capability of the engine to operate at the extreme condition prescribed by the Rules is therefore guaranteed.