POLISH MARITIME RESEARCH Special Issue 2008; pp. 27-30
DOI: 10.2478/v10012-007-0074-1

Calculation of oil outflow from fuel oil tanks of a containership with polymer coatings applied to double bottom tanks – in the light of Resolution MEPC.141(54) of IMO

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ABSTRACT

Introduction of the semi-elastic barrier into fuel tanks rise environmental protection level in case of ship collision or grounding. Last law regulations requires change of localisation of fuel tanks in ship structure in a such way to increasing distance between fuel and surounding water. Application of semielastic barrier into fuel tank make possible to localise fuel tanks in double bottomspace. Calculation of hipothetical outflow of fuel from damaged fuel tan in case of application of senielastic barier is presented.

Keywords: fuel tank protection, outflow calculation

INTRODUCTION

For the presented calculation analysis an existing design of SINE202 containership was used. The technical design of the containership having typical arrangement of deep fuel oil tanks, was elaborated entirely by the SINUS design office. All amount of fuel oil contained in the deep tanks was accommodated in double-bottom tanks due to application of polymer coatings in them. This way, the so designed modernization of the ship made its cargo capacity greater. For the new arrangement of fuel oil and ballast tanks a hypothetical fuel oil outflow was calculated for various values of hull damage probability.

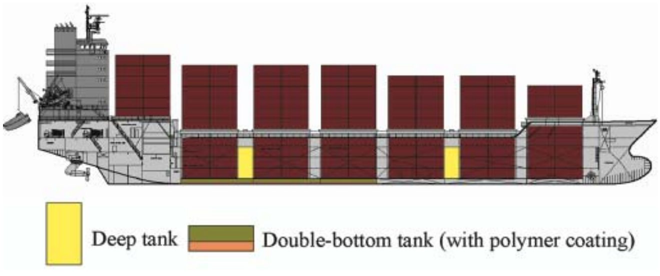

Fig. 1. SINE 202 ship – the analyzed object

Ship main dimensions:

Length overall	138.10 m
Length b.p.	132.00 m
Breadth	22.50 m
Depth	11.20 m
Design draught	7.60 m

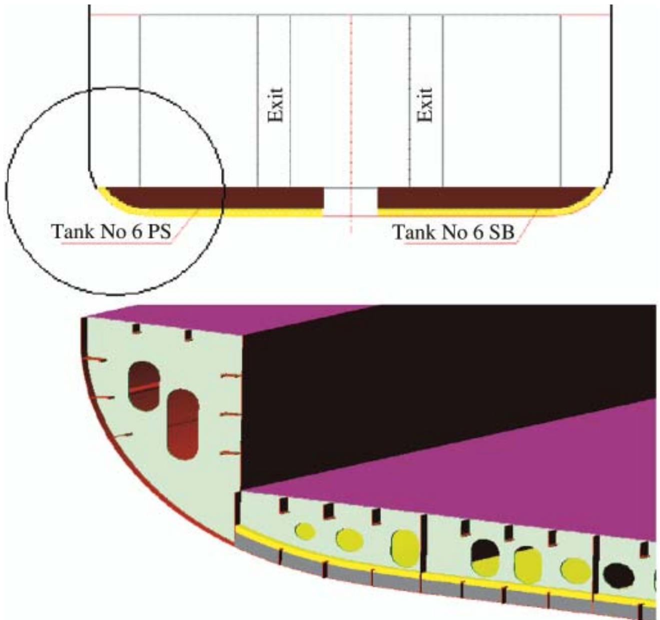

Fig. 2. Arrangement of alternative bottom oil fuel tanks on board the containership

The application of polymer coatings to tanks of the considerd ship was aimed at making it possible to transfer fuel oil from the deep tanks located between cargo holds to the low-depth double-bottom tanks, at simultaneous maintaining compliance with conditions imposed by rules. Such design action could result a.o. in possible using the resulting free space between holds for other purposes.

Though the theoretical distance between fuel oil and ship outer plating has been made radically smaller the level of ship protection against possible oil outflow (in the case of outer plating failure) has been maintained due to physical and chemical properties of the applied protective coatings.

REQUIREMENTS FOR MACHINERY COMPARTMENTS ONBOARD ALL SHIPS ACCORDING TO RESOLUTION MEPC.141(54) [1]

Regulation 12 - Tanks for oil residues (sludge)

1. Every ship of 400 GT or more shall be fitted with a tank or tanks of adequate capacity with a view of kind of its machinery equipment and time of voyage, to serve for storing oil residues (sludge) which cannot be treated in any other way in compliance with provisions of this Annex, and which are produced as a result of centrifugation of fuel and lubricating oils and oil leakages in machinery compartments.
2. Piping leading to and from such sludge tanks shall not have other direct outboard connections than the standard discharge connection defined in the Resolution's provision.
3. On ships delivered after 31 December 1979, the oil residue tanks shall be so designed and built as to made their cleaning and discharging the residues to receiving devices, easier.

Regulation 12A – Fuel oil tank protection

This regulation shall apply to all ships with an aggregate fuel oil capacity of 600 m^3 and above which are delivered on or after 1 August 2010.

For the purpose of this regulation, the following definitions shall apply:

Length	(L)
Waterline	(dB)
Breadth	(B)
Fuel oil	
Breadth	(B_B)
Fuel oil tank	
Depth	(D_S)
Light ship draught	(d_{LS})
Load line draught	(d_S)
Partial load line draught	(d_P)

☆ "Length (L)" means 96% of the total length (L') on a waterline at 85% of the least moulded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel the waterline on which this length is measured shall be parallel to the designed waterline. The length (L) shall be measured in metres.

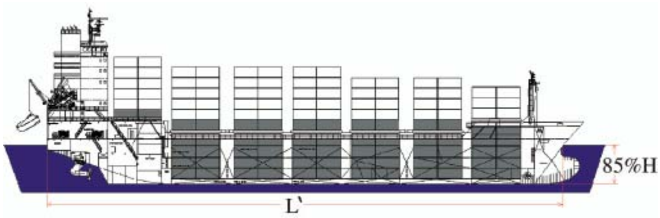

Fig. 3. *Definition of the calculation length according to regulation 12A*

☆ "Breadth (B)" means the maximum breadth of the ship, in metres, measured amidships to the moulded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material.

☆ "Breadth (BB)" is the greatest moulded breadth of the ship, in metres, at or below the waterline (dB).

☆ "Depth (DS)" is the moulded depth, in metres, measured at mid-length to the upper deck at side. For the purpose of the application, "upper deck" means the highest deck to which the watertight transverse bulkheads except aft peak bulkheads extend.

☆ "Fuel oil" means any oil used as fuel oil in connection with the propulsion and auxiliary machinery of the ship in which such oil is carried.

☆ "Fuel oil tank" means a tank in which fuel oil is carried, but excludes those tanks which would not contain fuel oil in normal operation, such as overflow tanks.

☆ "Fuel oil capacity" means the volume of a tank in m^3, at 98% filling.

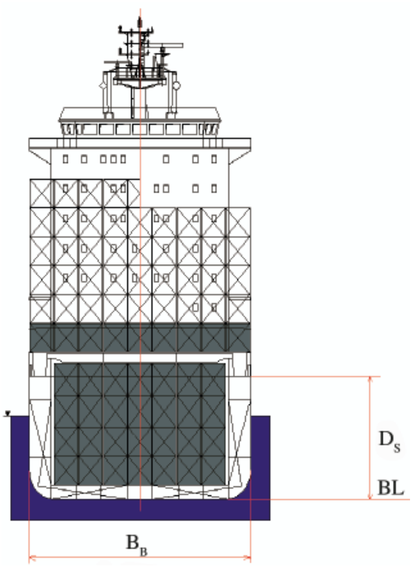

Fig. 4. *Definition of the calculation depth and breadth according to regulation 12A*

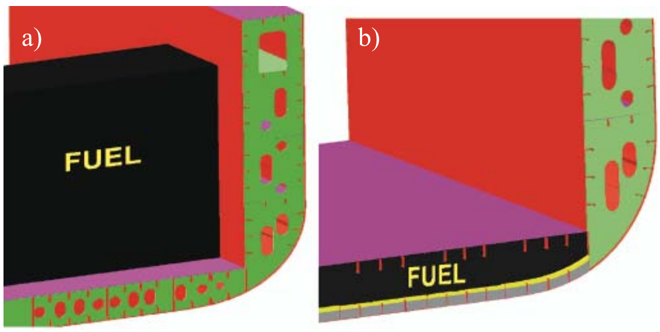

Fig. 5. a) *Fuel oil in deep tank,* ***b)*** *Fuel oil in double bottom tank*

☆ „Light ship draught (d_{LS})" is the design draught measured at mid-length (L/2), corresponding to light ship mass.

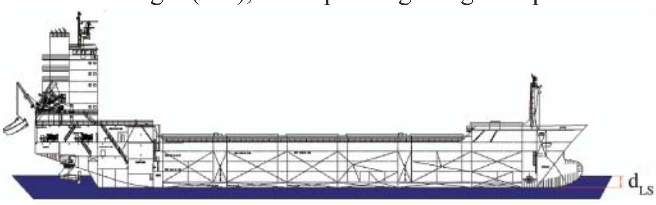

Fig. 6. *Definition of the light ship draught according to regulation 12A*

☆ "Load line draught (dS)" is the vertical distance, in metres, from the moulded baseline at mid-length to the waterline corresponding to the summer freeboard draught to be assigned to the ship.

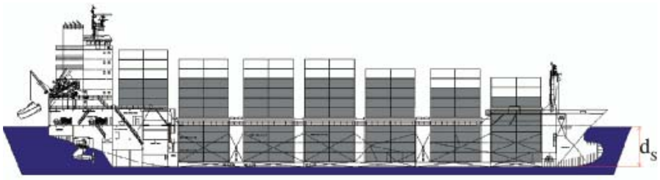

Fig. 7. *Definition of the load line draught according to regulation 12A*

- ✰ "Partial load line draught (dP)" is the light ship draught plus 60% of the difference between the light ship draught and the load line draught dS. The partial load line draught (dp) shall be measured in metres.

$$d_p\text{: Partial load draught} = d_{LS} + (d_S - d_{LS})\cdot 60\%\ [m]$$

- ✰ "Waterline (dB)" is the vertical distance, in metres, from the moulded baseline at mid-length to the waterline corresponding to 30% of the depth DS.

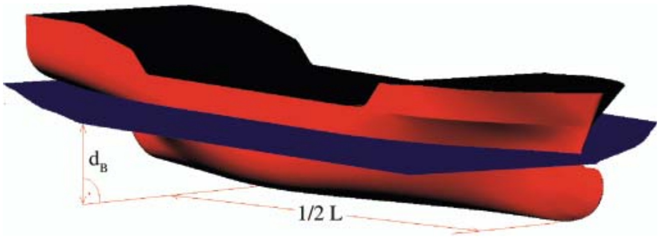

Fig. 8. *Definition of the base waterline according to regulation 12A*

Par. 6. For ships, other than self-elevating drilling units, having an aggregate fuel oil capacity of 600 m^3 and above, fuel oil tanks shall be located above the moulded line of the bottom shell plating nowhere less than the distance h as specified below:

h = B/20 m or,
h = 2.0 m, whichever is the lesser.
The minimum value of h = 0.76 m.

In the turn of the bilge area and at locations without a clearly defined turn of the bilge, the fuel oil tank boundary line shall run parallel to the line of the midship flat bottom as shown in Fig. 9.

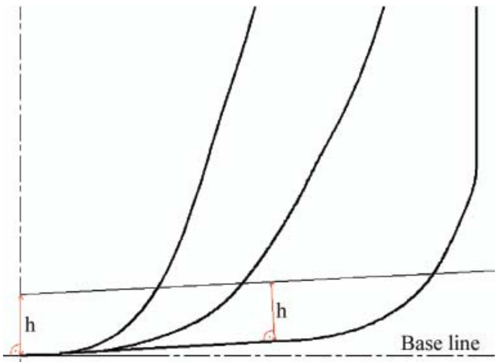

Fig. 9. *The oil fuel tank boundary line running parallel to the line of the midship flat bottom*

Par. 7. For ships having an aggregate fuel oil capacity of 600 m^3 or more but less than 5,000 m^3, fuel oil tanks shall be located inboard of the moulded line of the side shell plating, nowhere less than the distance w which, as shown in Fig. 10, is measured at any cross-section at right angles to the side shell, as specified below:

w = 0.4 + 2.4 C/20,000 m

The minimum value of w = 1.0 m, however for individual tanks with a fuel oil capacity of less than 500 m^3 the minimum value is 0.76 m."

Par. 8. For ships having an aggregate fuel oil capacity of 5,000 m^3 and over, fuel oil tanks shall be located inboard of the moulded line of the side shell plating, nowhere less than the distance w which, as shown in Fig. 10, is measured at any cross-section at right angles to the side shell, as specified below:

w = 0.5 + C/20,000 m or
w = 2.0 m, whichever is the lesser.
The minimum value of w = 1.0 m.

As applied to SINE202 ship:
To SINE 202 ship the following quantities apply:
h = B / 20 m or h = 2.0 m; whichever is the lesser.
The minimum value of w = 1.0 m

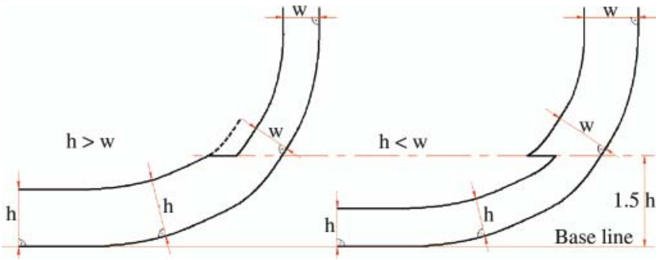

Fig. 10. *Fuel oil tank boundary lines for the purpose of par. 7 and 8*

Par. 11. Alternatively to par. 6 and either 7 or 8, ships shall comply with the accidental fuel oil outflow performance standard specified below:

The level of protection against oil fuel pollution in the event of collision or grounding shall be assessed on the basis of the mean oil outflow parameter, as follows:

$$OM < 0.0157\text{-}1.14E\text{-}6\cdot C \quad 600\ m^3 = C < 5{,}000\ m^3$$

where:
OM = mean oil outflow parameter
C = total fuel oil volume.

As applied to SINE202 ship:

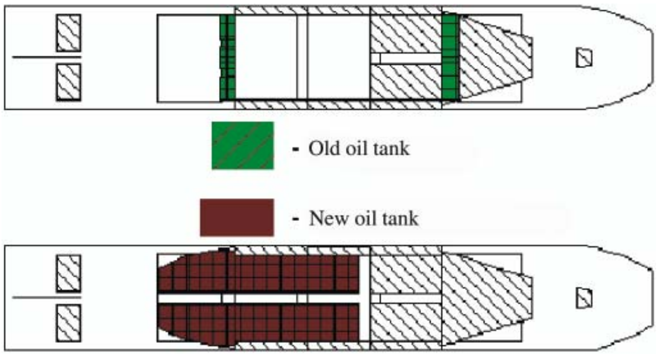

Fig. 11. *Arrangement of oil fuel tanks onboard the analyzed ship*

As for the ship in question the total volume of its fuel oil tanks - both before and after their modification - does not exceed 5000m^3 hence the above given formulae apply to it.

According to par. 11 the following general assumptions shall be used when calculating the mean oil outflow parameter:

- ⇨ The ship shall be assumed loaded to the partial load line draught (d_P) without trim or heel;
- ⇨ The nominal density of the fuel oil (ρ_n) shall generally be taken as 1,000 kg/m^3. If the density of the fuel oil is specifically restricted to a lesser value, the lesser value may

be applied; and the permeability of each fuel oil tank shall be taken as 0.99.

As applied to SINE202 ship:

For the relevant calculations of the ship in question the fuel oil density $\rho_n = 0.9$ t/m^3 and the permeability of fuel oil tanks equal to 0.99 was assumed (Fig. 12).

⇨ The mean oil outflow shall be calculated independently for side damage and for bottom damage and then combined into a non-dimensional oil outflow parameter OM, as follows:

$$OM = (0.4\ OMS + 0.6\ OMB) / C$$

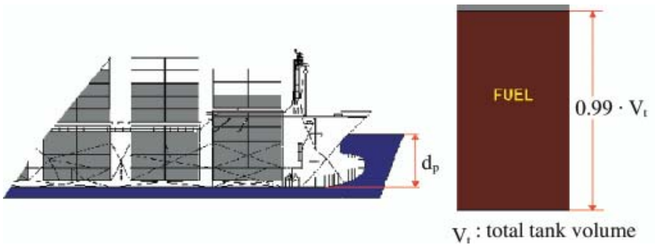

***Fig. 12.** Tank permeability calculation coefficient*

where:
OMS = mean outflow for side damage [m^3]
OMB = mean outflow for bottom damage [m^3]
C = total fuel oil volume.

⇨ For bottom damage, independent calculations for mean outflow shall be done for 0 m and 2.5 m tide conditions, and then combined as follows:

$$OMB = 0.7\ OMB(0) + 0.3\ OMB(2.5)$$

where:
OMB(0) = mean outflow for 0 m tide condition, and
OMB(2.5) = mean outflow for minus 2.5 m tide condition [m^3].

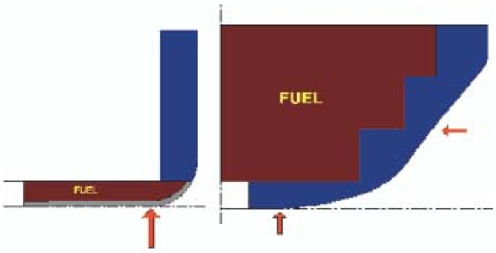

***Fig. 13.** Location of "calculated" damages*

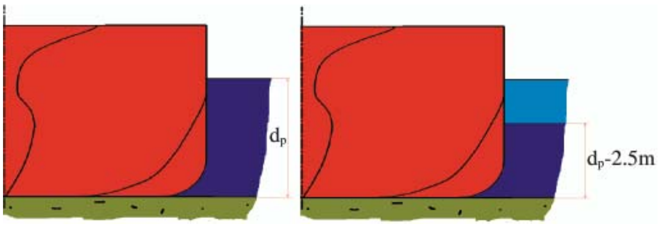

***Fig. 14.** Influence of rise- of- tide change*

CALCULATIONS OF THE MEAN OIL OUTFLOW COEFFICIENT (O_M) FOR SINE 202 SHIP

In order to perform the calculations in question a calculation sheet was elaborated by means of which the mean oil outflow coefficient (O_M) for the considered ship both before and after modification of its fuel oil tanks, was determined. Results of the calculations are given in the Tab. 1. below.

***Tab. 1.** Results of calculations of the mean outflow coefficient for SINE 202 ship*

SINE 202	O_M (permissible)	O_M (determined)
Before modification	0.01478*	0.01051
After modification	0.01477*	0.01497

* the permissible values calculated separately for the fuel oil double bottom tanks and deep tanks.

SUMMARY

- On the basis of the performed analysis it can be stated that after the modification of fuel oil tanks and application of protective coatings the mean oil outflow coefficient (O_M) has become worser as compared with its value before the modification.
- However its deviation from the permissible value is so small that it may be reduced by introducing minor changes in tank construction, e.g. a greater depth of protective coating.

BIBLIOGRAPHY

1. IMO: *Resolution MEPC.141(54): Amendments to the Annex of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973, (MARPOL 73/78),* March 2006.