Marijan Vukičević*

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LOADING AND UNLOADING CALCULATION FOR THE TANKER DESIGN PURPOSE

PRORAČUN PREKRCAVANJA U OSNIVANJU TANKERA

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Pregledni rad
Review

Summary

The problem of loading and unloading procedure of new tankers is dealt with in the preliminary and project design stage as one of the predominant tasks. The new port arrangement, such as the increase of loading and unloading capacity, is the second important request for the control of discharging and the control of the ship's technical behavior. Due to the uncontrolled loading/unloading procedure, the technical calculation of loading/unloading procedure is nowadays more and more requested because of the incidents which are dangerous both for life and property. This conclusion about the necessary calculation by which we are continuously controlling the unloading/loading procedure concerns all ship types. The calculation of the loading/unloading procedure for certain double hull tankers is based on-line specially oriented ship stability control.

In recent years, the main design parameters in cargo and ballast tanks arrangement in double hull tankers have resulted in partially undefined design solutions. The dilemma is focused on whether to incorporate, or not, the central longitudinal bulkhead in cargo tanks area. The additional dilemma is whether to incorporate, or not, the longitudinal central girder in double bottom. The choice of main dimension ratio is also an element for further investigation in recent new tankers design. The new rules requirements about satisfying damage stability in comparison with the ship's intact stability requirement, also influences the adequate recommendations for evaluation of damage condition with reduced damage extents. The future tanker design optimization for double hulled tankers will be one of the most attractive tasks for shipyard and shipping companies, and the continuation and enlargement of this work has to be expected

Sažetak

Problematika prekrcaja brodova rješava se u predprojektu i u projektu u novije vrijeme kao ravnopravni važniji zadatak. Promjene u lučkim uređajima za prekrcaj su drugi bitni zahtjev za praćenje i kontrolu prekrcaja broda. Zahtjev za kontrolom tehničkih proračuna kontinuiranog praćenja prekrcaja broda uzrokovan je nezgodama i nesrećama proizašlim iz nekontroliranog postupka prekrcaja broda. Ovi zaključci o kontroli praćenja prekrcaja vrijede za sve tipove brodova. Kod tankera proračuni kontinuiranog prekrcaja su posebno naglašeni za kontrolu stabiliteta broda.

Bitna promjene u rasporedu teretnih tankova i tankova balasta posljednjih godina na tankerima dvostrukog trupa utjecale su na djelomična lutanja u projektnim rješenjima izražena s dilemom ugradnje uzdužne pregrade u teretnim tankovima, te dilemom pregradnje balastnih tankova s uzdužnom pregradom u dvodnu kao i izborom važnijih odnosa glavnih izmjera broda. Zahtjevi iz novijih propisa o zadovoljenju stabiliteta oštećenog broda u usporedbi sa stabilitetom neoštećenog broda, također utječu na proširenje analiza mogućih havarija tankera i odgovarajućih preporuka za ublažavanje posljedica tih havarija. Optimalizacija budućih projekata tankera s dvostrukim trupom će se kao opći cilj brodogradnje i brodarstva rješavati i nastavkom i proširenjem našeg rada.

*Prof. dr. sci. Marijan Vukičević
Sveučilište u Zagrebu, Fakultet strojarstva i brodogradnje, Zavod za brodogradnju i pomorsku tehniku
Zagreb

Introduction
Uvod

The shipbuilding practice till now has treated the design request as well as design solution for ship's loading and unloading as a solution on which the designer has little influence. This fact was explained with the technological solutions in ports which are mostly constructed and equipped in the old way. The modern new ports (tanker terminals, ore and container terminals) have strongly influenced the types and the

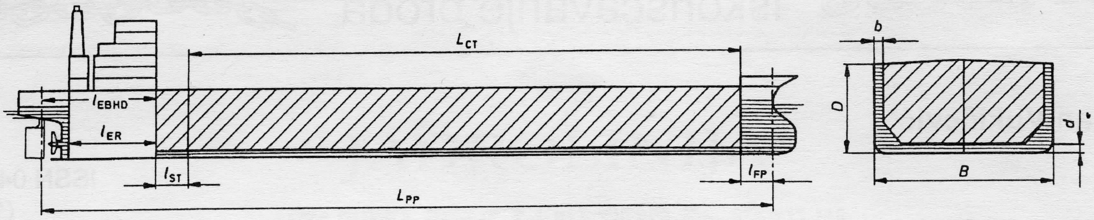

Table no. 1. Main dimensions with general arrangement particulars
Tablica br. 1. Glavne izmjere sa značajkama općeg plana

	L_{pp},m	B,m	D,m	T,m	b,m	d,m	L_{CT}	No_{CT}	No. BWT in CT	area	$1_{E\ BHD}$	1_{ER},m	1_{ST},m	1_{FP},m
40000 DWT Base ship	189,40	31,10	17,278	10,60	2,00	2,08	138,30	2x8	2x5"L"	3"U"	35,60	25,60	8,80	11,10
47000 DWT Project	174,80	32,20	17,50	12,20	2,00	2,15/ 2,30	132,60	2x5	2x2"L"	3"U"	28,60	20,80	4,00	9,60
80000 DWT Base ship	219,00	37,30	18,65	13,10	2,00	2,10	165,90	2x7	7x2"L"		33,67	24,67	9,65	9,775
100000 DWT Base ship	233,00	41,80	20,00	14,30	2,00	2,10	176,50	2x5	5x2"L"		37,80	27,80	7,30	10,40
101000 DWT Project	236,00	39,40	21,30	14,65	2,05	2,63	174,44	7	4x2"L"	3"U"	37,80	28,80	10,68	13,08
15000 DWT Base ship	264,00	48,00	24,00	16,80	2,00	2,32	198,00	2x6	6x2"L"		45,50	33,50	7,50	13,00

sizes of related ships as well as the completed cargo gear. The new requirements resulting from the use of the new cargo gears in ports are of the biggest importance to the cargo loading/unloading capacity. All of the above mentioned has influenced the majority of ship types and sizes.

Up to now it has been common to control buoyancy trim, longitudinal strength and stability by calculation of different ship sailing conditions. In the last few years it has been recommended to control these parameters before loading/unloading procedure as a preparation for the intended procedure in the same way as the control of the sea going condition has been made. All these loading/unloading problems concern all types and sizes of ships, and can be classified as those dealing with the stress longitudinal strength (Bulk-carriers and container ships) and those dealing with the stress to the stability (tankers and container ships). Consequently, in further discussion, we classify the loading/unloading problems according to the ship types.

Up to now, the calculation of trim, stability and longitudinal strength particular determining the allowable ship sailing condition for every ship has been based, directly or indirectly, on the sailing conditions described in so called "Trim and stability book" which is on of the most important ship design documents. The present requirement is that the ship should be equipped with a personal computer for the control of sailing conditions (multi-point loading instrument). The PC is programmed and used exclusively for determination of ship sailing condition, described or not described, but similar to the condition in the approved "trim and stability book".

The new approach to the control of the calculation results for the loading/unloading period would use the same logic of multi-point loading instrument with the additional information from automation or standardized procedure data (so called computer programs off-line and on-line).

The knowledge developed from the software for determining the results of loading/unloading procedure, as well as the results from sailing condition calculation, should be used by the designer for optimization of the new ship design.

The common design request for the new ship is that the cargo loading/unloading procedure should be economical and should satisfy the safety requirements (human life, property and environment protection) at the same time. The ship owner can expect rules by which the loading/unloading procedure will be prescribed. This prescribed procedure will contain technical and other safety conditions, as well as port conditions (speed, pipes capacity, cranes and so on). The International Maritime Organization (IMO) prescribes conditions for new ship design approval, and classification societies and maritime authorities implement these international regulations to real life.

In making modern and competitive ship design, the shipyards must analyze the advantages and disadvantages of the new design in view of the loading/unloading procedure. Apart from improving ship safety procedure for crew and environment, it is necessary to analyze possible human factor error and automation failure, and consequently, the prescribed improved action.

This general analysis of cargo transfer operation of ships has to be enlarged with the specific solution on some ship types, i. e. tankers, bulk carriers, container ships, general cargo and Ro-Ro ships. In the last few years there have been alterations in geometry configuration and other technical particulars of these ship types, such as double hull tankers and some bulk carriers, container ships with the introduction of container cells below and above deck even without hatch covers, as well as other specific solutions on these and other ship types. These specific solutions would include loading/unloading sequence planning, simultaneous cargo/ballast transfer planning and even stores transfer planning. The example for specific requirement of liquid transfer operation for tankers includes the analysis of potenetial loss of the intact stability known as lolling prevention. The term lolling determines the ship's caused by the instability in upright ship position. This loss of stability can be caused by free surface effect generated during the simultaneous liquid transfer for ballast and cargo with various intermediate levels and by the relatively higher center of gravity of the cargo due to the introduction of double bottom.

The incidents caused by this starting instability (lolling) have caused a lot or problems to ship designers, ship operators, ship charters, to the IMO and Classification Society, and they ask for additional expertise dealing with the substantial ship and port equipment damages.

Loading and unloading of double hull tankers
Prekrcaj tankera s dvostrukim trupom

At the beginning of 90s, a new type of tankers with double hull (double bottom + double skin) was designed. This new tanker configuration is used for tankers of about 40,000 DWT and above.

Table no. 2. Study of introduction of the number of "U" ballast tanks
Tablica br. 2. Razmatranje primjene broja "U" tankova balasta

	GM$_0$					
"U" tanks	40000	47000	80000	100000	101000	150000
No "U" tanks	1,23		2,33	3,04	-0,08	3,00
1 "U" tank	0,84		2,09	1,86		1,97
2 "U" tanks	0,02		0,60	0,70		0,84
3 "U" tanks	-0,45	~2,0			-1,13	

Table no. 3. Results of B/D parametric study
Tablica br. 3. Rezultati odnosa B/D

	GM$_0$					
B/D	40000	47000	80000	100000	101000	150000
1,50	-0,01		-0,12			
1,60				0,57		0,87
1,80	1,23			1,56		1,66
1,84		~2,00				
1,85					~0,2-0,3	
2,00	2,02		2,33	2,58		3,00
2,09				3,04		
2,20				3,64		4,16
2,40				4,76		5,39
2,50	4,17		4,50			

The possible alternative of geometrical configuration of ballast and cargo tanks have not as yet been fully analyzed, and a number of tankers with various configurations resulting in different economical efficiency in the period of cargo transfer have been built. The aim of this analysis,and we hope of future similar analyses, is to come up with proper conclusion confirmed by the ship operation period. The further goal is that the double hull tanker design has to be satisfactory safe during all liquid transfer[operations without unnecessary building expenses, and especially without unnecessary operation expenses.

The result from lit. [1] of the analysis of loading/unloading procedure lit. [1] were used for comparison of our experience from lit. [2] and the corresponding data of a 47,000 DWT tanker design from lit [3]. In addition to the goal of making a design with satisfactory safety during liquid transfer (not too high, not too low), the aim is to execute transfer of liquid in the shortest possible time. The transfer period is limited by the character's request regarding the complete ship cargo system (for example piping, pumps, valves, inert gas) and today's ship port staying period is 12 hours for loading and 20 hours for cargo discharging for bigger deadweight tankers, primarily for crude oil tankers. tankers of smaller deadweight are primarily intended for the transport of oil product and/or chemical.

Research of the intact stability particulars for double hull tankers, as described in table 1., by varying design variables of 4 base ship particulars, i. e. 40,000 DWT, 80,000 DWT, 100,000 DWT and 150,000 DWT has been caried out. We added 2 additional double hull

Table no. 4. Results of KG/D parametric study
Tablica br. 4. Rezultati razmatranja odnosa KG/D

	GM$_0$					
KG/D	40000	47000	80000	100000	101000	150000
0,50	1,09		2,75	2,99		3,12
0,55	0,96		2,64	2,88	~0,3	2,97
0,589		~2,0				
0,60	-0,82		2,52	2,76		2,83
0,65	0,69		2,40	2,65		2,68
0,70	0,56		2,28	2,53		2,54
0,75	-0,42		2,16	2,41		2,39

Table no. 5. Results of cargo specific gravity parametric study
Tablica br. 5. Rezulati razmatranja ukrcaja različitih

	GM$_0$					
SG	40000	47000	80000	100000	101000	150000
0,65	0,37	2,30	2,70	3,57		3,10
0,70	0,38	2,34	2,55	3,38	0,70	3,08
0,75	0,42	2,38	2,45	3,24	0,55	2,93
0,80	0,48	2,45	2,38	3,14	0,32	2,92
0,85	0,54	2,49	2,35	3,55	0,23	2,95
0,90	0,62	2,52	2,33	3,04	-0,05	3,00
0,95	-0,71	2,57	2,34	3,04		3,08
1,00	0,83	2,65	2,37	3,06		3,19
1,50		3,37				

Note: STA Tanker 101000 DWT is without the central line cargo bulkhead

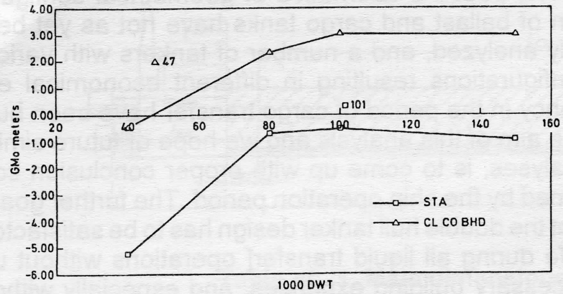

Diagram no. 1 Minimum values of GM_0 versus tank arrangement

Dijagram br. 1. Minimalne vrijednosti GM_0 naprama rasporedu tankova

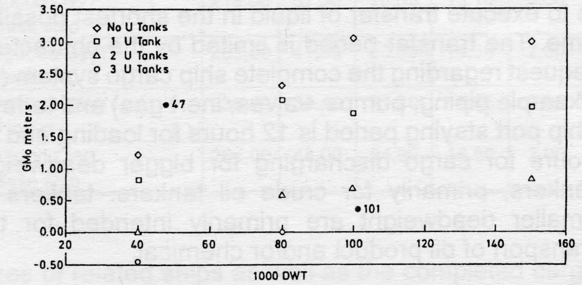

Diagram no. 2. Minimun of GM_0 versus number of "U" ballast tanks

Dijagram br. 2. Minimalne vrijednosti GM_0 naprama broju "U" balastnih tankova

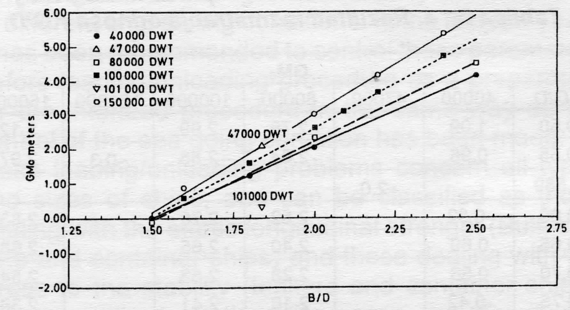

Diagram no. 3. Minimum value of GM_0 versus B/D ratio (at constant KG/D ratio and cargo specific gravity)

Dijagram br. 3. Minimalna vrijednost GM_0 naprama odnosu B/D (kod konstantnog odnosa KG/D i specifične težine tereta)

project tankers, i.e. 47,000 DWT and 101,000 DWT (see table no. 1).

From the paper lit. [1], the investigation of tankers based on ship particulars explained and defined in table 1 was performed. Our 2 additional double hull project tankers, i.e. a 47,000 DWT product and chemical tanker, and a 101,000 DWT tanker without central longitudinal cargo bulkhead were excluded.

In the tables no. 2, 3, 4 an 5 the results of minimum GM for every analysis of the stated particulars are

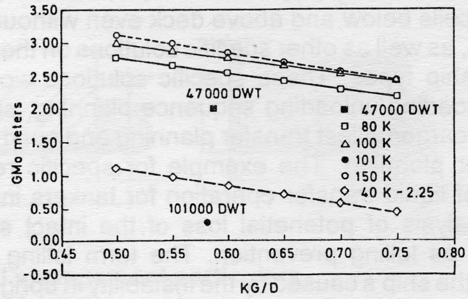

Diagram no. 4. Minimum values of GM_0 versus KG/Depth ratio

Dijagram br. 4. Minimalne vrijednosti GM_0 naprama odnosa KG/D

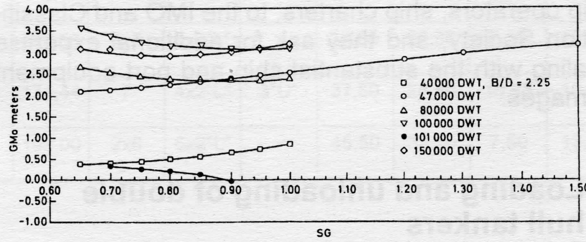

Diagram no. 5. Minimum values of GM_0 versus specific gravity of cargo (SG)

Dijagram br. 5. Vrijednosti minimalnog GM_0 naprama specifičnim težinama tereta (SG)

given: "U" ballast tanks, B/D ratio, KG/D and SG (cargo specific gravity). All GM_0 results are stated in meters, and correspond to minimal available GM_0 values from the investigation of the condition of small ballast level equally distributed as well as high cargo filling.

The worst case condition for ships with the centerline bulkhead in the cargo block is associated with small ballast levels, i.e. 5%, and high cargo level, i.e. 98%.

For ships with so called "U" ballast tanks, the critical amount of ballast increases to the level near 10%. For ships without central bulkhead in cargo tanks (STA ship single cargo tank across) the cargo level drops to about 90%.

Tankers with the central line bulkheads in cargo tanks do perform with better GM_0 value (Diagram no. 1).

Tankers with double bottom central divisor also have higher value of GM_0 (Diagram no. 2).

The B/D ratio has an important role in the intact stability of the ship (Diagram no. 3).

The variables for ships of 47,000 DWT and 101,000 DWT are not given, so the particulars are stated for the actual ratio KG/D /Diagram no. 4).

From the diagram no. 4 it can be proven that the influence of the ratio KG/D, as the influence of light ship vertical center of gravity, is very important because the change is directly proportional to the change GM_0 for the stated displacement. The influence of cargo specific gravity is smaller than other influencing particulars (Diagram no. 5).

In the range of cargo specific gravity from 0,65 to 1,00 GM_0, there is no significant minimum and the change is about 0,5 m.

For the tanker of 47,000 DWT in diagram no. 5, the range of cargo specific gravity is up to. 1.50.

Conclusion and future work
Zaključak i budući rad

Everyday practice adds to and improves today's regulations and rules, especially for the control of damage stability, and decisions about the choice of loading condition which is based upon the evaluation of survival after standardized case of damage.

These rules have brought about additional requirements to tanker design and we did not introduce the mentioned damaged stability problem in this work. An increasing number of countries requested that the ballast sea water has to be tested and/or exchanged on open deep-sea before entering their territorial waters. By this request our task is even enlarged, e.g. after defining ship sailing condition and defining liquid transfer condition in port, we have to define ballast exchange on the open sea.

This task includes definition of all real loading condition of ballast and cargo at sea and in port, including trim, stability and longitudinal strength calculation results, together with the liquid cargo transfer procedure with the exact loading/unloading steps. This research has the intention of giving to the designer enough exact information relevant for the intact ship stability. The starting instability (lolling) can be avoided either by changing particulars or by stating and following strict restrictions in the ship exploitation.

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The initial instability is quite rare condition but it has, or can have, very bad and dangerous consequences. It would be recommendable to introduce into the design a solution expertise from rules and ship exploitation solution. It would be recommendable both in the evaluation of relative risks and in the evaluation of possible expenses as well. The evaluation of expenses in the design solution is combined with the evaluation of the expenses during the ship operation. The future research will include the analysis of the damage stability result in the variants of the new design solution. We can expect further standardization of the ship loading condition for calculation of the damage stability particularly in longitudinal and transversal ship strength. This standardization will enable to avoid or to reduce the outflow of oil due to damage, and the optimization of the new design elements can be expected in many ways for a number of design elements.

The maximum allowable vertical center of gravity curves are calculated from the stability criteria that have prescribed the range for given draughts between the stability of the intact and damaged ship. Defining of this range is indicated by economical evaluation of the new design for the new ship building, as well as for the ship exploitation.

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