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Comparative study of the safety of two tugboats using new harmonized stability rules

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Abstract. Tugboat operations present a high degree of risk and to prevent accidents, the crew must know and manage very well all the necessary maneuvers. Stability is a critical aspect for the safety of tugboats and towing operations, so recently new international regulations have been developed. The tugboats perform several functions, the main one being pulling, but by being equipped with certain equipment and installations, the tugboats are intended for rescue, firefighting, depollution, ice breaking and occasional transport. For this study, two categories of tugboats were considered to determine the geometric characteristics, hydrostatic, of stability and longitudinal strength. The Modelmaker module is used to create the ship's body (Geometry File), the superstructure and all appendages, after which the compartmentation is created and the types of compartments and tanks are positioned in the ship's body. To determine the safety of the two tugboats from the point of view of stability, the heeling moment (the heeling arm) that occurs during towing with the righting arm was checked. At the end, the safety status of the two categories of tugboats was analyzed and new projects were proposed for the future, regarding the use of stability criteria for tugboats.

Keywords: tugboat, intact stability, self-tripping, tow-tripping, heeling arm

1. Introduction

Tugboats are intended for operation in the open sea, harbors and offshore conditions, canals or on inland waters. In addition to the main pulling function, the tugboats are equipped with installations and equipment that allow the performance of other activities, such as: rescue, fire fighting, depollution, ice breaking, and occasional transport. The tugboats are specialized on different types of operations, which lead to different constructive and functional characteristics. The main characteristic of a tugboat is its power and, in direct correlation with this, its traction on the hook (bollard pull) [7].

In order to prevent accidents, in the case of all described tugboat operations, the degree of risk must be permanently known and managed very well by the crew. The loss of towing stability was the main cause in most accidents.

Since stability is a critical aspect for the safety of tugboats and towing operations, new international regulations have been developed [1], [2], [3], [4], [5], [6].

To this end, three sets of stability criteria were included: self-tripping towing stability, tow-tripping towing stability and escort stability, whereby the self-tripping and escort. These were based on the

Bureau Veritas Safety Guidelines for Design, Construction and Operation of Tugs (NI617, July 2014), which have been developed in the wake of the SafeTug JIP6 [3]. These rules are mandatory for ships with a length of more than 24 meters.

Tugboats with a freeboard length L_{LL} less than 24 meters should as far as practicably comply with the requirements given in this section. Other stability requirements may however be applied provided the Society upon consideration in each case finds these requirements to be appropriate for the ship.

These stability assessment criteria applied to ships constructed after 1 January 2020, engaged in port towing, coastal or ocean towing and escort operations and to ships being converted to carry out towing operations after this date [4].

2. Geometric modelling of the tugboats

The dimensioning of the tugboats is done taking into account their type, as well as the port regulations, the dimensions of the escorted ships, the maneuvering space, the local environmental conditions (wind, current, tide, etc.). The determining elements in the design of the forms are: - optimization of the area where the thrusters are located in terms of the required space and ensuring a correct flow in the area of the thrusters, - the good behavior of the ship in rough seas, - consideration of the possibility of marching backwards at full speed , - consideration of the specific conditions of use, namely the risk of collision with escorted ships, with the dock, as well as the risk of failure, - technological simplicity of construction [7].

For this study, two categories of tugboats were considered to determine the geometric characteristics, hydrostatic, of stability and longitudinal strength [8], [9], [10].

The Autoship module is used to design the ship's shapes using NURBS (non-uniform rational B-spline) curves and surfaces, in a parametric system, the elements being also represented by tabular values [12].

Tugboat P1 with the dimensions the length 22.275m, the beam 10.882m, the draft 3.279m; the displacement 445t, having the lines of ship from figure 1.

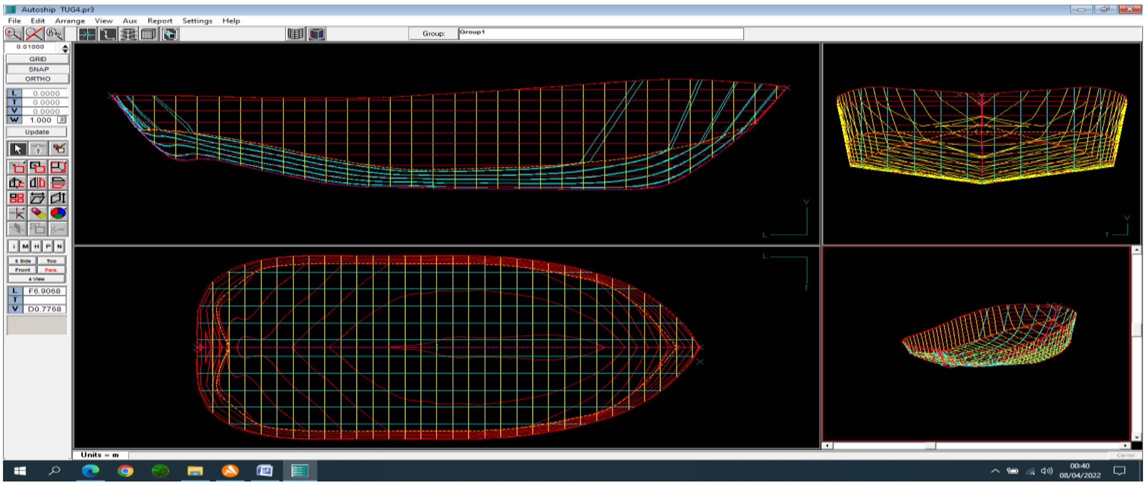


Figure 1. Lines of ship for tugboat P1 (author source)

Tugboat P2 with the dimensions the length 29.508m, the beam 10.882m, the draft 3.342m; the displacement 570t, having the lines of ship from figure 2.

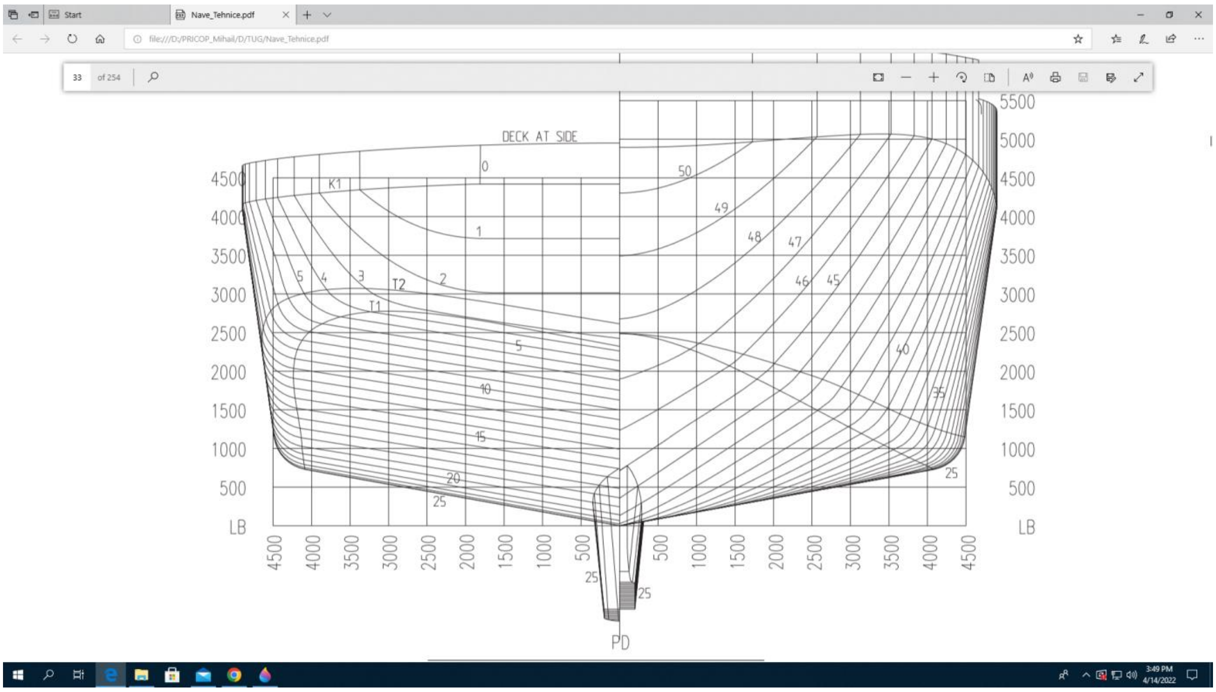


Figure 2. Lines of ship for tugboat P2 (source [7])

The Modelmaker module is used to create the ship's body (Geometry File), the superstructure and all the appendages, after which the compartmentalization and positioning of the compartments in the ship's hull is carried out [13].

3D model for tugboat P1 (autohydro):

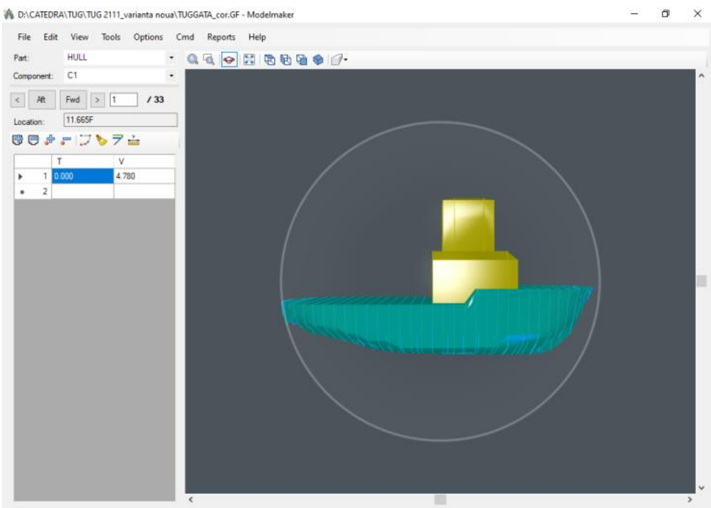


Figure 3. Tugboat P1 Geometry File (author source)

3D model for tugboat P2 (autohydro):

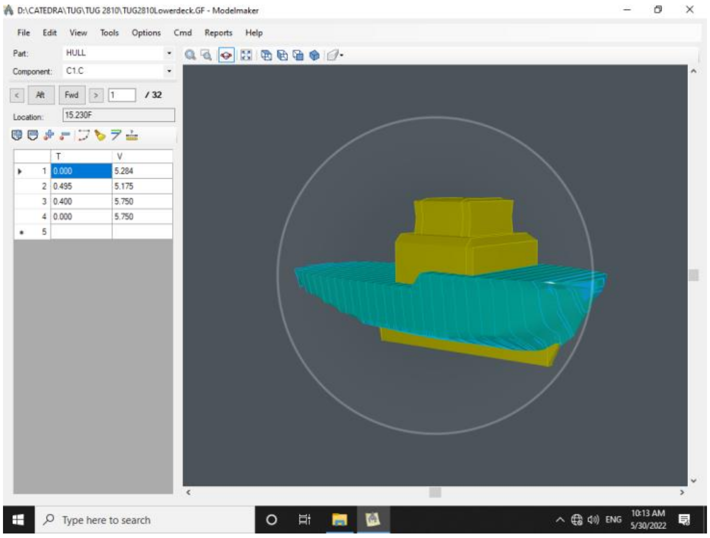


Figure 4. Tugboat P1 Geometry File (author source)

3. Determination of the main characteristics of hydrostatic, stability and longitudinal strength for the specific loading situations

In this paper, the international stability criteria currently applied to tugboats, for the two marine tugboats P1 and P2, are simulated and investigated.

In the first part, the hydrostatic, stability and longitudinal strength requirements are analyzed in general, using the Autohydro software, and in the second part, based on the information and assumptions of loading and operation, the stability criteria are evaluated according to the International Rules.

Ventilation openings for tugboats which are positioned less than 2.3 m above the main deck are provided with weather-tight closure in the event of hazardous navigation. For ventilation openings located at a height greater than 2.3m, Rule 17 of the Load Line Convention does not provide for weather-tight closing devices. Openings in the hull, superstructures or deckhouses that cannot be weather-tight are considered unprotected openings and, consequently, the corresponding angles of inclination are considered down-flooding points and are used in stability calculations (the smallest inundation angle).

In conclusion, the paper considered the stability and safety criteria for the following loading conditions of the tugboats, with the ventilation openings and the doors closed:

- 100% loaded condition
- 50% loaded condition
- 50% loaded condition with ballast
- 10% loaded condition
- 10% loaded condition with ballast.

Tugboat P1

Table 1. Comparative study of the main characteristics of hydrostatic, stability and longitudinal strength depending on the loading situations

Loading situation [%]	Displacement [TM]	VCG [m]	Draft [m]	GM_{fluid} [m]	GZ_{max} [m]	Φ_{max} [grade]	Max. shear force [TM]	Max. bending moment [TM-m]
100%	429,8	2,239	3,168	3,293	0,899	33,4	-44,8	257

50%	405	1,917	3,055	3,714	1,295	38,2	-46,4	288
50%+balast	418,9	1,974	3,126	3,607	1,196	37,8	-51,9	325
10%	385	1,978	2,952	3,77	1,359	37,8	-45,9	305
10%+balast	398,9	2,036	3,025	3,649	1,265	37	-51,7	344

Tugboat P2

Table 2. Comparative study of the main characteristics of hydrostatic, stability and longitudinal strength depending on the loading situations

Loading situation [%]	Displacement [TM]	VCG [m]	Draft [m]	GM_{fluid} [m]	GZ_{max} [m]	Φ_{max} [deg.]	Max. shear force [TM]	Max. bending moment [TM-m]
100%	570	2,454	3,34	3,047	1,394	42	-52,9	482
50%	516	2,586	3,12	3,009	1,376	39,2	-57,2	534
50%+balast	570	2,745	3,34	2,721	1,166	37,2	-80,5	739
10%	469	2,730	2,94	3,055	1,418	39	-62,1	584
10%+balast	531,8	2,895	3,19	2,70	1,185	36,6	-85,7	807

4. Determining the heeling arm and checking the stability criteria

4.1 Determination of the heeling arm

In order to determine the safety of a tugboat from the point of view of stability, the following must be checked:

a) The heeling moment (heeling arm) that occurs during towing,

b) Safety margin applied.

The heeling moment of the tugboat occurs in the following situations [4]:

- when dragging by the assisted ship with the tow cable (tow tripping), which is based on the hydrodynamic resistance of the tugboat in lateral movement, a situation that depends on the speed of the tugboat, the lateral projected area of the underwater hull and the angle between the tugboat and the tow cable;
- when braking is based exclusively on the power of the engines (self-tripping);
- by combining the two situations (escort regime).

a) The tow tripping heeling lever $HL\varphi$ is calculated with the formula:

$$HL_{\varphi} = C_1 \cdot C_2 \cdot \rho \cdot v^2 \cdot A_p \cdot \frac{(h \cdot cos\varphi - r \cdot sin\varphi + C_3 \cdot d)}{(2g \cdot \Delta)}, \qquad (1.)$$

where:

C_1 - lateral traction coefficient, $C_1 = 2{,}8 \cdot \left(L_s/L_{pp} - 0{,}1\right)$, with $0{,}1 < C_1 < 1{,}0$,

C_2 - correction for C_1 for angle of heel $C_2 = (\varphi/3\varphi_D + 0{,}5)$, $\varphi_D = arctg(2f/B)$, with $C_2 > 1{,}0$,

C_3 - distance from center of A_P to the waterline as fraction of the draft related to the heeling angle, $C_3 = (\varphi/\varphi_D) \cdot 0{,}26 + 0{,}30$, with $0{,}5 < C_3 < 0{,}83$,

ρ - specific gravity of water (t/m^3),

v - lateral velocity, in m/s, to be taken as 2.57m/s (5 knots),

A_p - lateral projected area of the underwater hull (m^2),

r - transverse distance between the centerline and the towing point, to be taken as zero when the towing point is at the centerline (m),

L_s - longitudinal distance from the aft perpendicular to the towing point (m),

L_{pp} - length between perpendiculars (m),

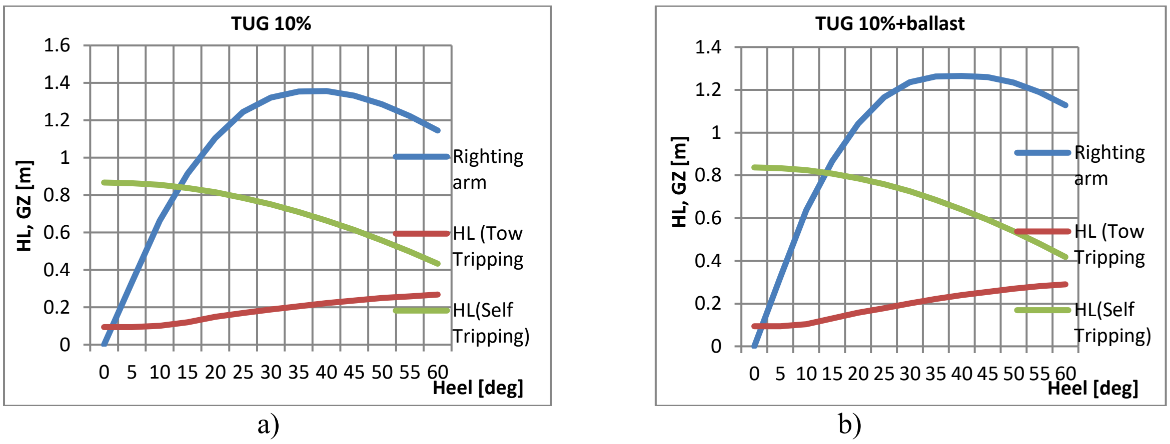
φ_D - angle to deck edge (deg),

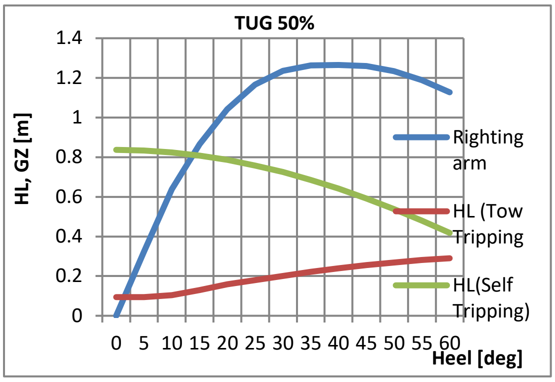
φ - angle of heel (deg),
f - freeboard amidships (m),
B - moulded beam (m),
h - vertical distance, from the waterline to the towing point (m),
d - actual mean draft (m),
Δ - displacement (t).

b) The self-tripping heeling lever HLφ is calculated with the formula:

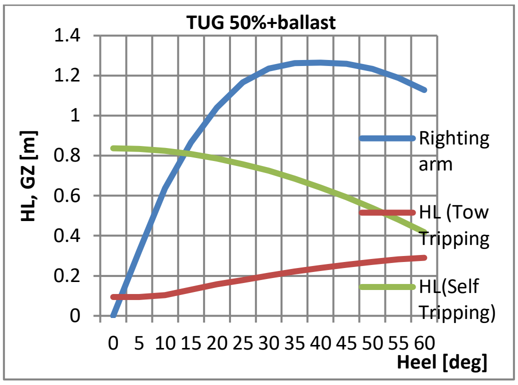
$$HL_{\varphi} = \frac{BP \cdot C_T \cdot (h \cdot cos\varphi - r \cdot sin\varphi)}{\Delta}, \quad (2)$$

where:
BP - bollard pull, which is the documented maximum continuous pull obtained from a static bollard pull test (t),
C_T - for ships with azimuth propulsion units installed at a single point along the length
$C_T = 0{,}90/(1 + l/L_{LL})$,
C_T should not be less than 0.7 for ships with azimuth stern drive towing over the stern or tractor tugboats towing over the bow, and not less than 0.5 for ships with azimuth stern drive towing over the bow or tractor tugboats towing over the stern.
Δ - displacement (t),
l - longitudinal distance between the towing point and the vertical centerline of the propulsion unit(s) relevant to the towing situation considered (m),
h - vertical distance between the towing point and the horizontal centerline of the propulsion unit(s) as relevant for the towing situation considered (m),
r - the transverse distance between the centerline and the towing point, to be taken as zero when the towing point is at the centerline (m),
L_{LL} - length (L) as defined in the International Convention on Load Lines in force (m).
Results for the tugboat P1 are presented in the figure 5.

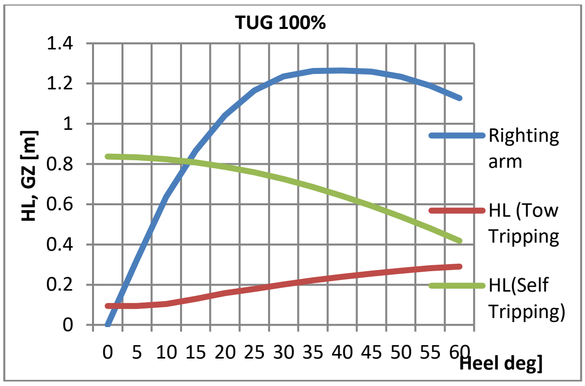




c)



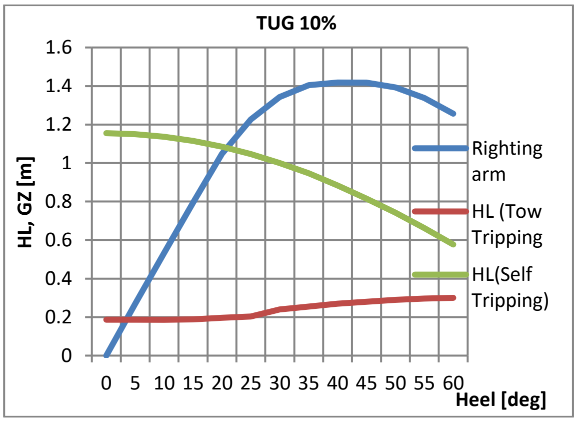
d)



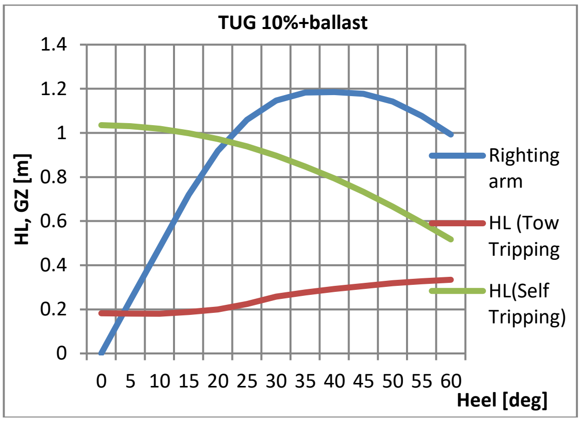
e)

Figure 5. Self-tripping and tow-tripping heeling lever curves for tugboat P1**,** different loading situations (author source)

Results for the tugboat P2 are presented in the figure 6.



a)



b)

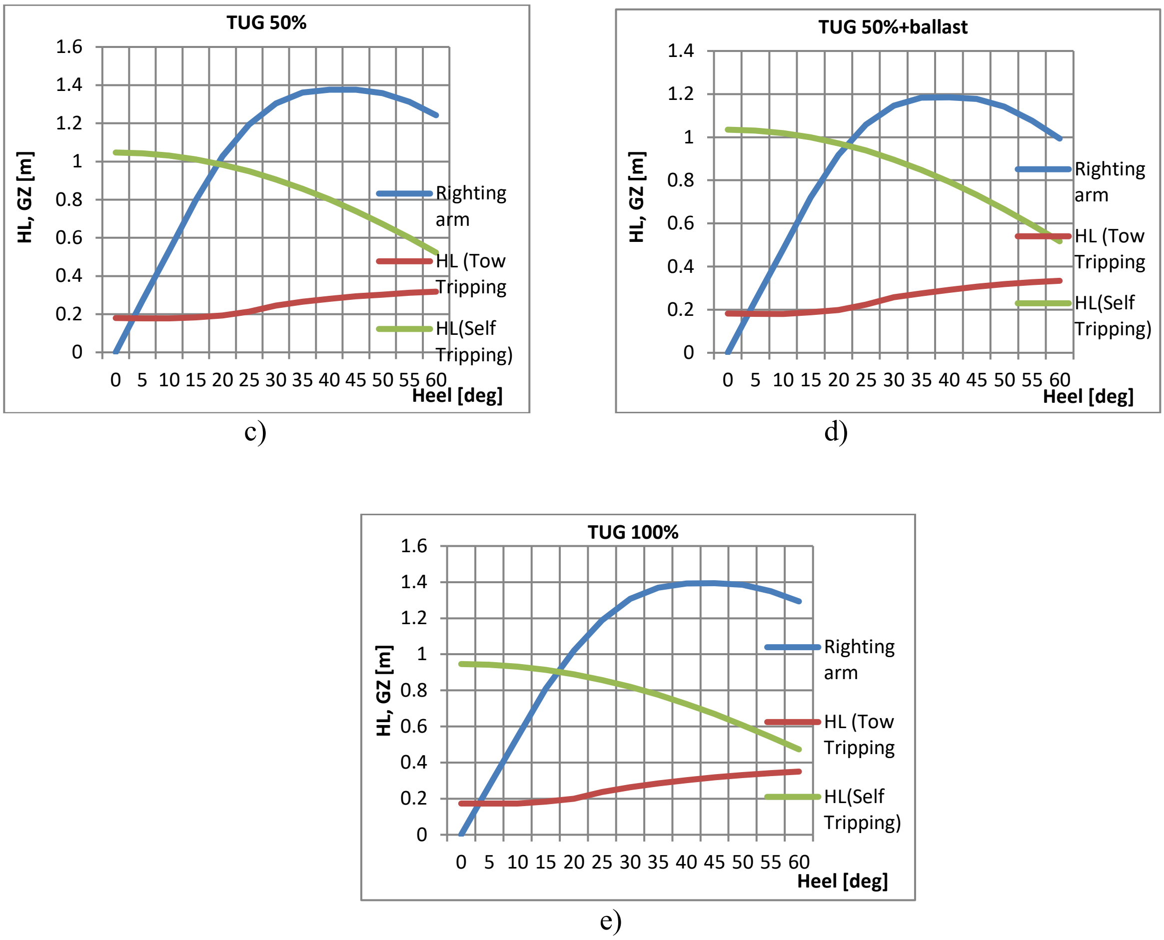


Figure 6. Self-tripping and tow-tripping heeling lever curves for tugboat P2, different loading situations (author source)

4.2 Checking the additional stability criteria

According to the rules of NR 467.E1 DT R04 E July 2021 [4], for ships engaged in port, coastal or ocean towing operations, area B between the righting arm curve and the heeling arm curve calculated in accordance with formula (2) (self-tripping), measured from the angle φ_e, to the angle φ_c, or the angle of down-flooding, φ_d, whichever is less, must be greater than the area A between the heeling arm curve and the righting arm curve, measured from at the angle of inclination $\varphi = 0$ to angle φ_e (figure 7).

For ships engaged in harbor, coastal or ocean towing operations, the first intersection of the righting arm curve with the heeling arm curve calculated by formula (1) (tow tripping) should occur at an angle of heel less than the of angle down-flooding, φ_d [4].

The angles presented in the stability criteria are defined as follows (figure 7.):

φ_e - the heeling angle corresponding to the first point of intersection between the curves of the heeling arm and the righting arm,

φ_d - the down-flooding angle as defined in Part A, clause 2.3.1.4 of IMO 2008 Intact Stability. Openings which are required to be provided with weathertight closures according to the ICLL but, for operational reasons must be kept open, must be considered down-flooding points in the stability calculation [14]; Consider $\varphi_d = 60$ deg;

φ_c - the heeling angle corresponding to the second point of intersection between the heeling arm and righting arm curves.

The centralized results for the P1 tugboat can be found in the tables 3-7.

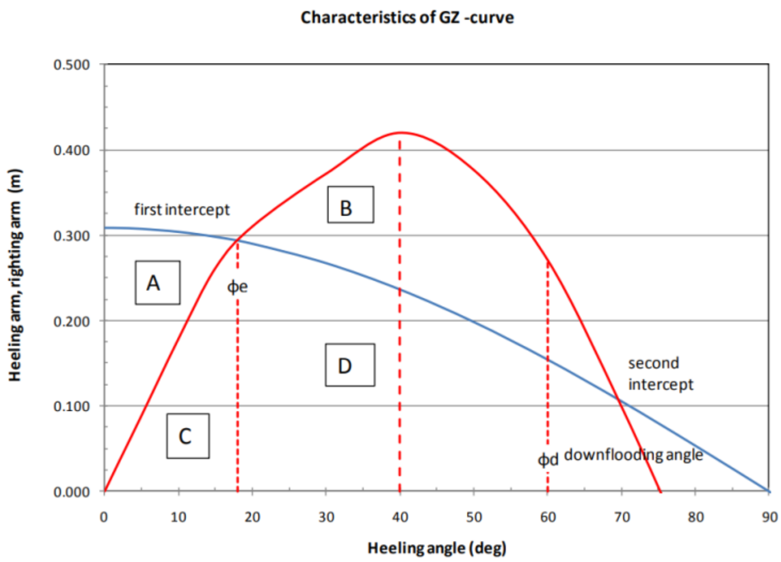


Figure 7. Heeling and righting arms curves (source [4])

Table 3.

LOADING SITUATION - 100%		
Stability criteria	Attained value	Complies
Area between 0^0 - 30^0 > 0,055 mrad	0,310 mrad	YES
Area between 30^0 - 40^0 > 0,03 mrad	0,156 mrad	YES
Area between 0^0 - 40^0 > 0,09 mrad	0,466 mrad	YES
GZmax > 0,2 m	0,899 m	YES
φ_{max} > 30 deg.	33,4 deg	YES
B – A > 0	0,093 mrad	YES
$\rho_{tow\text{-}tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	1,62 deg	YES

Table 4.

LOADING SITUATION - 50%		
Stability criteria	Attained value	Complies
Area between 0^0 - 30^0 > 0,055 mrad	0,410 mrad	YES
Area between 30^0 - 40^0 > 0,03 mrad	0,223 mrad	YES
Area between 0^0 - 40^0 > 0,09 mrad	0,633 mrad	YES
GZmax > 0,2 m	1,295 m	YES
φ_{max} > 30 deg.	38,2 deg	YES
B – A > 0	0,362 mrad	YES
$\rho_{tow\text{-}tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	1,41 deg	YES

Table 5.

LOADING SITUATION - 50% + Ballast		
Stability criteria	Attained value	Complies
Area between 0^0 - 30^0 > 0,055 mrad	0,385 mrad	YES
Area between 30^0 - 40^0 > 0,03 mrad	0,207 mrad	YES
Area between 0^0 - 40^0 > 0,09 mrad	0,592 mrad	YES
GZmax > 0,2 m	1,196 m	YES

$\varphi_{max} > 30$ deg.	37,8 deg	YES
$B - A > 0$	0,310 mrad	YES
$\rho_{tow-tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	1,41 deg	YES

Table 6.

LOADING SITUATION - 10%		
Stability criteria	Attained value	Complies
Area between $0^0 - 30^0 > 0{,}055$ mrad	0,429 mrad	YES
Area between $30^0 - 40^0 > 0{,}03$ mrad	0,234 mrad	YES
Area between $0^0 - 40^0 > 0{,}09$ mrad	0,663 mrad	YES
GZmax > 0,2 m	1,369 m	YES
$\varphi_{max} > 30$ deg.	37,8 deg	YES
$B - A > 0$	0,358 mrad	YES
$\rho_{tow-tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	1,41 deg	YES

Table 7.

LOADING SITUATION - 10% + Ballast		
Stability criteria	Attained value	Complies
Area between $0^0 - 30^0 > 0{,}055$ mrad	0,406 mrad	YES
Area between $30^0 - 40^0 > 0{,}03$ mrad	0,219 mrad	YES
Area between $0^0 - 40^0 > 0{,}09$ mrad	0,625mrad	YES
GZmax > 0,2 m	1,265 m	YES
$\varphi_{max} > 30$ deg.	37 deg	YES
$B - A > 0$	0,326 mrad	YES
$\rho_{tow-tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	1,45 deg	YES

The centralized results for the P2 tugboat can be found in the tables 8 -12.

Table 8.

LOADING SITUATION - 100%		
Stability criteria	Attained value	Complies
Area between $0^0 - 30^0 > 0{,}055$ mrad	0,391 mrad	YES
Area between $30^0 - 40^0 > 0{,}03$ mrad	0,237 mrad	YES
Area between $0^0 - 40^0 > 0{,}09$ mrad	0,628 mrad	YES
GZmax > 0,2 m	1,394 m	YES
$\varphi_{max} > 30$ deg.	42 deg	YES
$B - A > 0$	0,288 mrad	YES
$\rho_{tow-tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	3,18 deg	YES

Table 9.

LOADING SITUATION - 50%		
Stability criteria	Attained value	Complies
Area between $0^0 - 30^0 > 0{,}055$ mrad	0,390 mrad	YES
Area between $30^0 - 40^0 > 0{,}03$ mrad	0,236 mrad	YES
Area between $0^0 - 40^0 > 0{,}09$ mrad	0,626 mrad	YES
GZmax > 0,2 m	1,376 m	YES

$\varphi_{max} > 30$ deg.	39,2 deg	YES
B – A > 0	0,187 mrad	YES
$\rho_{tow\text{-}tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	3,33 deg	YES

Table 10.

LOADING SITUATION - 50% + Ballast		
Stability criteria	Attained value	Complies
Area between 0^0 - 30^0 > 0,055 mrad	0,344 mrad	YES
Area between 30^0 - 40^0 > 0,03 mrad	0,202 mrad	YES
Area between 0^0 - 40^0 > 0,09 mrad	0,546 mrad	YES
GZmax > 0,2 m	1,166 m	YES
$\varphi_{max} > 30$ deg.	37,2 deg	YES
B – A > 0	0,118 mrad	YES
$\rho_{tow\text{-}trippingg} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	1,41 degg	YES

Table 11.

LOADING SITUATION - 10%		
Stability criteria	Attained value	Complies
Area between 0^0 - 30^0 > 0,055 mrad	0,396 mrad	YES
Area between 30^0 - 40^0 > 0,03 mrad	0,243 mrad	YES
Area between 0^0 - 40^0 > 0,09 mrad	0,639 mrad	YES
GZmax > 0,2 m	1,418 m	YES
$\varphi_{max} > 30$ deg.	39 deg	YES
B – A > 0	0,119 mrad	YES
$\rho_{tow\text{-}tripping} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	3.46 deg	YES

Table 12.

LOADING SITUATION - 10% + Ballast		
Stability criteria	Attained value	Complies
Area between 0^0 - 30^0 > 0,055 mrad	0,348 mrad	YES
Area between 30^0 - 40^0 > 0,03 mrad	0,205 mrad	YES
Area between 0^0 - 40^0 > 0,09 mrad	0,553mrad	YES
GZmax > 0,2 m	1,185 m	YES
$\varphi_{max} > 30$ deg.	35,6 deg	YES
B – A > 0	0,049 mrad	YES
$\rho_{tow\text{-}trippingg} > \varphi_{downflooding}$ $\varphi_{downflooding} = 60$ deg	3.74 deg	YES

5. Discussions and conclusions

Since the combined tug and escorted ship system operates in special conditions, the risks regarding stability and safety will have to be taken into account. This is due to the high level of forces in the towing cable when they are tied to the ship. Over time, there have been many tugboats losses and crew deaths. It is required to educate seafaring personnel about the regulations and hazards regarding the stability of tugboats and to recommend practical loss prevention measures.

From the results presented in the paper, when a tugboat is analyzed independently, without the escorted ship, the stability criteria are met for all loading situations. In addition to the weight of the light ship, towing equipment, fuel, stores, fresh water and crew are also included.

The tugboat is in danger as soon as the tow cable of the tug is attached to a ship that is significantly heavier than the tug. At this moment, an additional and lateral force (which has a negative impact on stability) appears in the point of the towing hook or connection winch point (bollard pull). The bollard pull, which acts in the towing point or the winch connection point, forms together with the thrusters force from the center of the propeller a couple of forces, which has the effect of reducing the stability of the tugboat.

The towing force can have different positions compared to the tugboat, the combination of which will cause a very dangerous instability called "girting". In this situation, the tugboat is dredged laterally until the lower edge of the main deck enters the water. This moment in terms of stability is called "vanishing stability". From this position, the tugboat becomes unstable and will capsize if the towing cable is not released quickly.

As a consequence of numerous tugboats losses and deaths IACS Recommendation No. 24 was developed and IMO's amendment to the ISC 2008 was subsequently agreed.

Harmonized regulations on the stability of tugboats and escorts were introduced in the Intact Stability Code of 2008, at the 97th session of the IMO Maritime Safety Committee in November 2016. It is considered that the new regulations will lead to fair competition for the shipping industry and they will increase safety from the design phase and later in the operation of the tugboats.

The new stability criteria during tugboat operation are: self-tripping towing stability, tow-tripping towing stability and escort stability. These criteria were based on the Bureau Veritas Safety Guide for the Design, Construction and Operation of Tugs (NI617, July 2014), developed through Safe Tug JIP6.

The presented harmonized criteria can be applied without restrictions to standard tugboats, but they can also be adapted to new modern and innovative tugboats models. Tugboats with longitudinally distributed propulsion also belong to this category. For these and others that are or will appear, the criteria must be customized, but they must be based on the same safety principles.

The main purpose of this study is to identify the stability characteristics with respect to changes in loading situations. In general, stability is known to increase when using bridle type towing cables as the distance from the center of gravity to the towed point increases.

The current rules, addressed in the article, are still based on the static action of forces, and the towing operation is considered without the prevailing forces of wind, waves or currents.

Towing operations take place in the presence of wind, waves and current. The forces of the environment give additional heeling moments, which must be added to the one coming from the towing or maneuvering operations undertaken by the tug, to correctly reflect the dynamic operations.

Tugboats maneuvering can become difficult in windy conditions or when it suddenly changes direction. Undesirable effects of wind on tugs are: drifting, collisions, groundings, towlines parting, injury and girting.

The speed and direction of the currents are unpredictable and manifest themselves strongly in narrow areas, with reefs, breakwaters or harbor walls.

For the calculations performed in this article, the standard speed from the regulations was considered, i.e. a low speed characteristic of towing operations. But there are situations when the tugboats' speeds are higher, for example when turning, escorting ships or other similar maneuvers. For escort tugboats, the Classification Societies introduced new IMO stability criteria, which were not applied in this study.

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References

[1] Allan RG, “A Proposal for Harmonised International Regulations for the Design and Construction of Tugboats”, 19th International Tug & Salvage Convention & Exhibition, Rotterdam, 24-28 April 2006

[2] De Jong G, “The Class Answer to the Rapidly Developing Tug Industry”, 21st International Tug & Salvage Convention & Exhibition, Vancouver, 17-21 May 2010

[3] Bureau Veritas, Safety Guidelines for Design,Construction and Operation of Tugs, NI 617, July 2014

[4] Bureau Veritas, “Rules for the Classification of Steel Ships”, NR 467, Part E Service Notations for Offshore Service Vessels and Tugs, July 2021

[5] Gijsbert de Jong, The Class Answer to the Rapidly Developin Tug Industry, Conference ITS 2010, Vancouver

[6] Gijsbert de Jong, Enhancing Tug Safety Through Internationally Harmonised Stability Regulations, Conference TUNOLOY’17, Rotterdam, 2017

[7] Ionaş O.” Nave tehnice”, Editura „Galaţi University Press”, 2014

[8] Maier V., Mecanica si constructia navei. Vol.1. Statica navei. Bucuresti. Editura Tehnica, 1985,

[9] Obreja, D., “Particularităţile hidrodinamice ale proiectării navelor mici”, Editura Fundaţiei Universitare “Dunărea de Jos“ , Galaţi, 2004

[10] Obreja, D., “Teoria navei. Concepte şi metode de analiză a performanţelor de navigaţie”, Editura Didactică şi Pedagogică, Bucureşti, 2005

[11] Obreja, D., “CAD-CAE Tools for the Initial Design“, Note de curs, 2005

[12] AUTOSHIP Users Guide Release 10.3, 2017

[13] AUTOHYDRO User’s Manual 6.8, 2017

[14] IMO MSC 97/22, Report of the Maritime Safety Committee on its Ninety-Seventh Session, 2 December 2016