Volume XXIX 2026
MBNA Publishing House Constanta 2026

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

Study on Equipping Conventional Tugboats with Carousel Towing Systems

To cite this article: Alexandru Pintilie, Mihaela Greti Manea, Elisabeta Buzilă, Paul Burlacu and Elena Rita Avram, Scientific Bulletin of Naval Academy, Vol. XXIX 2026, pg. 123-129.

Submitted: 24.04.2026
Revised: 31.07.2026
Accepted: 04.08.2026

Available online at www.anmb.ro

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-26-I1-012

Study on equipping conventional tugboats with carousel towing systems

A. Pintilie[1,*], M.G. Manea[1], E. Buzilă[1], P. Burlacu[1], E.R. Avram[1]

[1] "Mircea cel Bătrân" Naval Academy, Constanta, Romania
*Corresponding author: A. Pintilie, e-mail address: alexandru.pintilie@anmb.ro

Abstract. Conventional tug design can be characterized by keeping the hull direction in line with the towing wire and rotating the thrust force 360 degree around. The carrousel tug design can be characterized by rotating the hull direction free from the towing wire. Carrousel tug consists of a large horizontal ring, rotating around the accommodation and fitted with the towing wire. The attachment in the side reduces the heeling moment sharply and enables to use the full extent of the dynamic hull forces for escorting (steering and braking).
This paper describes a brief analysis of the carrousel towing system amd comes with proper arguments for implementing it on conventional tugs, for large improvements in operational performance and safety.
Keywords: tug, propulsion, stability, heeling, carrousel, lift, drag

1. Introduction

In the construction of conventional tugboats, special emphasis is placed on the development and improvement of the propulsion system and maneuverability. In general, the propulsion of conventional tugboats is single or double, and the types of rudders have changed until omnidirectional propulsion with two or more propellers was achieved [1], [2]. These improvements are the basis for omnidirectional propulsion trends with the continued increase in fixed-point dynamic positioning and the reduced use of hydrodynamic forces.

The development of mechanisms for attaching towing cables to the ship's hull, however, has had an insignificant evolution. Most tow hooks are based on classic technologies and consist of a radial support (e.g. Seebeck patent) which uses a vertical sector guide for the hook (Figure 1) in order to move the towing point laterally, thus reducing the bending arm. In the case of conventional tugs, this support is located near the ship's center of gravity (Figure 2).

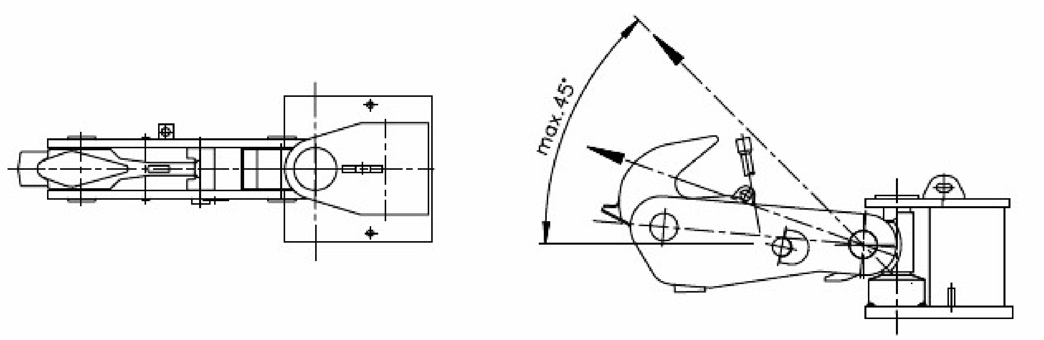

Figure 1 Classic tow hook [8]

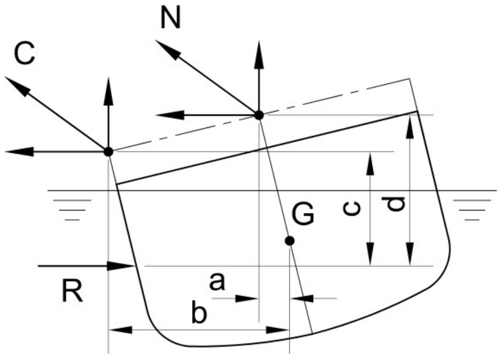

Figure 2 Distribution of towing forces in the case of conventional tug (N) and carousel (C)

With the advent of modern tugboats and new types of propulsion systems, the towing point has been moved forward or aft to ensure that the overload in the towing cable leads to a rapid return of the ship's hull axis in line with the towing force, thus avoiding overthrow.

The carousel towing system represents an unconventional approach, which allows the towing cables to be attached to the tugboat body by means of a circular ring [3], as can be seen in Figure 3.

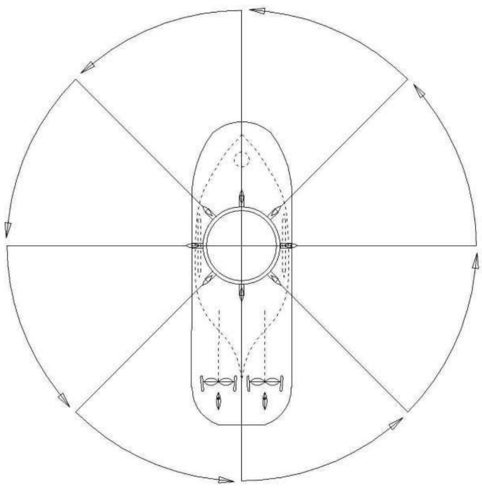
Figure 3 Schematic diagram of the carousel towing system

2. Particularities of the carousel towing system

The carousel towing system offers three important features:

- Total flexibility. The carousel ring can rotate freely without restrictions and towing operations can be changed from bow to stern or vice versa with great ease;
- High stability. The carousel is based on the same principle as the classic hook, with the difference that the carousel ring extends over the entire width of the tug. Therefore, an increase in stability is achieved, which leads to an increase in hydrodynamic forces;
- Clamping mechanism. The stability feature allows the carousel to be positioned above the center of gravity and, therefore, there is a maximization of forces in the tow cables, as well as a reduction in propulsion maneuvers during towing.

The carousel is independent of the type of propulsion used and can be mounted on any type of tug. Future research can be directed towards combining the carousel type towing system with conventional axial line driven thrusters. This combination can lead to the optimization of conventional tugs and their alignment with the performance of modern tugs [3].

In Table 1, some characteristics of the conventional tug and the carousel tug can be seen in comparison.

Table 1 Comparative analysis of the characteristics of conventional tugboat and carousel

Tugboat feature	Conventional	Carousel
Traction point	fixed	360^0
Endorsement risk	great	low
Safety	average	great
Escort	limited	excellency
Crew safety	average	great

3. The operating principle of the carousel towing system

The construction of a conventional tug focuses on stern towing, providing a towline reach of approximately 180^0. Sometimes, for certain towing operations, a greater degree of freedom is required so that the tug's body must be rotated through an angle of 180^0. Modern tugs use the same principle and rotate the entire body, together with the towlines, around the steering propeller.

In the case of the carousel towing system, the location of the cables is coincident with the lateral center of resistance of the body, and changes in the load in the cables no longer affect the direction of travel of the tug. This allows for better maneuverability and offers a wide range of assistance maneuvers.

Figures 4 and 5 show two examples of towing using the carousel system, one for stern towing and the second for bow towing.

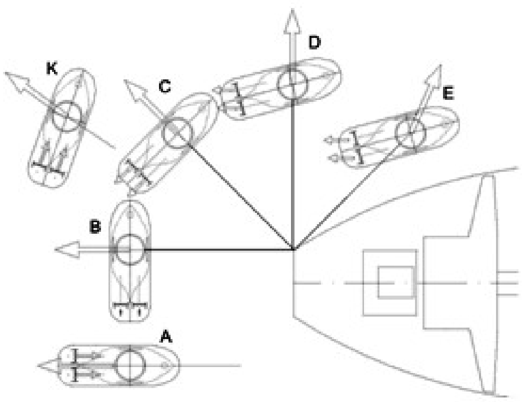

Figure 4 Stern carousel towing

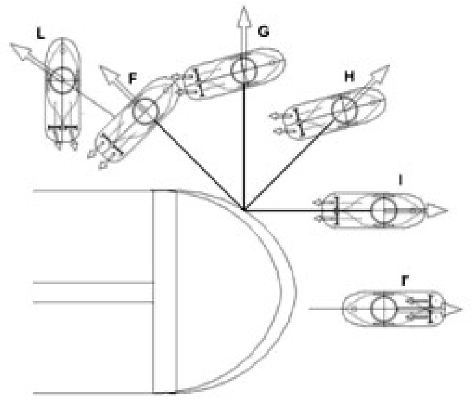

Figure 5 Bow carousel towing

For stern towing (Figure 4), the tugboat sails with the bow forward with the tow cable over the bow (A). To brake the ship at high speeds, the hull of the tugboat is turned perpendicular to the direction of travel using the maximum hydrodynamic pulling forces (cable from the side) (B). To tow the ship, the tugboat advances along the outer circle towards the bow of the ship (C, D) and begins to tow the ship (cable over the stern) (E).

For bow towing (Figure 5), the tugboat sails with the bow forward with the tow cable over the stern (I). To brake the vessel at high speeds, the tugboat sails along the outer circle towards the stern of the vessel (H, G, F), and the body of the tugboat is turned perpendicular to the direction of travel, pulling alongside the vessel (cable over the bow/side) (L). To brake the vessel at low speeds, the tugboat turns and sails backwards with maximum braking (cable over the stern).

The high stability effect given by the ring support for the Multratug12 tug, equipped with a carousel-type towing system, is highlighted in Figure 6.

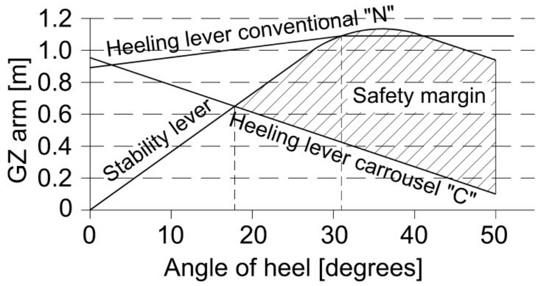

Figure 6 Stability curves for conventional tug and carousel [5]

In the case of the conventional towing mechanism, located near the tug's center of gravity, the heeling arm shows a slight increase. For the carousel system, the heeling arm decreases rapidly until it is zero, around 50^0. For the maximum permissible load in the towing cable, the static equilibrium for the conventional tug is obtained at 310, while for the carousel system it decreases to 18^0.

Analyzing the stability curve, it can be concluded that the overturning of the carousel tug due to the forces from the towing cables is practically no longer possible. Even with a substantial amount of water on board, stability within the normal limits necessary for towing operations is still ensured, so that towing maneuvers can be performed even in areas with high waves [3].

In modern escort tugs, the towing mechanism is placed well ahead of the center of gravity for reasons of stability in case of overload. In the carousel tug, the stability problem is solved by the ring support. Therefore, the towing mechanism can be positioned above the center of gravity, producing the highest towing forces. The towing force/hydrodynamic force ratio is almost unity, however higher than the values obtained for the Towliner system (0.78) or Tractor (0.63) [4].

The force diagram for the carousel tug is shown in Figure 7.

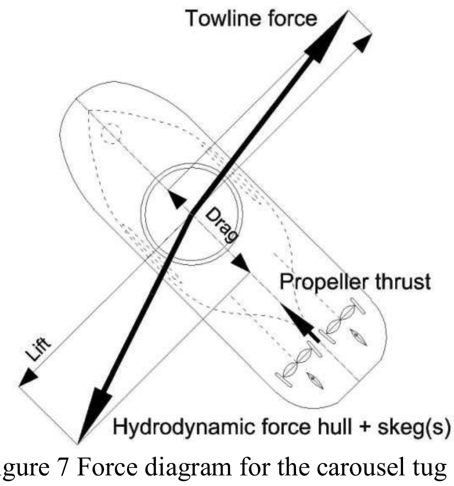

Figure 7 Force diagram for the carousel tug [6]

4. Efficiency analysis of the carousel towing system

Compared to omnidirectional propulsion systems, the conventional axial line system offers a substantial cost reduction. Furthermore, the efficiency of axial propulsion with large diameter propellers is higher by (12…39) % as shown in Table 2. This aspect can be used either to obtain higher towing forces or to install main engines with lower powers.

Table 2 Comparative analysis of propulsion efficiency for a series of tugboats [3]

Tugboat name	Number of engines	Installed power P [kW]	Towing force R [kN]	R / P [kN/kW]	[%]
VSP Ajax	2	3460	90	13	61%
ASD Thorax	2	2646	90	17	80%
ASD Smit Mississippi	2	1830	63	17	79%
RT Magic	3	1566	75	16	75%
Zeus	2	2709	101	19	88%
Multratug 12	3	331	21	21	100%
Carousel	2	2025	86	21	100%

The relatively low additional cost for the standard carousel tug further favors the total construction cost and offers a (15…25) % reduction compared to omnidirectional thrusters.

The use of hydrodynamic forces to supplement the propulsion power offers a significant reduction in operating costs due to reduced fuel consumption and reduced operating time. This also leads to reduced environmental pollution. Furthermore, the axial line technology involves lower maintenance costs. In addition, the carousel ring is based on encapsulated roller bearings, which have a relatively long service life.

The greatest savings are achieved from fuel consumption when braking the ship at the stern by the carousel tug by pulling at 90^0 to the direction of travel, using minimum propulsion power (Figure 3).

The carousel tug can be used for both bow and stern towing and allows for easy and flexible handling. At the same time, it offers added safety by controlling the tug independently of the external towing force.

Also, the forces required to steer and brake the ship increase proportionally with the ship's speed and can be used effectively to assist a ship at high sailing speeds.

Last but not least, the risk of overthrow due to towing forces is minimal, and the tug can be used without problems in areas with large waves, the high safety margin offering the possibility of counteracting possible accidents.

5. Results of implementing the carousel system on the conventional tugboat

In order to mount the carousel system on board the conventional tugboat, several types of tugboats were tested, with research targeting the maneuverability and structural integration of the carousel [3].

Finally, the Multratug 12 Combi tug from Multraship Towage & Salvage was selected (Figure 8, Table 3). The chosen model has a small freeboard, which leads to the limitation of the maximum hydrodynamic forces.

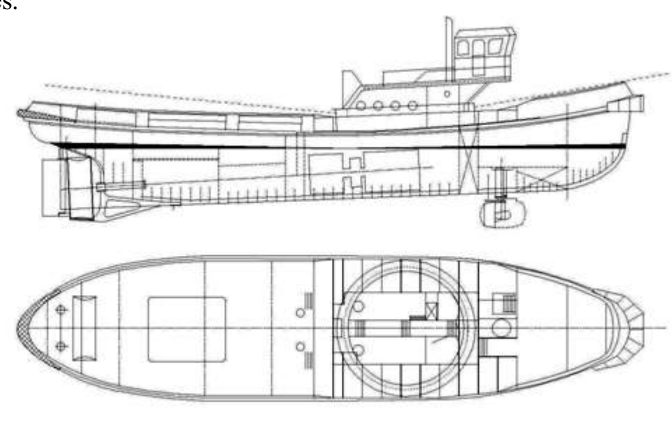

Figure 8 Arrangement of the Combi Multratug 12 tugboat, equipped with a carousel towing system

Table 3 Main features of the Multratug 12 Combi tug [3]

Length L	28.50 m
Width B	6.60 m
Draft T	2.60 m
Propeller	900 CP / 2.6 m
Thruster	450 CP / 1.0 m
Fixed point tug	21 kN
Lateral surface	60 m²

The model was tested in the 1:5 scale tanks at Delft University of Technology. The tests involved a systematic variation of towing angles and steering speed (Figure 9). The maximum forces were limited as follows [3]:

- a small angle of attack limits the buoyancy of the ship's hull (the stern sinks at over 80 t);
- a high angle of attack limits thrust control against rotation.

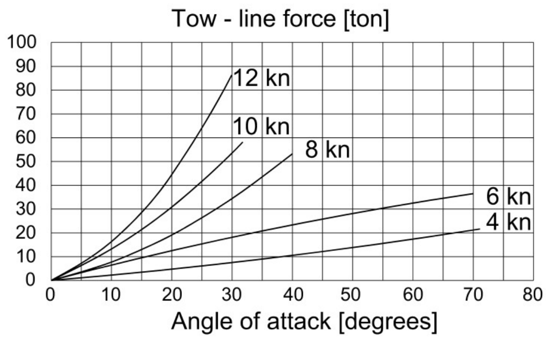

Figure 9 Towing force depending on angle of attack

The systematic measurements were brought together in the tugboat performance diagram represented in Figure 10. The diagram shows the high potential of the hydrodynamic forces developed by the carousel tugboat. It is remarkable that the high steering forces are comparable to those of the ASD/VS escort tugboats, as a result of the narrow hull of the vessel (tow/thrust ratio reaches up to 9:1).

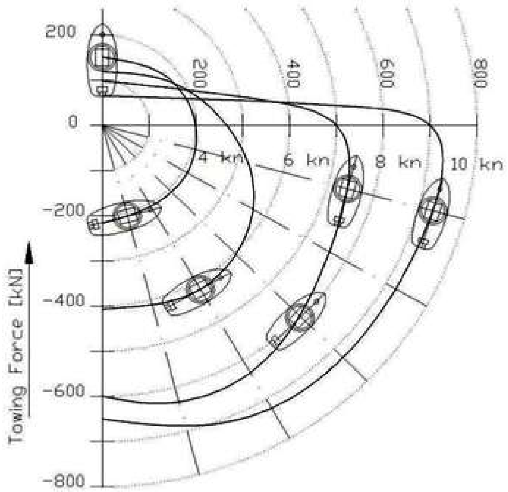

Figure 10 Carousel tug performance chart [3]

6. Conclusions

The carousel towing system has good prospects, offering an unconventional and cost-effective approach to securing towing cables to the ship's hull. The system has two clear operational advantages, full flexibility and high hydrodynamic forces. The use of hydrodynamic forces instead of propulsion reduces fuel consumption, pollution and engine operating hours.

The high stability of the carousel system allows the towing point to be located near the lateral center of resistance. This allows for control of the direction of travel, regardless of the variation in load loads.

The carousel towing system can be combined with different types of thrusters, depending on the operating requirements. Combining the carousel system with conventional axial lines offers an attractive economic alternative, both in terms of construction cost and operational cost.

Due to the bow-forward navigation and high stability, towing operations can be carried out in adverse weather conditions. Furthermore, the carousel tug allows towing operations to be carried out safely even at high speeds.

The carousel tug offers high efficiency with low investment. The use of high hydrodynamic forces can lead to a reduction in the number of tugs required to assist ships.

Thus, in light of the current efforts to equip and equip the military forces of the European Union against the aggression of the Russian Federation, a case study on the reconsideration of the performances of the port and quay tugs “Vârtosul” and “Voinicul”, which are in the possession of the Romanian Naval Forces, is particularly appropriate (Figure 11).

Figure 11 The port and quayside tugboats “Vârtosul” (103) and “Voinicul” (104) [7]

References

[1] Jansen, Joop. Damen ASD Tugs – an Ongoing Development, ITS 2000, Proceedings of the 16th International Tug & Salvage Convention, May 2000;

[2] Kooren Ton, Quadvlieg Frans, Aalbers Arie. Rotor Tugnology, ITS 2000, Proceedings of the 16th International Tug & Salvage Convention, May 2000;

[3] M. van der Laan. Carrousel Tug Design, ITS 2002, Proceedings of the 17th International Tug & Salvage Convention, May 2002;

[4] Gale, C. Perceived Advantages of Z-Drive Escort Tugs, ITS 1994, Proceedings of the 13th International Tug & Salvage Convention, 1994.

[5] ***, Intact Stability Requirements for Tugs, Report ASD no. 11-03, 2012, ASD Ship Design B.V.

[6] Santiago I.B. et al. Review Ship Handling in Unprotected Waters: A Review of New Technologies in Escort Tugs to Improve Safety, Applied Mechanics Journal, 2021, 2(1), pp. 46-62, https://doi.org/10.3390/applmech2010004

[7] https://www.navy.ro/despre/organizare/flotila_56/date_remorchere.php (Accesed 06.02.2026)
https://www.tsu-gmbh.de/fileadmin/tsu/tsu-product-information-seebeck-mooring-equipment.pdf (Accesed 08.02.2026)