

GLOBAL SHIPPING TRENDS AND THE CARROUSEL RAVE TUG: CONNECTING THE DOTS

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THE MARITIME TRANSPORT CHAIN

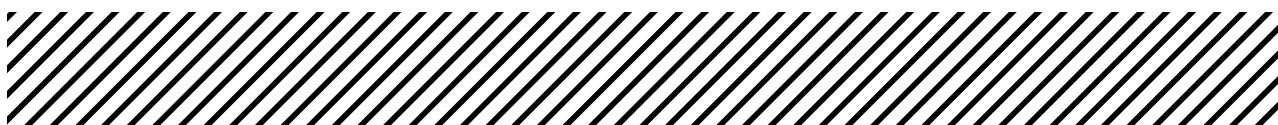
The maritime transport chain arranges the efficient flow of large volumes of physical goods between countries and continents. This facilitates international trade of those goods, which in turn is the main driver for prosperity for people around the world.

This transport chain itself consists of sequential co-ordinated steps to manage the interplay of cargo ships with the infrastructure facilities (access channels, docks, cranes, hinterland connections and the like) available in a worldwide network of ports where loading and discharging of cargo takes place. Harbour towage services are also a step in that chain.

At its core, the purpose of harbour towage services is to help cargo ships perform their port-call turn-around as quickly as possible. In for discharging/loading of cargo and out again. Just like an airport is an awkward place for an aircraft, a port is however an awkward place for a cargo

ship. Aircraft are designed to fly through the air and ships are designed to sail at sea. Ports, with their limited room, dense traffic and the need to come to a full stop, are in essence a necessary evil for cargo ships. The sooner the ship is back at sea sailing towards its next port of call, the better.

Novatug is fully committed to develop harbour towage solutions to help deliver on that simple goal. Novatug has taken the initiative in 2013 to develop the CARROUSEL RAVE TUG, only driven by shipping needs. In this paper Novatug will explain the development of the CRT in that context.



5 MEGATRENDS IN SHIPPING

There are 5 megatrends in shipping¹.
These trends are:

1. Scale
2. Speed
3. Safety
4. Sustainability
5. Smartness

Most of these trends are not new. What is definitely new however is the way these trends are interlinked and the unprecedented pace at which they are together changing the physical reality of shipping, driven by the general technological possibilities that have become available and accessible at every level in this open information age. By now, these trends are having a profound impact on the entire maritime transport chain.

Particularly the scale-trend, by which the relentless drive for ever larger ships is meant, is by now challenging the efficiency of the maritime transport chain as it has developed in the industrialised world over the past 150 years, with a dense physical network of ports around the world. And given the enormous amount of capital invested in the infrastructure that makes up that physical network as well as the costs involved in making significant changes to that infrastructure, the scale trend has the largest impact on the efficiency of the entire chain. To get more of a feel of the trend towards ever larger ships means (Figure 1) shows container vessel growth over the 50 years that have passed since 1968. As the picture shows, the size of container vessels has grown over that period by 7.3% Compounded Annual Growth Rate (CAGR). That means that the largest container vessels now have become almost 15 times as big as they were in 1968.

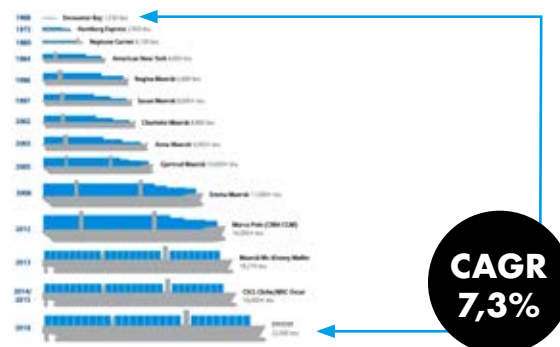


Figure 1

The cargo volume that is arriving into the world's ports on board of very large containerships (over 10,000 TEU) is growing fast too. In the port of Rotterdam for instance, in 2011 only about 16% of the total number of TEU's discharged arrived on board of a such a very large container ship. Five years later, in 2016, that number had already risen to almost half of all the containerised cargo². The same trend is visible in other ports around the world, with ever more cargo arriving on board of giant ships.

The relative size of ships having grown compared to the infrastructure they are in makes for a double-dip of cumulative problems. Because there is simply less physical room left for correcting any mechanical failure and/or navigation error on the side of the ship, any such event leads to a real problem sooner.

On top of that, once things do go wrong, the increased size of the ships also means that any problem also has much larger potential consequences.

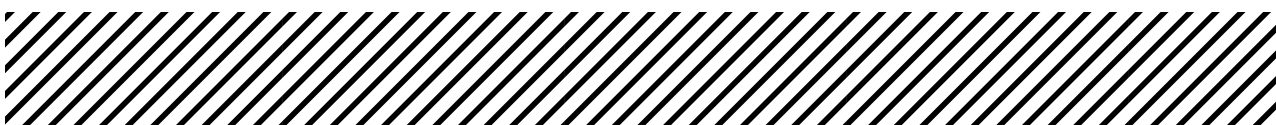
All this causes a huge increase in the tail risks of the shipping industry as a whole. Not only are the ship and its cargo at risk, but so is the integrity of the entire logistics chain as any of these very large ships can potentially block the port and (with that) even the global port network. This risk of such a domino effect is by no means a theoretical concern, as shown by the incidents with the CSCL Indian Ocean on the Elbe river underway to the port of Hamburg on the evening of 3 February 2016 (*Figure 2*) and the CSCL Jupiter on the Scheldt river outbound to sea from the port of Antwerp on 14 August 2017 (*Figure 3*). In the latter case the Antwerp port was effectively blocked for a full day.



Figure 2



Figure 3



Despite these risks it is not expected that giant ships will disappear. After all, big cargo ships have big benefits too. Megaships benefit from enormous economies of scale and drive down vessel costs per unit for containers (or any other cargo or passengers for that matter). But apart from vessel costs related to transport there are other cost elements in the total transport chain to consider as well. These so-called “handling costs” involve all the infrastructure and services required to accommodate and handle the ships when they call on ports around the world, like bridges, locks, fairways, quays and the like but also towage services. *Figure 4* shows a graph taken from a 2015 report by the OECD on this topic and which explains the problem³. According to the report the shipping industry was already in 2015 at risk of missing out on the optimum for the costs of the entire maritime logistics chain. That is the worst possible outcome for everybody as it can potentially slow down trade and with that overall prosperity decreases as well.

Can we find a way to keep the benefits of vessel scale, without the downside of prohibitive handling costs?

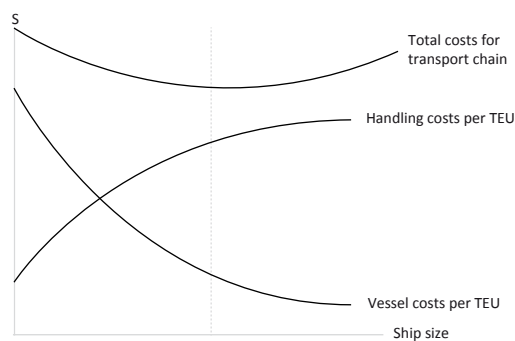


Figure 4

THE CARROUSEL RAVE TUG SOLUTION

Novatug has always been convinced that a positive answer to this question lies in reinventing harbour towage services. After all, if tugs would be better at controlling the tow, smaller margins for safety are needed and even the largest ships can continue to call at existing ports without extensive investments to upgrade their infrastructure.

The existing paradigm in harbour towage so far has been to only look at how much weight a tug can pull under controlled static “laboratory” conditions. This is historically the only proxy for how good a tug is at controlling a tow. In line with that, the response so far to increasing towed vessel size is to simply get tugs with ever more static bollard pull. Meaning tugs with more, stronger and bigger engines and propellers. Figure 5 shows a graph with bollard pull trend from 1960 until 2014 for both azimuth as cycloidal propellers⁴. As expected the scale trend in shipping thus coincides with a pretty steep rise in installed power on board of tugs to increase the static bollard pull. In line with the observations of the OECD report, this indeed also ensures handling costs go up. Tugs with more installed power are just more expensive. The graph figures however also show there is a much more fundamental problem than costs and

that is that increasing static bollard pull fails as a solution. After all, CAGR for bollard pull growth of tugs stands only at 2.7%, much lower than the more than 7% CAGR over the same period of the vessels these tugs are supposed to assist and control. By now the gap is huge and getting ever bigger, even if it would be assumed that static bollard pull is actually a good proxy at all for a tug’s ability to control ships calling on ports (which Novatug is convinced it is not).

It is this basic analysis that sparked Novatug to rethink harbour towage, to be able to change it so it provides what is really needed. What is needed is significantly enhanced control over all ships, however big, also in the knowledge that the large modern merchant (container) ships steer very well themselves, much like a yacht, but they only do so as long as they have speed through the water.

This all means that on the quest for more control through towage services we should be looking to maintain as much as possible the speed through the water of the assisted ships. In other words, going forward harbour towage services should be effective in dynamic rather than in static situations.

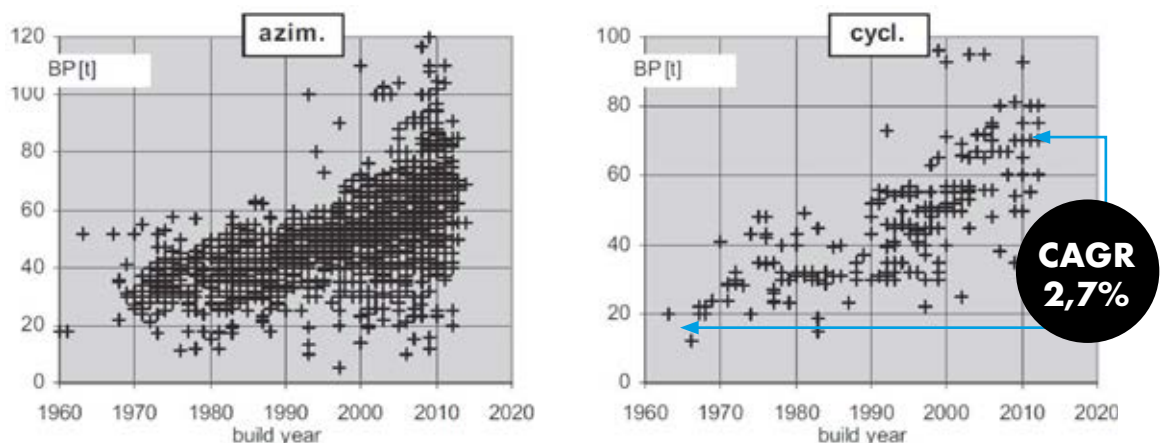


Figure 5: 53 years of static Bollard Pull trend 1960-2013

ON THE QUEST FOR MORE CONTROL THROUGH TOWAGE SERVICES WE SHOULD BE LOOKING TO MAINTAIN AS MUCH AS POSSIBLE THE SPEED THROUGH THE WATER OF THE ASSISTED SHIPS. GOING FORWARD, HARBOUR TOWAGE SERVICES SHOULD BE EFFECTIVE IN DYNAMIC RATHER THAN IN STATIC SITUATIONS.



Figure 6

CARROUSEL RAVE TUG

At Novatug we believe that the CARROUSEL RAVE TUG is the best solution available to realise this. The CRT is at heart based on Novatug's patented Carousel Technology.

The towing-point on the tug is on a freely rotating ring, the actual carousel, with the diameter of the tug's beam (*Figure 6*), compared to the usual solution to have a fixed point somewhere along the tug's centreline. This in turn means that under a transverse line

load the centre of attack of the force moves to the side of the tug as well, so that the upward line force is more or less automatically lined up with the centre of gravity of the tug. This is very definitely not the case in the usual arrangement, where the tug will capsize under a transverse line load. The CRT's dynamic centre of attack following transverse loads thus simply eliminates such capsize risk. (*Figure 7*) shows the effect of the Carousel arrangement under a transverse line load compared to the traditional set-up.

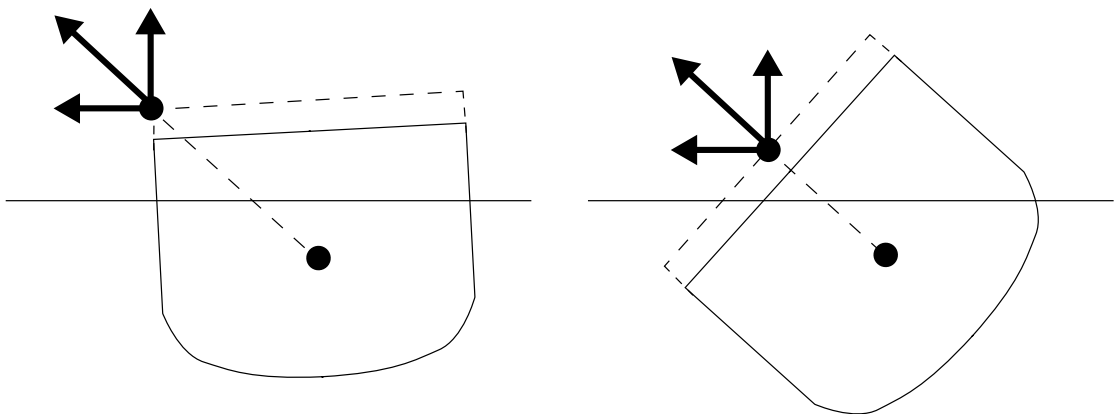


Figure 7



CARROUSEL RAVE TUG





Image 1

PATENT ON NATURE

Because a Carrousel tug cannot capsize under a transverse line load, it is subsequently possible to use the hull of the tug to create lift for controlling (braking and steering) the tow as it is moving. After having successfully tried and tested the Carrousel technology for over a decade with a prototype in real jobs in 2013 Novatug set to work to develop a comprehensive tool with all the lessons learnt, together with a team of established experts in tug design, propulsion technology and winch manufacturing. The result is the CARROUSEL RAVE TUG, with the first one, Multratug 32, having started operations in February 2018 (*Image 1*).

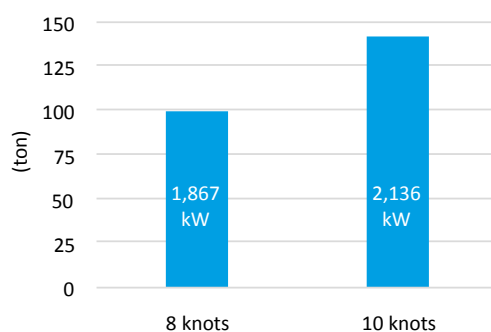
The dynamic performance of the Multratug 32 is very impressive. It generates some 100 tonnes braking force at 8 knots and 140 tonnes at 10 knots. The installed power is then only used to keep the CRT in position to neutralise any steering moment and at around 2,000 kW during these braking manoeuvres the engine power is in any case very limited given the line force.

Steering is even more effective, with some 160 tonnes of steering force reached at 10 knots with less than 3,000 kW of engine power, again only to keep the CRT in position and neutralize the braking force (see Figure 8). Without any engine power, the CRT is still very much effective, combining steering forces of 62-100 tonnes and braking forces of 35-85 tonnes at 8 and 10 knots respectively.

In all the CRT provides a package that is able to provide the enhanced control over the assisted ships while they are moving and however big they are.

In fact, by providing enhanced control over the tow the CRT addresses all of the current shipping trends as listed above in a way that is superior to any alternative, particularly also including investments in fixed port infrastructure. In doing so, the CRT significantly improves overall shipping and logistics industry performance.

BRAKE FORCE



STEERING FORCE

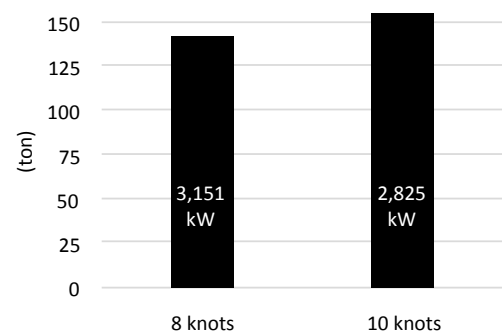
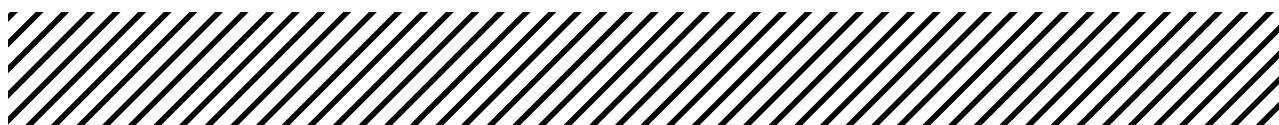


Figure 8



TESTIMONIALS

Hear from tug masters, designers and owners after 10 months of operation with CRT.

HILDEBRAND KAMERLING

47 YEARS OLD AND 23 YEARS IN SERVICE AS TUGBOAT CAPTAIN IN THE BUSIEST PORTS IN THE WORLD (ROTTERDAM AND ANTWERP)

"There are two ways to work with a tugboat at the bow of a seagoing vessel. At speeds of more than 4 to 5 knots, the hydrodynamic effect is so great that, partly by working as a spring line more backwards than transversely, what works very well due to the maneuverability of the CRT, large steering forces and simultaneous braking forces can be generated. The forces also increase as the speeds increase. Just because of this effect, we have 'saved' already some ships because they entered the harbour with a too large bend or there was miscommunication with other ships, so the waterway was limited.

RATE OF TURN

Often the seagoing vessel has a too small a rate or turn to get out of the dangerous situation. The big advantage is that the CRT in this position can increase the rate of turn of the seagoing vessel, but can also slow down the speed of the seagoing vessel, while other tugboats increase the speed just because they are more forward than

transversely at higher speeds. In the above situation, the pilots were delighted with the input of the CRT.

MANEUVERABILITY

The second way as a tugboat at the bow of a seagoing vessel is that the CRT can steer a backward sailing seagoing vessel perfectly on the bow by means of the so-called 'bugsieren' and maneuver the seagoing vessel through a navigation channel or in the direction of a berth. Here too the speed does not matter, so to say if it is possible up to 10 miles. The CRT has a quick reaction time in both above maneuvers, which means a lot of time is gained, which in turn is a plus for the assistance.

For me as a captain, this means that the work is easier because the tug offers more possibilities by his maneuverability. It brings more rest because the risk of capsizing due to the towline forces is no longer present and there is a challenge to do the job with as little fuel consumption as possible."

ROBERT RODENBURG

NAVAL ARCHITECT AT NOVATUG SINCE 2004

"When analyzing the tug's data coming from the monitoring system, we clearly see the trends that we predicted in the design phase; as soon as the Carousel system is being used for dynamic braking and steering, the towline forces go up whilst the power consumed stays low.

It is also very appealing that it is not a matter of generating huge forces, but it is more a matter of generating just enough force, but with much lower power, and thus lower emissions, than you would see on a conventional tug of this power."

PIET SPERLING

40 YEARS OLD AND 9 YEARS IN SERVICE AS TUGBOAT CAPTAIN IN THE BUSIEST PORTS IN THE WORLD (ROTTERDAM AND ANTWERP)

"A good example is a container ship, which we have brought in at the port of Europoort, Rotterdam - dimensions 336x48.5x9.5 meters, dead slow or 9 knots. The ship had to be assisted through the port to its berth with a maximum speed of 6 knots. This in order to prevent inconvenience to the other ships, which are moored at the jetties and quays. The pilot had asked the CRT to reduce the speed to 6 knots. The CRT had aligned itself with a 90-degree angle and had therefore reduced the container ship to 6 knots.

LINE FORCE

The force we used was 60% power (9 knots) in the

beginning and had been reduced to a 25% power (6 knots). The line force has remained between 50 and 60 tons of bollard pull during this assistance. This has the advantage that the pilot had excellent control over the ship because the propeller did not have to be stopped (rudder pressure). We also use this way of assisting with container ships of up to 400 meters in length and drafts up to 16 meters.

As a captain, I think this is a good way of working because you can perform the maneuver quickly and precisely, what the pilots and captains of the sea-going vessels also do appreciate."

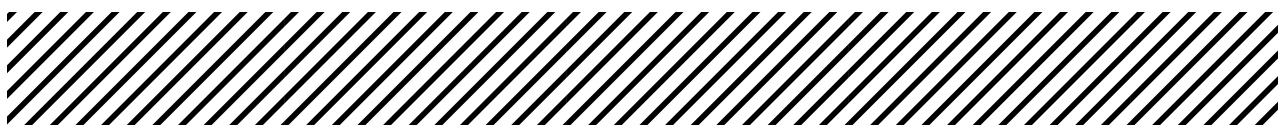
LEENDERT MULLER

MANAGING DIRECTOR OF TOWAGE OPERATOR MULTRASHIP, LAUNCHING CUSTOMER OF NOVATUG FOR THE FIRST CRTS

"CRT saves a lot of fuel and emissions, this is certain. For example, Multraship chartered a CRT to the port authorities of Antwerp for three months earlier this year for tests. The actual measured difference over a this charter period was an average of 260 liters/hour on the port's own tugs (which have the same engines and propellers as the CRT) and 160 liters/hour for the CRT, so 38.5% saved compared to the 260 liters/hour

on the conventional VWT or 62.5% extra fuel compared to the 160 liters/hour on the CRT. Our experience so far also in our own ports is in line with that. In an operation with a lot of indirect dynamic pulling, the numbers are even better.

There is no doubt the CRT is showing significant savings on fuel and reduced emissions across all operations."



**BY PROVIDING ENHANCED
CONTROL OVER THE TOW THE
CARROUSEL RAVE TUG ADDRESSES
ALL CURRENT SHIPPING TRENDS
IN A WAY THAT IS SUPERIOR TO
ANY ALTERNATIVE, INCLUDING
INVESTMENTS IN FIXED PORT
INFRASTRUCTURE. THE CARROUSEL
RAVE TUG SIGNIFICANTLY IMPROVES
OVERALL SHIPPING AND LOGISTICS
INDUSTRY PERFORMANCE.**

CONSIDERATIONS AND BENEFITS

THE NEED FOR SPEED

The dynamic properties of the CARROUSEL RAVE TUG needed to deal with larger ships, also meets the general need for speed in the maritime transport chain in the drive to reach an ever more efficient flow. Because it cannot capsize under a tow-load, there is no need for a wide design and the CRT can return to be a real ship. This is positive for the own mobilizing speed, as well as for its capability to be dragged by a tow. The CRT will easily do 14 knots under its own power and if dragged by a tow the CRT can be fully controlled up to speeds of at least 16 knots, all geared to meet the needs and characteristics of the ships it is meant to assist. Ports are by nature already bottlenecks in the flow of the maritime transport chain. Further limitations as to the navigation in and around ports should naturally be minimised. More control over towed vessels opens up the potential for weather and tidal windows to open up wider or even disappear altogether.

SAFETY FOR TUG AND TOW

Safety is another important trend that is inherently incorporated in the CRT and the way it deals with the scale trend. The CRT and its crew benefit from enhanced safety by finally eliminating the danger of capsizing for tugs. The CRT however also provides enhanced safety for the tow, as well as (even) for the entire port network. For Example, in the case of the CSCL Jupiter grounding in Antwerp, Novatug has established through simulations that this accident could have been prevented by using the CRT attached aft, as a rudder. In fact, it is probable that the CSCL Jupiter would not have had to wait for high tide before it left Antwerp in the first place.

SUSTAINABILITY THROUGH LOWER FUEL CONSUMPTION AND EMISSIONS

The CRT's core capability of using energy that is already there, momentum of the tow, by nature

also means that it uses very little of its own installed power for its actual towing operations when the tow is moving. This is certainly true when comparing the CRT with other tugs in dynamic operations. The slender design of the CRT however also helps to save fuel when mobilising, which typically consumes some 40-50% of any tug's operational profile.

To show the huge effect of harvesting kinetic energy for the CRT's force generation, Figure 9 shows a comparison of the CRT with a conventional 70 ton BP tug, using a specific parameter of kW of installed power required per tonne of line force as a proxy for fuel consumption. The graph shows that with speed of the tow the consumption per tonne of steering force drops significantly to even only some 25% of the conventional tug at a speed of 10 knots, so saving some 75% of fuel.

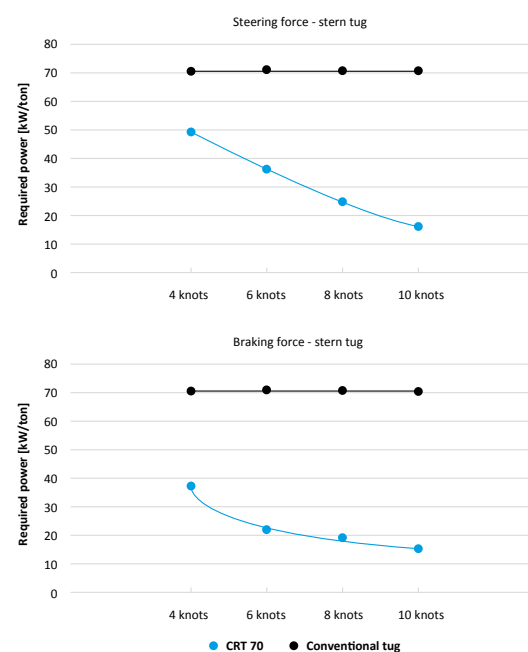


Figure 9

With fuel saved obviously also the emission of harmful substances decreases pro-rata, and with this the CARROUSEL RAVE TUG also addresses the trend in shipping towards a (much) more sustainable operation.

LESS MAINTENANCE, LESS REPAIRS

For companies that operate tugs the CARROUSEL RAVE TUG is also particularly attractive since using the hull to create force instead of the propulsion train has a positive effect on maintenance and repair.

SMARTNESS

The final trend, towards smart and connected systems that make use of information technology (IT) to optimise effectiveness further, is relevant for the CARROUSEL RAVE TUG too. Novatug has concrete plans to merge IT solutions already generally available with its operational technology (OT), but instead of a detailed technical description of the steps taken there, below some general insights.

Novatug believes that in the regulated and capital-intensive physical activities of harbour towage the only right order is to start with a deep understanding and analysis of the business context (here: the entire maritime transport chain) as well as the problem there (here: get cargo ships in and out of ports quickly), next

develop and realise hardware that can physically provide a solution (the CRT), and only then move on to develop a software layer on top of that solution to optimise its effectiveness further.

Novatug does not believe fully autonomous towing will happen within the foreseeable future (e.g. 15 years). It does believe in 'computer assisted' and 'human in the loop' IT-systems in this context.

Building on the experience of people in Novatug's team that have previously introduced artificial intelligence into highly regulated safety critical operating environments, the most important considerations to remember around OT optimisation through IT:

- There is a large gap between something that works in the lab and something operational professionals will not work without
- Early on both the IT and OT people have the wrong ideas about where the IT application is most needed to achieve the OT optimisation sought
- There will be many naysayers. Some reasons are valid, others are not. Picking fights with the naysayers only slows down progress
- It takes time to work together with partners to explore the possibilities and find the best options

NOTES:

¹ Analysis Continental Commercial Specialty Tires and Portstrategy communication 11 July 2017

² CBS publication 27 September 2017

³ The Impact of Mega-Ships, a Case-Specific Policy Analysis. Report by the International Transport Forum of the OECD. OECD/ITF 2015

⁴ Artyszuk 2014

FINAL TAKEAWAY

At Novatug we think that from all available alternatives the CARROUSEL RAVE TUG is the best way to deal with the trend in shipping towards ever larger ships. Here's the real reason why: port infrastructure around the world is simply not adequate anymore and expanding it, if possible at all, is prohibitively expensive. Not only in terms of money, but also in terms of effort, time and environmental concerns. The CARROUSEL RAVE TUG with its enhanced control extends the life and capabilities of this existing infrastructure.

**THE CARROUSEL RAVE TUG
IS NOT JUST A TUG, IT IS
FLOATING INFRASTRUCTURE.**

NOVATUG

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