Safeguard of Tankers by Voith Water Tractors

By Voith Hydro Marine Technology

1. Introduction

Increasing ship size and speed has long posed a growing threat to ship and tug in confined waters. To meet the demand for improved safety a detailed analysis of the dangers involved and the systematic application of the Voith-Schneider propulsion principle was undertaken, resulting in the development of the Voith Water Tractor. Here a brief summary is given of the main criteria to be taken into consideration when designing a tug in general and how they have been considered in the concept of the Voith water tractor.

With the introduction of the Voith water tractor, the fundamental hazards in ship-handling had been eliminated. A decisive step towards higher safety of ships had been taken.

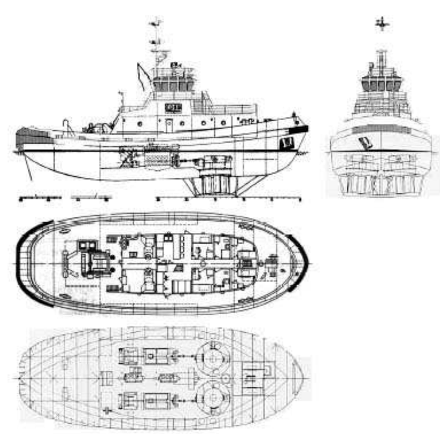
New hazards and risks were caused by the tankers for crude oil, liquefied gas, and chemicals, which quickly increased both in size and number. Not only the safety of ship and tug was at risk here. Insufficient safety meant an incalculable risk also for ports and the environment. The experts only became fully aware of this after the catastrophic accident of the *"Amoco Cadiz"* off the French coast. Two Voith water tractors, *"Abeille 31"* and *"Abeille 32"* (see photograph) were taken into service in the wake of the accident. After the even more disastrous accident of the *"Exxon Valdez"* the world took note. Measures were called for to restrict the risks originating from these floating tanks.

One of these measures is the use of escort vessels on highly frequented tanker routes and in narrow or dangerous waters. However, the fundamental hazards of ship-handling continue to apply but the range of assistance required is now extended to a considerable degree in speed, towline force and time giving a new impetus to the demand for maximum safety in ship assistance.

In most major oil terminals of the world the Voith water tractor has become a hallmark of safety in handling even the largest tankers. It is the only appropriate concept capable of meeting the stringent safety requirements of the future.

2.0 The Voith water tractor with respect to ship-handling requirements.

Figure at right shows a typical modern Voith water tractor.



2.1 Bow control was chosen for the Voith water tractor in order to

- be able to cope with the forces interacting between the tug and the ship to be assisted also at high speeds, and
- establish a stable equilibrium between the two principle forces acting on the tug, namely the propeller thrust and towline force, with the aim of minimizing the danger of capsizing under all operating conditions.

These are the key prerequisites of safety in tug service.

2.2. The free arrangement of propellers underneath the hull was chosen in order to permit an easy operation in all directions, as there is no fixed working direction in ship-handling. This minimizes the negative hull influence on the propellers.

2.3. The free arrangement of propellers underneath the hull was accepted in ship-handling only because a nozzle plate could be fitted below the blade tips for reliable protection. The plate was connected to the hull by a statically balanced support system, providing all-round protection for the propeller against grounding. The propellers are thus located between the actual keel and the buoyant hull.

2.4 The aft fin is used for increasing directional stability, for shifting the hydraulic center of pressure towards the end of the ship opposite the propellers, and especially for improving the "hydrofoil effect" of the entire hull when using it as an active "rudder" in the indirect steering mode.

2.5 When using the tractor in the indirect mode, the Voith-Schneider drive is essential for safety reasons. When thrust is reversed 180^{o}, the thrust component is first reduced down to zero and built up again in the opposite direction.

No undesirable side thrust components occur so that the same steering method can be retained even if one propulsion unit should fail. Thrust control according to X/Y coordinates permits a twin-propeller ship to be operated in the same way as a single propeller one, i.e. both propellers are controlled simultaneously like one single unit. As a consequence, a breakdown of one power train during operation will not cause any basic change in the running behavior or in control procedures. Safety will not be at risk and assistance need not be interrupted.

2.6 The freely arranged propellers, the variable-pitch propeller characteristic of the Voith-Schneider drive, and the stable equilibrium between towline force and propeller thrust enable the use of the tractor as an active braking aid even at high ship speeds, i.e. with a high negative flow into the propeller.

2.7 Safety considerations also led to the selection of mechanical transmission of control pulses from the bridge to the propellers, since it offers complete independence from any kind of auxiliary power and is robust, maximizing reliability.

2.8 The principle of bridge control by one wheel for combined alternation of transverse pitch of both propellers and one lever each for longitudinal pitch control has been selected since it offers the helmsman a logical or human engineered control method regardless of the running or working direction. This is an extremely important safety aspect, since ship handling requires both the amount of thrust and its direction to be constantly changed. In conjunction with the operating mode of the Voith-Schneider propeller this control arrangement ensures that the direction of the operation of the controls corresponds to the working or running direction of the tractor.

2.9 The end of the vessel opposite the propellers has been selected for pushing in order to:

- obtain a maximum lever arm between the contact point with the ship to be handled and the thrust application point for precise control of the tractor.
- Minimize the influence between ship to be handled and propeller
- Maximum the distance between contact point with the towed ship and the tractor superstructure, which is important when working on hull shapes with a large flare.
- guarantee a continuous transition from towing to pushing without changing the direction of the tractor relative to the ship handled.

An analysis of the tractor concept in respect of the requirements of modern ship handling reveals that the concept provides the right answer to each individual requirement. The Voith tractor is a logical concept precisely matched to all service conditions.

3.0 Fields of application of the Voith water tractor for tanker safety.

There are three different fields of application for maintaining safety of tankers.

- escorting and rendering active assistance if required at speeds of 7 to about 12 knots depending on the range of operation.
- normal ship-handling assistance in ports, starting from free running speeds of the tanker between 7 and 10 knots.
- making the connection between the tanker and loading station via floating hose lines in terminals with single-point mooring (SPM) or single-buoy mooring (SBM).

In all these fields the properties of the Voith water tractor will make a valuable contribution to safety. In the case of applications b) and c) above, the situation is clear. Extensive experience has been gained in tanker handling over the years.

Tanker escorting, in contrast, is comparatively new field of application, although it only comprises the potential necessity of tanker handling at higher speed. The logical concept of the Voith tractor takes this possibility into account. However, the function of an escort vessel will have to be defined before this conclusion can be made.

4.0 Escort safeguard vessel

4.1 The call for escort safety vessels was put forward after some severe tanker accidents had occurred. The concept of such a vessel must therefore be based on possible causes of accidents. The main function of a safety vessel will be to immediately assist the vessel escorted when potentially dangerous situations arise that might lead to an accident.

The very important factor in the fighting of safety hazards is time. The more time is lost between the occurrence of an incident and the adoption of countermeasures the higher will the risk of the adopted measures being useless. The importance of this aspect can only be fully understood if one considers the masses involved and the inertia of the tankers.

4.2 Consequences

To minimize the time lag between the moment assistance is needed and the time it actually takes effect, the escort vessel will in most cases have to be in permanent contact with the tanker. The optimum position for it to make fast will be at the stern of the tanker, since engine or rudder failures can be assumed to be the most frequent causes of problems. Moreover, it is here that braking and steering forces can be applied most effectively.

There are cases, however, when external circumstances such as fire, explosions, etc., impede fastening at the stern or remaining there so that the only alternative is making fast at the bow of the tanker.

4.3 Speed of the escorted tanker

The speed of the tanker to be escorted needs to be reduced during escorting to a level permitting the escort vessel to provide efficient assistance in case of loss of control, taking into consideration the inertia forces of the tanker. On the other, and, however, tanker speed must be high enough for self-control under normal circumstances so that safe running under the prevailing conditions can be guaranteed.

The escort vessel needs a sufficient safety margin between escorting speed and free running speed in order to be able to react to unpredictable circumstances and events. Apart from that, it must be so designed that it can render assistance immediately at escorting speed with running a risk itself.

4.4 Basic requirements made on the escort vessel according to the above application profile:

- The vessel shall be able to make fast at the stern of a tanker quickly and safely at escorting speed.
- Under normal circumstances it shall follow the tanker with as little interference to the behavior of the tanker as possible.
- It shall be able to immediately exert effective braking force at high negative approach flow conditions.
- It shall be able to immediately apply active steering forces of an amount preferably exceeding the steering force of the normal rudder of the tanker under the prevailing running conditions, without sacrificing its own safety.
- It shall be able to make fast at the bow of a tanker safely and at high speed, taking into consideration the existing pressure conditions in this area.
- The vessel should be able to immediately fight any fire on board the tanker while moving.
- In case of oil leaks the vessel should be able to take appropriate action immediately in order to prevent the oil film spreading.

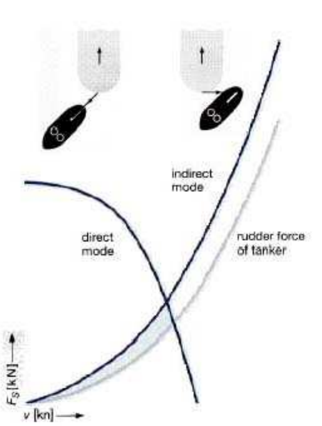
4.5 Consequences of these requirements for the concept:

A careful analysis of the requirements leads to the following conclusions for the concept of the escort vessel:

- The escort vessel has to be built according to the concept of the Voith water tractor in order to guarantee sufficient safety when braking and steering and when picking up the bow line.
- The variable-pitch propeller characteristics of the Voith-Schneider propeller is essential for developing sufficient steering forces at high speed.
- The free arrangement of propellers typical of the tractor concept is required for minimizing the interaction of propeller thrust and hull when braking.
- To maintain safety during indirect control and in case of failure of one propulsion system, the special control characteristic of the Voith-Schneider propeller will be indispensable.
- To avoid misreaction by the helmsman in cases of emergency, e.g. in panic situations, the vessel should have a logical (human engineered) control system like the one described above for the Voith water tractor.
- For propeller protection when working in shallow water or close to the tanker, the guard plate construction only available with the Voith water tractor will be required.
- A highly autonomous system like that offered by the propulsion and control system of the Voith water tractor is essential for minimizing the risk of failure of the escort vessel.
- The design above the waterline (sheer at both ends) has to be matched to a higher operation speed when braking and steering.

5.0 Achievable steering forces

Apart from the above-mentioned fundamental aspects of the design of an escort vessel it will be necessary to assess the achievable steering forces in order to be able to determine the size the vessel must have for a given tanker size and operating environment. For this purpose Voith has conducted comprehensive tests in its own test laboratory permitting definite statements to be made on this today. In order to demonstrate that the tractor also offers considerable advantages over stern-propelled tug concepts with conventional hull in terms of steering forces, a typical hull of such a tug known as “pusher tug” or “reverse tractor” was included in the investigation as well.

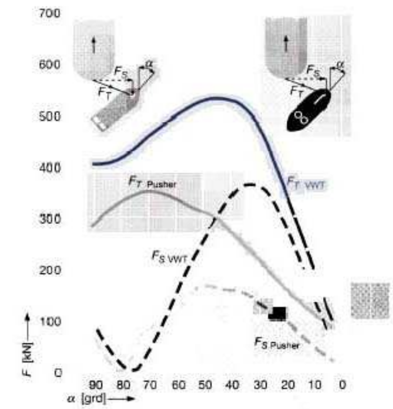


Maximum steering forces (direct and indirect mode)

The tests covered the entire working range between “ship at rest” and “ship running under sufficient self-control”. The “direct operating method” has to be employed when the ship is at rest, i.e. the engine output of the ship-handling vessel has to be used for developing necessary steering forces via the propulsion systems. As soon as the ship to be handled gathers speed, this method will become less effective and gathers speed, this method will be less effective and finally approaches zero. The speed at which direct steering force becomes zero depends on various parameters such as power, propeller position, underwater lateral resistance, center of lateral resistance, and stability of the tug.

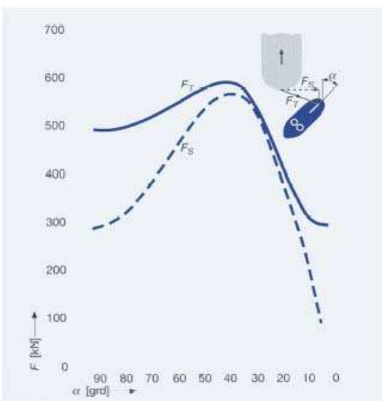
The “indirect operating method” makes use of hydrodynamic lift of the submerged part of the hull in conjunction with the engine power passed on to the water through the propulsion units. This method is almost ineffective when the ship handled is at rest, but increases by the square of the incoming headway.

The critical speed for the ship to be handled lies in the point of intersection of the limit curves of these two operating methods. It is at this point that the steering force the assistance vessel can develop is lowest (See diagram). Nevertheless, the required escorting speed will be determined on the one hand by the speed at which the ship to be assisted as sufficient self-control and on the other hand by the requirement of staying sufficiently high above the “critical speed” in order that adequate steering forces can be introduced from outside in a case of emergency.



Steering forces comparison Pusher / VWT (v= 8 kn)

Diagram 2 shows the steering forces of a Voith water tractor compared with those of a typical pusher, the parameter of comparison being of identical displacement. The steering forces of a Voith water tractor compared with those of a typical pusher, the parameter of comparison being of identical displacement. The steering forces can be increased by means of longitudinal thrust components of the propulsion units of the Voith water tractor as shown in diagram 3.



3 Maximum steering forces (v= 8 kn)

The stability-critical limit speed has been defined as the condition when the deck edge touches the water. It would certainly exceed the scope of this brochure to describe all the tests in detail. Please contact Voith for further information about specific aspects.

Results of the tests have been confirmed by similar investigations by an independent party, where the advantages of the Voith water tractor for escorting have been clearly shown as well. Furthermore, these tests have demonstrated once again that “bollard pull”, which has remained the only comparison figure usually considered, is not sufficient for assessing a safeguard vessel in reality. If escorting is taken seriously and the optimum safety vessel available today is sought, the only choice is the “Voith water tractor”.

6.0 Handling of Floating Hoses

In offshore loading stations with single-point mooring (SPM or SBM), oil is handled via floating hoses. Special tugs connect the hose lines to the tanker. As the lines are easily kinked or squeezed, control must be extremely sensitive and precise. Heavy sea frequently makes the task even more difficult. For this special application, too, the distinctive features of the Voith water tractor can be benefited from. Experience gained in practice has been extremely positive. The photograph shows one of three such vessels at work at Ras Tanura oil terminal, Saudi Arabia.

7.0 Fire-fighting equipment

The Voith water tractor is the ideal fire-fighting vessel because a considerable amount of power can be deviated from the main engines to power fire-fighting pumps without rendering the Voith-Schneider propellers ineffective or incapable of keeping the vessel under control against the fire-fighting pressure of the monitors and external influences such as wind and tide.

The excellent performance of these vessels has been proved on many occasions, and the tractors have made an invaluable contribution to restricting damage. In the case of escort vessels, effective fire-fighting could even begin already while the tanker is still on the move.

8.0 Combating oil pollution

Whether positioning skimmer arms or operating skimmer vessels without self-propulsion, the Voith water tractor clearly offers advantages also when fighting environmental catastrophes like oil pollution. The photograph below shows a Voith water tractor during successful trials with a skimming vessel in the North Sea. The following features of the Voith water tractor are of particular benefit in this context, underlining once more the logical safety concept of the vehicle:

- the safety-relevant properties of the Voith-Schneider propulsion system and its control described already in chapter 2,
- quick and precise generation of thrust from zero to full in a 360^{o} range,
- minimum advance speed and precise variation of thrust without affecting accuracy of maneuvering,
- comparatively deep immersion of the propellers and large distance from the surface,
- minimum surface turbulence due to the vertical inflow component resulting from the vertical rotor axis of the Voith-Schneider propeller with centrifugal pump action,
- reliable 360^{o} protection from ground contact, permitting work also in shallow waters as the propeller rotates freely between ship and keel,
- protection from damage by ropes, chains, etc. by the guard plate in case of an accident.

If you have any questions concerning the effect of assistance vessels on tanker safety, please contact Voith. They shall be pleased to provide all the information you may need.

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