With such high speeds highly manoeuvrable tugs with a high, free sailing speed are required and, of course, very experienced tug captains.

6.2.4 Tug–ship interaction with respect to tug performance

The flow pattern around a ship affects tug performance when operating close to a ship's hull, although it is difficult to say to what extent due to the interaction between flow patterns generated by both ship and tug. To make it even more difficult, with changes in tug position the situation may change rapidly.

It has been explained that the relative speed of water along a ship's hull between bow and stern increases in speed compared to a free stream. With wide body ships the water speed near the forward and aft shoulders might be even more than at the ship's midsection. A ship steaming at, say, three knots through the water may have a speed of four knots relative to the water flow along the ship and relative ship's speed at the shoulders may be higher still. A tug pushing at a ship's side is affected by this increased water speed and tug performance is adversely affected, particularly when operating near the shoulders (see figure 6.5 positions 1 and 2). As already explained, shallow and narrow waters increase water flow speed along the ship sides, further decreasing a tug's effectiveness.

For tugs towing on a line the situation is more complicated. Firstly, tugs are operating in areas where they are under the influence of different interaction effects as mentioned in section 6.2.3. Secondly, tugs – when in positions 3 and 4 and rendering assistance – frequently change position and heading. Thirdly, interaction effects differ by ship's hull form, loading condition and speed. So it is hard to say whether interaction effects affect the performance of a tug or tug type when towing on a line in positions such as 3 and 4.

Apart from speed, an important aspect is towline length and the distance to a ship's hull. With respect to tug no. 3 the shorter the towline and the closer to the ship's hull, the larger the interaction effects are. The towing effectiveness of tug no. 4 decreases with a short towline due to the reducing effect of propeller wash impinging on the ship's hull. The effect is larger in tugs with propulsion aft.

It is advisable for tugs towing on a line, like tugs nos. 3 and 4, to use a somewhat longer towline length and operate at a farther distance from the ship's hull, which is also safer. This reduces interaction effects and the negative effect of the tug's propeller wash impinging on the ship's hull.

In position 5 a tractor tug, which could also be an ASD/reverse-tractor tug, is operating in a ship's wake as well as in the propeller slipstream. The wake and propeller slipstream have opposite directions. It depends totally on the assistance required whether or how wake and/or propeller slipstream influence tug performance. For instance, when retarding forces are required, a ship's propeller is normally stopped or astern thrust applied. Compared to a free stream situation the wake causes a decrease in the tug's underwater resistance and propeller braking performance, assuming the same amount of engine power is used, resulting in a smaller towline force. The wake is a combined influence of potential wake and frictional wake. In figure 6.2 the frictional wake behind the ship's stern and the incoming water flow near the stern, which causes the potential wake, are shown. As relative water speed in the ship's wake decreases in shallow and narrow waters, the negative effect of the wake on a tug's braking performance increases. The effect of the propeller slipstream is opposite.

It can be concluded, as interaction effects differ by ship, that so does the influence on tug performance when tugs are operating close to a ship and in the wake or propeller slipstream. It is difficult to assess what the influence is on tug performance. The most marked influence is experienced by tugs pushing at a ship's side and tugs applying braking forces in a ship's wake.

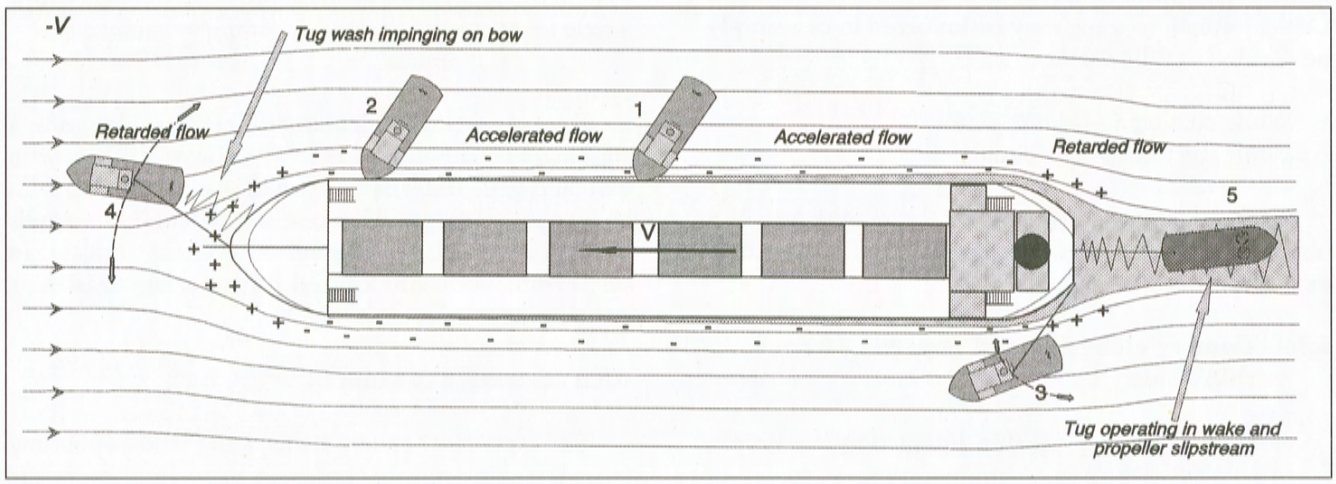


Figure 6.5 Effect of flow pattern around a ship on tug performance

6.3 Tug safety

6.3.1 Introduction

The explanation of various interaction effects on a tug when close to a ship underway at speed has already showed some of the risks involved for the tug. There are, however, various other situations which involve risk for an assisting tug.

Not all of the following situations are related to the same kind of interaction as discussed earlier. Interaction between ship's propeller and tug is considered along with several other situations related to tug safety. Some have already been addressed while discussing the capabilities and limitations of various tug types, but are also mentioned here for the sake of completeness. Most situations are well known to experienced pilots and tug captains. Still, it is worth paying attention to the risks in which harbour tugs are often involved, because many serious accidents have been reported. The more one knows about these risks, the better one can anticipate and take the right measures. Besides, pilots often have only a limited view from the bridge on the assisting tugs. They are not always aware of the critical situations a tug may find itself in.

The following risky situations are just a few examples; it is impossible to cover all situations. What is mentioned here may be representative for similar situations encountered by pilots and tug captains. Several of the situations to be discussed are related to the method of tugs towing on a line. This is understandable, because with this method of assistance tugs often operate close to the bow or stern of a ship underway at speed, locations where interaction forces can have large and alternating effects. On the other hand, in ports where tugs normally operate at a ship's side, it is also possible that in specific situations these tugs tow on a line as, for instance, in confined areas, in dry docks or when passing bridges.

It goes without saying that readers could probably name other critical situations from their own experience. Critical situations a tug may be involved in can simply be divided as follows:

- While passing a towline.
- While the towline is secured.

Next, attention is first paid to the manoeuvre of a tug coming alongside a ship at speed. This is a practical example of interaction.

6.3.2 Coming alongside and departing from a ship's side

When considering tug-ship interaction it is safest, when coming alongside a ship underway at speed, to approach near the midsection where a more uniform flow pattern exists. At positions further forward or aft the interaction effects are larger and less predictable.

Departing from a ship's side can sometimes be problematic, as the following example shows. In some ports the pilot boards a ship from a harbour tug that is to assist a ship. The ship has headway and the tug is coming alongside near the pilot ladder. After boarding the pilot it can be difficult to manoeuvre the tug free from the ship's hull. This can happen with twin screw tugs having an underwater body which is rather flat at the sides. Trying to get free from a ship's hull by moving to a far forward or far aft position along the hull does not help. This can be explained by the earlier discussion on flow patterns around a ship. Tug captains note from experience that when they apply astern thrust with the inner propeller, completely against the expected manoeuvring procedure, the tug comes free from the ship's hull. The explanation is that the water speed between ship and tug hull decreases and consequently pressure rises. The increased water pressure between the two hulls, in combination with bow cushion effect, force the tug to come off. A nice example of Bernoulli's law! Another solution is to decrease ship's speed, because the higher a ship's speed the larger the suction forces.

Tugs with azimuth propellers controlled in the way shown in figure 2.30 have the thrusters pointed somewhat outwards when proceeding at low speeds. When coming alongside a ship having a low speed the wash of the inward propeller causes an increase in water speed between tug and ship and the tug may be sucked violently towards the ship.

This becomes more problematic for tugs with fixed pitch azimuth propellers not equipped with speed modulating clutches. Such tugs have a relatively high minimum propeller speed, causing much propeller wash at minimum tug speeds. This has resulted in much contact damage while landing alongside a stationary or moving vessel and during berthing and unberthing, which, however, can be avoided by proper tug handling. The same may happen when the clutch-on/clutch-off system of the separate azimuth propellers of tugs with a single lever control are not in complete balance.

Note:
Operating close to a ship and coming alongside a stationary or moving vessel should always be done with care and in a controlled way. Approaching a ship with an inappropriate speed has resulted in dents in ship hulls and damage to tugs and even oil spills have occurred on several occasions caused by mooring assist tugs penetrating bunker spaces.

6.3.3 Passing a towline near the bow

The most risky situations for a tug when operating close to a ship's bow have already been discussed while considering interaction effects. Some other situations

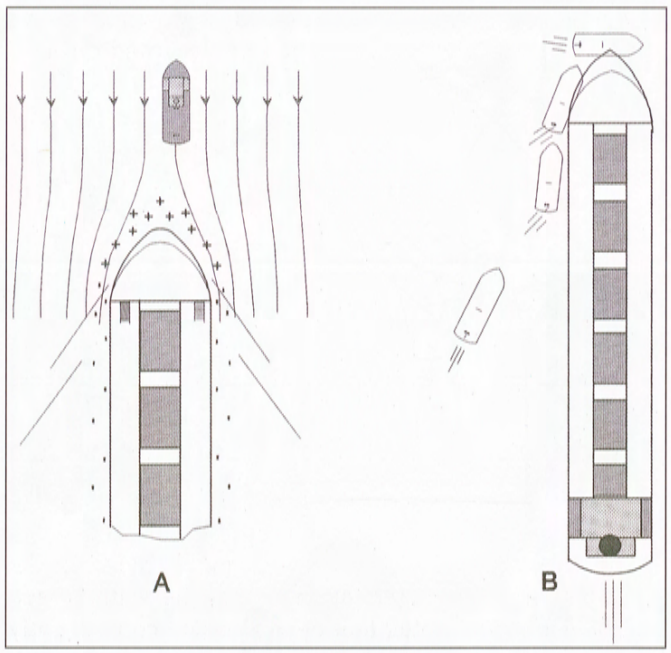


Figure 6.6 A: Tug is waiting for the approaching ship to come closer to pass the tow line. There is risk of an unexpected sheer to port due to the ship's bow pressure wave. B: Conventional tug preparing to take the tow line at ship's bow. Due to interaction effects and inadequate reactions from the tug captain, the tug comes under the ship's bow

are now highlighted (see figure 6.6A and 6.2). A tug has to make fast at the bow of an approaching ship and is steaming at some distance ahead. Tug speed is less than the speed of the ship to be attended and the tug is waiting till the ship gets close enough to pass a towline. However, due to the changes in the stream pattern caused by the overtaking ship the tug may experience a turning moment. When the tug captain is aware of this effect in time he can, irrespective of the type of tug, take measures to counteract the turning moment.

A large turning moment can be experienced, particularly when attending loaded ships with a full-shaped bow and still having reasonable speed. With this type of ship the bow wave may also have another specific effect on tugs awaiting the approaching ship. It has been experienced by tug captains that when attending VLCCs or large ore-carriers having a speed of about four to five knots and a small underkeel clearance, the bow pressure wave may be such that the tug is pushed forward and the tug captain may even be forced to reverse thrust in order to come closer to the ship's bow.

Another example of interaction is shown in figure 6.6B. A conventional tug approaches a ship under speed to take a towline at the bow. At a particular moment the tug captain considers his tug too close to the ship's hull and tries to clear the ship's side using engines full ahead while steering to port. Due to this action the tug is pushed against the ship by the steering forces and moves steadily forward along the ship's bow, unsuccessfully trying to get free. Finally the tug comes broadside under the bow and is run down. The only satisfactory manoeuvre in such circumstances is to go full astern. Some damage might then occur to the tug, but the situation is not disastrous. A tractor type of tug is safer in such a situation, because the steering forces are directed away from the ship.

Taking or passing a towline at the bow of large loaded wide bodied ships is not so dangerous. When abeam of the fore part of the bow the tug is pushed aside by the earlier mentioned cross flow. Tug captains learn from experience that when near the fore part of the bow and steering a little inwards towards the bow, the tug does not get closer. However, when the tug is moving further forward it experiences the earlier mentioned turning moment towards the ship. This effect will probably be largest with a small underkeel clearance.

Without going into further detail, it can be concluded from the foregoing that operating a tug near the bow of a ship under speed involves risks. These vary depending on the type and loading condition of the ship and increase with a higher ship's speed. As already mentioned, ship's speed can be rather high when tugs are making fast. Therefore when approaching the bow of a ship to pass or take a towline careful attention and quick reaction is needed from a tug captain in order to avoid dangerous situations developing. Skilful tug captains know the interaction effects and related risks near the bow by experience. Therefore, not just good tug manoeuvrability but experience too is an indispensable factor.

It is not the tug captain alone who masters the situation near the bow or is solely responsible for the extent of risk into which his tug gets involved. As already stated, an important factor is ship's speed which is under the control of the pilot or master. An experienced ship's crew standing by forward in good time and keeping sufficient heaving lines of the proper length and strength ready available is important. This can help to avoid a tug captain being forced to come too close to a ship's bow. Sometimes quite thick lines of insufficient length are lowered from the forecastle, forcing a tug captain to come very close to a ship's bow and involving increased risk.

On the other hand, when a tug is pushed away from a ship and a too short messenger line is used by the tug itself, this line may break during transfer of the towline from the winch. The towline then drops into the water and may foul a tug's propeller which brings about another dangerous situation. When a tug has to make fast on a ship's line, the line should be hung at a suitable height above the water, ready to be paid out as soon as the tug has got hold of the line.

6.3.4 Passing a towline at the stern

When making fast, after tugs are often very close astern of a ship – sometimes just abeam of the after end of the stern in order to pick up or pass a towline. The

interaction forces at these locations are not so large or dangerous. However, when approaching a ship having headway from astern, the tug captain should be aware that when coming close to the ship's stern, the tug is pushed towards the stern, as has been explained earlier. One should always be aware of the ship's propeller. When a tug is making fast at the stern a ship's propeller should always be stopped in case of a fixed pitch propeller. A controllable pitch propeller should be set for minimum pitch. A propeller turning ahead disturbs the water and makes it more difficult for a tug to keep a steady position behind the stern. This effect is also experienced by tugs making fast near the aft shoulder. An unsteady tug position affects smooth handling of a towline and in the worst case an unsecured towline may drop in the water and foul a tug's or ship's propeller.

A critical situation also arises when a tug is passing or taking a towline close behind a ship's stern, or is preparing to do so, and suddenly the ship applies astern thrust by giving astern on the engine or by reversing the pitch. Particularly when large ships with powerful engines suddenly apply astern thrust a deep wave trough is created close behind the ship's stern, sucking a tug towards the ship. A tug may touch a ship's stern causing damage to the ship or tug. This kind of accident has happened occasionally. Even with smaller ships this effect is noticeable. When, for one reason or another, a ship's propeller has to be used for astern thrust, a tug captain should be informed by the pilot to allow him to manoeuvre his tug out of the dangerous area.

The conclusion is that when tugs are making fast at or near the stern, a ship's propeller should be stopped and in case of a controllable pitch propeller be set for mimimum pitch. When for some reason or another the propeller has to be used, the tug captain should be informed.

Now some critical situations are discussed when towlines are secured. Some situations relate to specific manoeuvres as used in some large ports.

6.3.5 Overtaking a bow tug on a line – Girting – Tripping

In figure 6.7A a tug with propulsion aft is assisting a ship in making a turn to starboard. Ship's speed may become too high for the tug (position 1), for instance because the tug is pulling too much to starboard or because the pilot has increased engine power to improve rudder effect in order to make the turn properly. In the given situation it is very likely that the tug will come abeam of the ship's bow (position 2) and even in a position further aft with the towline coming under high tension (position 3). It is almost impossible for the tug captain to manoeuvre his tug back in line with the ship and the tug is liable to capsize. This may not only be caused by the strong athwartships forces in the towline, but while trying to bring the tug back in line with the

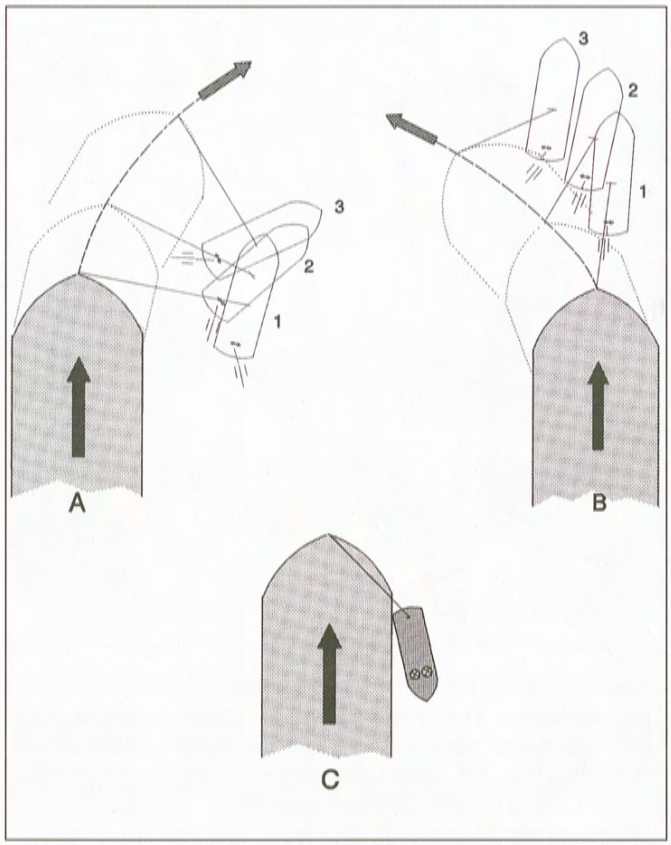


Figure 6.7 Girting and tripping
Two examples of girting (A & B, both with a conventional tug):
A – due to excessive ship's speed with respect to tug limitations
B – due to misunderstanding
Example C shows tripping with a tractor tug

ship, the tug captain applies high steering forces, adding to the heeling forces. With a reliably working quick release system the tug captain can release the towline, so avoiding capsizing. On the other hand, if the pilot recognises the dangerous situation arising in time he may be able to reduce ship's speed. In doing so the towline force reduces, creating the possibility for the tug captain to come back in line with the ship.

It is obvious that the more manoeuvrable tugs are, e.g twin screw tugs, the less likely they are to get involved in similarly dangerous situations. In addition, proper stability, freeboard and deck equipment contribute markedly to safe operations and enlarge the capabilities of a tug. Doors and other openings on deck should be closed during towing operations.

The above situation is less dangerous for a tractor tug because of the aft lying towing point. A tractor tug swings around on the towline and comes alongside an attended ship unless the towline is released in time – so-called 'tripping' (see figure 6.7C).

Similar situations can arise with a tractor tug when the towing angle – the angle between ship's heading and direction of the towline – is getting too large with respect to the forward speed of a ship. The tug is unable to come back in line with the ship and swings around.

Although the above mentioned situations do occur, the following comparable situations are also possible.

The danger of 'girting' or 'tripping' does not only exist when a ship rounds a bend. Even when a ship is proceeding on a straight course girting can occur. In that case excessive speed of the ship is the main cause. When a ship increases speed to a level which is rather high for a forward tug towing on a line, the tug captain probably does not keep position right ahead of a ship's bow, because that is too dangerous. The tug steers out towards a position more aside in order to keep well clear of the ship's bow. It is understandable that if ship's speed further increases, a comparable girting or tripping situation will arise for the tug as indicated before.

Although pilots should be aware of the implications of too high a ship's speed for the safety of assisting tugs, it is again an indication of the importance of good communications between tug captains and pilots. The pilot may not have a good view of what is happening at the bow and the tug captain should therefore inform the pilot in good time if he considers a speed increase too high.

Another example of how the danger of girting can arise is shown in figure 6.7B. A ship is making a turn to port, say, to enter a harbour basin. Because the tug captain has not been informed that the ship has to enter head first into the basin he starts pulling to starboard to control ship's heading, assuming the ship is veering off course. If the pilot is not aware of this, the same dangerous situation for the tug as described above develops, in particular when the pilot observes a decrease in rate of turn due to the tug captain's action and increases engine power while applying a large rudder angle. This is just an example, to show how important it is for tug captains to be well informed about a pilot's intentions. On the other hand, of course, the tug captain could have asked the pilot what his intentions were.

A further example. A tug has taken position right ahead of a ship, waiting for the ship's crew to release the towline. With the small number of crew members on board ships nowadays, this may take some time. In the meantime the ship is already increasing speed. In the case of beamy full-bodied ships it may happen that the tug, with the towline still not yet released, gets pushed forward by the bow wave of the ship and thus reaches a speed which can be higher than the free running speed of the tug. When the tug moves sideways towards a position abeam the bow, due to the danger of the increasing ship's speed, the forward pushing effect of the bow wave diminishes. The tug may not be able to keep pace with the ship while still waiting for the towline to be released. A dangerous girting or tripping situation may arise. This example shows again the importance of appropriate speed and good communications.

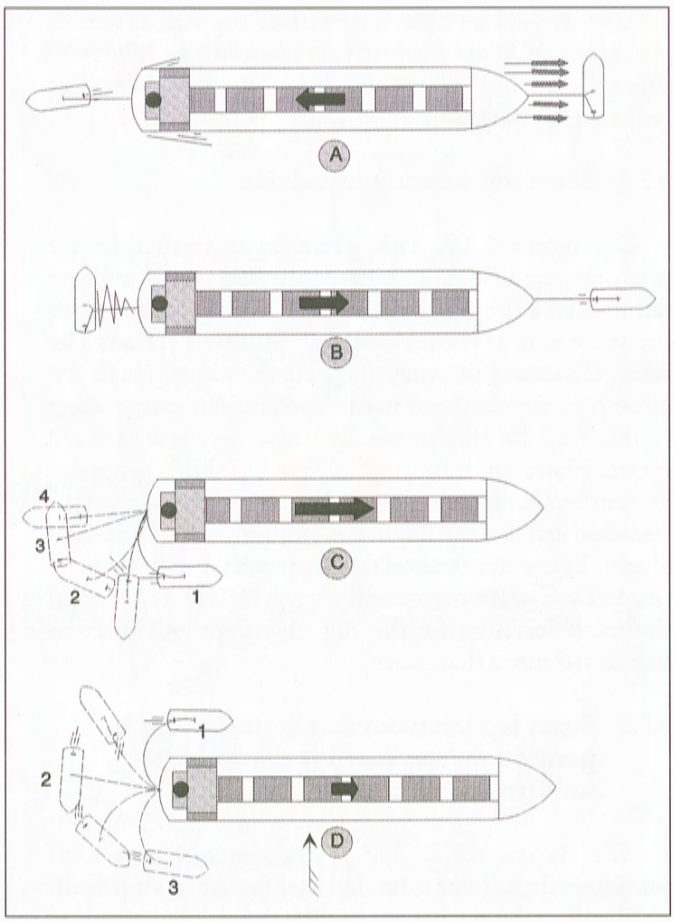


Figure 6.8 Some specific manoeuvres by conventional tugs towing on a line including risk of girting or capsizing when a ship's speed is too high with respect to tug limitations

6.3.6 Forward tug steering broadside

In several ports, ships enter harbour basins stern first. Departure is then easier and in case of emergency most ships are able to leave without tug assistance. Entering a harbour basin stern first can be done with e.g. two tugs of which the forward tug is a conventional tug operating broadside as shown in figure 6.8A. The forward tug, acting as a drogue, steers the ship effectively by going astern or ahead on the engine and so applying steering forces to port or starboard. The tug usually uses a gob rope, although with twin screw tugs this is not always the case. This method of tug operation has already been described in Chapter 4. For small ships often only one forward tug is used operating in the same way. The ship maintains sternway using its engine.

A dangerous situation arises when a tug's capabilities and limitations are not sufficiently taken into account. When a ship's astern speed is becoming too high, tug heel caused by high athwartships towline forces may increase until the tug capsizes. This may not only be caused by the large transverse resistance of the tug as it is pulled bodily through the water, but also by the water acting on the tug speeded up by the wash of the ship's propeller. Tug stability, freeboard and deck equipment determine the limits of safe operation.

Care should be taken when using the engine ahead. A ship should take care not to gather headway, otherwise she will collide with the tug due to the small distance between bow and tug.

6.3.7 Stern tug steering broadside

See figure 6.8B. This situation is similar to the previous one. The ship is now moving ahead and the after conventional tug is the steering tug operating in the same way as the forward tug discussed earlier. The main difference between the two situations lies in the close presence of the ship's propeller. When operating in this way the ship generally has a very low forward speed. However, it is essential that the ship's propeller is handled with the utmost care. A very dangerous situation arises if the engine is suddenly set, say, to half ahead. The water flow on the tug together with the wild propeller wash may cause the tug to list severely and in the most serious case the tug may capsize. This has happened more than once.

6.3.8 Stern tug manoeuvring from a stand by position on starboard or port quarter towards a position astern the ship

See figure 6.8C. During a certain phase of manoeuvring it may be necessary for a ship with headway to have the port or starboard position tug (position 1) move astern of the ship (positions 3 or 4) to assist in steering or for speed control. This might be necessary when a ship has to wait in a river, swing or be stopped. This manoeuvre is dangerous to conventional tugs when carried out at too high a ship's speed. This is at speeds of more than about three knots, and depends on tug manoeuvrability, stability and freeboard. In situations 2 and 3 risk of girting exists due to the high athwartships towline forces that may occur. If a tug capsizes it has been observed that the tug is pulled underwater stern first.

The manoeuvre just described is no problem for tractor or reverse-tractor tugs, even with a fairly high ship's speed. Conventional tugs with a gob rope system, whereby the towing point can be transferred towards a far aft position, can also swing around at a higher speed. The gob rope system should be strong enough and fully reliable otherwise such a manoeuvre becomes really dangerous for the tug.

A conventional tug manoeuvring from a position astern of the ship (e.g. position 3) to a position on the starboard or port quarter can only do this at minimum ship's speed, otherwise risk of girting may arise.

6.3.9 Stern tug manoeuvring from starboard to port quarter or vice versa

See figure 6.8D. Sometimes it is necessary for a conventional after tug to move from a position on the port to starboard quarter or vice versa. This may happen, for instance, when assisting a departing ship. A ship has just left her berth and has been turned around in the turning basin by assisting tugs. The after tug is on the port quarter. The ship still has to pass through a channel and it may be necessary to have the after tug stand by on the starboard quarter to compensate for wind or current forces. It may also be necessary to compensate for the transverse effect of the ship's propeller when she uses engine astern to wait somewhere in the channel. The tug has to manoeuvre from port to starboard quarter, close underneath the stern. Because of the risk of girting this manoeuvre should be carried out while the ship is nearly stopped in the water. This kind of manoeuvre also involves great risk due to the ship's propeller. A pilot not aware of the tug manoeuvre could go ahead on the engine or apply ahead pitch while the tug is near position 2. The conventional tug comes into danger. This kind of tug manoeuvre, whenever considered necessary, should always be carried out with the utmost care.

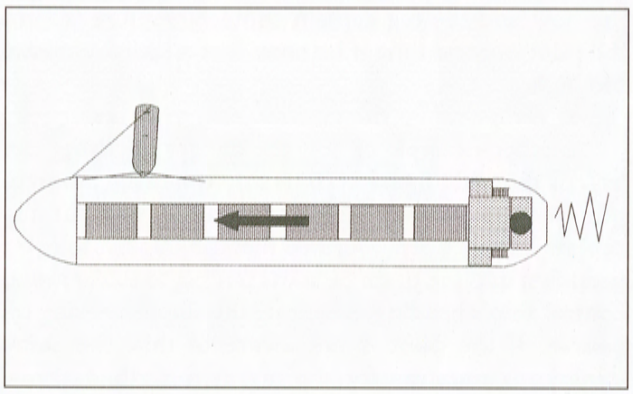


Figure 6.9 Due to excessive speed a tug at a ship's side may capsize if the stern line cannot be released

6.3.10 Tug operating at ship's side

Conventional tugs operating at right angles to a ship's side may use quarter lines or stern lines as shown in figure 6.9 to stay in position when the ship moves ahead. When the tug is secured in that or a similar way, excessive speed should be avoided to prevent possible parting of the towline or capsizing the tug.

6.3.11 Fog

All the situations mentioned above can cause a critical situation for tugs. However, during dense fog these situations may involve even more risk. As mentioned in paragraph 4.4, during fog it is very difficult for tug captains towing on a line to orientate themselves with respect to an attended ship and surrounding area, in spite of the availability of a radar. Furthermore, the pilot loses his view of the tugs. It is absolutely necessary, therefore, that ship's speed is kept very low during fog and that tug captains are kept well informed about intended manoeuvres. Communications between pilot and tug captains should be optimal.

It should be noted that although the use of towing bitts may be necessary for certain specific manoeuvres, their use is not recommended for tugs towing on a line during fog conditions. In case of emergency it may be almost impossible and certainly dangerous to release the towline under tension rapidly. The same applies to quick release hooks, unless they are one hundred per cent reliable. A good towing winch with a quick release system which can be operated from the wheelhouse as well as at the winch is safest in these conditions.

On the other hand, tug captains sometimes prefer to have a ship's line on the towing bitt or towing hook during fog conditions. The ship's line can then be released by the tug crew as soon as the tug captain thinks the situation is becoming critical. If he has to wait for the ship's crew to release his towline in a developing critical situation, it could well be too late.

6.3.12 Some other practical aspects

Bulbous bows

Although there is a mark on a ship's bow indicating that she has a bulbous bow, tug captains cannot see the bulbous bow when it is underwater. Even when only partly submerged the exact position is difficult to determine. This is a problem for forward tugs when taking position to pass or take a towline or when they are assisting using a very short towline. It is most dangerous when the stern of the tug touches the bulbous bow, and the ship has a rather high forward speed. The tug may be severely damaged and lives may be lost. Tug captains have to be particularly careful when operating close to a bulbous bow, especially during fog and darkness.

Releasing towlines

If a crew on board ship is not able to release a tug's towline when required, problems may arise if a ship is already increasing speed. This is particularly the case with heavy steel wire towlines on powerful tugs. The towline has to be slacked off by a tug in order to make it possible for a ship's crew to release it. The slack towline is then dragged through the water. When ship's speed increases the resistance of the towline also increases, creating more tension in the line. Releasing it then becomes almost impossible. Chain stoppers, when used, may break. It is a difficult situation which can only be avoided by proper control of ship's speed, an experienced ship's crew, sufficient crew members on station and good cooperation between ship and tug crew.

The aforementioned situation can get very critical for the tug when the ship is further increasing her speed and as a result overtakes the tug. The risks stemming from these situations have been discussed already.

Finally, a tug's towlines should not be dropped into the water but preferably be lowered onto the tug's deck guided by the tug's crew. When applicable, Norman pins should be raised on board the tug to prevent the towline slipping along the sides. This avoids the towline fouling the ship or tug propeller. In the case of a fixed pitch propeller the ship's propeller should be stopped when the ship's stern towlines are released.

Underestimating wind and current forces

Underestimating wind and current forces can create risky situations for a ship and have resulted in accidents. Tugs operating at a ship's side can also be endangered (see figure 6.10). Tugs can be jammed between ship and shore when they don't get out in time. The situation is particularly dangerous when tugs are secured by towlines. The bollard pull of tugs to compensate for wind and current forces should be more than sufficient to avoid such situations.

Sudden changes in a ship's heading and speed

While passing or taking a towline, tugs are very close to a ship's hull and a tug captain's attention is fully focused on keeping in position and on line handling. It should be understood that during these operations sudden changes in ship's heading or speed without warning can create critical situations for a tug.

Engine starts of the large high powered container ships may seriously affect the controllability of a tug operating behind the ship's stern.

It is necessary, therefore, as already mentioned earlier, to inform assisting tugs about intended ship's engine/propeller and course changing manoeuvres. This applies too for tugs operating at a ship's side. In that way tugs can anticipate expected manoeuvres.

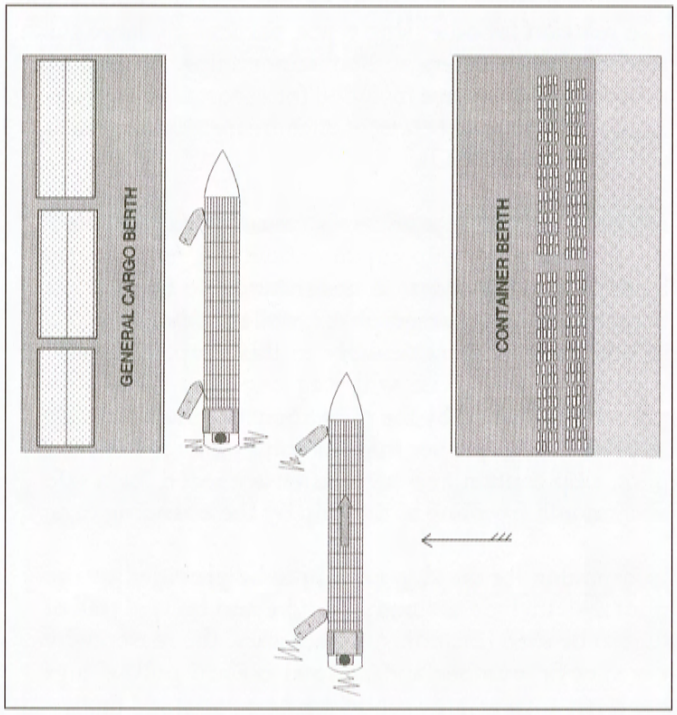


Figure 6.10 Due to low powered tugs and a strong beam wind, a container ship is drifting and the tugs are getting jammed between the ship and the general cargo berth

Ship design consequences

Due to the use of tension winches on board ships the number of bollards at their forecastle and stern may be reduced. The location of the remaining bollards is not always optimal for towlines. This may affect proper securing of towlines and lengthen the time for securing tugs, especially when more than one tug is used forward and aft.

There are specific ship types, such as submarines and aircraft carriers, where it can be problematic to pass or secure towlines, due to the underwater form of the hull or overhanging structures. With modern merchant ships such as ro-ro vessels it can sometimes be awkward to secure a towline in such a position that a tug can operate effectively. Ship designers should take into account that, even when ships are very manoeuvrable, there will always be situations during a ship's life when the assistance of one or more tugs is necessary. On the other hand tugs should meet, as far as possible, the requirements of ships calling at the port regarding safe and effective towline handling.

Apart from the need to have sufficient and properly located bollards and fairleads available for securing the number of tugs that may be needed, it is furthermore necessary that bollards and fairleads are in good condition and suitable for the towlines to be used, and strong enough to withstand the forces that can be applied by the modern powerful tugs. Not meeting this requirement has resulted in failures.
Regarding this important subject, recommendations are given in the OCIMF publication 'Recommendations for ships' fittings for use with tugs' (see References); recommendations that apply to tankers, but which are also relevant for other ship types, particularly large gas carriers, bulk carriers and container ships. Additional recommendations are included for escort tugs and tugs engaged in station keeping at offshore installations, such as SPMs and F(P)SOs.

Information exchange pilot- ship master – tug captain

Informing the ship captain about tug manoeuvres by the use of tug orders in understandable English has been addressed in paragraph 4.7, while at other locations in this book, and particularly in this chapter, several arguments are given why tug captains should be properly informed by the pilot about the intended ship manoeuvres. A proper information exchange between pilot, ship captain and tug master is needed for a safe and smooth handling of the ship by the attending tugs.

Information for the ship captain to be provided by the pilot may include the number, type and bollard pull of tugs to be used (including, if necessary, the reason why the specific number and/or total bollard pull of tugs has been advised), the rendezvous position and time of the tug(s); where at the ship and how tug(s) to be fastened; when tug(s) to be released and how to be done; transit speeds and intended manoeuvres. If the ship has special manoeuvring devices or limitations regarding manoeuvring, tug securing, mooring and anchoring equipment, the ship captain should inform the pilot. With respect to the information exchange the reader is also referred to the earlier mentioned OCIMF publication 'Recommendations for ship's fittings for use with tugs'.

Operating bow-to-bow

The relatively low effectiveness of tractor tugs, reverse-tractor tugs and ASD-tugs (when operating as reverse-tractor) as bow tug towing on a line with a ship having headway, including the reasons why and the risks involved, have been discussed in par. 4.3.1.

For reverse-tractor tugs and ASD-tugs this way of operating is generally called 'bow-to-bow'. When operating in this way with a ship having headway the tugs are sailing astern. Directional stability of these tug types when sailing astern is generally rather low, particularly at higher speeds. Pulling straight astern at a relative high speed might not immediately present a problem, but as soon as the tug deviates from the straight line, for instance, to give steering assistance to the ship, position keeping becomes difficult. It may easily result in a loss of control. The reader is with respect to this referred to the report 'Performance and effectiveness of omni-directional stern drive tugs' (see References).

A high underwater resistance, e.g. a large skeg, worsens the situation, while a bow skeg may improve the situation to some extent. The restriction in movement of the bow by the tow rope increases the difficulties in maintaining a safe position and direction relative to the ship under tow. Furthermore, if the tug is working on a short towline, tug-ship interaction effects may play a role, destabilising the tug's position (see par. 6.2.4), while time left to react is minimal. A comparable situation has led to accidents, amongst others in a severe collision between ship and tug. See the investigation report of the collision between *River Yarra* and tug *W.J. Trotter* (see References). This incident resulted in a speed restriction for bow-to-bow operations. A maximum speed of five knots was introduced.

6.4 Summary and conclusions

Several interactions exist, some influencing tug performance, others tug safety or even both. Interaction effects influencing tug safety are the kind of interactions which occur between ships when close to each other. These interaction effects are more pronounced in shallow and narrow waters and when a tug is in the relatively close vicinity of a ship and increase sharply with increasing ship's speed.

Because tugs have to operate close to ships which are often underway at speed these effects should always

source: Foto & Video Produkties van der Kloet, the Netherlands

Figure 6.11 ASD-tug `Smit Marne´ of Smit Harbour Towage, Rotterdam, assisting a container vessel having headway while operating `bow-to-bow´. The `Smit Marne´ (l.o.a. 30.6m, beam 10.6m, draught 5m, bollard pull ahead 61.2 tons, astern 56.4 tons) is built by Damen Shipyards, the Netherlands.

be taken into account. Considering the interaction effects and all other risky situations that have been discussed, it is clear that the following aspects are essential for safe shiphandling with tugs:

- Experience in recognising risky situations and knowing how to deal with them.
- Good knowledge of the limitations of tugs.
- Appropriate ship's speed taking account of interaction effects and tug limitations.
- Careful use of ship's propellers when tugs are operating close to the stern or when passing or releasing towlines at the stern. Tug captains should be informed in good time about the intended use of ship's propellers.
- Optimal communication, information exchange and cooperation between pilots, ship masters and tug captains. Pilots should inform tug captains well in advance of intended manoeuvres and should, as far as possible, keep an eye on assisting tugs. Tug captains should inform pilots about developing or suspected risky situations and contact the pilot whenever in doubt. Ship masters should inform the pilot about the manoeuvring capabilities of the ship, and relevant aspects of ship's mooring, anchoring and towline securing equipment. The pilot should inform the ship master about the tug assistance and manoeuvres to be executed.

- Tugs should be fully appropriate for the assistance required and should comply with the following minimum requirements: sufficient bollard pull, high manoeuvrability and free running speed, good stability and sufficient freeboard, suitable towing equipment with a properly working quick release system and an optimal horizontal and vertical angle of view from the wheelhouse.
- Tugs operating at a ship's side should be sufficiently powerful and secured so that the risk of becoming jammed between ship and shore due to wind, current and/or wave forces can be avoided.
- Sufficient ship crew members should be available and well prepared on station to secure tugs with minimum delay.
- Ship's crews should not drop a tug's towline into the water but lower it gently onto the tug's deck.
- Ships should be designed so that sufficient towlines can safely and properly be secured for effective tug assistance.

Finally, openings in superstructures, deckhouses and exposed machinery casings situated on the weather deck of tugs, providing access to spaces below deck, should be fitted with watertight doors. These openings should be kept closed during towing operations, so enhancing tug safety. If these openings are not closed, water can easily flow into a tug when she is forced into a list.

Earlier in this book the importance of good towing equipment in relation to tug performance has been mentioned a number of times. In this chapter the importance of proper towing equipment and quick release mechanism in relation to tug safety is emphasised. In the next chapter attention is paid to the deck equipment of harbour tugs.

Chapter SEVEN

TOWING EQUIPMENT

7.1 Introduction

IN PREVIOUS CHAPTERS, ON SEVERAL OCCASIONS, the importance of the location of the towing point in relation to safety and performance of a tug was mentioned. The strong relationship between safety and performance was emphasised because the more safely a tug can operate under different circumstances the smaller its limitations are. For instance, the higher the towing point of a conventional tug the larger the list when towing on a line. This is due to the athwartships forces and increases the risk of girting. Consequently a high towing point limits towing performance which is particularly the case for conventional tugs but for other tug types as well.

There are ways to enhance tug performance and safety, such as:

- Making the towing point transferable or having more than one fixed towing point, which affects tug performance as well as safety.
- Fitting a quick release system, which is an emergency safety system.

Another important aspect mentioned in previous chapters is the need to be able to vary the length of the towline when assisting a ship. For example, when dynamic forces due to waves are high, to reduce the counteracting effect of a tug's propeller wash on a ship's hull, or when tug manoeuvring space is limited.

In this chapter ways of varying the towing point and towline length by means of deck equipment is discussed. The importance of good deck arrangement in relation to performance and safety is dealt with, as well as whether and how a towline can be released in case of emergency – a quick release system. Of course, attention is also paid to the towline itself, being the crucial connection between tug and ship.

7.2 Additional towing points and gob ropes

The possibility of varying towing point location particularly enhances the performance and safety of conventional tugs. Transferable towing point systems can be distinguished by facilities which can move the towing point:

- Along a semi-circular track.
- Along the centre line of the tug in a longitudinal direction.

Radial system

Moving the towing point along a semi-circular track, in particular using the radial towing hook, has already been addressed in section 4.2.3. An example is shown in figure 7.1. A radial system can also be used with a towing winch. In that case the lead of the towline goes from the winch via a fixed fairlead and then a second fairlead which moves along a circular rail on the tug's deck. The principle is similar to the radial towing hook (see figure 7.3). Radial systems cause smaller heeling angles so higher athwartships towline forces can be applied, resulting in an increase in tug performance. It is currently only used by conventional tugs, though the intention is to use a similar system in other tugs types as well, see for instance 'The Towliner '-concept discussed in par. 9.5.1 and the Carrousel tug discussed in par. 10.1.2

Additional fixed towing points

Moving the towing point along the centre line of the tug can be achieved, firstly by making use of more than

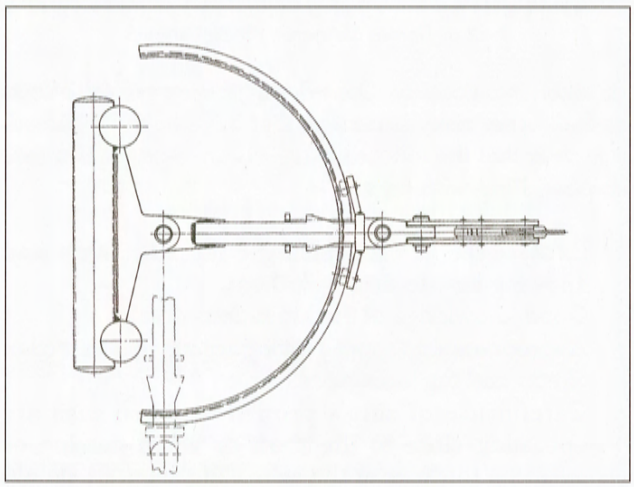


Figure 7.1 Radial towing hook with rail track

Photo: Author

Figure 7.2 Radial towing hook of conventional twin screw tug 'Saona', Dominican Republic (l.o.a 26m, beam 7·8m, bollard pull 30t).

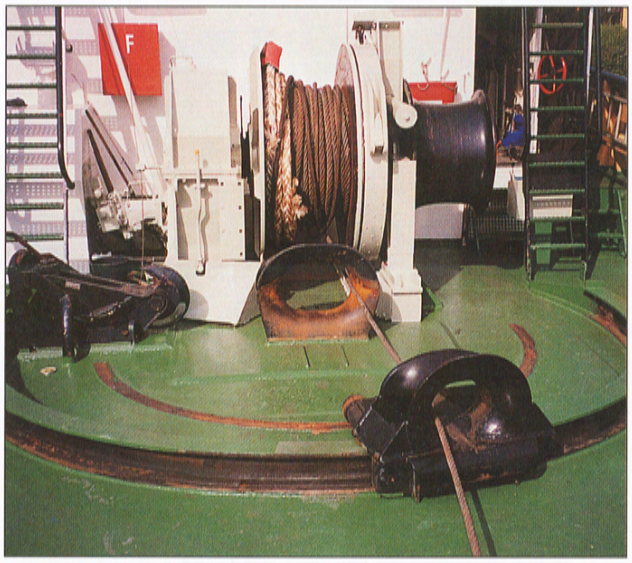


Photo: Author

Figure 7.3 After deck of a conventional twin screw tug with a towing winch with radial system

Photo: Author

Figure 7.4 Additional fairlead/towing point near the stern of combi-tug 'Hendrik P. Goedkoop', Amsterdam, Holland. The fairlead can be opened to put the towline in or take it out. Particulars of the tug are given in Chapter 2

one fixed towing point. This provision is found on board some combi-tugs, as mentioned when discussing this type of tug. The additional towing point enhances the capabilities of the tug as stern tug to a large extent and enables it to perform almost as a tractor tug. On the photograph the additional towing point can clearly be seen.

Some VS tractor tugs designed for escorting have an additional towing point far aft to minimise the steering effort required to keep the tug in line with the escorted ship. When required to deliver steering forces the original towing point has to be used.

Gob rope systems

A second method, used only on conventional tugs, is the use of a gob rope to vary towing point location in a longitudinal direction. This can be done in two ways. Firstly, by using a certain length of wire, one end secured to a side bollard, the other passing through a fairlead or small H-shaped bollard situated on the centreline of the work deck. This end of the wire holds a large shackle which can be attached around the towline as shown in figure 7.5A. The large shackle is free to slide along the

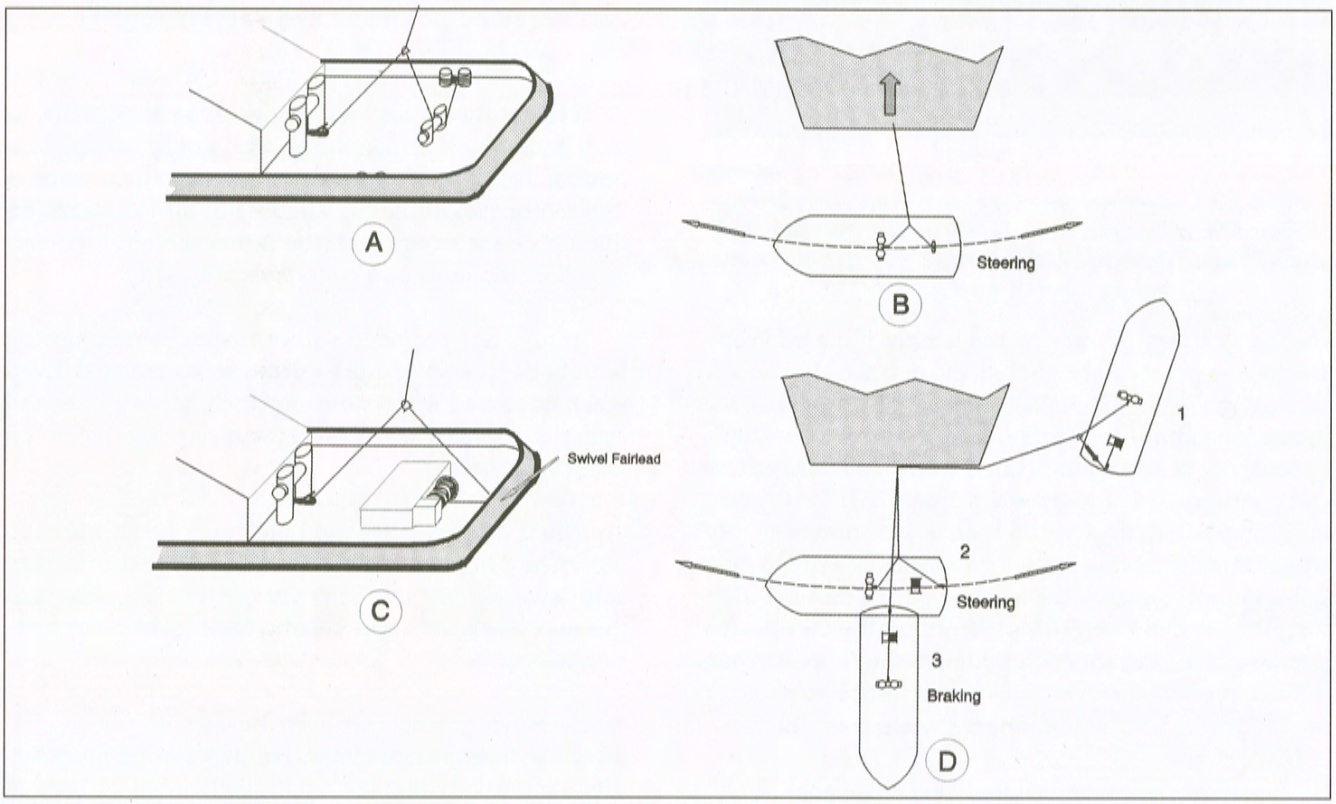


Figure 7.5 Two different gob rope systems

towline. When the towline moves into a more abeam position the gob rope tightens and relocates the towing point between the original fixed towing point and the position of the fairlead or H-bollard. The shackle of the gob rope should always be large enough to allow the towline to slip through it if the towline breaks or has to be released in an emergency. As well as wire gob ropes, fibre lines are sometimes used and different gob rope arrangements can be found. By using a gob rope a conventional tug, at low ship's speeds, can operate in the way shown in figure 7.5B for steering control to starboard or port by going ahead or astern on the engine.

An improved arrangement is to have a separate gob rope winch (see figure 7.5C), controlled from the wheelhouse if possible, with the gob rope wire led through a central swivel fairlead at the utmost end of the stern. A large shackle is attached to the wire, which again can slide along the towline (see also figure 7.6 –

Photo: Author

Figure 7.6 Conventional single screw tug 'Adelaar' (l.o.a. 26·6m, beam 8·1m, bollard pull 30 tons) of former towing company Jan Kooren Towing, Rotterdam, Holland, using a gob rope to steer a ship entering a harbour basin stern first

the tug *Adelaar*). By varying the length of the gob rope the towing point can be shifted, even to the after end of the tug. The system enhances tug capability and is, for instance, compulsory in German ports. At low ship's speeds, conventional tugs fitted with this arrangement can operate in the way shown in figure 7.5D for steering control (position 2) or speed control (position 3) simply by shifting the towing point location. By heaving on the gob rope and bringing the towing point to the tug's after end, the tug can swing around from position 1 towards position 2 or 3 at somewhat higher ship's speed than without this arrangement. This is comparable to a tractor tug having its towing point near the stern as well.

It should be borne in mind that high peak forces can occur in the gob rope; 70% or more of the bollard

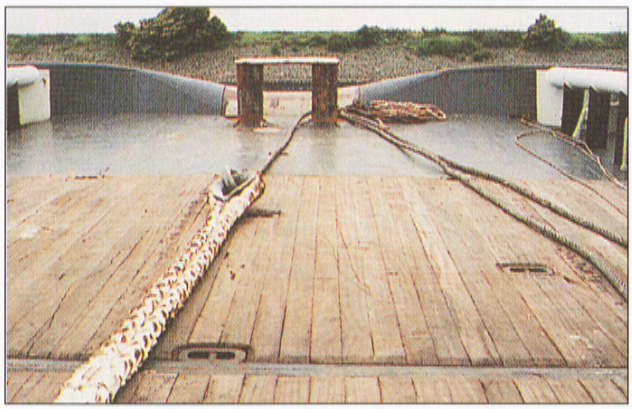


Photo: Smit Harbour Towage, Rotterdam, Holland

Figure 7.7 After deck of ASD-tug 'Maasbank' (l.o.a. 37·4m, beam 11m, bollard pull 62 tons) showing the towing pins

pull has been measured. The gob rope arrangement must be able to withstand these high forces.

The gob rope is used by a conventional tug when operating as stern tug on a line and the ship is moving ahead. When a ship is moving astern and the tug acts as forward tug a conventional tug, when required, can operate in the same way as described.

Several ASD-tugs are equipped with hydraulically operated towing pins (see figure 7.7), which have more or less the same function as the gob rope system, viz. shifting the towing point to aft. However, these towing pins are principally used when towing at sea.

7.3 Towing bitts, hooks and winches

7.3.1 Method of towing and varying towline lengths

It is not always easy, or may even be impossible, to vary a towline's length when this would be the best option. This largely depends on the way the towline is secured on board the tug and this in turn depends on the tug's deck equipment, the assistance required and whether ship lines or tug towlines are used.

In tugs not provided with a towing winch, towing bitts, bollards and/or quick release hooks are used. Even when equipped with a towing winch, towing bitts and bollards are used when more than one line has to be fastened aboard.

When ship lines are used they are often secured to the towing hook. In this case the crew of the assisted ship have to vary the line's length if so required and this may take some time with the shortage of manpower nowadays.

Even though not equipped with a towing winch, tugs often use their own towlines. For tugs towing on a line, these are usually of fixed length with an eye spliced at each end. One eye is secured to the ship's bollard and

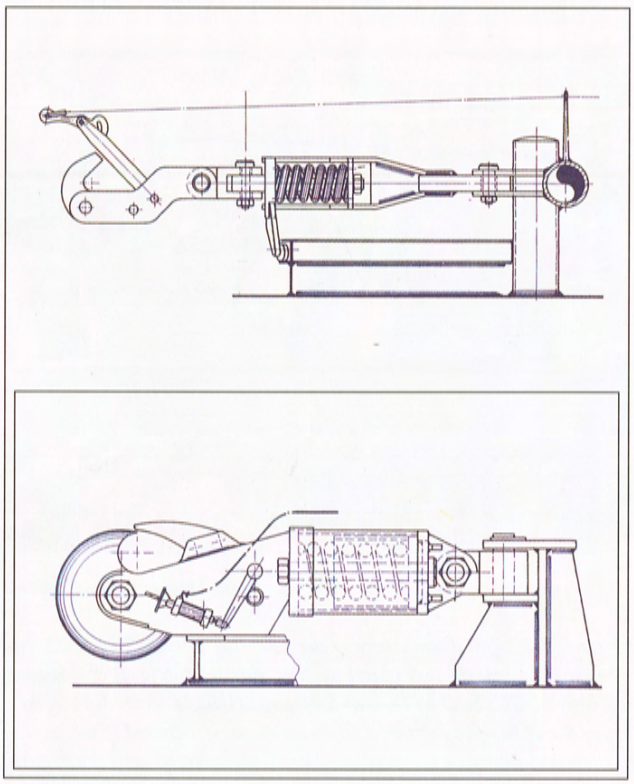
the other to the tug's towing hook. The length of such lines cannot be varied. These tugs often have two (or more) towlines of different fixed lengths.

The length of a towline secured to a tug's bollard or towing bitt can be changed, although it takes time and manpower to do so and can only be done when the line is slack. In an emergency it is almost impossible to release a towline secured to a towing bitt, whereas when secured to a quick release towing hook, release should not be problematic.

So, although different methods of towline usage and securing exist, they hardly allow towline length to be varied efficiently unless a towing winch is used. It should be noted carefully that operational safety is involved if towlines cannot be slackened or released in an emergency.

7.3.2 Towing hooks

Different types of hook in addition to the radial towing hook are on the market and in use. There are two basic systems – the normal standard towing hook and the disc towing hook (see figure 7.8). The disc towing



Mampaey, Dordrecht, Holland

Figure 7.8 Standard hook and a disc-hook with spring shock absorbers and different quick release systems

hook has been developed to absorb the energy stored in a towline under tension when being released. Particularly when using fibre towlines with large stretch a lot of energy can build up in the line. When towlines under tension are released they have a large impact on the hook and deck construction when normal standard hooks are used. Some of these have rubber buffers to absorb, as much as possible, the impact energy of the hook itself. With disc towing hooks the hook is a round plate with a hook shaped opening for the towline. As soon as a line under tension is released, the stored energy causes an enormous acceleration of this disc but avoids the large impact on hook and deck construction.

Towing hooks can be equipped with spring shock absorbers to reduce high dynamic peak forces in the towline. Load monitoring systems for towing hooks also exist.

Towing hooks are normally equipped with a quick release system, operated locally and by remote control from the wheelhouse. Systems vary from a simple one, manually operated by a steel wire up to electric-pneumatic or electric-hydraulic remote control systems.

7.3.3 Towing winches

Installing a towing winch allows adjustments to be made to the length of the towline at any time to fit the circumstances. On modern tugs the winch can be controlled from the wheelhouse. The advantage is that normally no additional manpower is needed for adjusting towline length. A towing winch allows faster and easier handling of the towline, especially when heavy ones are used.

At the winch control panels one should have a good view of the towing winch because, for instance, the line can be trapped between lower layers preventing it from being paid out freely. If not noticed the towline is, instead of being paid out, automatically heaved in again with all its consequences. When the towing winch is controlled locally at the winch the tug captain should have a good visual contact with the person handling the winch.

Photo: Author

Figure 7.9 Single drum towing winch of azimuth tractor tug 'Texelbank' (l.o.a. 27·9m, beam 9·7m, bollard pull 45 tons) of Smit Harbour Towage Company, Rotterdam

Types of towing winch

Different types of towing winch exist. The most common is the *single or double drum winch.* In case of a double drum, one drum is generally used for harbour towage and the other for a towline used at sea.

Waterfall winches can be found on sea going tugs and on some harbour tugs that are also are used at offshore locations e.g oil rigs They have two or three drums. Each drum is located a bit higher and further back than the other, like a waterfall. They are mainly used on anchor handling tugs. A waterfall winch with two drums can be used as follows: the top drum holds the main tow wire, while the lower drum holds a working wire for anchor handling. On some harbour tugs the top drum holds the sea towing line, while on the lower drums the towlines for harbour work are stored.

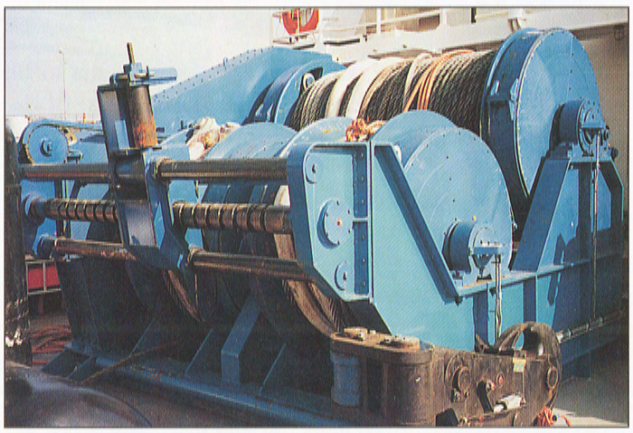
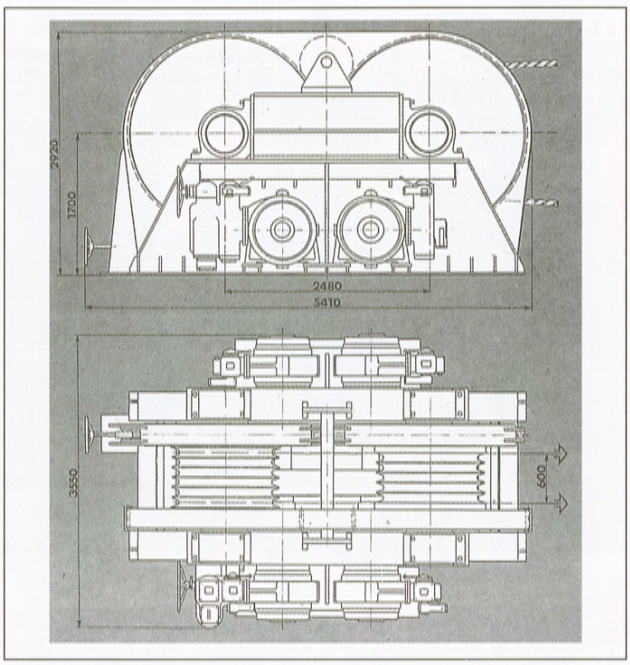


Photo: Author

Figure 7.10 Waterfall winch on board 'RT Spirit' (see paragraph 10.1.1) of towing company KOTUG, Rotterdam, The Netherlands. The winch has one upper drum and two lower drums.



Norwinch

Figure 7.11 The friction drums of a traction winch

Another type is the *friction or traction winch.* Basically it consists of a towage section and a separate storage section. The towage section consists of two grooved drums lying parallel to each other and driven in unison. The towline passes around both drums about five or six times and is then led to a separate storage drum, which can be situated below deck. The storage drum is driven in such a way that it keeps the towline under slight tension. This is usually about 2% of the nominal pulling capacity of the winch. This type of winch, originally used on sea going tugs, offshore work boats and even on ships such as LPG carriers, is occasionally used on harbour tugs though in very limited numbers. The winch is very suitable for fibre ropes, especially on recovery, since the line is always under slight tension and easily spooled onto the storage drum. When the towline is under high load it is not pulled down onto the storage drum, becoming trapped and crushed. The disadvantage is the large deck space required, which is limited on harbour tugs and the lack of flexibility in choice and type of higher strength fibre towlines that are available today, since the profile of the grooves on the winch drums are designed to suit a specific diameter of rope. The use of an incompatible diameter of rope compared to the winch groove profile results in rope deformation, increased wear and shorter rope life.

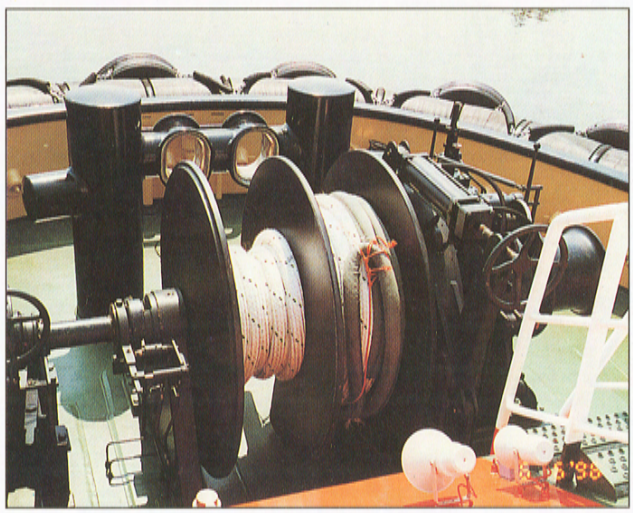


Photo: Damen Shipyards, Holland

Figure 7.12 Split drum winch of the ASD-tug 'Melton' (l.o.a. 32·7m, beam 12m, bollard pull ahead 60 tons, astern 56·6 tons) of Adsteam Towage, UK, built by Damen Shipyard, Holland. According to the yard the application of this split drum winch is different. Each part of the winch carries a separate tow line. Consequently, each drum part has a fairlead at the forward H-bitt. The fairleads are of stainless steel, reducing the wear on modern fibre towlines

A type of winch very suitable for fibre towlines is the *split drum winch.* With undivided drums the outer layers of the towline tighten excessively when high bollard pull is applied. This causes crushing and damage to the layers of the rope nearer the centre of the drum. The split drum winch has a single drum comprising a tension section and a line storage section. On the tension section the amount of rope for normal use is available.

Photo: Bildservice, Gothenborg, Sweden

Figure 7.13 Double winch forward on the reverse tractor tug 'John' (l.o.a. 32·9m, beam 10·2m, bollard pull ahead 53 tons, astern 51 tons) of towing company Buksér og Berging, Norway

When more rope is needed, the split provided in the separation disc enables any length of rope to be taken from the storage section. It has the advantage that the fibre line has only a few layers on the tension drum, so wear is less. In practice, however, even with this type of winch, it sometimes happens that a synthetic line becomes trapped between a slacker lower layer, preventing the line from being further freely deployed without manual assistance. A disadvantage of the split drum is that it is somewhat more difficult to operate. However with good training and some experience that should not cause a problem.

Some harbour tugs, e.g. several Japanese built reverse-tractor tugs, are equipped with a *double winch* at the bow. Two bow lines can be used independently at the same time.

Towing winches used on harbour tugs can be equipped with a self rendering or tension device, which is a towline load reducing system. The rendering facility is in case the shock load on the towing gear should exceed preset parameters. The winch automatically heaves when line tension is below a certain value. Towline length can be preselected. The facility can be adjusted by means of a tension control, allowing the winch to render more easily when working in difficult conditions such as waves or swell. Such systems are not suitable for operation in narrow port areas. Harbour tugs can simply be equipped with a device measuring towline tension and rope pay out with a display in the wheelhouse. Most harbour tugs don't have such devices at all.

Automatic spooling gears, which spool the towline properly around the towing drum, can be found on harbour towing winches. However, because of the short towlines used in harbour towage in relation to the long towlines at sea, many harbour towing winches are not equipped with a spooling gear. When so equipped they are not always used, particularly when a steel wire towline with stretcher and pendant is used. The spooling gear is then of little use for the short part of the main towline.

Towing winches are driven through reduction gears by a motor which may be powered by hydraulic pressure or electricity. Most harbour tug towing winches have hydraulic drives. Electric controls are sensitive to moisture and corrosion and the relatively simple AC pole changing motor is inferior to hydraulic drives in pull/speed characteristics. The reasons are that speed is variable in steps only, the high starting torque and on/off control only. The AC/DC (Ward-Leonard) drive has excellent drive characteristics, but is expensive and more sensitive to moisture, corrosion and overheating than any other type.

However, there are many variations in electric and hydraulic drive types that may significantly influence performance, reliability and costs. One example is the frequency-controlled towing winch. Compared to a hydraulically driven winch, a frequency-controlled winch has a number of advantages, such as a smooth and stepless control, easier installation, space savings (no hydraulic power package required) and immediate readiness for use. The control system can be arranged under deck, so avoiding corrosion and moisture. Costs are slightly higher than those of a hydraulic winch.

Towing winch characteristics

For ship assistance by harbour tugs, the following aspects of a towing winch are important:

- Brake holding power
- Maximum pulling capacity
- Rated pull or pull/speed characteristics
- Slack line speed

Brake holding capacity is the holding capacity of the brake and usually refers to the first layer. The more layers, the lower the braking capacity. Braking capacity of towing winches for harbour towing is two to three times the bollard pull of the tug, although it is often dependent on a towing company's policy. Lower values can be found such as a brake holding capacity equal to bollard pull.

There is an important relationship between brake holding capacity and the minimum breaking strength

of a towline. The latter is higher than the bollard pull of the tug, which is considered later. With low brake holding capacity and a high safety factor in the towline, the brake slips before the towline breaks, preventing too high loads in the towline and consequently lengthening the towline's life. However, a relatively low brake holding capacity may limit a tug's performance because in certain situations, such as steep towline angles, towline forces can be much higher than bollard pull and in order to avoid brake slippage tug power has to be reduced.

The opposite can also be the case. With a high brake holding capacity, e.g. three times the bollard pull, the towline may break before the brake slips, unless quick release is used in time. On the other hand a tug's performance is less limited, which can be of importance during ship assistance in adverse weather and/or current conditions. Therefore when building a new tug the brake holding capacity of the towing winch is an important factor, to be carefully considered in relation to the minimum breaking strength of the towline and required performance of the tug.

It should be noted that with a steadily increasing towline force the brake may slip at the brake holding power of the winch. However, in case of shock loads the brake will mostly not slip at that stage due to the inertia of the braking system and the towline may break. When a load reducing system is operational the brake system is disengaged and the winch drive engaged. Modern towing winches may have an adjustable brake holding power, with automatic release on a preset line tension, while winch brakes open in case of 'dead ship'.

Other important aspects are the *maximum pulling capacity and pull/speed characteristics* of a towing winch. The maximum pulling capacity of a winch is the stall heaving capacity or stalling load. That is the maximum line pull the winch exerts at first layer when control is in heave and the line is kept stationary. The maximum achievable pull depends on the drive type and control. A 15 tons towing winch means a maximum pulling capacity of 15 tons. As drum speed increases the pulling capacity reduces. Pull/speeds characteristics or rated pull of a winch give the pull at a nominal or rated speed. Pull/speeds characteristics are given, for instance, in the following way: 10 tons x 10m/min, which means that the winch is capable of pulling 10 tons at a hauling speed of 10 metres per minute.

Some harbour towing companies establish a maximum pull for their tugs which is half the bollard pull, though a number of harbour tugs can be found having a maximum pulling capacity equal to their bollard pull.

Maximum pulling capacity and pull/speed characteristics are particularly important when towing in narrow port areas and when influences of wind and/or current are high. For example: A large container ship has to be berthed during high onshore winds. The tugs towing on a line are pulling at full power. Because the available manoeuvring space in the harbour basin narrows, the tugs have to shorten towlines. The maximum pull of the towing winches is less than the bollard pull, therefore the tugs reduce power to be able to shorten the towline. Because the hauling speed of the towing winches is also low while pulling, power is further reduced to be able to shorten line as quickly as possible and it takes rather a long time before the line is at the correct length. All the time the ship is drifting, which easily results in an accident. Therefore the higher the pull and related speed of towing winches the better.

Note: Towline length should normally be adjusted in good time, particularly in tugs with winch types that cannot be put in gear while the towline is under load.

Slack line speed is also important, because when letting go tugs the faster the towline can be retrieved the better, and the risk of fouling the ship or tug propeller is less. In ports where tugs are towing on a line during berthing operations they often have to change to pushing at a ship's side. The faster the towline can be retrieved the sooner tugs are available to push. Achievable slack line speeds are different for different types of drives and this must also be considered when specifying the performance and drive type of new equipment.

Towing winches are provided with quick release systems which can be operated at the winch and from the wheelhouse. As explained in a previous chapter about conventional tugs, risk of girting exists. When these tugs are equipped with a towing winch with a quick release system the risk is minimised, because when danger of girting arises the towline can be slacked or slipped entirely by means of the quick release mechanism.

7.4 Quick release systems

By the nature of their work harbour tugs can easily get involved in risky situations. From the point of view of safety of tug and crew, quick release systems are of the utmost importance. That is why specific attention is given here in particular to quick release towing hooks.

In case of emergency, towing lines under high tension cannot or can only with difficulty be released from a towing bitt. If release is absolutely necessary this can be very dangerous for the crew. An axe could be used, but this only works with light towlines. An alternative emergency method sometimes used in the USA is a quick release strap. It is a short line with an eye at one end. The eye is put on the towing bitt and the free end passed through the eye of the towline and also secured to the towing bitt. In an emergency this line is cast off and the towline is released with little danger for the tug's crew. But it is clear that, in general, towing on a towing bitt has consequences for safety.

As mentioned earlier, towing winches and towing hooks are normally equipped with quick release systems. Experience teaches that in many cases it is nearly impossible to open the quick release hook in very critical situations, often with dramatic consequences. When a tug is listing caused by very high tension in the towline, as is nearly always the case in critical situations, it is often impossible to open the hook. One cannot rely on such a system.

Quick release hooks should therefore be tested under the most severe circumstances that may be experienced during critical situations. They should also be well maintained. Investigations are recommended into whether towing hooks can be constructed in such a way that with steep towing angles the ultimate lead of the towline towards the towing hook is kept parallel to the deck plane, as shown in the photograph of the tug with a towing winch with radial system (figure 7.3).

There are modern types of quick release hooks. One of these is the hydraulically locked towing hook (by Brusselle Marine Industries in Belgium). This looks more or less like a normal standard towing hook but the hook itself is kept in position by a hydraulic cylinder. As soon as the quick release system is operated, hydraulic pressure falls and the hook opens. A similar but further improved towing hook from the same company, developed in close co-operation with the Belgian tug company URS, is the hydraulically locked towing bitt. The towing hook is a small bitt which can tumble and is also kept in position by a hydraulic cylinder. Construction is such that in normal operating conditions the towline cannot slip off the small bitt. When the quick release system is operated the hydraulic cylinder tumbles the bitt and the towline slips off.

Another quick release system for towing hooks is an automatic release system. Such a system is used on older Russian tugs in St. Petersburg. It is an ingenious mechanical system which basically works as follows. At a certain preset maximum heeling angle an iron ball, locked when the tug has no or only a small list, comes free and falls down. Due to the weight of the iron ball the wire connected to the quick release is tightened and the hook opens. Modern electronic systems which automatically release the towline at a preset angle also exist.

Irrespective of the system used for towing hooks only one thing is important. That is that the system must be fully reliable and function trouble-free under normal and severe circumstances. As for wheelhouse lay-out, quick release controls should be situated so that they are always within the captain's hand reach. When releasing or cutting the towline, the line should run freely overboard and not become jammed somewhere on deck.

The conclusion is that the method of towing, whether by towing bitt, hook or winch is also important for the safety of the tug and its crew and that towing winches with a quick release system are safest. The same applies to quick release towing hooks, provided those hooks are fully reliable.

7.5 Towlines

7.5.1 Towline requirements

A towline must fulfil certain basic functions. Firstly to function as the load carrying link between tug and ship and secondly to cope with dynamic loads resulting from relative motion between tug and ship.This leads to the following basic requirements for towlines for harbour tugs:

- Strength.
  A towline should be of sufficient strength to cope with the forces that can be experienced during shiphandling operations.
- Stretch.
  Dynamic loads should be well compensated for by a towline in order to avoid excessive loads in the line and attachment points.
- Weight/diameter.
  A towline should be manageable on board a tug as well as on board a ship. When no towing winch is used a towline should be flexible enough for easy handling.
- Life.
  When in use a towline should suffer a minimum of wear, distortion and loss of strength, providing as long a life as possible.

All these aspects are considered while discussing different types of rope.

7.5.2 Steel wire ropes and synthetic fibre ropes

Although ship lines are used in a number of ports (see section 7.5.6) many harbour tugs use their own towlines. They can be of various types: steel wire, synthetic fibre, or partly steel and fibre. There are many different types of fibre lines, consisting of one type of fibre, or a combination of fibres and various constructions. It is only possible, therefore, to give general information on towline composition and construction. The best information regarding a specific type of wire or rope can be obtained from the manufacturer. Development in conventional as well as modern synthetic fibres is continuous, much research is being carried out, and this will result in further improved performance of man-made fibre ropes. Somewhere during the design stage of a tug, it should be decided whether fibre or steel towlines are to be used, because the type of towline used influences such items as winch drum size and the type and size of fairleads.

Steel wire ropes

A steel wire rope consists of a number of strands wound around a central core of fibre or wire. Each strand

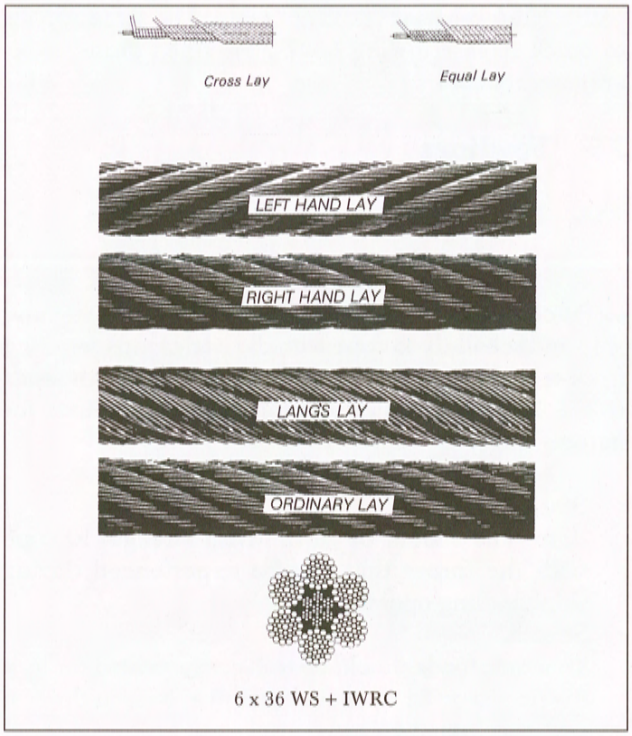


Figure 7.14 Steel wire construction

in turn consists of a number of wires wound to form a strand. Wire ropes are constructed in various ways. The following definitions and illustrations (see figure 7.14) are helpful in identifying different wire types:

Lay:
The twisting of strands to form a rope, or wires to form a strand, during manufacture.

Right hand or left hand lay:
The angle or direction of strands relative to the centre of a rope. When looking along the line of the rope and the direction of the strands is anti-clockwise it is called left hand lay. If the direction is clockwise it is called right hand lay.

Cross lay and equal lay:
Terms describing the lay of wires used to make up strands. In a cross lay strand all wires have a different lay length. High stress concentration at the cross-over points leads to early internal failure. Equal lay wire ropes tend to last longer, mainly due to less internal wear. They also withstand cyclic loading better and are stronger. There are a number of constructions available for equal lay strands: Seale, Warrington, Filler or a combination, all depending on the number, different dimensions and combination of wires in the different layers of a strand. The most suitable is the Warrington/Seale construction.

Lang's lay:
A method of making a rope where the lay of wires in a strand is the same as the lay of strands in the rope. It has better wearing properties than ordinary lay but tends to untwist so has only limited use.

Ordinary lay:
A method of making a wire rope where the lay of wires in a strand is opposite to the lay of strands in the rope.

It is usual to describe wire rope in terms of strands, number of wires and type of core e.g. 6 x 36 IWRC. The first number is the number of strands, the second number gives the number of wires in each strand and the letters IWRC (Independent Wire Rope Core) give the type of core.

Ropes with more wires have greater flexibility and fatigue resistance but resistance to abrasion is less. Fibre cores allow easier handling and are ideal for use with smaller wire sizes and where wire is to be handled manually.

Where steel wire ropes are used on towing winches it is advantageous to use a steel wire core. Wires constructed with a steel wire core offer greater resistance to the crushing forces experienced on winches, are 7% to 8% stronger and stretch slightly less than a fibre core wire of the same diameter.

Wire ropes can be supplied in different grades of steel, usually 180 kgf/mm^2 (1770 N/mm^2) or 200 kgf/mm^2 (1960 N/mm^2). The latter has a higher minimum breaking strength and generally better performance. In the USA other indications used for tensile strength include Improved Plow Steel (IPS) which has about the same tensile strength as 180 kgf/mm^2 (1770 N/mm^2) steel wire and Extra Improved Plow Steel (XIPS) which has a higher tensile strength.

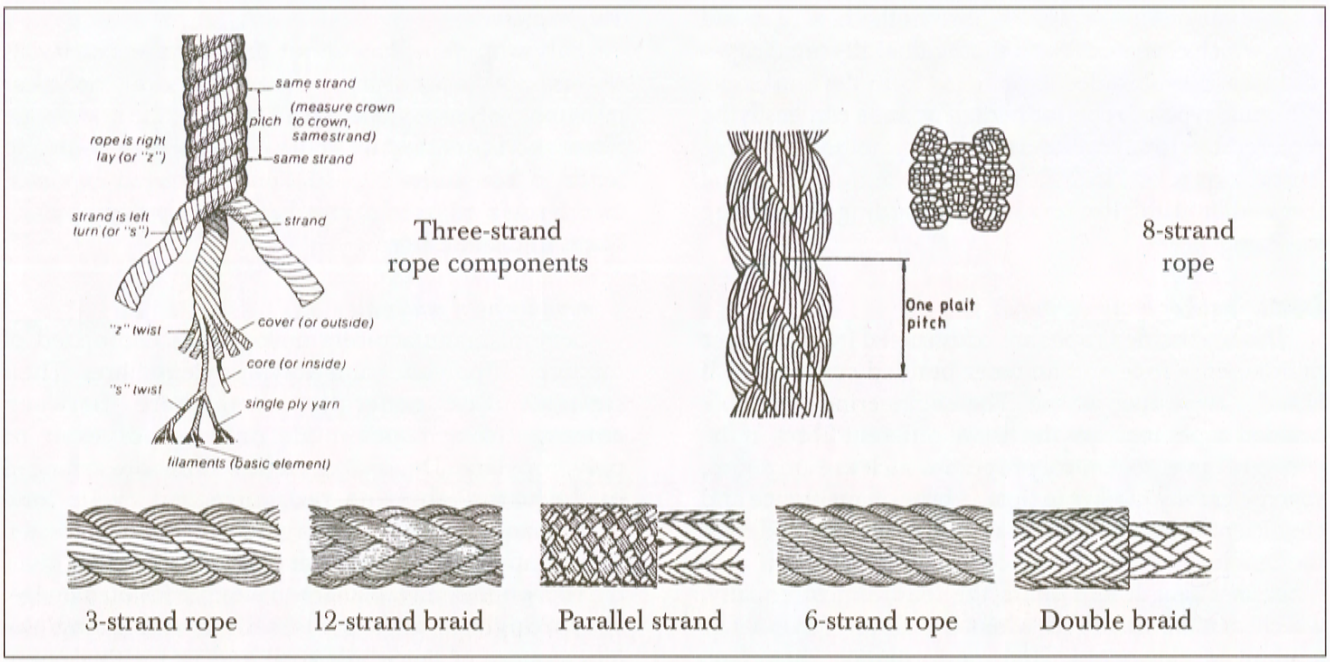
Figure 7.15 shows some typical minimum breaking strengths of 6 x 36 WS (Warrington/Seale) IWRC wire ropes.

Diameter (mm)	**Mass** (kgs/100m)	**Minimum Breaking Load** 1770 Tensile Grade (tons)	**Minumum Breaking Load** 1960 Tensile Grade (tons)
24	241	37	41
26	283	44	48
28	328	50	56
32	428	66	73
36	542	83	92
40	669	103	114

Figure 7.15 Typical minimum breaking strengths

Maintenance of steel wires

Steel wires should be properly maintained and regularly inspected. Visual inspection is vital, particularly around eyes and those shackled to stretchers, as the shackle tends to increase wear on the wire at this point. Inspection should focus on such aspects as: broken wires in strands, corrosion, rope deformation (kinks, flattened areas, misplaced outer wires, etc.).



Source: Fibre Rope Technical Manual

Figure 7.16 Fibre rope components and constructions

Synthetic fibre ropes

Due to the increased bollard pull of tugs, the diameter and weight of steel wire towlines has increased. Consequently they are increasingly difficult to handle, not only by a tug's crew but also by the low number of crew members available aboard ships to fasten or release towlines. Escort tugs put an additional demand on towline performance not only because of their large bollard pull but also due to the high towline forces experienced when operating in indirect towing mode. Because of their strength, stretch, and weight, there is a growing preference for fibre towlines.

The different types and constructions of fibre towlines all have their own specific characteristics. Depending on the rope type and its application, rope making consists of spinning the fibres into initial yarns, initial yarns are further twisted into final yarns. Final yarns are then twisted to form strands or plaits. Strands or plaits are formed into ropes. To prevent the rope unlaying, the strands are laid up in the opposite direction to the yarns.

As an example, the components and the way of construction of a three-strand rope are shown in figure 7.16. Some definitions will be given and some of the most common rope types will be reviewed. There are several different construction methods, also of rope types discussed below, depending on the manufacturer and fibre type. Nevertheless the overview gives an impression of rope types and rope characteristics.

Left hand and right hand lay:

The same as with wire ropes. Left hand lay is also called S-lay and right hand lay Z-lay. When holding the rope vertical the direction of the strands corresponds to the diagonal line in the letter S or Z.

Three strand ropes:

The three strand rope, or hawser-laid rope, is the most common of twisted ropes. They have a tendency to 'kink' or 'hockle' which significantly reduces strength. Specific strand constructions can reduce the tendency to kink. The rope has good abrasion resistance.

Six strand ropes:

Six strand ropes with core are twisted ropes similar to conventional wire ropes. It is not as prone to hockling as a three strand rope.

Eight strand ropes:

Eight strand plaited ropes, also called square braid, are made up of four pairs of two strands. The pairs of strands are alternately left hand lay and right hand lay. The balance between left and right hand strands makes them virtually unkinkable and very flexible. The rope has a square profile, and it is more durable than twisted ropes. It has a high energy absorption capability and essentially the same strength as a three strand rope of the same dimensions.

Twelve strand ropes:

Twelve strand braids consists of twelve twisted strands that have been braided into a single braid construction. A single braid construction leaves a void in the centre. The hollow is instrumental in the easy splice procedure. Hollow braids are non-rotating and are a very efficient way to utilise fibre. Fibres used include nylon, polyester, polypropylene, composites of polyester and polypropylene, and HMPE fibres. Also other construction methods of twelve strand ropes exist.

A new type of rope of HMPE fibres is the 12 x 12 strand rope, which consists of twelve individual 12-strand ropes that have been braided together to form the final rope. With this type of rope individual strands can easily be repaired by using traditional splicing methods. Twelve strand ropes of HMPE fibres are, amongst others, frequently used for towlines, including escort tug towlines.

Double braid or braid-on-braid:

Double braided ropes are constructed from an inner braided core rope and an outer braided cover rope. It is really two ropes in one. The engineering of double braided ropes includes the use of different fibres in the core and cover to control properties such as elongation, specific gravity (ability to float), abrasion resistance and coefficient of friction. In a 'standard' double braid design the braided cover rope and core rope supplement each other in strength and share the load almost equally, which can be achieved when the fibres have a fair amount of elongation. High performance fibres (e.g. Spectra, Dyneema, Kevlar) have a very low stretch, consequently it is very difficult to get both cover and core to share the load if the entire rope was made of such fibres. When, for instance, Dyneema or Spectra fibres are used in double braid, the cover is merely a protective jacket, often made of polyester, and does not contribute to the strength of the rope.

If selecting a rope for a certain application, it will be clear from the foregoing that consultation with qualified manufacturers and/or engineering consultants is needed in order to be able to make the most efficient and cost-effective choice.

Description of different fibres for ropes

Firstly we will look at conventional fibres – polyester, nylon and polypropylene and some combinations of these.

Polyester

Polyester is the heaviest of the conventional fibres and does not float. It is also the most durable. It has high strength, both wet and dry and an exceptional abrasion resistance. It does not lose strength rapidly due to cyclic loading. Polyester has a low extension under load. The low friction coefficient allows it to slide relatively easily around bitts. Its relatively high melting point reduces the chances of fusion.

Nylon

Nylon is the name for the polyamide fibres. Nylon does not float. Dry nylon is slightly stronger than polyester rope and is the strongest of the man-made fibres, except for Aramid, Dyneema and Spectra. Wet strength is about 80-85% of dry strength. Wet nylon loses strength much faster under cyclic loading than polyester. Thus a heavily used nylon rope becomes weaker than a heavily used polyester rope of the same size. Nylon has high stretch and is more elastic than the other two fibres.

Polypropylene

Polypropylene has about the same elasticity as polyester but is significantly weaker than either polyester or nylon. Polypropylene is the lightest of the man-made fibres and floats in water. It has a low melting point and tends to fuse under high friction. Prolonged exposure to the sun's ultraviolet rays can cause polypropylene fibres to disintegrate.

Combinations of materials

Several manufacturers make ropes comprised of mixtures of polyester and polypropylene fibres. Their strength lies generally somewhere between corresponding ropes made only of polyester or polypropylene. Depending on how fibres are arranged in the yarns, abrasion resistance and cyclic load performance can be almost as good as for pure polyester. The combination of polyester and polypropylene gives the ropes optimum resistance to internal fusion damage. Polypropylene always fuses first, stabilising the temperature of the whole rope and its melting point, consequently protecting the polyester yarn component from any fusion damage.

Other mixtures can be found, such as combinations of nylon, polyester and polypropylene or a melt mixture of polyester and polypropylene. All have their own specific characteristics, not only because of the combination of materials, but also as a result of the different construction methods used.

In very cold areas the performance of ropes made of synthetic fibre changes in different ways. A few examples:

- Strength of polyester ropes increases by about 20% at an extreme temperature of minus 35–40°C, although icing causes a larger internal abrasion, consequently reducing the breaking strength.
- Nylon loses up to 10% strength at these cold temperatures, with an additional strength loss due internal abrasion caused by icing.

If working in very cold areas one should be aware of the changes in towline performance, which also may apply to the towlines made of the modern fibres mentioned hereafter.

Now the newer synthetic materials for ropes are considered, viz. Aramid (with trade names such as Kevlar (Du Pont) and Twaron (Akzo Nobel) and the HMPE (High Modulus PolyEthylene) and UHMPE (Ultra High Modulus PolyEthylene) fibres which are available for use in high-performance ropes under the trade names Spectra (Allied-Signal) and Dyneema (DSM). The name HMPE will be used from now on for both HMPE and UHMPE fibres.

Aramid and HMPE (Dyneema, Spectra)

Aramid and HMPE fibres have a large breaking