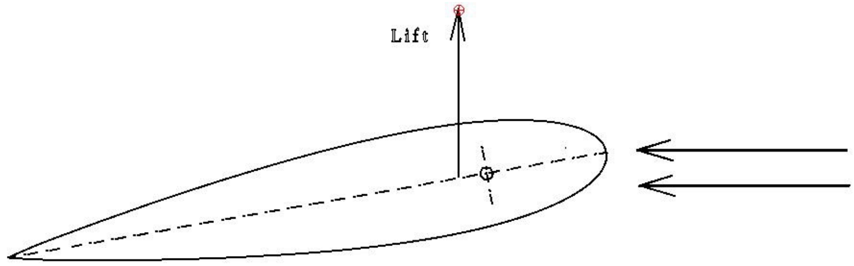
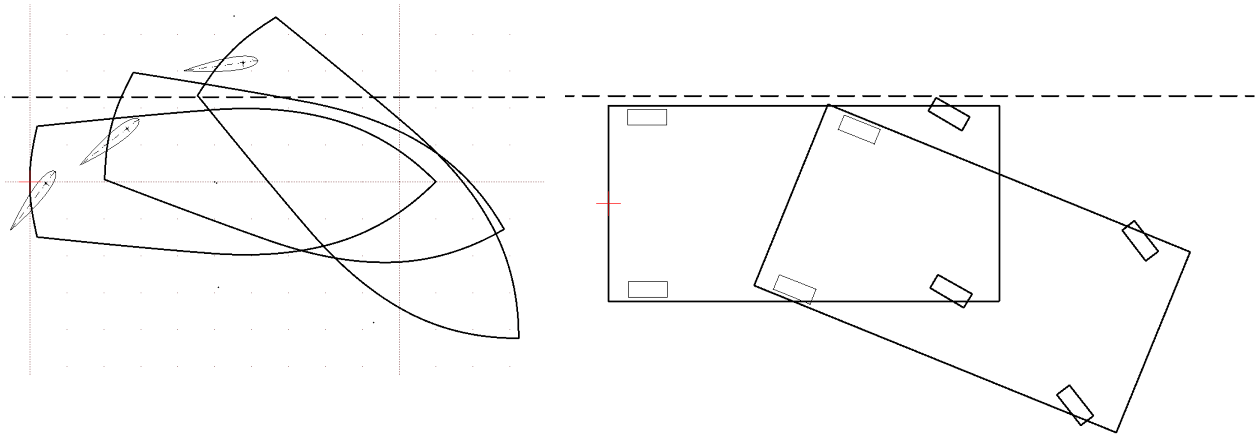
Rudderaction and design

Steering with a rudder

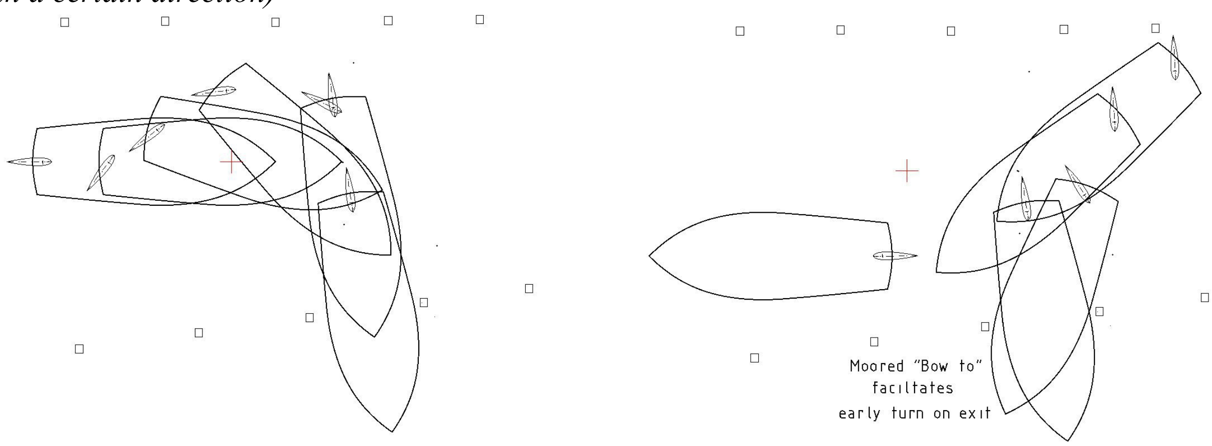
The forces and the effect
When steering with a rudder, the rudder blade is put at a certain angle with the passing water.
The moving water will cause a lateral force. Similar as with airplane wings, one speaks of lift.
The force will depend on the **angle** of the rudder and the **speed** of the passing water.



This lateral force pushes **the stern** sideways. This changes the direction (the course) of the vessel.



Please note that there must be **enough room at the stern** to turn a ship. This is clearly different from a car, where a steering action moves the **fron**t sideways
Especially when sailing away from a quay, this deserves attention. Judging by the traces on many rental ships, this is not seldom forgotten. Also when turning into a marina box it is good to realize that you shouldn't follow the widest possible curve, as you would preferably do when parking a car.
(*When using a tiller in stead of a steering wheel, it will often be more clear that **the stern** is pushed in a certain direction)*



Remark: When moored "bow to" you will be able to exit your slip already at an angle.

Turning in a narrow spot

The slower one sails, the shorter the radius of the turn can be. By starting your turn while **stationary** your the turning radius will be the smallest. Putting the propeller **forward briefly with the rudder at a large angle,** will build up a turning movement. By regularly stopping the propulsion, the ship gets more time to turn and runs less strongly forward. By occasionally propelling backwards, one can keep the forward movement in check.
For the effectiveness of the turning movement, it is important that the rudder is already **in the correct position when putting your propeller in forward gear.** Therefore, if the rudder is **left** at it's large angle during the whole maneuver, it is ready to optimally strengthen the turning movement at any time you go forward.
In the short period that the propeller turns backwards, no usable water flow will build up along the rudder. The propeller will draw the (turbulent) water from many directions.
The wheel effect, the side ways pulling away of the stern due to the rotation of the propeller, occurs in particular during reversal and with relatively light ships. This could amplify the turning motion during reversal. For example, if one turns to SB with a clockwise-turning propeller. (which turns counterclockwise when backing up)

Reversing

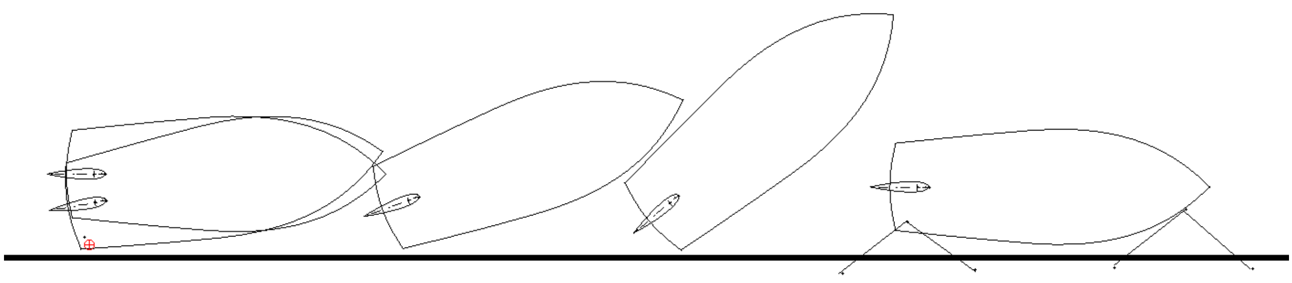
When motoring backwards, you pull water towards your propeller and this flows less focused and slower along the rudder blade . The possible effect on the rudder occurs later and is less predictable than when sailing forward. Usually you first need to have a certain (and mostly undesired) boat speed before the rudder takes any effect. When moving slow, the actual **direction/ course of the vessel**, usually matters more where you are going than the angle of the rudder. Therefore, primarily **keep an eye on the direction** of the ship and correct it, if necessary, with **a short turn forward** or with the help of a **bow-thruster.**

Steering without rudder

The rudder cannot always be used to change the direction of a vessel. If the stern is locked between piles or against a quay, the fore-ship will have to be moved in the right direction. This can be done, for example, by pushing off with hand, foot, sailing boom or a bow-thruster or with the use of a tugboat. Sailing yachts can sometimes also use their forward sail(s).

Often, with a little clever pushing off, one can already **help a vessel on its way in the right direction**:

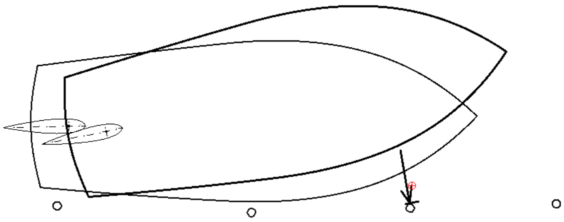
Example of pushing away from a quay.



A person on the shore loosens the ship, except for the stern line, and presses it an arm's length away. Then he/she pulls the stern back close to the quay and pulls the stern **forward along the quay** with the stern line (with the stern as close as possible to the quay). While doing so the bow will turn further and further out. Get on board at the last minute and sail away **with the rudder straight**.

Pushing off from the fore-ship

Sailing away with the rudder to port would press the rear of the ship against and/or between the piles. First bring the vessel in the right direction by pushing off from the fore-ship. After that, one can just sail straight away.
(A mop/broom is more convenient when pushing than a boat-hook because it slips less quickly)



The bow-thruster

The bow-thruster creates a water flow in a transverse direction. It takes a while before the flow is established and takes effect. If the current can be set against a quay or lock wall, the lateral force is the most effective.
It is important to be in a stationary position to build up a useful water-flow. When using the bow-thruster while moving, you sail away from the water you want to oppose. The resultant of your "thrust jet" then flutters away in the direction of the stern.

The bow-thruster uses a **lot of power** and the (mostly only air cooled) motor gets **hot**. Therefore, do not use it longer than necessary. *(Note: Keep an eye on the quality of the batteries, they are often in an ill ventilated area and might produce poison-es gas when defect.)*
When **changing the direction of rotation**, it is better to let the thruster come to a stop first. If the changeover is too fast, the **break pin** might shear in some systems.
The break pin transfers the force from the shaft of the motor to the transmission of the propeller in the tunnel. In order to replace the break pin, the motor has to be removed from the tunnel. (Mostly possible while afloat)

Steering with an outboard motor

Steering with an outboard motor or sometimes a z-drive is a fairly common choice for **fast-moving** motorboats and dinghies. Steering takes place by pushing water in a certain direction with a **propelling** propeller. However **if the propeller is stopped, steering is lost.**
(You might have noticed this while mooring an inflatable dinghy)
To steer without propulsion a rudder is necessary.

Electrically driven sloops mostly have narrow waterways as their sailing area. They often encounter sensitive vessels which they have to evade (canoe's sup-boards etc) . Careful and accurate steering while moving dead slow is needed. I would therefore **always opt for a rudder to steer** and certainly **not an outboard motor or rotating pod**.
In addition to the greater safety, this will be less stressful for the skipper.
In order to be able to steer, one no longer has to give short thrusts, combined with reversing as with an outboard engine. The steering itself will therefore not require extra energy from the batteries.
Also a possible tendency to sail (too) fast, because this steers better, is no longer fed by the system of steering.
In addition, one also has control when propelled by other means, for example by the wind catching your boat or if one is towed by another boat or towed with a line from the shore.

Warning: *This POD might look a bit similar as an outboard engine but it is designed (and prescribed) for* ***fixed mounting*** *and not swivel. If you mount it swivel you can get into trouble (Shaking and cavitation are known problems). So mount it as instructed and steer with a rudder*

Rudder design

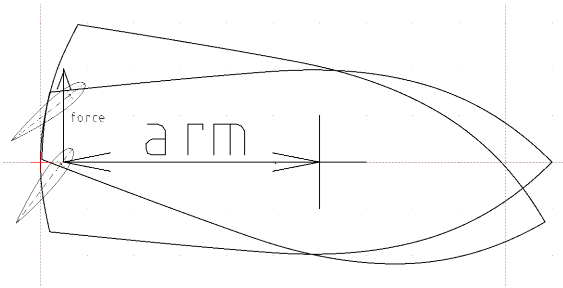
The shape and suspension of the rudder

On narrow/ busy inland waterways its very useful to be able to steer when moving slow, without propulsion. For this, the water must be able to flow unhindered along, at least part of, the rudder. Therefore, when constructing a rudder, try to use the full available height.
Supporting the rudder at the bottom with a bearing, mounted on a heel, has the advantage that the rudder shaft can be thinner than with a free suspension. The chance of scooping dirt / weed by the rudder is also reduced. For sailing yachts with a short keel and large seagoing ships, this is usually not done and one sees thicker rudder shafts.

End cams

It is wise to provide the quadrant or tiller of the rudder with end cams to prevent a hydraulic cylinder or other control devices from reaching their extreme position. The rudder can also be limited externally but this can cause paint damage and will increases resistance.

The location of the rudder

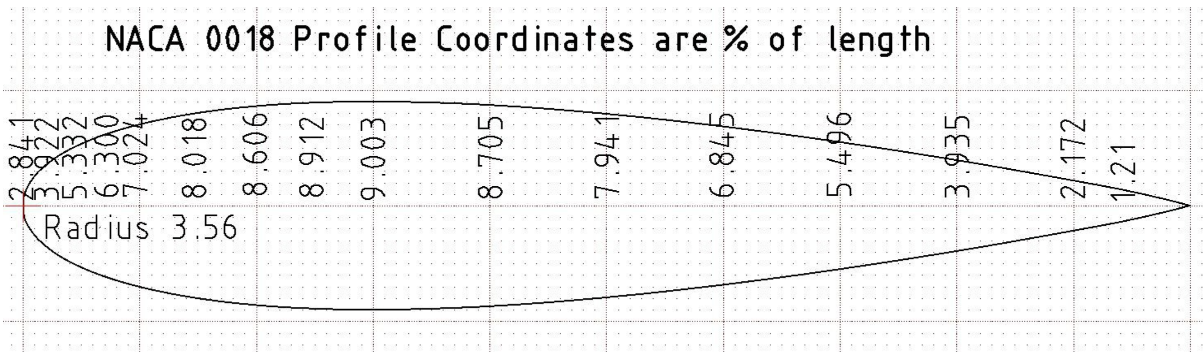


The further a rudder is placed to the stern, the greater the steering torque. (force x arm)
You need a larger (more powerful) rudder if it is placed more forward (the arm becomes shorter) to have the same steering effect.

The profile

The profile of the rudder is particularly important to **minimize the resistance**. The illustrations in this article show a symmetrical NACA0018 profile. This shape has my preference because of its high lift-coefficient and has the advantage that the water continues to flow nicely along the rudder blade when making angles and doesn't let go (as with a flat plate rudder). The pressure point remains almost in the same place, at a quarter length from the front.

This profile stems from the recommendations of the U.S. National Advisory Committee for Aeronautics (NACA) for aircraft wings. For ships, the top of the aircraft wing is used and mirrored. These, now symmetrical profiles, have an optimal shape. A lot of research has been done on them and they are used in shipbuilding worldwide. The thickness varies and must not be too thin, otherwise the water will not follow the shape.
For an extensive scientific substantiation, see publication MT521, 3733.PDF of the Tu Delft.



See also: "2023 01 27 Symmetric NACA 0018 Dimensions.pdf" (2 pages) at the downloads page for a calculation example and a blank profile shape to put your own dimensions on.

The trailing edge of the profile may be cut straight to a thickness of 2% of the length without increasing the resistance. This will facilitate the construction, the paint holds better and the edge is less dangerous when swimming.

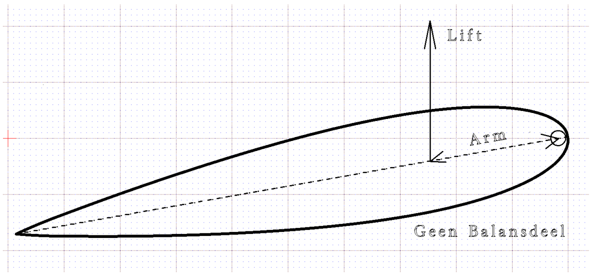
The lift grips at 25% of the length from the leading edge. This is important when determining the balance part. (The part of the rudder that sits in front of the pivot point)

Horizontal, protruding plates counteract the water that wants to flow along the top and bottom and guide the water-flow more or less along the profile.The construction is also easier to carry out with these plates.

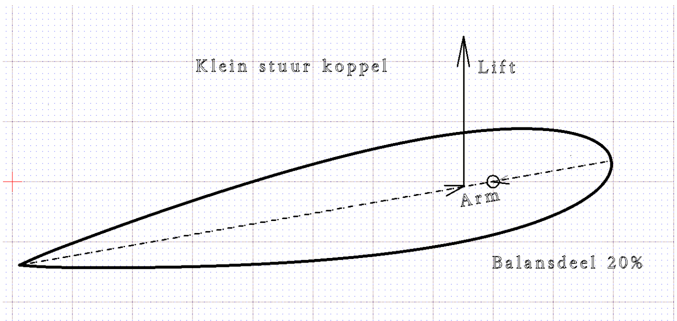
The balance part

By moving the rudder shaft (pivot point) further back, the balance part becomes larger. The required steering torque (and thus the force on the tiller or quadrant) becomes smaller.
This usually also means that a wider part of the, stronger flowing water behind the propeller, can be used during maneuvering when large rudder angles are used:

No balance part - maximal torque



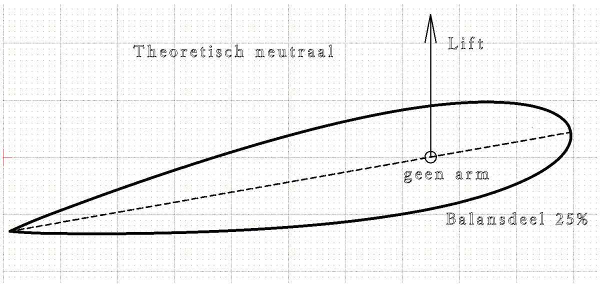
My choice: balance part 20%:



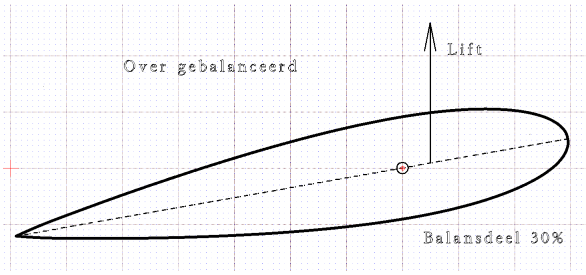
Without specific computer simulations or tests, I would not choose a larger balance part than 20% for small vessels. The mentioned (lift) distance of (0.25 x length), is after all a measured value and concerns a test set-up with an even flow. This is not necessarily equivalent to the actual situation. The propeller for example, rotates at a short distance in front of the rudder.

The illustrations below indicate how I would **not** design a rudder because, among other things, one runs the risk that the torque will unintentionally change direction when a propeller blade passes the rudder. This makes the rudder **sensitive to flapping** and steering becomes a **constant effort** because of the **hypersensitivity.**

Balance part 25% - theoretic neutral



Balance part 30% Over balanced



In the case of large shipbuilding, larger than 20% balance percentages are used, but larger forces play a role that one wants to avoid and heavy hydraulic steering machines are used to control a rudder. Also specific tank test and/or computer simulations are carried out beforehand.

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