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VOITH

Precise and safe maneuvering
Voith Schneider Propeller

Voith Schneider Propeller

Voith Turbo offers tailor-made propulsion systems for a wide variety of applications – for harbor assistance and escort duties, offshore supply vessels, ferries, yachts and military applications as well as for specialized ships.

Voith Schneider Propeller

90 for more than years

For 90 years now, Voith Turbo has been designing and producing systems in Germany that are safe for people, the environment and the machinery they support.

You benefit from low-maintenance and operationally safe systems, which guarantee a high level of availability and outstanding quality. The very high degrees of efficiency ensure a reduction of both fuel consumption and emissions. Vessels equipped with Voith Schneider Propellers have maximum maneuverability.

The Voith Schneider Propeller (VSP) allows the quickest generation of thrust in all directions – stepless and precise. VSPs combine propulsion and steering in one unit, thereby eliminating the need for rudders.

Thrust and steering forces can be generated in any direction from zero to maximum. On Voith Schneider Propellers, propeller blades protruding from the rotor casing at a right angle rotate around a vertical axis. Each propeller blade performs an oscillating motion around its own shaft axis, which is superimposed on the uniform rotary motion. VSP installation in the vessel is such that only the blades protrude from the vessel hull, thereby avoiding any parasitic resistance (rudder, pods, shafts, etc.).

The VSP design

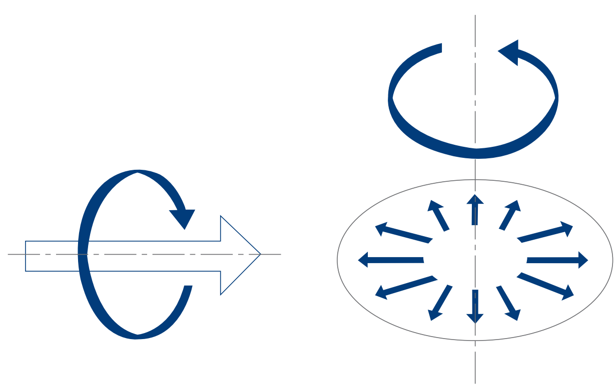
The Voith Schneider Propeller generates thrust by means of profiled blades that protrude from the vessel bottom and rotate around a vertical axis. The blades are mounted in a rotor casing which is flush with the bottom of the vessel.

A local oscillating motion of the individual propeller blades around their own axis is superimposed on the rotary motion of the blades around the common vertical axis. Generation of this oscillating motion is via a kinematic mechanism (kinematics).

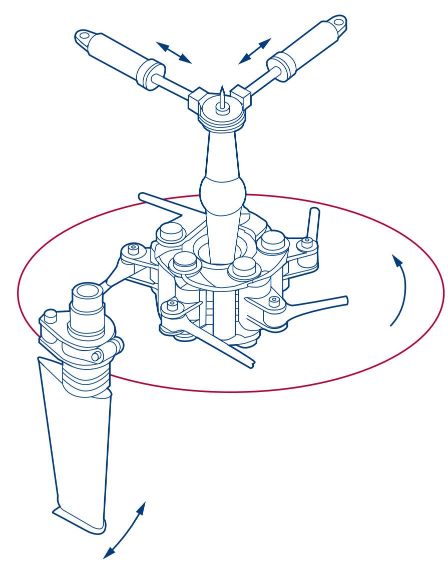
Since the VSP simultaneously generates propulsion and steering forces, there is no need for additional appendages such as propeller brackets, rudders, pods, shafts, etc. A significant difference between the Voith Schneider Propeller and a screw propeller is the direction of the axis of rotation relative to the direction of thrust.

On screw propellers, the axis of rotation and the direction of thrust are identical, on the VSP they are perpendicular to one another (Figure 1). Thus the Voith Schneider Propeller has no preferential direction of thrust and allows stepless variation of thrust magnitude and direction.

Axis of rotation and direction of thrust (1)



Kinematic principle (2)



The flexible VSP control concept
helps to safely transport all cargo
to its destination.

The blades are mounted in a rotor casing
which is flush with
the bottom of the vessel.

The direction of thrust can for example be changed from full ahead to full astern at a constant speed of rotation without creating disturbing transverse forces or requiring changes affecting the main engine. The division into propulsion thrust and steering forces, i.e. steering according to Cartesian coordinates, makes vessel handling an easily understood and user-friendly process for the helmsman (human engineering).

On the VSP, a self-contained propulsion and steering system with mechanical servomotor control can be used. The hydraulic energy required for lubrication and control is supplied by a flanged-on oil pump (12), driven by the main engine.
(Not available for ECR Propeller Systems).

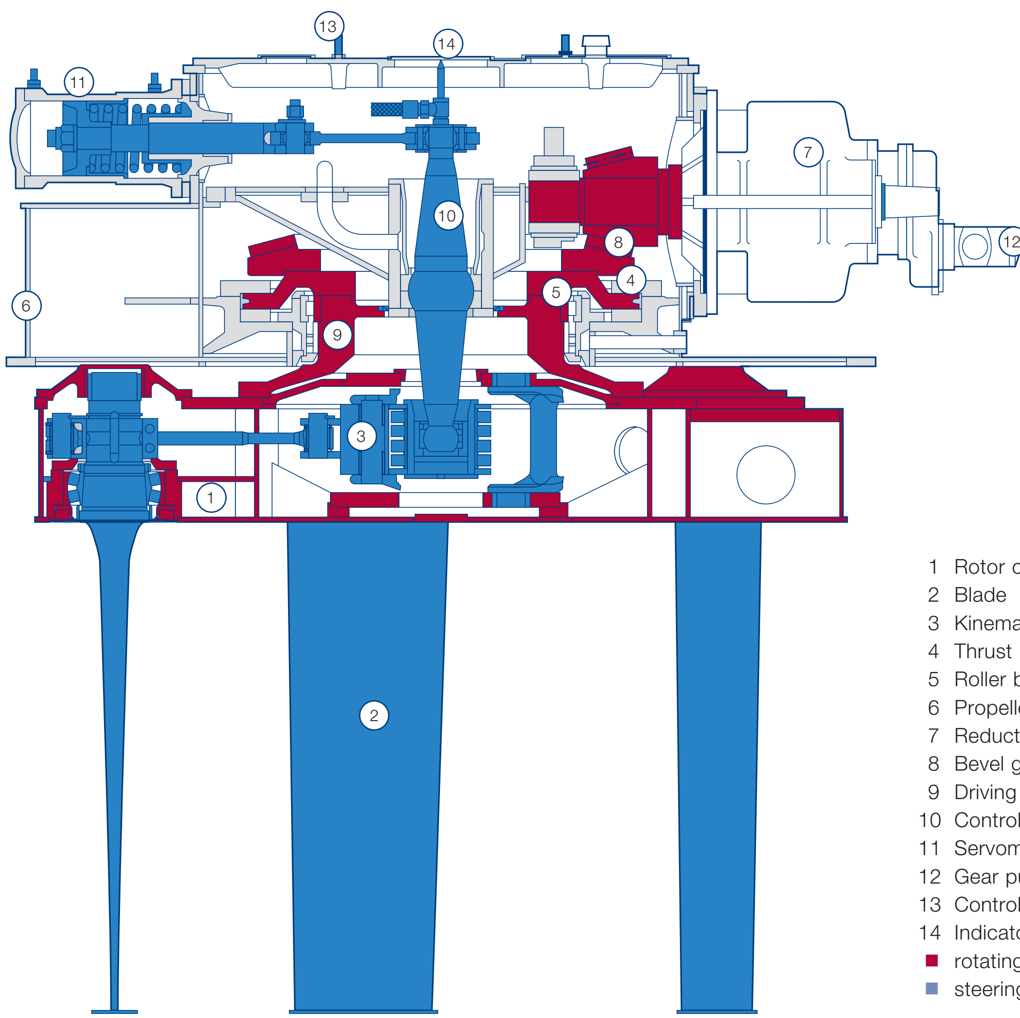
VSPs are equipped with robust, crank-type kinematics. Figure 2 illustrates the kinematic principle of the VSP. If the center of the lower spherical bearing (steering center) is at the center of the rotor casing, the blades are not angled relative to the tangent to the blade circle (Page 8, Figure 1a). If the lower spherical bearing is moved away from the center of the rotor casing by the actuation of one or both servomotors and the lever action of the control rod, the blades are set at an angle to the tangent of the path as they revolve (Page 8, Figure 1b). The maximum angle of attack of the blades increases with the eccentricity. As the blades are very well balanced, the eccentricity can be varied very quickly and with little power being required from the servomotors (11). The force resulting from hydrodynamics and mass inertia acts in the area of the blade shaft axis.

Figure 3 (on page 7) shows an illustration of a Voith Schneider Propeller. The sectioned view (Figure 3) illustrates its construction. The energy required for thrust generation is supplied to rotor casing (1) via flanged-on reduction gear (7) and bevel gear (8). Gland bearings or special roller bearings are used to support the blade shafts. The rotor casing is axially supported by thrust plate (4) and centered radially by a roller bearing. Due to kinematics (3), the blades (2) perform an oscillating motion (Figure 3 and Page 8, Figure 1). Amplitude and phase of the blade motion are determined by the position of the steering center. Thrust magnitude and direction can therefore be varied via control rod (10). The control rod is actuated by two orthogonally arranged servomotors (11). The propulsion servomotor is used to adjust the pitch for longitudinal thrust (forward and reverse motion of the ship). The rudder servomotor is used for transverse thrust (motion to port and starboard). The two servomotors permit steering according to Cartesian X/Y coordinates (identical with the principal axes of the ship). Controlled changes in thrust are possible via the thrust-free condition.

With the VSP, positions can be maintained precisely in all applications

The Voith Schneider Propeller allows precise and stepless thrust generation; propulsion and steering forces can be varied simultaneously. As a result of its vertical axis of rotation, the same amount of thrust can be created over 360°. Blades with hydrodynamically shaped profiles and end plates create thrust with a high degree of efficiency.Two servomotors per propeller enable steering to X/Y coordinates. The steering system is easy to understand and user-friendly (human engineering).

Longitudinal section of a VSP (3)



1 Rotor casing
2 Blade
3 Kinematics
4 Thrust plate
5 Roller bearing
6 Propeller housing
7 Reduction gear
8 Bevel gear
9 Driving sleeve
10 Control rod
11 Servomotor
12 Gear pump
13 Control shaft
14 Indicator plate
■ rotating parts
■ steering parts

Hydrodynamic principle of thrust generation

Kinematics (Figure 1) form the basis for the rapid and precise thrust variation of Voith Schneider Propellers. All blades of the Voith Schneider Propeller move along a circular path while at the same time performing a superimposed pivoting motion.

The perpendiculars of the chords of the profiles intersect at a single point, the steering center N, as the blades revolve. Figure 2 shows the blade velocities at zero thrust. N indicates the steering center at zero thrust (no thrust), N' a steering center position for a thrust setting (Page 10, Figure 5).

Figure 3 shows the blade movement a) for an observer standing on the propeller and b) for a stationary observer. The eccentricity e – also referred to as pitch – of the Voith Schneider Propeller is defined as:

$$e = \frac{ON}{D/2}$$

The pitch of the Voith Schneider Propeller can be varied within a range of $e \leq 0.8$.

The advance coefficient λ of the VSP is the ratio of the inflow velocity on the propeller (V_A) to the circumferential velocity of the blades (u):

$$\lambda = \frac{V_A}{u}$$

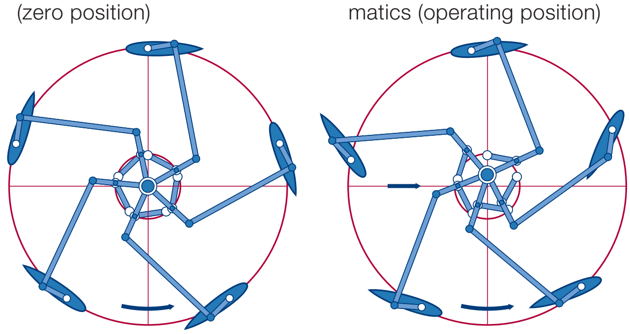
The circumferential velocity u at the blade circle, with rotor speed (n) and blade orbit diameter (D), is given by:

$$u = \pi \cdot D \cdot n$$

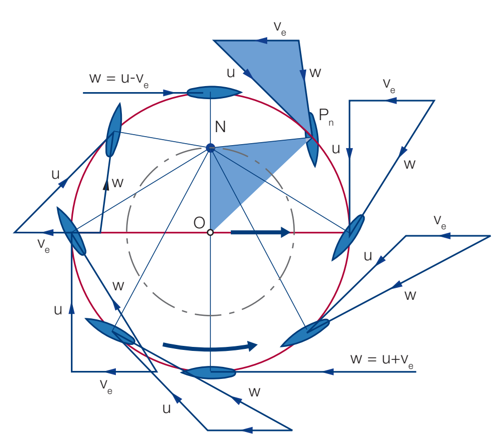
Crank-type kinematics (1)

a) No blade angle (zero position)

b) Blade angle due to kinematics (operating position)



Velocity triangles at the blade (2)



The motion of the blade relative to a stationary observer, as illustrated in Figure 3b, results from the superimposition of the rotary movement of the rotor casing and a straight line representing the forward motion of the vessel. The blade follows a curve of a cycloid. The rolling radius of the cycloid is $\lambda \cdot D/2$. During one revolution, the propeller travels a distance $\lambda \cdot D \cdot \pi$ in the direction of motion of the vessel. Since the blades travel along a cycloidal path, the Voith Schneider Propeller is also referred to as a cycloidal propeller. Figure 2 and 3 illustrate the blade settings at zero thrust. There is no hydrodynamic lift being created at any angle. The drag for the profiles can be neglected for the purpose of this analysis.

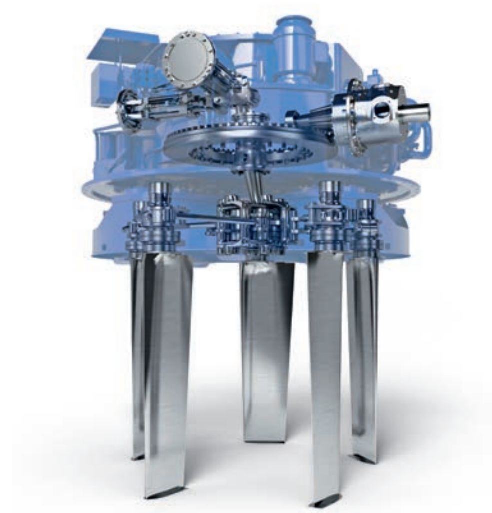
To generate thrust, the blades are set at an angle a relative to their path. To achieve this, the steering center is moved from N to N'. The resulting angle of attack a leads to the generation of hydrodynamic lift (A) and drag force (W) on the blade.

The thrust of the propeller is perpendicular to the line ON' (bollard pull) or to the line NN' (open water). By shifting the steering center N', it is possible to produce thrust in any direction.

It maneuvers you through any bottleneck.

- **Kinematics allow rapid and precise variation of thrust. The VSP blades travel along a circular path while at the same time performing a super-imposed oscillating motion.**
- **The VSP blades travel along a cycloidal path; the VSP is therefore also referred to as cycloidal propeller.**
- **The VSP pitch can be adjusted flexibly over 360°; thrust can be modified from the zero position under all operating conditions.**

VSP Kinematics



Cycloidal path of a VSP blade (3)

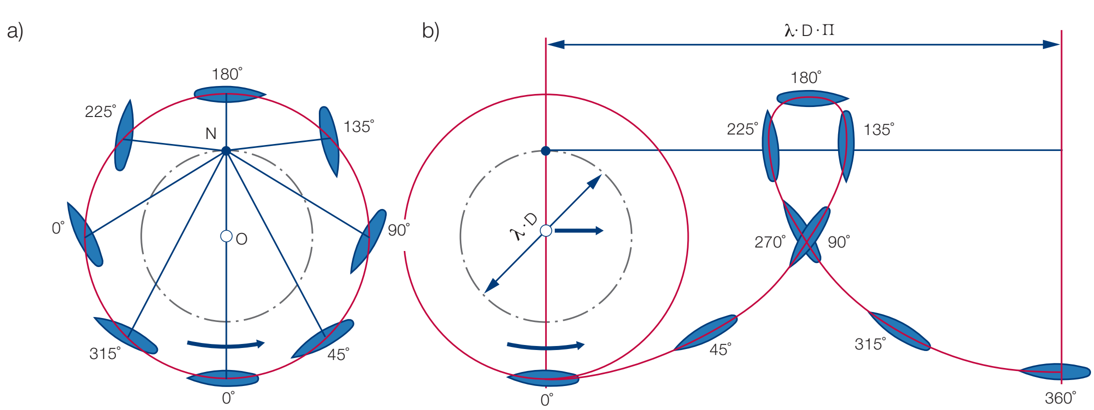


Figure 4 illustrates the generation of thrust. The steering center is varied by means of kinematics (Page 4, Figure 2).

Figure 5 shows individual blade positions that contribute to VSP thrust generation. The VSP employs a two-stage thrust generation. The blades produce forces in the desired direction of thrust both in the front and the rear half of the rotor. Since the profiles in the front and rear half of the rotor are moving in opposite directions, the VSP gives rise to hydrodynamic effects comparable to the interactions familiar from counter-rotating propellers.

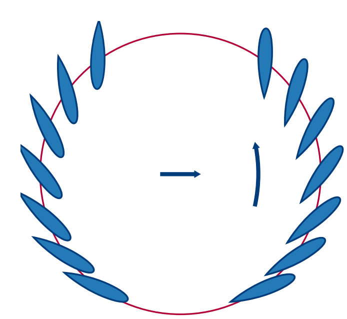
Figure 6 shows the thrust forces generated by a blade. Owing to the varying angle of attack of the blade, there is continuous variation in lift during each revolution. The force components acting transversely to the desired direction of thrust cancel each other out, while the force components acting in the direction of thrust, add up over the circumference of the propeller.

Its blades make the VSP the most maneuverable propulsion system in the world

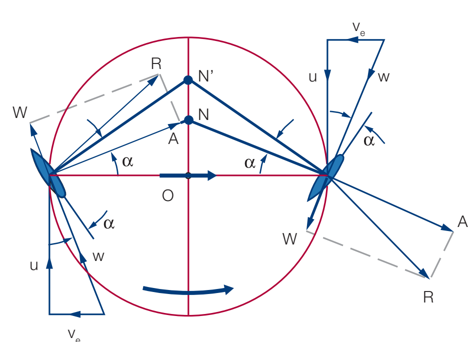
The VSP blades generate thrust based on the principle of hydrodynamic lift in almost all positions of their revolution. Thrust generation of the VSP is very similar to that employed by a dolphin. The profile shapes are virtually identical, and the profile path through the water is also comparable.

Blade positions (5)

Positions in the front and rear part of the rotor



Forces on the blade (4)



Thrust generation on the VSP (6)

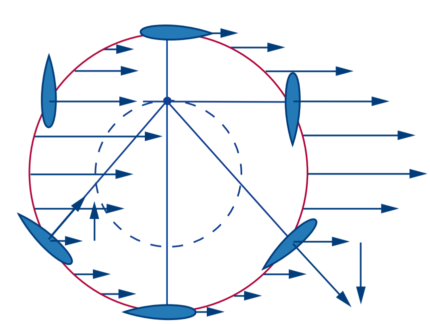
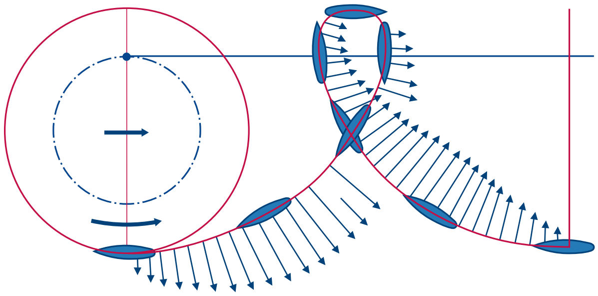


Figure 7 shows the lift conditions as a function of the cycloidal path for a stationary observer. The physical principle involved in the generation of thrust by the Voith Schneider Propeller is that of hydrodynamic lift and is similar to screw propellers. Thrust generation is fundamentally different from that represented by the flow conditions of a paddlewheel blade, where resistance forces are the decisive factor for thrust generation. Propulsion generation of the VSP is very similar to that employed by a dolphin. The illustration shows the movement of a dolphin's tail fin (8). If the pitch were increased to e > 1, the movement of the VSP profile would be identical to that of a dolphin. In both cases the profiles are symmetrical and very similar. On both the dolphin's tail fin and the VSP blade, suction and pressure side alternate constantly.

(Figure 8) Fish, F.: Power Output and Propulsive Efficiency of Swimming Bottlenose Dolphins (Tursiops, truncatus), J. exp. Biol. 185, 179 – 93 (1993).

Lift distribution over the blade path curve (7)



α = Angle of attack of the dolphin's tail fin (8)

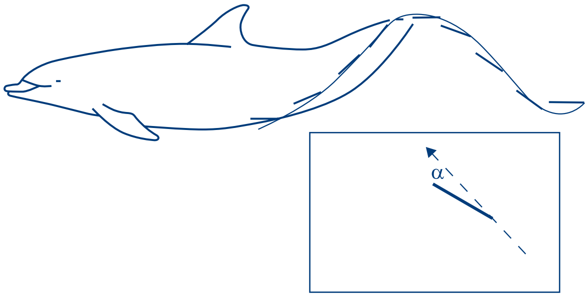
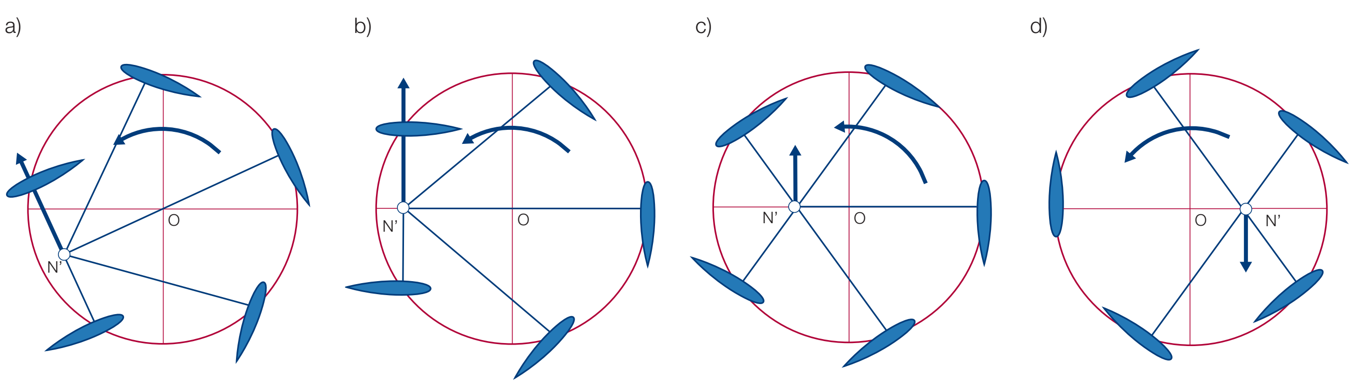


Figure 1 shows the effect of changing the steering center N'. Figure 1a shows a position N' in which both thrust and steering forces are generated. If N' is moved towards the center of the rotor from a particular starting point, e.g. that in Figure 1b, the thrust is reduced (Figure 1c). Shifting the steering center N' into a different quadrant results in reversing the direction of thrust (Figure 1d). It is therefore possible to reverse thrust simply by adjusting the steering center without suffering the effects of unwanted transverse forces. The zero-thrust setting can be selected at any time, making the vessel very safe to handle.

Voith Schneider Propellers operate at very low rotational speeds.

Thrust variation through alteration of the steering center N' (1)



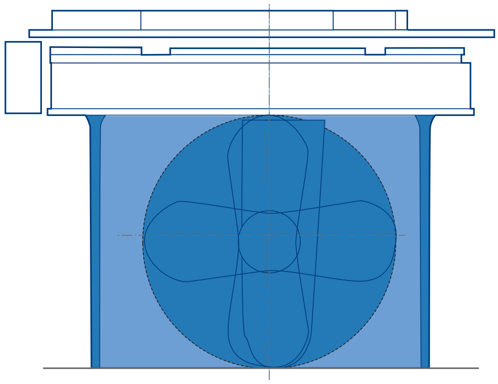
The rotational speed is only approx. 40% of that found on screw propellers of comparable size and power. The reasons can be summarized as follows:

- Under normal installation conditions, the rectangular swept area of a VSP is approximately twice as large as that of a screw propeller (Figure 2).
- The blades are arranged at the periphery of the rotor. The inflow resulting from the rotation of the rotor and the vessel speed is constant over the entire vertical length of the blade. On screw propellers, the inflow speed is a function of the radius. Due to the small radius, there is only a low inflow speed at the hub.
- The flow conditions at the blade are non stationary. Larger effective angles of attack can therefore be achieved without flow separation.
- Similar to counter-rotating propellers, the VSP generates thrust in two stages: in the front and rear half of the rotor (Page 10, Figure 5).

The low rotational speeds result in high torques, which call for a robust design. This leads to a higher weight. However, the low rotational speeds of the VSP have significant advantages:

- High degree of efficiency.
- Long service life, especially of bearings and seals.
- Reduced vulnerability to obstacles such as driftwood and ice. The blades generally strike such objects with their leading edge, which means that the blade has the maximum section modulus.
- Low hydroacoustic signatures; from a hydroacoustic perspective the VSP is very suited to the propulsion of research vessels and minehunters.
- The VSP components have a very high shock resistance.

VSP and screw propeller – Comparison of swept areas (2)



With its particularly robust components, the VSP reliably transfers maximum power to the water

- **Thrust can be varied as desired by adjusting steering center N’. Adjustments are also possible across the zero position.**
- **The VSP rotational speed is only approx. 40% of that found on screw propellers. VSPs are therefore very robust propulsion systems with a long service life. They are outstanding in their low susceptibility to driftwood and ice.**
- **The low rotational speeds result in very favorable hydroacoustic signatures and high shock safety.**

To illustrate the effects of rotational speed on the VSP characteristics, an analogy may be drawn to diesel engines (low-speed, medium-speed, high-speed). There too, rotational speed has a decisive effect on technical parameters such as degree of efficiency, service requirements, weight and cost.

The hydrodynamic characteristics of the Voith Schneider Propeller are represented by dimensionless coefficients which, as a result of the historic development, differ by constant factors from those of screw propellers. A brief summary as well as the corresponding conversion factors are given in Table 3.

In the dimensionless representation, it is useful to incorporate the blade length L into the corresponding coefficients for thrust and torque. The Reynolds number for Voith Schneider Propellers, based on the mean chord length c of a profile, is defined as follows:

$$Re = \frac{c}{\nu}\sqrt{V_A^2 + u^2}$$

As an alternative, correction factors obtained by validated numeric flow solvers (CFD) can be used (Figure 2). To increase the efficiency of Voith Schneider Propellers, the blade ends are equipped with end plates (Figure 1).

Here, n is the kinematic viscosity. Owing to the low number of revolutions of Voith Schneider Propellers, the Reynolds number obtained for a model propeller in propulsion tests is relatively low. It is therefore necessary to correct the results obtained with the model. This can be done with measured values obtained by the Hamburg Ship Model Basin (HSVA).

Voith Schneider Propellers can be optimized for:
- Maximum efficiency in open water,
- maximum bollard pull,
- minimum power requirement during dynamic positioning and roll stabilization or
- minimum noise emissions.

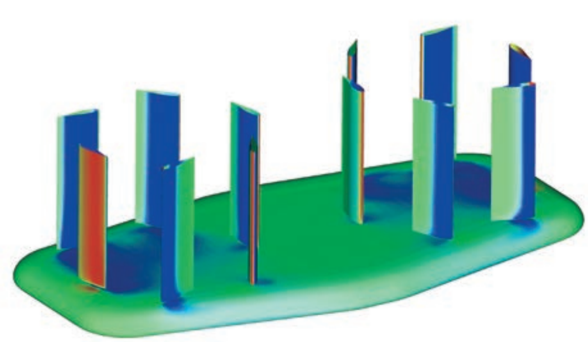
For vessels with multifunctional requirements, the above criteria are combined accordingly.

Hydrodynamic coefficients for the Voith Schneider Propeller (3)

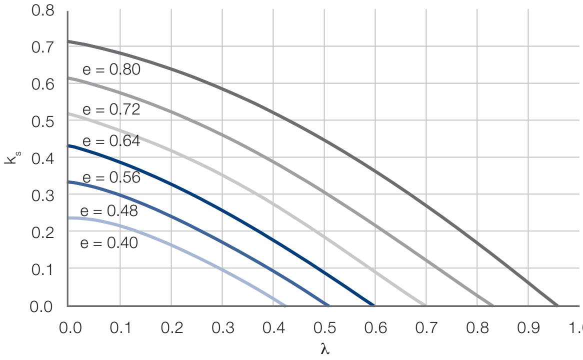
	Voith definition	Coefficients by analogy with screw propeller	Conversion
Advance coefficient	$\lambda = \frac{V_A}{\pi \cdot n \cdot D}$	$J = \frac{V_A}{n \cdot D}$	$J = \lambda \cdot \pi$
Thrust coefficient	$k_S = \frac{T}{0{,}5 \cdot \rho \cdot D \cdot L \cdot u^2}$	$k_T = \frac{T}{\rho \cdot n^2 \cdot D^3 \cdot L}$	$k_T = 0{,}5 \cdot \pi^2 \cdot k_S$
Torque coefficient	$k_D = \frac{4 \cdot M}{\rho \cdot D^2 \cdot L \cdot u^2}$	$k_Q = \frac{M}{\rho \cdot n^2 \cdot D^4 \cdot L}$	$k_Q = k_D \cdot \frac{\pi^2}{4}$
Open-water efficiency	$\eta_O = \frac{k_S}{k_D} \cdot \lambda$	$\eta_O = \frac{k_T}{k_Q} \cdot \frac{J}{2 \cdot \pi}$	—
Circumferential velocity of the VSP blades	$u = \pi \cdot n \cdot D$	—	—

VSP blade with end plate (1)

Pressure distribution on VSP blades / guard plate (CFD calculation) (2)



Thrust coefficient (k_s) (2)
as a function of advance coefficient (λ) and pitch (e)



Figures 2 and 3 show the open-water characteristics of a Voith Schneider Propeller for various pitch angles e of the large version. Figure 2 shows the thrust coefficient k_s as a function of advance coefficient λ and pitch e; Figure 3 in analogy the degree of efficiency.

Figure 4 shows an example of the steering forces of a Voith Schneider Propeller, divided into longitudinal vessel direction (k_{sx}) and transverse vessel direction (k_{sy}).

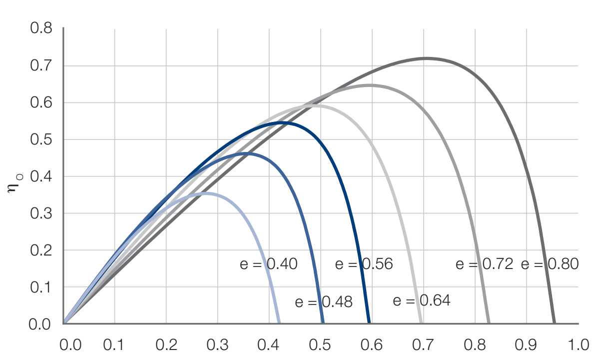
As the advance ratio increases (vessel speed increases while propeller speed remains constant), the steering forces also increase. Since the VSP is a variable-pitch propeller, high steering forces can be generated by very rapid changes in pitch. These are used efficiently for roll stabilization and dynamic positioning.

The VSP design

For the design of Voith Schneider Propellers, hydrodynamic coefficients analog to those of screw propellers are used. Blade length L and blade orbit diameter (D) are incorporated in the dimensionless representation. At present, the maximum open-water efficiency is 73 %.

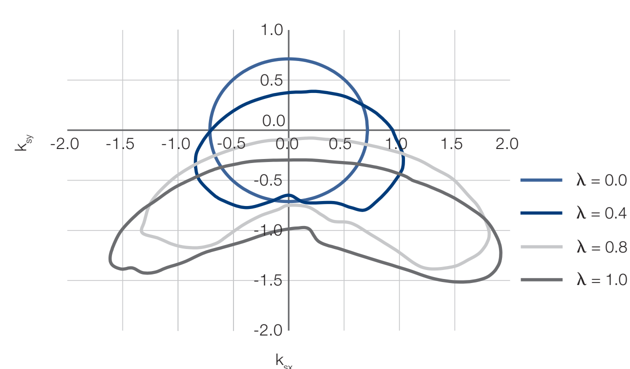
Degree of efficiency (h_0) (3)

as a function of advance coefficient (λ) and pitch (e)



Steering force coefficients (k_{sx} and k_{sy}) (4)

as a function of the advance coefficient

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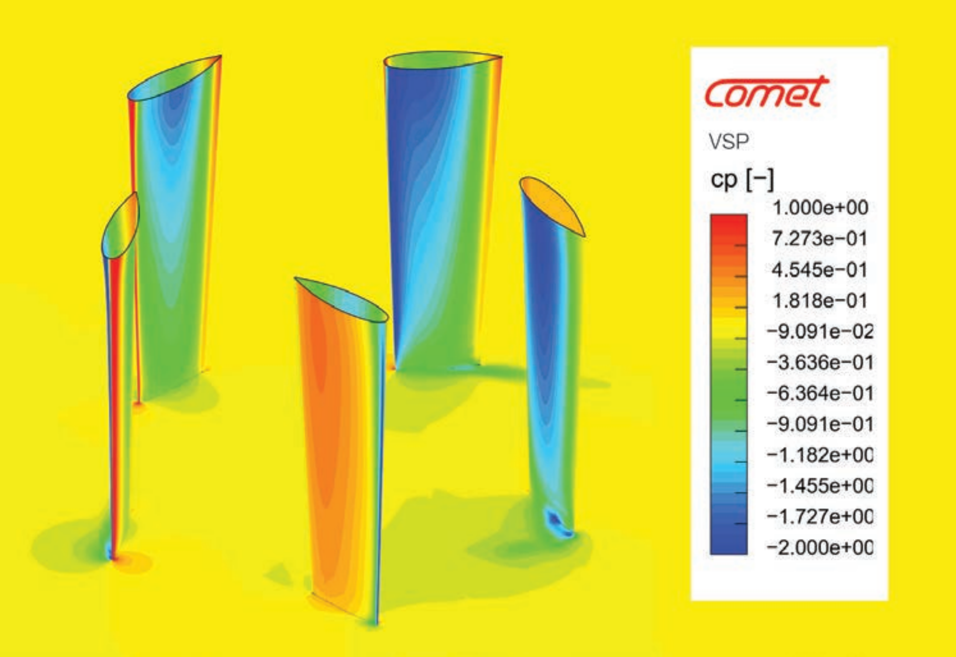

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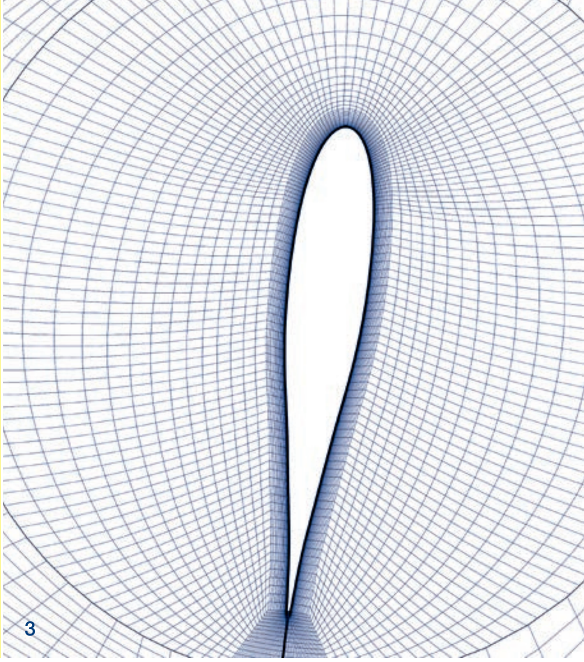

3

The intelligent propulsion system for safe shipping.

- An increase in pitch results in a higher maximum efficiency. Unlike with bow thrusters, the steering forces increase as the velocity increases.
- The flow characteristics of Voith Schneider Propellers are reliably calculated with the numeric flow mechanics method (CFD = Computational Fluid Dynamics).
- VSPs can be optimized for:
  – Maximum efficiency in open water
  – Maximum bollard pull
  – Minimum power requirement during dynamic positioning and roll stabilization or
  – Optimum hydroacoustic signature

1 Voith Water Tractor Shinano.

2 Pressure distribution on VSP blades (CFD calculation).

3 Calculation mesh: blade discretization.

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Please scan QR-Code to contact our experts:

Voith Group
St. Poeltener Str. 43
89522 Heidenheim, Germany

Contact:
Phone + 49 7321 37-2055
marine@voith.com
www.voith.com/marine

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