Case 2.2: Velocity field

The velocity field in front and behind the rotating propeller was measured in the cavitation tunnel of the SVA Potsdam.

Test set up:
The velocity field was measured by means of LDV (Laser Doppler velocimetry) in the cavitation tunnel K 15 A (Kempf & Remmers) of the SVA Potsdam. For this purpose a test section with the length of 2600 mm and a cross section of 600x600 mm was used. In Fig. 1 the cavitation tunnel is shown.

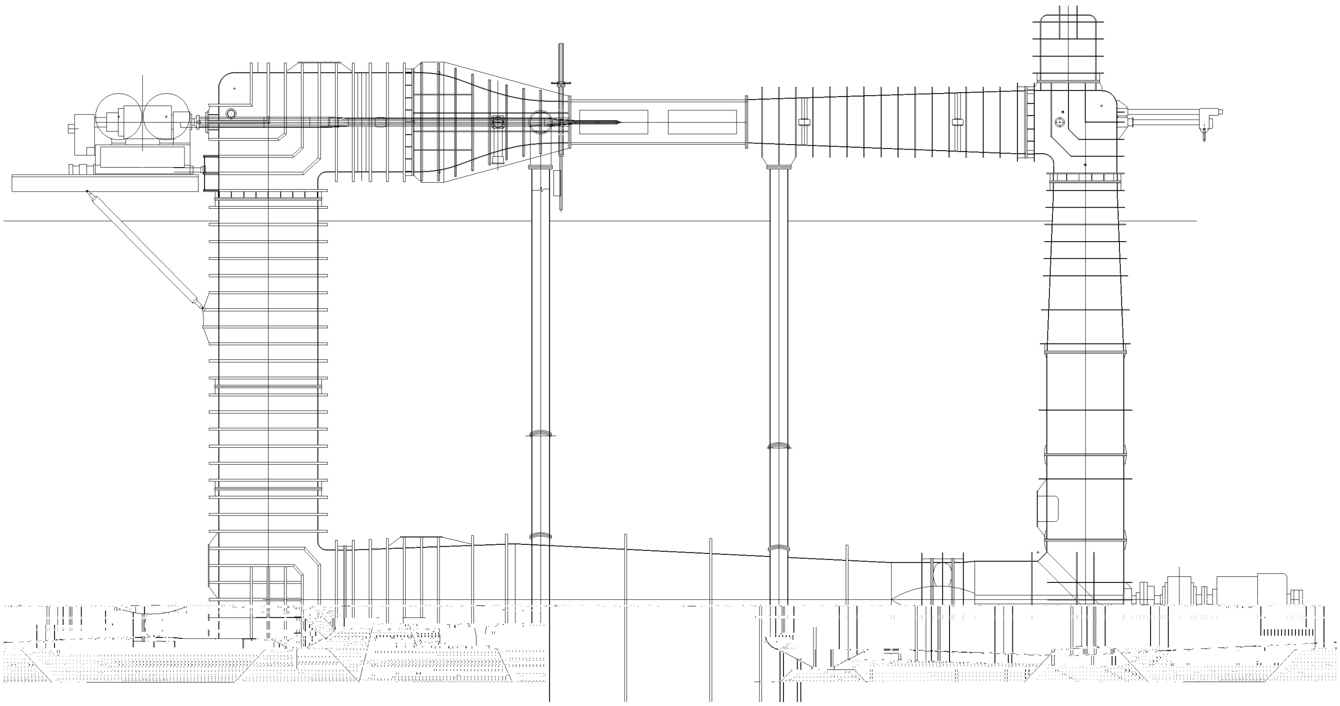


Fig. 1: Cavitation tunnel

The propeller is positioned in the vertical and lateral centre of the test section. The longitudinal position of the propeller is 570 mm from the beginning of the test section, as shown in Fig. 2.

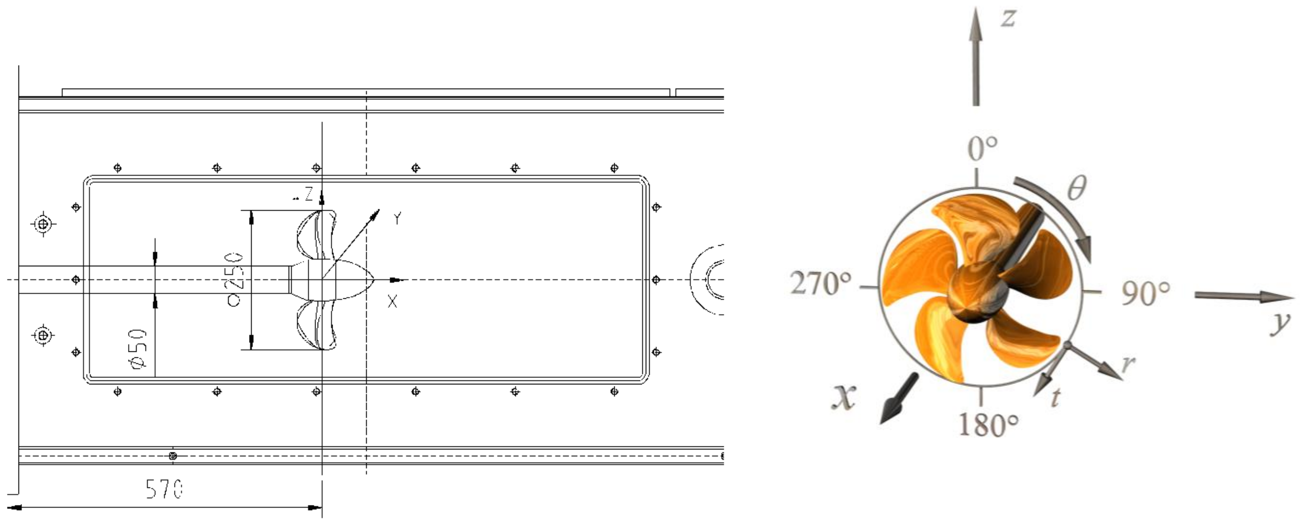


Fig. 2: Test section (left) and coordinate system (right)

Test description:
The LDV measurements were conducted for homogeneous inflow conditions in different measuring planes in front and behind the rotating propeller. The position of the measuring planes is illustrated in Fig. 3 left and given in Tab. 1. The angular based measurements (with respect to the rotating propeller) were carried out along a line of constant angular position $\theta = 225°$, Fig. 3 right. The data is than related to the zero degree position, being defined as the 12 o'clock position. The radial distribution of the measuring points is given in table, Tab. 3. Special attention was laid upon resolving the tip vortex.

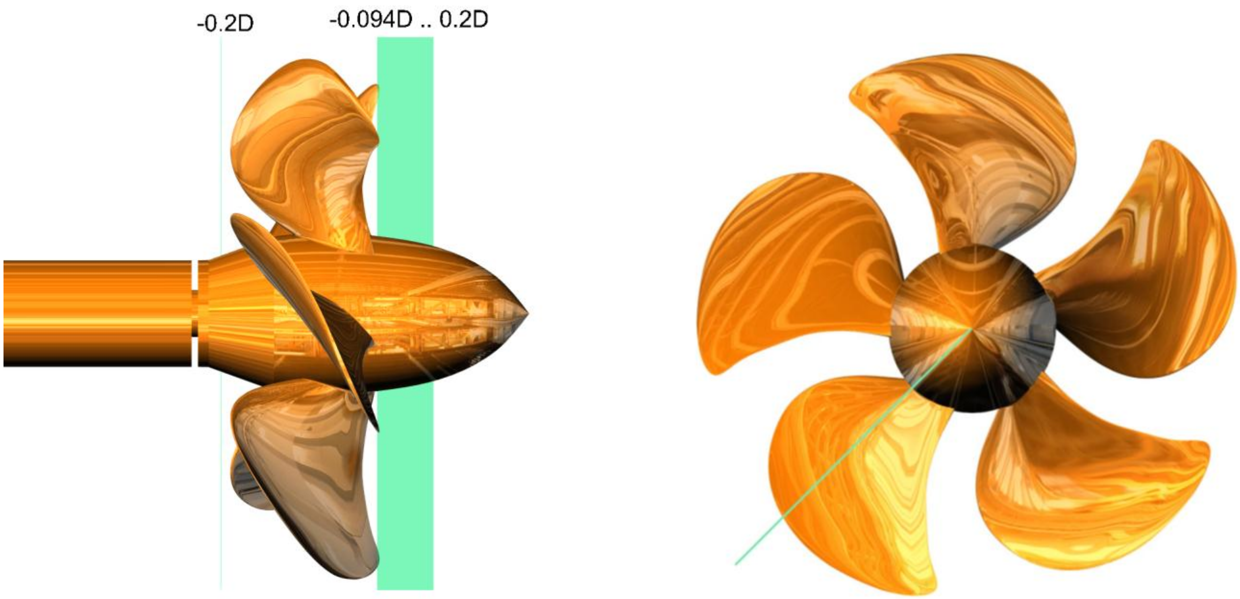


Fig. 3: Measuring planes (left) and angular position (right)

x/D [-]	-0.200

..001 g-0 ·

- In addition to the three velocity components, the propeller blade position was recorded in the measuring campaign, enabling to relate the velocity field to the blade position. The velocities were collected every 0.25°, resolving one propeller revolution within 1440 steps.
- The tests were conducted with a non-cavitating propeller
- The test conditions in the cavitation tunnel of the SVA were as follows:

Water density (for t_w = 24.7°C)	ρ	[kg/m^3]	997.1
Kinematic viscosity of water (for t_w = 24.7°C)	ν	[m²/s]	0.903E-6

- The working point of the measurements was as follows:

Number of revolutions	n	[1/s]	23.0
Velocity	V	[m/s]	7.204
Advance coefficient	J	[-]	1.253
Thrust coefficient	K_T	[-]	0.250
Torque coefficient	$10K_Q$	[-]	0.725

- Axial velocities are positive in flow directions
- Radial velocities are positive for increasing radii
- Tangential velocities are positive in direction of rotation
- The velocities should be provided in a dimensionless form, with respect to the inflow velocity
- Velocities should be given in stationary frame of reference.
- The angles should be given in degrees
- The zero degree position corresponds to the 12 o'clock position, see Fig. 2 (as given in the IGS-file).
- All evaluations shall be conducted with the propeller being in the zero degree position
- The origin of the geometry corresponds to the propeller plane position
- The calculations should be carried out according to the thrust identity, with K_T = 0.250 (in case the thrust identity was not accomplished n should be kept constant at n = 23 1/s)

Requested computations:

Case 2.2.1

Dimensionless radius	r/R	[-]	0.70
Plane	x/D	[-]	0.10, 0.20

- Evaluation of the three velocity fractions $1\text{-}V_x/V$, V_t/V and V_r/V for the given working point.
- Data format:

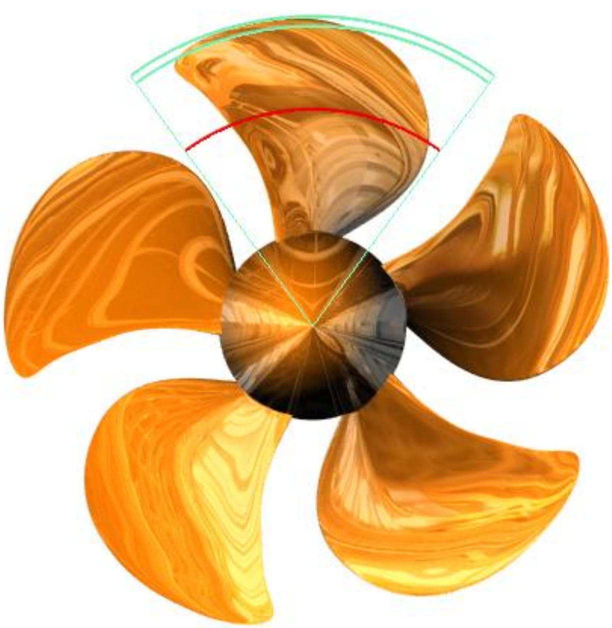
  The data shall be provided in ASCII-format, with the propeller blade position θ in the first, the $1\text{-}V_x/V$ components in the second, the V_t/V components in the third and the V_r/V components in the forth column. Angular positions should be given in the range of $-50° \leq \theta \leq 22°$, in ascending order. Blanks should be used as separator. The column descriptors should have a preceding hash key.

  Example:

```
#PHI    1-VX/V  VT/V    VR/V
-50.00  1.000   0.000    0.000
-47.75  1.010   0.100   -0.020
-45.50  1.050   0.150   -0.040
…
22.00   1.020   0.080   -0.0342
```

- File name:

  [identifier]_vel_case2-2-1_01.dat for plane 0.1 D
  [identifier]_vel_case2-2-1_02.dat for plane 0.2 D
  The identifier should be [Institute Name]-[Solver Name]. For the SVA Potsdam using the CFX solver it would be for example SVA-CFX_vel_case2-2-1_0*.dat

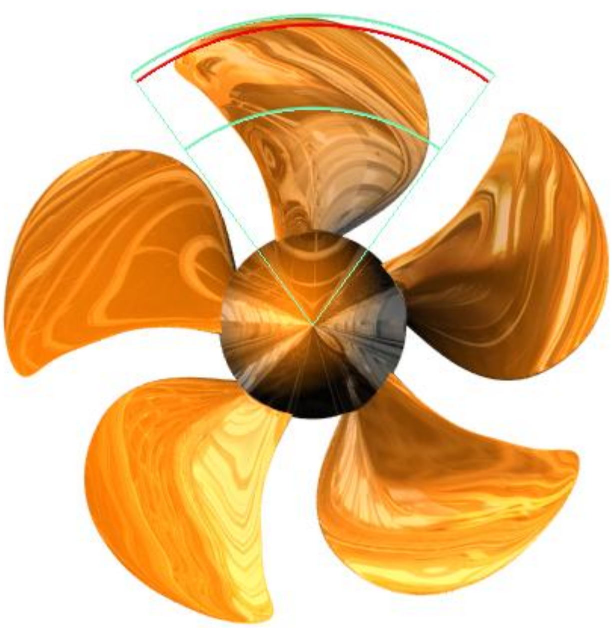


Case 2.2.2

Dimensionless radius	*r/R*	[-]	0.97
Plane	*x/D*	[-]	0.10, 0.20

- Evaluation of the three velocity fractions $1\text{-}V_x/V$, V_t/V and V_r/V for the given working point.
- Data format:
  The data shall be provided in ASCII-format, with the propeller blade position θ in the first, the $1\text{-}V_x/V$ components in the second, the V_t/V components in the third and the V_r/V components in the forth column. Angular positions should be given in the range of -50° ≤ θ ≤ 22°, in ascending order. Blanks should be used as separator. The column descriptors should have a preceding hash key.

  Example:
```
#PHI 1-VX/V    VT/V    VR/V
-50.00  1.000   0.000   0.000
-47.75  1.010   0.100  -0.020
-45.50  1.050   0.150  -0.040
...
22.00   1.020   0.080  -0.0342
```
- File name:
  [identifier]_vel_case2-2-2_01.dat for plane 0.1 D
  [identifier]_vel_case2-2-2_02.dat for plane 0.2 D
  The identifier should be [Institute Name]-[Solver Name]. For the SVA Potsdam using the CFX solver it would be for example SVA-CFX_vel_case2-2-2_0*.dat



Case 2.2.3

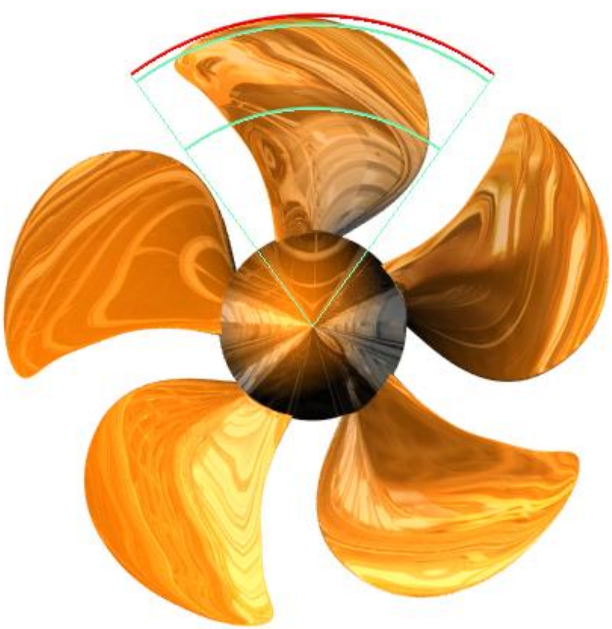
Dimensionless radius	*r/R*	[-]	1.0
Plane	*x/D*	[-]	0.10, 0.20

- Evaluation of the three velocity fractions $1\text{-}V_x/V$, V_t/V and V_r/V for the given working point.
- Data format:

  The data shall be provided in ASCII-format, with the propeller blade position θ in the first, the $1\text{-}V_x/V$ components in the second, the V_t/V components in the third and the V_r/V components in the forth column. Angular positions should be given in the range of $-50° \leq \theta \leq 22°$, in ascending order. Blanks should be used as separator. The column descriptors should have a preceding hash key.

  Example:
```
#PHI 1-VX/V    VT/V    VR/V
-50.00  1.000   0.000   0.000
-47.75  1.010   0.100  -0.020
-45.50  1.050   0.150  -0.040
...
22.00   1.020   0.080  -0.0342
```
- File name:

  [identifier]_vel_case2-2-3_01.dat for plane 0.1 D
  [identifier]_vel_case2-2-3_02.dat for plane 0.2 D
  The identifier should be [Institute Name]-[Solver Name]. For the SVA Potsdam using the CFX solver it would be for example SVA-CFX_vel_case2-2-3_0*.dat



Case 2.2.4

Plane	*x/D*	[-]	0.1, 0.2

- Evaluation of the velocity field behind the propeller plane.
- Data format:
  The data shall be provided in ASCII-format with the angular position in the first, the dimensionless radius in the second, the V_x components in the third, the V_y components in the forth and the V_z components in the fifth column. Angular positions should be given at least in the range of $-40° \leq \theta \leq 0°$, in ascending order. The step size $\Delta\theta$ is arbitrary but has to be identical for all radii. The dimensionless radius should be given in ascending order in the range of $0.40 \leq r/R \leq 1.10$, with the step size being arbitrary. Blanks should be used as separator. The numbers of radii (nrad) and angular steps (ntheta) have to be specified in the file header.

  Example:
  Nrad = n1   ntheta = n2
```
#PHI    r/R     VX       VY       VZ
-40.00   0.40    7.000    1.000    1.000
-39.75   0.40    7.010    1.100   -1.020
-39.50   0.40    7.050    1.150   -1.040
```
  ...
```
-0.25    1.10    1.020    0.080   -0.0342
 0.00    1.10    1.020    0.080   -0.0342
```

- File name:
  [identifier]_vel_case2-2-4.dat
  The identifier should be [Institute Name]-[Solver Name]. For the SVA Potsdam using the CFX solver it would be SVA-CFX_vel_case2-2-4.dat

Formula:

Advance coefficient: $$J = \frac{V}{n \cdot D}$$

Thrust coefficient: $$K_T = \frac{T}{\rho \cdot n^2 \cdot D^4}$$

Torque coefficient: $$K_Q = \frac{Q}{\rho \cdot n^2 \cdot D^5}$$

Axial velocity component: $$W_a = 1.0 - \frac{V_a}{V}$$

Tangential velocity component: $$W_t = \frac{V_t}{V}$$

Radial velocity component: $$W_r = \frac{V_r}{V}$$

With D being the propeller diameter, T the propeller thrust, Q the propeller torque, V_a the local axial velocity, V_t the local tangential velocity, V_r the local radial velocity, V_x the local velocity in direction of the x-axis, V_y the local velocity in direction of the y-axis and V_z the local velocity in direction of the z-axis.

Comment:

- The propeller is operating in homogeneous inflow conditions.
- In order to reduce the computational effort it is desirable to carry out steady state calculations. Therefore it is considered feasible to idealise the cavitation tunnel as a cylinder of equal cross-sectional area than the real tunnel geometry. Since it is requested to carry out the calculations with respect to the thrust identity, it might also be feasible to use an “unbounded” solution domain. The choice which approach it used has to be decided by the participants.
- It is requested to conduct the calculation according to the thrust identity. For this reason also the thrust coefficient is given in addition to the rate of revolution and the inflow velocity.
- The open water curves of the propeller differ slightly if measured in the cavitation tunnel or in the model basin. However, in case of thrust identity the flow field behind the propeller is believed to be identical.
- For case 2.2.1-.2.2.3 the data will be presented for angular positions of $-50° \leq \theta \leq 22°$. The tip vortex is around the $\theta = -30°$ position. In case the given angular range differs to the requested range, please consider that the data range well covers the tip vortex region.