Case 2.3: Cavitation

The cavitation tests with the propeller were conducted in the SVA Potsdam.

Test set up:
The cavitation tests were conducted in the cavitation tunnel K 15 A (Kempf & Remmers) of the SVA Potsdam. For the cavitation observation tests a test section with the length of 2600 mm and a cross section of 600 x 600 mm was used. In Fig. 1 the cavitation tunnel is shown.

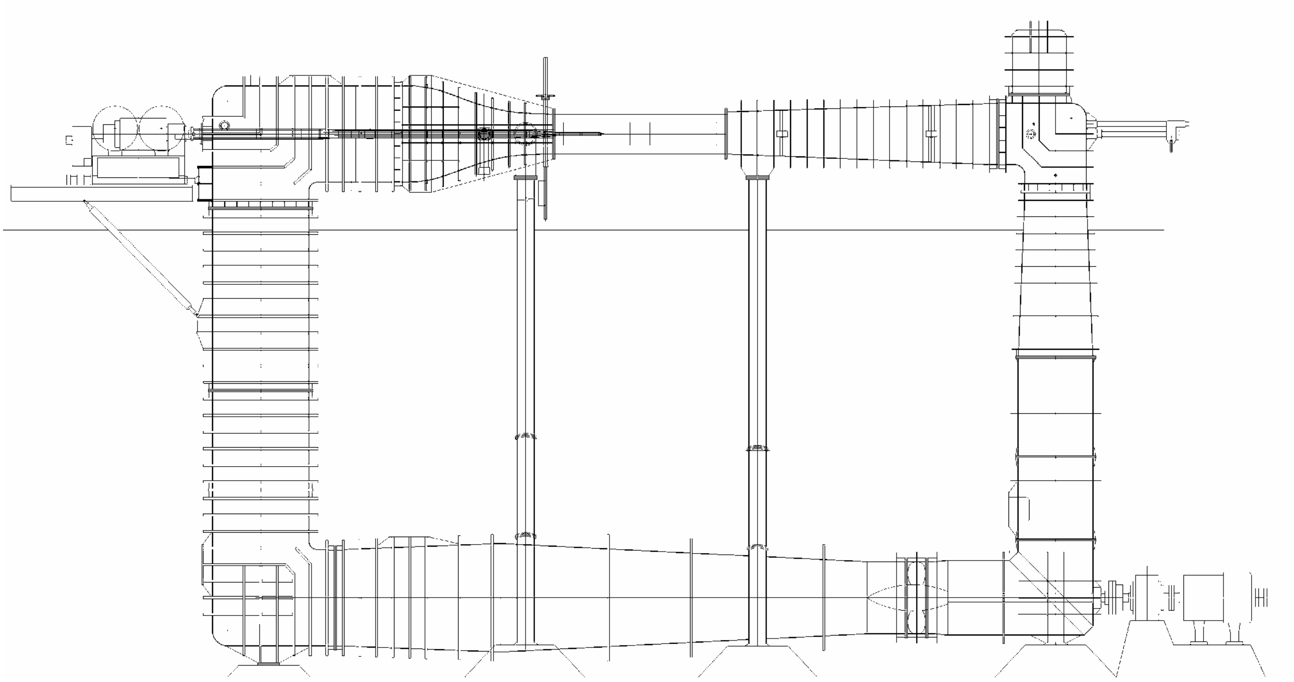


Fig. 1: Cavitation tunnel

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.

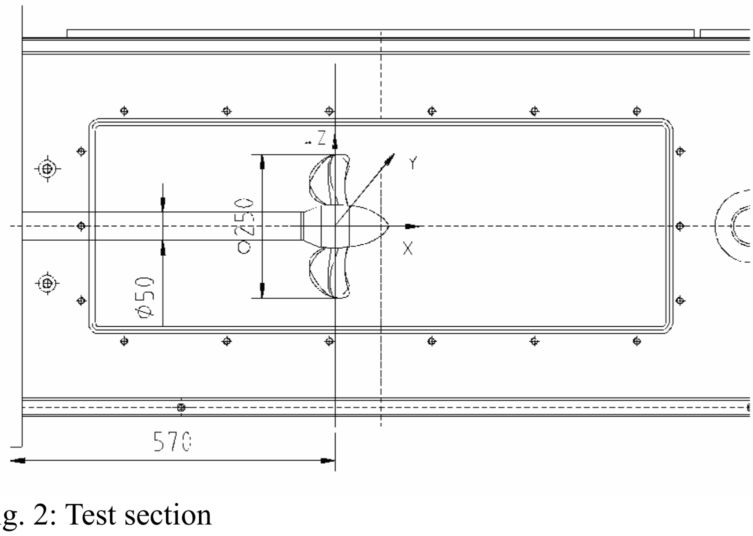


Fig. 2: Test section

Description:

- The inflow velocity in the numerical calculations can be determined with the advance coefficient.
- The pressure level in the numerical calculations can be determined with the cavitation number.
- The zero degree position of the propeller blade corresponds to the 12 o'clock position (blade stands upright, corresponds to the position in the IGS-file).
- All evaluation shall be conducted with the propeller being in the zero degree position.
- The origin of the geometry corresponds to the propeller plane position (x = 0 m)
- For each case two different evaluations are requested (Part A and Part B):
    - Part A: Evaluation of the cavity surface
    - Part B: Evaluation of the pressure distribution on different radial propeller sections
- Evaluation:
    - Part A: The CFD will be compared with the corresponding EFD results
    - Part B: The CFD results will be compared among each other
- Different views upon the propeller are requested (Part A):
    - View along the x-axis, facing the suction side of the propeller (identifier SS)
    - View along the x-axis, facing the pressure side of the propeller (identifier PS)
    - Side view, facing the suction side of the propeller (identifier SVSS)
    - Side view, facing the pressure side of the propeller (identifier SVPS)

  For each case 2 different views, specified below, are requested, giving 6 figures per case.
- The views upon the propeller are case sensitive (Part A):
    - For case 2.3.1: SS and SVSS
    - For case 2.3.2: SS and SVSS
    - For case 2.3.3: PS and SVPS
- Case 2.3.1 and 2.3.3 are off-design conditions, while case 2.3.2 is for the operation point.
- Pressure side cavitation occurs for case 2.3.3
- The calculations shall be conducted according to the thrust identity (K_T values are provided, non-cavitating), with the inflow velocity being free to alter. The rate of revolution has to be kept constant, since it is used for the definition of the cavitation number.
- The idea is to have in the computations for the non-cavitating propeller the same thrust coefficient as in the experiments. As the propeller is calculated with cavitation it will affect the propeller thrust. Therefore it is requested to provide the propeller thrust considering cavitation (top right in the figures)
- For Part A a second file identifier is introduced: see figure format
- For Part B a third file identifier is introduced:

  The third identifier should be [radial section]-[cavitation state]. For the radial sections 070, 090 and 095 are possible entries for r/R = 0.70, 0.90 and 0.95. For the cavitation state **ncav** and **wcav** should be used, for the computations of the non-cavitating and the cavitating propeller. The first identifier should be [Institute Name]-[Solver Name].

  For the SVA Potsdam using the CFX solver and evaluating case 2-3-1 on the radial section r/R = 0.70 for the cavitating propeller it would be: SVA-CFX_cav_case2-3-1_070-wcav.dat

Requested computations:

Case 2.3.1

Advanced coefficient	J	[-]	1.019
Cavitation number based on n	σ_n	[-]	2.024
Thrust coefficient (non-cavitating!)	K_T	[-]	0.387
Number of revolutions	n	[1/s]	24.987
Water density (for t_w = 23.2°C)	ρ	[kg/m^3]	997.44
Kinematic viscosity of water (for t_w = 23.2°C)	ν	[m²/s]	$9.337 \cdot 10^{-7}$
Vapour pressure (for t_w = 23.2°C)	p_v	[Pa]	2818
Air content	α/α_s	[%]	53.5

Part A:

- Evaluation of the cavity surface, defined by the interface between vapour and water, for a volume fraction of 20%, 50% and 80% of vapour.
- Thrust coefficient K_T (cavitating)
- The following views are requested: SS and SVSS
- File name:
  [identifier1]_cav_case2-3-1_[identifier2].* for [identifier2] see figure format

Part B:

- Evaluation of the pressure distribution on the propeller blade for different radial sections: r/R = 0.70, 0.90 and 0.95, for the non-cavitating and for the cavitating propeller
- The pressure coefficient should be calculated with the section advance speed of the corresponding radius
- Data format:
  The data shall be provided in ASCII-format, with the x-, y- and z-coordinate in the first three columns and the dynamic pressure in the forth column. Blanks should be used as separator. The column descriptors should have a preceding hash key.

  Example:
  ```
  # X     Y       Z       CP
  0.1   1.000   0.000   0.000
  0.5   1.010   0.100  -0.020
  ```
- File name:
  [identifier1]_cav_case2-3-1_[identifier3].* for [identifier3] see description

Case 2.3.2:

Advanced coefficient	J	[-]	1.269
Cavitation number based on n	σ_n	[-]	1.424
Thrust coefficient (non-cavitating!)	K_T		0.245
Number of revolutions	n	[1/s]	24.986
Water density (for t_w = 23.2°C)	ρ	[kg/m^3]	997.44
Kinematic viscosity of water (for t_w = 23.2°C)	ν	[m²/s]	$9.337 \cdot 10^{-7}$
Vapour pressure (for t_w = 23.2°C)	p_v	[Pa]	2818
Air content	α/α_s	[%]	53.5

Part A:

- Evaluation of the cavity surface, defined by the interface between vapour and water, for a volume fraction of 20%, 50% and 80% of vapour.
- Thrust coefficient K_T (cavitating)
- The following views are requested: SS and SVSS
- File name:
  [identifier1]_cav_case2-3-2_[identifier2].* for [identifier2] see figure format

Part B:

- Evaluation of the pressure distribution on the propeller blade for different radial sections: r/R = 0.70, 0.90 and 0.95, for the non-cavitating and for the cavitating propeller
- The pressure coefficient should be calculated with the section advance speed of the corresponding radius
- Data format:
  The data shall be provided in ASCII-format, with the x-, y- and z-coordinate in the first three columns and the dynamic pressure in the forth column. Blanks should be used as separator. The column descriptors should have a preceding hash key.

  Example:
  ```
  # X     Y       Z       CP
  0.1   1.000   0.000   0.000
  0.5   1.010   0.100  -0.020
  ```
- File name:
  [identifier1]_cav_case2-3-2_[identifier3].* for [identifier3] see description

Case 2.3.3

Advanced coefficient	J	[-]	1.408
Cavitation number based on n	σ_n	[-]	2.000
Thrust coefficient (non-cavitating!)	K_T		0.167
Number of revolutions	n	[1/s]	25.014
Water density (for t_w = 23.2°C)	ρ	[kg/m^3]	997.37
Kinematic viscosity of water (for t_w = 23.2°C)	ν	[m²/s]	$9.272 \cdot 10^{-7}$
Vapour pressure (for t_w = 23.2°C)	p_v	[Pa]	2869
Air content	α/α_s	[%]	58.50

Part A:

- Evaluation of the cavity surface, defined by the interface between vapour and water, for a volume fraction of 20%, 50% and 80% of vapour.
- Thrust coefficient K_T (cavitating)
- The following views are requested: PS and SVPS
- File name:
  [identifier1]_cav_case2-3-3_[identifier2].* for [identifier2] see figure format

Part B:

- Evaluation of the pressure distribution on the propeller blade for different radial sections: r/R = 0.70, 0.90 and 0.95, for the non-cavitating and for the cavitating propeller
- The pressure coefficient should be calculated with the section advance speed of the corresponding radius
- Data format:
  The data shall be provided in ASCII-format, with the x-, y- and z-coordinate in the first three columns and the dynamic pressure in the forth column. Blanks should be used as separator. The column descriptors should have a preceding hash key.

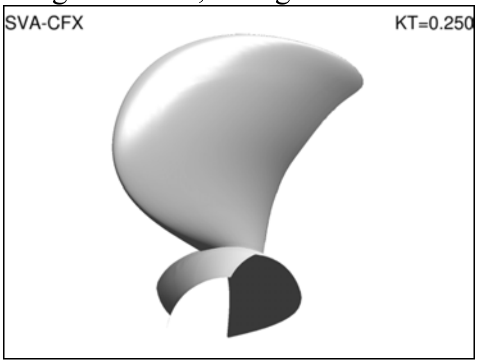
  Example:
```
# X     Y       Z       CP
0.1   1.000   0.000   0.000
0.5   1.010   0.100  -0.020
```
- File name:
  [identifier1]_cav_case2-3-3_[identifier3].* for [identifier3] see description

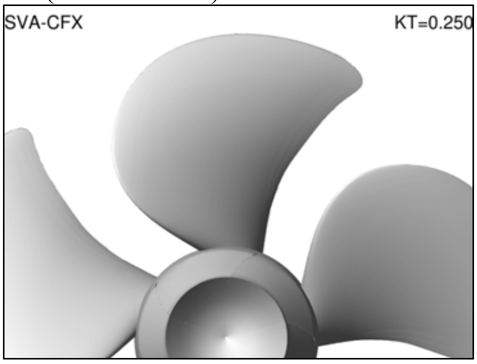
Figure format:

The view upon the propeller should resemble the one from the figures given below. For steady state calculations with one blade passage, please use the figures in the first column. In case the entire propeller is calculated, please use the figures in the second column.

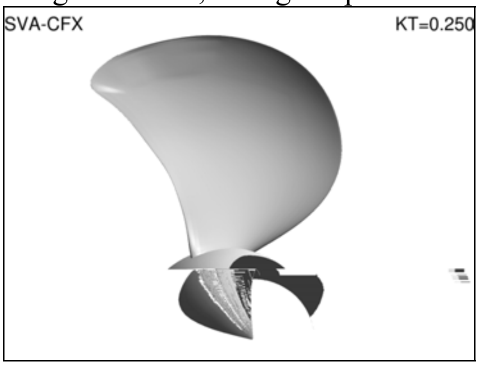
- Image size should be 800*600 pixel
- Propeller surface should be coloured in grey
- The isosurfaces of the cavity should be coloured as follows:
  20% vapour: green
  50% vapour: red
  80% vapour: blue
- Figure format can be either jpg or png.
- The institutes name and the flow solver should be added in the top left corner of the figure
- The calculated K_T (cavitating) value should be added in the top right corner of the figure
- All figures should be taken for the propeller being in the zero degree position, corresponding to the 12 o'clock position.
- The first identifier should be [Institute Name]-[Solver Name]. The second identifier should be [vapour fraction]-[view upon propeller]. For the SVA Potsdam using the CFX solver and evaluating case 2-3-1 for 20% vapour fraction and looking upon the pressure side of the propeller it would be: SVA-CFX_cav_case2-3-1_20-PS.png

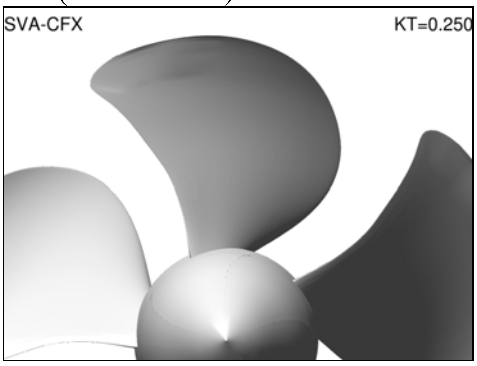
View along the x-axis, facing the suction side of the propeller (identifier SS)



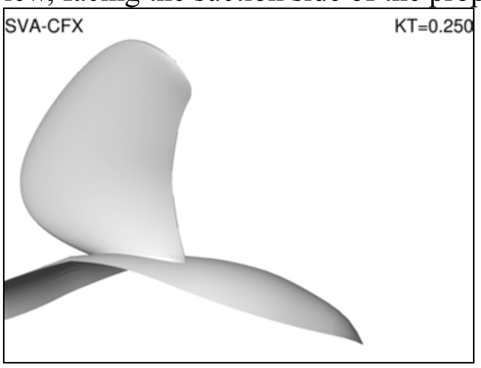


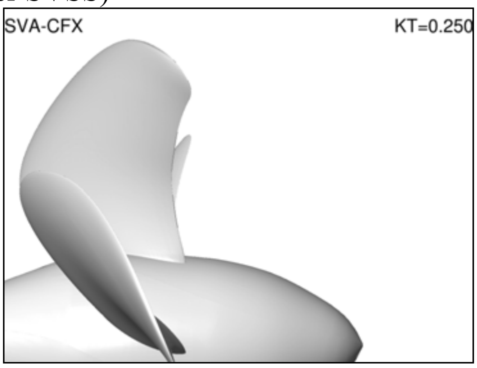
View along the x-axis, facing the pressure side of the propeller (identifier PS)



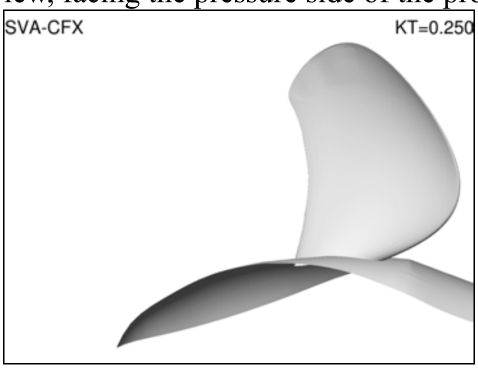


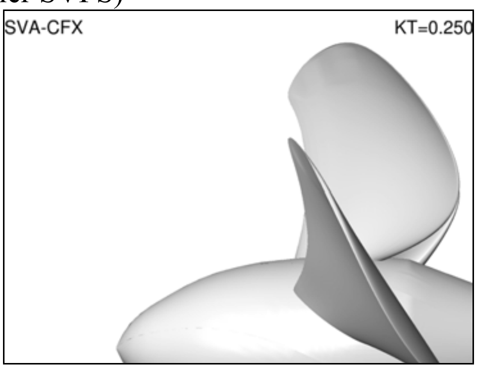
Side view, facing the suction side of the propeller (identifier SVSS)





Side view, facing the pressure side of the propeller (identifier SVPS)





Formula:

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

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

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

Open water efficiency: $\eta_0 = \dfrac{J}{2\pi} \cdot \dfrac{K_T}{K_Q}$

Reynolds number (r/R = 0.7) $Re_{07} = \dfrac{C_{0.7R}}{\upsilon} \cdot \sqrt{V^2 + (0.7D \cdot \pi \cdot n)^2}$

Thrust loading: $C_{Th} = \dfrac{8}{\pi} \cdot \dfrac{K_T}{J^2}$

Cavitation number with respect to n $\sigma_n = \dfrac{(p - p_v)}{0.5 \cdot \rho \cdot (nD)^2}$

Pressure coefficient: $c_P = \dfrac{(p - p_0)}{0.5 \cdot \rho \cdot \left(V^2 + (2 \cdot \pi \cdot n \cdot r)^2\right)}$

With D_P being the propeller diameter, T the propeller thrust, Q the propeller torque, $C_{0.7R}$ the chord length of the propeller section at radius $r/R = 0.7$, p the tunnel pressure, p_v the vapour pressure, p_0 the static pressure and r the radius.

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.
- 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.