Case 2: Cavitation observation in oblique flow

Description:

The cavitation tests were conducted in the cavitation tunnel K 15 A (Kempf & Remmers) of the SVA Potsdam, on basis of thrust identity. During testing the propeller was positioned according to the setup shown below with a 12° inclination of the propeller towards the inflow direction.

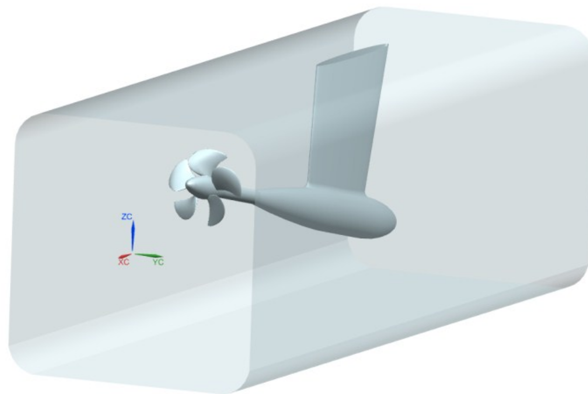


Fig. 1: Test section

Due to the propeller inclination of 12° and the hub cap the homogeneous inflow in the cavitation tunnel is for the propeller of inhomogeneous nature. The propeller encounters tangential velocities which act on one side against and on the other side with the direction of blade rotation, having impact on the performance and the cavitation behaviour.

It is requested to calculate the cavitation pattern for three operation points for a blade position of 0°. The zero degree position of the propeller blade corresponds to the 12 o'clock position (corresponding to the position of the most upright blade in the CAD files). The blade angles are counted in direction of rotation.

Also different views upon the propeller are requested:

- 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 SV1)
- Side view, facing the pressure side of the propeller (identifier SV2)

However each operation point shall only be evaluated for 2 different views.

It is also requested to provide the cavity surface between water and vapour for three different volume fractions and the thrust coefficient (along the rotation axis, in PCS) without cavitation and with cavitation for each operation point.

In total 3 simulations have to be carried out and 12 figures have to be generated (3 operation points, 1 blade positions, 2 volume fractions and 2 views).

Please note that case 2.1 and 2.3 are off-design conditions, while case 2.2 is for the operation point.

Requested computations:

Case 2.1:

Advanced coefficient	J	[-]	1.019
Cavitation number based on n	σ_n	[-]	2.024
Number of revolutions	n	[1/s]	20.000
Water density (for t_w = 22.0°C)	ρ	[kg/m^3]	997.780
Kinematic viscosity of water (for t_w = 22.0°C)	ν	[m²/s]	$9.567 \cdot 10^{-7}$
Vapour pressure (for t_w = 22.0°C)	p_v	[Pa]	2643
Oxygen saturation	α/α_s	[%]	46.05
Inclination angle	Ψ^{bP}	[°]	12

- Evaluation of cavitation for a blade position of 0°
- Evaluation of the cavity surface, defined by the interface between vapour and water, for a volume fraction of 40% (green) and 60% (blue) of vapour.
- Thrust coefficient K_{Tx} (PCS), for the non-cavitating and for the cavitating propeller.
- The following views are requested: SS and PS
- File name: [identifier1]_case2-1_[identifier2]. see figure format

Case 2.2:

Advanced coefficient	J	[-]	1.269
Cavitation number based on n	σ_n	[-]	1.424
Number of revolutions	n	[1/s]	20.000
Water density (for t_w = 21.9°C)	ρ	[kg/m^3]	997.800
Kinematic viscosity of water (for t_w = 21.9°C)	ν	[m²/s]	$9.591 \cdot 10^{-7}$
Vapour pressure (for t_w = 21.9°C)	p_v	[Pa]	2626
Oxygen saturation	α/α_s	[%]	46.74
Inclination angle	Ψ^{bP}	[°]	12

- Evaluation of cavitation for a blade position of 0°.
- Evaluation of the cavity surface, defined by the interface between vapour and water, for a volume fraction of 40% (green) and 60% (blue) of vapour.
- Thrust coefficient K_{Tx} (PCS), for the non-cavitating and for the cavitating propeller.
- The following views are requested: SS and PS
- File name: [identifier1]_case2-2_[identifier2]. see figure format

Case 2.3

Advanced coefficient	J	[-]	1.408
Cavitation number based on n	σ_n	[-]	2.000
Number of revolutions	n	[1/s]	20.000
Water density (for t_w = 23.2°C)	ρ	[kg/m^3]	997.410
Kinematic viscosity of water (for t_w = 23.2°C)	ν	[m²/s]	$9.229 \cdot 10^{-7}$
Vapour pressure (for t_w = 23.2°C)	p_v	[Pa]	2904
Oxygen saturation	α/α_s	[%]	42.54
Inclination angle	Ψ^{bP}	[°]	12

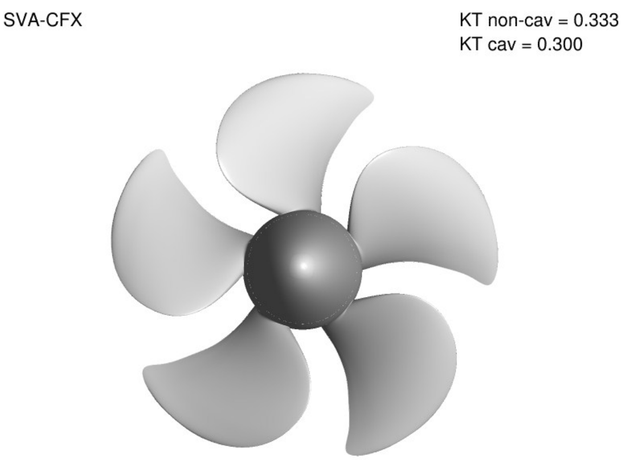
- Evaluation of cavitation for a blade position of 0°
- Evaluation of the cavity surface, defined by the interface between vapour and water, for a volume fraction of 40% (green) and 60% (blue) of vapour .
- Thrust coefficient K_{Tx} (PCS), for the non-cavitating and for the cavitating propeller.
- The following views are requested: SS and PS
- File name: [identifier1]_case2-3_[identifier2]. see figure format

Figure format:

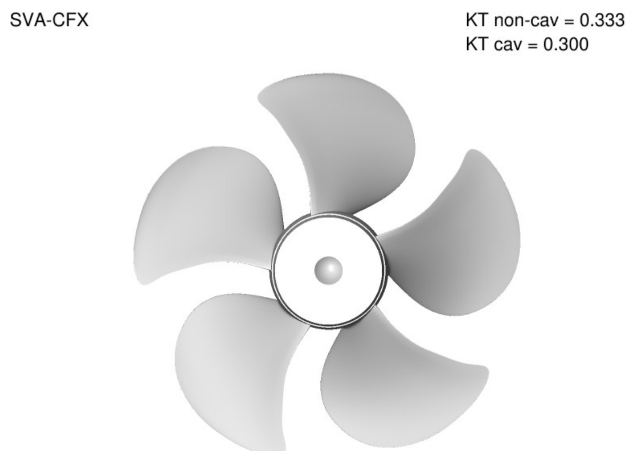
The view upon the propeller should resemble the one from the figures given below.

- Image size should be 800*600 pixel
- Propeller surface should be coloured in grey
- The isosurfaces of the cavity should be coloured as follows:
  40% vapour: green
  60% 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_{Tx} (**non-cavitating**) value should be added in the top right corner of the figure.
- The calculated K_{Tx} (**cavitating**) value should be added in the top right corner of the figure, below the thrust coefficient without cavitation.
- 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 2-1 for 40% vapour fraction and looking upon the pressure side of the propeller it would be: **SVA_CFX_case2-1_40PS.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)



Formula:

Advance coefficient: $$J = \frac{V_A}{n \cdot D_P}$$

Thrust coefficient: $$K_{Tx} = \frac{T_x}{\rho \cdot n^2 \cdot D_P^4}$$

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

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

With D_P being the propeller diameter, T_x the propeller thrust (PCS), Q the propeller torque, p the tunnel pressure and p_v the vapour pressure.

Propeller coordinate system (PCS)

An orthogonal coordinate system is used for the propeller, with the x-axis pointing upstream against the flow direction and the z-axis upwards.

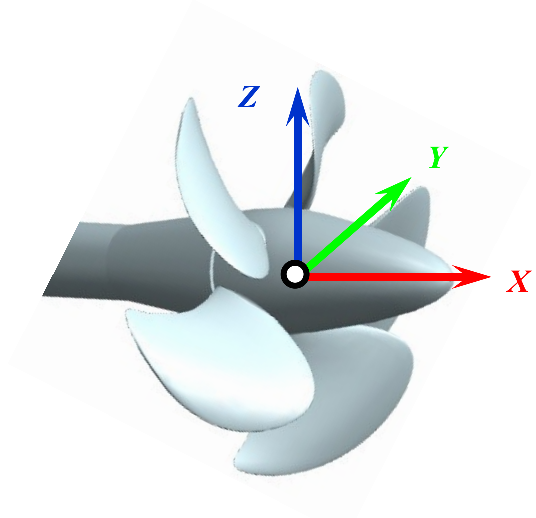


Fig. 2: Propeller coordinate system