Potsdam Propeller Test Case (PPTC)

Measurement of the Cavitation Nuclei in the Tunnel Water and Cavitation Observations with the Model Propeller VP1304

Report 3890

Potsdam and Rostock, March 2013

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This report includes
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24 pages diagrams/drawings
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Management Authors

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1 Summary

For the SMP'11 workshop the SVA provided the controllable pitch propeller VP1304 as a test case [1].

The open water characteristic and the cavitation behaviour of the model propeller VP1304 were investigated in the small test section of the cavitation tunnel K15A of the Potsdam Model Basin (SVA) [2].

The propeller VP1304 was used in the research project "KonKav I", funded by the Federal Ministry of Economics and Technology, for investigations about the influence of the water quality on the cavitation behaviour of propellers. The R&D-project is a joint project with the partners Hamburg Ship Model Basin (HSVA), Institute of Fluid Dynamics and Ship Theory, Hamburg University of Technology (TUHH), Institute of General Electrical Engineering, University Rostock (UniHRO) and Potsdam Model Basin (SVA).

This report presents results of systematic measurements of the water quality and the cavitation behaviour of the propeller VP1304 (PPTC).

2 Introduction

The prediction of the cavitation behaviour of a propeller is important to analyse the propeller in design and off-design conditions. The propeller VP1304 was designed to generate a tip vortex. Extensive model tests had been carried out to get data for the validation of potential and viscous flow propeller analysis programs [1].

This report presents the measured open water characteristics and cavitation behaviour of the model propeller VP1304, measured in the large test section of the cavitation tunnel K15A [3]. In addition measurements were carried out to characterise the water quality and to determine the cavitation characteristic. Results of the R&D-project are presented in different papers [4] – [10].

3 Tasks

The model propeller VP1304 was tested in the cavitation tunnel of the Potsdam Model Basin in homogeneous flow. The aim of the tests was the investigation of the influence of the water quality (gas content and nuclei distribution) on the cavitation behaviour of the propeller. The following tests should be carried out:

- Variation of the cavitation number at the propeller thrust coefficients K_T = 0.38 and 0.17
- Variation of the number of revolutions (n = 17, 21 and 25 s^{-1}) at the propeller thrust coefficient K_T = 0.38 and cavitation numbers 3.0 and 2.0
- Variation of the number of revolutions (n = 17 and 21 s^{-1}) at the propeller thrust coefficient K_T = 0.17 and the cavitation number 2.0
- Observation of the cavitation behaviour (sketches, photographs) for each measuring point

- Variation of the gas content (oxygen saturation) of the tunnel water in three steps (α/α_S about 80%, 60% and 40%)

4 Description of the model propeller VP1304

The propeller was designed by the SVA in 1998. For the manufacture of the propeller cold-rolled brass was used as raw material. The blades were manufactured on a CNC-based milling machine with HSC (high speed cutting) technology.

The propeller main properties are shown in table 1 and in the drawing on page 3.1. Photos of the propeller are shown on pages 4.1 and 4.2. The propeller is a controllable pitch propeller. This affects the propeller blade design near the hub and results in a 0.3 mm gap between hub and propeller blade near the leading and trailing edge of the propeller.

Table 1: Main data of model propeller

			VP1304
Diameter	D	[m]	0.250
Design pitch ratio r/R = 0.7	$P_{0.7}/D$	[–]	1.635
Area ratio	A_E/A_0	[m]	0.77896
Chord length r/R = 0.7	$c_{0.7}$	[m]	0.10417
Skew	θ_{EXT}	[°]	18.837
Hub ratio	d_h/D	[–]	0.300
Number of blades	Z	[–]	5
Sense of rotation		[–]	right
Type			controllable pitch propeller

5 Test arrangement

5.1 Cavitation tunnel

The tests were carried out in the large test section of the cavitation tunnel K15A from Kempf & Remmers. The dynamometer J25 from Kempf & Remmers was used for the tests. The dynamometer was arranged in front of the propeller model (drawings on page 3.2, photos on pages 4.1 and 4.2). The shaft inclination was zero degrees.

5.2 Cavitation nuclei spectra and cavitation behaviour characterization

The measurement of bubble sizes and concentrations is performed by a commercially standard two-component phase Doppler system from Dantec Dynamics (photos on page 4.3) with following parameters:

Transmitter focal length: 310 mm
Receiver focal length: 1000 mm
Scattering angle (in water): 88°
Beam diameter: 151 µm
Nominal detection area: 0.058 mm²
Meas. range (max. *D*p): 227 µm

The measurement point is located in the lateral direction next to the propeller shaft as possible and in the flow direction in the first possible position.

Shadow imaging was used for detailed characterization of the cavitation behaviour of the propeller. Standard CCD cameras with different viewing angles have been arranged at the test section (photos on page 4.4). The first camera was set up to a straight viewing angle with least aberrations. The second camera was horizontally displaced by a small margin and provided a better estimate of the physical extension of the tip vortex. High speed cameras had been arranged additional to capture the tip vortex on the propeller blade itself.

6 Test procedure

Apart from the calibration of the measuring device, runs had been made in order to measure the idle torque with a dummy hub, having the same shape as the real propeller hub.

A variation of the cavitation number had been carried out at two propeller thrust loading coefficients (propeller thrust coefficients $K_T = 0.38$ and 0.17).

A variation of the number of revolutions (n = 17, 21 and 25 s^{-1}) had been carried out at the propeller thrust coefficient $K_T = 0.38$ and cavitation numbers 3.0 and 2.0.

A variation of the number of revolutions (n = 17 and 21 s^{-1}) had been carried out at the propeller thrust coefficient $K_T = 0.17$ and the cavitation number 2.0.

The thrust coefficient was adjusted at the given number of revolutions and atmospheric pressure by variation of the inflow speed. The cavitation number was adjusted by the change of the pressure in the test section.

The values velocity V_c, number of revolutions n, thrust T, torque Q and pressure D_{H2} were measured at each measuring point. The cavitation behaviour of the propeller was observed by sketches and photographs.

The gas content (oxygen saturation) of the tunnel water was varied in three steps (α/α_S about 80%, 60% and 40%).

An overview of all tests and test parameters is given on the pages 2.2 and 2.3. The pages 2.4 and 2.5 show tables with the test numbers and the pages for the tables, sketches and photographs.

7 Test results

7.1 Open water characteristics

The tables on the pages 2.8 to 2.10 contain the characteristics of the model propeller in model scale in the cavitation tunnel, measured in the small test section of the cavitation tunnel in November 2010. The influence of the test section on the propeller coefficients was corrected with the method from Glauert.

The figure on page 3.4 shows the open water characteristics of the model propeller VP1304. The Reynolds number effect on the open water characteristics is small in the tested range.

The figure on page 3.5 shows the working points, determined by the propeller thrust coefficients $K_T = 0.38$ and 0.17, in connection with the open water characteristics.

7.2 Cavitation behaviour

The tables on pages 2.11 to 2.25 present the measuring points for the cavitation observations and measurements of the nuclei distributions.

The cavitation behaviour was observed on the blade 1 of the model propeller. The cavitation is documented in cavitation sketches and in photographs.

Tip vortex and suction side cavitation appear in the working point at $K_T = 0.38$. The tip vortex cavitation starts behind the propeller blades in the propeller stream. The observation point in which the cavitating tip vortex meets to about 50% the blade tip was chosen as the inception point (BTVC). The point without tip vortex cavitation at the blade tip was determined as end of tip vortex cavitation (ETVC). The determination of these points was difficult due to the intermittent character of the tip vortex cavitation.

The table 2 shows the cavitation numbers for the inception $\sigma_{n\mathrm{i}}$ and for the end of the tip vortex cavitation $\sigma_{n\mathrm{d}}$ at blade 1 at the varied gas content of the tunnel water. The gas content is influencing the inception of the tip vortex cavitation. At high gas content the tip vortex cavitation starts at higher cavitation numbers (diagram on page 3.6 above).

Table 2: Begin and end of tip vortex cavitation on blade 1, $K_T = 0.38$

Test No.	Gas content α/α_S	BTVC σ_{ni}	ETVC σ_{nd}
12KM0028	0.80	6.389	8.871
12KM0032	0.60	4.762	8.478
12KM0037	0.40	4.167	6.907

Pressure side cavitation appears in the working point at $K_T = 0.17$. The pressure side cavitation starts at the leading edge in the radius range $r/R = 0.8$ to 0.9.

The table 3 shows the cavitation numbers for the inception σ_{ni} and for the end of the pressure side cavitation σ_{nd} at blade 1 at the varied gas content of the tunnel water. The gas content isn't influencing the inception of the pressure side cavitation (diagram on page 3.6 below).

Table 3: Begin and end of pressure side cavitation on blade 1, K_T = 0.17

Test No.	Gas content α/α_S	BPSC σ_{ni}	EPSC σ_{nd}
12KM0029	0.80	4.144	4.813
12KM0033	0.60	3.712	4.939
12KM0021	0.40	4.055	4.863

7.3 Bubble sizes and concentrations

The tables on pages 2.6 and 2.7 show the test numbers and parameters for the bubble size and concentration measurements.

Bubbles are detected via a coincidence check between two measured phase differences. The phase difference values are visualized in a 2D phase plot as shown in Figure 1 for a typical measurement.

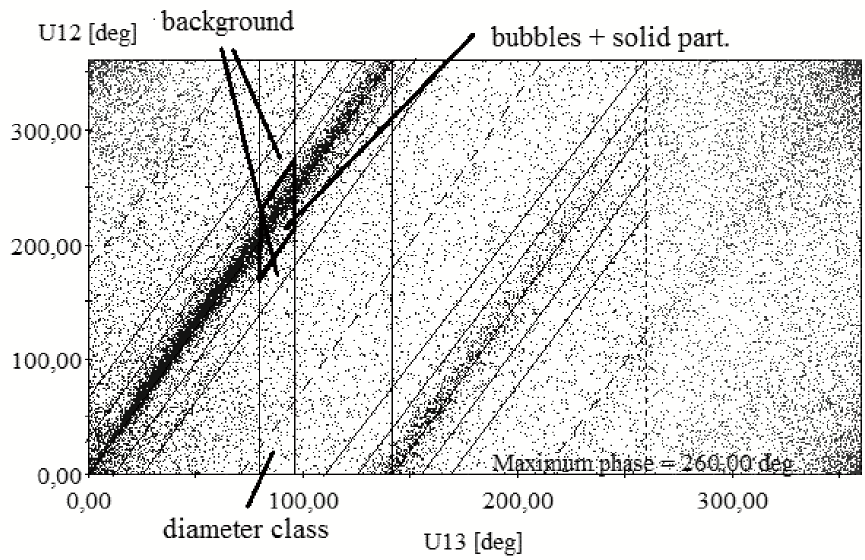


Figure 1: 2D phase plot with signals from bubbles and solid particles. [8]

The estimation of the bubble concentration spectrum is also described in [8]. The results are two concentration values for each diameter class. The basis of the first values is the numbers of measurements in the inner parallelogram (see Figure 1). The second one is the values corrected by subtracting the estimated concentrations of non-spherical particles. Figure 2 show a typical result for moderate bubble concentrations. The results for all described experiments are listed in the tables on the pages 2.26 to 2.31.

In case of slow bubble concentration the corrected concentration in the same diameter classes is negative. It is recommended for numerical models to use an averaged envelope and/or to replace negative value to zero.

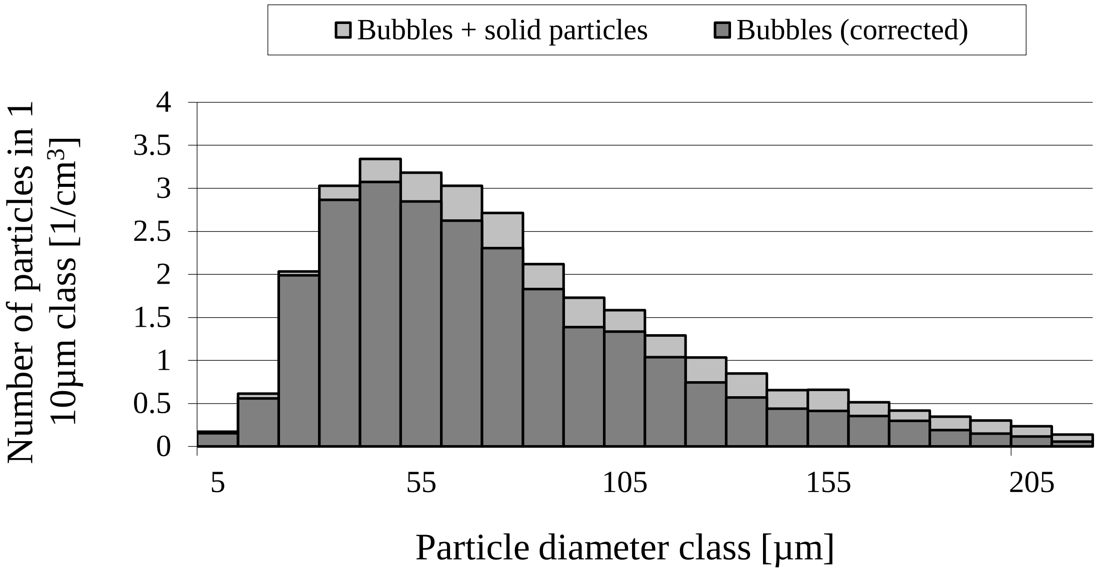


Figure 2: Example for estimated bubble concentration distribution by background subtraction

The analysis of the measurements with the propeller VP1304 in homogeneous inflow shows the following tendencies:

- Pronounced bubble concentration spectra have been measured only at high gas contents (oxygen saturation) and low pressure in the test section.
- The characteristic bubble concentration spectrum is changing with the gas content of the tunnel water.
- The bubble concentration spectrum will be influenced by the sequence of the tests (sequence of pressure in the test section, increasing or decreasing pressure between two measuring points).
- The water quality (gas content, bubble concentration spectrum) is mainly influencing the cavitation inception and the end of cavitation as well as the stability and thickness of the cavitation.

The Figure 3 shows exemplary the change of the bubble concentration spectrum with the increasing of the gas content of the tunnel water for two working conditions of the propeller.

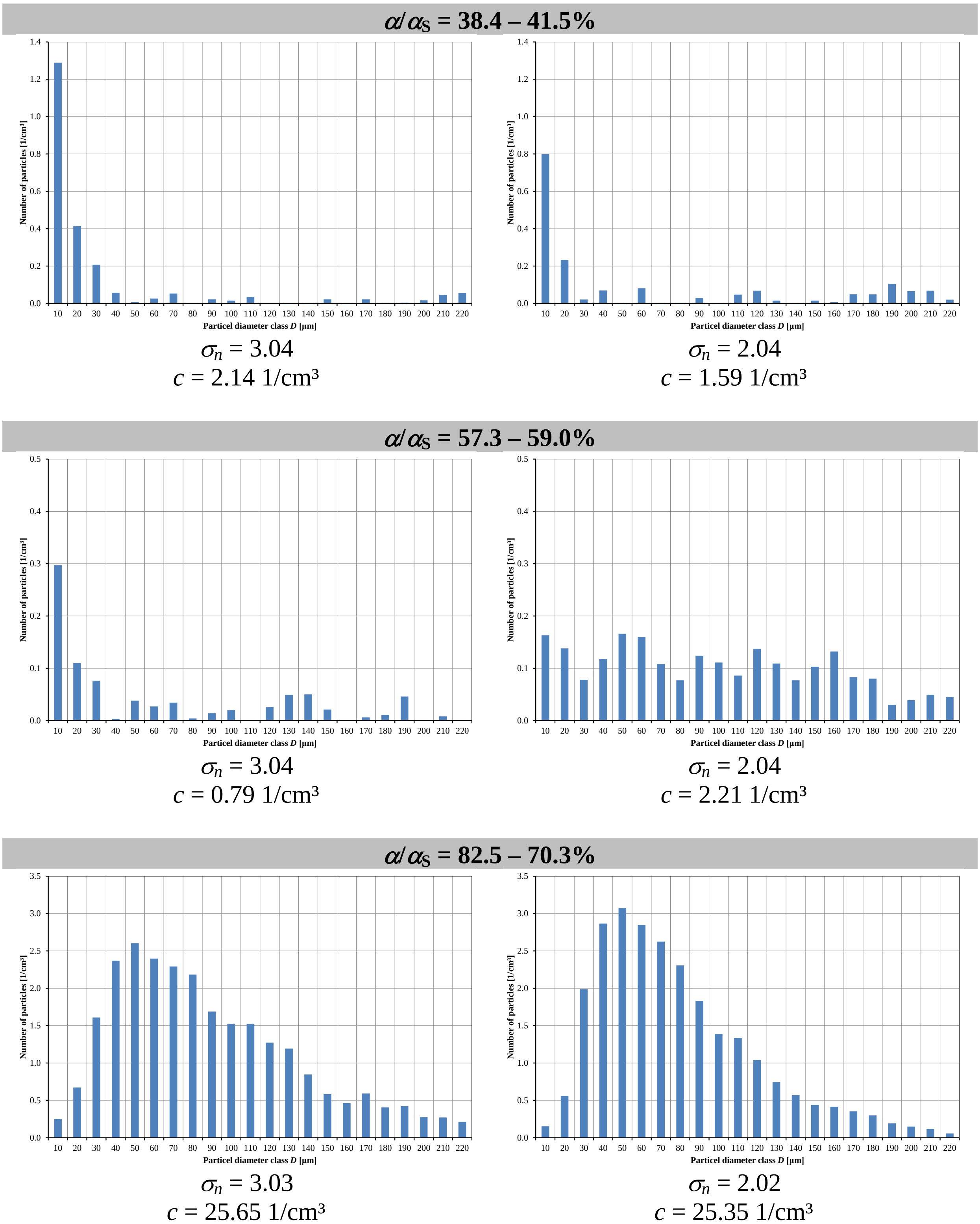


Figure 3: Bubble concentration spectra, VP1304, K_T = 0.38, variation of the gas content

The observation of differences in the cavitation behaviour due to the variation of the gas content is difficult, if the cavitation is full developed. Special cavitation observations have been carried out with cameras to get more information about the cavitation characteristic. The

Figure 4 shows an example from the determination of the cavitation intensity with stereo pictures [4].

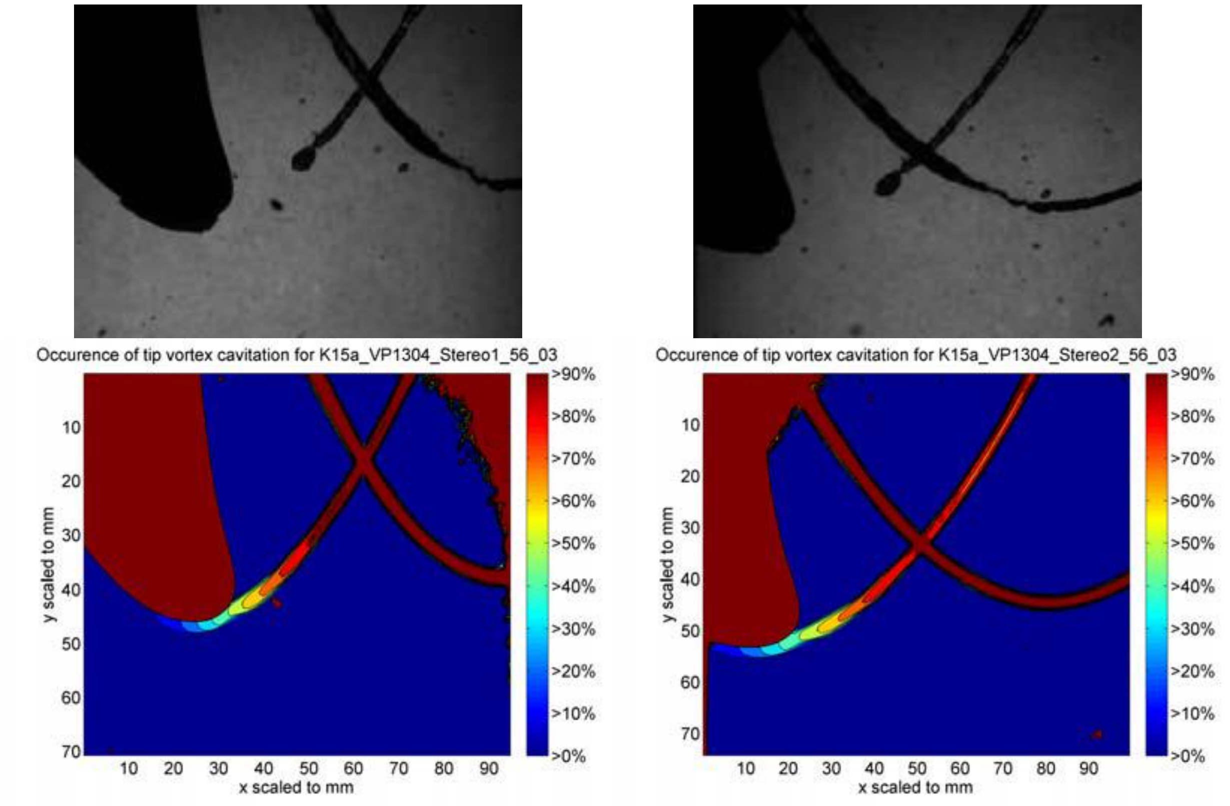
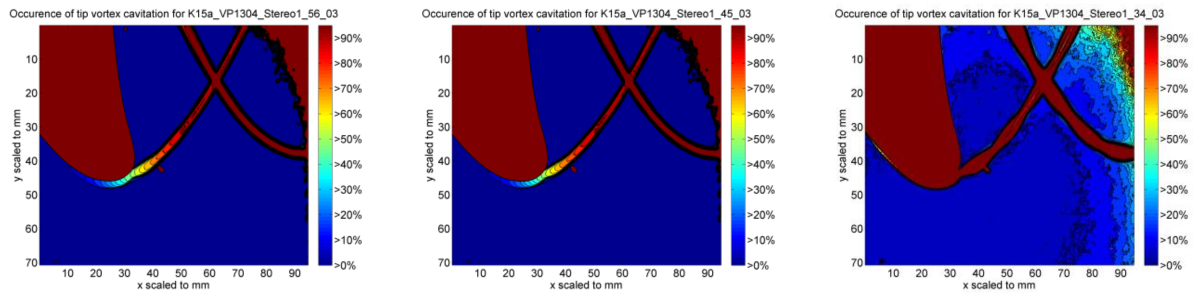


Figure 4: Pictures of the tip vortex cavitation with both cameras,
K_T = 0.38, σ_n = 3.03, α/α_S = 40% [9]

The comparison of the intensity of the tip vortex cavitation, measured with the stereo cameras, shows that the tip vortex cavitation of the propeller VP1304 is more stable and stronger developed if the gas content in the tunnel water is higher (Figure 5).



α/α_S = 40% α/α_S = 60% α/α_S = 80%

Figure 5: Intensity of tip vortex cavitation at VP1304, K_T = 0.38, σ_n = 3.03,
variation of the gas content

The Figure 6 shows the bubble spectra of the tunnel water for the tested working point at the three different gas contents. The bubble spectra of the tunnel water with an oxygen saturation of 40 and 60% are characterised by small bubbles in the diameter range 10 to 30 µm. The water with an oxygen saturation of 60% contains also a low number of bubbles with a larger diameter. The water with an oxygen saturation of 80% shows a developed bubble spectra with the maximum number of bubbles in the diameter range 40 to 80 µm. The total bubble concentration is distinctly larger in the water with the oxygen saturation of 80%.

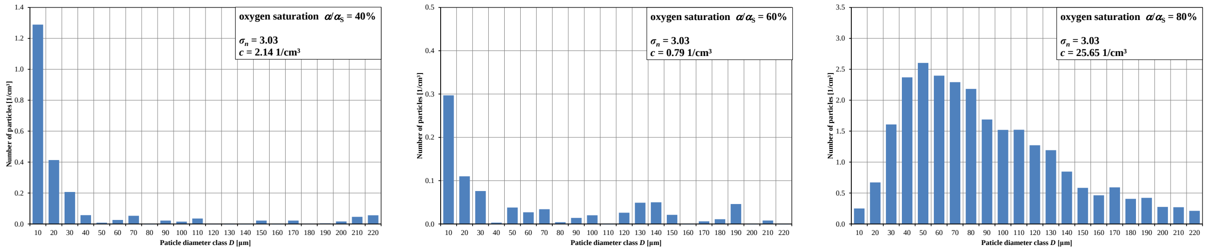


Figure 6: Bubble spectra, VP1304, K_T = 0.38, σ_n = 3.03, variation of the gas content

The analysis of the measurements with the propeller VP1304 in homogeneous inflow shows the following tendencies:

- Pronounced bubble concentration spectra have been measured only at high gas contents (oxygen saturation) and low pressure in the test section.
- The characteristic of the bubble spectrum is mainly changing if the gas content reaches high values.
- The bubble spectrum and the total bubble concentration in the test water are influenced by the sequence of the tests (sequence of pressure in the test section, increasing or decreasing of the pressure between two measuring points) (Figure 7).
- The water quality (gas content, bubble spectrum) is mainly influencing the cavitation inception and the end of cavitation as well as the stability and thickness of the cavitation.

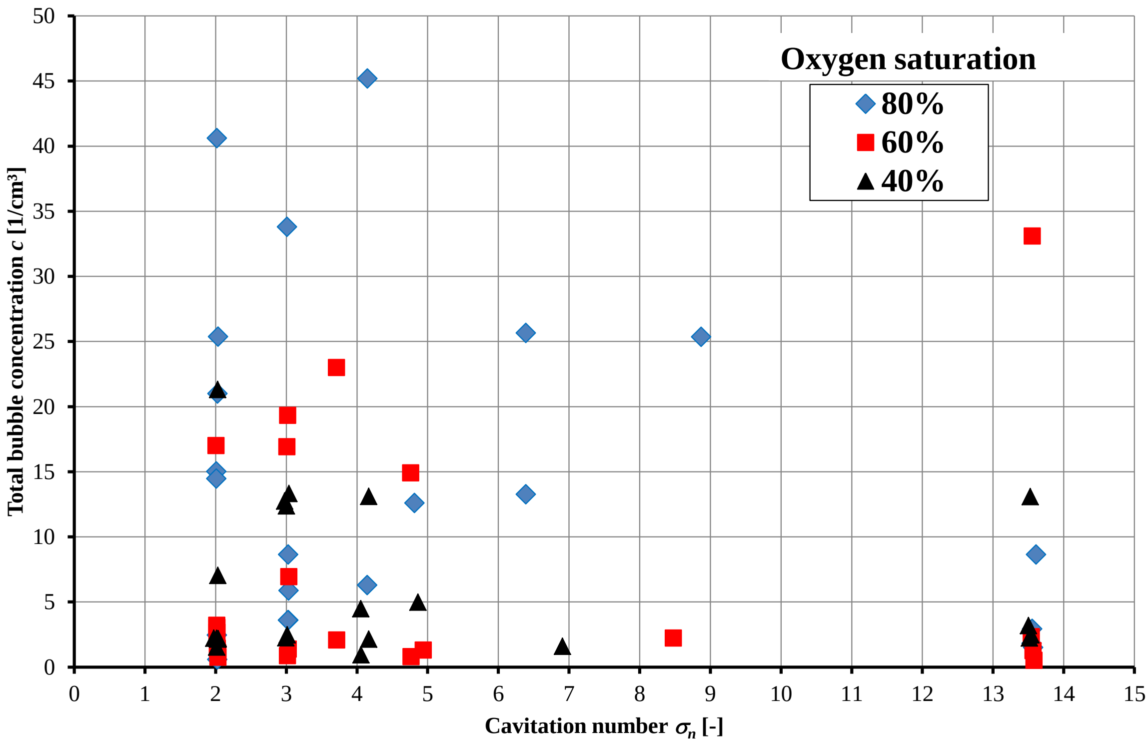


Figure7: Total bubble concentration during the tests with the VP1304

8 References

[1] Potsdam Propeller Test Case (PPTC)
Proceedings of the Workshop on Cavitation and Propeller Performance
Second International Symposium on Marine Propulsors - smp'11
17 – 18 June 2011, Hamburg, Germany

[2] Heinke, H.-J.
Potsdam Propeller Test Case (PPTC) - Open Water and Cavitation Tests with the Model Propeller VP1304
Report 3753, Schiffbau-Versuchsanstalt Potsdam, April 2011

[3] Heinke, H.-J.
Measurement of the Propeller Characteristics and Cavitation Tests with the Model Propeller VP1304 at Different Gas Contents of the Tunnel Water
Report 3890.1, Schiffbau-Versuchsanstalt Potsdam, February 2012

[4] Höhne, S.; Kröger, W.; Borchert, S.; Damaschke, N. A.
Optical methods for nuclei spectra characterization in cavitation tunnels
Proceedings of the Eighth International Symposium on Cavitation (CAV 2012), Singapore, 2012

[5] Borchert, S.; Kröger, W.; Höhne, S.; Damaschke, N. A.; Zhou, Z.
On Optical Quantification of Cavitation Properties
Proceedings of the Eighth International Symposium on Cavitation (CAV 2012), Singapore, 2012

[6] Heinke, H.-J.; Johannsen, C.; Kröger, W.; Schiller, P.; Weitendorf, E.-A.
On Cavitation Nuclei in Water Tunnels
Proceedings of the Eighth International Symposium on Cavitation (CAV 2012), Singapore, 2012

[7] Yakubov, S.; Cankurt, B.; Schiller, P.; Abdel-Maksoud, M.; Rung, T.
An Advanced Euler-Lagrange Approach to Numerical Simulation of Cavitating Engeneering Flows
Proceedings of the Eighth International Symposium on Cavitation (CAV 2012), Singapore, 2012

[8] Yakubov, S.; Cankurt, B.; Marquil, T.; Schiller, P.; Abdel-Maksoud, M.; Rung, T.
Euler-Euler and Euler-Lagrange Approaches to Cavitation Modeling in Marine Applications
IV International Conference on Computational Methods in Marine Engineering, MARINE 2011, Lisabon, Portugal, September 2011

[9] Kröger, W.; Borchert, S.; Höhne, S.; Damaschke, N.
Messungen des Spektrums von Kavitationskeimen vor Strömungsprofilen mittels Phasen-Doppler-Technik
Fachtagung "Lasermethoden in der Strömungsmesstechnik", Ilmenau, September 2011

[10] Kröger, W.; Borchert, S.; Höhne, S.; Damaschke, N.
Quantitative Measurements of water quality and cavitation phenomena in cavitation tunnels
29th Symposium on Naval Hydrodynamics, Gothenburg, Sweden, August 2012

Details of model tests

VP1304

Cavitation tunnel	K15A (Kempf & Remmers)
Dimensions of the test section	0.850 m · 0.850 m with rounded edges
Propeller	VP1304
Material of the propeller	brass
Type of propeller	controllable pitch propeller
Diameter of propeller	0.250 m
Measuring equipment in cavitation tunnel for:	
Number of revolutions, thrust and torque	dynamometer J25 with: T_{max} = 3000 N Q_{max} = 150 Nm
Inflow velocity	manometer (principle of Venturi nozzle)
Maximum inflow velocity	V_{max} = 8 m/s
Measurement of bubble sizes and concentrations	PDA-system from Dantec Dynamics

Overview of model tests with the VP1304

Open water tests in the cavitation tunnel, small test section (600 x 60 mm)

Test No.	Date	Test	Test parameters	Table	Diagram
10PH0544	09/11/10	Open water test	V_V = 1.76 – 6.25 m/s, n = 15 s^{-1}	2.8	3.4
10PH0545	09/11/10	Open water test	V_V = 2.36 – 8.45 m/s, n = 20 s^{-1}	2.9	3.4
10PH0546	09/11/10	Open water test	V_V = 2.97 - 10.38 m/s, n = 25 s^{-1}	2.10	3.4

Overview of model tests with the VP1304

Cavitation observation and measurement of the nuclei in the tunnel water, gas content about 80%

Test No. SVA	No. KonKav	Date	α/α_S [%]	K_T [-]	n [s^{-1}]	V_c [m/s]	σ_{nc}, σ_{ni}, σ_n, σ_{nmin}, σ_n, σ_{nd}, σ_{nc} [-]
12KM0028	34	16.01.12	82.5 70.3	0.38	21	5.237	13.55, 6.39, 3.03, 2.02 6.39, 8.87, 13.57
12KM0029	35	16.01.12	83.4 75.1	0.17	21	7.363	13.55, 4.14, 3.01, 2.02 4.15, 4.81, 13.55
12KM0027	41 40 39	16.01.12	77.7 70.1	0.38	25 21 17	6.215 5.251 4.264	3.03
12KM0030	38 37 36	16.01.12	81.9 62.6	0.38	25 21 17	6.194 5.243 4.237	2.02
12KM0031	43 42	16.01.12	80.0 59.1	0.14	21 17	7.342 5.982	2.01

Test No. SVA	No. KonKav	Date	Tables	Sketches Diagrams	Photographs
12KM0028	34	16.01.12	2.11, 2.26, 2.29	3.7, 3.8	4.5
12KM0029	35	16.01.12	2.12, 2.26, 2.29	3.9	4.6
12KM0027	41 40 39	16.01.12	2.13, 2.26, 2.29	3.10	4.7
12KM0030	38 37 36	16.01.12	2.14, 2.26, 2.29	3.11	4.8
12KM0031	43 42	16.01.12	2.15, 2.26, 2.29	3.12	4.9

Overview of model tests with the VP1304

Cavitation observation and measurement of the nuclei in the tunnel water, gas content about 60%

Test No. SVA	No. KonKav	Date	α/α_S [%]	K_T [-]	n [s^{-1}]	V_c [m/s]	σ_{nc}, σ_{ni}, σ_n, σ_{nmin}, σ_n, σ_{nd}, σ_{nc} [-]
12KM0032	45	17.01.12	57.3 59.0	0.38	21	5.246	13.55, 4.76, 3.04, 2.04 4.76, 8.45, 13.58
12KM0033	46	17.01.12	59.0 65.4	0.17	21	7.352	13.54, 3.71, 3.01, 2.01 3.72, 4.94, 13.57
12KM0034	52 51 50	17.01.12	58.6 57.8	0.38	25 21 17	6.193 5.222 4.227	3.02
12KM0035	49 48 47	17.01.12	57.8 56.3	0.38	25 21 17	6.211 5.228 4.224	2.03
12KM0036	54 53	17.01.12	56.3 55.3	0.17	21 17	7.371 5.969	2.02

Test No. SVA	No. KonKav	Date	Tables	Sketches	Photographs
12KM0032	45	17.01.12	2.16, 2.27, 2.30	3.13, 3.14	4.10
12KM0033	46	17.01.12	2.17, 2.27, 2.30	3.15	4.11
12KM0034	52 51 50	17.01.12	2.18, 2.27, 2.30	3.16	4.12
12KM0035	49 48 47	17.01.12	2.19, 2.27, 2.30	3.17	4.13
12KM0036	54 53	17.01.12	2.20, 2.27, 2.30	3.18	4.14

Overview of model tests with the VP1304

Cavitation observation and measurement of the nuclei in the tunnel water, gas content about 40%

Test No. SVA	No. KonKav	Date	α/α_S [%]	K_T [-]	n [s^{-1}]	V_c [m/s]	σ_{nc}, σ_{ni}, σ_n, σ_{nmin}, σ_n, σ_{nd}, σ_{nc} [-]
12KM0037	56	17.01.12	38.4 41.5	0.38	21	5.228	13.53, 4.17, 3.04, 2.04 4.17, 6.91, 13.54
12KM0042	57	18.01.12	42.0 52.8	0.17	21	7.368	13.50, 4.06, 2.98, 1.97 4.06, 4.86, 13.52
12KM0040	63 62 61	18.01.12	42.4 45.7	0.38	25 21 17	6.229 5.243 4.224	3.03
12KM0038	60 59 58	17.01.12	41.5 41.7	0.38	25 21 17	6.203 5.230 4.221	2.03
12KM0041	65 64	18.01.12	40.9 42.0	0.17	21 17	7.372 5.940	2.01

Test No. SVA	No. KonKav	Date	Tables	Sketches	Photographs
12KM0037	56	17.01.12	2.21, 2.28, 2.31	3.19,3.20	4.15
12KM0042	57	18.01.12	2.22 2.28, 2.31	3.21	4.16
12KM0040	63 62 61	18.01.12	2.23 2.28, 2.31	3.22	4.17
12KM0038	60 59 58	17.01.12	2.24 2.28, 2.31	3.23	4.18
12KM0041	65 64 66	18.01.12	2.25 2.28, 2.31	3.24	4.19

Overview of model tests with the VP1304

Measurement of bubble sizes and concentrations, gas content about 80%

Test No. SVA	No. KonKav	n [s^{-1}]	V [m/s]	σ_n [-]	α/α_S [%]	Date	Time	Table
12KM0027	41	25	6.290	3.030	77.7	16/01/2012	11:59:33	2.13
	40	21	5.314	3.026		16/01/2012	12:21:06	
	39	17	4.314	3.024	70.1	16/01/2012	12:38:38	
12KM0028	34.1	21	5.237	13.608	82.5	16/01/2012	14:07:40	2.11
	34.2	21	5.237	6.389		16/01/2012	14:20:40	
	34.3	21	5.238	3.031		16/01/2012	14:33:26	
	34.4	21	5.239	2.024		16/01/2012	14:44:17	
	34.5	21	5.238	6.391		16/01/2012	14:56:10	
	34.6	21	5.238	8.871		16/01/2012	15:08:51	
	34.7	21	5.237	13.569	70.3	16/01/2012	15:21:54	
12KM0029	35.1	21	7.361	13.545	83.4	16/01/2012	16:11:21	2.12
	35.2	21	7.363	4.144		16/01/2012	16:21:45	
	35.3	21	7.363	3.010		16/01/2012		
	35.4	21	7.367	2.017		16/01/2012	16:42:57	
	35.5	21	7.362	4.147		16/01/2012	16:54:01	
	35.6	21	7.362	4.813		16/01/2012	17:08:50	
	35.7	21	7.361	13.553	75.1	16/01/2012	17:22:50	
12KM0030	38	25	6.194	2.019	81.9	16/01/2012	18:03:57	2.14
	37	21	5.243	2.026		16/01/2012	18:21:20	
	36	17	4.237	2.034	62.5	16/01/2012	18:36:24	
12KM0031	43	21	7.342	2.009	80	16/01/2012	19:17:15	2.15
	42	17	5.982	2.011	59.1	16/01/2012	19:38:33	

Measurement of bubble sizes and concentrations, gas content about 60%

Test No. SVA	No. KonKav	n [s^{-1}]	V [m/s]	σ_n [-]	α/α_S [%]	Date	Time	Table
12KM0032	45.1	21	5.245	13.557	57.3	17/01/2012	07:41:54	2.16
	45.2	21	5.246	4.762		17/01/2012	08:05:36	
	45.3	21	5.246	3.037		17/01/2012	08:16:25	
	45.4	21	5.246	2.035		17/01/2012	08:27:18	
	45.5	21	5.246	4.766		17/01/2012	08:41:50	
	45.6	21	5.246	8.478		17/01/2012	08:54:10	
	45.7	21	5.246	13.581	59	17/01/2012	09:06:56	
12KM0033	46.1	21	7.35	13.544		17/01/2012	10:37:26	2.17
	46.2	21	7.351	3.712		17/01/2012	10:54:37	
	46.3	21	7.352	3.011		17/01/2012	11:10:00	
	46.4	21	7.353	2.007		17/01/2012		
	46.5	21	7.352	3.715		17/01/2012	11:34:45	
	46.6	21	7.351	4.939		17/01/2012	11:46:34	
	46.7	21	7.35	13.568	65.4	17/01/2012	12:01:42	
12KM0034	52	25	6.193	3.029	58.6	17/01/2012	13:04:06	2.18
	51	21	5.222	3.022		17/01/2012	13:20:23	
	50	17	4.227	3.019	57.6	17/01/2012	13:38:38	
12KM0035	49	25	6.211	2.035	57.8	17/01/2012	14:05:03	2.19
	48	21	5.228	2.025		17/01/2012	14:20:54	
	47	17	4.224	2.022	56.3	17/01/2012	14:35:07	
12KM0036	54	21	7.371	2.019	56.3	17/01/2012	15:05:52	2.20
	53	17	5.969	2.021	55.3	17/01/2012	15:21:30	

Overview of model tests with the VP1304

Measurement of bubble sizes and concentrations, gas content about 40%

Test No. SVA	No. KonKav	n [s^{-1}]	V [m/s]	σ_n [-]	α/α_S [%]	Date	Time	Table
12KM0037	56.1	21	5.227	13.526	38.4	17/01/2012	16:40:14	2.21
	56.2	21	5.227	4.167		17/01/2012	17:00:58	
	56.3	21	5.228	3.038		17/01/2012	17:11:50	
	56.4	21	5.228	2.036		17/01/2012	17:22:33	
	56.5	21	5.227	4.167		17/01/2012	17:33:23	
	56.6	21	5.227	6.907		17/01/2012	17:49:04	
	56.7	21	5.227	13.537	41.5	17/01/2012	18:02:10	
12KM0038	60	25	6.203	2.033	41.5	17/01/2012	18:31:15	2.24
	59	21	5.230	2.029		17/01/2012	18:48:23	
	58	17	4.221	2.029	41.7	17/01/2012	19:02:49	
12KM0040	63	25	6.229	3.012	42.4	18/01/2012	11:44:45	2.23
	62	21	5.243	3.001		18/01/2012	12:02:50	
	61	17	4.224	2.995	45.7	18/01/2012		
12KM0041	65	21	7.372	2.014	40.9	18/01/2012	13:03:40	2.25
	64	17	5.940	2.014	42	18/01/2012	13:20:50	
12KM0042	57.1	21	7.367	13.503	42	18/01/2012	13:50:51	2.22
	57.2	21	7.386	4.055		18/01/2012	14:03:40	
	57.3	21	7.386	2.976		18/01/2012	14:14:44	
	57.4	21	7.371	1.973		18/01/2012	14:26:24	
	57.5	21	7.368	4.057		18/01/2012	14:41:43	
	57.6	21	7.368	4.863		18/01/2012	14:53:17	
	57.7	21	7.367	13.515	52.8	18/01/2012	15:07:17	

Open water test in the cavitation tunnel, $n = 15\ s^{-1}$

Test	**10PH0544**				Date		09.11.2010
Type of test	**OWT, $n = 15\ s^{-1}$**						

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	22.1	ν	[m²/s]	9.581e-7	ρ	[kg/m³]	997.71
Air content	[%]	46.70	p_A	[kPa]	98.237	p_V	[kPa]	2.687
Test section		600 x 600	w_a	[-]	0.000	t_A	[°C]	21.9

Characteristic of propeller (model scale), velocity correction by Glauert

No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
1	0.4255	0.6824	1.6220	0.285	143.841	26.039	5.190	0.912	9.60
2	0.5379	0.6194	1.4854	0.357	90.047	26.053	5.083	0.922	5.45
3	0.6553	0.5568	1.3539	0.429	60.689	26.063	4.950	0.934	3.30
4	0.7676	0.4930	1.2240	0.492	44.337	26.127	4.816	0.947	2.13
5	0.8851	0.4363	1.1018	0.558	33.350	26.127	4.649	0.964	1.42
6	1.0132	0.3708	0.9693	0.617	25.309	25.980	4.432	0.987	0.92
7	1.1432	0.3057	0.8361	0.665	19.877	25.977	4.229	1.011	0.60
8	1.2467	0.2492	0.7194	0.687	16.759	26.050	4.076	1.029	0.41
9	1.3776	0.1837	0.5795	0.695	13.681	25.963	3.856	1.058	0.25
10	1.4875	0.1187	0.4472	0.628	11.731	25.956	3.682	1.083	0.14
11	1.5708	0.0633	0.3326	0.476	10.517	25.948	3.553	1.102	0.07
12	1.6680	-0.0100	0.1705	-0.156	9.323	25.937	3.405	1.125	-0.01

Open water test in the cavitation tunnel, $n = 20\ s^{-1}$

Test	**10PH0545**	Date	09.11.2010
Type of test	**OWT, $n = 20\ s^{-1}$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	23.6	ν	[m²/s]	9.251e-7	ρ	[kg/m³]	997.34
Air content	[%]	47.90	p_A	[kPa]	98.264	p_V	[kPa]	2.944
Test section		600 x 600	w_a	[-]	0.000	t_A	[°C]	22.2

Characteristic of propeller (model scale), velocity correction by Glauert

No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}	comment
1	0.4274	0.6798	1.6035	0.288	85.542	15.624	3.113	1.261	9.48	TVC
2	0.4999	0.6426	1.5139	0.338	62.670	15.664	3.080	1.268	6.55	
3	0.6155	0.5788	1.3798	0.411	41.365	15.672	3.005	1.284	3.89	
4	0.7273	0.5160	1.2606	0.474	28.694	15.178	2.829	1.302	2.48	
5	0.8361	0.4603	1.1476	0.534	21.718	15.181	2.743	1.322	1.68	
6	0.9641	0.3923	1.0105	0.596	16.330	15.179	2.633	1.350	1.07	
7	1.0876	0.3297	0.8799	0.649	12.409	14.677	2.439	1.379	0.71	
8	1.2035	0.2729	0.7657	0.683	10.131	14.673	2.335	1.409	0.48	
9	1.3135	0.2162	0.6503	0.695	8.500	14.665	2.235	1.440	0.32	
10	1.4295	0.1548	0.5228	0.674	7.173	14.657	2.131	1.474	0.19	
11	1.5305	0.0885	0.3790	0.569	6.251	14.643	2.040	1.506	0.10	
12	1.6112	0.0315	0.2548	0.317	5.638	14.637	1.969	1.532	0.03	
13	1.6939	-0.0354	0.1075	-0.889	5.099	14.631	1.899	1.560	-0.03	

Open water test in the cavitation tunnel, n = 25 s^{-1}

Test	**10PH0546**				Date		09.11.2010
Type of test	**OWT, n = 25 s^{-1}**						

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	22.6	ν	[m²/s]	9.470e-7	ρ	[kg/m³]	997.59
Air content	[%]	48.20	p_A	[kPa]	98.285	p_V	[kPa]	2.771
Test section		600 x 600	w_a	[-]	0.000	t_A	[°C]	22.3

Characteristic of propeller (model scale), velocity correction by Glauert

No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}	comment
1	0.4300	0.6849	1.6109	0.291	54.122	10.005	1.993	1.541	9.43	SSC
2	0.5320	0.6297	1.4917	0.357	35.456	10.033	1.960	1.555	5.67	SSC
3	0.6425	0.5686	1.3620	0.427	24.316	10.038	1.912	1.574	3.51	SSC
4	0.7534	0.5047	1.2278	0.493	17.461	9.912	1.834	1.597	2.26	
5	0.8560	0.4513	1.1220	0.548	13.355	9.786	1.757	1.621	1.57	
6	0.9777	0.3870	0.9940	0.606	9.837	9.403	1.624	1.653	1.03	
7	1.0877	0.3299	0.8803	0.649	7.944	9.400	1.562	1.686	0.71	
8	1.2026	0.2719	0.7608	0.684	6.363	9.203	1.465	1.722	0.48	
9	1.3090	0.2162	0.6471	0.696	5.219	8.943	1.365	1.758	0.32	
10	1.4134	0.1607	0.5286	0.684	4.378	8.745	1.280	1.796	0.20	
11	1.5090	0.1005	0.4007	0.603	3.752	8.545	1.201	1.832	0.11	
12	1.5891	0.0422	0.2752	0.388	3.355	8.472	1.151	1.864	0.04	PSC
13	1.6621	-0.0163	0.1504	-0.287	3.041	8.400	1.106	1.894	-0.02	PSC

Cavitation number variation, $K_T \approx 0.38$, $\alpha/\alpha_S \approx 80\%$

Test	**12KM0028**				Date		16.01.2012
Type of test	**Cavitation number variation, $n \approx 21\ s^{-1}$, $K_T \approx 0.38$**						

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	23.9	ν	[m²/s]	9.186e-7	ρ	[kg/m³]	997.26
Air content	[%]	82.50	p_A	[kPa]	102.466	p_V	[kPa]	2.997
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.5

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]	Remark
34	1	5.237	20.991	655.05	42.089	86.51	
	2	5.237	20.985	648.98	41.863	-11.89	BTVC
	3	5.238	20.983	643.13	41.599	-57.96	TVC
	4	5.239	20.981	620.88	40.332	-71.77	SSC
	5	5.238	20.980	647.65	41.562	-11.89	TVC
	6	5.238	20.980	651.51	41.872	22.10	ETVC
	7	5.237	20.979	652.55	42.015	86.51	

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}	Remark
34	1	0.9980	0.3816	0.9808	0.618	13.608	13.554	2.324	1.437	0.98	
	2	0.9983	0.3783	0.9761	0.616	6.410	6.389	1.095	1.437	0.97	BTVC
	3	0.9985	0.3750	0.9702	0.614	3.040	3.031	0.520	1.437	0.96	TVC
	4	0.9989	0.3620	0.9407	0.612	2.028	2.024	0.347	1.437	0.92	SSC
	5	0.9986	0.3777	0.9695	0.619	6.409	6.391	1.096	1.437	0.96	TVC
	6	0.9986	0.3800	0.9768	0.618	8.896	8.871	1.521	1.437	0.97	ETVC
	7	0.9986	0.3806	0.9802	0.617	13.608	13.569	2.326	1.436	0.97	

Variation α/α_S from 82.5 % (t_W = 23.9 °C) to 70.3 % (t_W = 24.5 °C)

BTVC	Begin of tip vortex cavitation
ETVC	End of tip vortex cavitation
TVC	Tip vortex cavitation
SSC	Suction side cavitation

Cavitation number variation, $K_T \approx 0.17$, $\alpha/\alpha_S \approx 80\%$

Test		**12KM0029**			Date		16.01.2012
Type of test		**Cavitation number variation, $n \approx 21\ s^{-1}$, $K_T \approx 0.17$**					

Particulars of the propulsor

Propeller		**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**

Environmental data

t_W	[°C]	24.6	ν	[m²/s]	9.037e-7	ρ	[kg/m³]	997.08
Air content	[%]	83.40	p_A	[kPa]	102.466	p_V	[kPa]	3.125
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	24.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]	Remark
35	1	7.361	20.984	291.44	23.729	86.51	
	2	7.363	20.985	276.55	22.900	-42.40	BPSC
	3	7.363	20.984	270.04	22.563	-57.96	PSC
	4	7.367	20.981	226.69	20.882	-71.56	PSC
	5	7.362	20.980	281.53	22.947	-42.40	PSC
	6	7.362	20.979	287.68	23.392	-33.27	EPSC
	7	7.361	20.978	288.36	23.485	86.51	

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c $[10^{-6}]$	C_{Thc}	Remark
35	1	1.4032	0.1699	0.5534	0.686	6.879	13.545	1.990	1.578	0.22	
	2	1.4034	0.1612	0.5340	0.674	2.104	4.144	0.609	1.578	0.21	BPSC
	3	1.4036	0.1575	0.5263	0.668	1.528	3.010	0.442	1.578	0.20	PSC
	4	1.4045	0.1322	0.4872	0.607	1.023	2.017	0.296	1.578	0.17	PSC
	5	1.4036	0.1642	0.5354	0.685	2.105	4.147	0.609	1.577	0.21	PSC
	6	1.4036	0.1678	0.5458	0.687	2.443	4.813	0.707	1.577	0.22	EPSC
	7	1.4036	0.1682	0.5480	0.686	6.879	13.553	1.991	1.577	0.22	

Variation α/α_S from 83.4 % (t_W = 24.6 °C) to 75.1 % (t_W = 25.8 °C)

BPSC	Begin of pressure side cavitation
EPSC	End of pressure side cavitation
PSC	Pressure side cavitation

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n \approx 3.03$, $\alpha/\alpha_S \approx 80\%$

Test	**12KM0027**	Date	16.01.2012
Type of test	**Number of revolutions variation, $n \approx 25, 21, 17\ s^{-1}$, $K_T \approx 0.38$, $\sigma_n \approx 3.03$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	23.4	ν	[m²/s]	9.294e-7	ρ	[kg/m³]	997.39
Air content	[%]	77.70	p_A	[kPa]	102.533	p_V	[kPa]	2.908
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.3

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
41	1	6.215	24.978	923.18	59.469	-40.93
40	2	5.251	20.995	647.99	41.767	-58.14
39	3	4.264	16.998	423.40	27.358	-72.35

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
41	1	0.9952	0.3798	0.9786	0.615	3.059	3.030	0.520	1.690	0.98
40	2	1.0004	0.3773	0.9728	0.618	3.023	3.026	0.518	1.421	0.96
39	3	1.0033	0.3761	0.9721	0.618	3.005	3.024	0.518	1.151	0.95

Variation α/α_S from 77.7 % (t_W = 23.4 °C) to 70.1 % (t_W = 23.8 °C)

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n \approx 2.02$, $\alpha/\alpha_S \approx 80\%$

Test	**12KM0030**	Date	16.01.2012
Type of test	**Number of revolutions variation, n = 25, 21, 17 s^{-1}, $K_T \approx 0.38$, $\sigma_n \approx 2.02$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	26.0	ν	[m²/s]	8.745e-7	ρ	[kg/m³]	996.71
Air content	[%]	81.90	p_A	[kPa]	102.480	p_V	[kPa]	3.393
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	24.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
38	1	6.194	25.037	912.77	59.731	-59.88
37	2	5.243	21.005	637.20	41.517	-71.31
36	3	4.237	17.014	422.12	27.327	-80.70

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
38	1	0.9895	0.3740	0.9790	0.602	2.062	2.019	0.347	1.798	0.97
37	2	0.9985	0.3709	0.9667	0.610	2.032	2.026	0.347	1.511	0.95
36	3	0.9962	0.3745	0.9699	0.612	2.049	2.034	0.349	1.223	0.96

Variation α/α_S from 81.9 % (t_W = 26.0 °C) to 62.5 % (t_W = 26.3 °C)

Number of revolutions variation, $K_T \approx 0.14$, $\sigma_n \approx 2.01$, $\alpha/\alpha_S \approx 80\%$

Test	**12KM0031**				Date		16.01.2012
Type of test	**Number of revolutions variation, $n \approx 21, 17\ s^{-1}$, $K_T \approx 0.14$, $\sigma_n \approx 2.01$**						

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	26.3	ν	[m²/s]	8.684e-7	ρ	[kg/m³]	996.62
Air content	[%]	80.00	p_A	[kPa]	102.480	p_V	[kPa]	3.453
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.7

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
43	1	7.342	21.008	234.29	21.407	-71.31
42	2	5.982	17.008	159.52	14.268	-80.75

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c $[10^{-6}]$	C_{Thc}
43	1	1.3979	0.1364	0.4984	0.609	1.028	2.009	0.296	1.642	0.18
42	2	1.4068	0.1417	0.5068	0.626	1.016	2.011	0.295	1.332	0.18

Variation α/α_S from 80.0 % (t_W = 26.3 °C) to 59.1 % (t_W = 26.4 °C)

Cavitation number variation, $K_T \approx 0.38$, $\alpha/\alpha_S \approx 60\%$

Test	**12KM0032**				Date		17.01.2012
Type of test	**Cavitation number variation, $n \approx 21$ s^{-1}, $K_T \approx 0.38$**						

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	25.3	ν	[m²/s]	8.890e-7	ρ	[kg/m³]	996.90
Air content	[%]	57.30	p_A	[kPa]	102.440	p_V	[kPa]	3.257
Test section		850 x 850	w_a	[-]	0.005	t_A	[°C]	21.9

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]	Remark
45	1	5.245	20.978	650.03	41.878	86.51	
	2	5.246	20.972	641.38	41.502	-34.05	BTVC
	3	5.246	20.967	639.39	41.396	-57.69	TVC
	4	5.246	20.965	630.68	41.274	-71.42	SSC
	5	5.246	20.963	636.77	41.236	-34.05	TVC
	6	5.246	20.961	637.68	41.728	16.73	ETVC
	7	5.246	20.959	642.31	41.666	86.51	

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}	Remark
45	1	1.0001	0.3793	0.9775	0.618	13.555	13.557	2.323	1.485	0.97	
	2	1.0005	0.3745	0.9692	0.615	4.757	4.762	0.816	1.484	0.95	BTVC
	3	1.0008	0.3735	0.9672	0.615	3.033	3.037	0.520	1.484	0.95	TVC
	4	1.0010	0.3685	0.9646	0.609	2.031	2.035	0.349	1.484	0.94	SSC
	5	1.0010	0.3721	0.9639	0.615	4.757	4.766	0.816	1.484	0.95	TVC
	6	1.0011	0.3727	0.9755	0.609	8.460	8.478	1.452	1.484	0.95	ETVC
	7	1.0011	0.3755	0.9743	0.614	13.552	13.581	2.326	1.484	0.95	

Variation α/α_S from 57.3 % (t_W = 25.3 °C) to 59.0 % (t_W = 26.1 °C)

BTVC	Begin of tip vortex cavitation
ETVC	End of tip vortex cavitation
TVC	Tip vortex cavitation
SSC	Suction side cavitation

Cavitation number variation, $K_T \approx 0.17$, $\alpha/\alpha_S \approx 60\%$

Test		**12KM0033**				Date	17.01.2012
Type of test		**Cavitation number variation, $n \approx 21\ s^{-1}$, $K_T \approx 0.17$**					

Particulars of the propulsor

Propeller		**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation		right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	26.1	ν	[m²/s]	8.725e-7	ρ	[kg/m³]	996.68
Air content	[%]	59.00	p_A	[kPa]	102.600	p_V	[kPa]	3.413
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.4

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]	Remark
46	1	7.350	20.981	291.09	23.744	86.51	
	2	7.351	20.975	281.02	23.132	-48.26	BPSC
	3	7.352	20.970	276.38	22.952	-57.88	PSC
	4	7.353	20.968	244.43	21.665	-71.62	PSC
	5	7.352	20.967	274.44	22.843	-48.26	PSC
	6	7.351	20.966	281.39	23.118	-31.52	EPSC
	7	7.350	20.963	288.04	23.578	86.51	

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}	Remark
46	1	1.4013	0.1698	0.5542	0.684	6.898	13.544	1.992	1.633	0.22	
	2	1.4018	0.1641	0.5402	0.678	1.889	3.712	0.546	1.633	0.21	BPSC
	3	1.4023	0.1614	0.5362	0.672	1.532	3.011	0.443	1.633	0.21	PSC
	4	1.4028	0.1428	0.5063	0.630	1.020	2.007	0.295	1.633	0.18	PSC
	5	1.4025	0.1604	0.5339	0.670	1.889	3.715	0.546	1.632	0.21	PSC
	6	1.4024	0.1644	0.5404	0.679	2.511	4.939	0.726	1.632	0.21	EPSC
	7	1.4025	0.1684	0.5513	0.682	6.898	13.568	1.994	1.632	0.22	

Variation α/α_S from 59.0 % (t_W = 26.1 °C) to 65.4 % (t_W = 27.4 °C)

BPSC	Begin of pressure side cavitation
EPSC	End of pressure side cavitation
PSC	Pressure side cavitation

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 3.02$, $\alpha/\alpha_S \approx 60\%$

Test	**12KM0034**	Date	17.01.2012
Type of test	**Number of revolutions variation, $n \approx 25, 21, 17\ s^{-1}$, $K_T \approx 0.38$, $\sigma_n \approx 3.02$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	27.5	ν	[m²/s]	8.440e-7	ρ	[kg/m³]	996.28
Air content	[%]	58.60	p_A	[kPa]	102.560	p_V	[kPa]	3.699
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	24.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
52	1	6.193	24.979	923.37	59.484	-40.24
51	2	5.222	21.003	646.92	41.844	-57.43
50	3	4.227	17.009	425.20	27.476	-71.63

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
52	1	0.9917	0.3803	0.9799	0.613	3.080	3.029	0.521	1.859	0.98
51	2	0.9945	0.3768	0.9750	0.612	3.056	3.022	0.519	1.564	0.97
50	3	0.9941	0.3777	0.9761	0.612	3.055	3.019	0.518	1.267	0.97

Variation α/α_S from 58.6 % (t_W = 27.5 °C) to 57.8 % (t_W = 27.6 °C)

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n \approx 2.02$, $\alpha/\alpha_S \approx 60\%$

Test	**12KM0035**	Date	17.01.2012
Type of test	**Number of revolutions variation, $n \approx 25, 21, 17\ s^{-1}$, $K_T \approx 0.38$, $\sigma_n \approx 2.02$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	27.6	ν	[m²/s]	8.419e-7	ρ	[kg/m³]	996.25
Air content	[%]	57.80	p_A	[kPa]	102.560	p_V	[kPa]	3.720
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.5

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
49	1	6.211	24.968	907.07	59.227	-59.57
48	2	5.228	21.005	642.79	41.984	-71.10
47	3	4.224	17.016	420.81	27.422	-80.58

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
49	1	0.9951	0.3739	0.9765	0.606	2.055	2.035	0.349	1.864	0.96
48	2	0.9955	0.3744	0.9781	0.606	2.044	2.025	0.348	1.568	0.96
47	3	0.9930	0.3734	0.9734	0.606	2.050	2.022	0.347	1.270	0.96

Variation α/α_S from 57.8 % (t_W = 27.6 °C) to 56.3 % (t_W = 27.9 °C)

Number of revolutions variation, $K_T \approx 0.14$, $\sigma_n \approx 2.02$, $\alpha/\alpha_S \approx 60\%$

Test	**12KM0036**	Date	17.01.2012
Type of test	**Number of revolutions variation, n = 21, 17 s^{-1}, $K_T \approx 0.14$, σ_n = 2.02**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	27.6	ν	[m²/s]	8.419e-7	ρ	[kg/m³]	996.25
Air content	[%]	56.30	p_A	[kPa]	102.560	p_V	[kPa]	3.720
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.5

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
54	1	7.371	21.008	234.29	21.407	-71.31
53	2	5.969	17.008	159.52	14.268	-80.75

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c $[10^{-6}]$	C_{Thc}
54	1	1.4034	0.1411	0.5009	0.629	1.025	2.019	0.297	1.694	0.18
53	2	1.4037	0.1479	0.5127	0.644	1.025	2.021	0.297	1.372	0.19

Variation α/α_S from 56.3 % (t_W = 27.9 °C) to 55.3 % (t_W = 28.1 °C)

Cavitation number variation, $K_T \approx 0.38$, $\alpha/\alpha_S \approx 40\%$

Test		**12KM0037**				Date	17.01.2012
Type of test		**Cavitation number variation, $n \approx 21$ s^{-1}, $K_T \approx 0.38$**					

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	28.3	ν	[m²/s]	8.278e-7	ρ	[kg/m³]	996.04
Air content	[%]	38.40	p_A	[kPa]	102.613	p_V	[kPa]	3.869
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]	Remark
56	1	5.227	20.986	650.94	41.986	86.51	
	2	5.227	20.979	643.21	41.652	-41.76	BTVC
	3	5.228	20.980	639.45	41.527	-57.22	TVC
	4	5.228	20.979	632.28	41.474	-70.94	SSC
	5	5.227	20.979	640.40	41.583	-41.76	TVC
	6	5.227	20.977	641.19	41.615	-4.26	ETVC
	7	5.227	20.978	646.28	41.869	86.51	

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}	Remark
56	1	0.9963	0.3799	0.9801	0.615	13.627	13.526	2.321	1.594	0.97	
	2	0.9967	0.3756	0.9730	0.612	4.195	4.167	0.715	1.593	0.96	BTVC
	3	0.9967	0.3734	0.9700	0.611	3.058	3.038	0.521	1.593	0.96	TVC
	4	0.9968	0.3692	0.9688	0.605	2.049	2.036	0.349	1.593	0.95	SSC
	5	0.9967	0.3740	0.9714	0.611	4.195	4.167	0.715	1.593	0.96	TVC
	6	0.9968	0.3745	0.9722	0.611	6.951	6.907	1.185	1.593	0.96	ETVC
	7	0.9967	0.3775	0.9782	0.612	13.627	13.537	2.322	1.593	0.97	

Variation α/α_S from 38.4 % (t_W = 28.3 °C) to 41.5 % (t_W = 28.4 °C)

BTVC	Begin of tip vortex cavitation
ETVC	End of tip vortex cavitation
TVC	Tip vortex cavitation
SSC	Suction side cavitation

Cavitation number variation, $K_T \approx 0.17$, $\alpha/\alpha_S \approx 40\%$

Test	**12KM0042**				Date		18.01.2012
Type of test	**Cavitation number variation, $n \approx 21\ s^{-1}$, $K_T \approx 0.17$**						

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	28.6	ν	[m²/s]	8.218e-7	ρ	[kg/m³]	995.95
Air content	[%]	42.00	p_A	[kPa]	102.466	p_V	[kPa]	3.935
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]	Remark
57	1	7.367	20.985	291.70	23.591	86.51	
	2	7.368	20.982	280.98	22.898	-42.94	BPSC
	3	7.368	20.980	274.52	22.793	-57.72	PSC
	4	7.371	20.978	243.91	21.435	-71.43	PSC
	5	7.368	20.976	276.68	22.709	-42.94	PSC
	6	7.368	20.975	279.36	22.812	-31.90	EPSC
	7	7.367	20.975	286.19	23.301	86.51	

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c $[10^{-6}]$	C_{Thc}	Remark
57	1	1.4043	0.1703	0.5508	0.691	6.847	13.503	1.983	1.735	0.22	
	2	1.4046	0.1641	0.5348	0.686	2.055	4.055	0.596	1.735	0.21	BPSC
	3	1.4048	0.1603	0.5324	0.673	1.508	2.976	0.437	1.735	0.21	PSC
	4	1.4054	0.1425	0.5008	0.636	0.999	1.973	0.290	1.735	0.18	PSC
	5	1.4051	0.1616	0.5307	0.681	2.055	4.057	0.596	1.735	0.21	PSC
	6	1.4051	0.1632	0.5331	0.685	2.463	4.863	0.714	1.735	0.21	EPSC
	7	1.4050	0.1672	0.5445	0.687	6.846	13.515	1.984	1.735	0.22	

Variation α/α_S from 42.0 % (t_W = 28.6 °C) to 52.8 % (t_W = 28.9 °C)

BPSC	Begin of pressure side cavitation
EPSC	End of pressure side cavitation
PSC	Pressure side cavitation

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n \approx 3.00$, $\alpha/\alpha_S \approx 40\%$

Test	**12KM0040**	Date	18.01.2012
Type of test	**Number of revolutions variation, $n \approx 25, 21, 17\ s^{-1}$, $K_T \approx 0.38$, $\sigma_n \approx 3.00$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	28.3	ν	[m²/s]	8.278e-7	ρ	[kg/m³]	996.04
Air content	[%]	42.40	p_A	[kPa]	102.560	p_V	[kPa]	3.869
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.5

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
63	1	6.229	24.999	918.86	59.176	-40.34
62	2	5.243	21.017	646.40	41.709	-57.53
61	3	4.224	16.997	425.28	27.344	-71.73

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
63	1	0.9966	0.3779	0.9735	0.616	3.032	3.012	0.517	1.899	0.97
62	2	0.9979	0.3761	0.9708	0.615	3.013	3.001	0.514	1.597	0.96
61	3	0.9940	0.3783	0.9731	0.615	3.031	2.995	0.514	1.290	0.98

Variation α/α_S from 42.4 % (t_W = 28.3 °C) to 45.7 % (t_W = 28.4 °C)

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n \approx 2.03$, $\alpha/\alpha_S \approx 40\%$

Test	**12KM0038**	Date	17.01.2012
Type of test	**Number of revolutions variation, $n \approx 25, 21, 17\ s^{-1}$, $K_T \approx 0.38$, $\sigma_n \approx 2.03$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	28.4	ν	[m²/s]	8.258e-7	ρ	[kg/m³]	996.01
Air content	[%]	41.50	p_A	[kPa]	102.693	p_V	[kPa]	3.891
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
60	1	6.203	24.961	901.89	59.145	-59.61
59	2	5.230	20.995	641.70	41.823	-71.06
58	3	4.221	17.003	421.12	27.455	-80.52

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c [10^{-6}]	C_{Thc}
60	1	0.9940	0.3720	0.9759	0.603	2.058	2.033	0.349	1.900	0.96
59	2	0.9964	0.3742	0.9755	0.608	2.043	2.029	0.348	1.598	0.96
58	3	0.9929	0.3744	0.9764	0.606	2.059	2.029	0.349	1.294	0.97

Variation α/α_S from 41.5 % (t_W = 28.4 °C) to 41.7 % (t_W = 28.7 °C)

Number of revolutions variation, $K_T \approx 0.15$, $\sigma_n \approx 2.01$, $\alpha/\alpha_S \approx 40\%$

Test	**12KM0041**	Date	18.01.2012
Type of test	**Number of revolutions variation, $n \approx 21, 17\ s^{-1}$, $K_T \approx 0.15$, $\sigma_n \approx 2.01$**		

Particulars of the propulsor

Propeller	**VP1304**	D	[m]	**0.25000**	$P_{0.7}/D$	[-]	**1.63500**
Sense of rotation	right-handed	$c_{0.7}$	[m]	0.10417	d_h/D	[-]	0.30000

Environmental data

t_W	[°C]	28.4	ν	[m²/s]	8.258e-7	ρ	[kg/m³]	996.01
Air content	[%]	40.90	p_A	[kPa]	102.480	p_V	[kPa]	3.891
Test section		850 x 850	w_a	[-]	0.000	t_A	[°C]	23.0

Measured values

No. KonKav	No.	V_c [m/s]	n [rps]	T [N]	Q [Nm]	D_{H2} [kPa]
65	1	7.372	21.002	255.85	21.971	-70.88
64	2	5.940	17.002	172.34	14.658	-80.35

Characteristic of propeller (model scale) with velocity correction by Glauert

No. KonKav	No.	J_c	K_T	$10K_Q$	η_{Oc}	σ_{Vc}	σ_{nc}	$\sigma_{0.7c}$	Re_c $[10^{-6}]$	C_{Thc}
65	1	1.4041	0.1491	0.5121	0.651	1.021	2.014	0.296	1.728	0.19
64	2	1.3976	0.1532	0.5213	0.654	1.031	2.014	0.297	1.397	0.20

Variation α/α_S from 40.9 % (t_W = 28.4 °C) to 42.0 % (t_W = 28.6 °C)

Concentrations of particles [1/cm³] in 10 µm-classes, $\alpha/\alpha_S \approx 80\%$

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
41	0.244	0.324	0.352	0.451	0.389	0.349	0.333	0.262	0.273	0.253	0.189
40	0.150	0.332	0.652	0.971	1.154	1.121	1.018	0.862	0.639	0.553	0.578
39	0.076	0.108	0.268	0.937	1.164	1.438	1.433	1.485	1.304	1.274	1.257
34.1	6.002	3.553	2.199	1.23	1.221	0.658	0.530	0.487	0.409	0.278	0.344
34.2	0.500	0.464	0.280	0.197	0.162	0.154	0.146	0.088	0.069	0.125	0.062
34.3	0.301	0.788	1.746	2.511	2.839	2.721	2.597	2.471	1.982	1.800	1.749
34.4	0.172	0.614	2.035	3.031	3.341	3.183	3.030	2.714	2.120	1.729	1.583
34.5	1.268	0.78	0.537	0.359	0.229	0.213	0.232	0.131	0.135	0.16	0.127
34.6	2.290	1.211	0.790	0.499	0.352	0.328	0.208	0.179	0.225	0.102	0.142
34.7	7.005	3.918	2.091	1.123	0.814	0.714	0.457	0.461	0.293	0.388	0.245
35.1	17.96	9.957	5.080	3.405	2.094	1.464	1.188	1.044	0.802	0.882	0.553
35.2	0.939	2.181	2.995	3.657	4.076	3.692	3.483	3.171	2.891	2.548	2.143
35.3											
35.4	0.015	0.245	1.071	2.005	2.283	1.847	1.725	1.366	1.079	0.846	0.699
35.5	0.548	0.436	0.408	0.363	0.414	0.289	0.312	0.280	0.252	0.199	0.171
35.6	1.128	0.652	0.570	0.402	0.323	0.341	0.318	0.313	0.165	0.240	0.125
35.7	23.429	11.879	6.277	3.742	2.278	1.762	1.238	1.153	0.812	0.796	0.641
38	0.386	1.162	2.335	2.777	2.898	2.443	2.409	2.072	1.718	1.634	1.437
37	0.104	0.342	0.932	1.398	1.857	2.047	1.797	1.828	1.257	1.240	1.015
36	0.095	0.102	0.397	0.943	1.176	1.552	1.515	1.784	1.392	1.476	1.33
43	0.563	1.967	3.270	4.484	4.599	4.110	3.432	2.889	2.301	1.919	1.722
42	0.267	0.538	0.949	1.401	1.596	1.602	1.398	1.253	1.097	1.047	1.109

No.	120µm	130µm	140µm	150µm	160µm	170µm	180µm	190µm	200µm	210µm	220µm
41	0.242	0.217	0.219	0.184	0.15	0.123	0.152	0.125	0.114	0.085	0.071
40	0.485	0.328	0.321	0.288	0.232	0.313	0.203	0.179	0.148	0.159	0.132
39	1.006	0.957	0.651	0.739	0.672	0.502	0.599	0.35	0.275	0.215	0.170
34.1	0.305	0.326	0.303	0.257	0.315	0.336	0.437	0.341	0.413	0.535	0.498
34.2	0.049	0.062	0.055	0.067	0.037	0.024	0.073	0.018	0.09	0.036	0.06
34.3	1.476	1.395	1.008	0.723	0.663	0.758	0.523	0.562	0.39	0.385	0.295
34.4	1.290	1.036	0.850	0.654	0.66	0.513	0.419	0.348	0.303	0.234	0.138
34.5	0.078	0.109	0.072	0.067	0.127	0.086	0.086	0.05	0.080	0.070	0.084
34.6	0.148	0.134	0.160	0.166	0.053	0.152	0.145	0.178	0.144	0.210	0.176
34.7	0.303	0.258	0.228	0.249	0.321	0.291	0.268	0.326	0.419	0.382	0.338
35.1	0.491	0.702	0.513	0.545	0.598	0.693	0.634	0.734	0.642	0.886	0.718
35.2	2.225	2.026	1.669	1.566	1.430	1.126	0.863	0.833	0.630	0.675	0.470
35.3											
35.4	0.605	0.491	0.404	0.336	0.305	0.231	0.151	0.164	0.116	0.115	0.073
35.5	0.201	0.168	0.129	0.166	0.108	0.068	0.126	0.059	0.097	0.080	0.069
35.6	0.131	0.146	0.171	0.102	0.149	0.117	0.091	0.085	0.094	0.127	0.093
35.7	0.523	0.598	0.689	0.643	0.699	0.722	0.693	0.691	0.713	0.978	0.842
38	1.199	1.135	0.889	0.795	0.834	0.649	0.624	0.503	0.43	0.327	0.262
37	0.858	0.725	0.625	0.443	0.467	0.316	0.340	0.316	0.176	0.171	0.13
36	1.050	0.896	0.833	0.785	0.596	0.520	0.4900	0.368	0.336	0.256	0.177
43	1.333	1.144	1.015	0.921	0.691	0.624	0.513	0.377	0.377	0.299	0.199
42	0.843	0.768	0.788	0.615	0.561	0.503	0.456	0.379	0.252	0.31	0.247

Concentrations of particles [1/cm³] in 10 µm-classes, $\alpha/\alpha_S \approx 60\%$

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
45.1	6.527	4.150	2.244	1.573	0.989	0.699	0.617	0.413	0.403	0.28	0.324
45.2	1.044	0.601	0.430	0.281	0.116	0.128	0.146	0.120	0.088	0.056	0.062
45.3	0.392	0.227	0.166	0.089	0.071	0.076	0.096	0.058	0.079	0.068	0.052
45.4	0.180	0.162	0.135	0.157	0.197	0.218	0.160	0.137	0.172	0.154	0.145
45.5	0.426	0.290	0.222	0.085	0.174	0.072	0.065	0.071	0.047	0.047	0.052
45.6	2.009	1.382	0.766	0.441	0.409	0.289	0.273	0.210	0.182	0.134	0.187
45.7	22.830	12.302	6.503	3.656	2.542	1.595	0.961	0.889	0.799	0.559	0.708
46.1	17.870	9.370	5.088	2.798	2.192	1.343	1.161	0.664	0.773	0.580	0.457
46.2	0.327	0.230	0.145	0.103	0.144	0.104	0.092	0.084	0.072	0.045	0.045
46.3	0.920	0.717	0.519	0.351	0.322	0.257	0.243	0.192	0.145	0.137	0.089
46.4											
46.5	1.044	0.639	0.403	0.286	0.195	0.181	0.175	0.075	0.079	0.086	0.070
46.6	1.469	0.851	0.540	0.366	0.288	0.233	0.188	0.134	0.125	0.111	0.093
46.7	20.279	11.058	5.257	3.279	1.88	1.512	0.982	0.909	0.661	0.601	0.582
52	0.640	0.369	0.249	0.227	0.117	0.170	0.094	0.142	0.097	0.062	0.052
51	0.673	0.320	0.254	0.181	0.134	0.144	0.104	0.071	0.086	0.075	0.037
50	0.575	0.318	0.251	0.167	0.125	0.123	0.128	0.168	0.089	0.153	0.099
49	1.233	0.707	0.443	0.436	0.302	0.310	0.298	0.236	0.152	0.244	0.194
48	0.701	0.415	0.314	0.289	0.253	0.286	0.314	0.333	0.262	0.165	0.168
47	0.300	0.194	0.202	0.274	0.300	0.236	0.295	0.245	0.294	0.281	0.314
54	0.862	0.808	0.945	1.077	1.158	1.044	1.017	1.004	0.992	0.832	0.854
53	0.486	0.539	0.682	1.011	1.066	1.050	1.064	1.077	0.932	0.891	1.021

No.	120µm	130µm	140µm	150µm	160µm	170µm	180µm	190µm	200µm	210µm	220µm
45.1	0.240	0.351	0.268	0.297	0.251	0.280	0.353	0.425	0.476	0.482	0.444
45.2	0.081	0.043	0.093	0.080	0.049	0.055	0.092	0.061	0.061	0.109	0.091
45.3	0.062	0.076	0.071	0.040	0.035	0.035	0.035	0.055	0.010	0.049	0.010
45.4	0.168	0.139	0.118	0.145	0.163	0.112	0.100	0.077	0.095	0.072	0.068
45.5	0.012	0.052	0.057	0.057	0.046	0.046	0.034	0.062	0.023	0.017	0.039
45.6	0.153	0.133	0.132	0.139	0.119	0.085	0.144	0.124	0.111	0.228	0.137
45.7	0.405	0.469	0.496	0.598	0.615	0.660	0.742	0.759	0.915	0.978	0.865
46.1	0.469	0.474	0.502	0.485	0.440	0.591	0.662	0.697	0.847	0.924	0.626
46.2	0.067	0.011	0.030	0.022	0.044	0.037	0.058	0.036	0.022	0.025	0.058
46.3	0.081	0.054	0.097	0.053	0.063	0.050	0.062	0.062	0.075	0.075	0.055
46.4											
46.5	0.057	0.077	0.073	0.065	0.061	0.081	0.052	0.076	0.092	0.076	0.036
46.6	0.097	0.084	0.066	0.093	0.084	0.101	0.075	0.110	0.114	0.092	0.088
46.7	0.500	0.466	0.409	0.423	0.609	0.498	0.745	0.627	0.818	0.793	0.691
52	0.099	0.057	0.056	0.056	0.060	0.051	0.064	0.041	0.046	0.055	0.045
51	0.027	0.053	0.068	0.073	0.042	0.073	0.031	0.047	0.072	0.046	0.041
50	0.052	0.069	0.092	0.063	0.136	0.118	0.073	0.101	0.089	0.061	0.039
49	0.125	0.172	0.155	0.178	0.114	0.157	0.136	0.124	0.132	0.123	0.127
48	0.259	0.209	0.217	0.181	0.133	0.141	0.136	0.135	0.118	0.168	0.104
47	0.206	0.165	0.154	0.261	0.132	0.175	0.155	0.188	0.091	0.110	0.072
54	0.818	0.835	0.622	0.665	0.652	0.465	0.466	0.360	0.354	0.274	0.293
53	0.892	0.697	0.749	0.693	0.583	0.509	0.575	0.387	0.424	0.337	0.279

TABLES

Concentrations of particles [1/cm³] in 10 µm-classes, $\alpha/\alpha_S \approx 40\%$

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
56.1	13.299	6.862	3.395	2.195	1.179	0.800	0.688	0.426	0.375	0.357	0.411
56.2	2.301	1.357	0.798	0.524	0.411	0.363	0.253	0.202	0.125	0.225	0.137
56.3	1.807	1.136	0.81	0.421	0.315	0.274	0.229	0.129	0.140	0.145	0.133
56.4	1.118	0.584	0.402	0.332	0.227	0.217	0.182	0.102	0.106	0.095	0.124
56.5	2.442	1.568	0.91	0.656	0.401	0.327	0.247	0.201	0.136	0.219	0.141
56.6	6.584	3.992	2.231	1.562	0.927	0.586	0.461	0.431	0.270	0.242	0.221
56.7	22.915	11.184	5.989	3.377	2.157	1.328	1.139	0.672	0.615	0.611	0.469
60	1.731	1.027	0.617	0.374	0.356	0.263	0.202	0.138	0.155	0.112	0.088
59	0.897	0.447	0.418	0.22	0.235	0.125	0.179	0.126	0.070	0.108	0.102
58	0.754	0.392	0.251	0.209	0.191	0.118	0.158	0.088	0.081	0.067	0.060
63	1.960	1.154	0.77	0.577	0.397	0.331	0.220	0.188	0.222	0.161	0.190
62	1.402	0.811	0.503	0.33	0.218	0.126	0.161	0.178	0.129	0.135	0.105
61											
65	0.391	0.331	0.44	0.384	0.382	0.332	0.324	0.271	0.209	0.212	0.254
64	0.577	0.358	0.435	0.426	0.439	0.457	0.429	0.433	0.294	0.308	0.291
57.1	13.320	6.851	4.016	2.228	1.422	0.993	0.709	0.612	0.501	0.458	0.411
57.2	1.999	1.013	0.624	0.464	0.368	0.248	0.210	0.187	0.128	0.202	0.118
57.3	0.960	0.447	0.324	0.243	0.187	0.132	0.143	0.071	0.078	0.070	0.085
57.4	0.485	0.376	0.514	0.639	0.582	0.507	0.461	0.427	0.334	0.315	0.281
57.4	2.176	1.236	0.713	0.465	0.39	0.312	0.254	0.197	0.219	0.127	0.118
57.6	2.758	1.753	1.046	0.64	0.408	0.338	0.312	0.277	0.164	0.196	0.158
57.7	12.242	6.943	3.421	1.902	1.268	0.939	0.741	0.516	0.392	0.438	0.398

No.	120µm	130µm	140µm	150µm	160µm	170µm	180µm	190µm	200µm	210µm	220µm
56.1	0.386	0.392	0.250	0.288	0.349	0.418	0.501	0.515	0.629	0.551	0.55
56.2	0.106	0.105	0.117	0.123	0.080	0.098	0.11	0.104	0.122	0.183	0.152
56.3	0.102	0.126	0.066	0.125	0.083	0.112	0.129	0.135	0.135	0.123	0.128
56.4	0.113	0.112	0.082	0.116	0.072	0.124	0.133	0.151	0.159	0.112	0.065
56.5	0.147	0.140	0.083	0.133	0.159	0.184	0.139	0.139	0.126	0.208	0.245
56.6	0.220	0.264	0.244	0.205	0.230	0.280	0.235	0.253	0.328	0.327	0.251
56.7	0.519	0.509	0.644	0.582	0.520	0.595	0.509	0.821	0.810	0.892	0.874
60	0.092	0.133	0.127	0.131	0.113	0.081	0.112	0.134	0.146	0.159	0.115
59	0.092	0.072	0.076	0.061	0.070	0.102	0.079	0.060	0.119	0.055	0.054
58	0.086	0.046	0.085	0.065	0.077	0.103	0.070	0.089	0.070	0.076	0.082
63	0.070	0.129	0.128	0.138	0.108	0.161	0.122	0.083	0.155	0.121	0.13
62	0.116	0.075	0.081	0.132	0.086	0.103	0.108	0.159	0.074	0.13	0.102
61											
65	0.193	0.166	0.132	0.145	0.096	0.121	0.126	0.089	0.075	0.070	0.059
64	0.293	0.254	0.26	0.285	0.303	0.201	0.178	0.141	0.188	0.136	0.139
57.1	0.376	0.417	0.415	0.38	0.416	0.404	0.550	0.569	0.620	0.581	0.600
57.2	0.113	0.130	0.091	0.108	0.103	0.086	0.103	0.171	0.120	0.132	0.111
57.3	0.057	0.072	0.049	0.098	0.064	0.060	0.056	0.052	0.052	0.067	0.037
57.4	0.275	0.262	0.296	0.205	0.176	0.156	0.142	0.135	0.097	0.067	0.067
57.5	0.117	0.108	0.170	0.129	0.102	0.106	0.093	0.115	0.084	0.176	0.096
57.6	0.139	0.106	0.110	0.124	0.165	0.182	0.127	0.182	0.222	0.199	0.171
57.7	0.364	0.378	0.381	0.374	0.478	0.398	0.449	0.531	0.602	0.512	0.500

Concentrations of bubbles [1/cm³] in 10 µm-classes, estimated by background substraction, $\alpha/\alpha_S \approx 80\%$

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
41	0.162	0.214	0.261	0.366	0.284	0.268	0.231	0.197	0.200	0.207	0.131
40	0.116	0.294	0.568	0.848	0.970	0.914	0.86	0.677	0.496	0.401	0.488
39	0.048	0.077	0.238	0.866	1.018	1.237	1.169	1.197	1.041	1.063	1.068
34.1	3.806	1.558	0.419	-0.104	0.233	-0.106	-0.071	0.028	0.038	-0.113	0.067
34.2	0.281	0.292	-0.018	-0.004	0.002	0.079	0.026	0.015	-0.016	0.026	-0.035
34.3	0.250	0.671	1.609	2.37	2.603	2.397	2.292	2.183	1.688	1.521	1.523
34.4	0.153	0.559	1.988	2.867	3.074	2.848	2.624	2.306	1.831	1.389	1.336
34.5	0.849	0.299	0.111	0.083	0.005	0.063	0.076	0.024	0.023	0.063	0.022
34.6	1.492	0.371	-0.045	-0.049	-0.147	0.094	-0.037	-0.016	0.078	-0.042	-0.036
34.7	4.844	1.815	0.249	-0.207	-0.048	0.03	-0.129	0.122	-0.073	0.023	-0.132
35.1	12.385	3.48	0.598	0.593	0.060	-0.066	-0.039	0.209	0.011	0.090	-0.136
35.2	0.895	2.059	2.875	3.459	3.822	3.362	3.089	2.861	2.673	2.309	1.953
35.3											
35.4	0.007	0.220	0.960	1.804	1.921	1.472	1.381	1.140	0.853	0.599	0.547
35.5	0.366	0.234	0.224	0.176	0.293	0.153	0.21	0.174	0.152	0.115	0.105
35.6	0.758	0.288	0.234	0.120	0.067	0.162	0.169	0.179	0.029	0.129	0.019
35.7	15.574	4.939	0.241	0.018	-0.195	-0.026	-0.072	0.226	-0.055	0.093	-0.013
38	0.351	1.075	2.233	2.666	2.665	2.255	2.157	1.825	1.438	1.408	1.271
37	0.099	0.283	0.852	1.269	1.662	1.801	1.518	1.527	0.988	1.014	0.827
36	0.039	0.057	0.357	0.851	1.058	1.394	1.295	1.539	1.158	1.246	1.191
43	0.530	1.809	3.083	4.255	4.210	3.619	3.016	2.456	1.988	1.590	1.415
42	0.222	0.443	0.852	1.272	1.471	1.409	1.167	1.057	0.901	0.825	0.952

No.	120µm	130µm	140µm	150µm	160µm	170µm	180µm	190µm	200µm	210µm	220µm
41	0.171	0.152	0.164	0.134	0.06	0.056	0.101	0.079	0.061	0.071	0.034
40	0.407	0.259	0.256	0.174	0.147	0.218	0.147	0.120	0.056	0.132	0.102
39	0.827	0.76	0.432	0.491	0.45	0.309	0.424	0.222	0.158	0.095	0.085
34.1	-0.015	0.097	-0.045	-0.119	-0.016	-0.076	-0.057	-0.062	-0.107	0.183	0.330
34.2	-0.010	-0.003	-0.010	0.014	-0.020	-0.027	-0.011	-0.058	0.030	-0.009	0.033
34.3	1.272	1.193	0.846	0.584	0.464	0.592	0.406	0.422	0.276	0.271	0.212
34.4	1.039	0.744	0.569	0.438	0.415	0.353	0.298	0.192	0.148	0.118	0.057
34.5	-0.030	0.000	-0.040	-0.038	0.056	0.008	0.008	-0.025	-0.046	-0.022	0.017
34.6	-0.036	-0.002	0.044	-0.01	-0.035	0.024	0.024	0.017	-0.037	0.090	0.075
34.7	0.031	-0.049	-0.122	-0.101	-0.006	-0.050	-0.08	-0.035	0.006	0.022	0.182
35.1	0.018	0.040	-0.079	-0.100	-0.109	0.056	-0.093	-0.074	-0.26	0.189	0.315
35.2	1.998	1.830	1.379	1.338	1.183	0.927	0.669	0.644	0.451	0.520	0.319
35.3											
35.4	0.441	0.321	0.179	0.204	0.172	0.148	0.036	0.073	0.026	0.053	0.036
35.5	0.134	0.119	0.079	0.087	0.069	0.014	0.071	0.020	0.047	0.040	0.050
35.6	0.008	0.012	0.074	0.034	0.036	0.022	-0.002	-0.034	0.029	0.069	0.049
35.7	-0.150	-0.168	0.103	0.016	0.224	0.166	-0.022	-0.217	-0.329	0.295	0.356
38	1.062	0.986	0.734	0.604	0.642	0.478	0.495	0.392	0.286	0.179	0.16
37	0.669	0.544	0.509	0.252	0.347	0.192	0.254	0.224	0.067	0.078	0.057
36	0.847	0.694	0.577	0.599	0.364	0.320	0.269	0.198	0.190	0.121	0.104
43	1.065	0.891	0.708	0.639	0.41	0.409	0.331	0.166	0.208	0.180	0.107
42	0.660	0.624	0.628	0.454	0.441	0.371	0.354	0.294	0.125	0.217	0.162

Concentrations of bubbles [1/cm^3] in 10 µm-classes, estimated by background substraction, $\alpha/\alpha_S \approx 60\%$

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
45.1	4.320	1.671	0.28	0.078	0.178	0.016	0.093	-0.071	-0.018	0.003	-0.048
45.2	0.672	0.249	0.163	0.085	-0.136	-0.044	0.001	0.026	-0.030	0.000	-0.018
45.3	0.297	0.11	0.076	0.003	0.038	0.027	0.034	0.004	0.014	0.020	-0.006
45.4	0.163	0.138	0.078	0.118	0.166	0.16	0.108	0.077	0.124	0.111	0.086
45.5	0.321	0.157	0.077	-0.043	0.105	-0.011	0.044	-0.036	-0.016	-0.016	-0.005
45.6	1.311	0.418	0.017	-0.063	0.138	0.06	0.059	0.037	-0.057	0.022	0.069
45.7	15.869	5.773	0.571	-0.08	0.127	0.086	-0.038	0.076	0.055	-0.090	0.082
46.1	12.081	4.004	0.424	-0.079	0.328	-0.02	0.154	-0.042	0.124	-0.200	-0.127
46.2	0.212	0.106	0.039	-0.020	0.049	0.024	0.049	0.019	0.039	0.001	0.009
46.3	0.627	0.412	0.218	0.145	0.103	0.108	0.122	0.090	0.065	0.036	0.032
46.4											
46.5	0.798	0.293	-0.016	0.014	0.024	0.003	0.062	0.000	-0.029	-0.010	-0.004
46.6	0.932	0.359	-0.02	0.005	0.003	-0.019	-0.012	0.029	-0.002	-0.011	-0.042
46.7	13.847	4.643	0.460	0.083	-0.091	0.152	0.046	0.096	-0.143	0.079	-0.051
52	0.494	0.181	0.000	0.061	-0.024	0.033	-0.024	0.098	0.015	0.015	0.006
51	0.533	0.089	-0.004	0.045	0.006	-0.001	0.024	-0.012	0.007	0.008	-0.028
50	0.411	0.178	0.11	0.016	-0.021	-0.001	0.044	0.072	0.039	0.066	0.043
49	0.805	0.267	-0.051	0.187	0.131	0.164	0.12	0.101	0.009	0.162	0.094
48	0.518	0.228	0.167	0.130	0.147	0.166	0.166	0.204	0.16	0.062	0.098
47	0.183	0.081	0.066	0.198	0.236	0.132	0.179	0.127	0.235	0.228	0.266
54	0.677	0.564	0.731	0.867	0.974	0.852	0.809	0.819	0.809	0.702	0.706
53	0.431	0.397	0.559	0.843	0.875	0.915	0.878	0.900	0.772	0.764	0.876

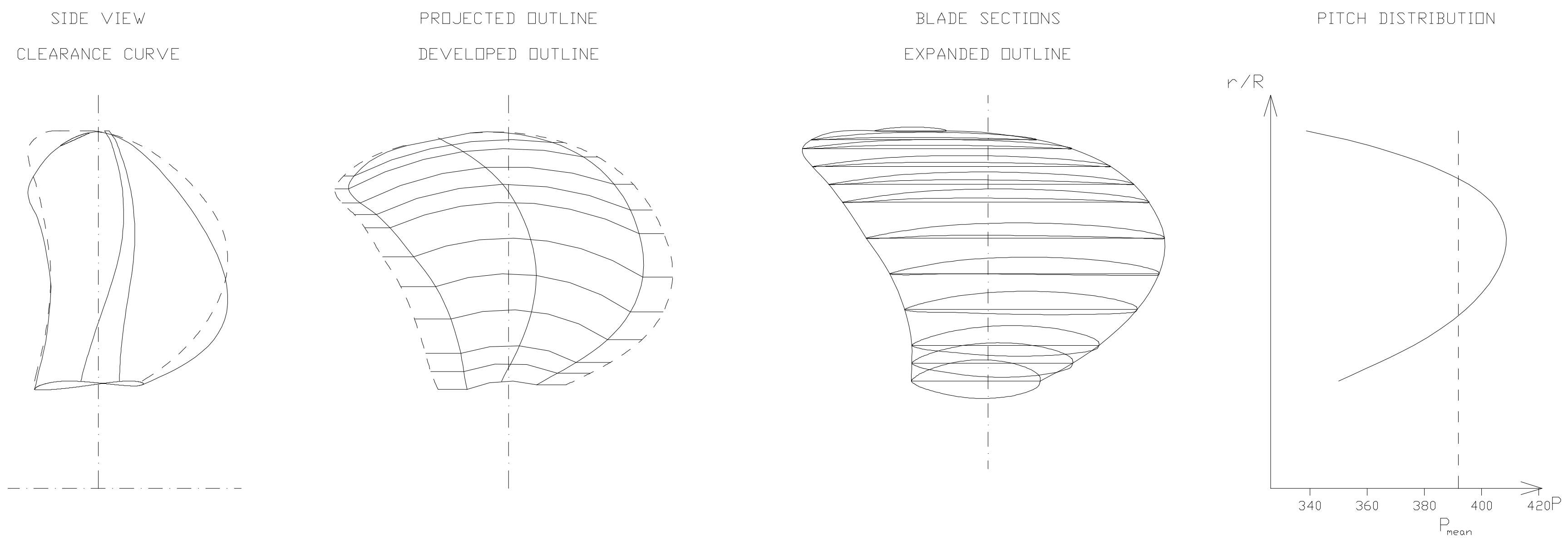
No.	120µm	130µm	140µm	150µm	160µm	170µm	180µm	190µm	200µm	210µm	220µm
45.1	-0.064	-0.003	0.026	-0.003	0.010	0.010	-0.018	0.026	0.072	0.093	0.287
45.2	-0.029	-0.073	0.058	0.032	0.019	-0.005	-0.015	0.014	-0.004	0.050	0.056
45.3	0.026	0.049	0.050	0.021	-0.005	0.006	0.011	0.046	-0.033	0.008	-0.001
45.4	0.137	0.109	0.077	0.103	0.132	0.083	0.080	0.030	0.039	0.049	0.045
45.5	-0.049	0.025	0.029	0.000	0.014	-0.004	-0.034	-0.002	-0.044	-0.008	0.006
45.6	0.042	0.003	0.015	0.010	0.049	-0.038	0.061	0.035	-0.055	0.096	0.088
45.7	-0.268	-0.025	-0.217	-0.01	0.074	-0.090	-0.05	-0.095	0.129	0.459	0.652
46.1	-0.045	-0.137	-0.024	-0.091	-0.133	-0.043	0.028	0.095	-0.014	0.408	0.226
46.2	0.038	-0.050	-0.02	0.006	0.016	0.029	0.019	-0.014	-0.001	0.002	0.046
46.3	-0.023	0.011	0.043	-0.001	0.03	0.018	0.004	-0.014	-0.001	0.013	0.03
46.4											
46.5	-0.021	-0.001	0.045	0.005	0.022	0.012	-0.004	0.011	0.023	0.02	-0.002
46.6	-0.011	0.021	-0.006	0.026	-0.001	-0.011	-0.036	0.070	0.042	-0.001	0.057
46.7	0.000	-0.047	-0.062	-0.253	0.059	-0.017	0.03	-0.147	0.042	0.168	0.421
52	0.036	0.017	0.030	0.006	-0.029	-0.008	-0.02	-0.028	-0.003	-0.004	0.019
51	-0.013	0.033	0.019	0.023	0.001	0.030	-0.032	-0.011	0.023	0.009	-0.011
50	0.039	0.027	0.027	0.011	0.094	0.110	0.010	0.089	0.032	0.032	-0.006
49	0.024	0.083	0.104	0.069	0.032	0.070	0.057	0.006	0.059	0.082	0.086
48	0.172	0.138	0.142	0.130	0.088	0.092	0.096	0.081	0.053	0.097	0.065
47	0.120	0.142	0.085	0.205	0.074	0.131	0.092	0.125	0.025	0.069	0.042
54	0.704	0.718	0.501	0.537	0.514	0.36	0.352	0.246	0.235	0.191	0.222
53	0.783	0.545	0.621	0.579	0.441	0.394	0.467	0.282	0.322	0.262	0.192

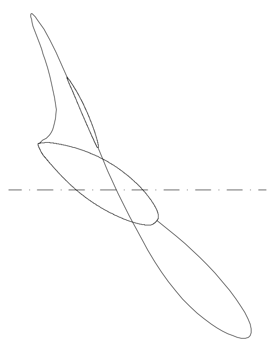
Concentrations of bubbles [1/cm³] in 10 µm-classes, estimated by background substraction, $\alpha/\alpha_S \approx 40\%$

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
56.1	9.490	3.059	0.324	0.294	-0.091	-0.053	0.086	-0.203	-0.097	0.007	0.151
56.2	1.651	0.585	-0.058	-0.107	-0.098	0.106	0.023	0.006	-0.052	0.049	-0.026
56.3	1.289	0.413	0.207	0.057	0.008	0.026	0.053	-0.033	0.022	0.015	0.035
56.4	0.799	0.233	0.021	0.069	-0.025	0.081	-0.011	-0.052	0.029	-0.013	0.047
56.5	1.696	0.711	0.083	0.009	-0.045	-0.025	0.013	-0.031	-0.134	-0.005	-0.025
56.6	4.574	1.895	0.261	0.269	0.094	-0.093	-0.09	-0.008	-0.026	-0.085	-0.012
56.7	16.26	4.846	0.816	0.277	-0.104	-0.171	-0.223	-0.182	-0.155	-0.068	-0.075
60	1.249	0.443	0.141	0.02	0.023	0.048	-0.013	-0.034	-0.002	-0.008	-0.016
59	0.703	0.151	0.110	0.001	0.018	0.025	0.037	0.017	-0.06	0.055	0.018
58	0.583	0.064	-0.058	-0.002	0.087	-0.034	0.093	0.047	-0.001	0.028	0.001
63	1.340	0.504	0.091	0.069	0.006	0.083	-0.034	0.031	0.033	0.037	0.035
62	1.113	0.274	0.081	-0.028	-0.047	-0.099	-0.033	0.028	0.034	-0.007	-0.03
61											
65	0.293	0.216	0.274	0.276	0.27	0.231	0.234	0.203	0.096	0.125	0.194
64	0.374	0.152	0.275	0.276	0.233	0.303	0.303	0.337	0.195	0.202	0.202
57.1	9.104	2.627	0.326	0.108	0.093	0.021	0.076	-0.025	-0.036	0.073	0.035
57.2	1.333	0.318	0.047	0.083	0.058	0.045	0.059	0.011	-0.047	0.094	0.012
57.3	0.641	0.097	0.089	0.01	0.036	0.001	0.042	0.000	-0.018	-0.004	0.018
57.4	0.363	0.275	0.386	0.478	0.461	0.412	0.374	0.329	0.239	0.239	0.211
57.5	1.554	0.467	0.121	-0.03	0.061	0.092	0.056	0.015	0.071	-0.038	-0.036
57.6	1.804	0.736	0.171	0.129	-0.001	-0.001	0.051	0.116	-0.033	0.028	-0.009
57.7	8.595	3.210	0.317	0.110	-0.113	-0.002	0.204	-0.169	-0.092	-0.011	-0.037

No.	10µm	20µm	30µm	40µm	50µm	60µm	70µm	80µm	90µm	100µm	110µm
56.1	0.040	0.038	-0.148	0.009	0.014	-0.081	0.072	-0.038	-0.057	0.131	0.379
56.2	-0.018	-0.020	-0.014	0.048	-0.006	-0.001	0.018	-0.025	-0.019	0.037	0.097
56.3	-0.002	-0.020	-0.072	0.022	-0.019	0.022	0.003	0.004	0.016	0.046	0.056
56.4	0.068	0.015	-0.043	0.015	0.006	0.049	0.048	0.105	0.066	0.068	0.020
56.5	0.020	0.006	0.007	0.006	0.008	0.046	-0.006	-0.049	-0.062	0.090	0.158
56.6	0.034	0.071	0.020	-0.011	-0.037	0.019	-0.05	-0.070	0.049	0.119	0.108
56.7	0.056	-0.047	0.028	-0.075	-0.049	-0.135	-0.167	-0.136	-0.12	0.268	0.472
60	-0.021	0.029	0.046	0.018	0.002	-0.006	0.011	0.028	0.034	0.061	0.097
59	-0.006	0.045	0.007	0.019	0.012	0.01	0	-0.017	0.046	0.01	0.003
58	0.047	0.002	0.039	-0.007	0.031	0.036	0.004	0.049	-0.015	0.051	0.037
63	-0.034	-0.003	0.022	0.027	-0.047	0.06	-0.033	-0.06	0.06	0.017	0.046
62	0.046	-0.005	-0.011	0.038	0.030	0.005	0.057	0.024	-0.022	0.043	0.034
61											
65	0.146	0.097	0.086	0.102	0.056	0.070	0.076	0.047	0.034	0.025	0.033
64	0.209	0.152	0.197	0.214	0.225	0.110	0.103	0.079	0.154	0.096	0.095
57.1	-0.025	0.061	0.005	-0.116	-0.063	-0.073	0.075	0.012	-0.013	0.152	0.323
57.2	0.030	0.038	-0.008	0.022	0.026	-0.021	0.000	0.045	0.009	-0.006	0.061
57.3	-0.005	0.034	-0.016	0.05	-0.013	-0.017	0.004	-0.016	-0.012	0.019	-0.009
57.4	0.208	0.196	0.211	0.145	0.074	0.093	0.083	0.090	0.046	0.029	0.041
57.5	-0.078	-0.008	0.035	-0.01	-0.013	0.000	-0.012	-0.053	-0.065	0.084	0.018
57.6	-0.032	-0.041	0.009	-0.008	0.042	0.072	-0.014	0.001	0.059	0.064	0.053
57.7	-0.074	0.012	0.005	-0.05	0.016	-0.023	-0.004	-0.039	0.069	0.050	0.213

Model propeller VP1304



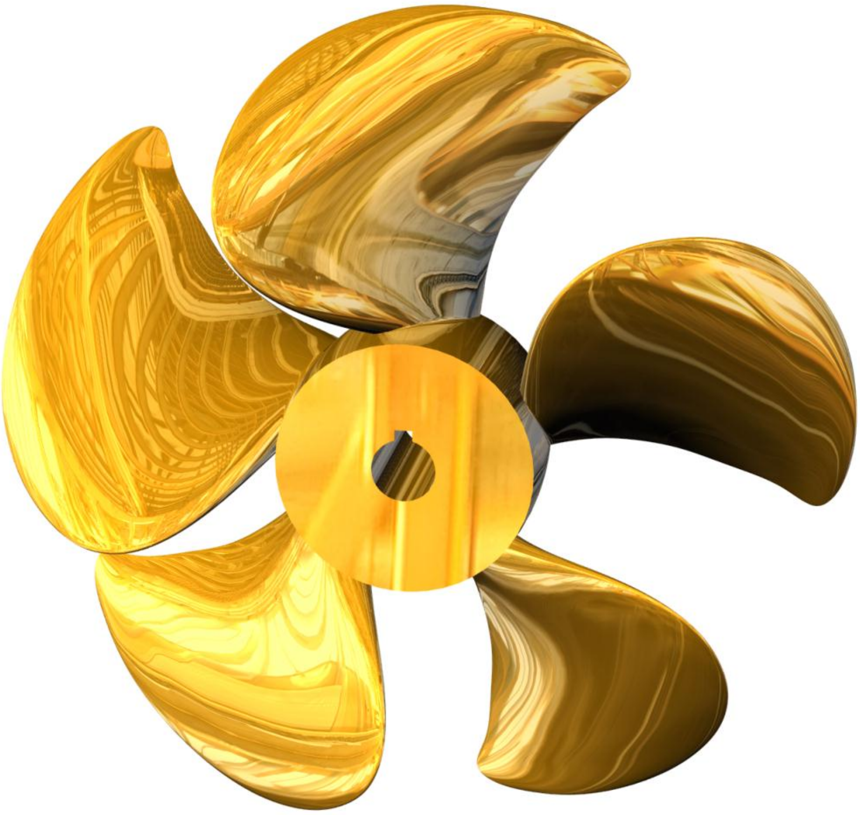


r/R	r	t	c	c_LE	f	rake	P
0.30000	37.50	13.525	45.00	18.25	0.675	0.000	350.00
0.35000	43.75	12.050	56.25	29.63	1.125	-0.500	363.75
0.40000	50.00	10.688	65.42	38.79	1.570	-1.250	376.25
0.50000	62.50	8.137	81.25	52.13	2.356	-3.350	394.50
0.60000	75.00	6.050	94.17	59.83	2.837	-5.875	405.00
0.70000	87.50	4.425	104.17	61.67	3.093	-7.500	408.75
0.80000	100.00	3.250	107.08	56.29	3.052	-7.375	403.50
0.85000	106.25	2.775	106.54	50.93	2.967	-6.625	395.50
0.90000	112.50	2.375	104.17	42.83	2.672	-5.450	382.75
0.95000	118.75	2.013	94.17	29.33	2.194	-4.033	364.50
0.97500	121.88	1.825	78.67	17.00	1.715	-3.300	352.75
1.00000	125.00	1.638	25.00	-14.58	0.500	-2.500	338.75

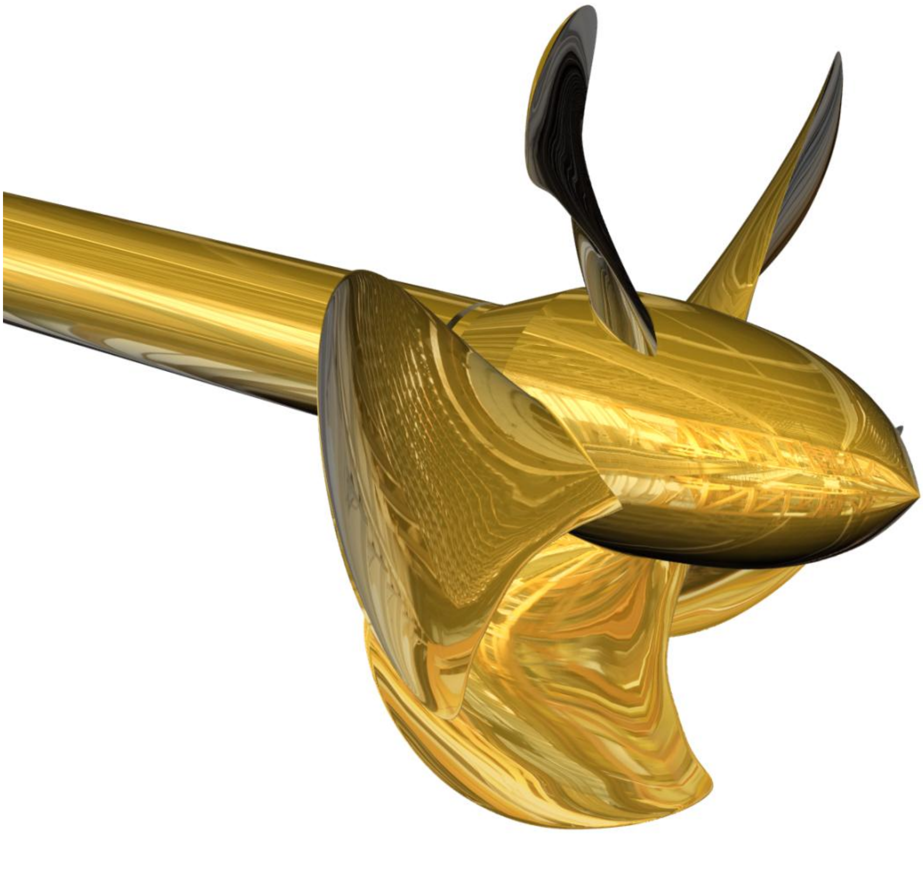
PROPELLER DIAMETER	D	250.0000mm
PITCH AT r/R=0.7	$P_{0.7}$	408.7500mm
PITCH AT r/R=0.75	$P_{0.75}$	407.3804mm
MEAN PITCH	P_{mean}	391.8812mm
CORDL. AT r/R=0.75	$c_{0.75}$	106.3476mm
THICKN. AT r/R=0.75	$t_{0.75}$	3.7916mm
PITCH RATIO	$P_{0.7}/D$	1.63500
MEAN PITCH RATIO	P_{mean}/D	1.56752
AREA RATIO	A_E/A_0	0.77896
SKEW		18.837°
HUB DIAMETER RATIO	d_h/D	0.30000
NUMBER OF BLADES	z	5
DIRECTION OF ROTATION		RIGHT-HANDED

MODEL SCALE 1 : 1.000000

Propeller VP1304

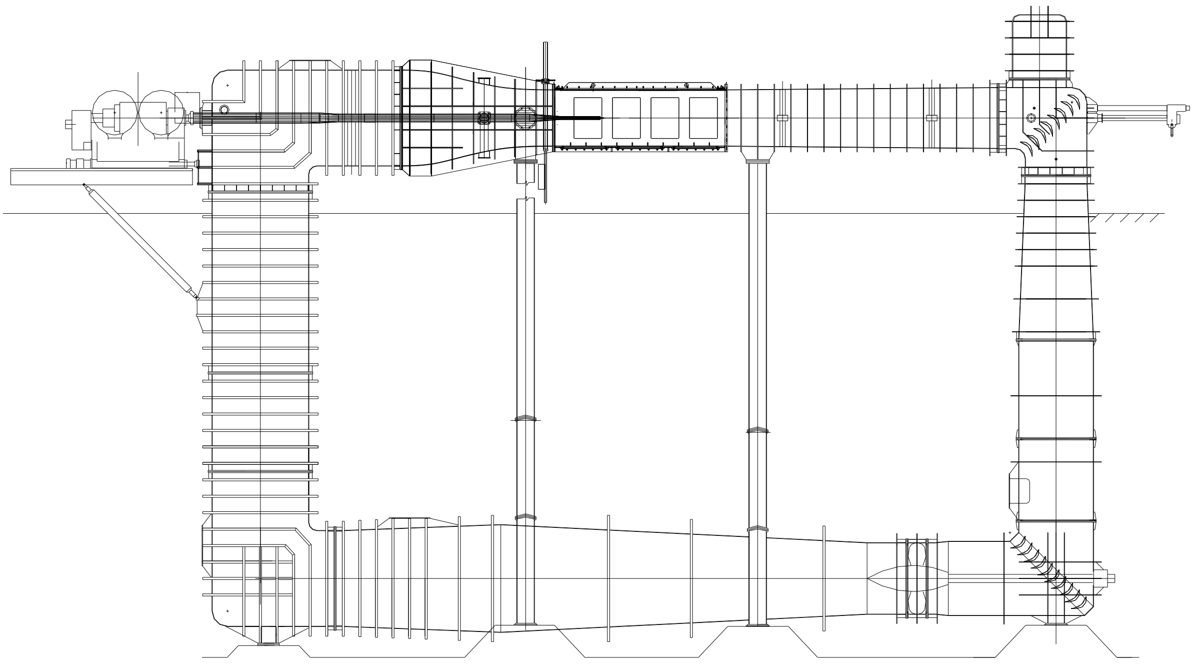


VP1304 in cavitation tunnel configuration

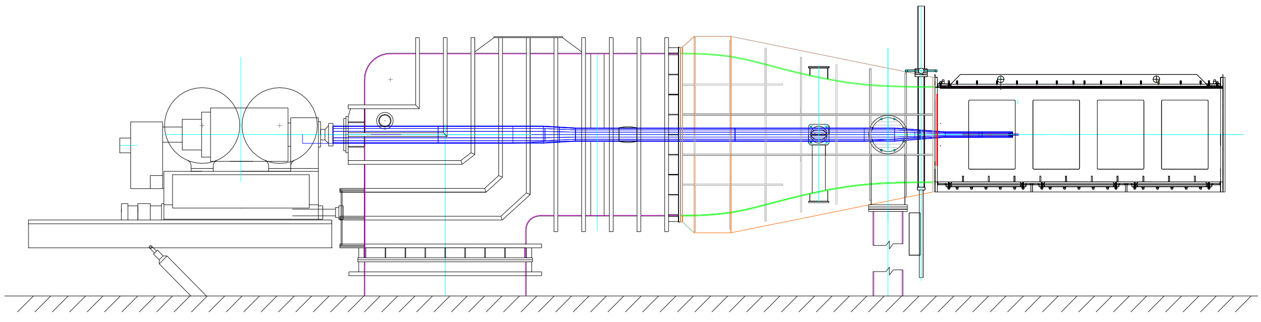


Cavitation tunnel K15A

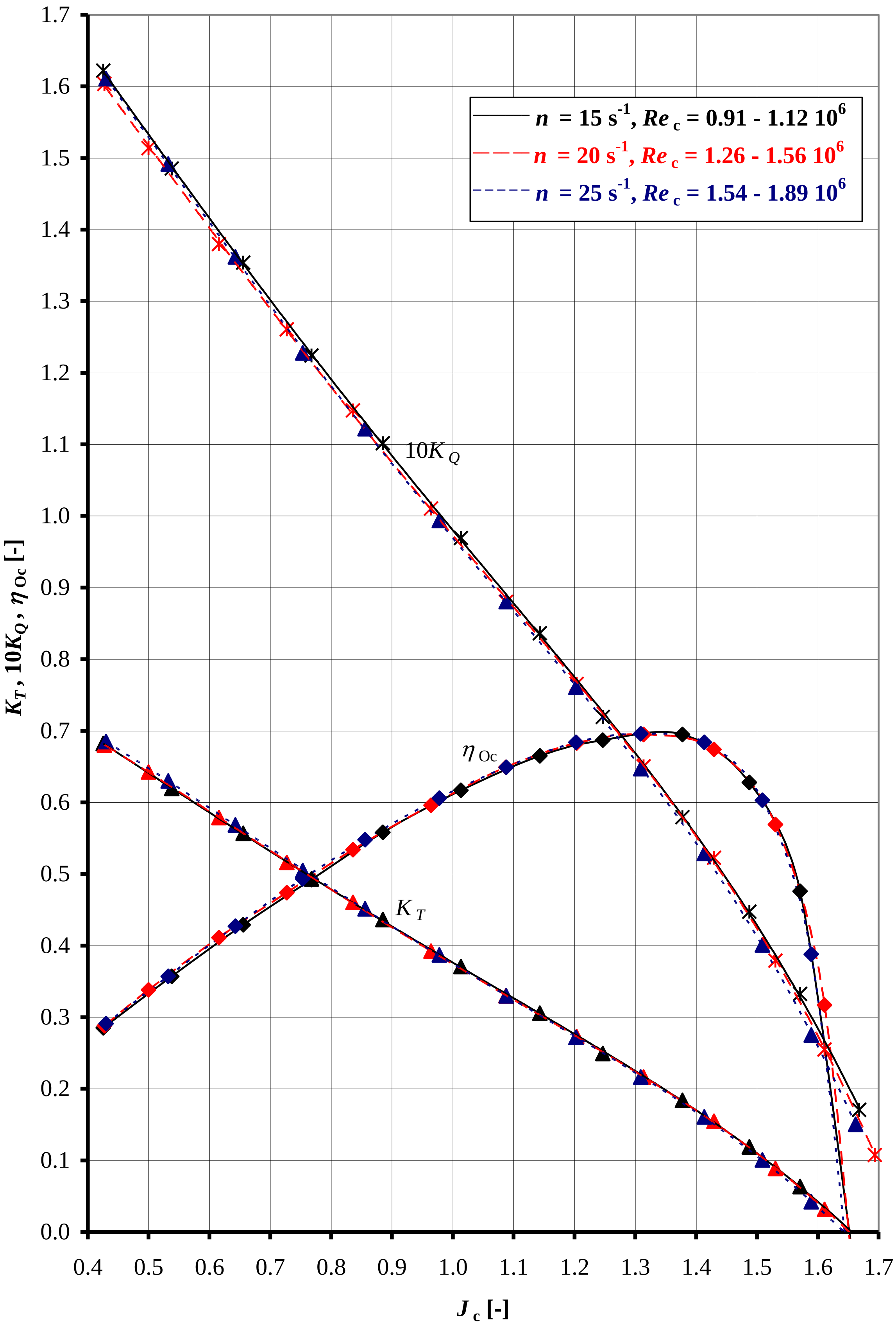
Cavitation tunnel K15A, test section 850 x 850



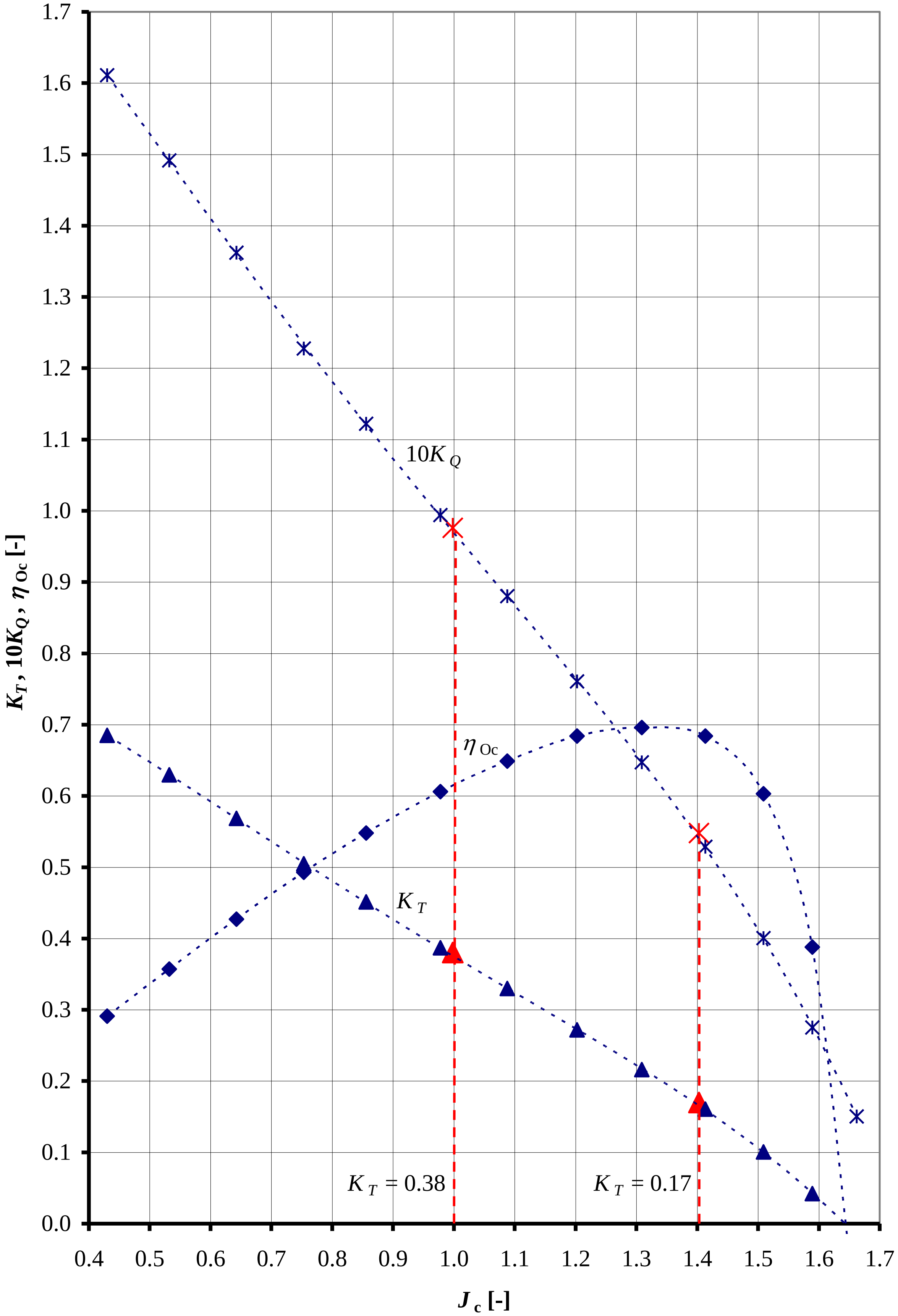
Cavitation tunnel K15A with dynamometer J25



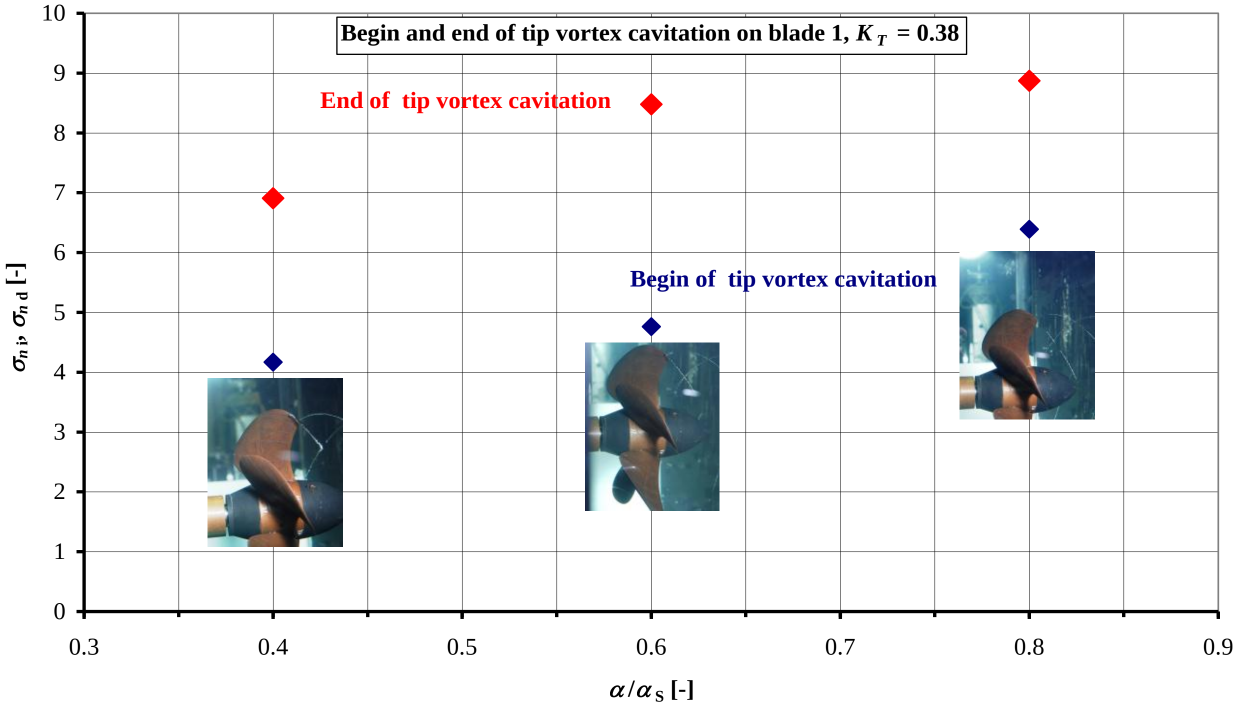
Open water characteristics, measured in the small test section



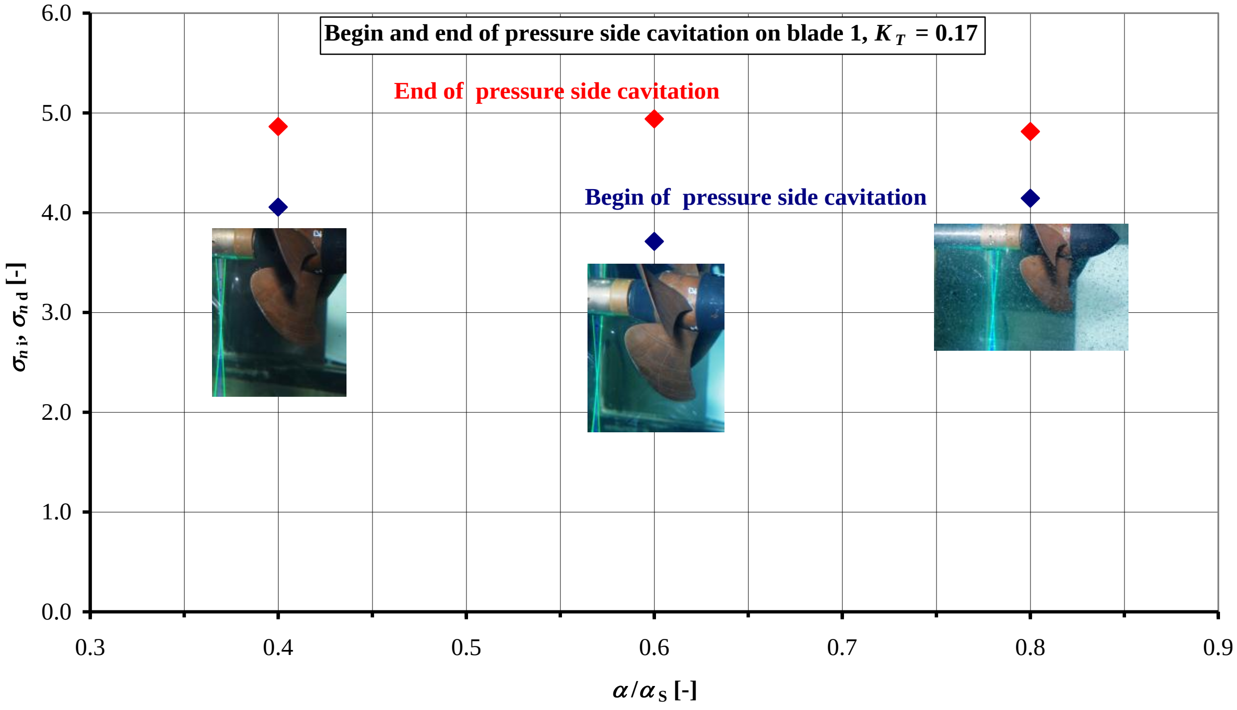
Working points for the cavitation tests and nuclei measurements



Begin and end of tip vortex cavitation, blade 1, K_T = 0.38

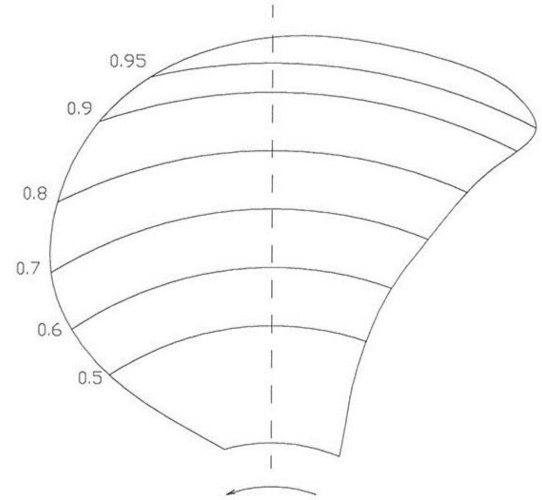


Begin and end of pressure side cavitation, blade 1, K_T = 0.17

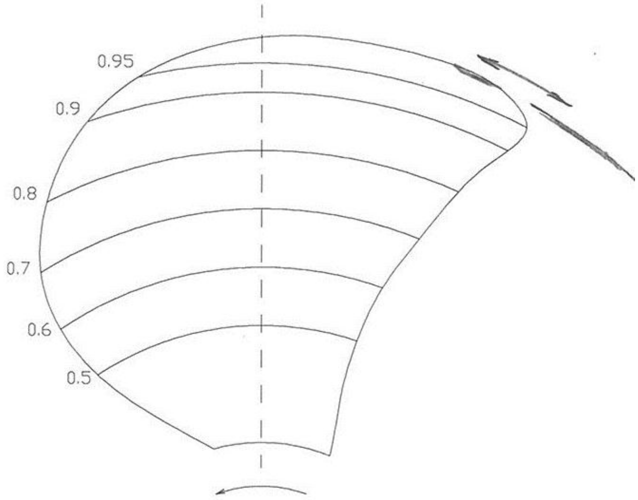


Cavitation number variation, $K_T \approx 0.38$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 82.5 – 70.3\%$

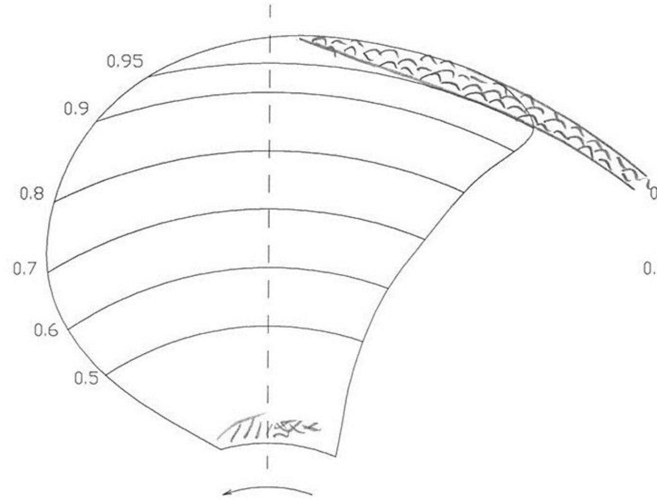
SVA Test 12KM0028, KonKav Test 34



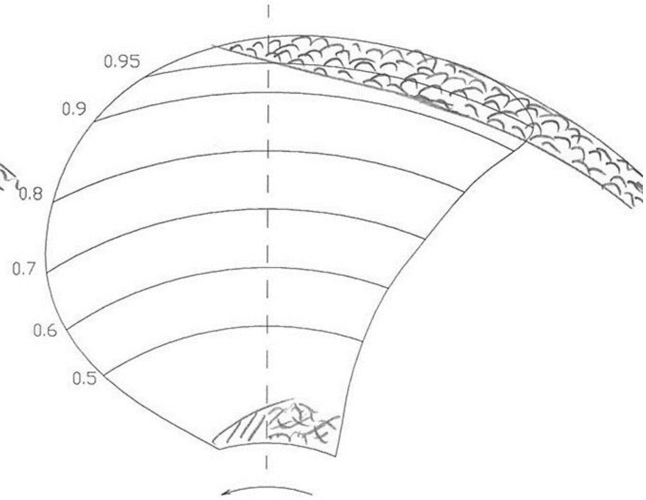
$\sigma_n = 13.55$



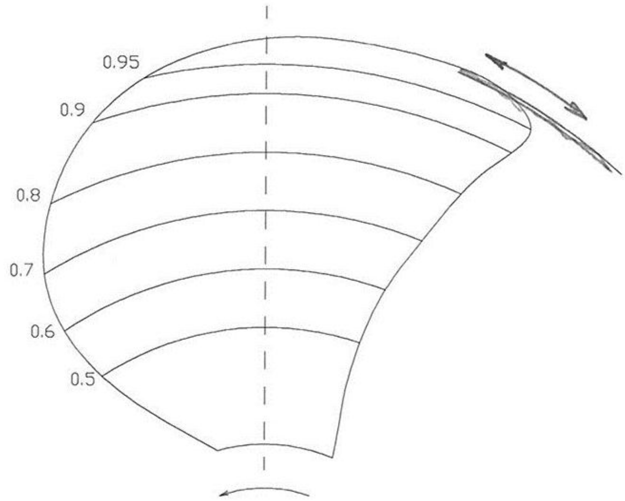
BTVC, $\sigma_n = 6.39$



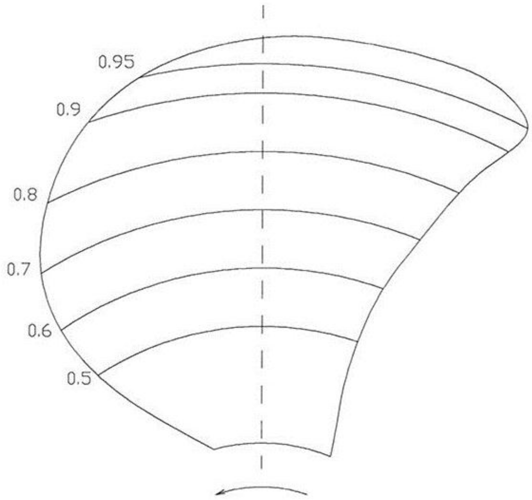
$\sigma_n = 3.03$



$\sigma_n = 2.02$



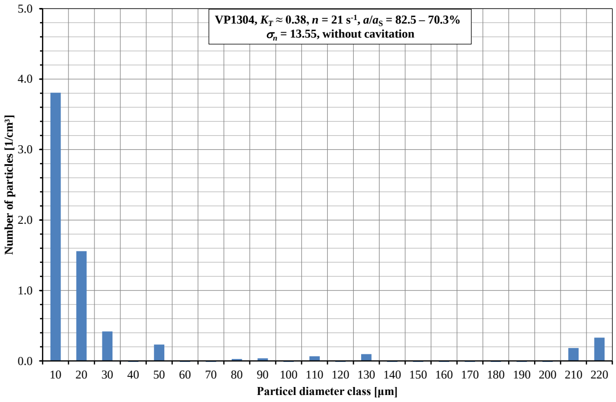
$\sigma_n = 6.39$



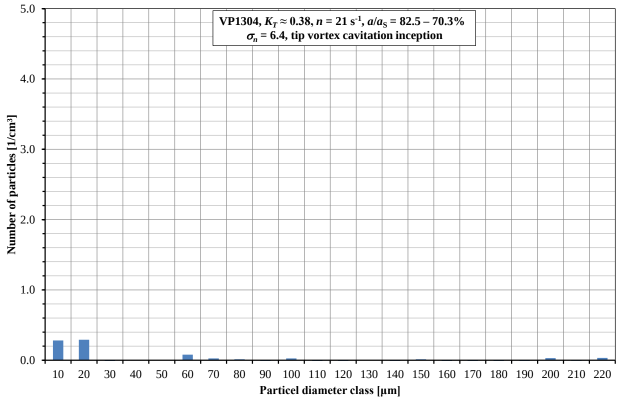
ETVC, $\sigma_n = 8.87$

Bubble concentration distribution, $K_T \approx 0.38$, n = 21 s^{-1}, α/α_S = 82.5 – 70.3%

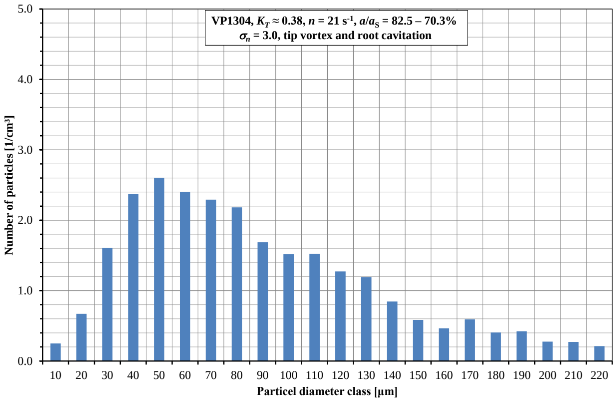
SVA Test 12KM0028, KonKav Test 34



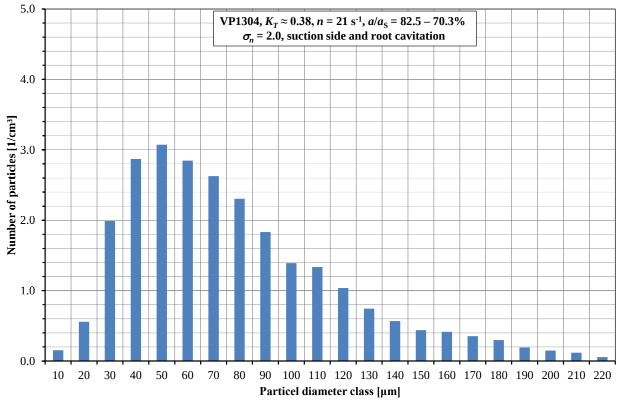
σ_n = 13.55



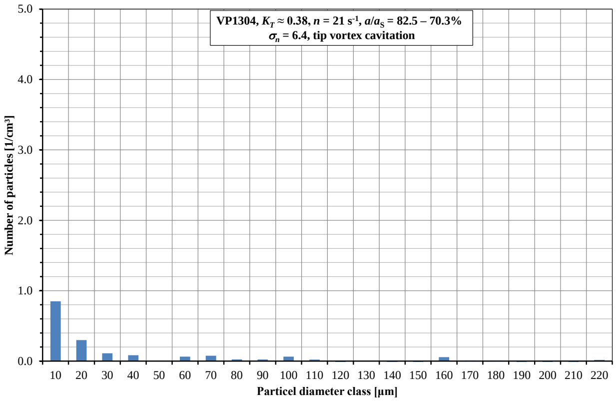
BTVC, σ_n = 6.39



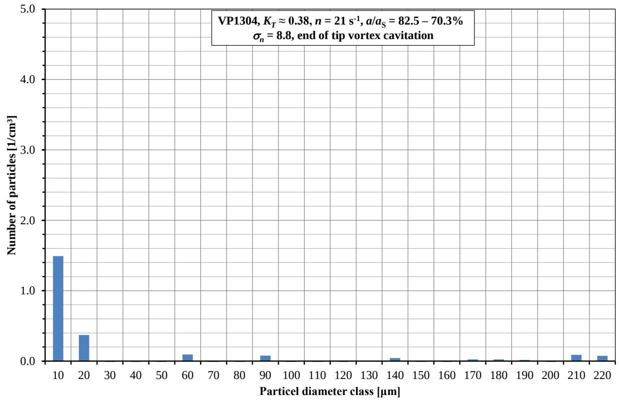
TVC, σ_n = 3.03



SSC, σ_n = 2.02

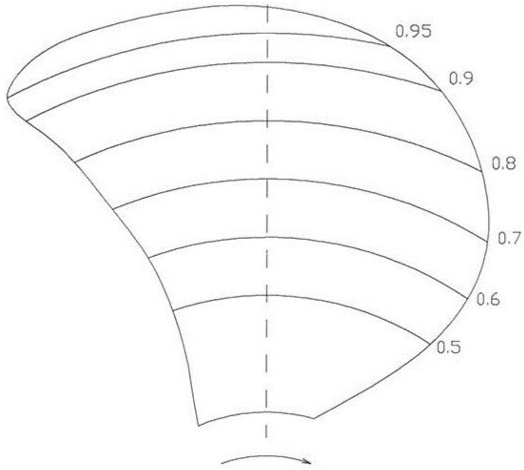


TVC, σ_n = 6.39

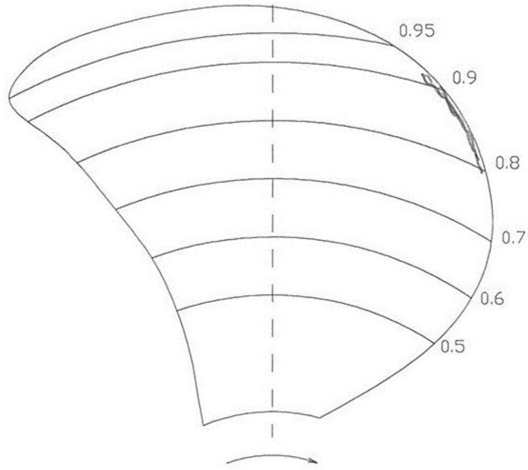


ETVC, σ_n = 8.87

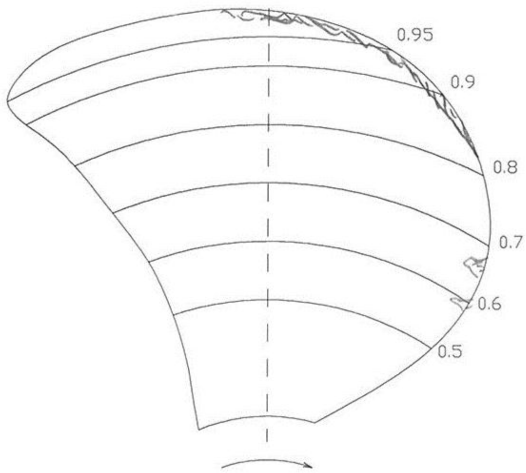
Cavitation number variation, $K_T \approx 0.17$, n = 21 s^{-1}, α/α_S = 83.4 – 75.1%
SVA Test 12KM0029, KonKav Test 35



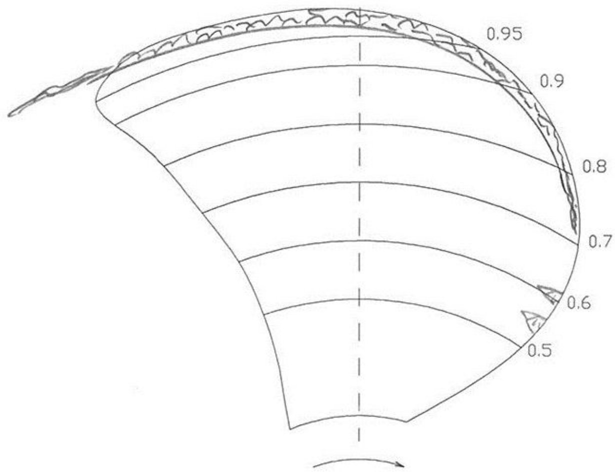
σ_n = 13.55



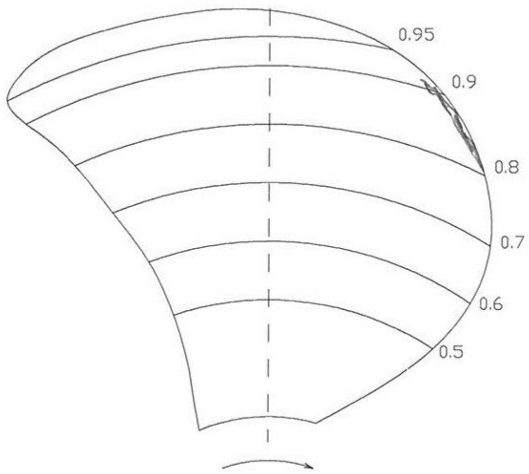
BPSC, σ_n = 4.14



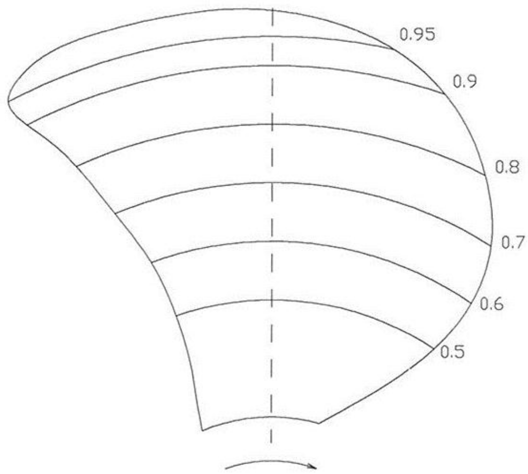
σ_n = 3.01



σ_n = 2.02



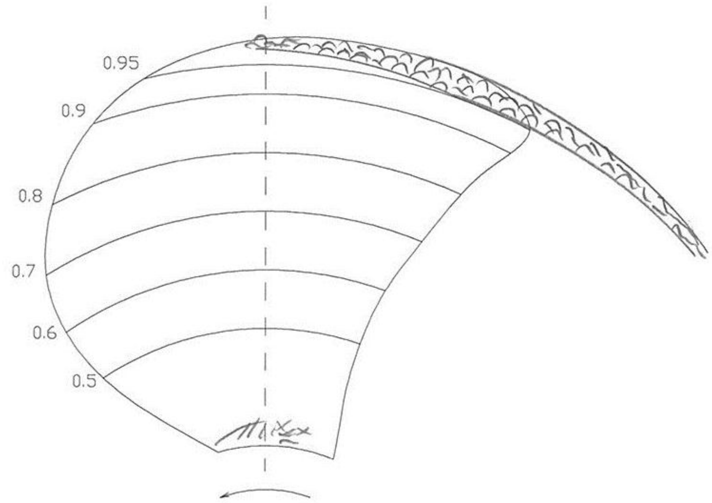
σ_n = 4.15



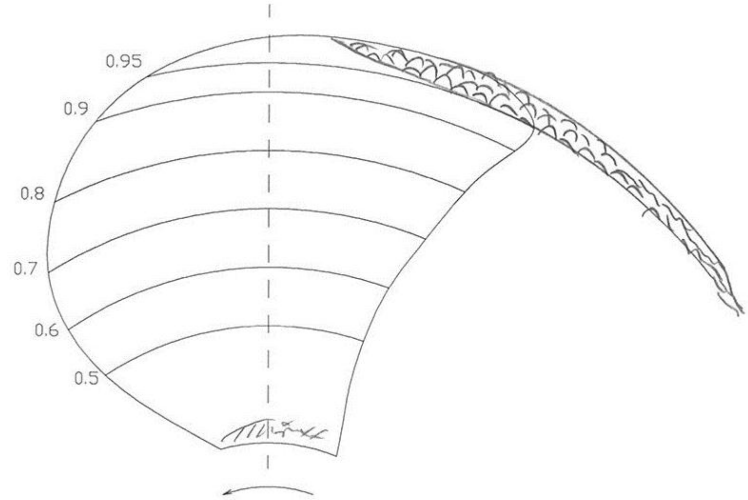
EPSC, σ_n = 4.81

Number of revolutions variation, K_T = 0.38, σ_n = 3.03, α/α_S = 77.7 – 70.1%

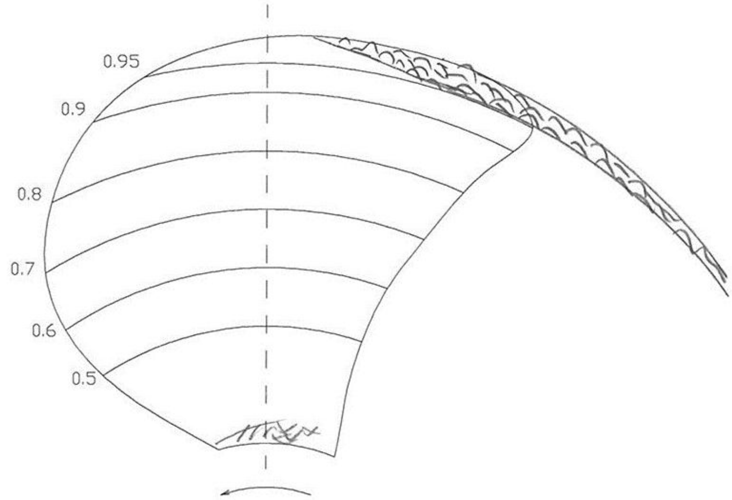
SVA Test 12KM0027, KonKav Tests 39, 40 and 41



n = 17 s^{-1}, V_c = 4.264 m/s

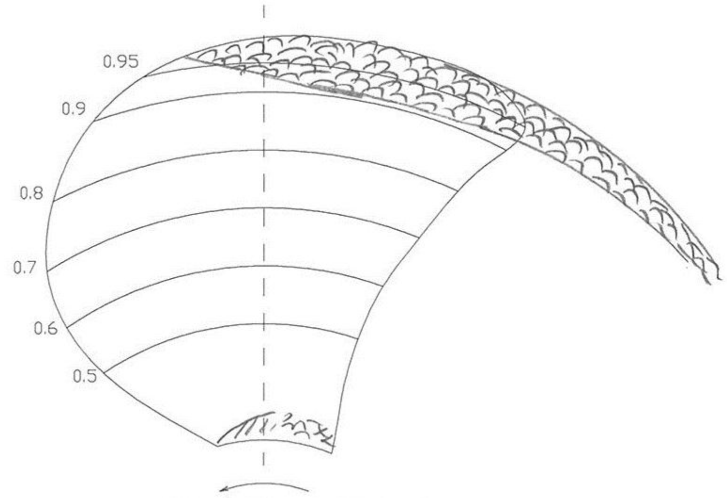


n = 21 s^{-1}, V_c = 5.251 m/s

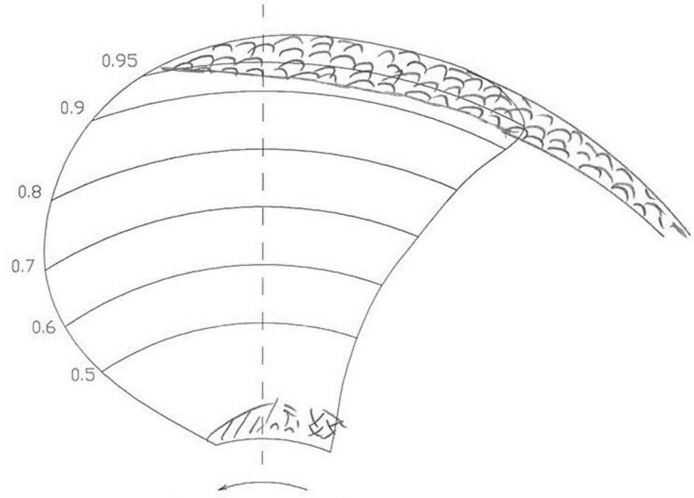


n = 25 s^{-1}, V_c = 6.215 m/s

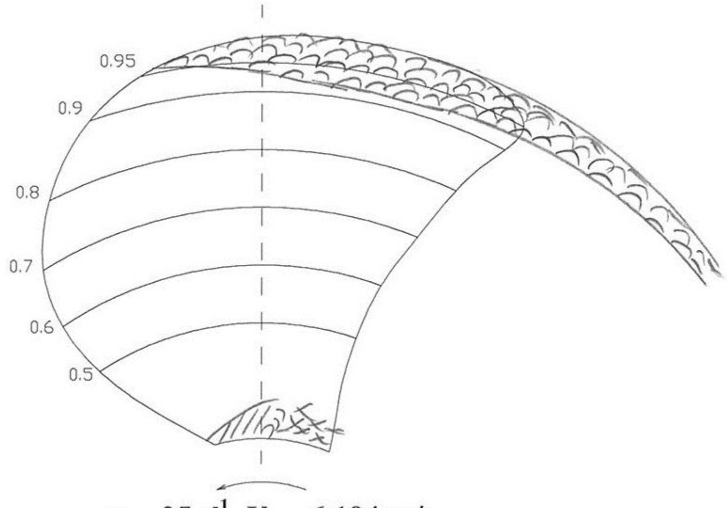
Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 2.02$, $\alpha/\alpha_S = 81.9 – 62.6\%$
SVA Test 12KM0030, KonKav Tests 36, 37, 38



$n = 17\ s^{-1}$, $V_c = 4.237$ m/s

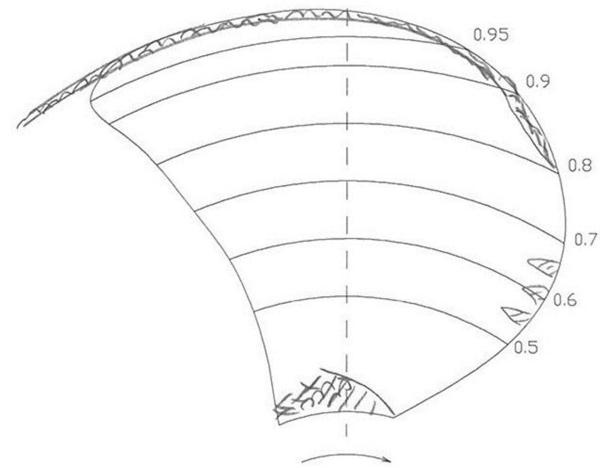


$n = 21\ s^{-1}$, $V_c = 5.243$ m/s

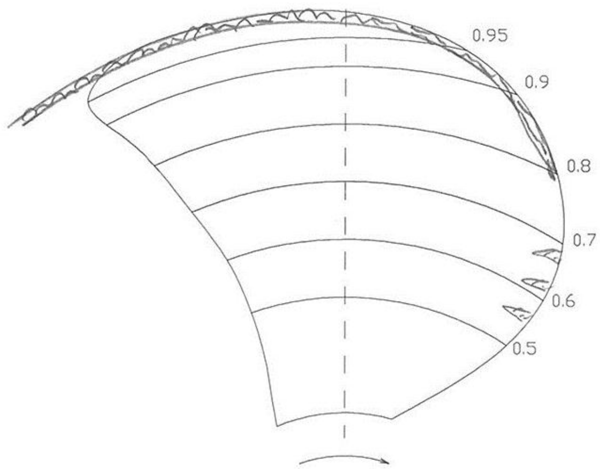


$n = 25\ s^{-1}$, $V_c = 6.194$ m/s

Number of revolutions variation, $K_T \approx 0.17$, $\sigma_n = 2.01$, $\alpha/\alpha_S = 80.0 – 59.1\%$
SVA Test 12KM0031, KonKav Tests 42, 43



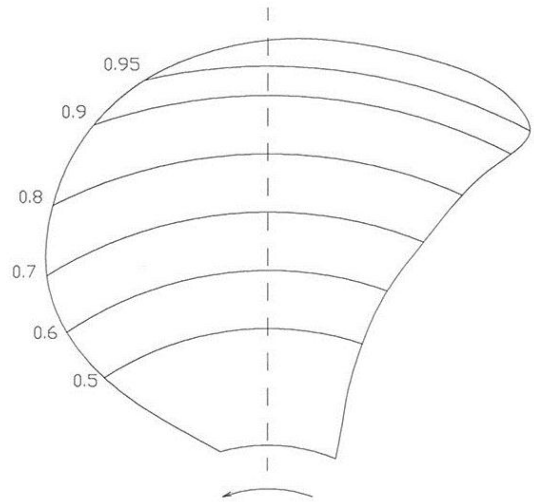
$n = 17\ s^{-1}$, $V_c = 5.982$ m/s



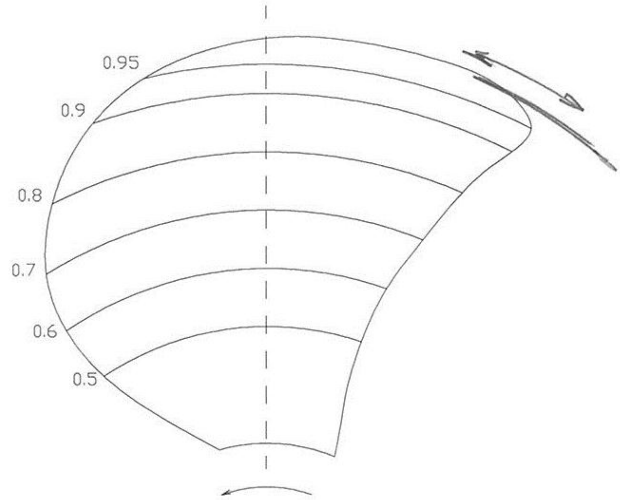
$n = 21\ s^{-1}$, $V_c = 7.342$ m/s

Cavitation number variation, $K_T \approx 0.38$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 57.3 – 59.0\%$

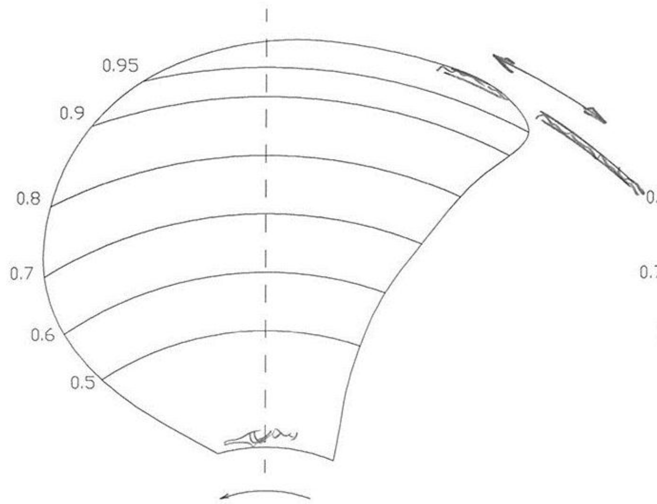
SVA Test 12KM0032, KonKav Test 45



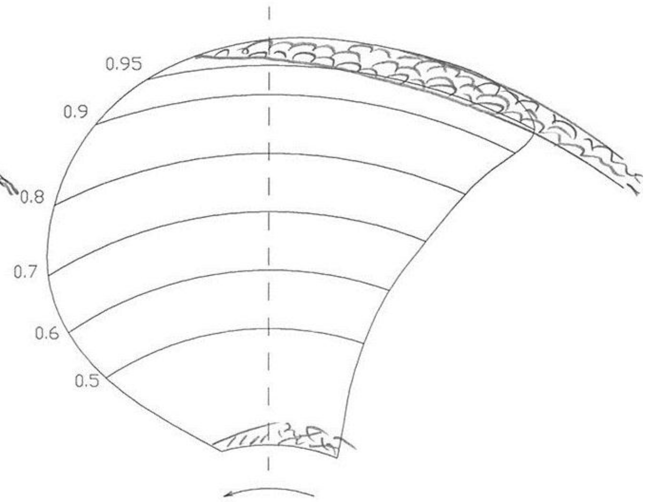
$\sigma_n = 13.55$



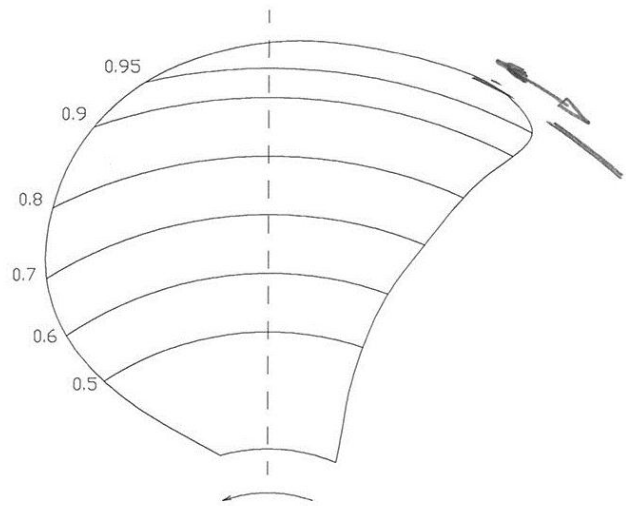
BTVC, $\sigma_n = 4.76$



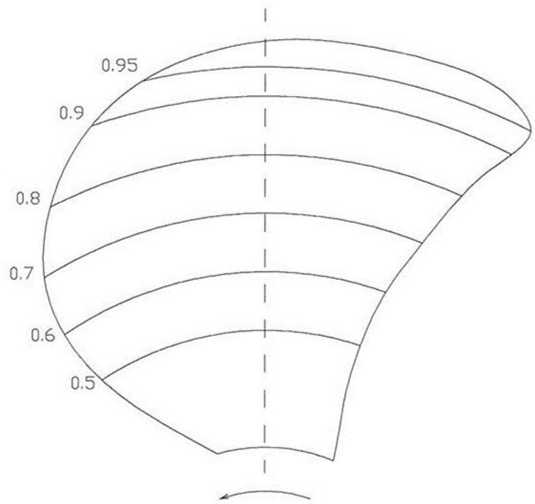
$\sigma_n = 3.04$



$\sigma_n = 2.04$



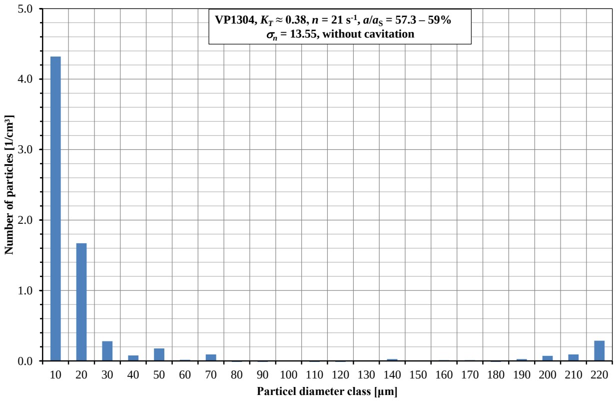
$\sigma_n = 4.76$



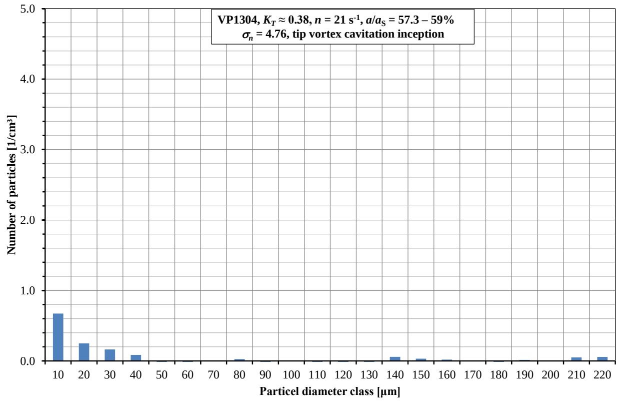
ETVC, $\sigma_n = 8.45$

Bubble concentration distribution, $K_T \approx 0.38$, n = 21 s^{-1}, α/α_S = 57.3 – 59.0%

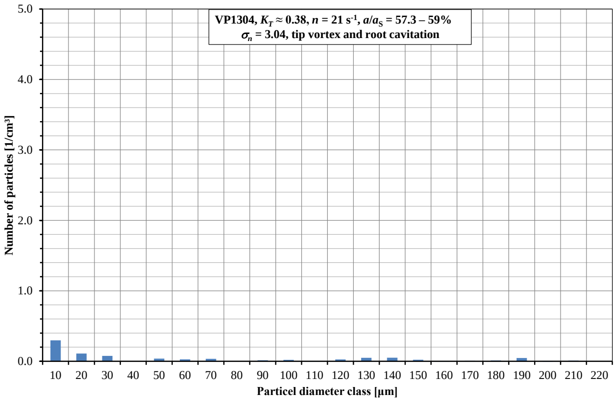
SVA Test 12KM0032, KonKav Test 45



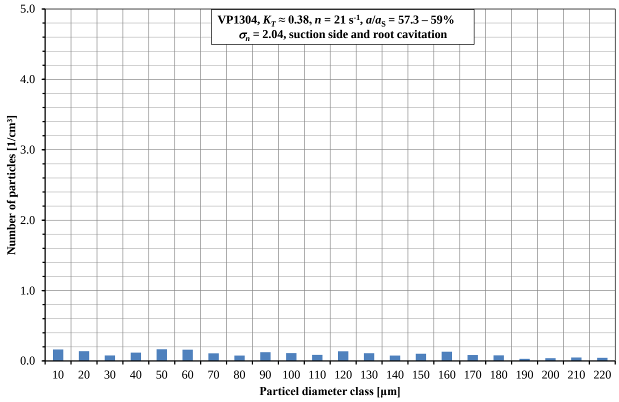
σ_n = 13.55



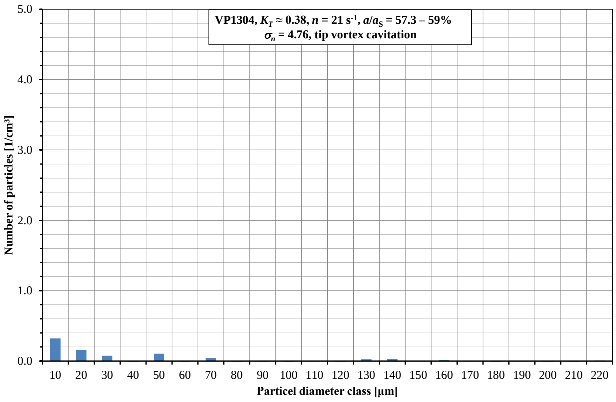
BTVC, σ_n = 4.76



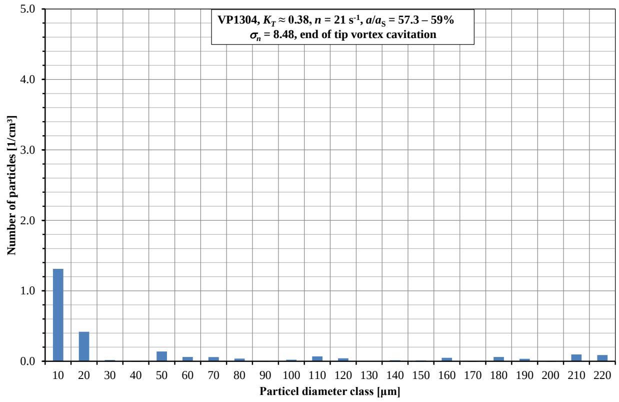
TVC, σ_n = 3.04



SSC, σ_n = 2.04



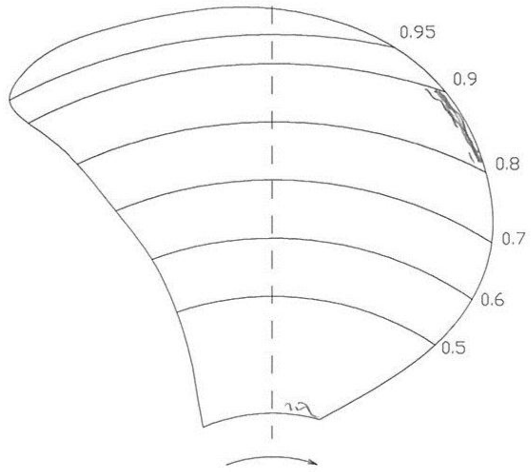
TVC, σ_n = 4.76



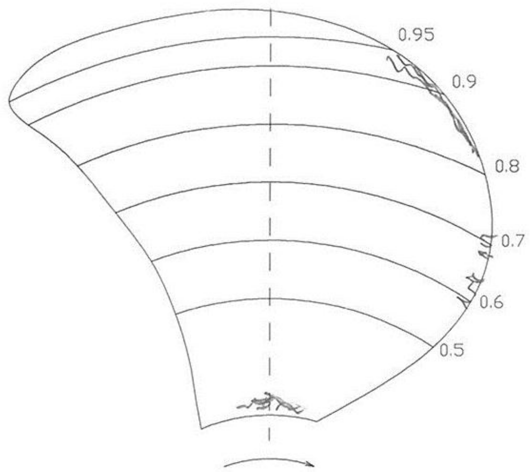
ETVC, σ_n = 8.45

Cavitation number variation, $K_T \approx 0.17$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 59.0 – 65.4\%$

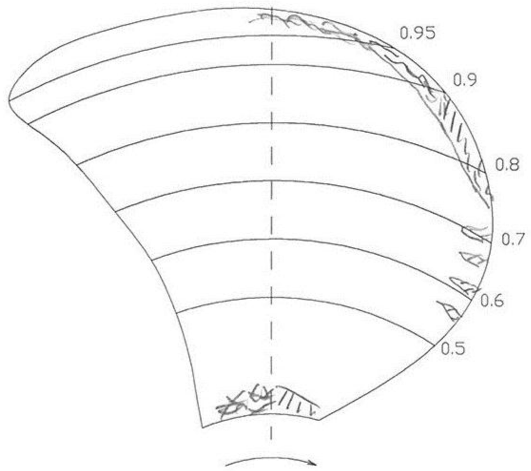
SVA Test 12KM0033, KonKav Test 46



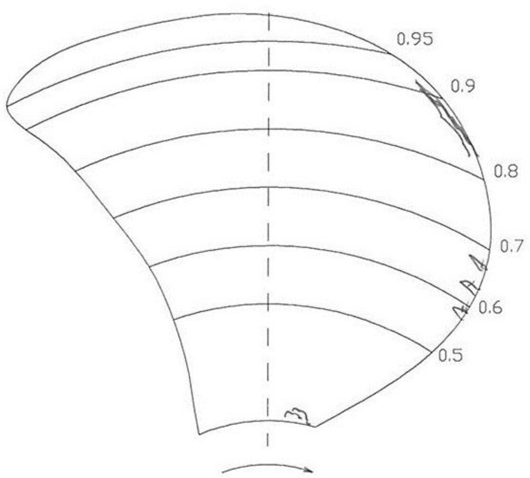
BPSC, $\sigma_n = 3.71$



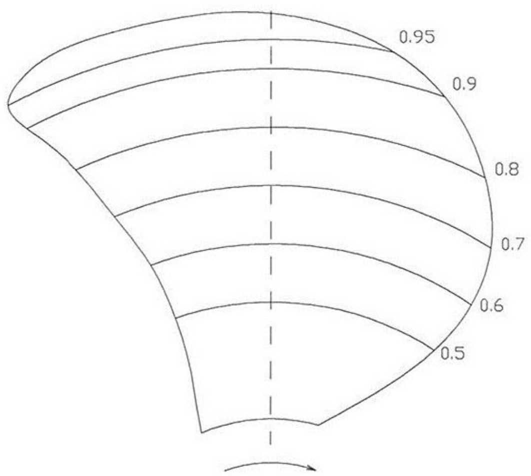
$\sigma_n = 3.01$



$\sigma_n = 2.01$



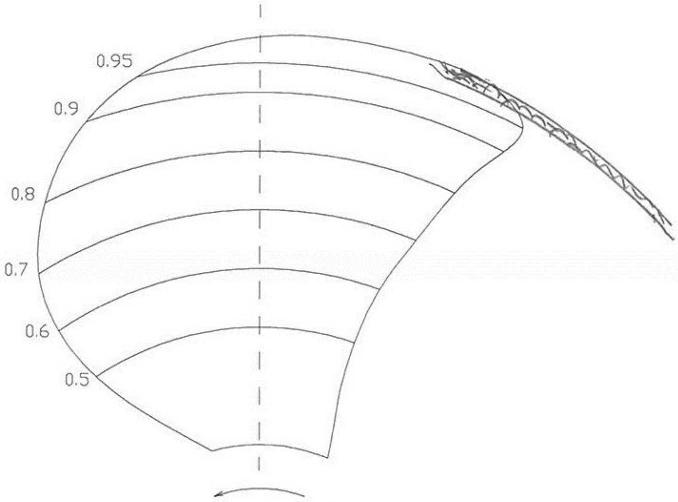
$\sigma_n = 3.72$



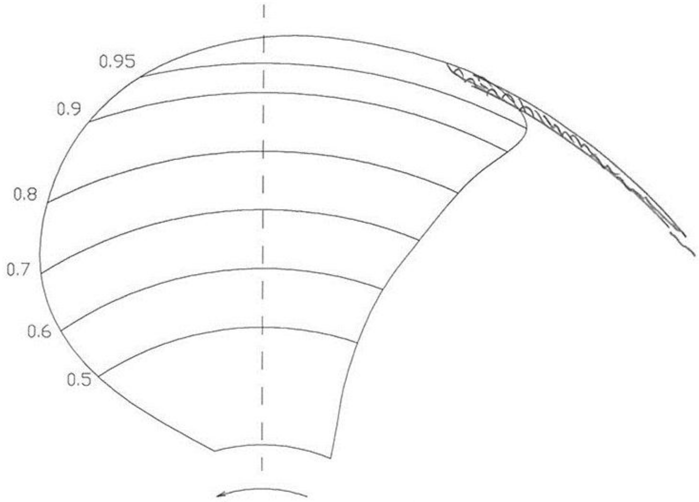
EPSC, $\sigma_n = 4.94$

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 3.02$, $\alpha/\alpha_S = 58.6 - 57.8\%$

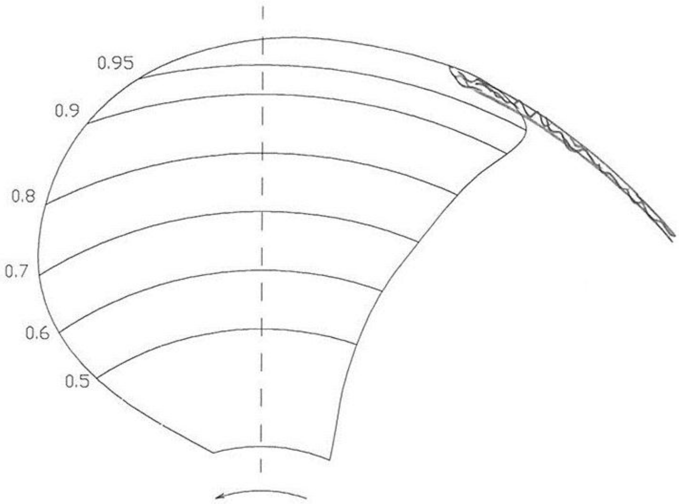
SVA Test 12KM0034, KonKav Tests 50, 51, 52



$n = 17\ s^{-1}$, $V_c = 4.227$ m/s

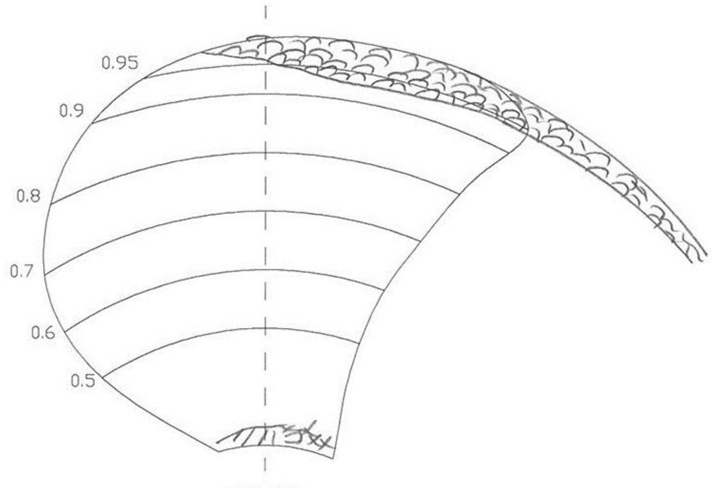


$n = 21\ s^{-1}$, $V_c = 5.222$ m/s

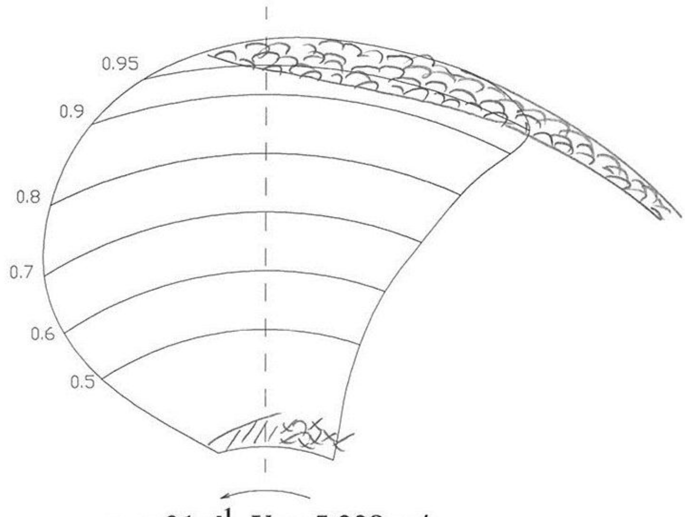


$n = 25\ s^{-1}$, $V_c = 6.193$ m/s

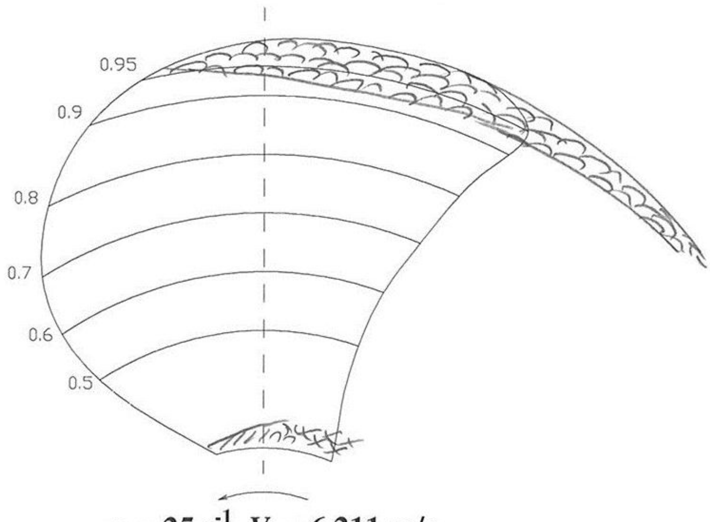
Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 2.03$, $\alpha/\alpha_S = 57.8 – 56.3\%$
SVA Test 12KM0035, KonKav Tests 47, 48, 49



$n = 17\ s^{-1}$, $V_c = 4.224$ m/s

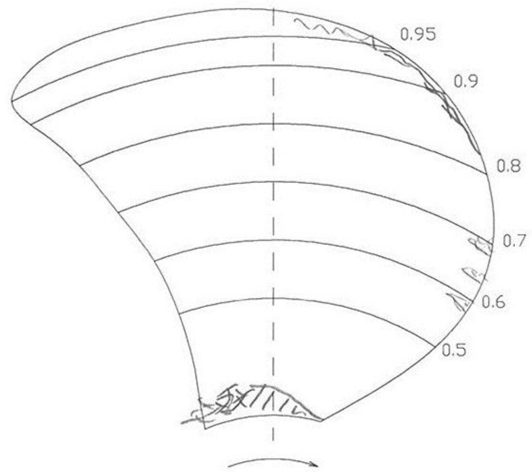


$n = 21\ s^{-1}$, $V_c = 5.228$ m/s

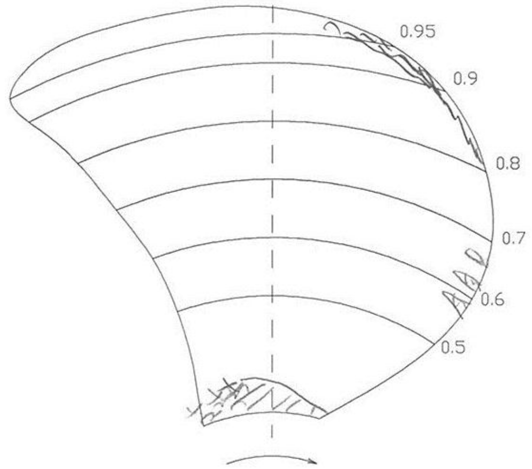


$n = 25\ s^{-1}$, $V_c = 6.211$ m/s

Number of revolutions variation, $K_T \approx 0.17$, $\sigma_n = 2.02$, $\alpha/\alpha_S = 56.3 – 55.3\%$
SVA Test 12KM0036, KonKav Tests 53, 54

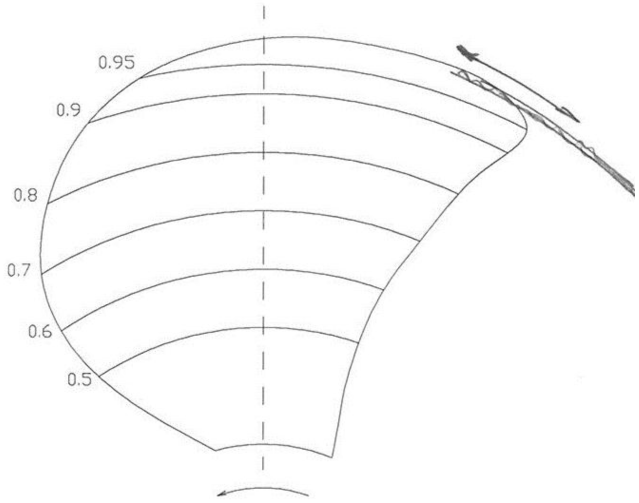


$n = 17\ s^{-1}$, $V_c = 5.969$ m/s

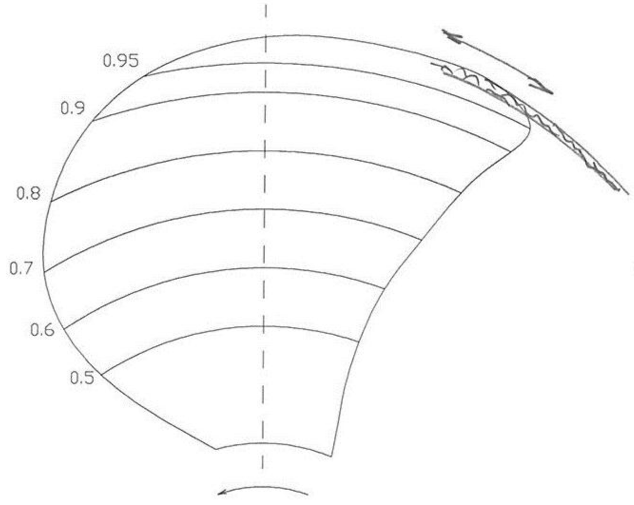


$n = 21\ s^{-1}$, $V_c = 7.371$ m/s

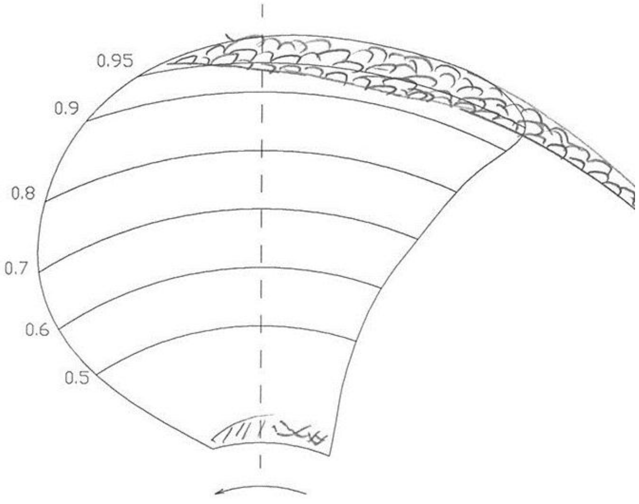
Cavitation number variation, $K_T \approx 0.38$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 38.4 – 41.5\%$
SVA Test 12KM0037, KonKav Test 56



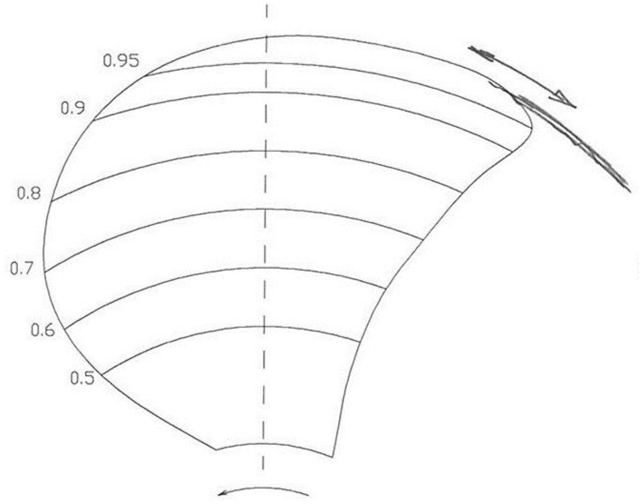
BTVC, $\sigma_n = 4.19$



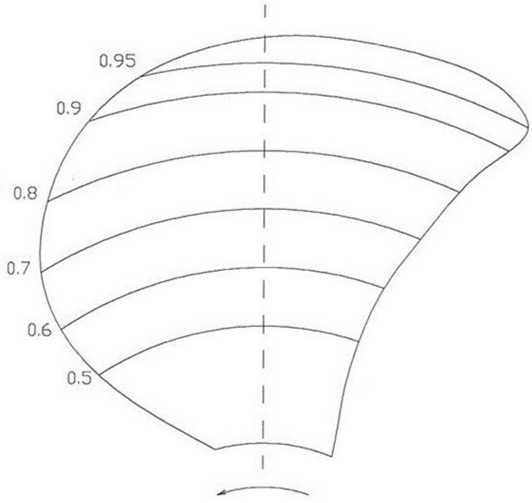
$\sigma_n = 3.06$



$\sigma_n = 2.05$



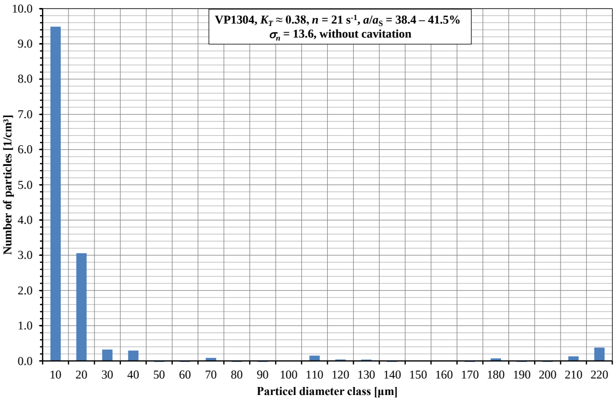
$\sigma_n = 4.19$



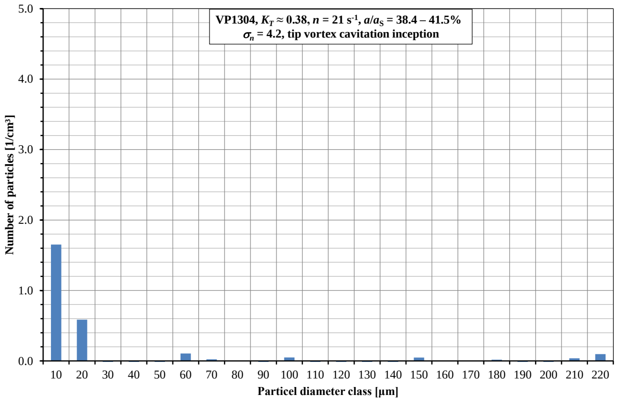
ETVC, $\sigma_n = 6.95$

Bubble concentration distribution, $K_T \approx 0.38$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 38.4 – 41.5\%$

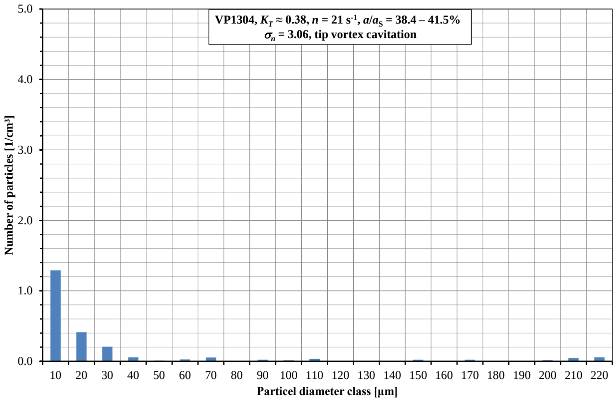
SVA Test 12KM0037, KonKav Test 56



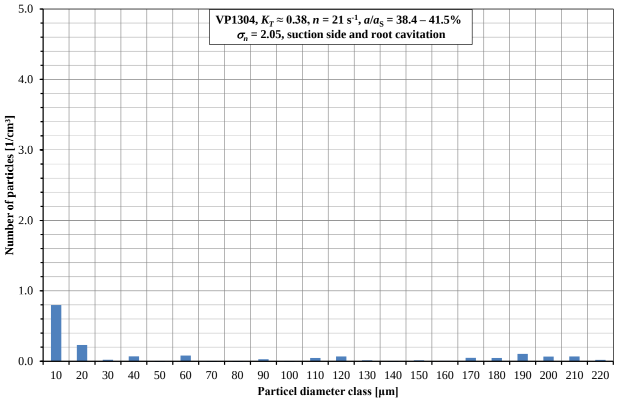
σ_n = 13.55



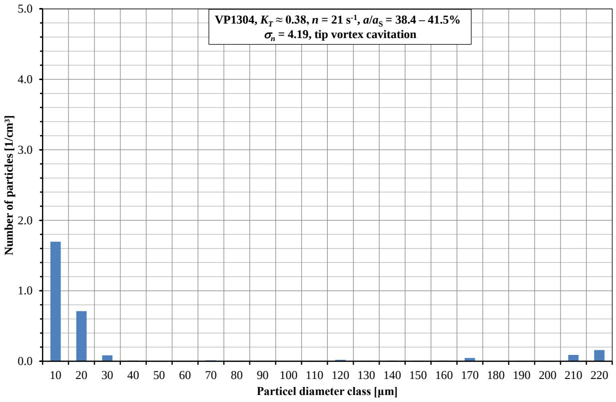
BTVC, σ_n = 4.19



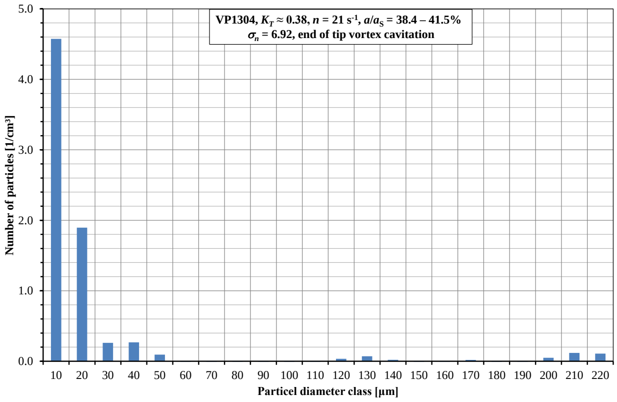
TVC, σ_n = 3.06



SSC, σ_n = 2.05

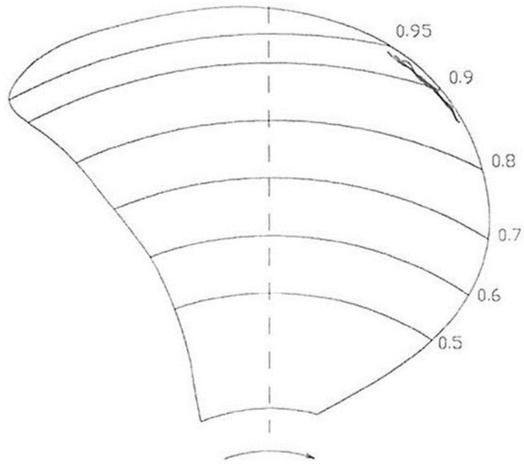


TVC, σ_n = 4.19

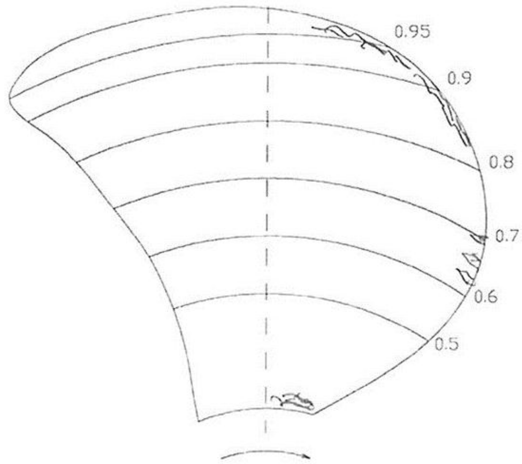


ETVC, σ_n = 6.95

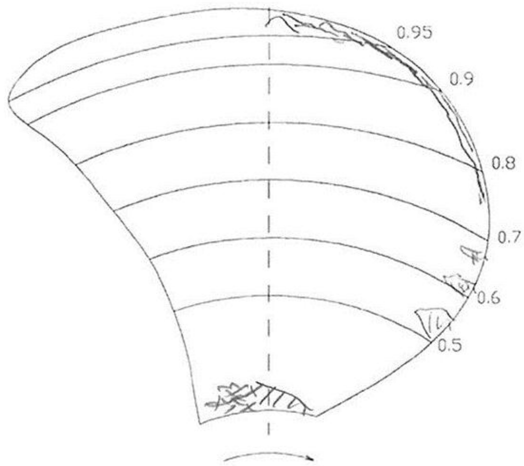
Cavitation number variation, $K_T \approx 0.17$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 42.0 – 52.8\%$
SVA Test 12KM0042, KonKav Test 57



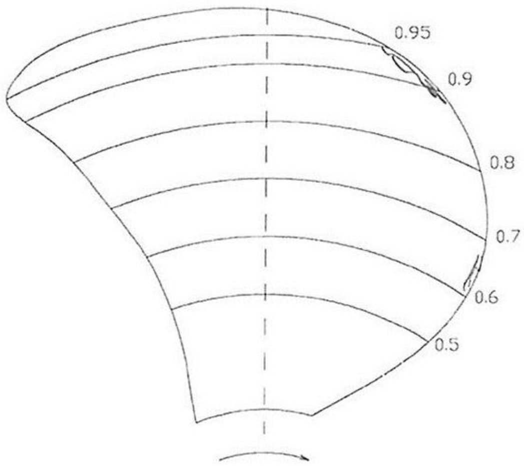
BPSC, $\sigma_n = 4.06$



$\sigma_n = 2.98$



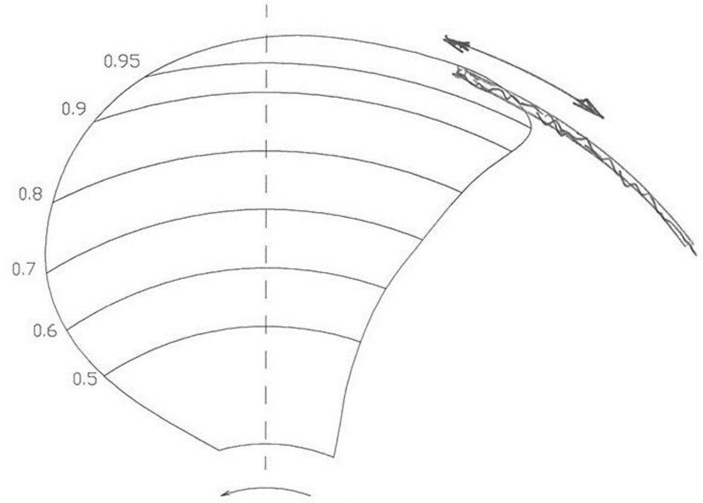
$\sigma_n = 1.97$



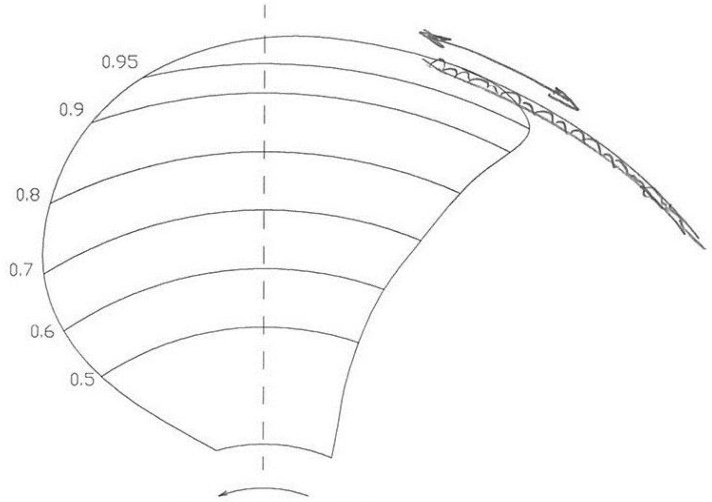
$\sigma_n = 4.06$

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 3.03$, $\alpha/\alpha_S = 42.4 – 45.7\%$

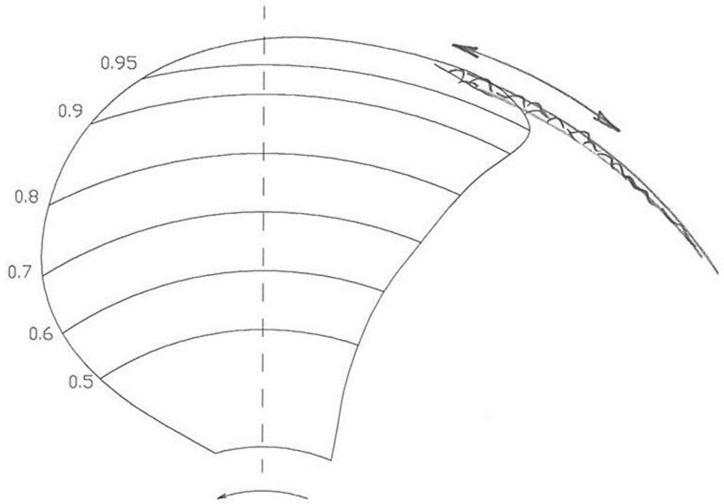
SVA Test 12KM0040, KonKav Tests 61, 62, 63



$n = 17\ s^{-1}$, $V_c = 4.224$ m/s



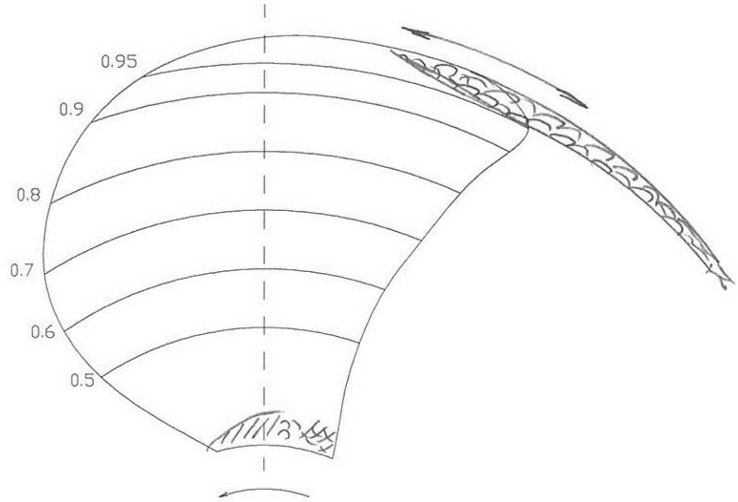
$n = 21\ s^{-1}$, $V_c = 5.243$ m/s



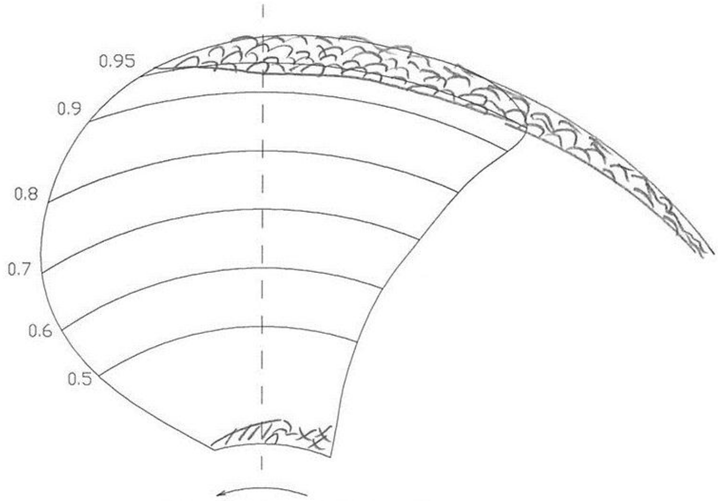
$n = 25\ s^{-1}$, $V_c = 6.229$ m/s

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 2.03$, $\alpha/\alpha_S = 41.5 – 41.7\%$

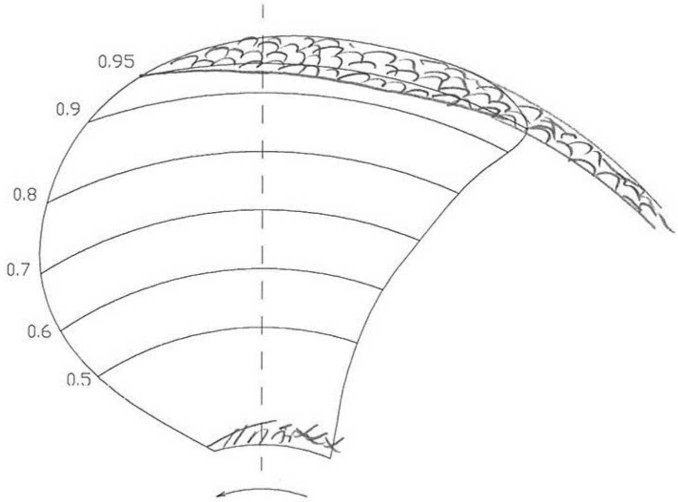
SVA Test 12KM0038, KonKav Tests 58, 59, 60



$n = 17\ s^{-1}$, $V_c = 4.221$ m/s

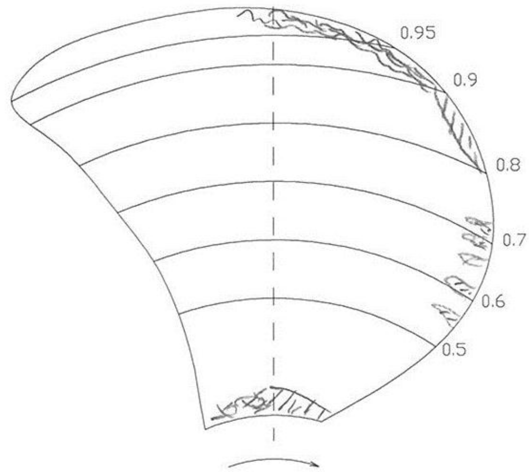


$n = 21\ s^{-1}$, $V_c = 5.230$ m/s

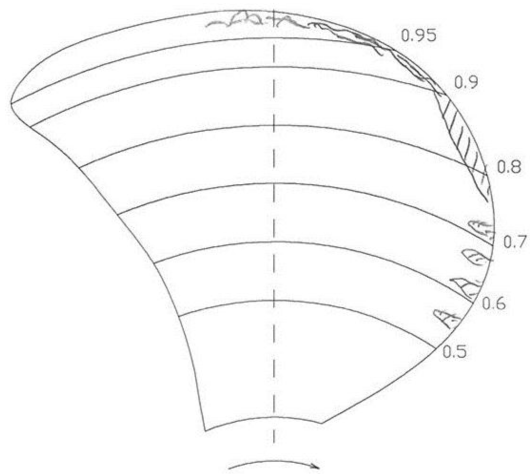


$n = 25\ s^{-1}$, $V_c = 6.203$ m/s

Number of revolutions variation, $K_T \approx 0.17$, $\sigma_n = 2.01$, $\alpha/\alpha_S = 40.9 – 42.0\%$
SVA Test 12KM0041, KonKav Tests 64, 65



$n = 17\ s^{-1}$, $V_c = 5.940$ m/s



$n = 21\ s^{-1}$, $V_c = 7.372$ m/s

Test arrangement in the cavitation tunnel

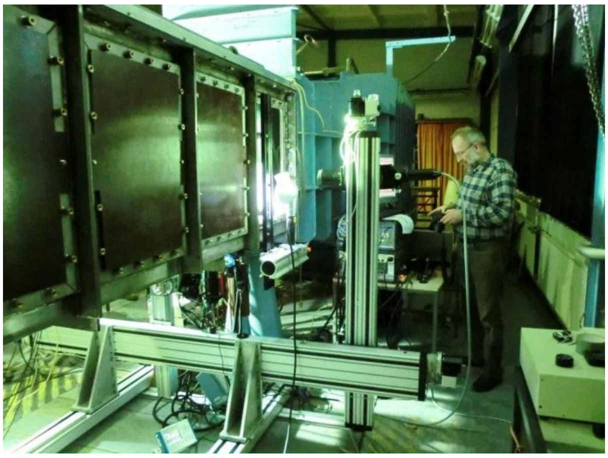
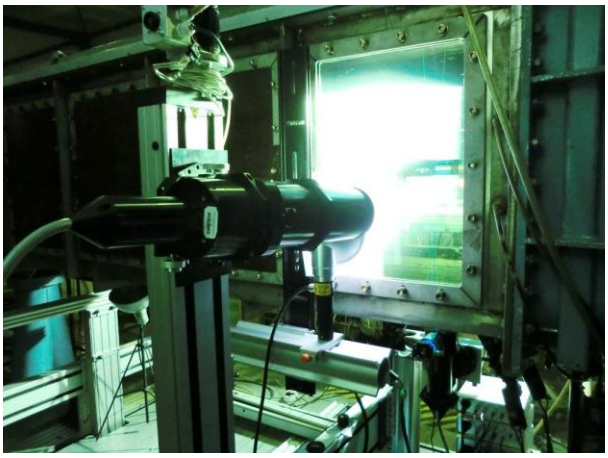
Measurement of idle torque with a dummy hub

Model propeller VP1304

Measurement of the cavitation behaviour, large test section

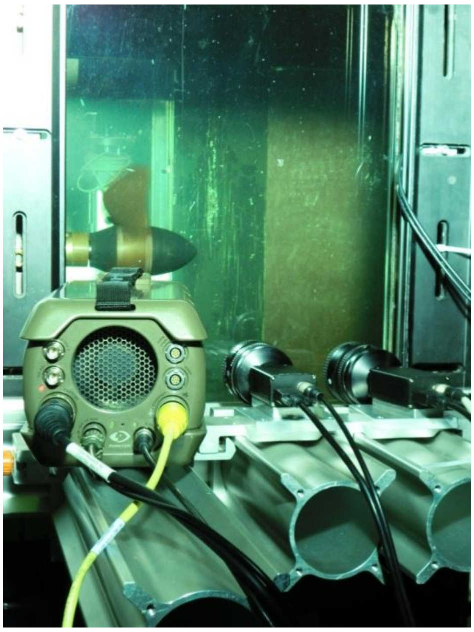
Test arrangement

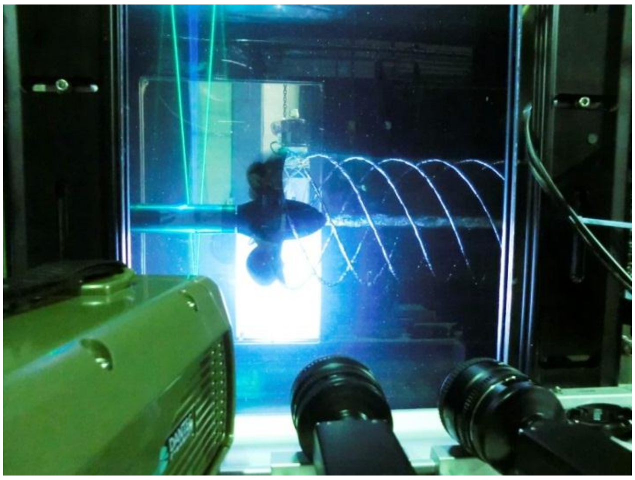
Particle dynamics analysis (two-component phase Doppler system from Dantec Dynamics)

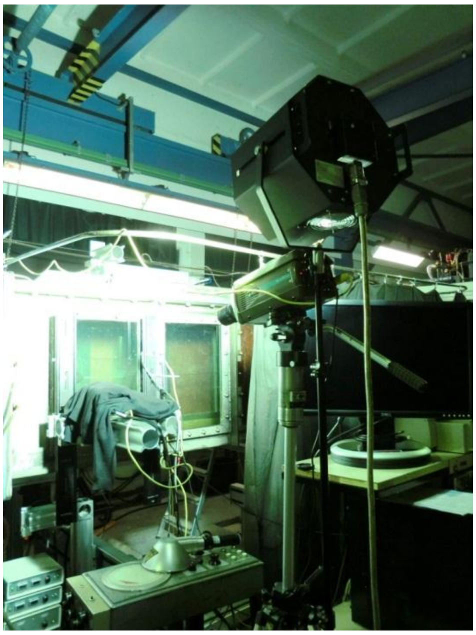

Test arrangement

Cavitation observation (shadow imaging)



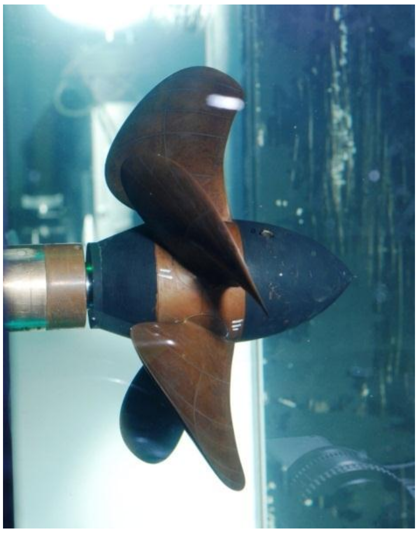


High Speed Video



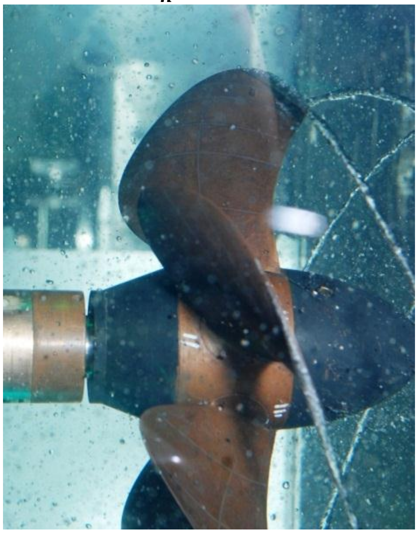
Cavitation number variation, $K_T \approx 0.38$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 82.5 – 70.3\%$

SVA Test 12KM0028, KonKav Test 34



$\sigma_n = 13.55$

BTVC, $\sigma_n = 6.39$



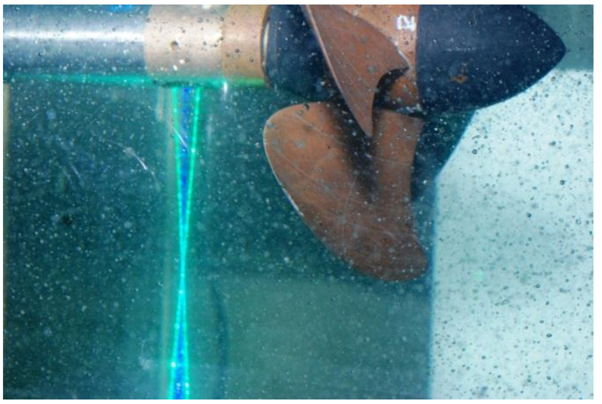
$\sigma_n = 3.03$

$\sigma_n = 2.02$

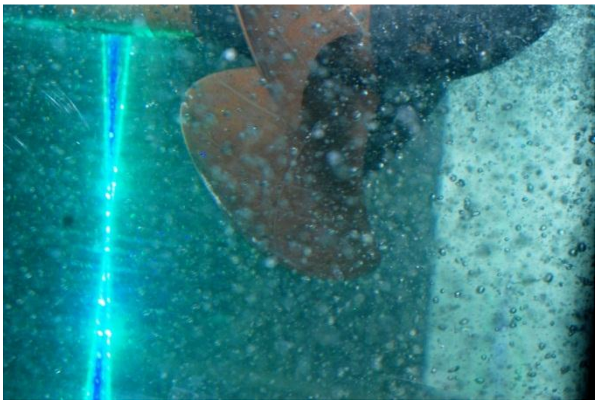
$\sigma_n = 6.39$

ETVC, $\sigma_n = 8.87$

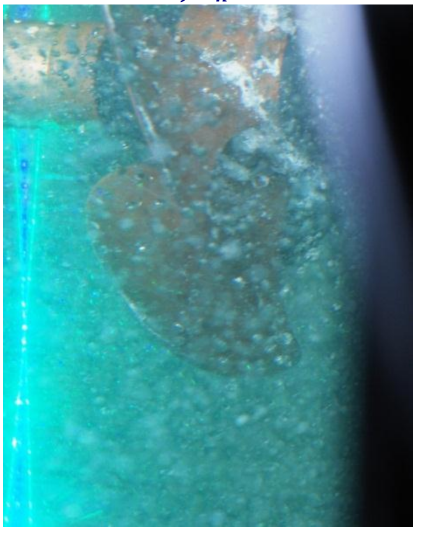
Cavitation number variation, $K_T \approx 0.17$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 83.4 – 75.1\%$
SVA Test 12KM0029, KonKav Test 35



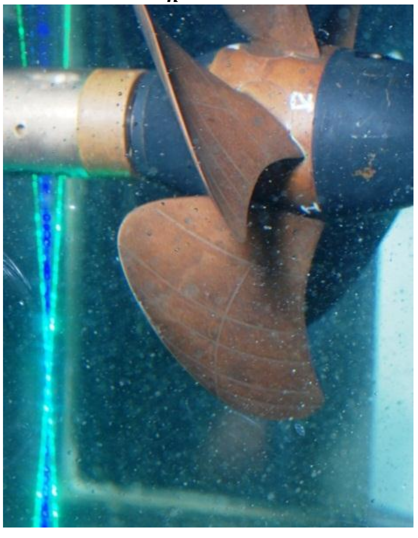
BPSC, $\sigma_n = 4.14$



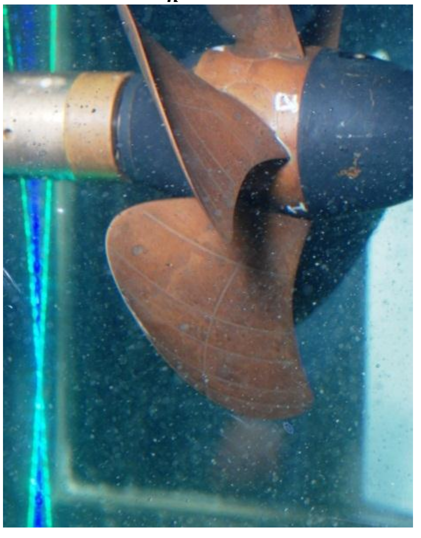
$\sigma_n = 3.01$



$\sigma_n = 2.02$



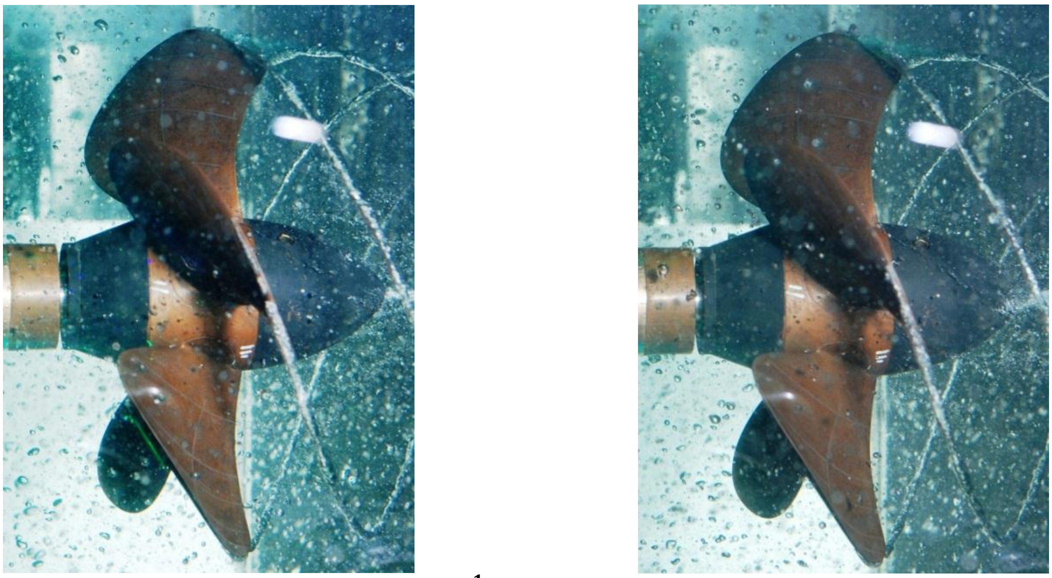
$\sigma_n = 4.14$



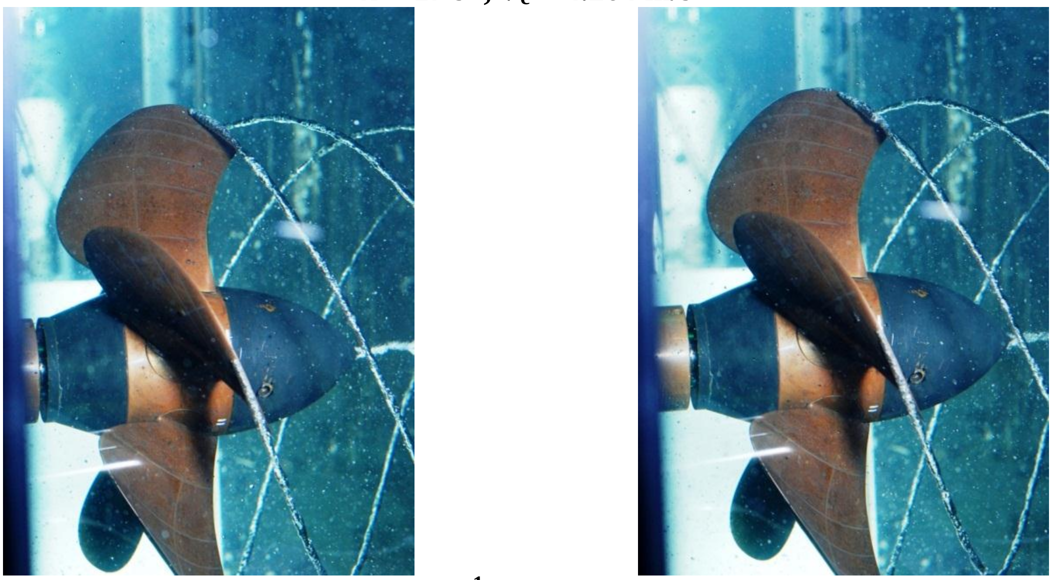
EPSC, $\sigma_n = 4.81$

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 3.03$, $\alpha/\alpha_S = 77.7 – 70.1\%$

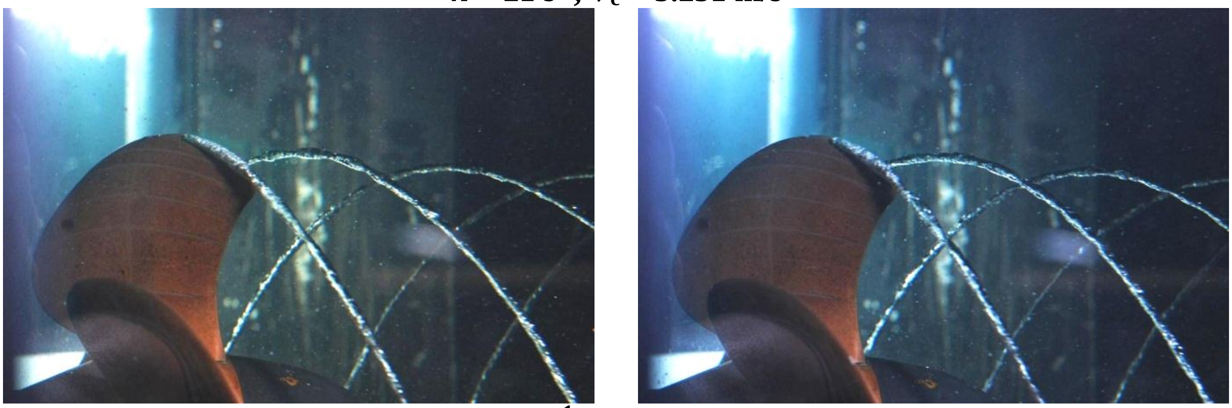
SVA Test 12KM0027, KonKav Tests 39, 40, 41



n **= 17 s^{-1}, V_c = 4.264 m/s**



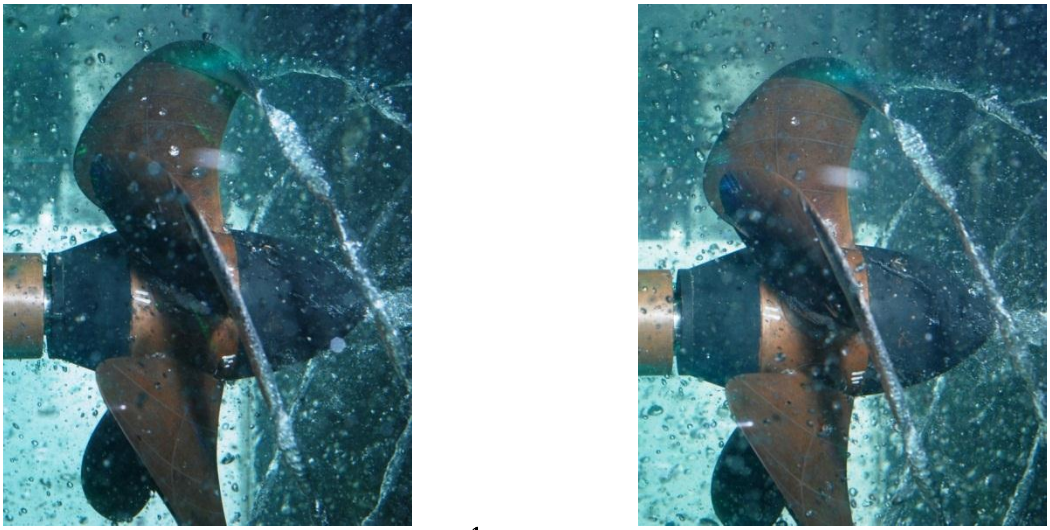
n **= 21 s^{-1}, V_c = 5.251 m/s**



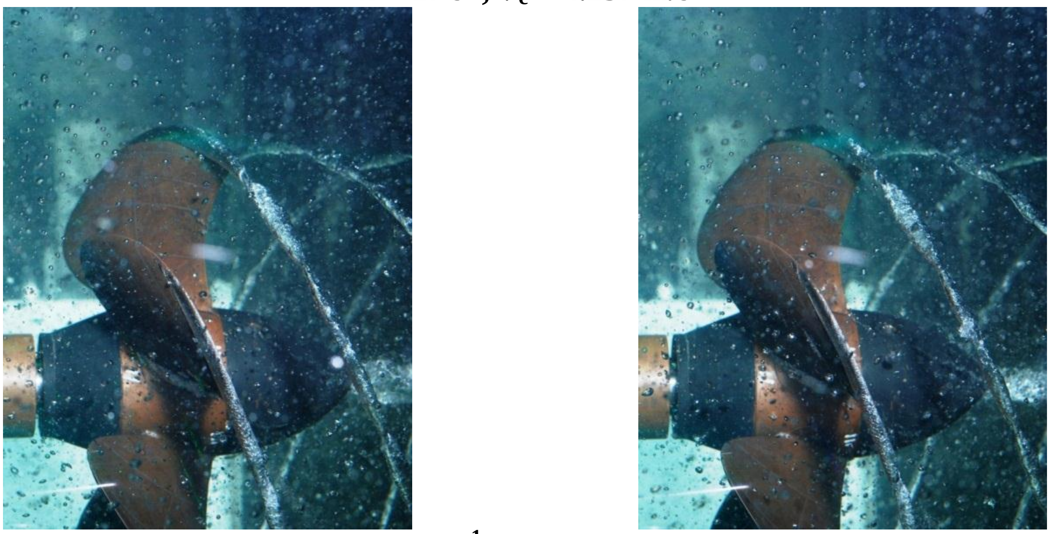
n **= 25 s^{-1}, V_c = 6.215 m/s**

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 2.02$, $\alpha/\alpha_S = 81.9 – 62.6\%$

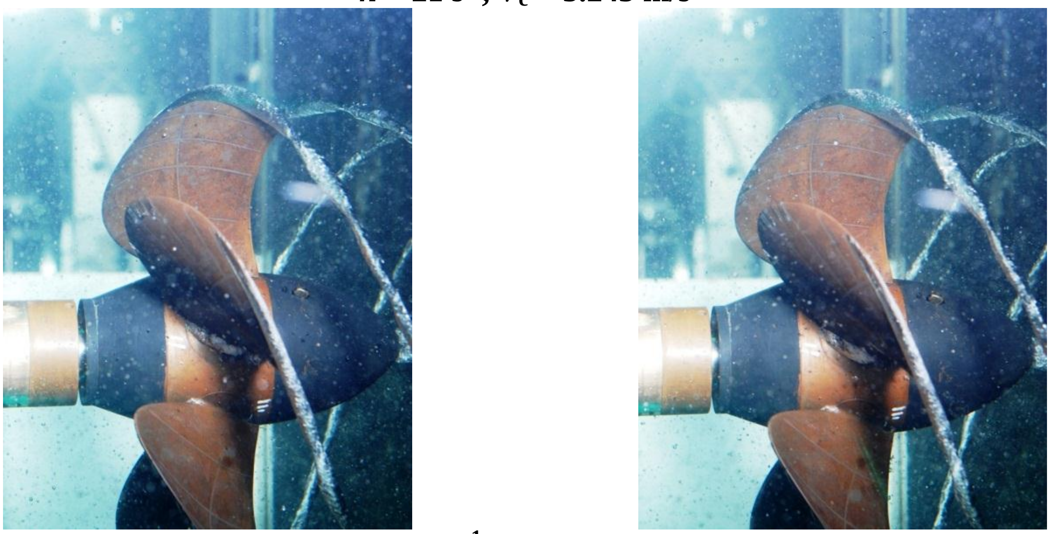
SVA Test 12KM0030, KonKav Tests 36, 37, 38



$n = 17\ s^{-1}$, $V_c = 4.237$ m/s

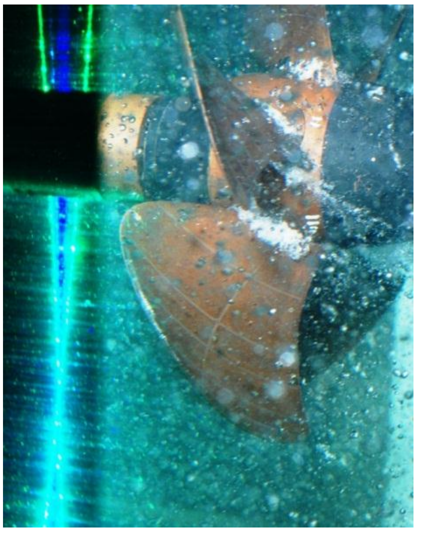


$n = 21\ s^{-1}$, $V_c = 5.243$ m/s



$n = 25\ s^{-1}$, $V_c = 6.194$ m/s

Number of revolutions variation, $K_T \approx 0.17$, $\sigma_n = 2.01$, $\alpha/\alpha_S = 80.0 - 59.1\%$
SVA Test 12KM0031, KonKav Tests 42, 43



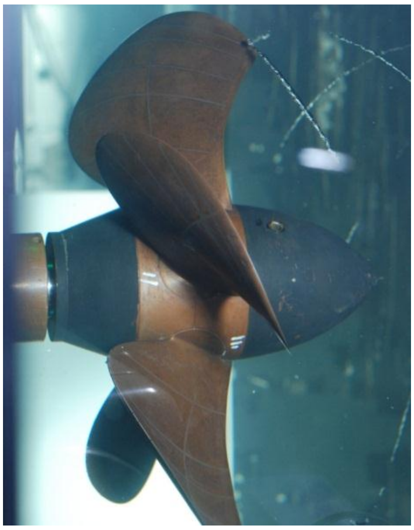
$n = 17\ s^{-1}$, $V_c = 5.982$ m/s

$n = 21\ s^{-1}$, $V_c = 7.342$ m/s

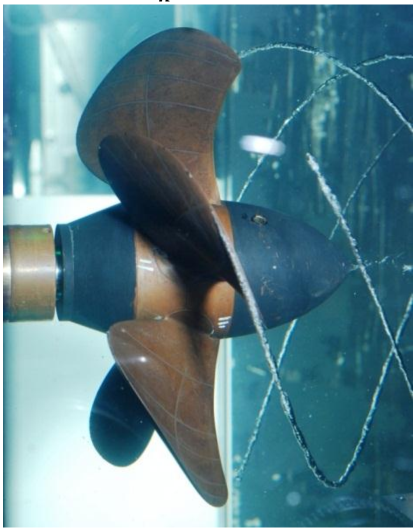
Cavitation number variation, $K_T \approx 0.38$, n = 21 s^{-1}, α/α_S = 57.3 – 59.0%

SVA Test 12KM0032, KonKav Test 45

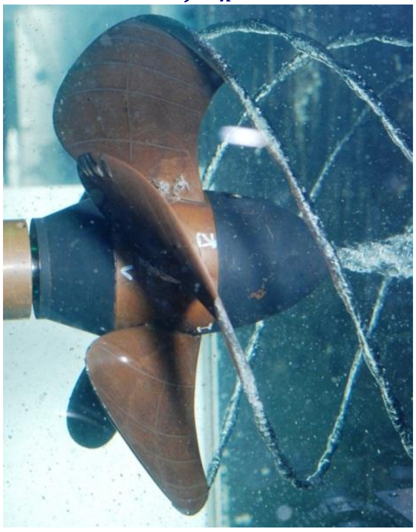
σ_n = 13.55



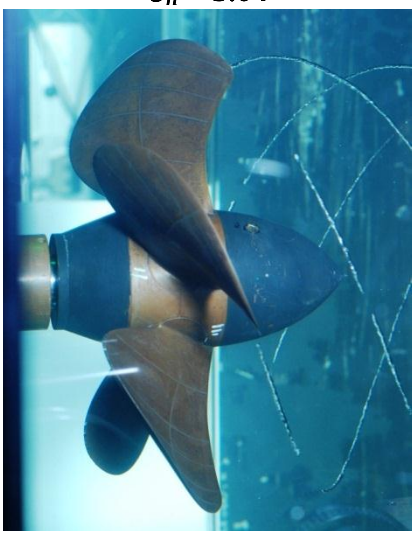
BTVC, σ_n = 4.76



σ_n = 3.04



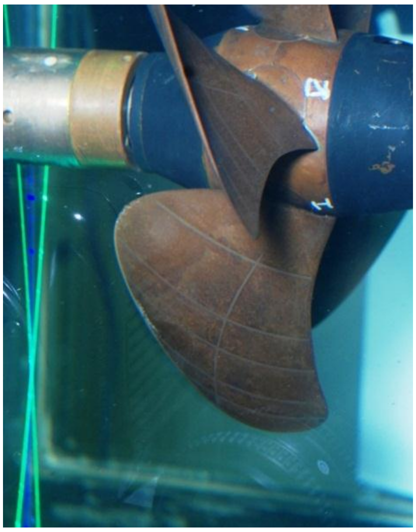
σ_n = 2.04



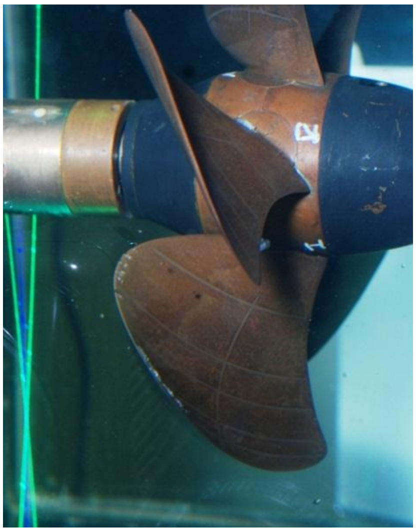
σ_n = 4.76

ETVC, σ_n = 8.45

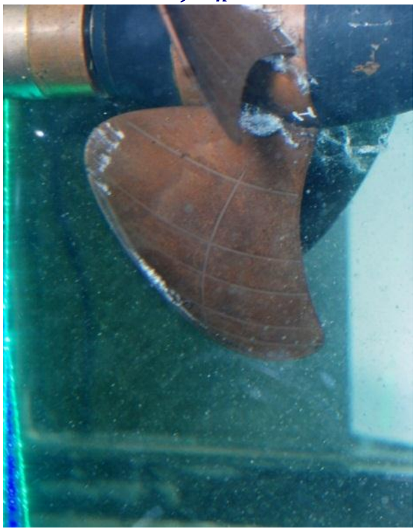
Cavitation number variation, $K_T \approx 0.17$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 59.0 - 65.4\%$
SVA Test 12KM0033, KonKav Test 46



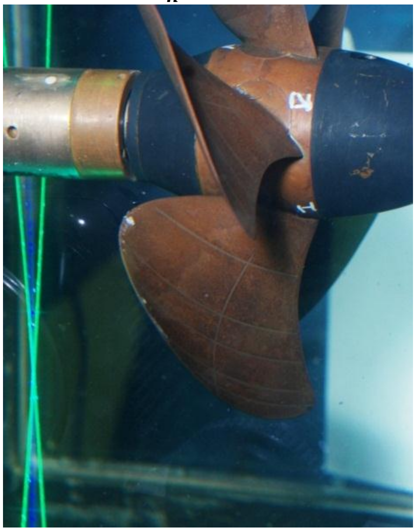
BPSC, $\sigma_n = 3.71$



$\sigma_n = 3.01$



$\sigma_n = 2.01$

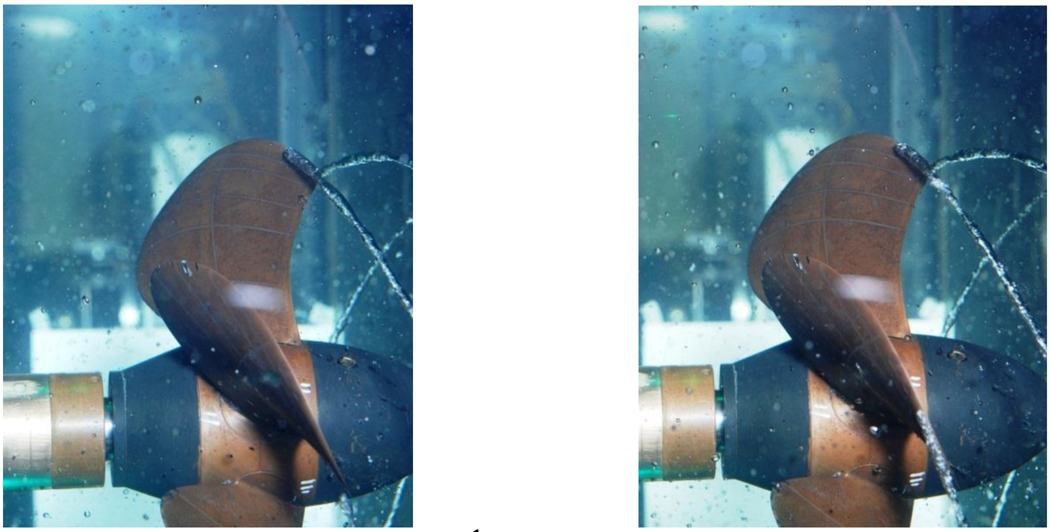


$\sigma_n = 3.72$

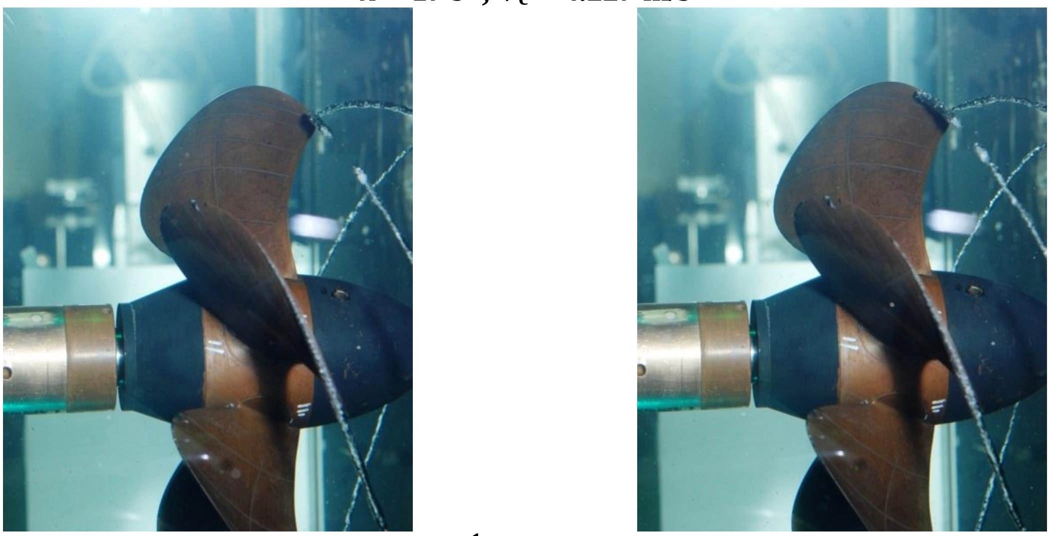
EPSC, $\sigma_n = 4.94$

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 3.02$, $\alpha/\alpha_S = 58.6 - 57.8\%$

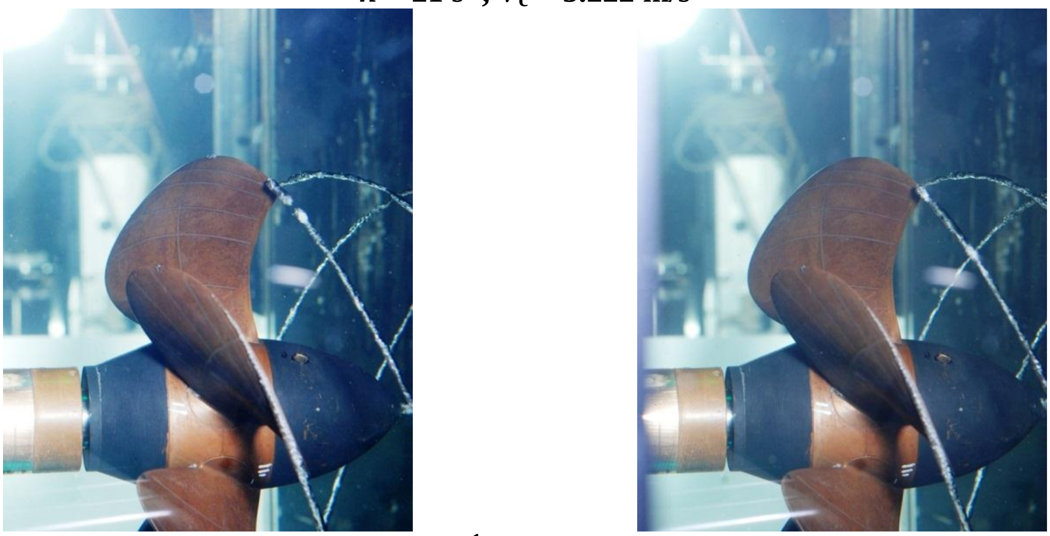
SVA Test 12KM0034, KonKav Tests 50, 51, 52



$n = 17\ s^{-1}$, $V_c = 4.227$ m/s



$n = 21\ s^{-1}$, $V_c = 5.222$ m/s

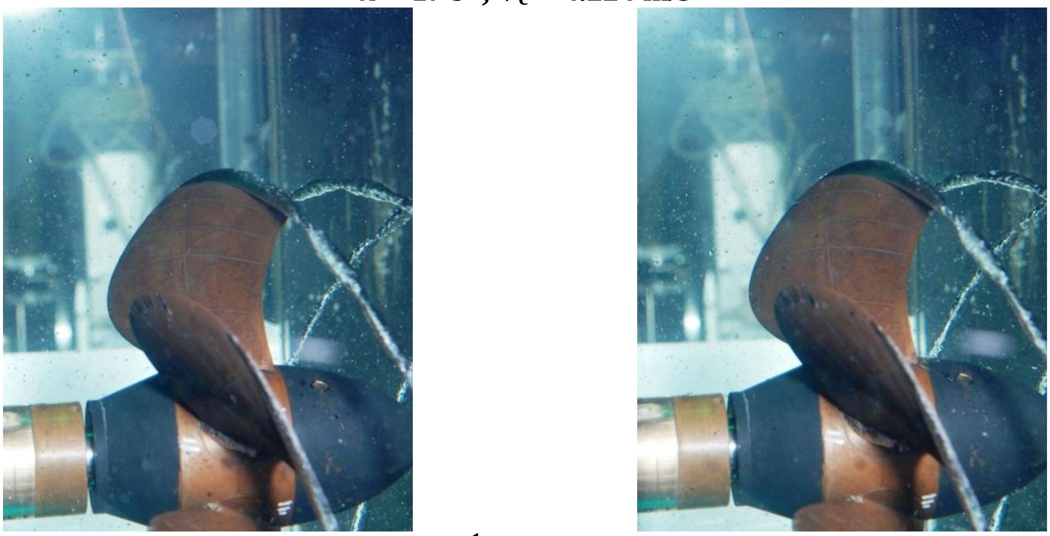


$n = 25\ s^{-1}$, $V_c = 6.193$ m/s

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 2.03$, $\alpha/\alpha_S = 57.8 – 56.3\%$

SVA Test 12KM0035, KonKav Tests 47, 48, 49

$n = 17\ s^{-1}$, $V_c = 4.224$ m/s

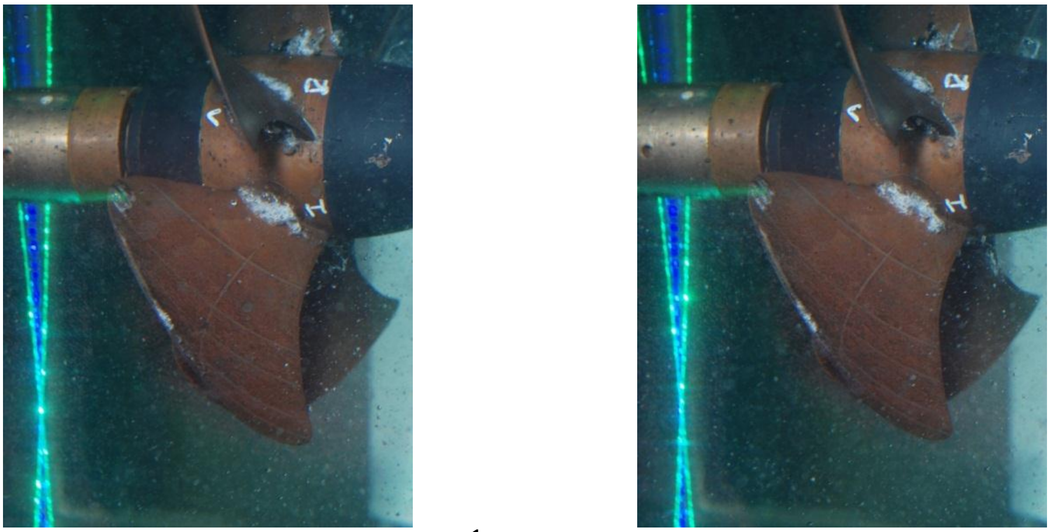


$n = 21\ s^{-1}$, $V_c = 5.228$ m/s

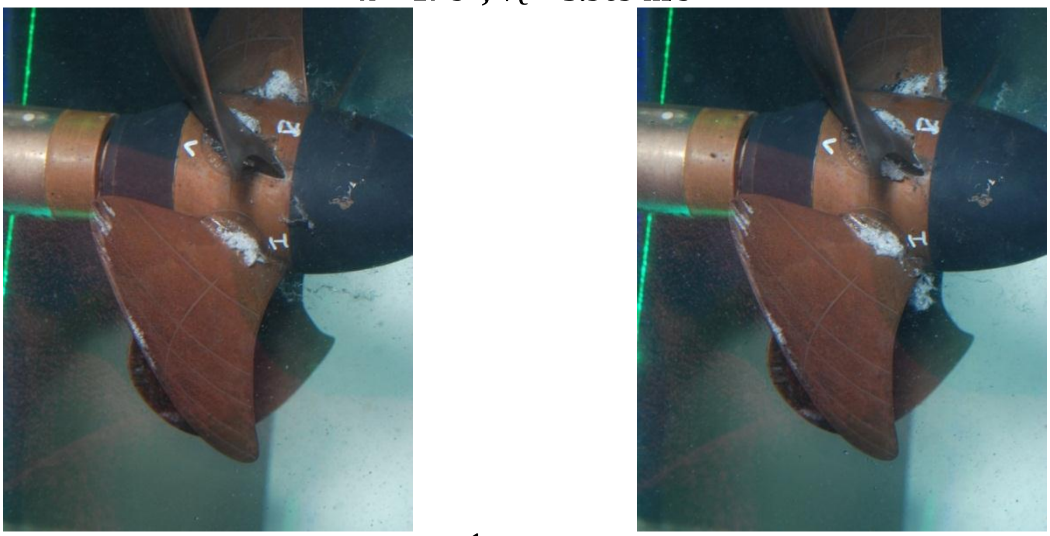
$n = 25\ s^{-1}$, $V_c = 6.211$ m/s

Number of revolutions variation, $K_T \approx 0.17$, $\sigma_n = 2.02$, $\alpha/\alpha_S = 56.3 – 55.3\%$

SVA Test 12KM0036, KonKav Tests 53, 54

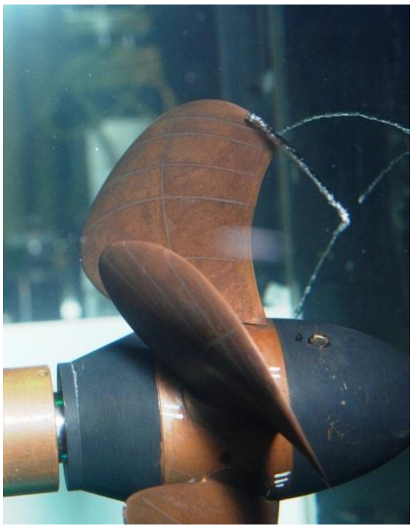


$n = 17\ s^{-1}$, $V_c = 5.969$ m/s

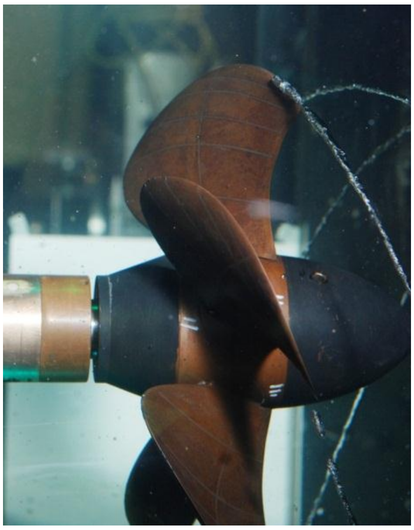


$n = 21\ s^{-1}$, $V_c = 7.371$ m/s

Cavitation number variation, $K_T \approx 0.38$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 38.4 – 41.5\%$
SVA Test 12KM0037, KonKav Test 56

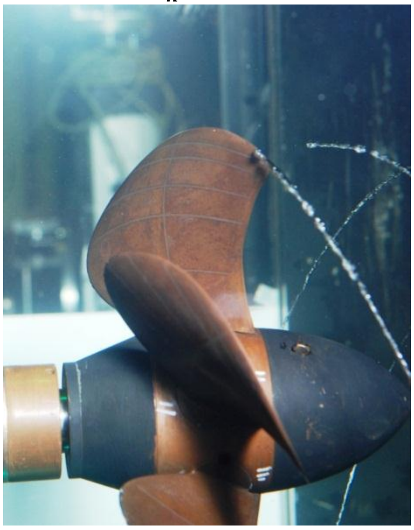


BTVC, $\sigma_n = 4.19$

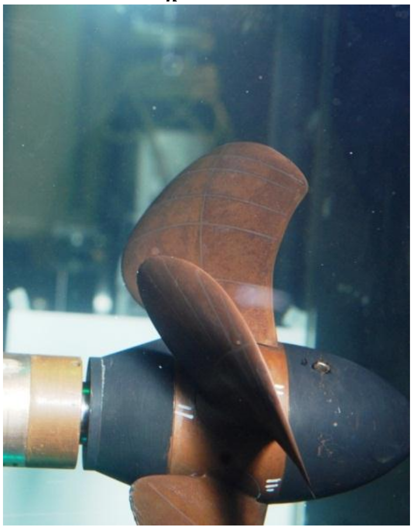


$\sigma_n = 3.04$

$\sigma_n = 2.04$



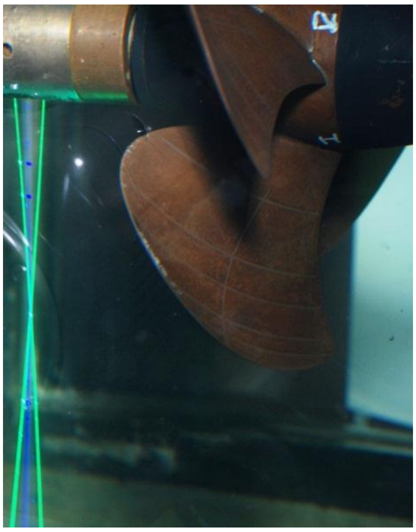
$\sigma_n = 4.19$



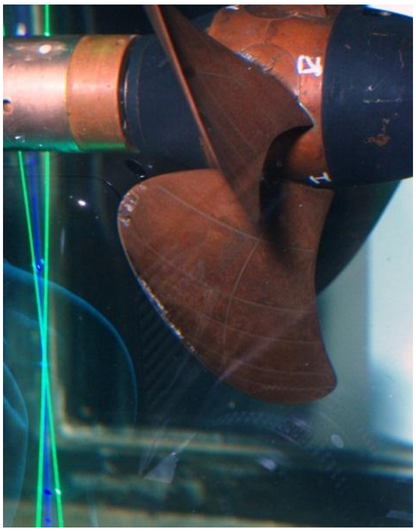
ETVC, $\sigma_n = 6.95$

Cavitation number variation, $K_T \approx 0.17$, $n = 21\ s^{-1}$, $\alpha/\alpha_S = 42.0 – 52.8\%$

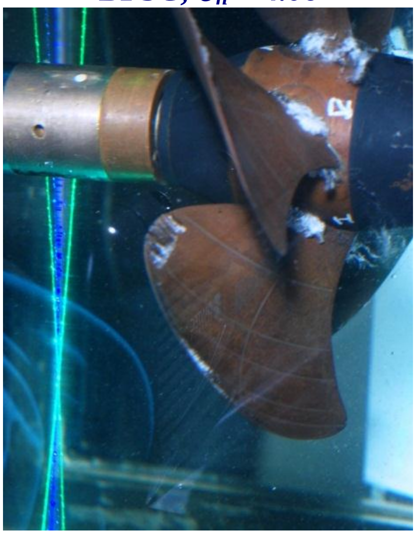
SVA Test 12KM0042, KonKav Test 57



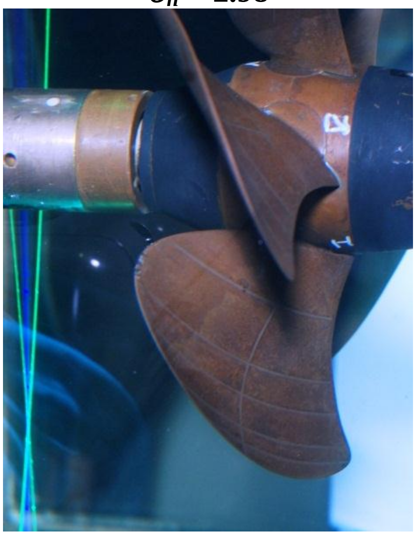
BPSC, $\sigma_n = 4.06$



$\sigma_n = 2.98$

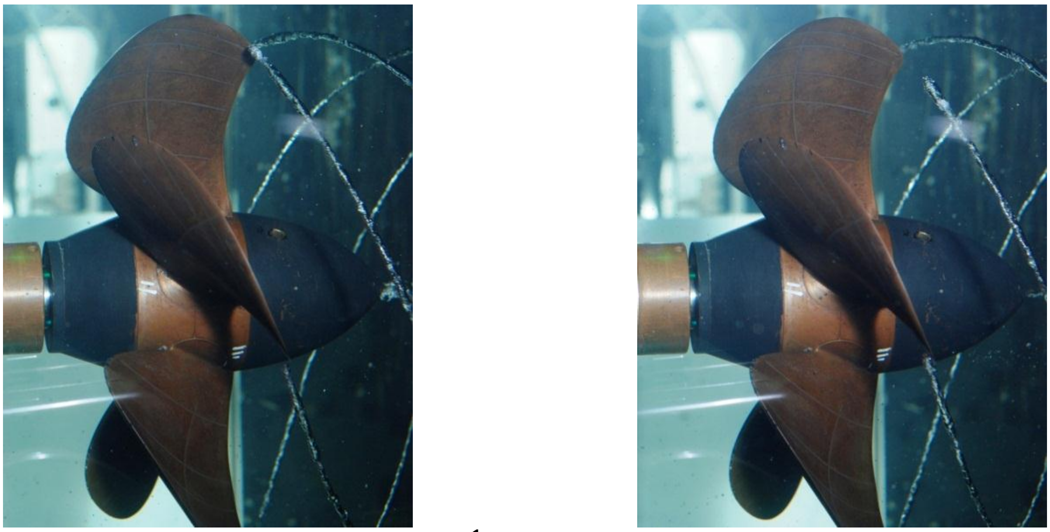


$\sigma_n = 1.97$

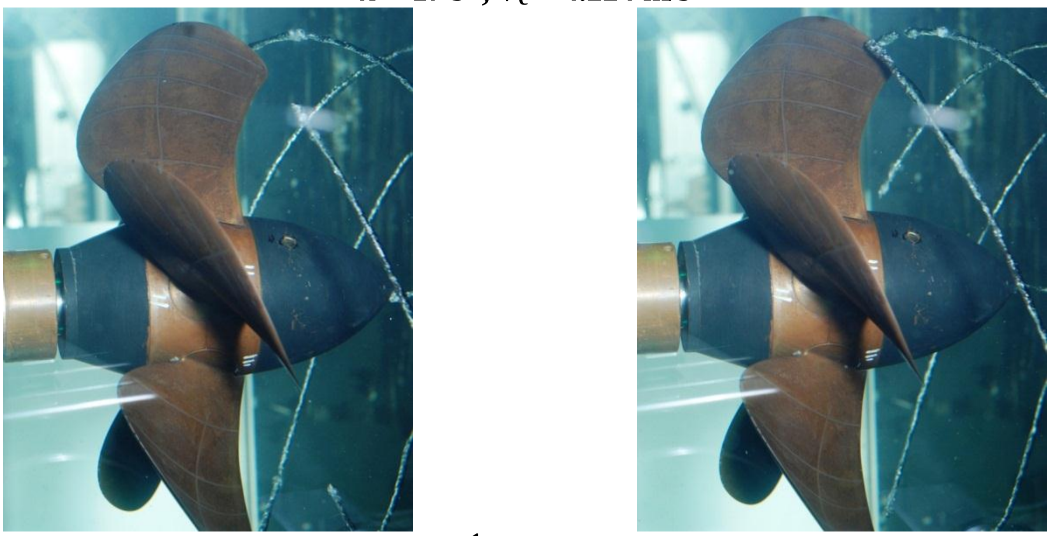


$\sigma_n = 4.06$

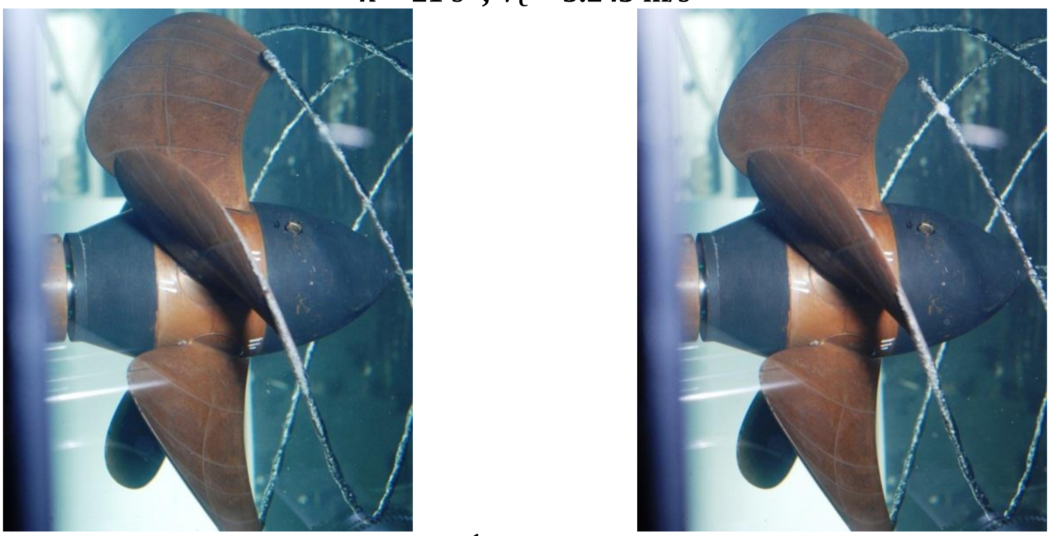
Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 3.03$, $\alpha/\alpha_S = 42.4 - 45.7\%$
SVA Test 12KM0040, KonKav Tests 61, 62, 63



$n = 17\ s^{-1}$, $V_c = 4.224$ m/s



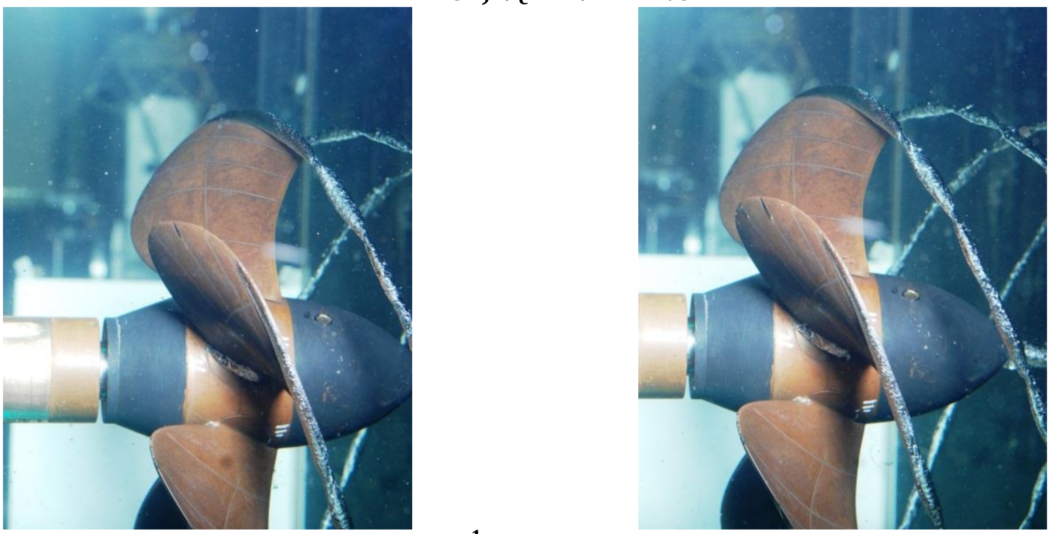
$n = 21\ s^{-1}$, $V_c = 5.243$ m/s



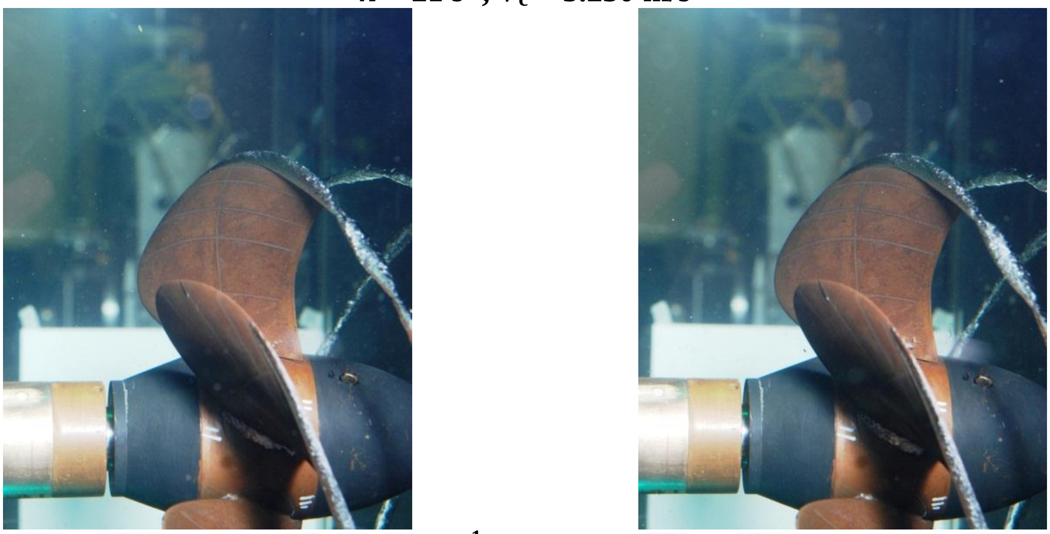
$n = 25\ s^{-1}$, $V_c = 6.229$ m/s

Number of revolutions variation, $K_T \approx 0.38$, $\sigma_n = 2.03$, $\alpha/\alpha_S = 41.5 – 41.7\%$
SVA Test 12KM0038, KonKav Tests 58, 59, 60

$n = 17\ s^{-1}$, $V_c = 4.221$ m/s



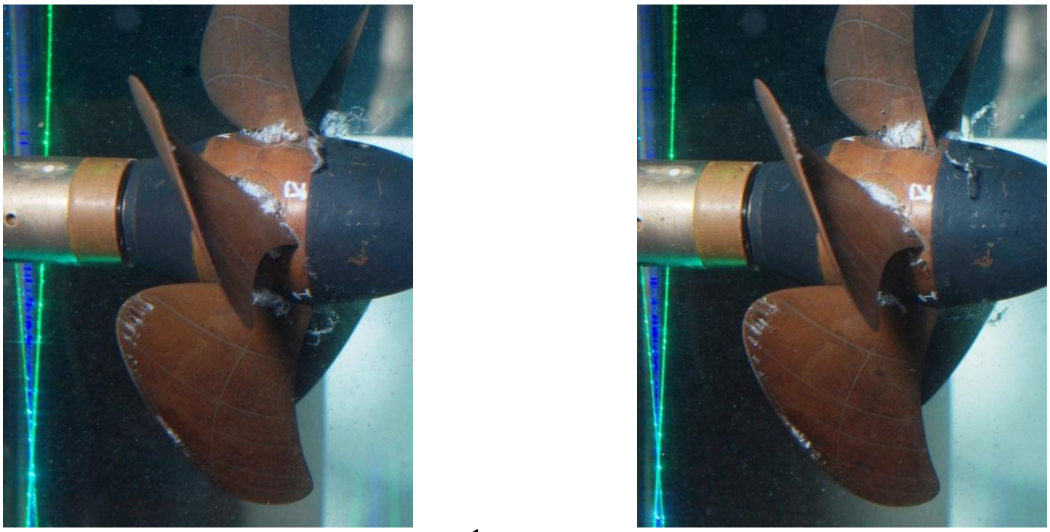
$n = 21\ s^{-1}$, $V_c = 5.230$ m/s



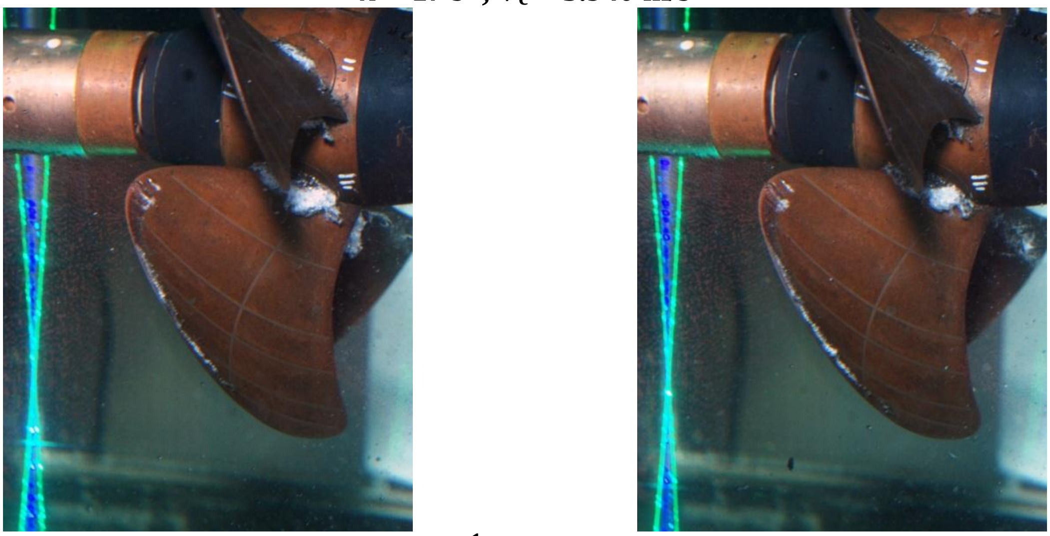
$n = 25\ s^{-1}$, $V_c = 6.203$ m/s

Number of revolutions variation, $K_T \approx 0.17$, $\sigma_n = 2.01$, $\alpha/\alpha_S = 40.9 – 42.0\%$

SVA Test 12KM0041, KonKav Tests 64, 65



$n = 17\ s^{-1}$, $V_c = 5.940$ m/s



$n = 21\ s^{-1}$, $V_c = 7.372$ m/s

Symbols

symbol	name	definition or explanation	SI - unit
A_0	Propeller disc area	$\pi D^2 / 4$	m^2
A_E	Expanded blade area	Expanded blade area of a screw propeller outside the boss or hub	m^2
c	Chord length		m
C_{Th}	Thrust loading coefficient	$T / (A_P q_A) = (T_P / A_P) / q_A$	1
D	Propeller diameter		m
d_h	Boss or hub diameter	$2 r_h$	m
D_{H2}	Pressure difference	Measured in the nozzle of the cavitation tunnel	Pa
f	Camber of a foil section		m
g	Acceleration of gravity	Weight force / mass, strength of the earth gravity field	m/s^2
h_0	Immersion	The depth of submergence of the propeller measured vertically from the propeller centre to the free surface	m
J	Propeller advance ratio	$V_A / (D n)$	1
K_Q	Torque coefficient	$Q / (\rho n^2 D^5)$	1
K_T	Thrust coefficient	$T / ((\rho n^2 D^4)$	1
l_h	Boss or hub length		m
n	Frequency or rate of revolution	Alias RPS (RPM in some propulsor applications)	s^{-1}
P	Propeller pitch in general		m
p	Pressure		Pa
p_A	Ambient pressure		Pa
p_C	Pressure within a steady or quasi-steady cavity		Pa
p_0	Ambient pressure in undisturbed flow		Pa
p_V	Vapour pressure of water	At a given temperature!	Pa
P/D	Pitch ratio of propeller		1
P_D	Delivered power, propeller power	$Q \omega$	W

Symbols

symbol	Name	definition or explanation	SI - unit
Q	Torque	P_D / ω	Nm
q	Dynamic pressure, density of kinetic flow energy,	$\rho V^2 / 2$	Pa
R	Radius		m
r	Radius		m
Re	Reynolds number	$Re = c_{0.7} / \nu \cdot \sqrt{V^2 + (0.7 D \pi n)^2}$	1
r_h	Hub radius		m
T	Propeller thrust		N
t_W	Temperature of water		°C
t_A	Temperature of air		
t	Blade section thickness		m
V	Velocity of a body, speed in general of the model or the ship		m/s
V_A	Advance speed of propeller	Equivalent propeller open water speed based on thrust or torque identity	m/s
V_S	Ship speed		m/s
w	Wake fraction in general	$w = 1 - V_A / V$	1
w_a	Wake fraction in axial direction	$w_a = 1 - V_A / V$	1
Z, z	Number of propeller blades		1
α	Solved gas content		mg/l
α_S	Solved gas content at saturation		mg/l
ε	Angle of rake		deg
η_O	Propeller efficiency in open water	$P_T / P_D = T V_A / (Q \omega)$ all quantities measured in open water tests	1
θ	Angle of propeller blade position		deg
θ_{EXT}	Skew angle extent	The difference between maximum and minimum local skew angle	deg

Symbols

symbol	name	definition or explanation	SI - unit
λ	Scale ratio, *l*inear scale of ship model	Ship (index $_S$) dimension divided by corresponding model (index $_M$) dimension $\lambda = L_S / L_M = B_S / B_M = T_S / T_M$	1
ν	Kinematic viscosity	μ / ρ	m²/s
π	Circular constant	3.1415926535	1
ρ	Mass density of fluid	dm / dV	kg/m³
φ	Pitch angle of screw propeller	arctg $(P / (2\,\pi\,R))$	1
σ	Cavitation number	$(p_A - p_C) / q$	1
σ_n	Cavitation number calculated with n	$(p_0 - p_V) / (\rho/2 \cdot n^2 \cdot D^2)$	1
σ_V	Cavitation number calculated with V	$(p_A + \rho \cdot g\, h_0 - p_V) / (\rho/2 \cdot V^2)$	1
$\sigma_{0.7}$	Cavitation number calculated with the resulting speed at $r/R = 0.7$	$(p_A + \rho \cdot g\, h_0 - p_V) / (\rho/2 \cdot (V + 0.7 \pi \cdot n \cdot D)^2)$	1
ω	Circular frequency	$2\,\pi\,f$	1/s
ω	Propeller rotational velocity	$2\,\pi\,n$	1/s

Indices

index	Name	definition or explanation
A	Air	
c	Velocity correction by Glauert method	
c	Construction, design	
M	Model	
S	Ship	
max	Maximum	
min	Minimum	
V	Venturi	
W	Water	
0.7	Related radius $r/R = 0.7$	

Description of the cavitation appearance

code	definition or explanation
BPSC	Begin pressure side cavitation
BRC	Begin root cavitation
BSSC	Begin suction side cavitation
BTVC	Begin tip vortex cavitation
EPSC	End of pressure side cavitation
ESSC	End of suction side cavitation
ETVC	End of tip vortex cavitation
FC	Foam cavitation
PS	Pressure side
PSC	Pressure side cavitation
SS	Suction side
SSC	Suction side cavitation
TVC	Tip vortex cavitation
TD	Thrust deduction

Methods and formulas

Open water test in the cavitation tunnel

The open water tests were carried out with the dynamometer J25 from Kempf & Remmers in the cavitation tunnel K15A. The influence of the test section on the propeller coefficients was corrected with the method from Glauert.

Measuring values: T, Q, n, V, p

with Glauert correction

Advance coefficient $J = \frac{V}{n \cdot D}$ $\qquad J_c = \frac{V_c}{n \cdot D}$

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

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

Propeller efficiency $\eta_O = \frac{J}{2\pi} \cdot \frac{K_T}{K_Q}$ $\qquad \eta_{Oc} = \frac{J_c}{2\pi} \cdot \frac{K_T}{K_Q}$

Reynolds number $Re = \frac{c_{0.7}}{\nu} \cdot \sqrt{V^2 + (0.7 \cdot D \cdot \pi \cdot n)^2}$ $\qquad Re_c = \frac{c_{0.7}}{\nu} \cdot \sqrt{V_c^2 + (0.7 \cdot D \cdot \pi \cdot n)^2}$

Thrust loading coefficient $C_{Th} = \frac{8}{\pi} \cdot \frac{K_T}{J^2}$ $\qquad C_{Thc} = \frac{8}{\pi} \cdot \frac{K_T}{J_c^2}$

Cavitation numbers $\sigma_V = \frac{p_{stat} - p_v}{\frac{\rho}{2} \cdot V^2}$ $\qquad \sigma_{Vc} = \frac{p_{statc} - p_v}{\frac{\rho}{2} \cdot V_c^2}$

$$\sigma_n = \frac{p_{stat} - p_v}{\frac{\rho}{2} \cdot (n \cdot D)^2} \qquad \sigma_{nc} = \frac{p_{statc} - p_v}{\frac{\rho}{2} \cdot (n \cdot D)^2}$$

$$\sigma_{0.7} = \frac{p_{stat} - p_v}{\frac{\rho}{2} \cdot (V + 0.7\pi \cdot n \cdot D)^2} \qquad \sigma_{0.7c} = \frac{p_{statc} - p_v}{\frac{\rho}{2} \cdot (V_c + 0.7\pi \cdot n \cdot D)^2}$$

ANNEX

Procedure of cavitation tests in the cavitation tunnel

The conditions for cavitation tests are chosen such that the average loading of the propeller is equal on model and full-scale.

As a measure for the propeller load in homogeneous inflow the tip speed ratio of the full-scale propeller is used.

λ-identity $\lambda_M = \lambda_S$ with $\lambda = \frac{\pi \cdot n \cdot D}{V_A}$

J-identity $J_M = J_S$ with $J = \frac{n \cdot D}{V_A}$

In addition the pressure is adjusted to such a level that model and full size cavitation numbers are equal at corresponding points in the propeller disc.

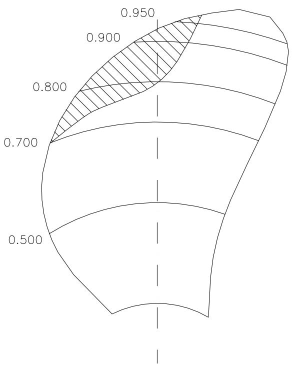
σ-identity $\sigma_{VM} = \sigma_{VS}$

For an arbitrary point at an immersion h_0 the propeller cavitation number is:

$$\sigma_V = \frac{p_A - p_V + \rho \cdot g \cdot h_0}{0.5 \cdot \rho \cdot V^2}$$

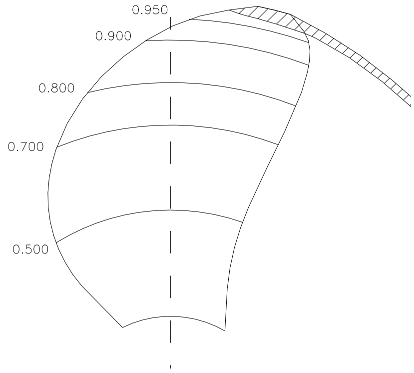
For the cavitation tunnel the inflow speed V_M of the propeller is chosen within practical limits related to the tunnel capacity, the particular test set-up and the ranges of static pressure to be adjusted. Requiring equal cavitation numbers on model and full-scale then leads to the pressure to be adjusted in the cavitation tunnel. Obviously, at only one horizontal level the condition of equal cavitation numbers can be fulfilled.

Definition of the kind of cavitation in the drawings



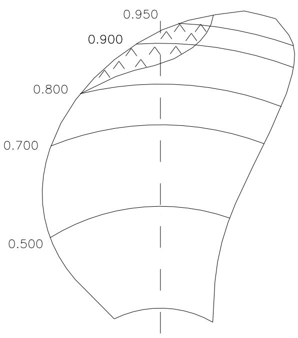
Sheet cavitation

Usually thin, smooth, transparent.
Initiating near leading edge.
Often foamy in appearance.



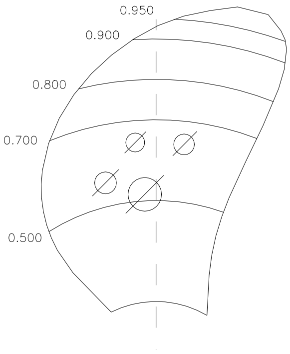
Vortex cavitation

Trailing, detached tip vortex cavitation incepts downstream of the blade tip.

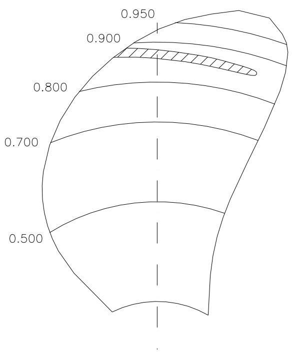


Foam cavitation

Sheet cavitation, foamy in appearance.

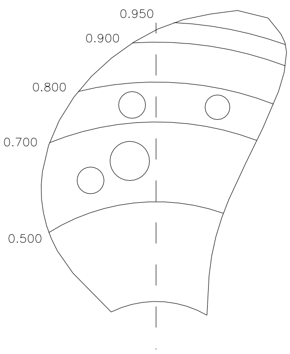


Spot cavitation



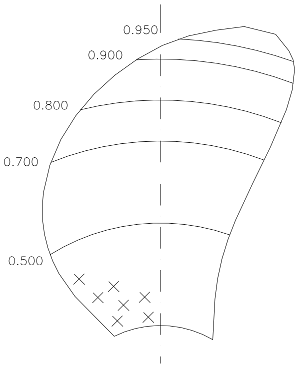
Streak cavitation

Special form of bubble cavitation, narrow, usually forms in parallel at isolated roughness spots or imperfections on the blade surface or at the leading edge.



Bubble cavitation

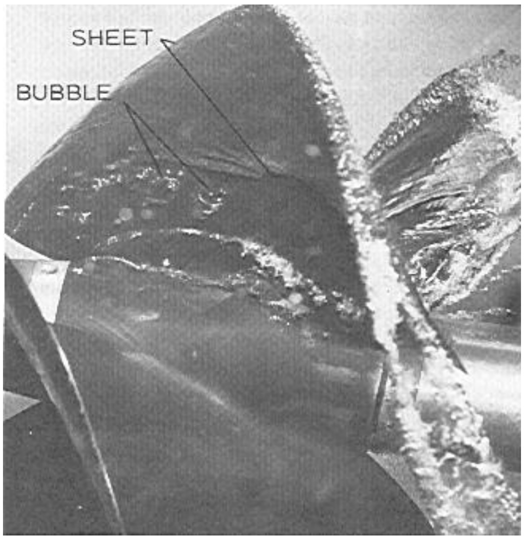
Small bubble type cavitation indicative of propellers with no suction peaks at the leading edge.



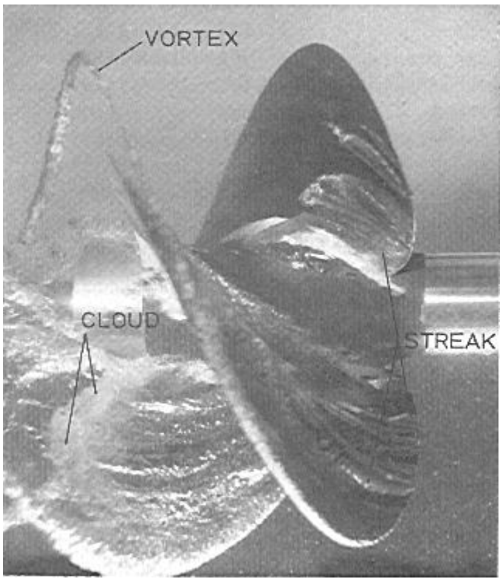
Cloud cavitation

Usually develops from the break-up of unsteady sheet cavitation.

Samples of cavitation patterns, ITTC 1999



Sheet and bubble cavitation

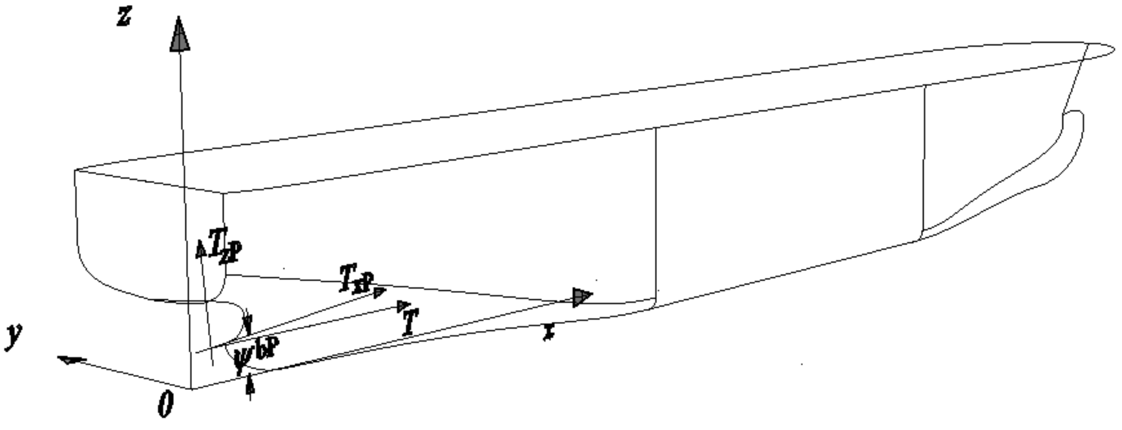


Vortex, cloud and streak cavitation

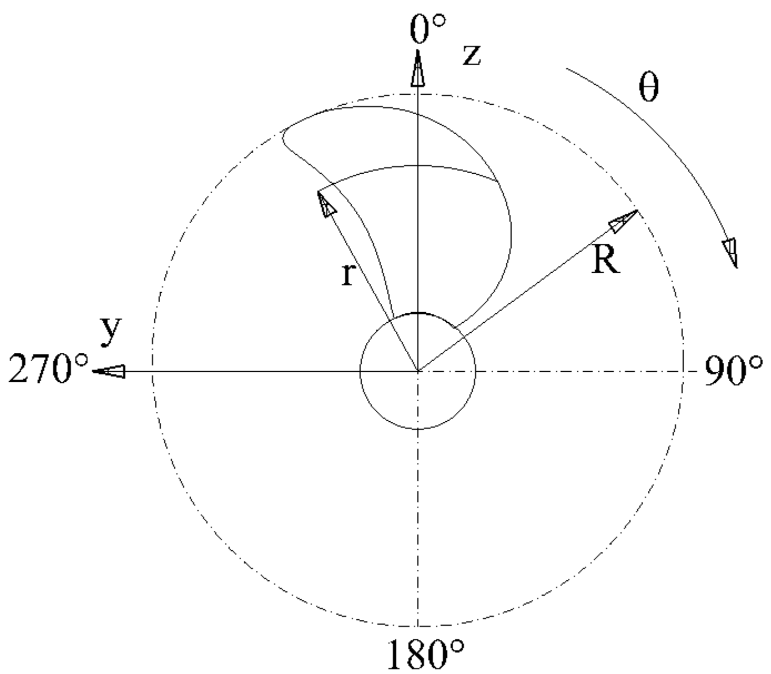
Bubble, spot and streak cavitation

Coordinate system

Cartesian coordinate system



Cylindrical propeller coordinate system looking on pressure side



ANNEX