POTSDAM MODEL BASIN

Update on Potsdam Propeller Test Case

The propeller workshops in course of the smp'11 in Hamburg and the smp'15 in Austin, Texas were carried out on basis of the measuring data obtained with the controllable pitch propeller VP1304.

Different companies asked the SVA to use the model propeller for their own measurements. To avoid problems with the adjustment of the pitch, the propeller was also manufactured as a fixed pitch propeller (P1790). In Figure 1 the geometry of the propellers is shown. The differences in the root area of the propellers are apparent.

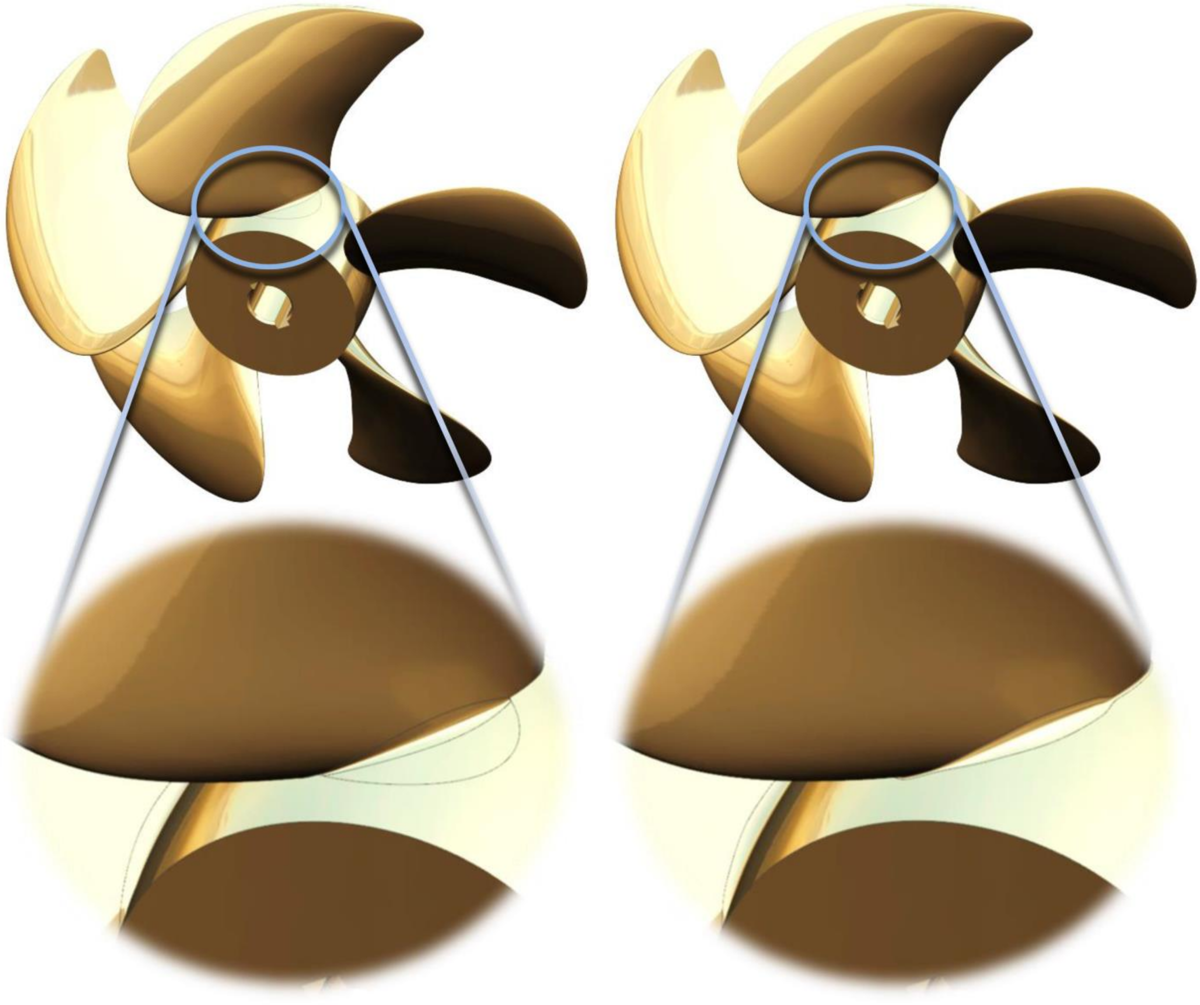


Fig. 1: Geometry of the CPP VP1304 (left) and the FPP P1790 (right)

In the following the test results for the propeller P1790 are compared with the data of the propeller VP1304. In addition, also the manufacturing accuracy is investigated.

Open water characteristics, VP1304 vs. P1790

On page 7 the open water characteristics of the model propellers VP1304 and P1790 are shown. The open water tests were conducted in the towing tank of SVA Potsdam with a shaft inclination of 0° (smp'11). The test results are corrected by the idle torque. On page 6 the corresponding measuring data of the propeller P1790 are given.

The comparison of the open water characteristics shows:

- The open water characteristics of the propellers VP1304 and P1790 match well.
- Minor differences can be found for the torque coefficients at higher advance coefficients (behind the maximum efficiency).

Cavitation tests, VP1304 vs. P1790

The cavitation tests with the propeller P1790 were conducted among others for the same operation points as demanded in the smp'11 workshop.

The cavitation at the propeller P1790 in the operating point OP1 (K_T = 0.384, σ_n = 2.024) is characterised by tip vortex and root cavitation on the suction side. Furthermore, streak cavitation occurs at the leading edge of the propeller, which is influenced by the oxygen saturation of the water.

In the operating point OP2 (K_T = 0.211, σ_n = 1.424) tip vortex and root cavitation at the suction and pressure side appear. The extent of the suction side root cavitation is slightly smaller for lower oxygen saturation.

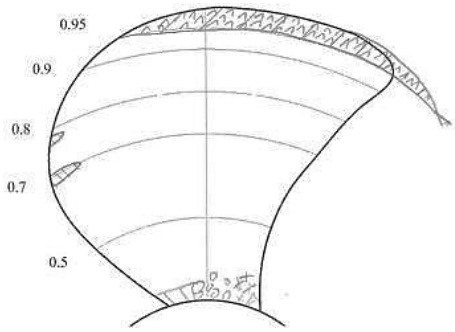
The cavitation in the operating point OP3 (K_T = 0.150, σ_n = 2.000) is dominated by pressure side sheet cavitation and foamy tip vortex cavitation. Root cavitation occurs at the suction and the pressure side.

On pages 8 and 9 the cavitation sketches are given for the three operation points and the oxygen saturation of α/α_S = 30 % and 60 %. On page 10 the photographs of the cavitation for OP1 are shown.

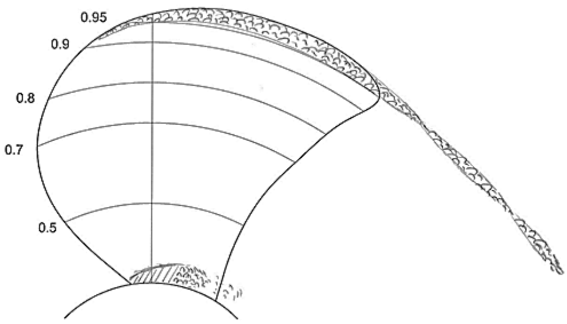
The comparison of the cavitation behavior between VP1304 and P1790 shows the following:

- For OP2 and OP3 no major differences could be detected between the cavitation patterns of VP1304 and P1790.
- For OP1 small differences in the cavitation pattern between the propeller VP1304 and P1790 could be found. At the leading edge of the propeller P1790 streak cavitation, particularly for an oxygen saturation of α/α_S = 60 %, could be observed, while for the propeller VP1304 this cavitation could not be seen. The differences in cavitation are illustrated in the sketches given in Figure 2.

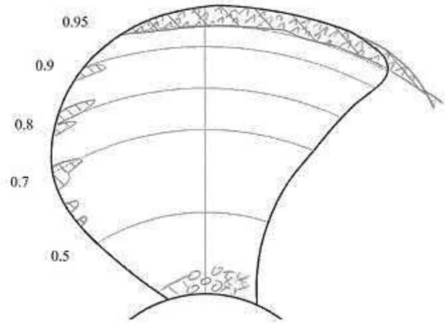
To find the reason for the difference in cavitation pattern for OP1, the leading-edge geometry of the propellers VP1304 and P1790 was further analysed.



P1790: J = 1.019, σ_n = 2.024,
α/α_s **= 31.9 %**, suction side



VP1304: J = 1.019, σ_n = 2.024,
α/α_s **= 53.5 %**, suction side



P1790: J = 1.019, σ_n = 2.024,
α/α_s **= 61.3 %**, suction side

Fig. 2: Comparison of the cavitation patterns between VP1304 (left) and P1790 (right) for OP1

Manufacturing accuracy

To assess the manufacturing accuracy of the propeller optical scanning systems were employed. The differences of the CAD model with the manufactured propeller VP1304 are shown in Figure 3. The geometry scans were conducted for the smp'15. The overall accuracy was considered as very good.

The scan of the propeller geometry was repeated for the propellers VP1304 and P1790 with the attention being laid upon the leading-edge geometry. Only since 2016 is the SVA Potsdam able to assess the differences at the leading edge by scanning. The evaluation was carried out for radius r/R = 0.7. In Figure 4 the differences in geometry of the propellers VP1304 and P1790 compared to the CAD model are shown. The lines of the scanned geometry have been smoothed. The comparison for the leading-edge shows:

- The scanned leading-edge geometry for the propellers VP1304 and P1790 does not show the "nose" at the leading edge as it is present in the CAD geometry.
- The geometrical deviations at the leading edge are within the recommended tolerance band of 50 µm from the ITTC [1].
- Propeller P1790 shows a slightly sharper leading edge and is closer to the CAD geometry, than propeller VP1304.

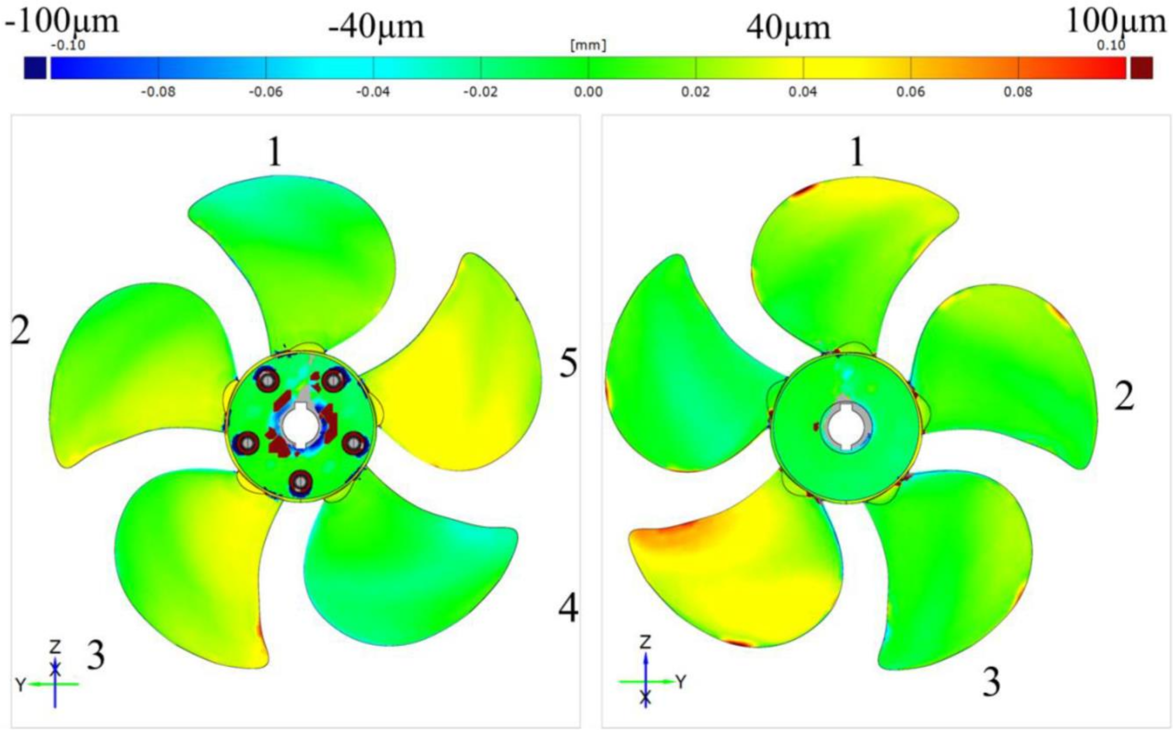


Fig. 3: Manufacturing accuracy of the propeller VP1304 for the pressure side (left) and for the suction side (right)

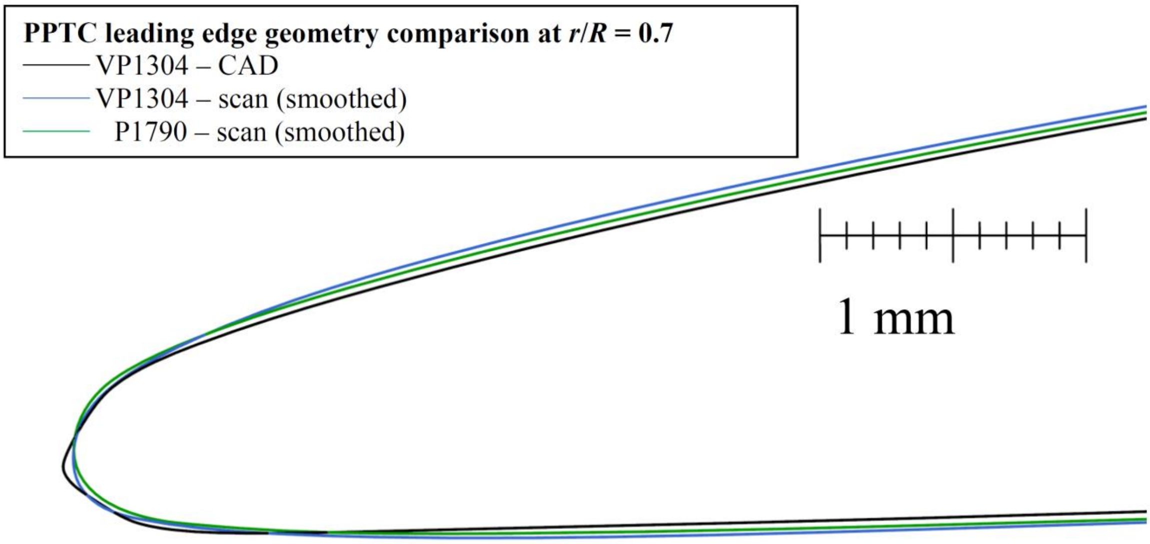


Fig. 4: Leading edge geometry at r/R = 0.7, propellers VP1304 and P1790

This means the following:

- The presence of streak cavitation at the leading edge for operation point OP1 and the sensitivity towards the oxygen saturation indicate that the pressure at the leading edge is around the vapour pressure and that small geometrical deviations can cause differences in the cavitation extent.
- The final leading-edge geometry is determined by manual grinding and polishing. The differences in CAD geometry and manufactured geometry are within the manufacturing accuracy.

Reference

[1] Model Manufacture, Propeller Models Propeller Model Accuracy
ITTC – Recommended Procedures and Guidelines 7.5 - 01 02 – 02
https://ittc.info/media/4036/75-01-02-02.pdf

Propeller P1790 with nose cap

Test	**15F1234**	Date	02.12.2015
Type of test	**OWT, n = 10 s^{-1}, ψ^{bP} = 0° - corrected with idle torque**		

Particulars of the propulsor

Propeller	**P1790**	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]	16.6	ν	[m²/s]	1.092e-6	ρ	[kg/m³] 998.85

Propeller characteristic (model scale)

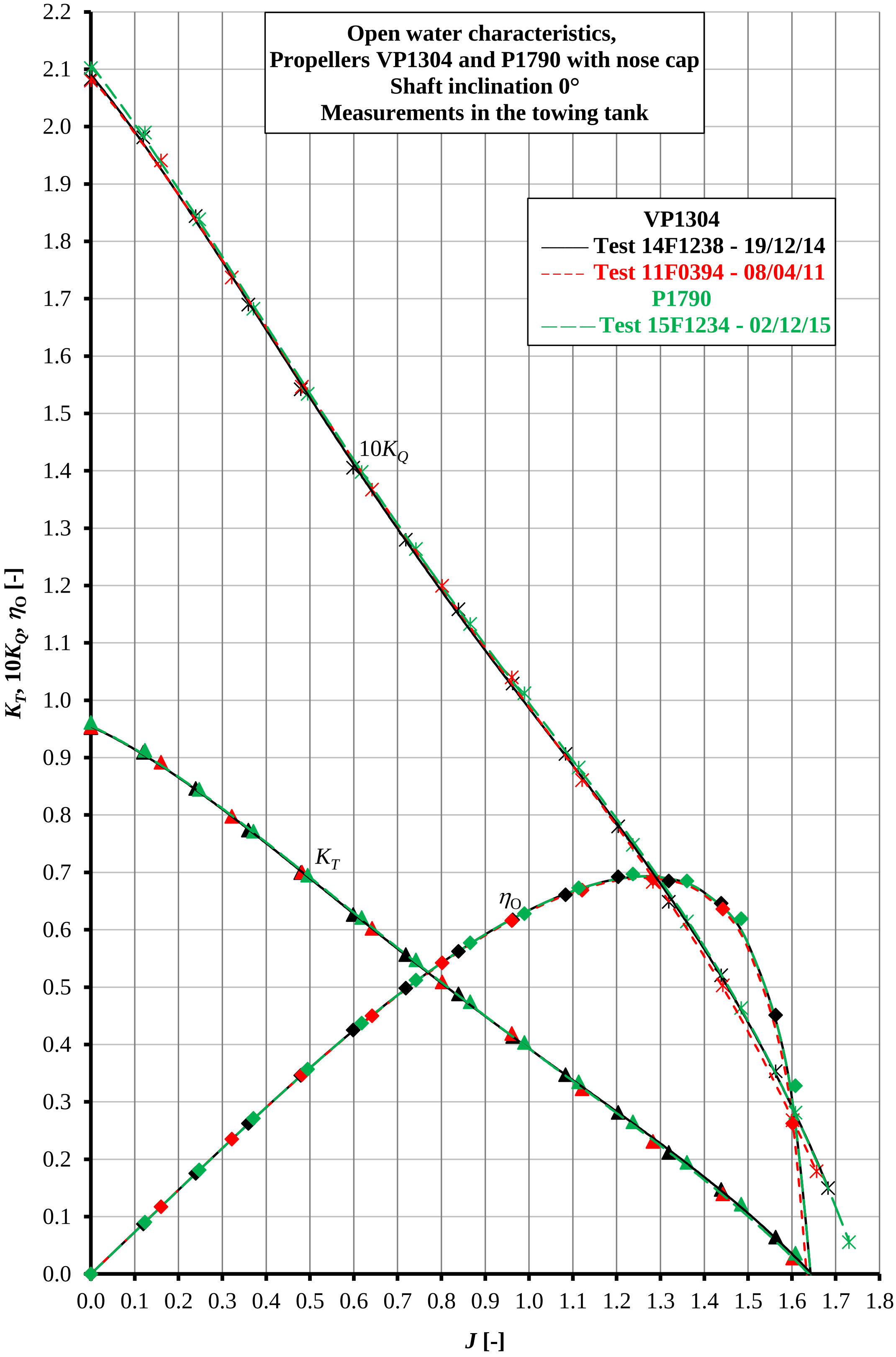
No.	J	K_T	$10K_Q$	η_O	C_{Th}	Re [10^{-6}]
1	0.0000	0.9611	2.1017	0.000		0.526
2	0.1237	0.9128	1.9894	0.090	151.85	0.526
3	0.2474	0.8447	1.8383	0.181	35.13	0.529
4	0.3710	0.7714	1.6823	0.271	14.27	0.533
5	0.4947	0.6950	1.5341	0.357	7.23	0.539
6	0.6184	0.6210	1.3978	0.437	4.14	0.546
7	0.7422	0.5473	1.2637	0.512	2.53	0.555
8	0.8660	0.4744	1.1328	0.577	1.61	0.565
9	0.9899	0.4032	1.0120	0.628	1.05	0.576
10	1.1136	0.3349	0.8825	0.673	0.69	0.589
11	1.2374	0.2648	0.7480	0.697	0.44	0.603
12	1.3605	0.1943	0.6145	0.685	0.27	0.618
13	1.4843	0.1214	0.4636	0.619	0.14	0.634
14	1.6081	0.0361	0.2811	0.328	0.04	0.651
15	1.7307	-0.0683	0.0553	-3.407	-0.06	0.669

Polynomial coefficients

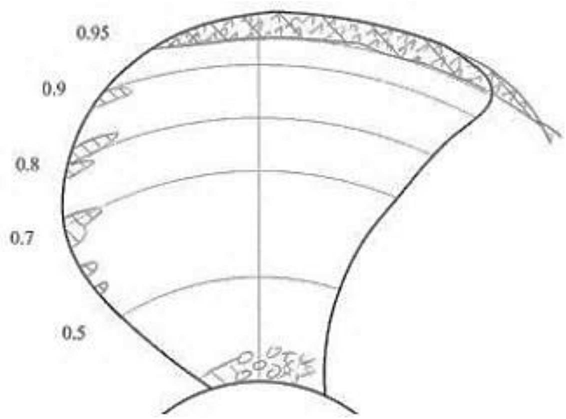
p	a_0	a_1	a_2	a_3	a_4
K_T	0.962514	-0.363437	-0.574134	0.533618	-0.161301
$10K_Q$	2.108020	-0.978838	-0.689034	0.863967	-0.309042

Valid in area 0.000 <= J <= 1.731, $p(x) = a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4$

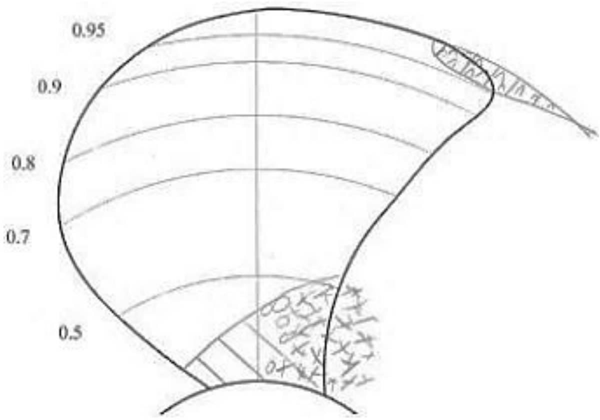
Open water characteristics (VP1304 vs. P1790)



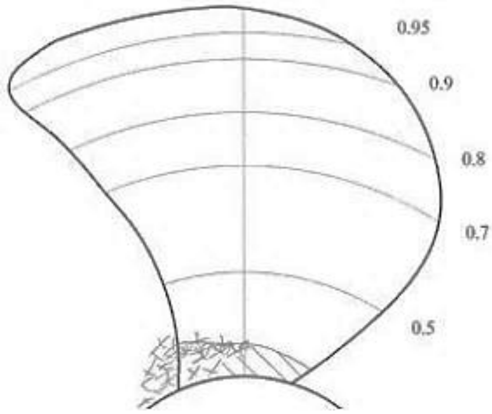
Cavitation sketches for P1790 with an oxygen saturation of α/α_S = 60 %



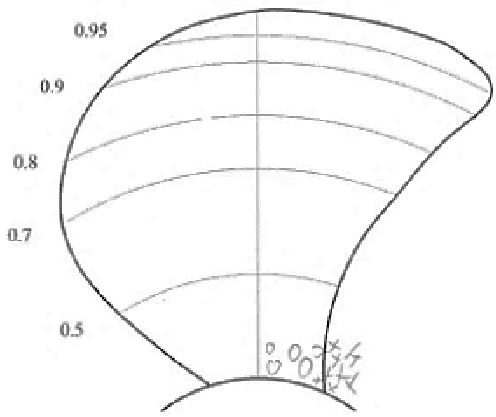
OP1 (suction side)



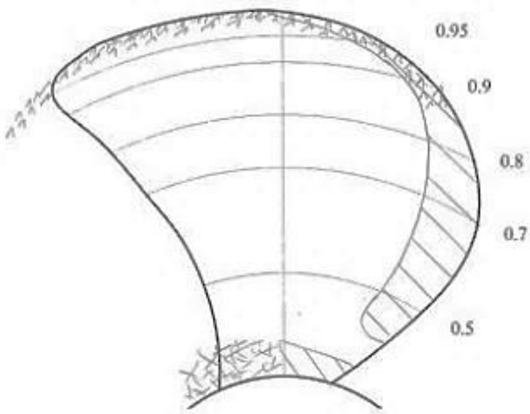
OP2 (suction side)



OP2 (pressure side)

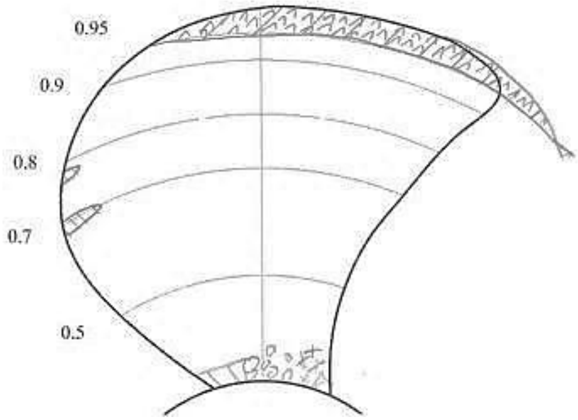


OP3 (suction side)

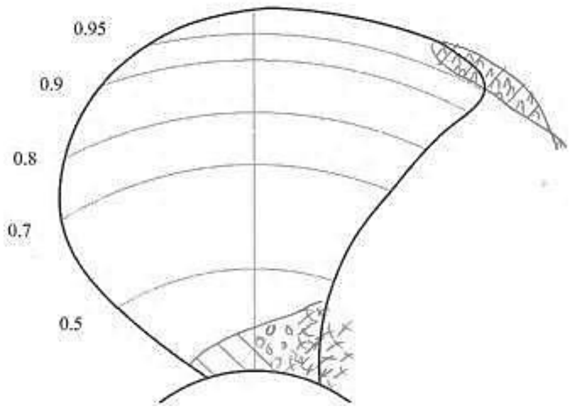


OP3 (pressure side)

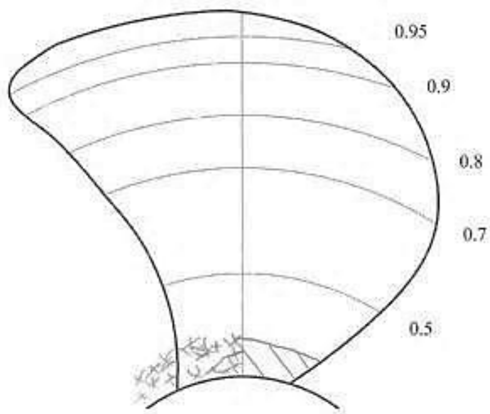
Cavitation sketches for P1790 with an oxygen saturation of α/α_S = 30 %



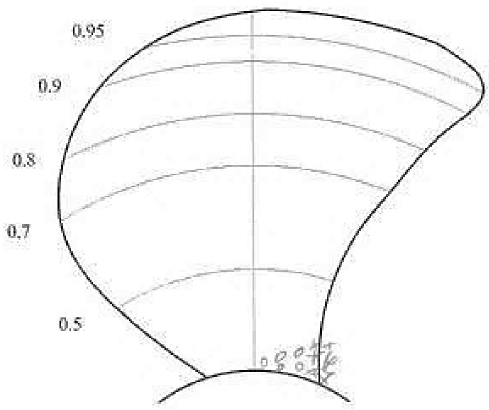
OP1 (suction side)



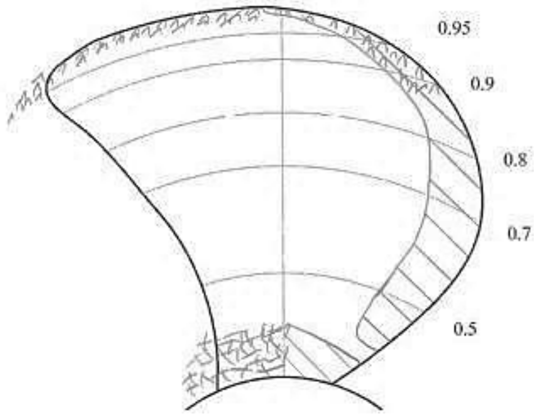
OP2 (suction side)



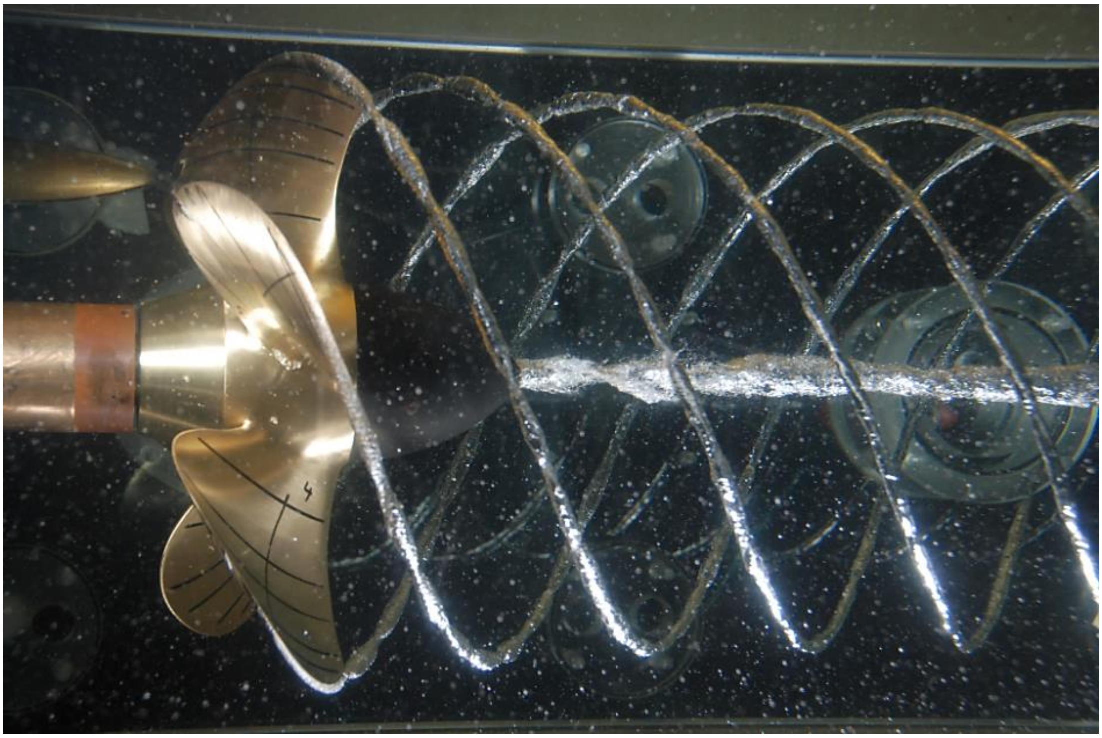
OP2 (pressure side)



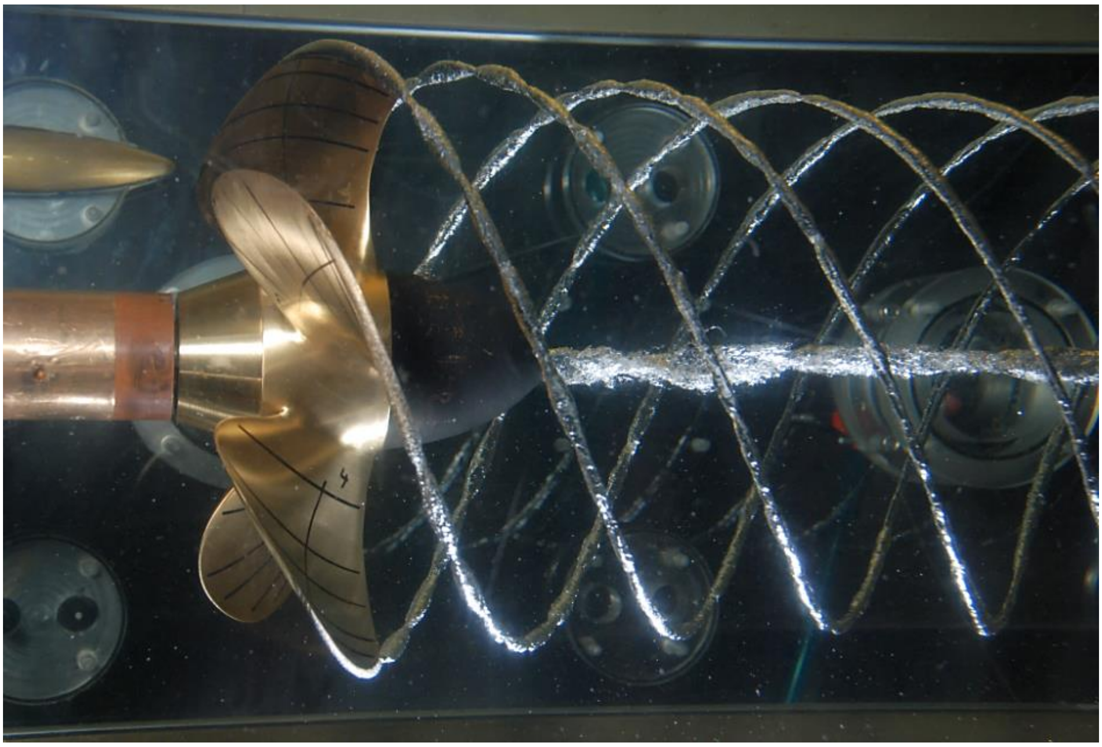
OP3 (suction side)



OP3 (pressure side)



Cavitation photo for P1790 – OP1: K_T = 0.384, σ_n = 2.024, α/α_S = 60 %



Cavitation photo for P1790 – OP1: K_T = 0.386, σ_n = 2.024, α/α_S = 30 %