Potsdam Propeller Test Case (PPTC)
Test Case Description

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1 AIM OF WORKSHOP

The purpose of the workshop is in-force the development of numerical methods for calculation of the performance of marine propulsors in cavitating and non-cavitating flows. The high demand for improving the accuracy and the quality of the numerical methods should be assess by providing high qualitative and intensive experimental validation data. The SVA Potsdam GmbH supported the smp organisation committee in monitoring the performance and accuracy of available numerical methods by offering test and validation data for a controllable pitch propeller SVA-VP1304. The test results are published in course of the propeller workshop of the Second International Symposium on Marine Propulsors 2011 (smp'11). The geometry and results of the propeller are presented under the name PPTC, an acronym for "Potsdam Propeller Test Case".

The experimental results were unknown for the participants of the workshop.

The experimental investigation includes open water test, velocity field measurements and cavitation tests. Different operation conditions were investigated. A detailed description of the open water tests conducted at the towing tank of the SVA is presented in the SVA report 3752 [1], which can be down loaded from the website (sva-potsdam.de).

2 GEOMETRY OF THE POTSDAM PROPELLER TEST CASE

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 the root of the propeller blade near the leading and trailing edge.

The hub cap and aft fairing where designed according to the 22nd ITTC (1999) proceedings. The gap between aft fairing and hub has a width of 3 mm. Also a dummy hub, having the same dimensions and mass as the propeller hub, was manufactured.

The main data of the propeller is given in Table 1. The propeller geometry can be down loaded from the website (sva-potsdam.de).

3 EXPERIMENTAL INVESTIGATIONS

3.1 Open Water Performance

3.1.1 Test Conditions

The propeller is investigated in a pull configuration in the towing tank of the SVA. For the open water tests the dynamometer H39 from Kempf & Remmers has been used. During the tests the propeller shaft is submerged by 1.5 D.

Measurements with a dummy hub were conducted, in order to get data of the idle torque, the force in the gap between the hub and the aft fairing and the resistance of the hub cap.

The open water tests were carried out at two different numbers of revolutions to evaluate the dependency on the Reynolds number. However for the evaluation of the computational results solely the tests with n = 15 s^{-1} are taken into account. The details of experimental setup and test conditions are given in table 2 and 3.

3.1.2 Requested Computations

It was requested to calculate the open water characteristics of the propeller for the advanced coefficients J = 0.6, 0.8, 1.0, 1.2 and 1.4. The computations should be conducted according to the operation conditions given in Table 4.

The thrust and torque of the propeller should be made dimensionless employing the rate of revolution n, the propeller diameter D and the density of water ρ as follows:

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

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

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

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

with V_A being the advance speed, T the thrust and Q the propeller torque

3.1.3 Open Water Test Results

The measured values in the open water tests were corrected with the values of the idle torque and the gap force.

The measured and corrected open water characteristics for the five requested advance coefficients are given in Table 4 for the number of revolutions n = 15 s^{-1}.

3.2 Velocity Field

3.2.1 Test Conditions

The velocity field was measured by means of LDV in the cavitation tunnel K 15 A (Kempf & Remmers) of the SVA Potsdam, utilising a test section with the length of 2600 mm and a cross section of 600x600 mm. The dynamometer J25 from Kempf & Remmers was arranged in front of the propeller model. The shaft inclination was zero degrees.

A 2D-LDV measuring system from TSI was used for the velocity measurements.

Angular based measurements of the transient flow field behind the rotating propeller operating in homogeneous inflow were carried out. Special attention was laid upon resolving the tip vortex. The velocity field around the model propeller VP1304 was measured in seven planes x/D = -0.2, 0.094, 0.10, 0.11, 0.13, 0.16 and 0.20, with respect to the propeller plane as shown in Table 5.

One revolution of the propeller was resolved within 1440 angle classes, giving an angular resolution of 0.25°. The resolution in radial direction is shown in Table 6.

All measurements were conducted for the same working point, given in Table 7. The test conditions are given in Table 8.

The LDV measurements were carried out along a line of constant angular position $\theta = 225°$. The data is than related to the zero degree position, being defined as the 12 o'clock position.

The tests were conducted with a non-cavitating propeller. Test results are summarized in in SVA report [2].

3.2.2 Requested Computations

It was requested to calculate the velocity field around the propeller for the working point and test conditions given in Table 4 and 5. The calculations should be conducted according to the thrust identity.

Four different evaluations were requested. The velocity distribution should be provided on three different radii each for two planes located 0.1 and 0.2 propeller diameters behind the propeller plane, see Table 9.

The velocity components for Case 2.2.1 -2.2.3 shall be made dimensionless by means of the inflow velocity, as follows $1-(V_x/V_A)$, V_t/V_A and V_r/V_A.

The axial velocities are defined positive in flow direction, the radial velocities for increasing radii and the tangential velocities in direction of rotation.

3.3 Cavitation

3.3.1 Test Conditions

The cavitation tests were conducted in the cavitation tunnel K 15 A (Kempf & Remmers) of the SVA Potsdam. For the tests a test section with the length of 2600 mm and a cross section of 600 x 600 mm was used. The dynamometer J25 from Kempf & Remmers was arranged in front of the propeller model. The shaft inclination was zero degrees.

The propeller characteristic in the cavitation tunnel had been measured at the numbers of revolutions n = 15, 20 and 25 s^{-1}. Cavitation buckets were measured with the number of revolutions n = 25 s^{-1}. Two blades had been selected for the cavitation tests.

The cavitation behaviour of the propeller was observed in three working points, corresponding to the test conditions required for test case 2.3.1-2.3.3. Test results are summarized in SVA report [3].

3.3.2 Requested Computations

It was requested to calculate the propeller cavitation for three working point, given in Table 10.

The calculation shall be conducted according to the thrust identity.

For the three working points it was requested to visualize the cavity surface for vapor fractions of 20, 50 and 80%. For case 2.3.1 and case 2.3.2 it was requested to look upon the suction side, while for case 2.3.3 on the pressure side of the propeller.

In order to quantify the thrust deduction it was additionally requested to provide the thrust coefficient of the propeller in cavitating condition.

It was also requested to provide the pressure distribution, made dimensionless with the section advance speed, on the propeller radii r/R = 0.7, 0.97 and 1.00 with and without cavitation.

The data is made dimensionless as follows:

Cavitation number with respect to n:

$$\sigma_n = \frac{(p - p_v)}{0.5 \cdot \rho \cdot (nD)^2}$$

Pressure coefficient:

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

with D_P being the propeller diameter, T the propeller thrust, Q the propeller torque, p the tunnel pressure, p_v the vapour pressure, p_0 the static pressure and r the radius.

REFERENCES

[1]Barkmann, U., Potsdam Propeller Test Case (PPTC) - Open Water Tests with the Model Propeller VP1304, Report 3752, Schiffbau-Versuchsanstalt Potsdam, April 2011

[2]Mach, K., Potsdam Propeller Test Case (PPTC), LDV with the Model Propeller VP1304, Report 3754, Schiffbau-Versuchsanstalt Potsdam, April 2011 (unpublished)

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

TABLES

Table 1: Main data of model propeller VP1304

			VP1304
Diameter	D	[m]	0.250
Pitch ratio r/R = 0.7	$P_{0.7}/D$	[–]	1.635
Area ratio	A_E/A_0	[–]	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

Table 2: Details of model tests

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Towing tank	
Dimensions of towing tank	280 x 9 x 4.5 m
Propeller:	VP1304
Propeller type	controllable pitch propeller
Material of model propeller	brass
Diameter of the propeller	0.25 m
Sense of rotation	right (looking on pressure side)
Arrangement:	
Shaft inclination	0°
Dynamometer shaft	behind the propeller
Measuring equipment:	dynamometer H39
	n_{max} = 60 s^{-1}
	T_{max} = 1 kN
	Q_{max} = 50 Nm

Table 3: Operation conditions

Water density (t_W = 17.5 °C)	ρ	[kg/m³]	998.67
Kinematic viscosity (t_W = 17.5 °C)	ν	[m²/s]	1.070E-06
Number of revolutions	n	[1/s]	15.00

Table 4: Measured open water characteristics (by polynomials)

J	K_T	$10K_Q$	η_O
0.60	0.6288	1.3964	0.4300
0.80	0.5100	1.1780	0.5512
1.00	0.3994	0.9749	0.6520
1.20	0.2949	0.7760	0.7258
1.40	0.1878	0.5588	0.7487

Table 5: LDV Measuring planes

x-position	x/D	[–]	-0.200	0.094	0.100	0.110	0.130	0.160	0.200
x-position	x	[mm]	-50.0	23.5	25.0	27.5	32.5	40.0	50.0

Table 6: LDV Positions of the measuring points

measuring plane	start radius	end radius	distance	
	r/R	r/R	$\Delta r/R$	[mm]
in front of the propeller x/D = -0.20	0.40	1.10	0.050	6.250
behind the propeller x/D = 0.094, 0.10, 0.11, 0.13, 0.16, 0.20	0.40	0.70	0.050	6.250
	0.70	0.90	0.025	3.125
	0.90	0.95	0.010	1.250
	0.95	1.05	0.002	0.250
	1.05	1.10	0.025	3.125

Table 7: Working point for the LDV measurements

Inflow speed	V_A	[m/s]	7.204
Number of revolutions	n	[s^{-1}]	23
Advance coefficient	J	[–]	1.253
Thrust coefficient	K_T	[–]	0.250
Torque coefficient	$10K_Q$	[–]	0.725
Water density (for t_w = 24.7°C)	ρ	[kg/m^3]	997.1
Kinematic viscosity of water (for t_w = 24.7°C)	ν	[m²/s]	0.903E-6

Table 8: Test conditions for the LDV measurements

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

Table 9: Requested Computations

	r/R [-]	*x/D* [-]	θ [°]
Case 2.2.1	0.70	0.1, 0.2	-50° - 22°
Case 2.2.2	0.97	0.1, 0.2	-50° - 22°
Case 2.2.3	1.00	0.1, 0.2	-50° - 22°
Case 2.2.4	0.40 - 1.10	0.1, 0.2	

Table 10: Working points for the cavitation tests

			Case 2.3.1	Case 2.3.2	Case 2.3.3
Advanced coefficient	J	[-]	1.019	1.269	1.408
Cavitation number based on n	σ_n	[-]	2.024	1.424	2.000
Thrust coefficient (non-cavitating!)	K_T	[-]	0.387	0.245	0.167
Number of revolutions	n	[1/s]	24.987	24.986	25.014
Water density (for t_w = 23.2°C)	ρ	[kg/m^3]	997.44	997.44	997.37
Kinematic viscosity water (for t_w = 23.2°C)	ν	[m²/s]	$9.337 \cdot 10^{-7}$	$9.337 \cdot 10^{-7}$	$9.272 \cdot 10^{-7}$
Vapour pressure (for t_w = 23.2°C)	p_v	[Pa]	2818	2818	2869
Air content	α/α_s	[%]	53.5	53.5	58.50