

# **Potsdam Propeller Test Case (PPTC)**

## **Cavitation in Oblique Flow**

### **Case 2**

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**Lars Lübke**

**Potsdam Model Basin (SVA)**



# Content

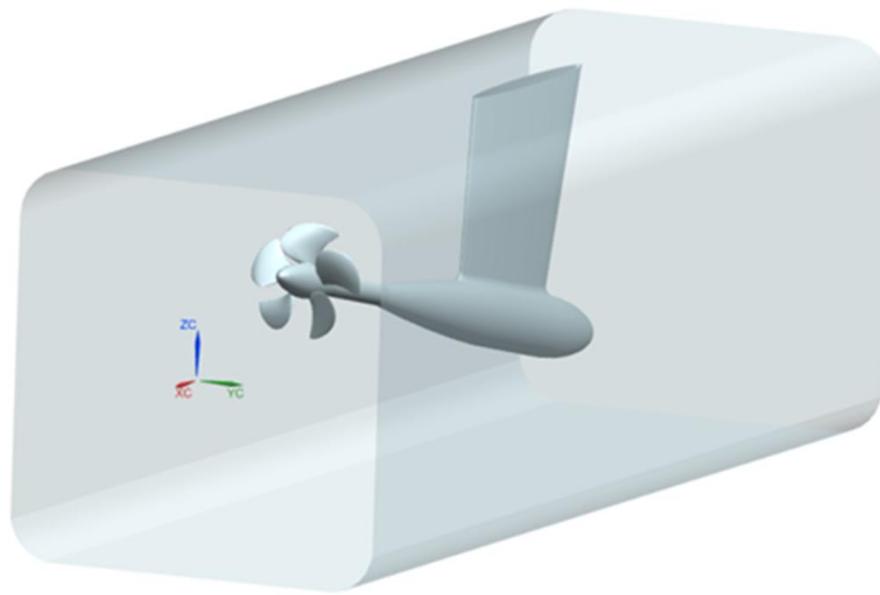
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- Test setup
- Observed cavitation pattern
- Submissions
- Case 2.1
- Case 2.2
- Case 2.3
- To discuss (?)

# Cavitation tunnel test

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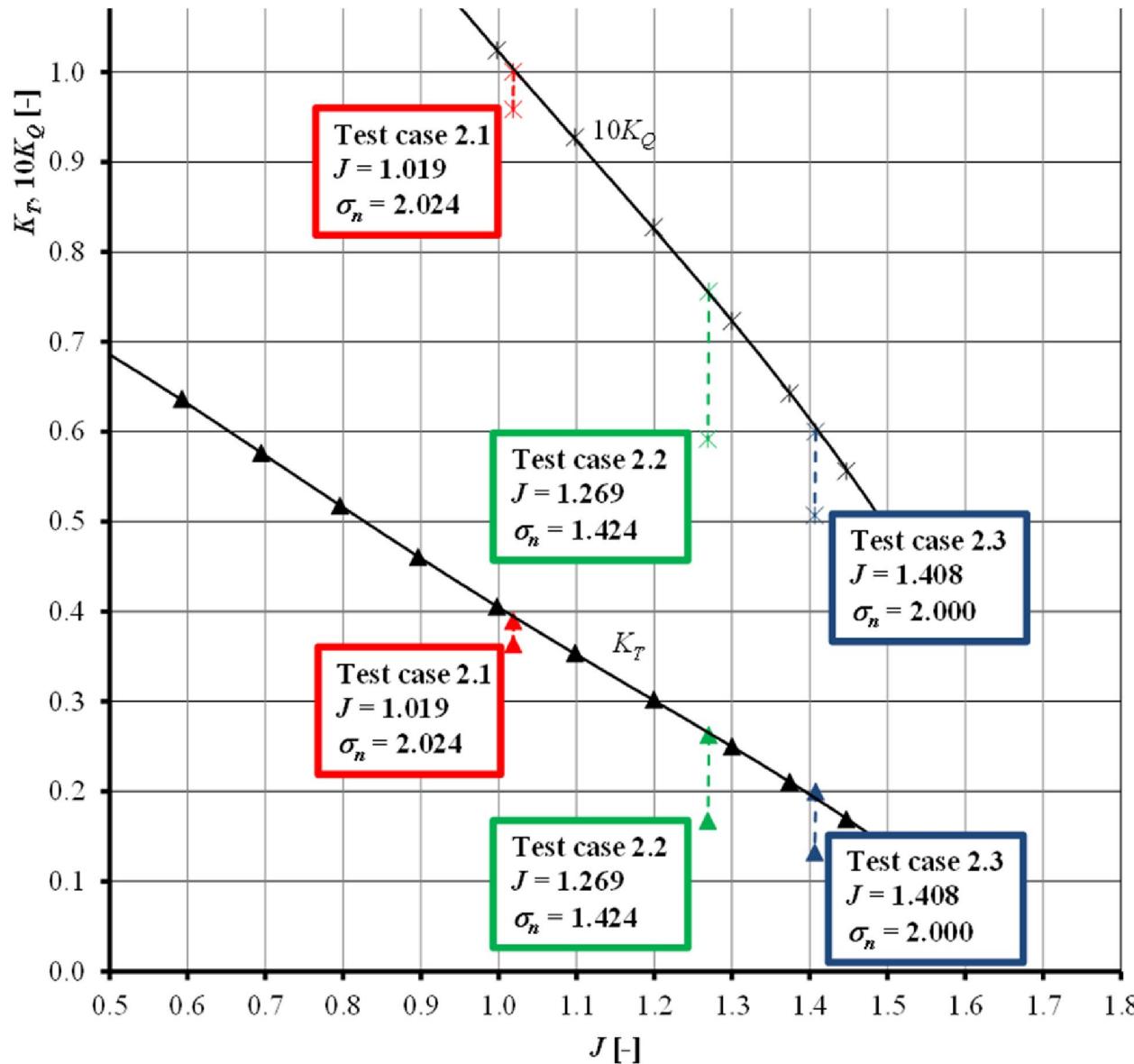
- Tests were conducted in the cavitation tunnel
- Dynamometer mounted behind the propeller with an inclination of 12°
- Test section 850 x 850 mm



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# **CAVITATION PATTERN (EFD)**

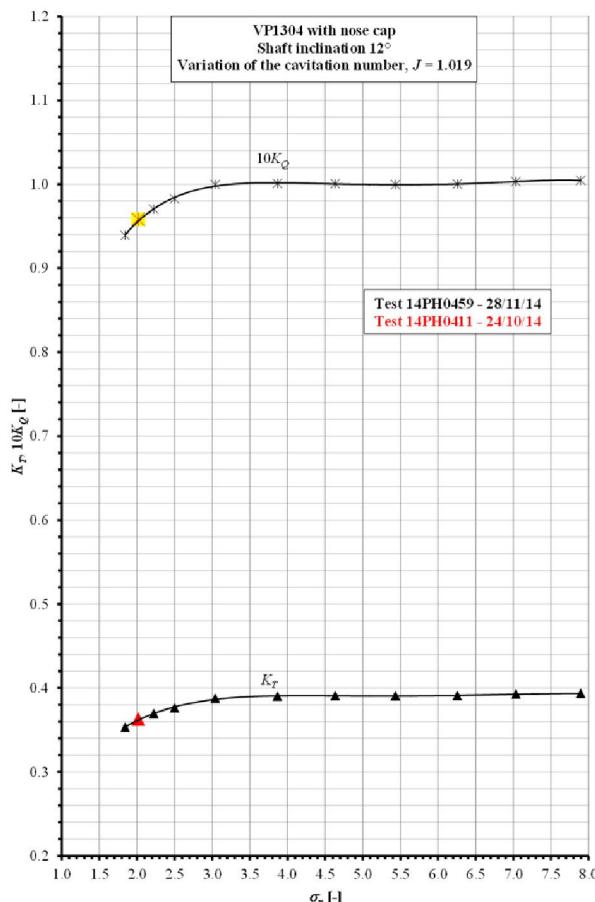
# Operation points - EFD



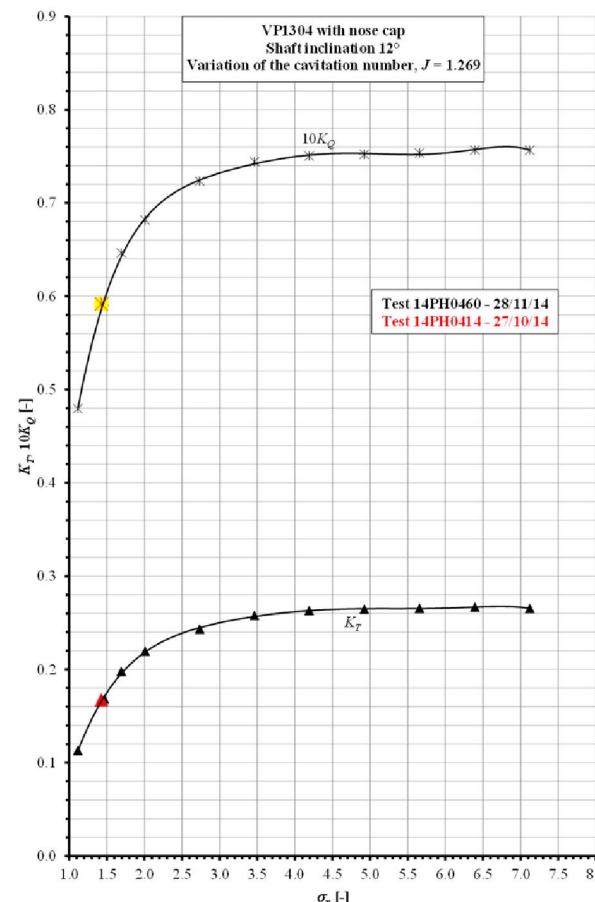
- VP1304 with nose cap
- Shaft inclination  $12^\circ$
- $n = 20 \text{ 1/s}$
- Open water curves
- Operation points for cavitation tests

# Variation in cavitation number

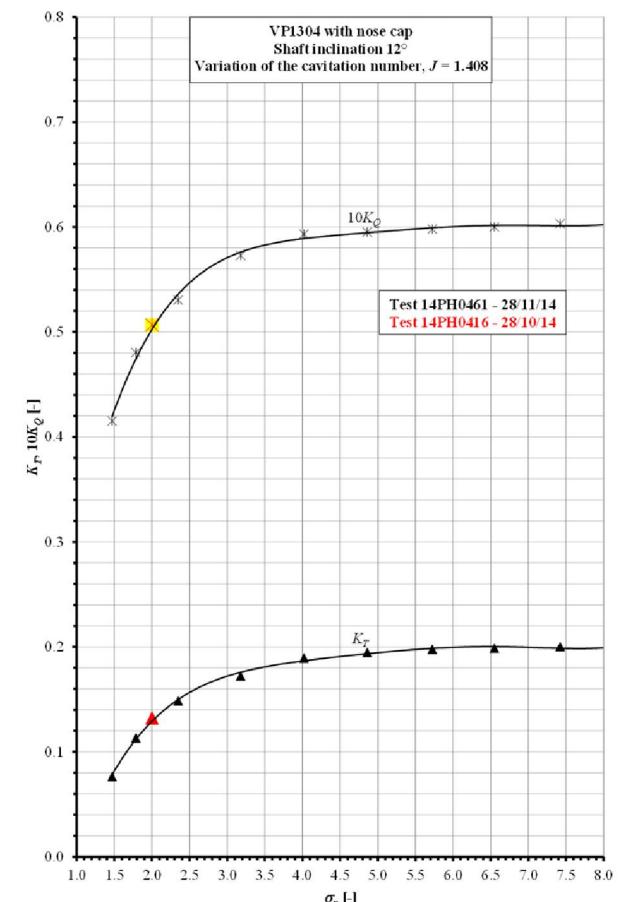
Case 2.1



Case 2.2



Case 2.3



## Case 2.1: Photo documentation

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In the report 6 photographs for the following angular position with respect of blade 1 will be given:



$$\Theta = 90^\circ$$

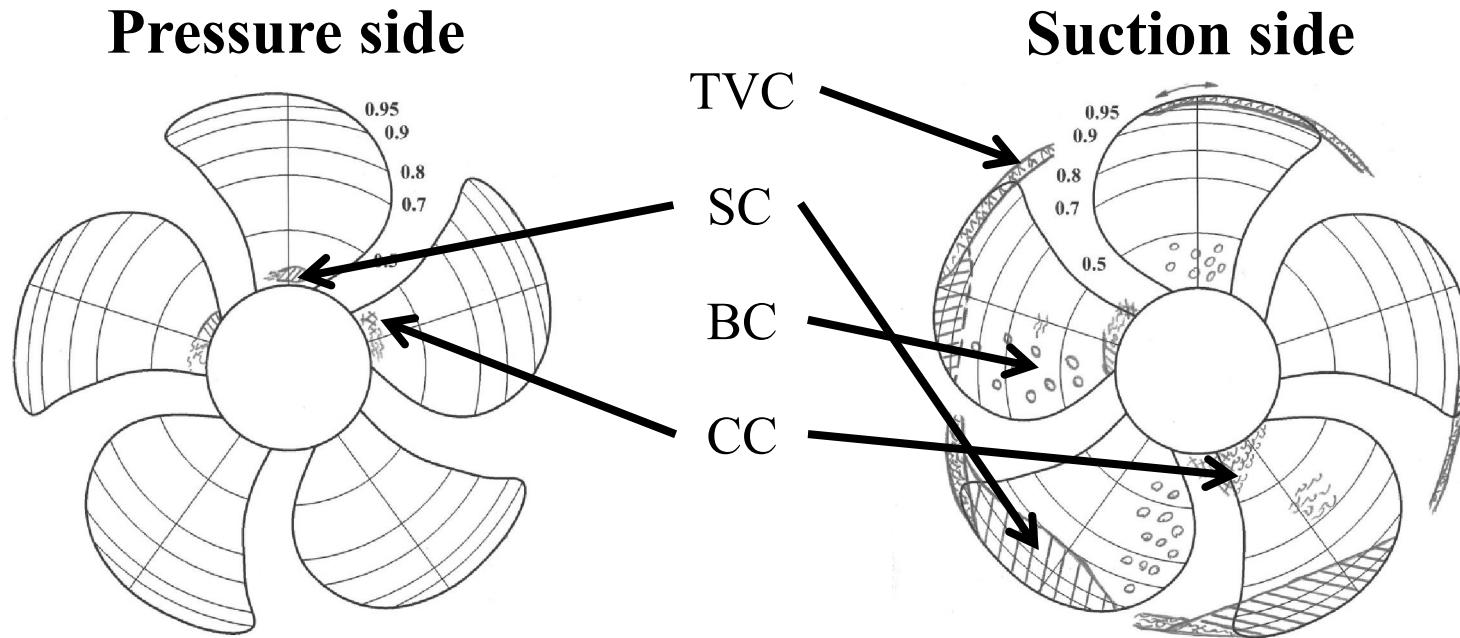


$$\Theta = 120^\circ$$



$$\Theta = 180^\circ$$

# Case 2.1: Cavitation types



Case 2.1		PS	SS
Tip vortex cavitation	TVC		X
Sheet cavitation	SC	X	X
Bubble cavitation	BC		X
Cloud cavitation	CC	X	X

- Cavitation is intermittent
- unsteady

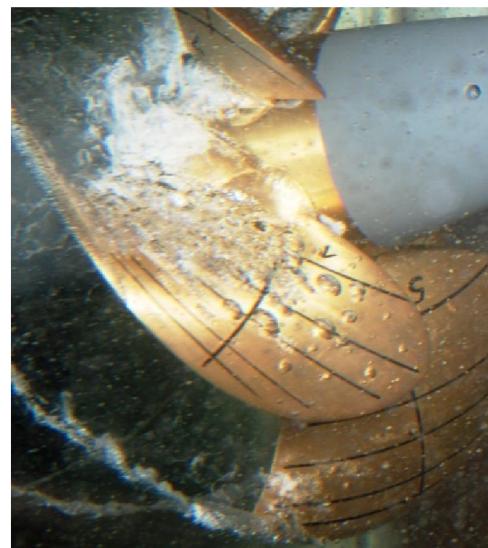
## Case 2.2: Photo documentation

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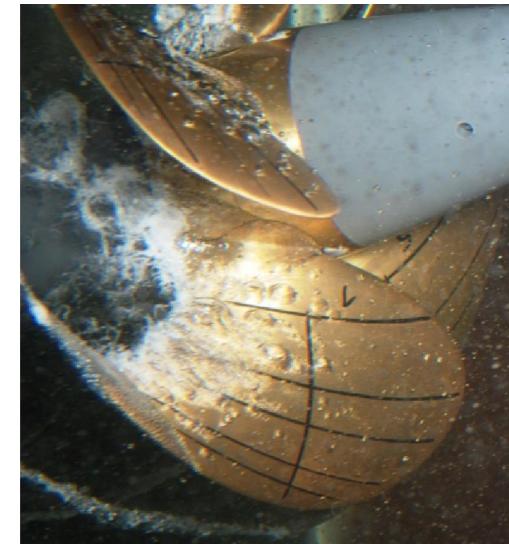
In the report 6 photographs for the following angular position with respect to blade 1 will be given:



$$\Theta = 0^\circ$$

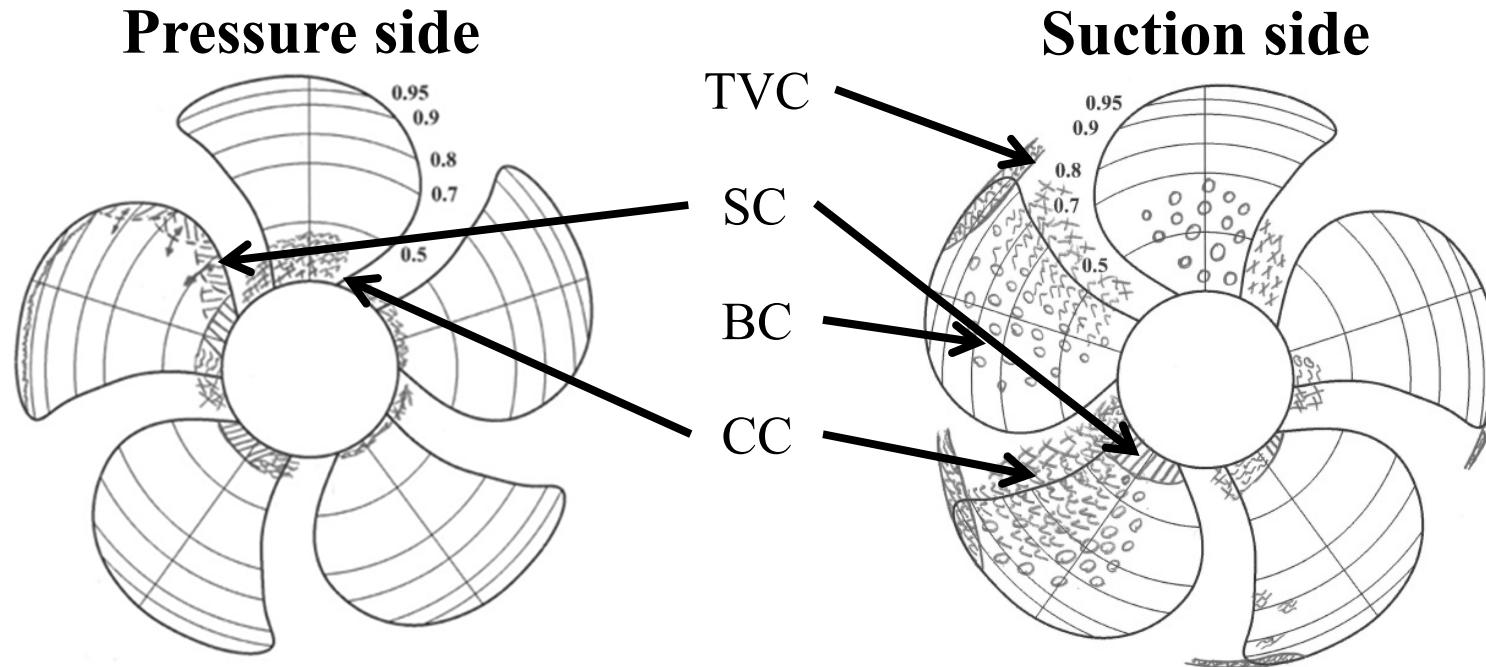


$$\Theta = 120^\circ$$



$$\Theta = 150^\circ$$

# Case 2.2: Cavitation types



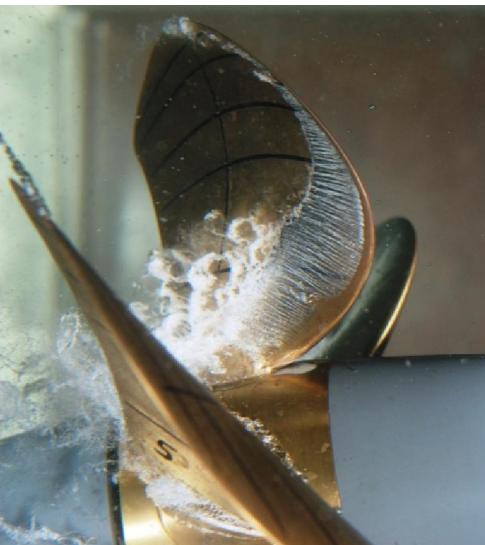
Case 2.2	PS	SS
Tip vortex cavitation	TVC	X
Sheet cavitation	SC	X
Bubble cavitation	BC	X
Cloud cavitation	CC	X

- Cavitation is intermittent
- unsteady

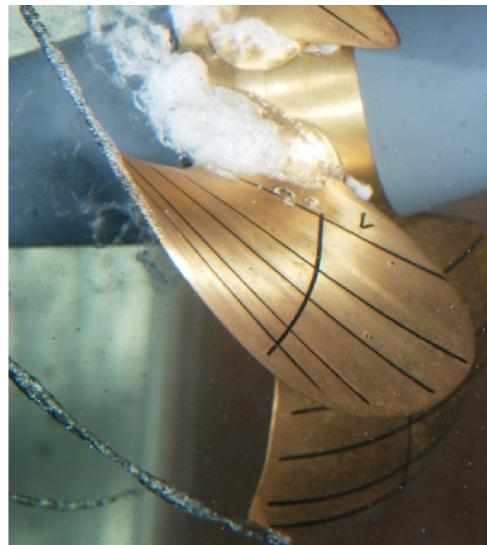
## Case 2.3: Photo documentation

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In the report 6 photographs for the following angular position with respect to blade 1 will be given:



$$\Theta = 0^\circ$$

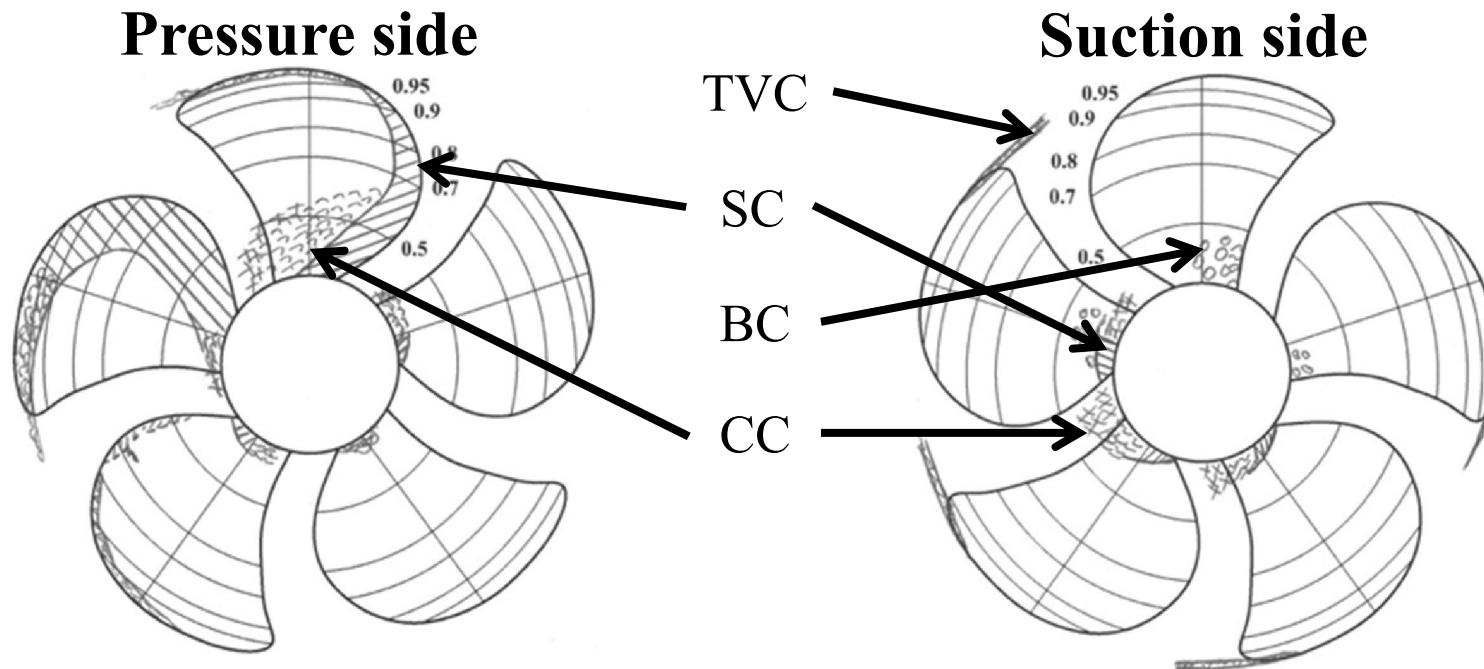


$$\Theta = 120^\circ$$



$$\Theta = 330^\circ$$

# Case 2.3: Cavitation types

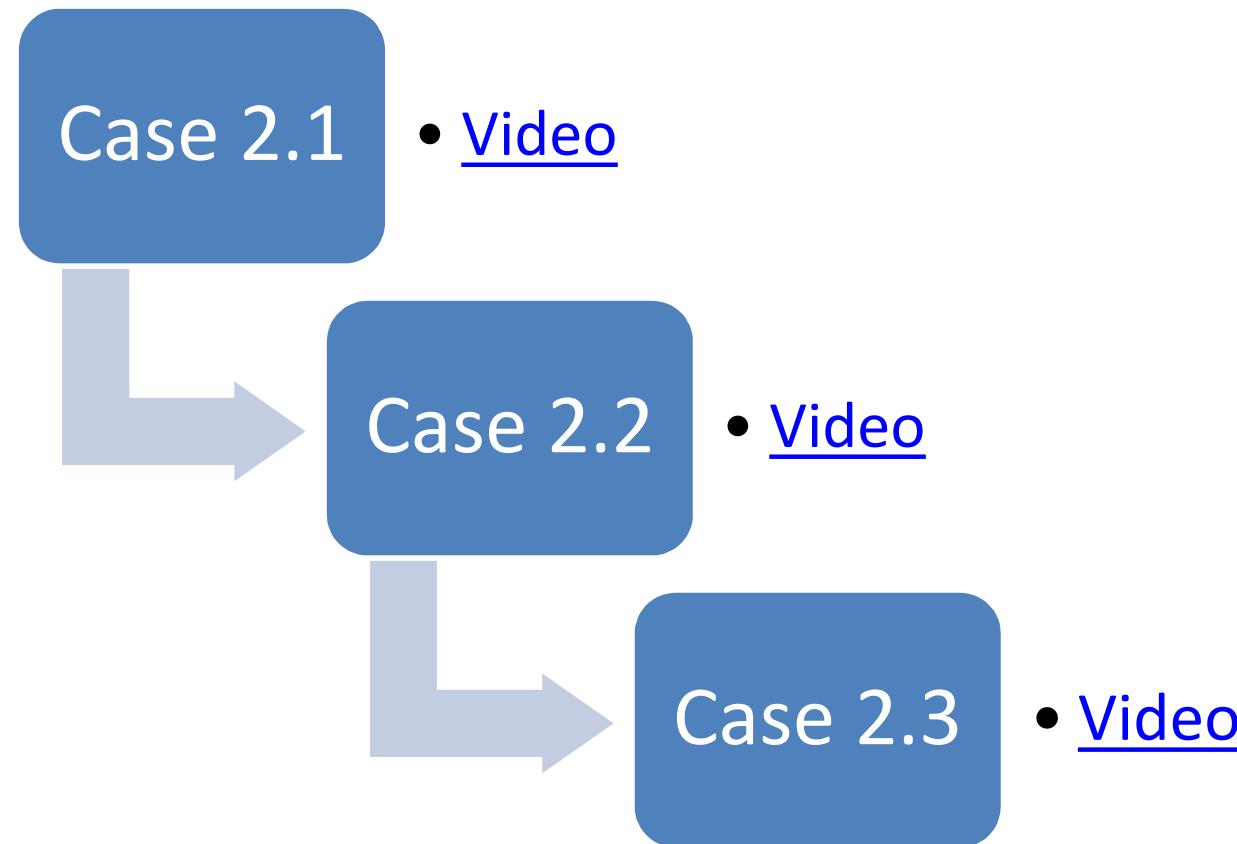


Case 2.3		PS	SS
Tip vortex cavitation	TVC	X	X
Sheet cavitation	SC	X	X
Bubble cavitation	BC		X
Cloud cavitation	CC	X	X

- Cavitation is intermittent
- unsteady

# Video documentation

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# SUBMISSIONS

# Participants

Group	Solver	Acronym
ACCUSIM	ANSYS-CFX, FCM	ACCUSIM-CFX-FCM
	ANSYS-CFX, Kunz	ACCUSIM-CFX-Kunz
	ANSYS-CFX, Zwart	ACCUSIM-CFX-Zwart
CAT-Propulsion	OpenFOAM	CAT-OF
Chalmers	OpenFOAM	Chalmers-OF
CNRS-ECN	ISIS	CNRS-ISIS
CRADLE	SC-Tetra	CRADLE-SCTetra
CSSRC	ANSYS-Fluent	CSSRC-Fluent
MARIN	ReFRESCO	MARIN-ReFresco
ROTAM	ANSYS-Fluent	ROTAM-Fluent
SSPA	ANSYS-Fluent	SSPA-Fluent-Sauer
	ANSYS-Fluent	SSPA-Fluent-Zwart1
	ANSYS-Fluent	SSPA-Fluent-Zwart2
TUHH	ANSYS-CFX	TUHH-CFX
	panMARE	TUHH-panMARE
University of Genoa	BEM	UniGenoa-BEM
	StarCCM+	UniGenoa-StarCCM+
UT Austin	PROPCAV	UTAustin-PROPCAV
VTT	FinFlo	VTT-FinFlo

13 groups, 11 solvers, 19 calculations (16 viscous, 3 potential flow)

# Computational setup I (viscous)

Acronym	Grid Typ	No. Cells [Mio.]	Cells blade [Mio.]	$Y^+$	Turb.
ACCUSIM-CFX-FCM	Tet-Prism	22.76 (4.57 nodes)		40.0	$k\omega$ -SST
ACCUSIM-CFX-Kunz	Tet-Prism	22.76 (4.57 nodes)		40.0	$k\omega$ -SST
ACCUSIM-CFX-Zwart	Tet-Prism	22.76 (4.57 nodes)		40.0	$k\omega$ -SST
CAT-OF	Polyhedral	9.56	0.09	1.1	RNG-k- $\varepsilon$
Chalmers-OF				10.0	ILES
CNRS-ISIS	unstr.-HEX	25.80	0.10	0.6	$k-\omega$
CRADLE-SCTetra	Tet-Prism	30.80	0.25	<1	RANS/LES
MARIN-ReFRESCO	unstr.-HEX	14.50	0.11	1.0	$k-\omega$
ROTAM-Fluent	Tet-Prism	5.00		10.0	
SSPA-Fluent-Sauer	str.-HEX	12.00	0.11	1.0	$k-\omega$
SSPA-Fluent-Zwart1	str.-HEX	12.00	0.11	1.0	$k-\omega$
SSPA-Fluent-Zwart2	str.-HEX	12.00	0.11	1.0	$k-\omega$
TUHH-CFX	str.-HEX	4.50	0.02	30.0	$k\omega$ -SST
UniGenoa-StarCCM+	Polyhedral	5.00	0.05	25.0	$k-\varepsilon$
VTT-FinFlo	str.-HEX	23.40	0.03	1.0	$k-\omega$

- All fully turbulent
- Spatial discretization: all 2<sup>nd</sup>-order
- Temporal discretization: half 2<sup>nd</sup> other half 1<sup>st</sup> order

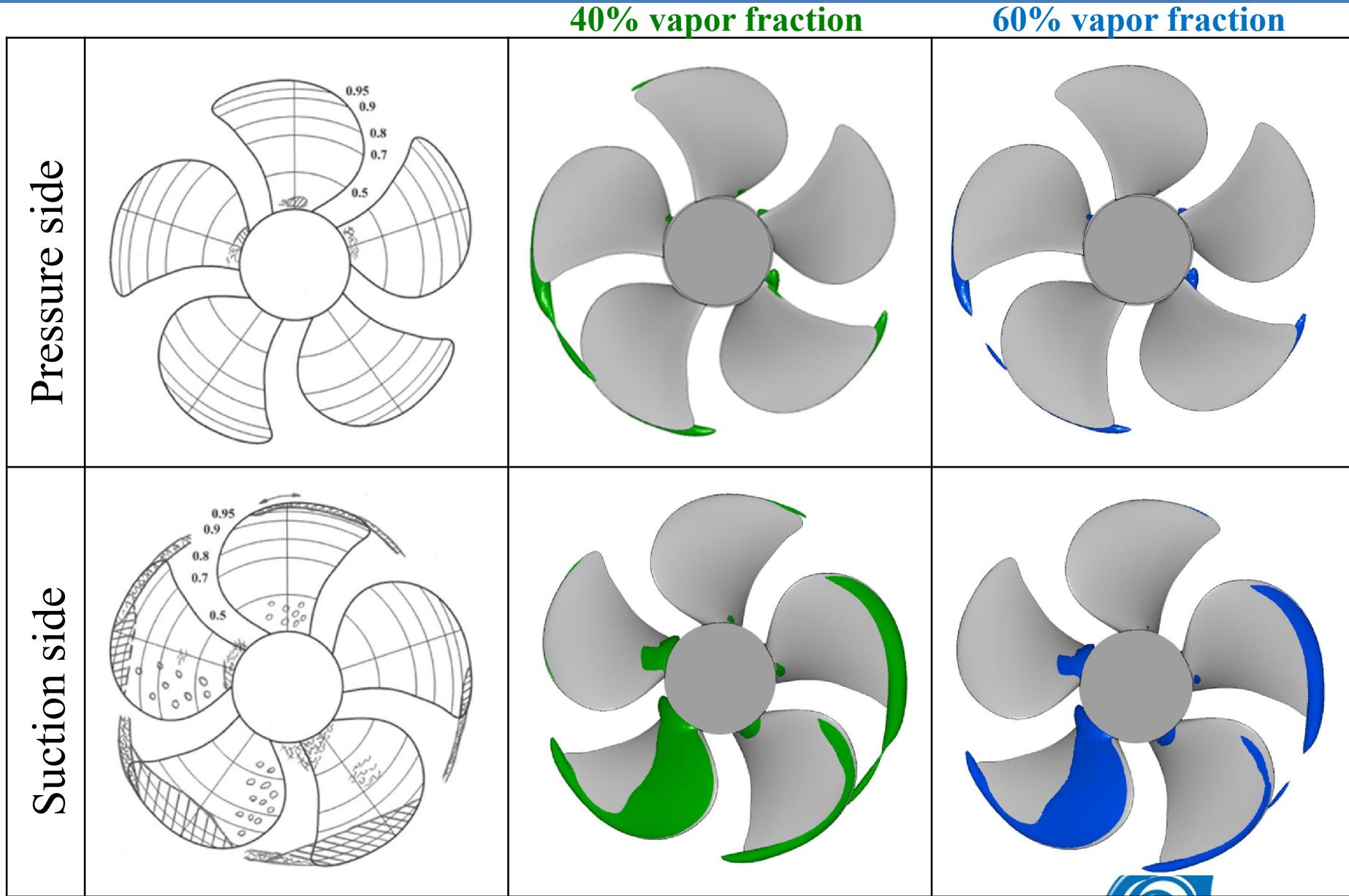
# Computational setup II (viscous)

Acronym	tstep [°]	Mass. transfer	Cond. coeff.	Vap. coeff	Bubbles /m³	Ini. Bubble diam. [mm]
ACCUSIM-CFX-FCM		FCM	455	4100		
ACCUSIM-CFX-Kunz		Kunz	2.3e-04	0.4		
ACCUSIM-CFX-Zwart		Zwart	0.03	300		
CAT-OF	0.025	Kunz	320	12500		
Chalmers					10 <sup>8</sup>	0.1
CNRS-ISIS	0.25	Sauer			10 <sup>8</sup>	
CRADLE-SCTetra	0.35	Singhal	0.01	0.02		
MARIN-ReFRESCO	1.00	Sauer			10 <sup>10</sup>	0.06
ROTAM-Fluent	1.00	Zwart				
SSPA-Fluent-Sauer	1.40	Sauer	0.01	50	10 <sup>13</sup>	
SSPA-Fluent-Zwart1	1.40	Zwart	0.01	50		0.001
SSPA-Fluent-Zwart2	1.40	Zwart	0.01	50		0.035
TUHH-CFX	2.80	Zwart	0.01	50		0.001
UniGenoa-StarCCM+	0.50	Sauer			10 <sup>12</sup>	0.001
VTT-FinFlo	0.50	Merkle	370	370		

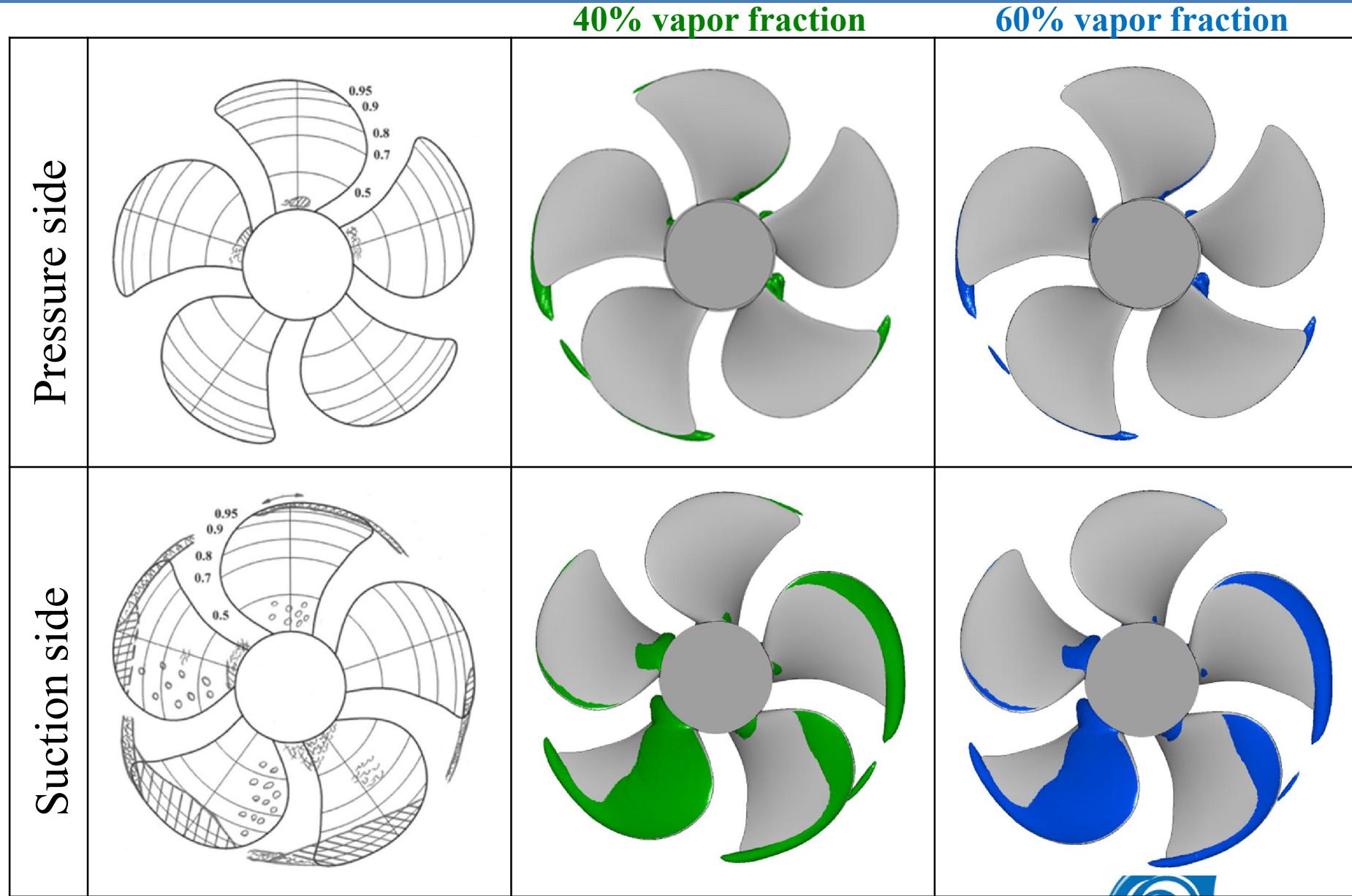
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# CASE 2.1

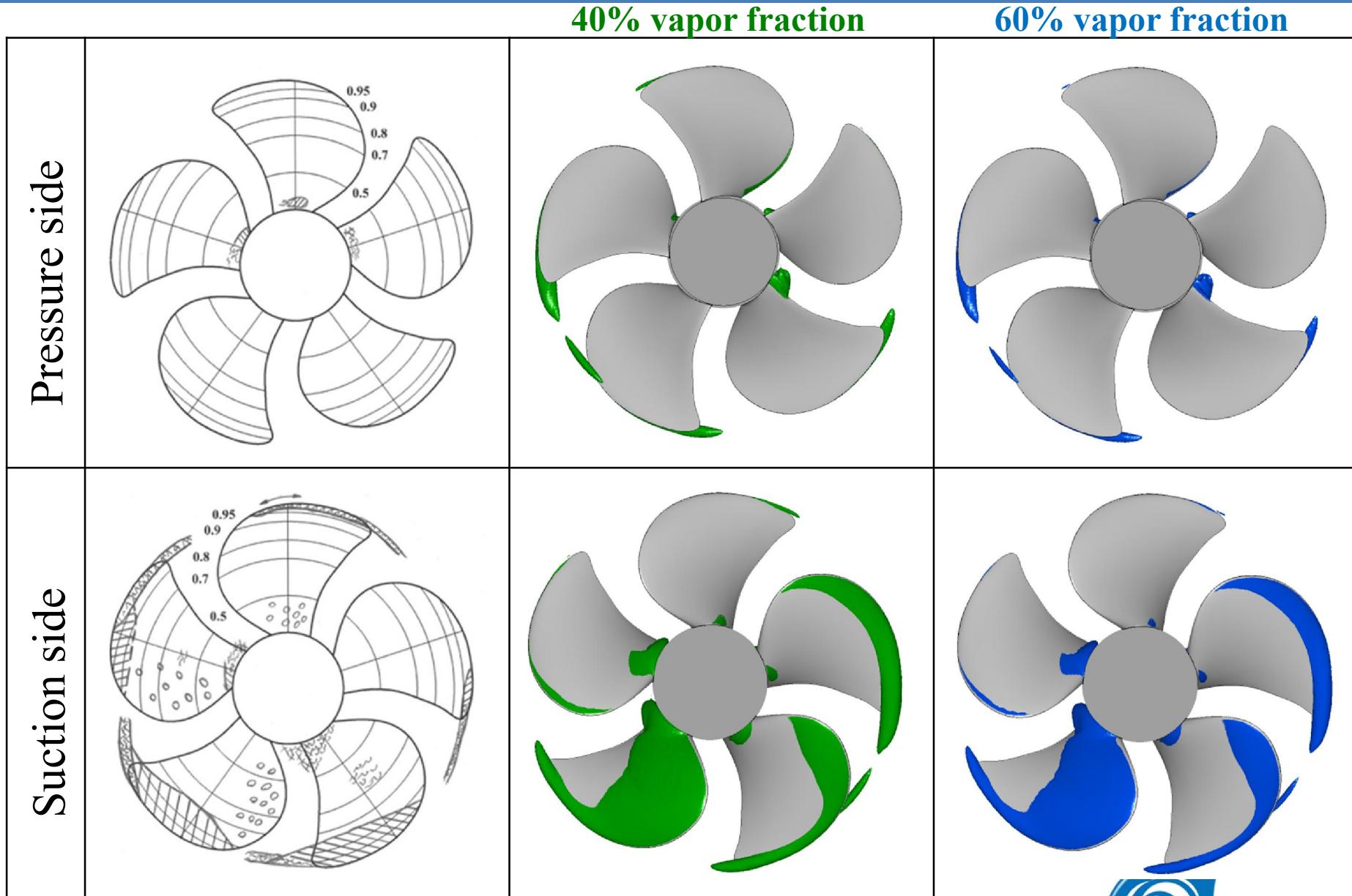
# Case 2.1: ACCUSIM CFX-FCM



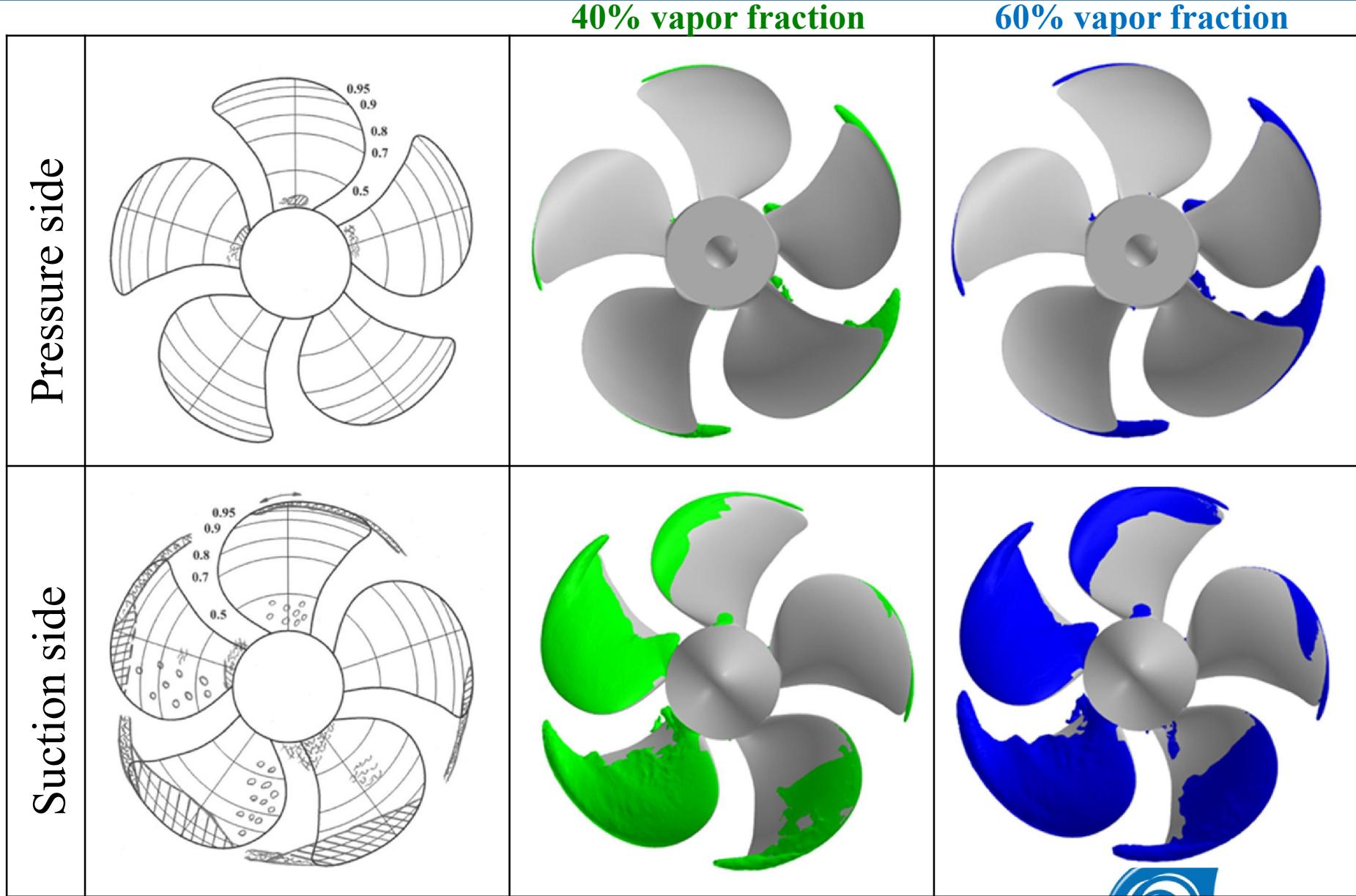
# Case 2.1: ACCUSIM CFX-Kunz



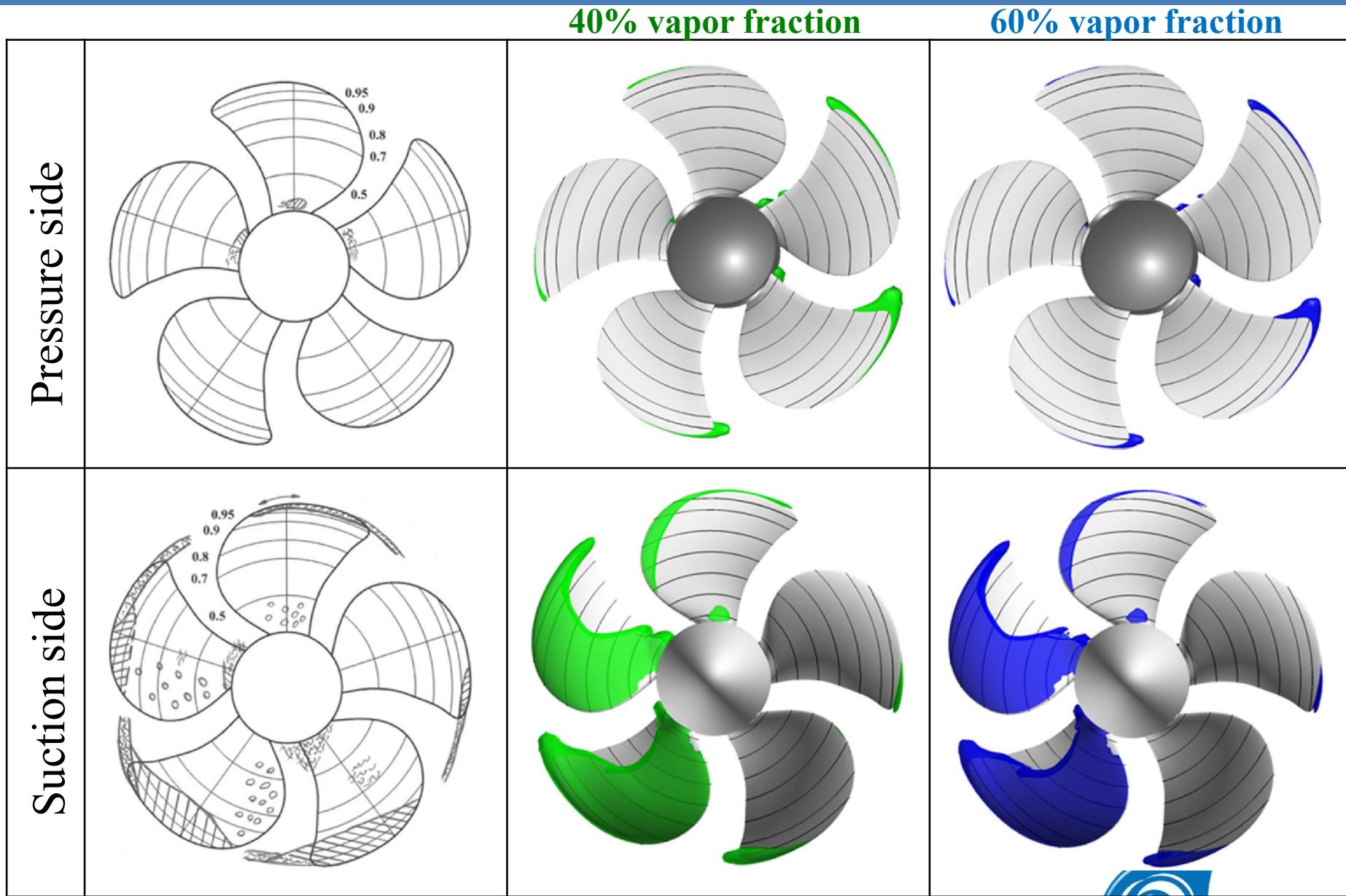
# Case 2.1: ACCUSIM CFX-Zwart



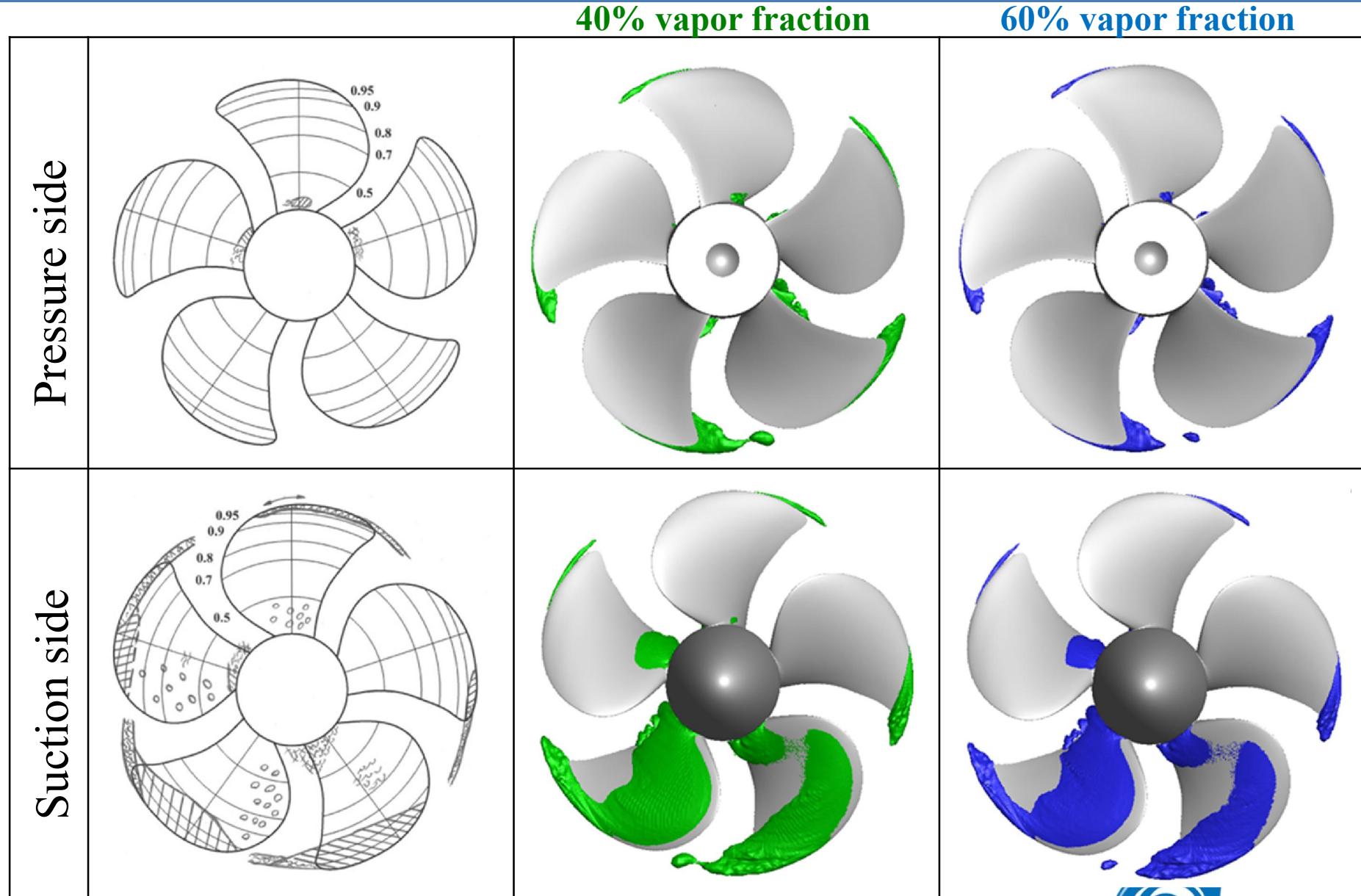
# Case 2.1: CAT-OF



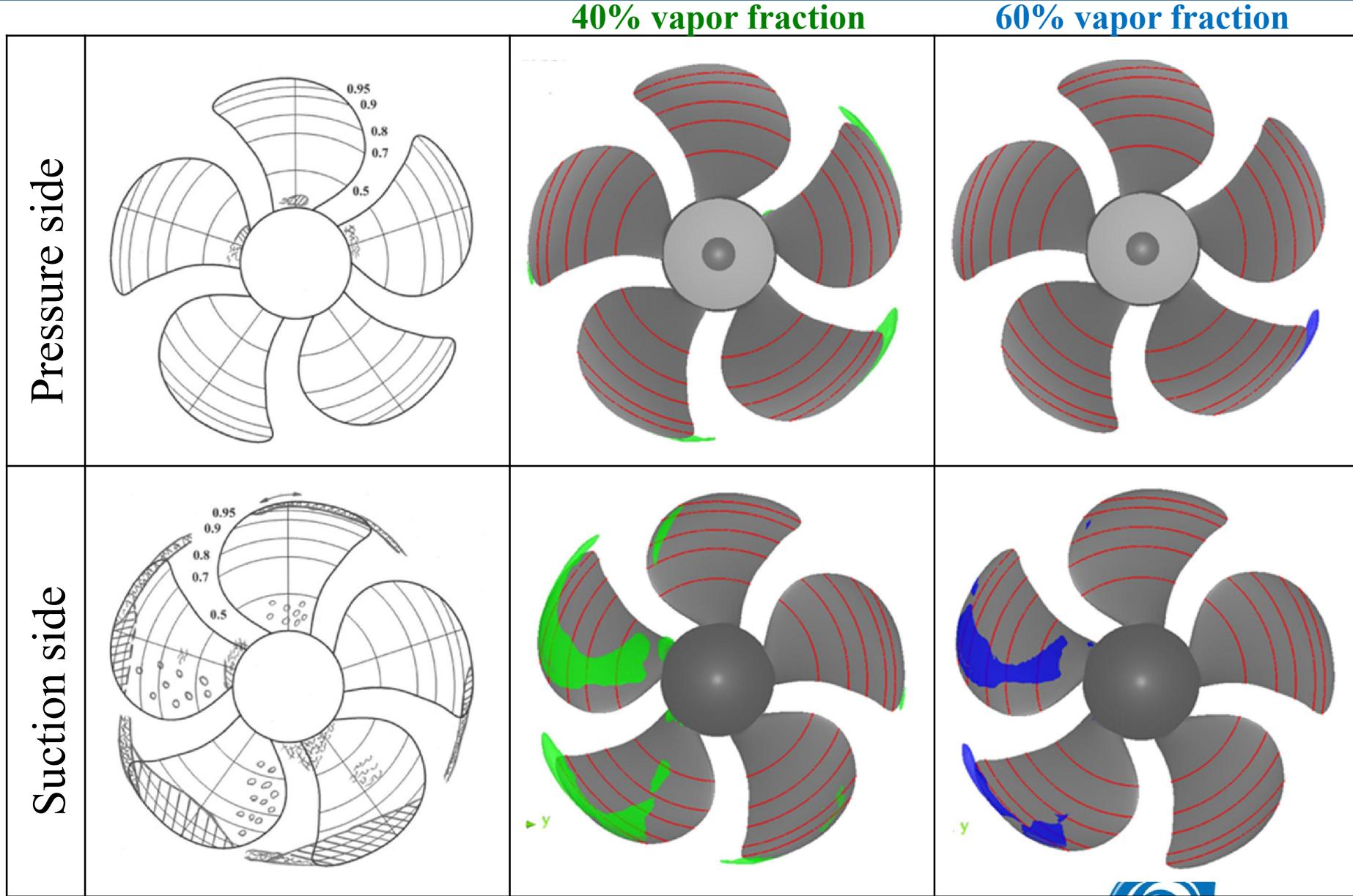
# Case 2.1: Chalmers-OF



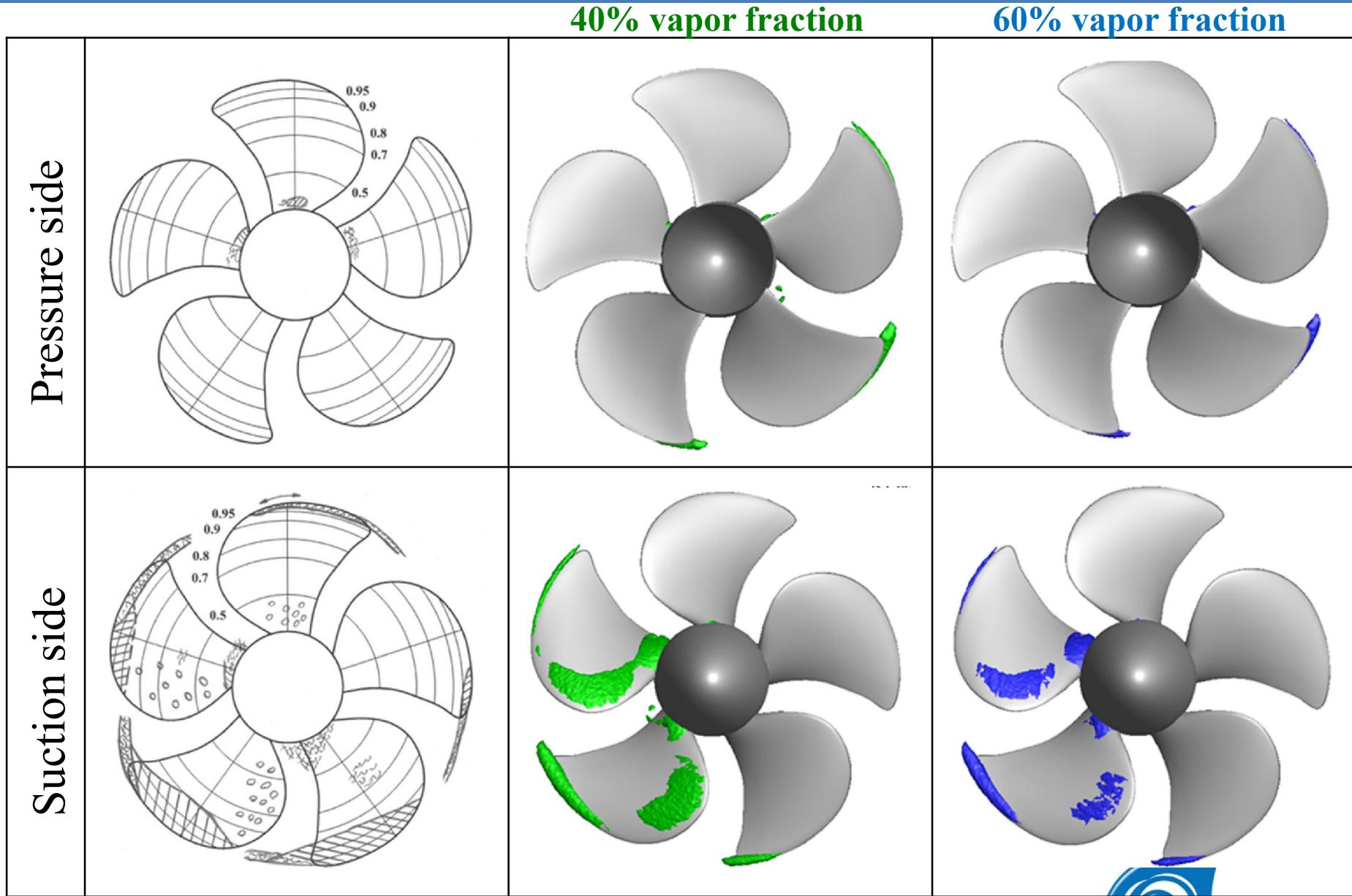
# Case 2.1: CNRS-ISIS



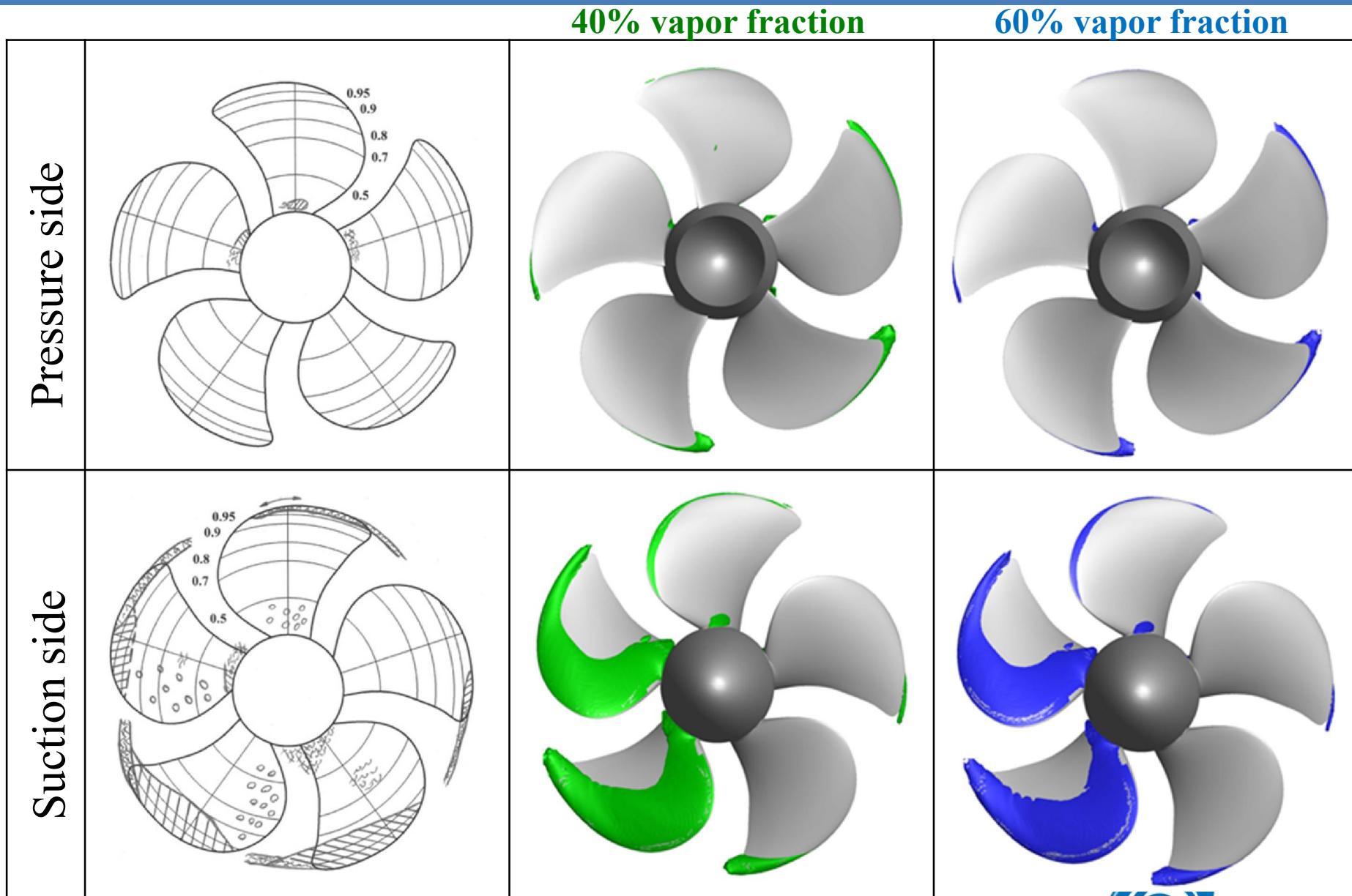
# Case 2.1: CRADLE-SCTetra



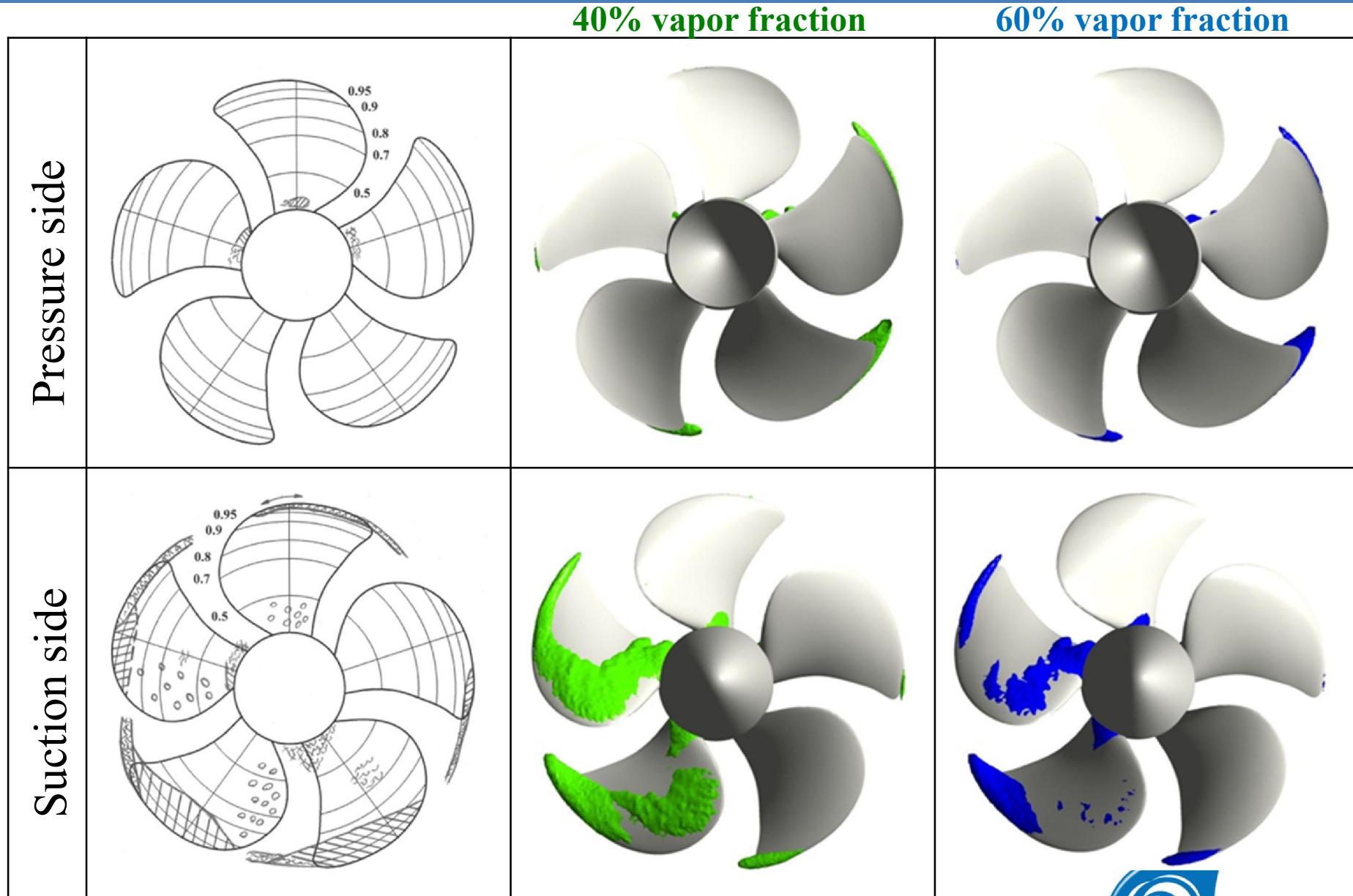
# Case 2.1: CSSRC-Fluent



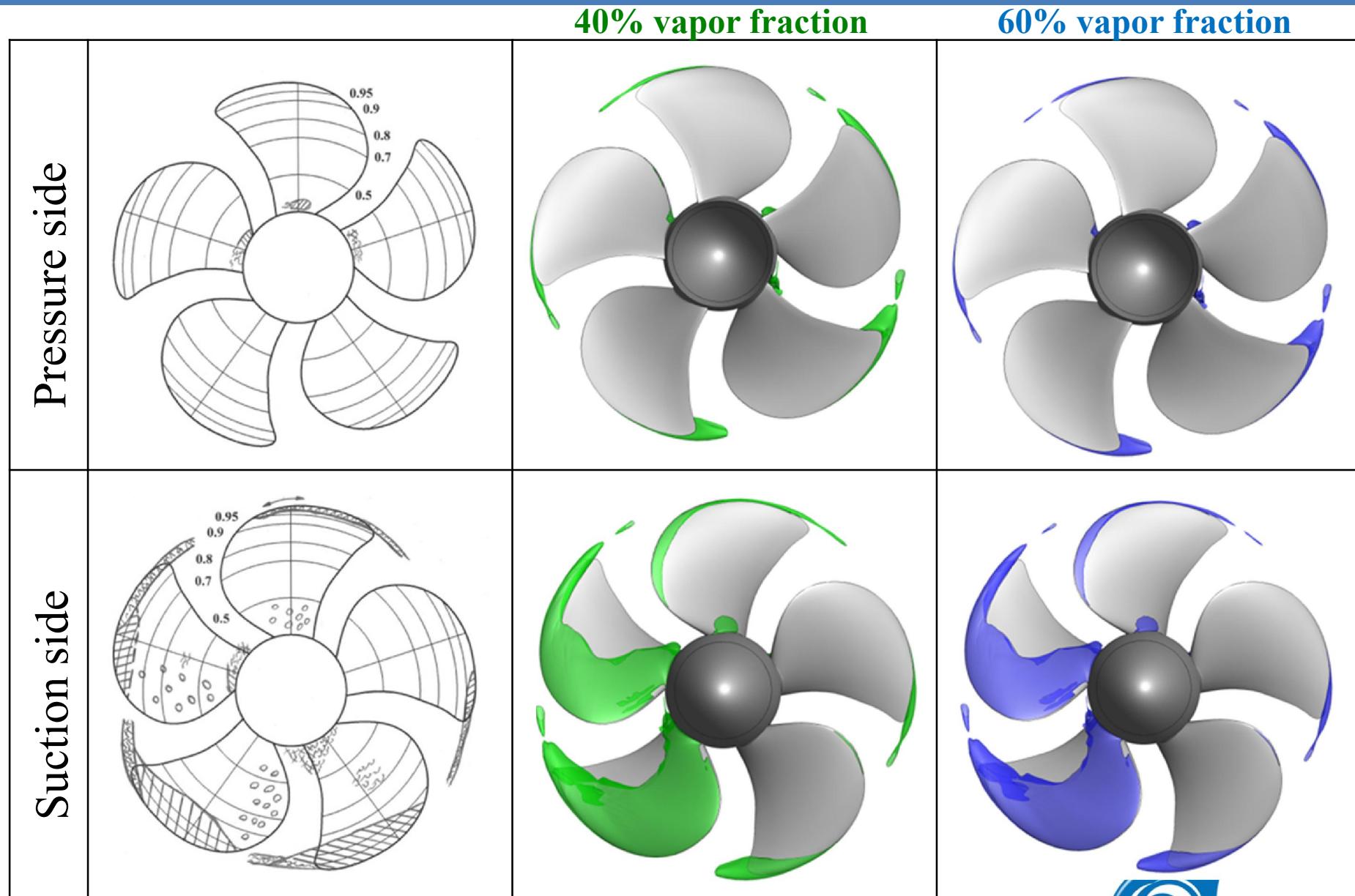
# Case 2.1: MARIN-ReFRESCO



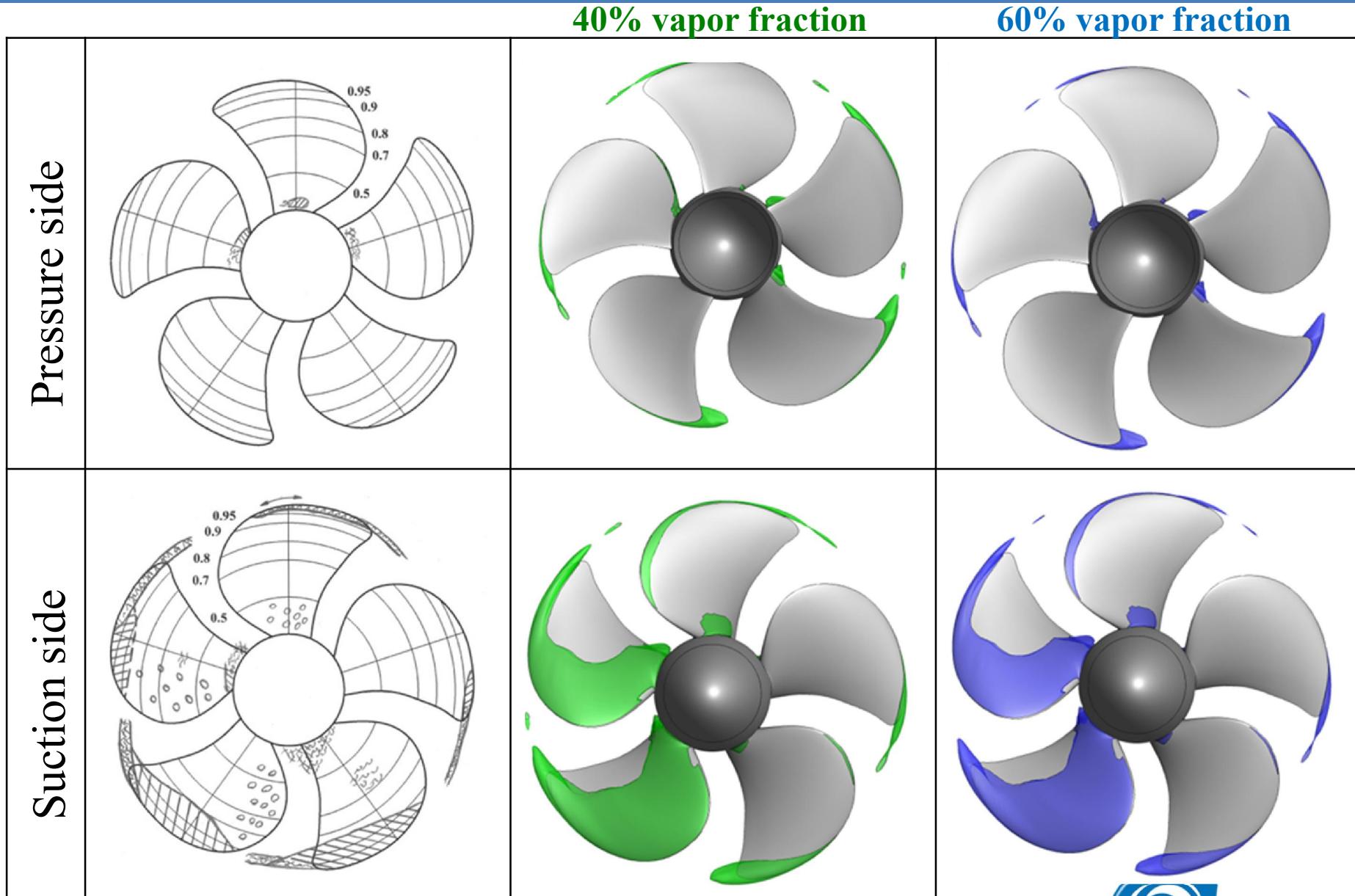
# Case 2.1: ROTAM-Fluent



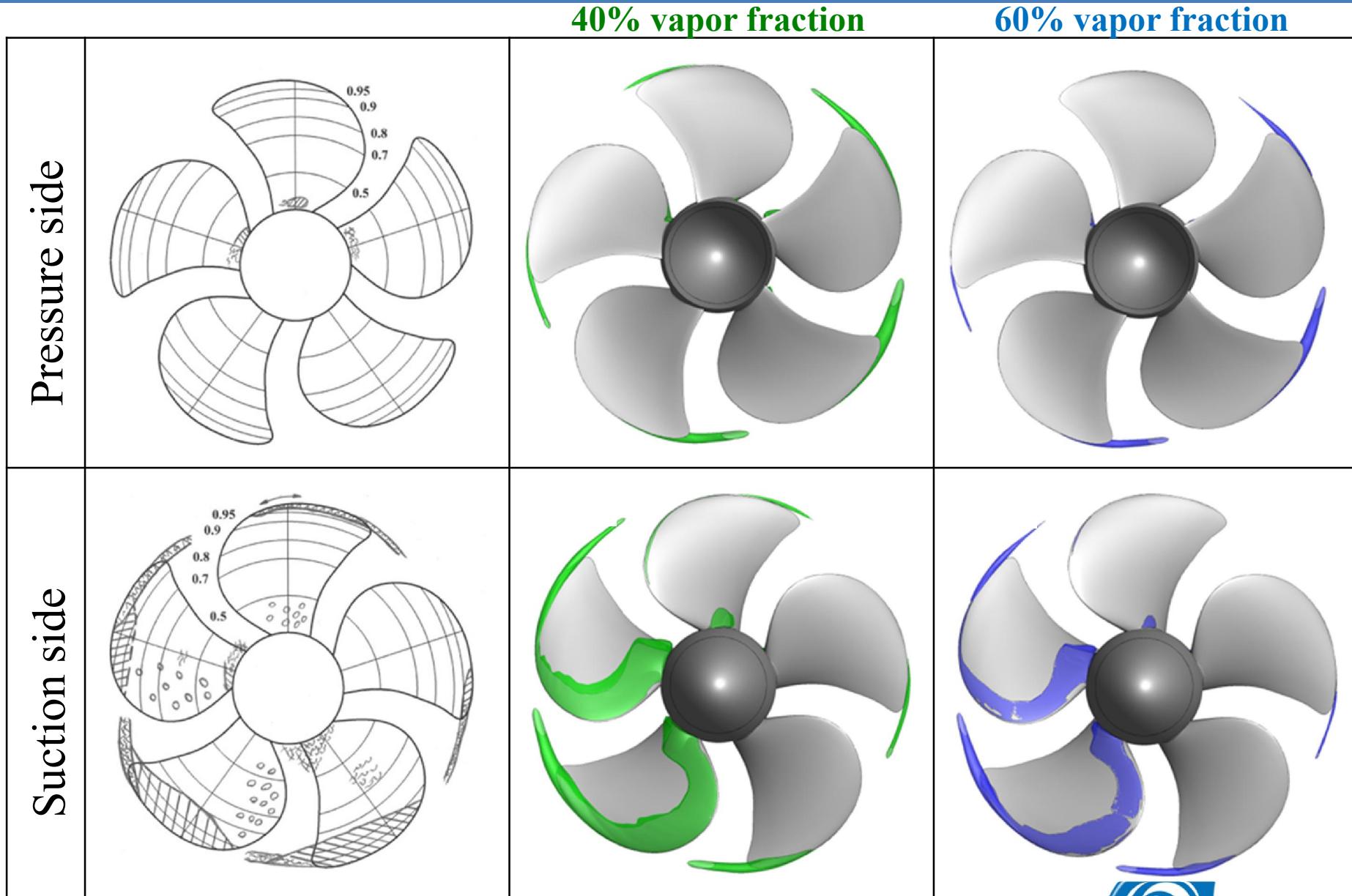
# Case 2.1: SSPA Fluent-Sauer



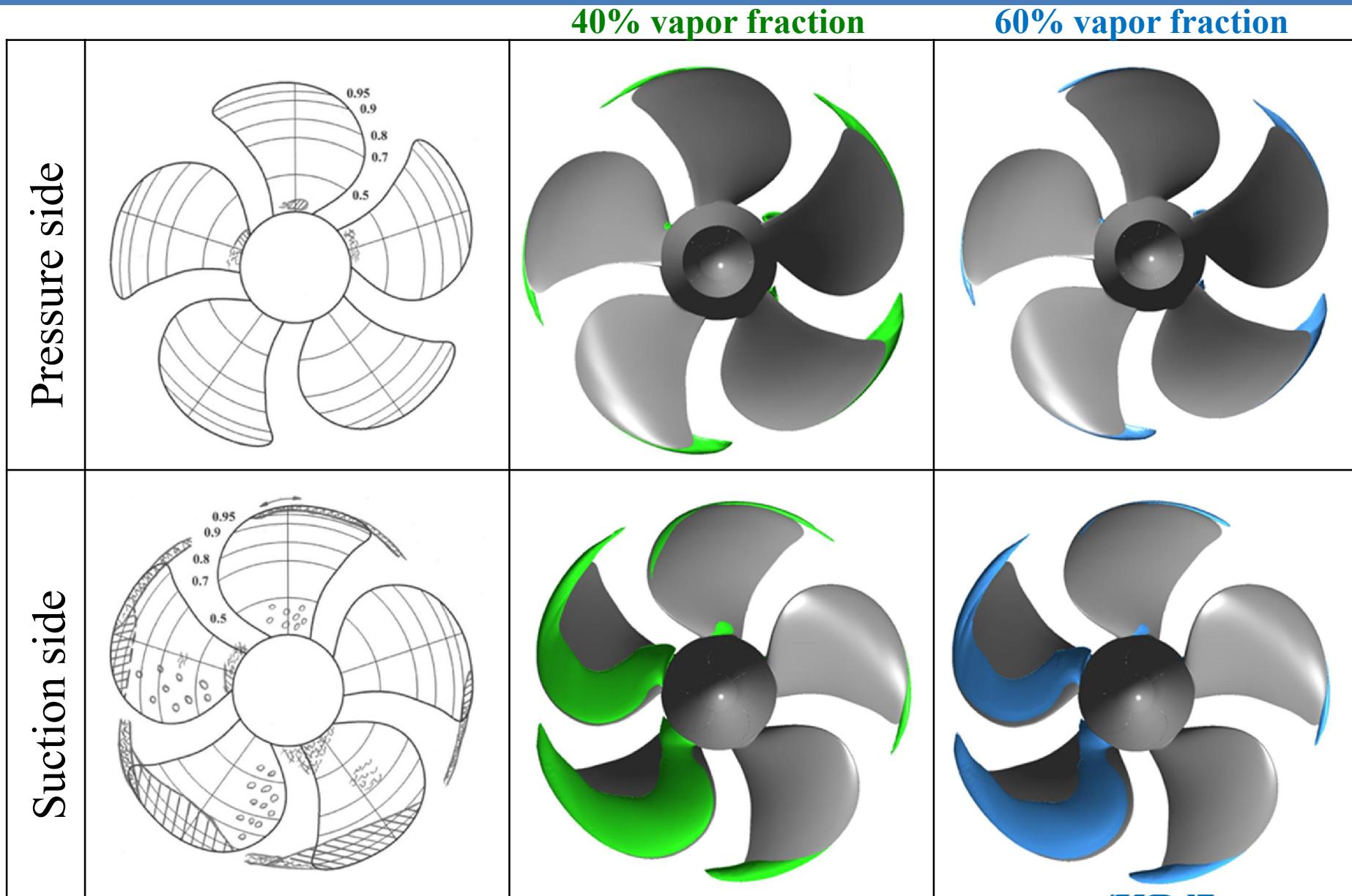
# Case 2.1: SSPA Fluent-Zwart1



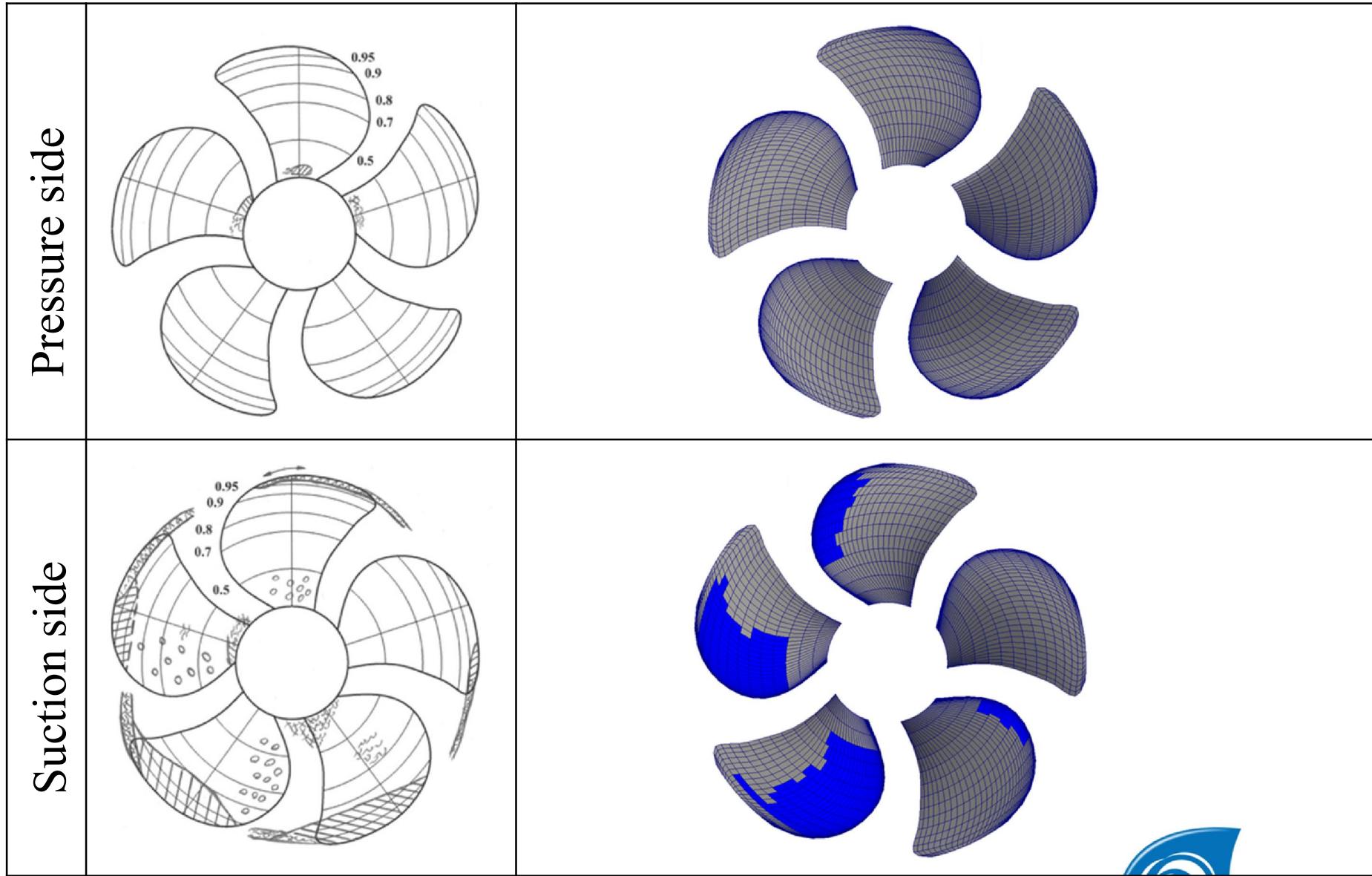
# Case 2.1: SSPA Fluent-Zwart2



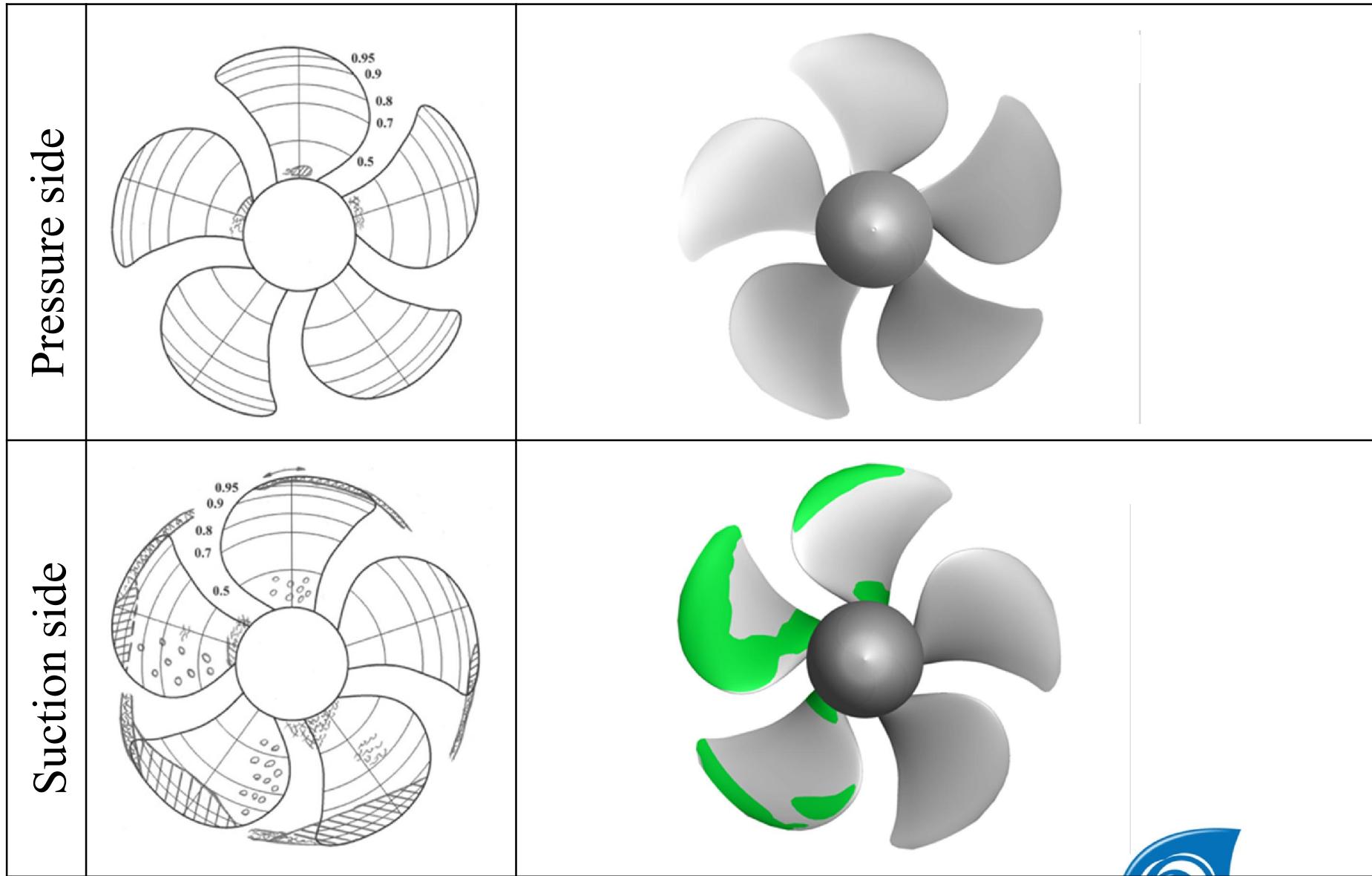
# Case 2.1: TUHH CFX



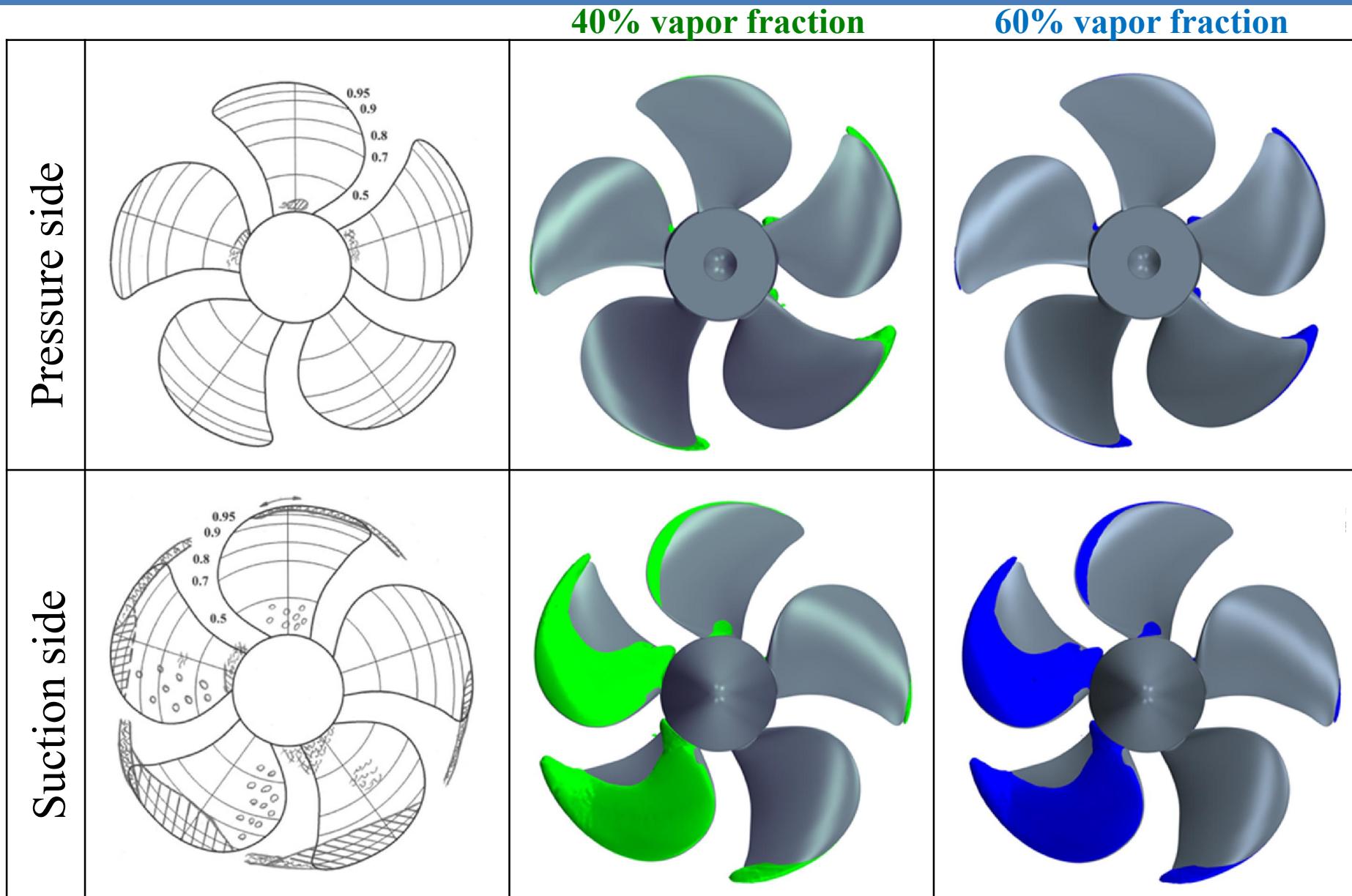
# Case 2.1: TUHH panMARE



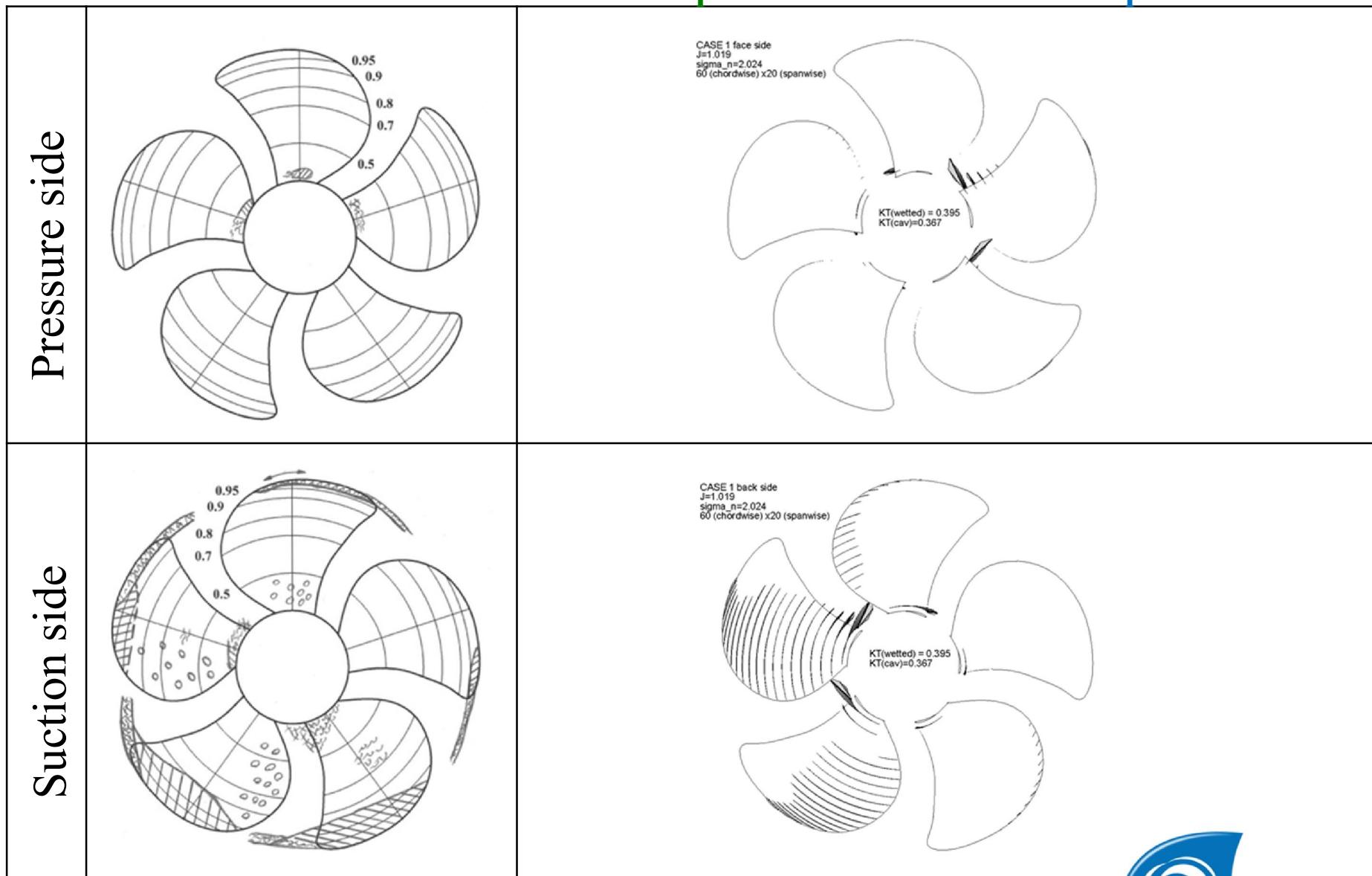
# Case 2.1: UniGenoa BEM



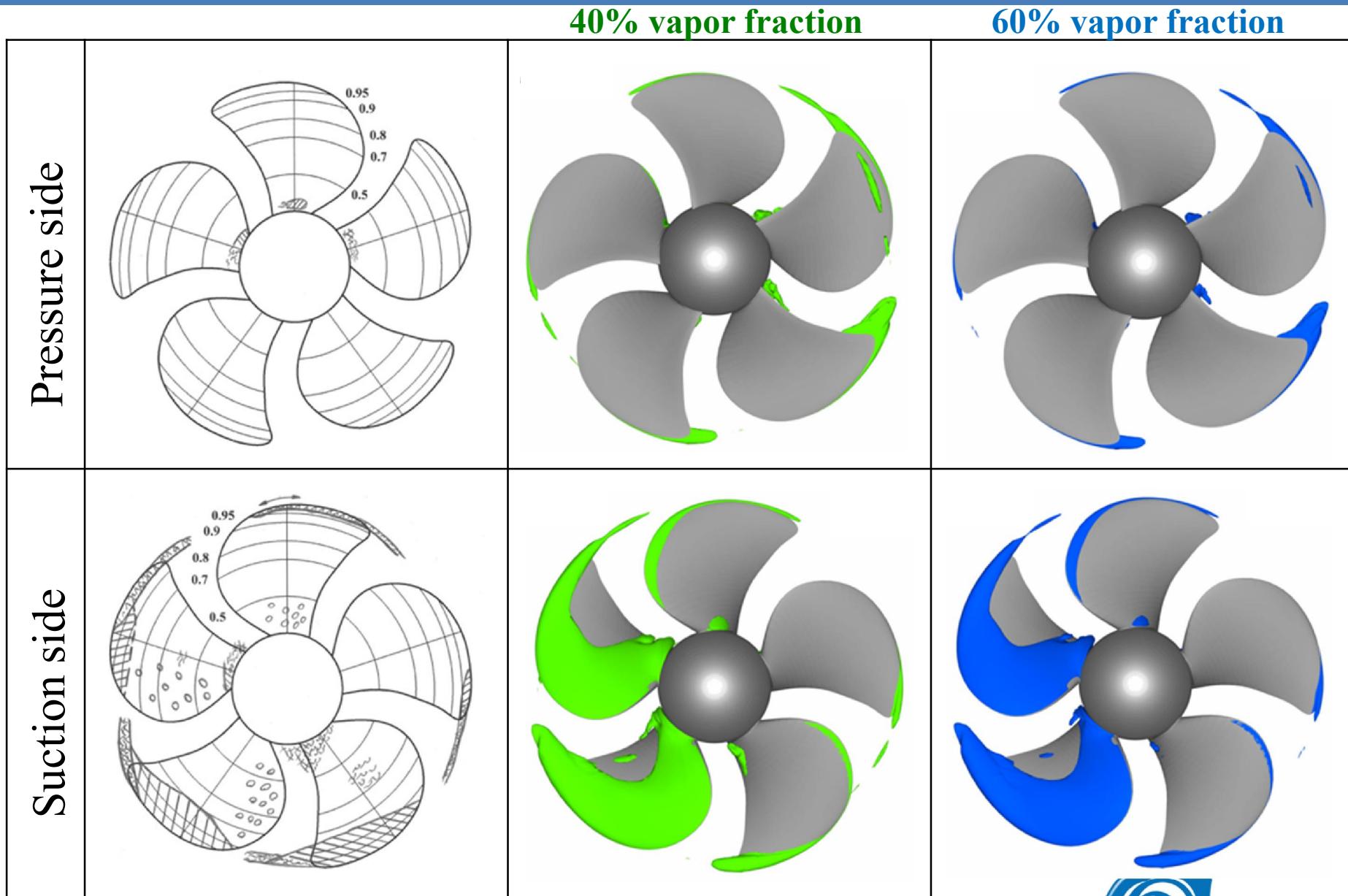
# Case 2.1: UniGenoa StarCCM+



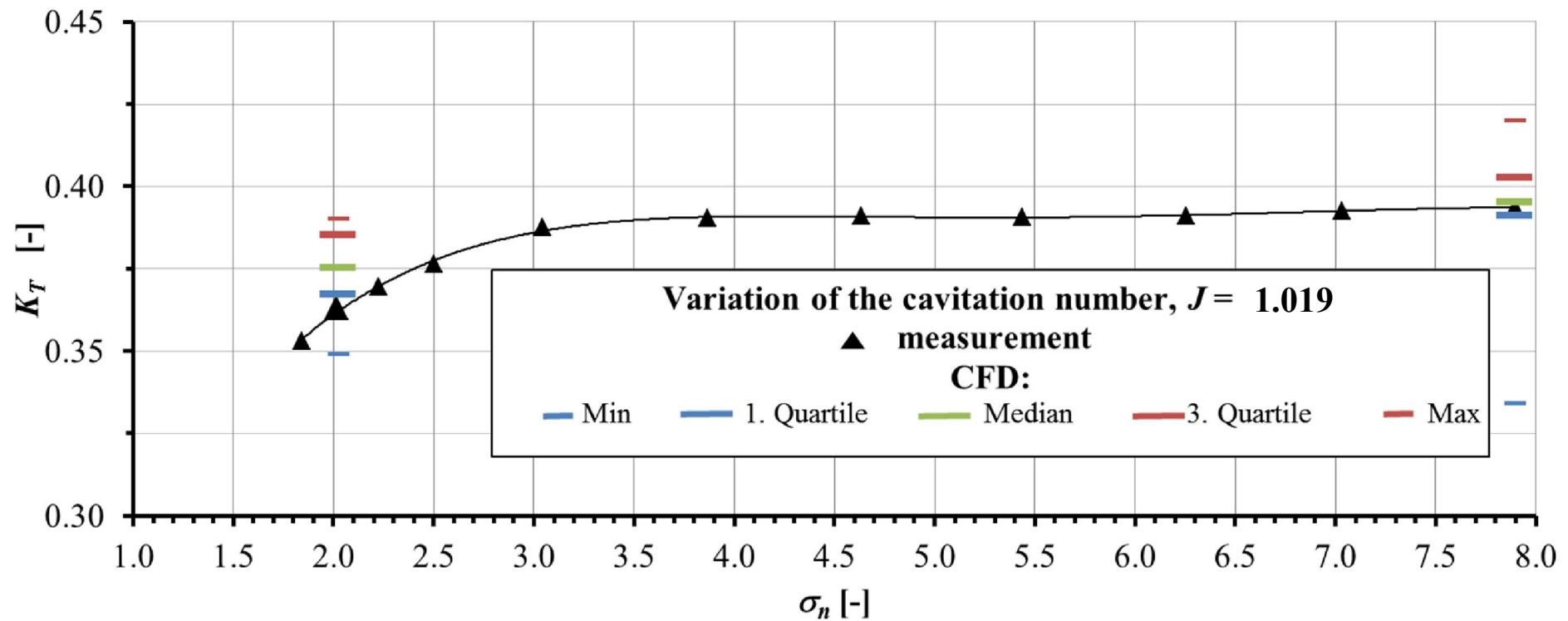
# Case 2.1: UT Austin-PROPCAV



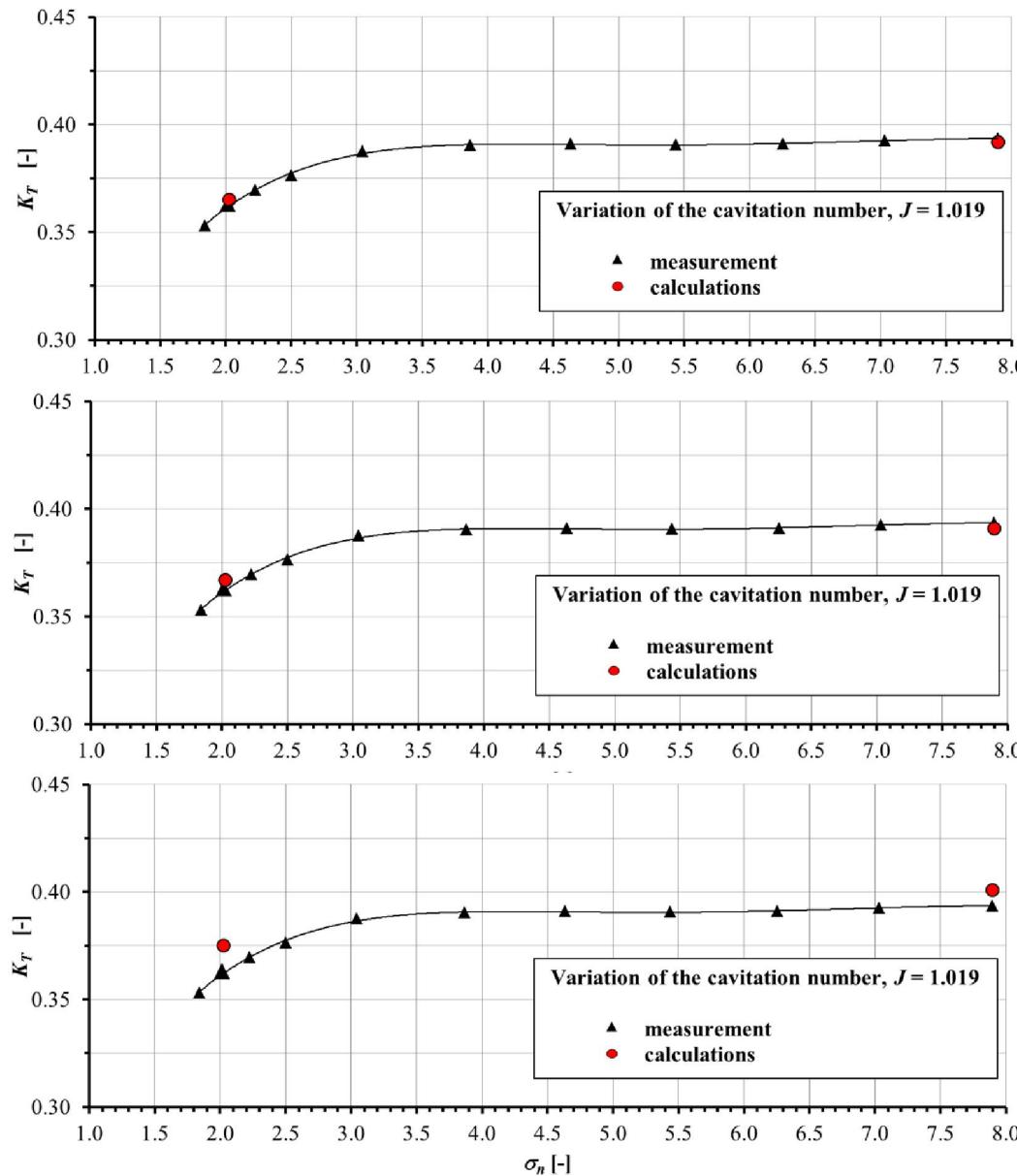
## Case 2.1: VTT-FinFlo



# Case 2.1: Thrust breakdown



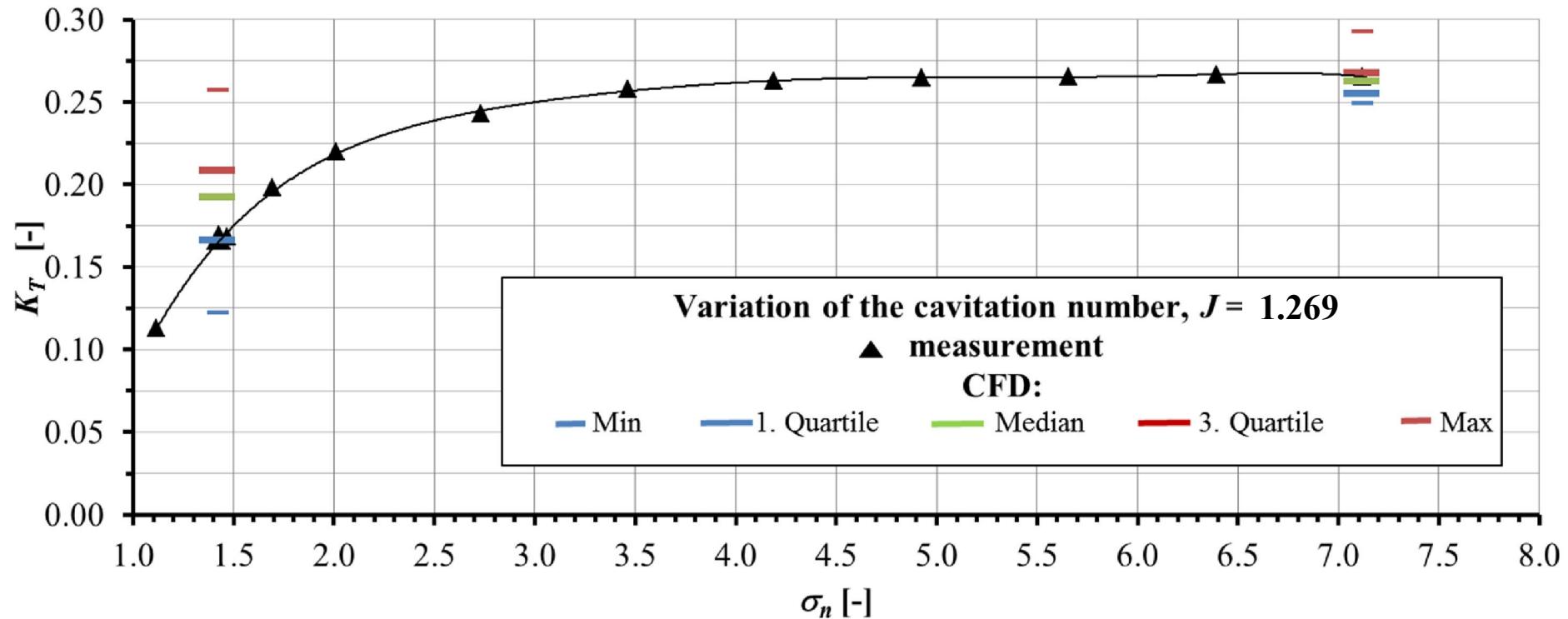
# Case 2.1: Selected examples



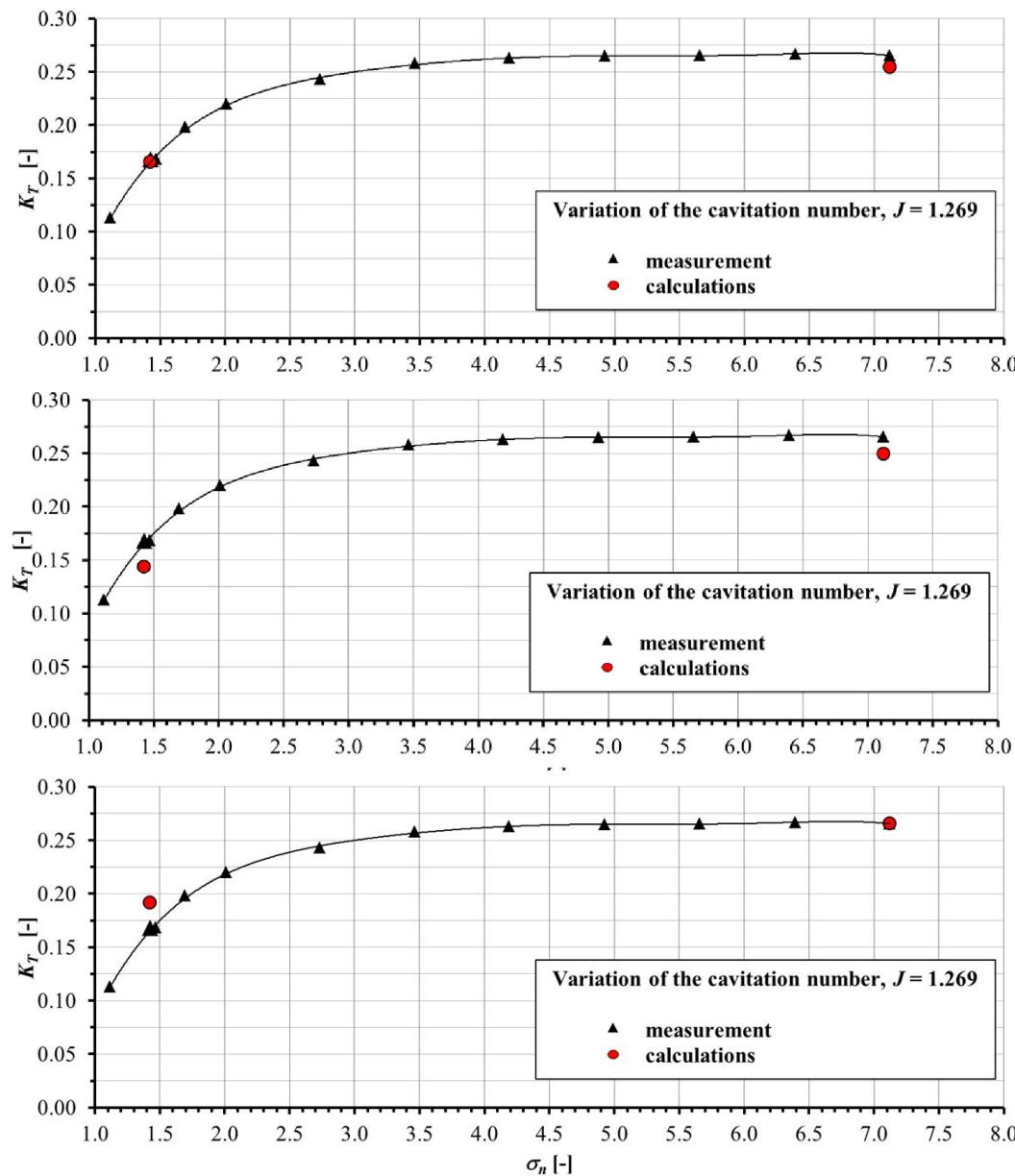
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# CASE 2.2

## Case 2.2: Thrust breakdown



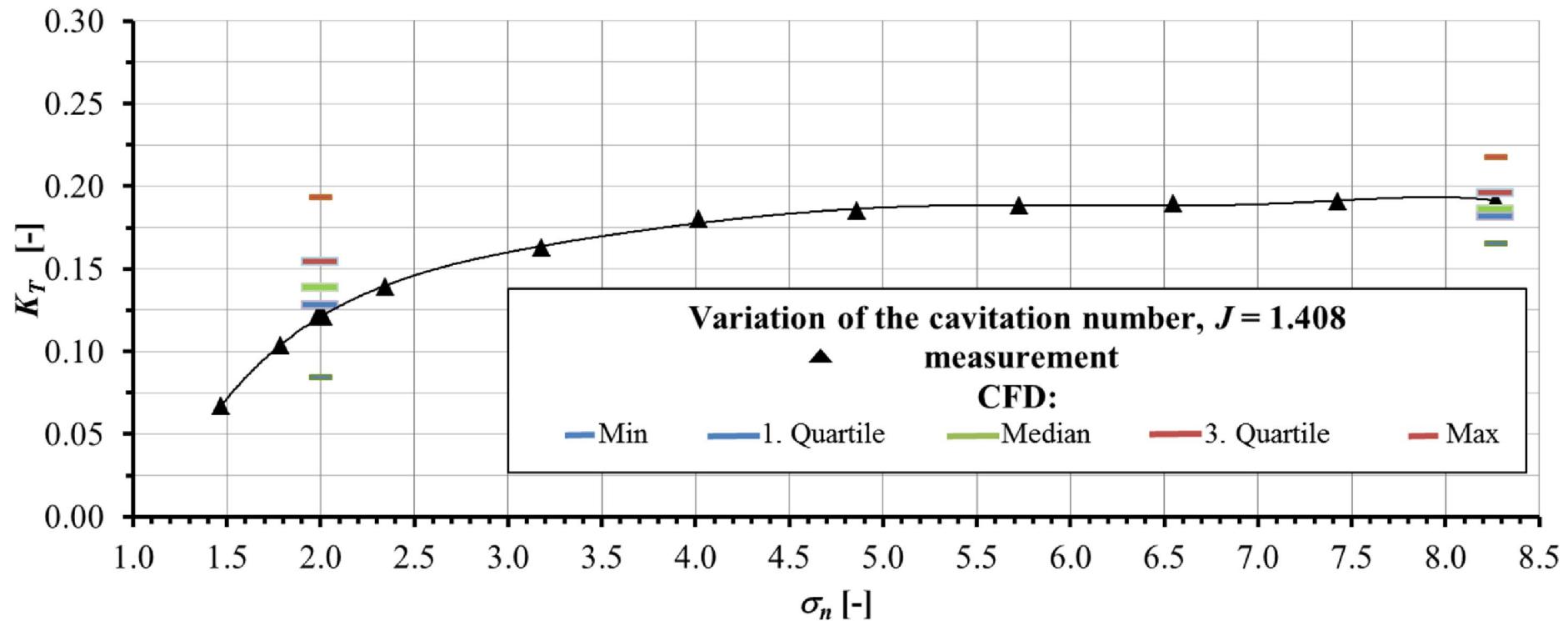
## Case 2.2: Selected examples



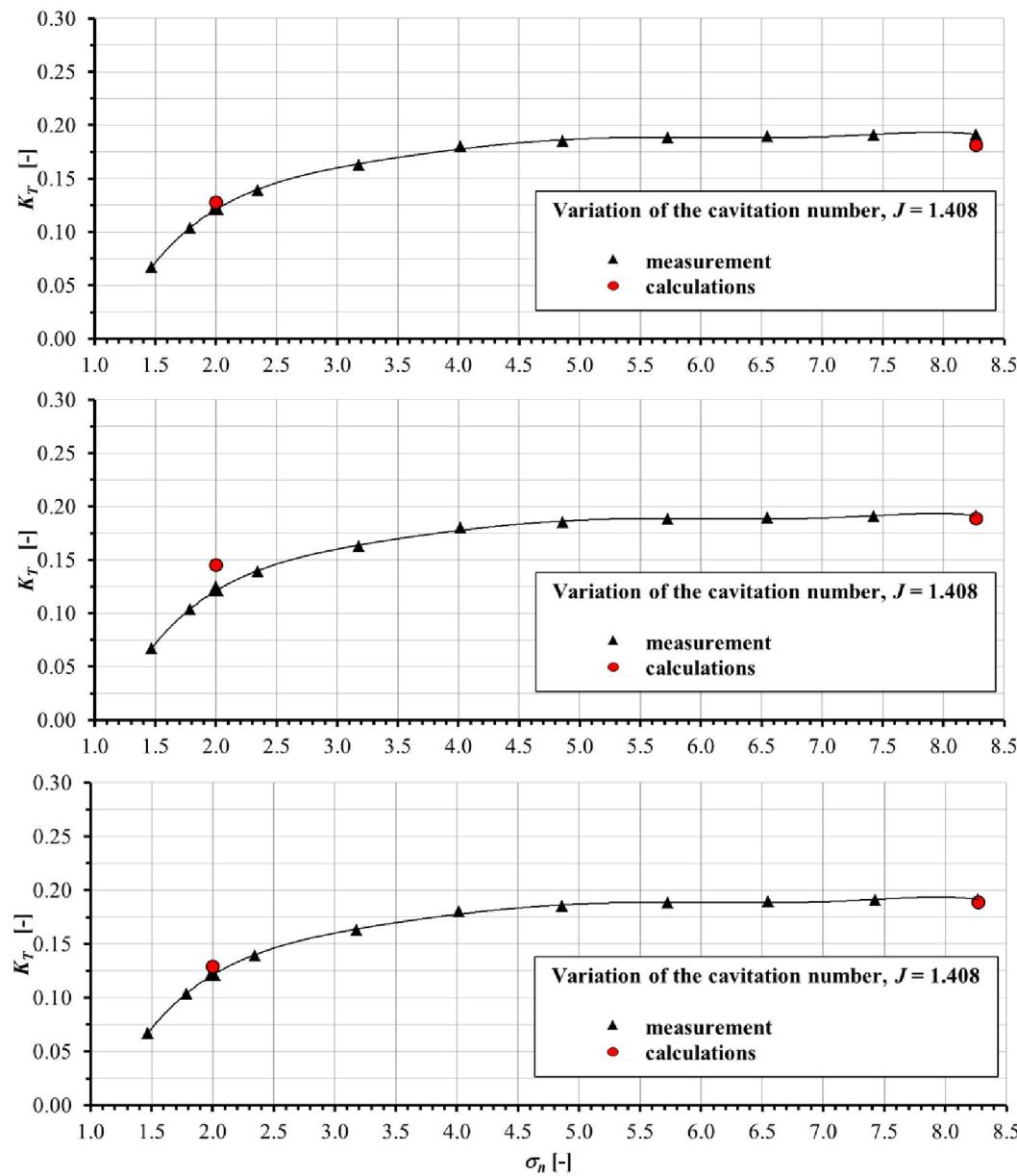
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# CASE 2.3

## Case 2.3: Thrust breakdown



# Case 2.3: Selected examples



# Thrust breakdown

Thrust breakdown	case 2.1	case 2.2	case 2.3
	$\Delta K_T$ [-]	$\Delta K_T$ [-]	$\Delta K_T$ [-]
<b>Exp</b>	<b>0.029</b>	<b>0.098</b>	<b>0.066</b>
ACCUSIM-CFX-FCM	0.027	0.082	0.050
ACCUSIM-CFX-Kunz	0.024	0.089	0.053
ACCUSIM-CFX-Zwart	0.027	0.089	0.051
CAT-OF	0.036	0.130	0.124
Chalmers-OF	0.032	0.066	0.024
CNRS-ISIS	0.049	0.144	0.098
CRADLE-SCTetra	0.045	0.067	0.054
CSSRC-Fluent	0.016	0.033	0.030
MARIN-ReFRESCO	0.016		
ROTAM-Fluent	0.035	0.075	0.047
SSPA-Fluent-Sauer	0.011	0.059	0.042
SSPA-Fluent-Zwart1	0.014	0.057	0.039
SSPA-Fluent-Zwart2	0.024		
TUHH-CFX	0.009	0.054	0.038
TUHH-panMARE	-0.048	0.106	0.001
UniGenoa-BEM	-0.010	0.011	0.034
UniGenoa-StarCCM+	0.017	0.060	0.044
UTAustin-PROPCAV	0.028	0.095	
VTT-FinFlo	0.026	0.074	0.060

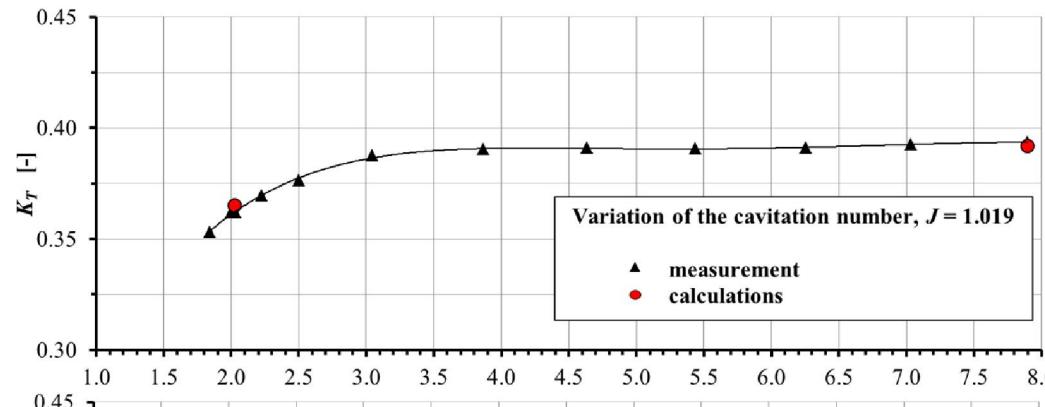
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# TO DISCUSS

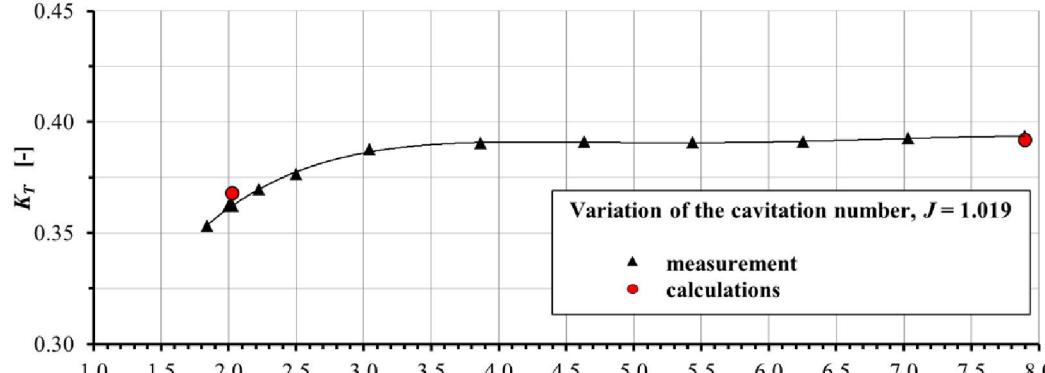
## (?)

# Mass transfer models

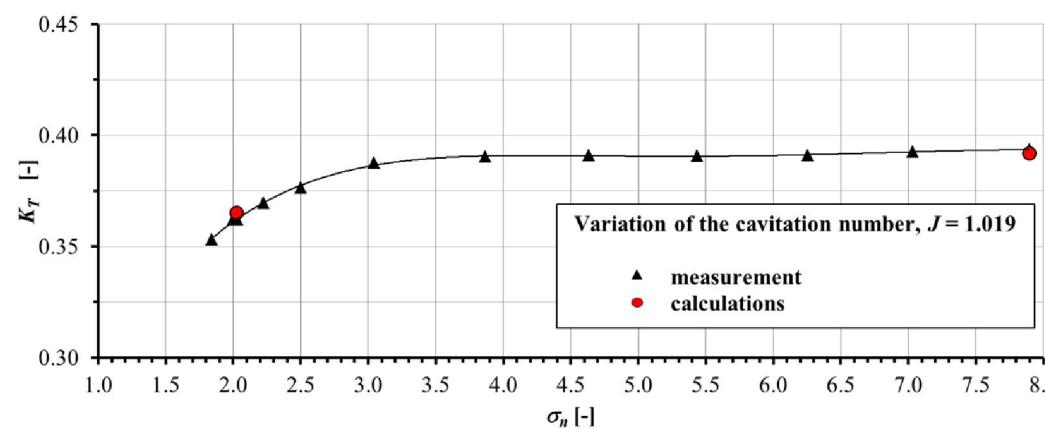
FCM



Kunz



Zwart

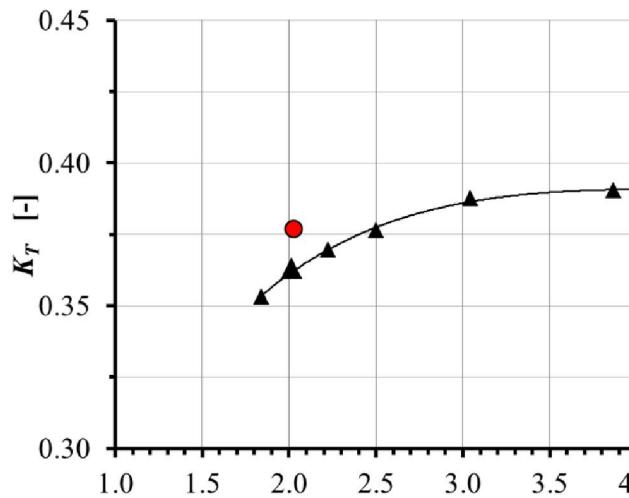


- Case 2.1 shown
- Agreement for Cases 2.2 and 2.3 similar

# Parameters

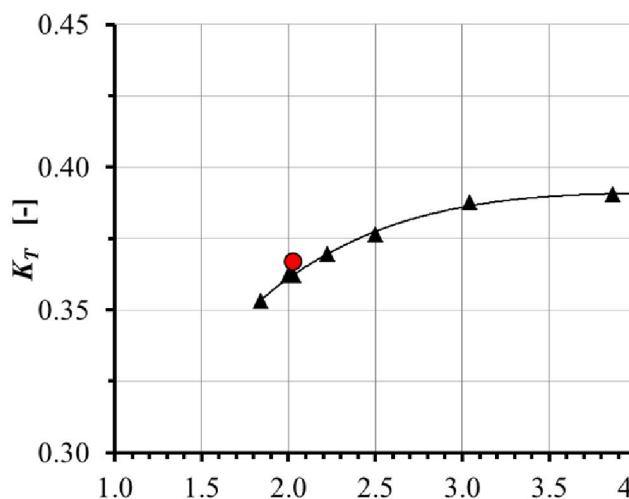
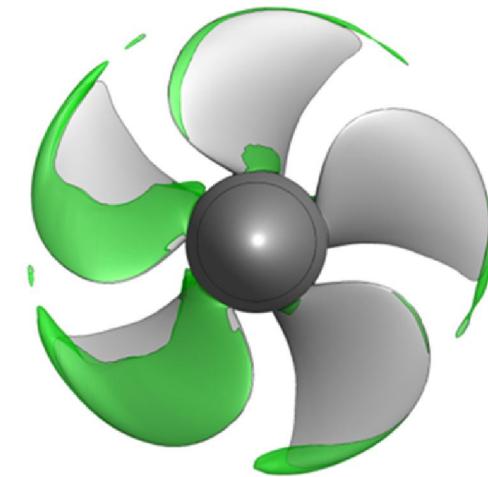
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## Case 2.1



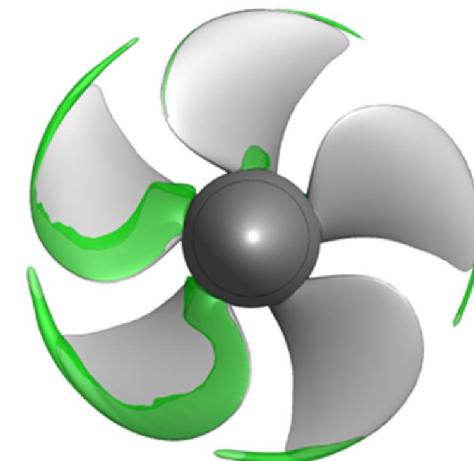
Setup 1:

- Zwart
- $r_{\text{Bubble}} = 0.001 \text{ mm}$



Setup 2:

- Zwart
- $r_{\text{Bubble}} = 0.035 \text{ mm}$
- Nucleation site volume fraction reduced



Thank you for  
your kind  
attention!