EXAMPLE OF CFD USE IN AN APPENDAGE DESIGN LOOP

Hydrodynamic analysis using FineMarine of T-shaped rudders

Numeca User Meeting – Nov 2017

VPLP design

Summary

1. Company profile
2. FineMarine in the appendage design loop
3. Example of a T rudder study
4. Conclusion

Company Profile

- Office founded in 1983
- 12 Naval Architects, 6 engineers, 1 Phd student, 2 designers, 3 supports / staff admin
- 2 sites in France, Paris and Vannes
- 2 main activities : sailing yacht industry and offshore racing

VPLP design


MACIF
MACIF
MACIF
MACIF
VPLP design


VPLP design

Performance Prediction and engineering

- ~2010 : decision to integrate more skills in engineering and performance prediction fields
- Science as a tool to keep innovating
  - Deeper understanding of boat behavior
  - Continuous discussion with architects to develop in house specific numerical tools
- Hydrodynamics and structural aspects studied all in one
- Integrate more and more numerical studies in a given time frame and financial environment

FineMarine in an Appendage Design Loop

First stage

- Design brief, geometrical constraints
- Pre scantling (Analytical models)
  - Principal dimensions
  - First structural calculations
- Building
  - Building process and structure type
  - Material choice and mechanical properties
- Performance prediction (VPP)
  - Target ok ? (take off speed, righting moment gain...)
  - Define optimisation strategy

Iterate, explore the design space

Lighweight calculation, quick evaluation of a large number of candidates

Optimisation

- Structural optimisation (FEA)
  - Mass, strength, stiffness...
- Hydrodynamic optimisation
  - Drag, righting moment, cavitation, versatility
- Global boat performance analysis (VPP)

Optimise conflicting constraints (ex. structural vs. Hydro)

Go deeper in the understanding

FineMarine

Optimisation of T-shaped rudders

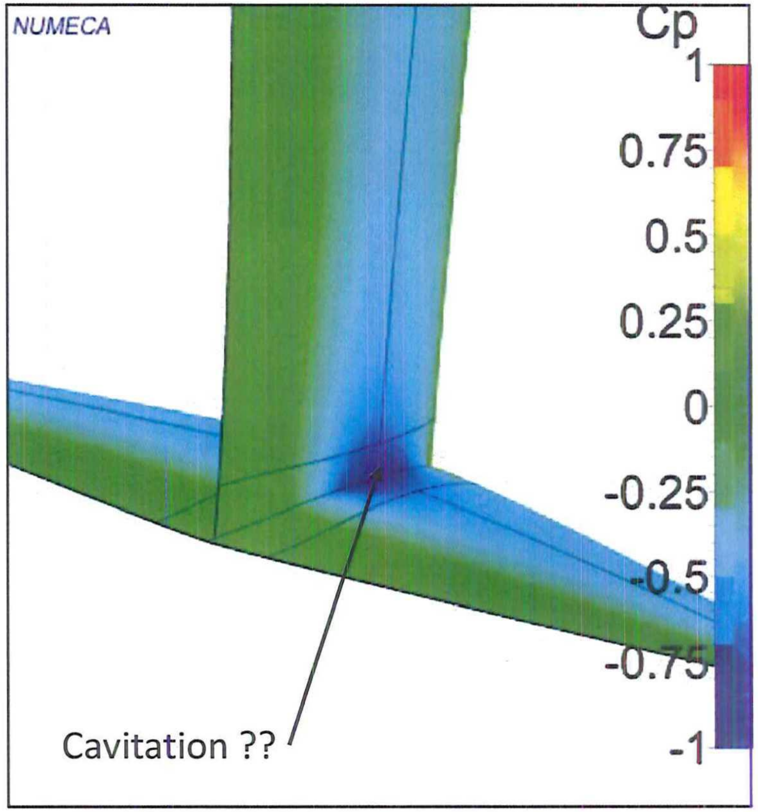
Context :

- Offshore maxi multi hull
- Design of a T Rudder for general equilibrium

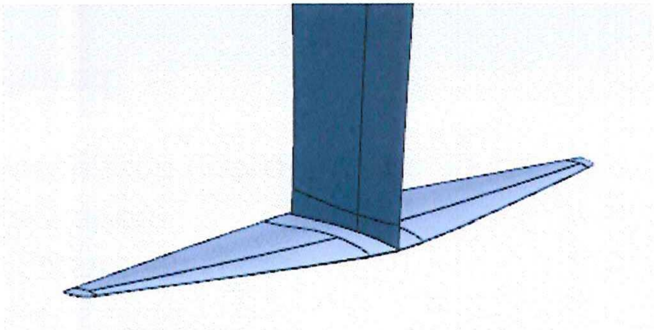
- What's at stake ?
  - Drag at high speed
  - Cavitation
  - Boat speed max of around 45 kts

Study followed:

- Run of different junction geometries
- Comparison of drag
- Comparison of dynamic pressure peaks for caviation prediction
- Local analysis of pressure distribution



Optimisation of T-shaped rudders



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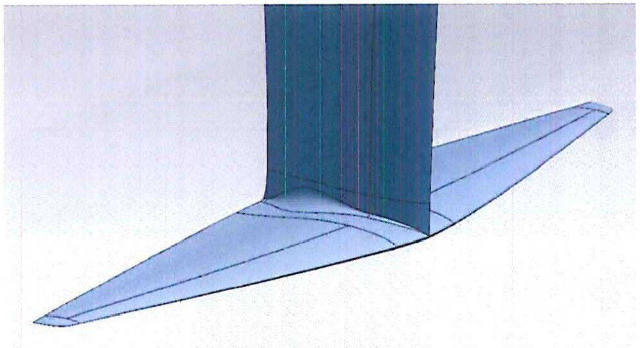
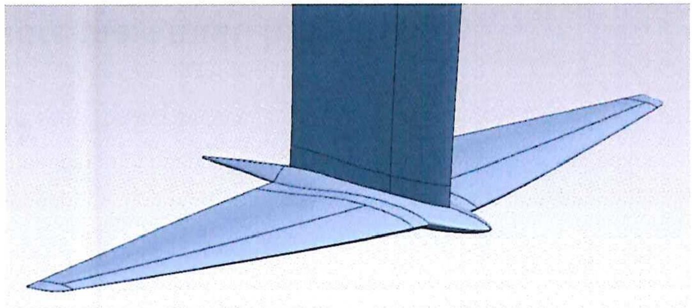
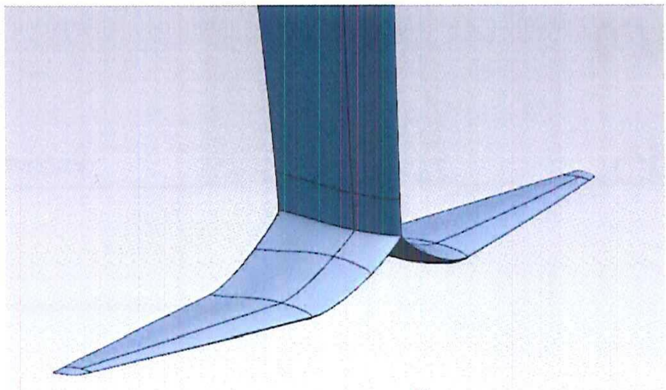


Blend



Bulb



Seagull

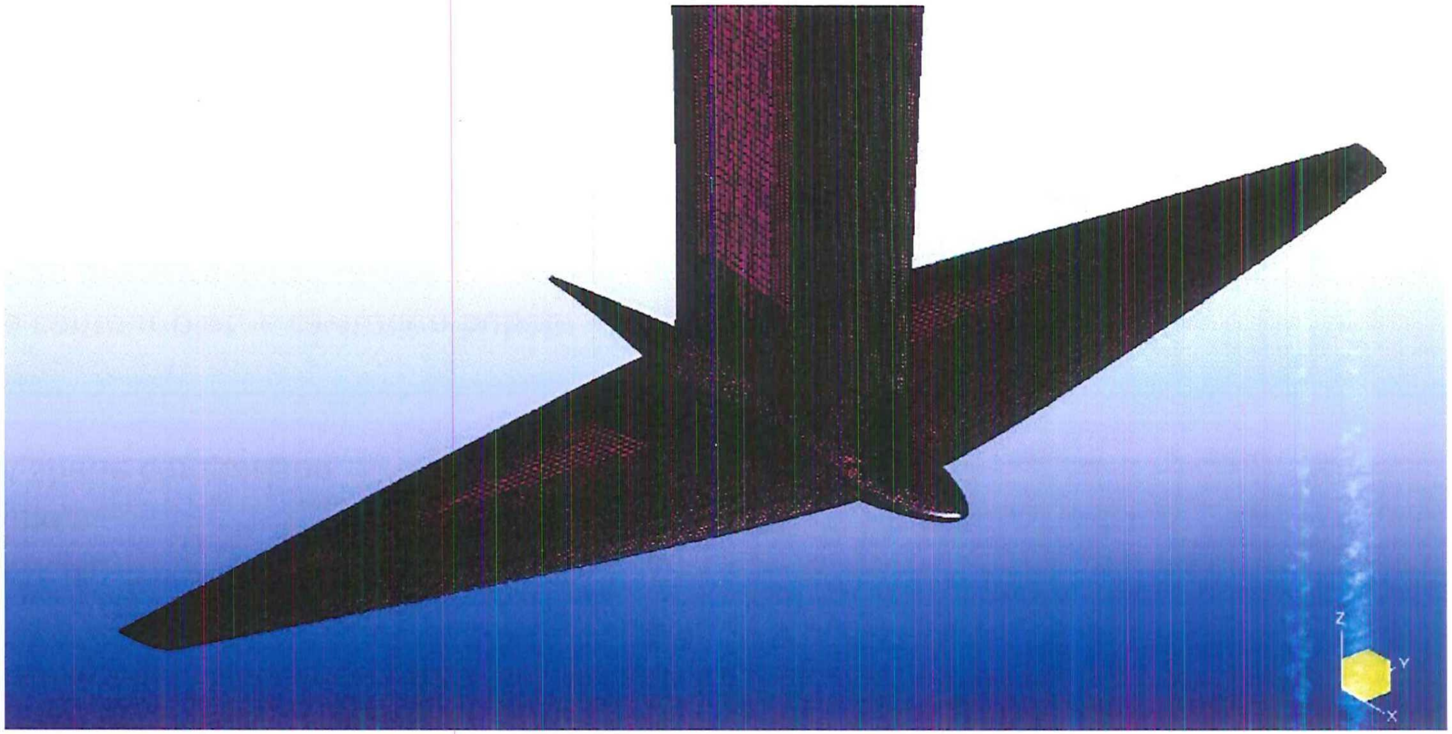
Model settings

Model settings:

- « wind tunnel » mode, mono fluid calculation
- Sweep of yaw and rake angles to interpolate at iso Fy / Fz

Mesh:

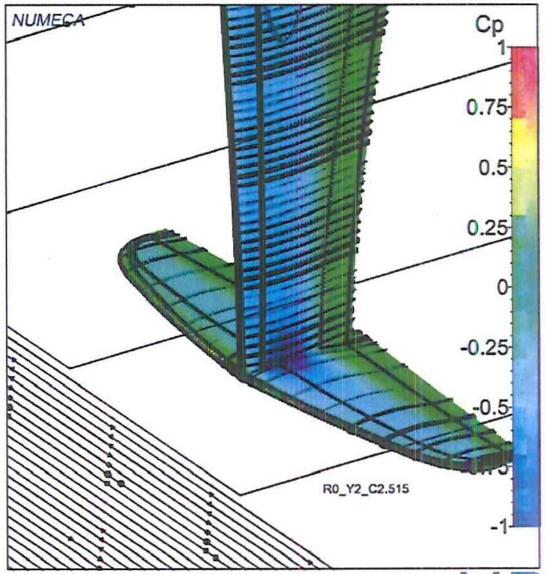
- Y+ = 80
- ~5.10^6 cells
- 5hours / run on a 12 cores machine



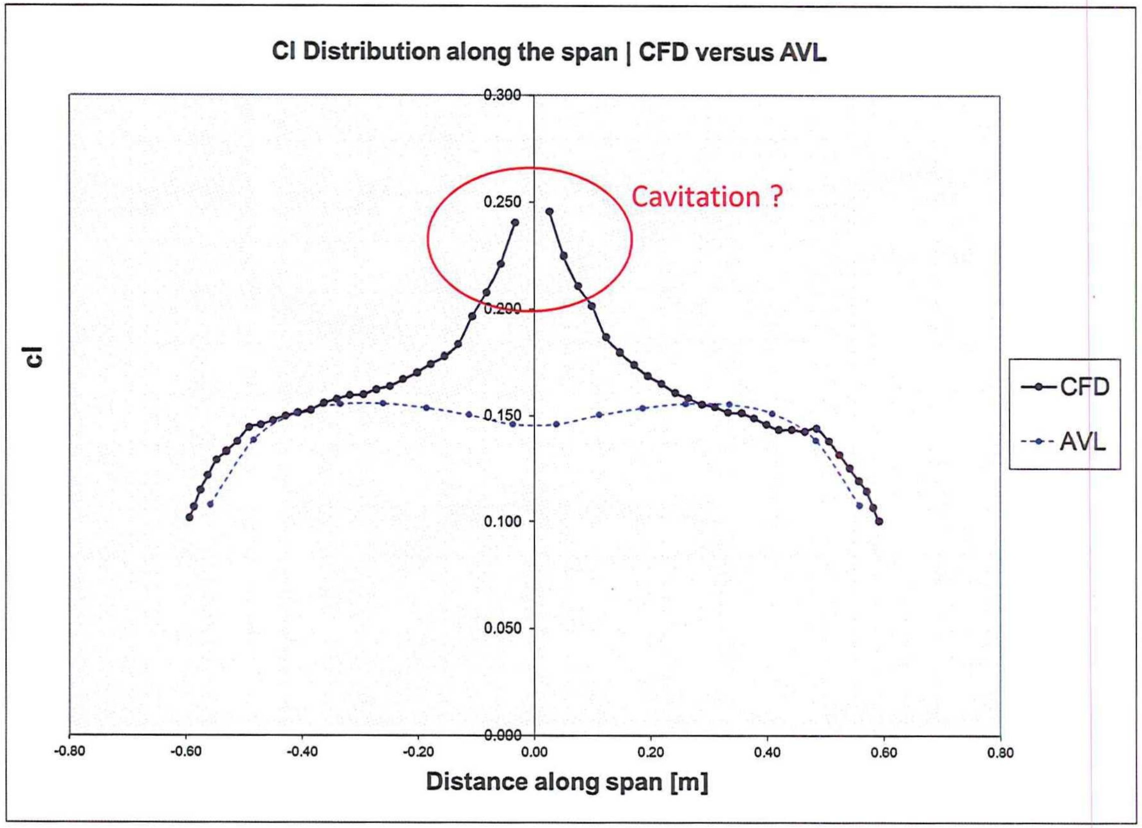
Python scripting

- **Automatise mesh and model settings**
  - Reduce human processing time
  - Standardise mesh for correct shape comparison

- **Automatise PostProcessing**
  - Contour plot comparison (Cp contour plot, « cavitation bubble »)
  - Use of cutting planes to analyse pressure distributions



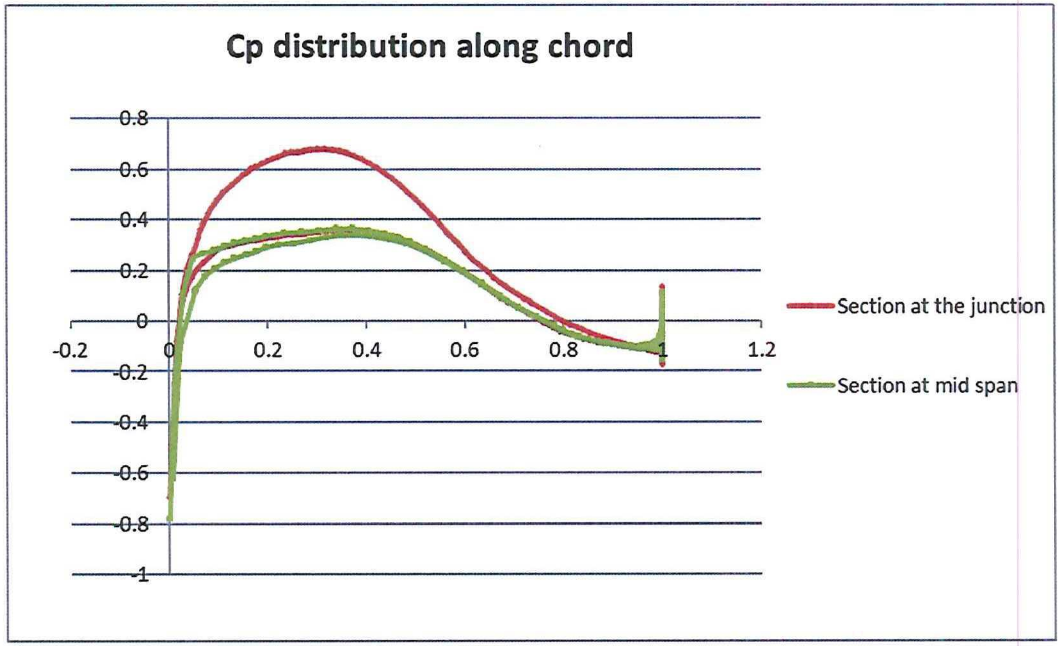
PostProcessing



Spanwise view:

- Pressure distribution along the chord integrated to calculate lift and drag coefficient
- More detailed analysis of lift along the span
  - Panel code (AVL) does not see the shaft thickness
  - The combination of the 2 pressures peaks creates dramatic change in Cl at the junction

PostProcessing

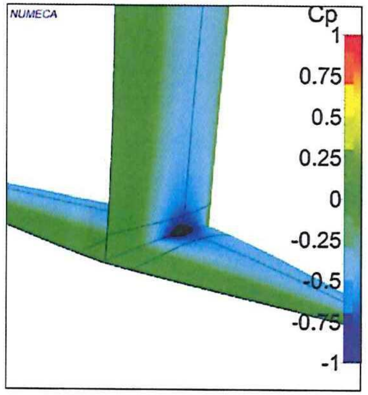


Comparison of Cp distribution along the chord:

- At the junction, Cp distribution very different from the 2d (theorical) isolated section shape
- Work can be done at the junction to design and analyse a specific 2D section

PostProcessing

35 kts



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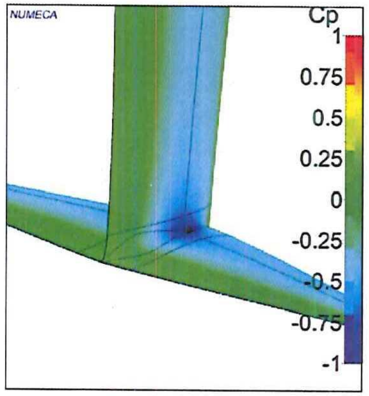

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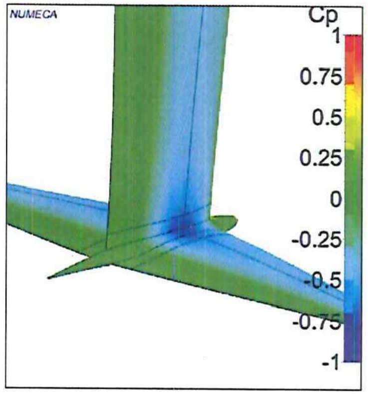
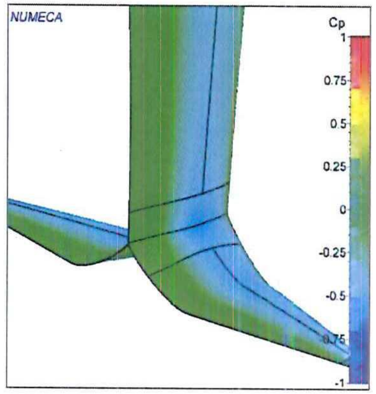
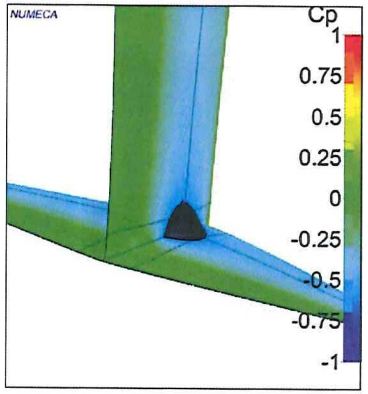


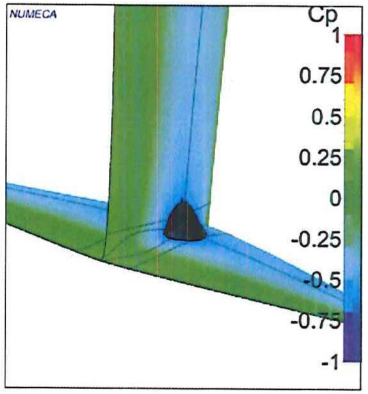
Bulb

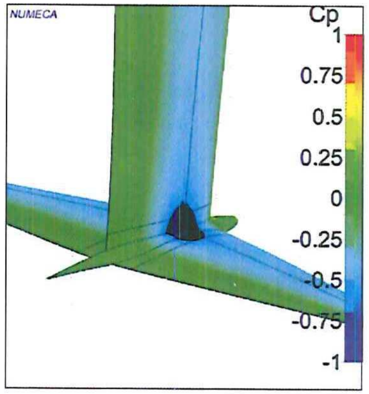


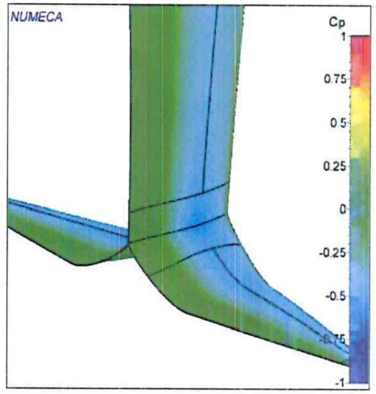
Seagull

40 kts









PostProcessing

Study outcomes:

- Clear differenciation of shapes performances in terms of cavitation
- Cavitation delay of around 5kts for the Seagull shape
- Pressure drag gain around junction

	Drag gain on shapes		
Fz	Blend	Bulb	Seagull
3%	-5.9%	-5.7%	-6.7%
5%	-5.3%	-5.1%	-6.4%
8%	-4.7%	-4.6%	-6.2%
10%	-4.1%	-4.1%	-6.0%

Conclusion

FineMarine at VPLP:

- One tool in the architect toolbox
- Extensive use of Python scripts to standardise / accelerate workflow

- On going development process
  - 6 years of use
  - Growing demand of CFD in a regular design process

29th Symposium on Naval Hydrodynamics
Gothenburg, Sweden, 26-31 August 2012

Hydrodynamic Mechanisms Controlling Cavitation Erosion

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ABSTRACT

In this paper we consider development of cavitation erosion having its origin in sheet cavitation. The discussion includes generation of cloud cavitation from sheet cavitation and how cloud collapses can be enhanced by energy cascading from the collapse of a glassy sheet cavity into the collapse of the cloud. Analysis of the energy cascading ends up in concepts, as asymmetric collapse, primary and secondary cavitation, generalized rebounds and more. A conceptual model for description and analysis of generation of erosion by mixed glassy and cloud cavitation is presented.

1 BACKGROUND AND PRESENT APPROACH

We start by a brief review of the generic example of erosive cavitation shown in Figure 1. This cavitation in the root region of a propeller develops from a large sheet cavity generating typically three erosion regions, of which two are shown in the Figure. The root cavity is beneficial for isolation of generally relevant events.

The propeller is operated on the upstream end of an inclined shaft, 8°, in a homogenous flow, meaning that the propeller blades experience an unsteady flow controlled by the shaft inclination only. The cavity in frame 1 is a narrow sheet cavity that was initially attached to a line close to the leading edge but has now started to move slowly downstream, frame 2. The closure region is moving upstream as a jet flow is filling the sheet. This jet, that can contribute significantly to the filling, started as an undisturbed re-entrant jet, but is now enhanced by flows induced by the shed vortices and by the increasing collapse forcing pressure on the blade. The jet is now almost as thick as the sheet cavity. Momentum and shear interaction between the filling flow and the flow outside the sheet cavity generate shedding of vortex cloud cavitation in the closure region. There are two erosive collapses shown in the frames. The first one is the collapse by the glassy part, almost captured by frame 3, and the second is the collapse of the cloud around frame 7. The collapse of the glassy sheet cavity contributes to the erosion (paint wear) in the upstream patch in frames 9 and 10 and the cloud collapse generates the larger downstream patch. The large extent of this patch is due to scattering in time and space of the cloud collapses, and the fact that also the rebounded cloud shown in frame 8 collapses in the downstream region of this patch.

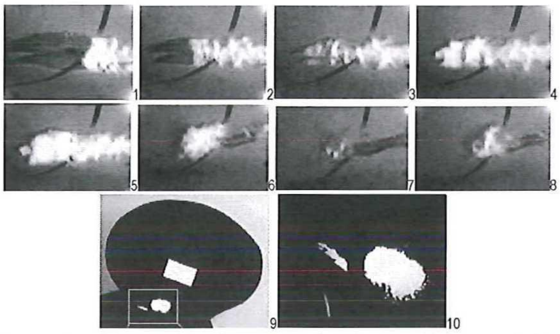

Figure 1. Frames 1 – 8 are samples from a high-speed film of a sheet cavity in the root region of a propeller in SSPA cavitation tunnel. The left patch in photos 9 and 10 shows the wear of soft paint due to collapses of the glassy sheet cavity with the attached bubble cloud, frame 3, and the right patch is due to the collapse of the cloud occurring after frame 7. Frame 8 shows the rebounding cloud. From Bark et al. (2004).

Presently, assessments of propeller erosion are mostly based on analysis of model scale experiments by:

a) Visual assessment of the wear/erosion of a soft paint being exposed during a certain time to the cavitation, as shown in Figure 1, and
b) Visual assessment of the cavitation aggressiveness, based on high-speed video recording of cavity collapses.

None of the methods are strictly quantitative, although some assessments of the cavitation aggressiveness are made in both methods. The mechanical properties of the soft paint, brings of course a rough scaling to the full-scale propeller. Without supplementary observations of the cavitation the bare paint method does hardly bring any information about the hydrodynamics behind the erosion. Assessment of propeller erosion by paint tests, empirically calibrated by model to full scale correlation of erosion data, is however surprisingly reliable.

The high-speed video analysis of the cavitation aggressiveness based on assessment the cavity collapse, brings useful information about the hydrodynamics, but in this method the erosion sensor is replaced by an approximate analysis of the collapse kinematics. The video and paint methods do however supplement each