AKPD/AKPA

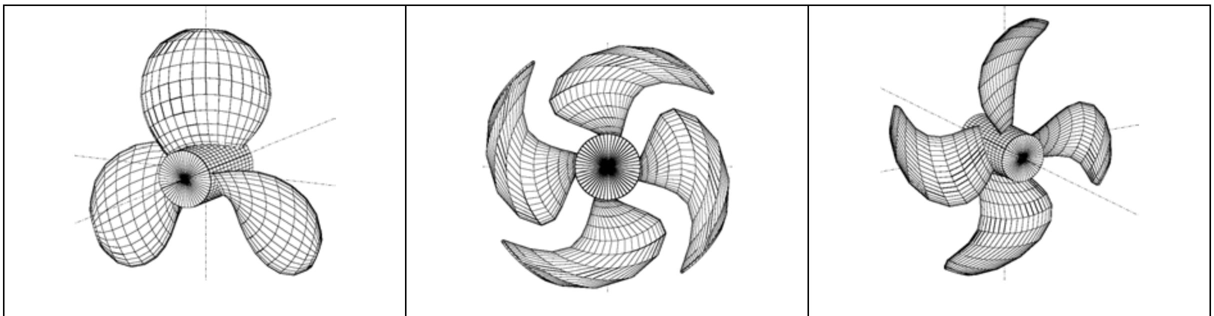
Propeller design and analysis program system

AKPD/AKPA is a Windows based program intended for the design and analysis of open propellers and multi-component propulsors developed by SMTU, St. Petersburg, and MARINTEK in cooperation.

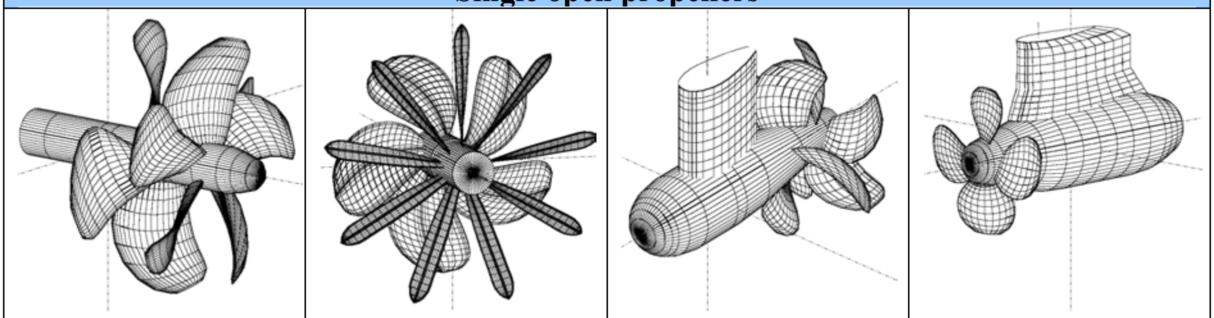
The current version runs under Windows NT/2000/XP, on standard PCs having CPU speed of 333 MHz and available disk space of 40 MB.

The design algorithm is based on a non-linear lifting surface theory while propeller analysis is a velocity based source Boundary Element Method (BEM).

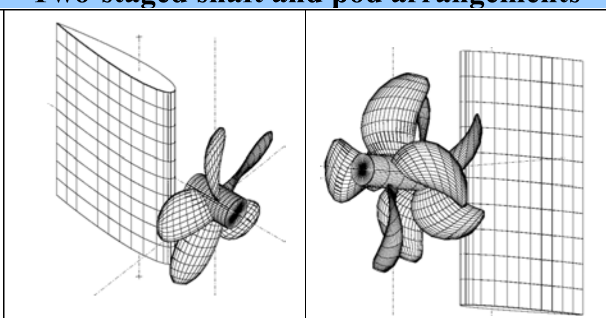
The program system AKPD/AKPA consists of two main parts: the design program AKPD and the analysis program AKPA. The Figures below show the different types of propulsors the analysis program can handle. The design program has the same possibilities with a few exceptions. The AKPA analysis program allows calculation of propeller of arbitrary geometry in open-water conditions and in prescribed inflow. The inflow velocity field can be circumferentially uniform and non-uniform, i.e. both steady and unsteady cases are handled. Calculation of propeller in oblique flow at given shaft tilt or heading angle is possible.



Single open propellers



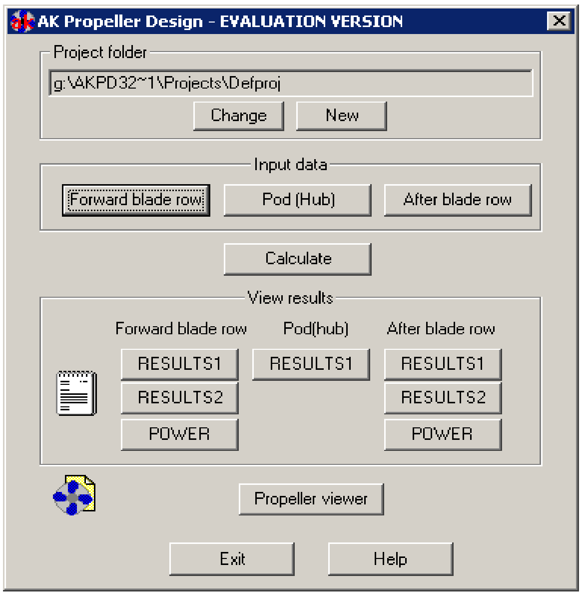
Two-staged shaft and pod arrangements



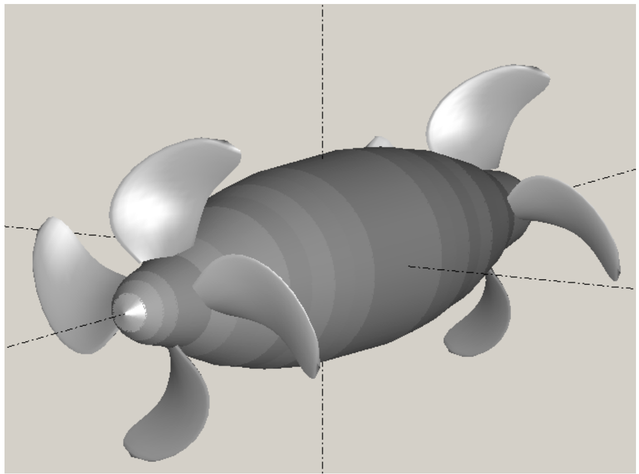
Propeller/rudder systems

Design program

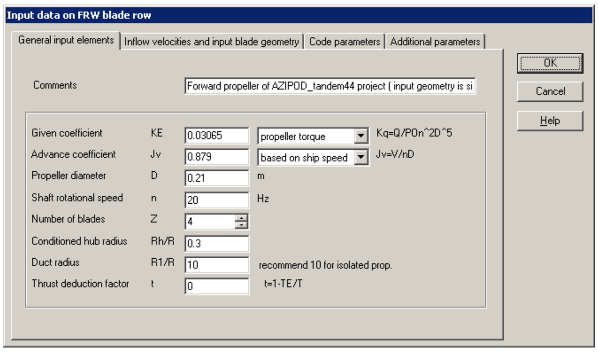
The design program AKPD implements the hydrodynamic design calculation of propeller, i.e. definition of pitch and camber of the blade sections at prescribed main propeller elements (diameter, rpm, number of blades, blade chord length, thickness, skew and rake distributions) to meet the required operation point (J,K_T) or (J,K_Q). The design calculation is performed either in uniform flow or in pre-set radially variable inflow specified at the propeller plane. The following two main design variants are handled by the program: 1) design of propeller with pre-set user-supplied spanwise circulation distribution, which allows improved cavitation and acoustic performance; 2) design of optimum wake-adapted propeller using the Generalized Optimum Condition (optimum spanwise circulation distribution). The important feature of this condition consists in accounting for the tangential component of the inflow, i.e. flow swirl, that is extremely important when designing optimum two-staged propulsor. Below some examples with the design program interface are given.



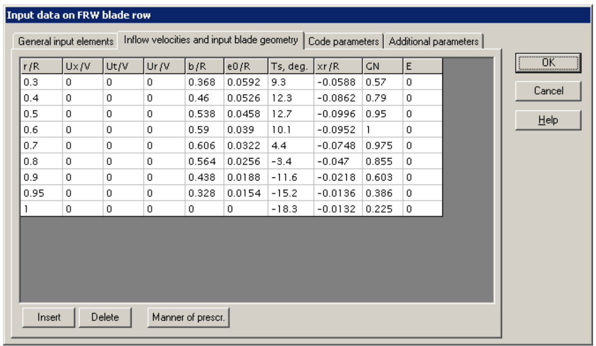
Main dialog window of the AKPD program



General view of designed propulsor in the *Propeller Viewer*



Input data on main propeller elements



Blade geometry input data

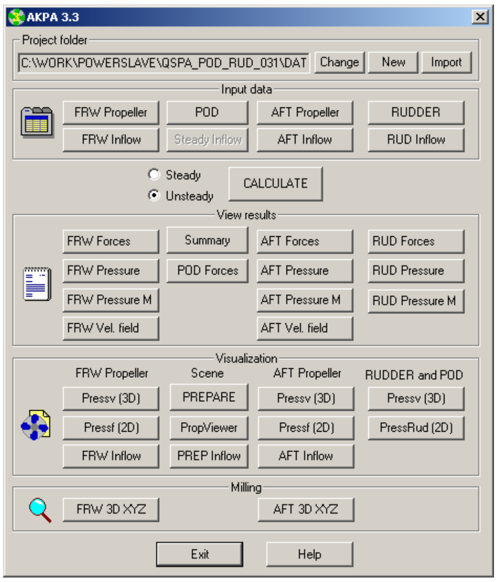
The definition of pitch and camber of the blade sections is based on a non-linear lifting surface theory accounting for the radial velocity component, which is important for highly skewed/raked propellers and propellers in strong radial crossflow, for instance, due to effect of conical centerbody. Propeller design is an iterative process with successive runs of the design and analysis programs. The convenient program shells and the possibility of easy data exchange simplify this routine and save time. The *Propeller Viewer* tool allows visual control of geometry and its manual correction at the different design/analysis stages.

Analysis program

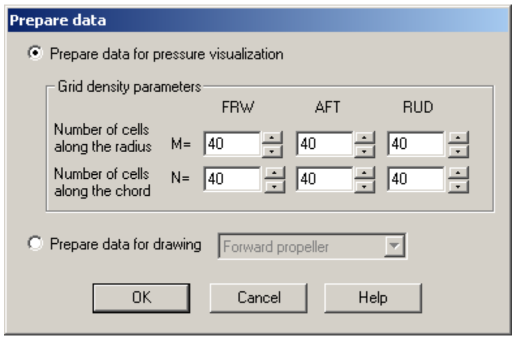
The analysis program performs steady and unsteady calculation of given propulsor in prescribed external velocity field (for instance, hull wake) featuring special cases of oblique flows due to shaft inclination or pod heading angle.
The main outputs of the analysis code are as follows:

- ✓ Propeller integral performance (K_T, K_Q, efficiency, force and moment cartesian component), which are given for each stage separately and as total figures in the case of two-staged propulsor;
- ✓ Total horizontal, vertical and side force components on the unit;
- ✓ Blade pressure distributions;
- ✓ Velocity field induced by propellers in the environment;
- ✓ Cavitation domains estimated from the comparison of local pressure coefficient with local cavitation number.

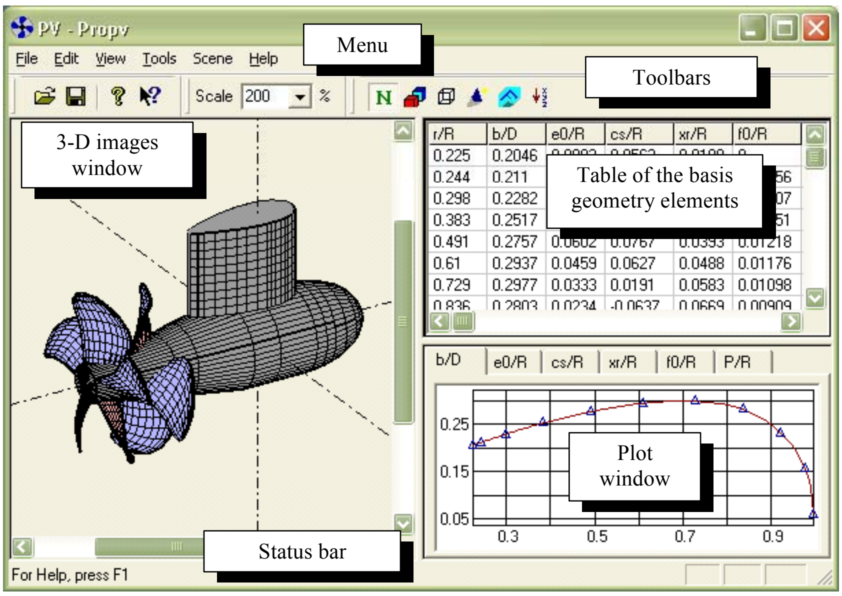
In the case of non-homogeneous flow propeller forces and blade pressure are given versus blade turn angle that – along with animation visual tool – allows the user to trace the change of the mentioned characteristics with propeller rotation.
The AKPD/AKPA program system offers different visual tools for viewing geometry and graphic presentation of the results. Some of these tools are briefly shown below.



Main dialog window of the AKPA program

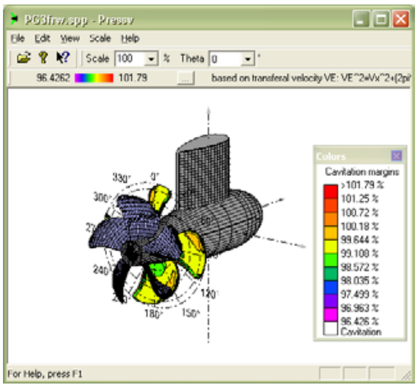
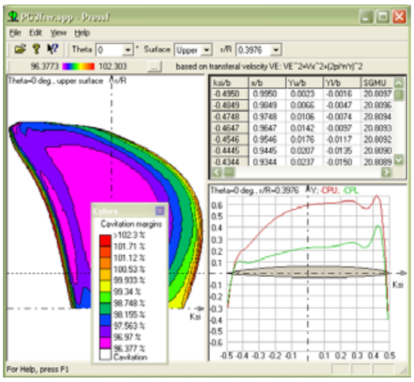


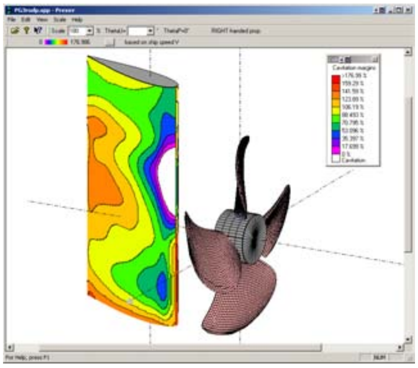
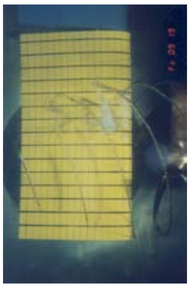
Prepare Data dialog of the AKPA program allows the user to request a desirable grid for visualization and produce propeller drawing

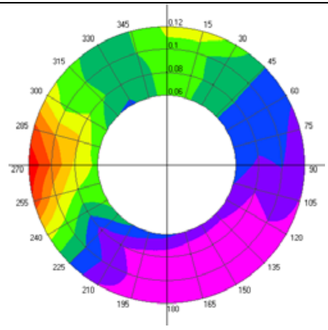
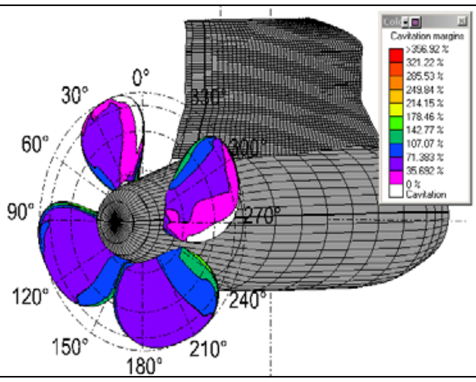


Graphic presentation of two-staged podded propulsor in the *Propeller Viewer*

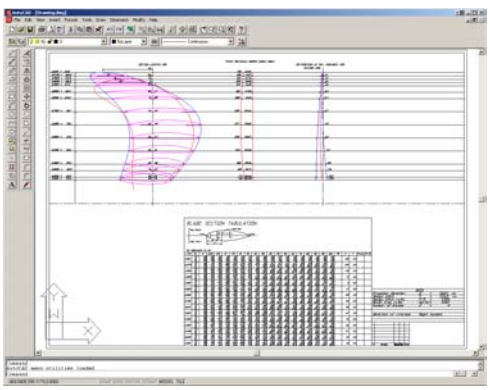
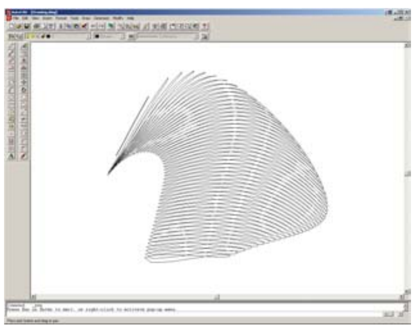
Propeller Viewer is the main link between AKPD (design) and AKPA (analysis) programs, which features handle correction of geometries.

		Example of graphic presentation of pressure distribution in the *Pressure Viewer*, 3D and 2D modes.

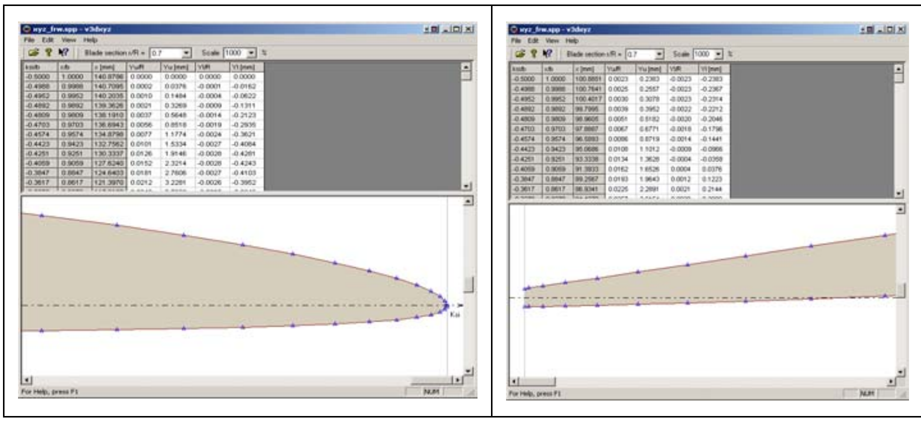
		Example of prediction of cavitation domain on the rudder surface behind operating propeller *J*=0.6. Starboard. *n*=15Hz; $\sigma^{(V)}$=6.677; δ_R=20°
Calculation	Experiment	

		Inflow velocity field at the propeller plane and cavitation domains on podded propeller in oblique flow. Shaft inclination: –3° Heading angle: –20° Left-handed prop

When design of propeller(s) is completed the blade geometry can be prepared for drawing and 3D surface model in a DXF file format supported by the CAD systems. The special tools *Drawing* and *3DXYZ* included in the program are intended for these purposes.

		Blade drawing and 3D blade surface model produced by the *Drawing* and *3DXYZ* tools.

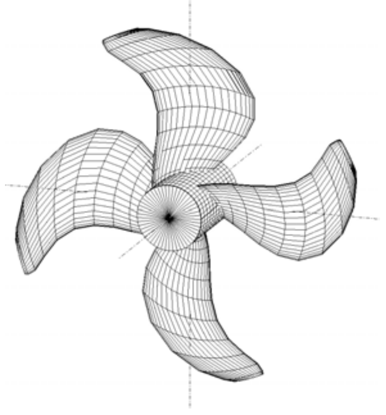
3D blade surface model produced by the program is ready for blade manufacturing on milling machines. It imposes higher requirements to the accuracy of mathematical description of the blade surface compared to one used in the analysis calculation. Therefore, the *3DXYZ* program features special interactive tools which allow for more accurate representation and control of the blade section geometry including the most frequent cases of round, sharp and cut edges.



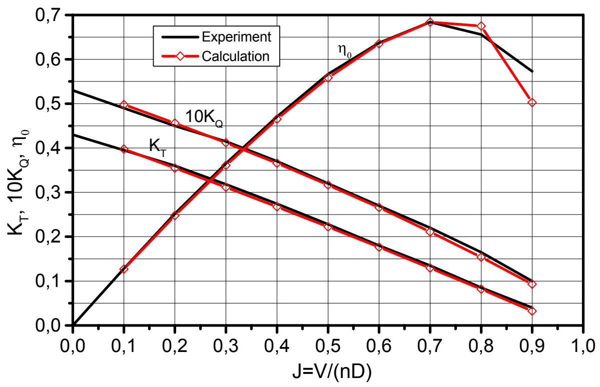
Dialog windows intended for the visual control and editing of the blade section geometry in the *3DXYZ* tool.

VERIFICATION RESULTS

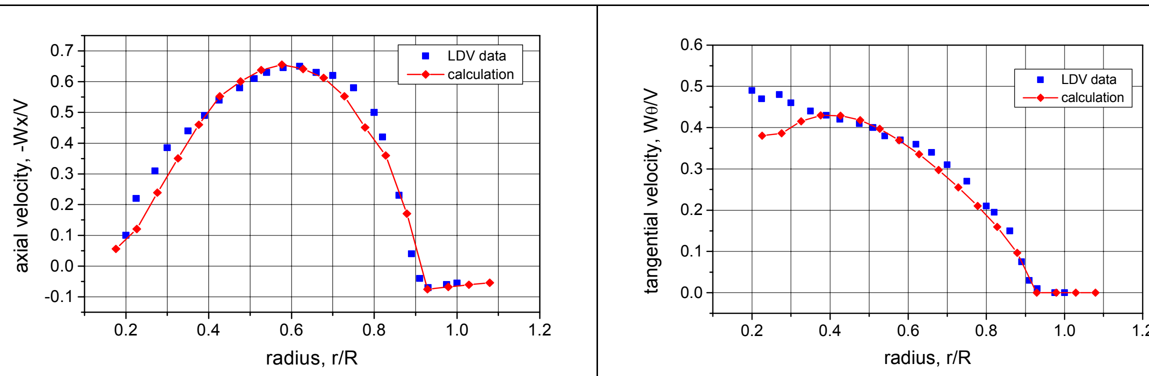
A case of single propeller in open-water conditions is considered below and the results of numerical prediction of propeller integral performance and propeller-induced velocity field are compared with experimental data.



General view and BEM grid of propeller BL2122.

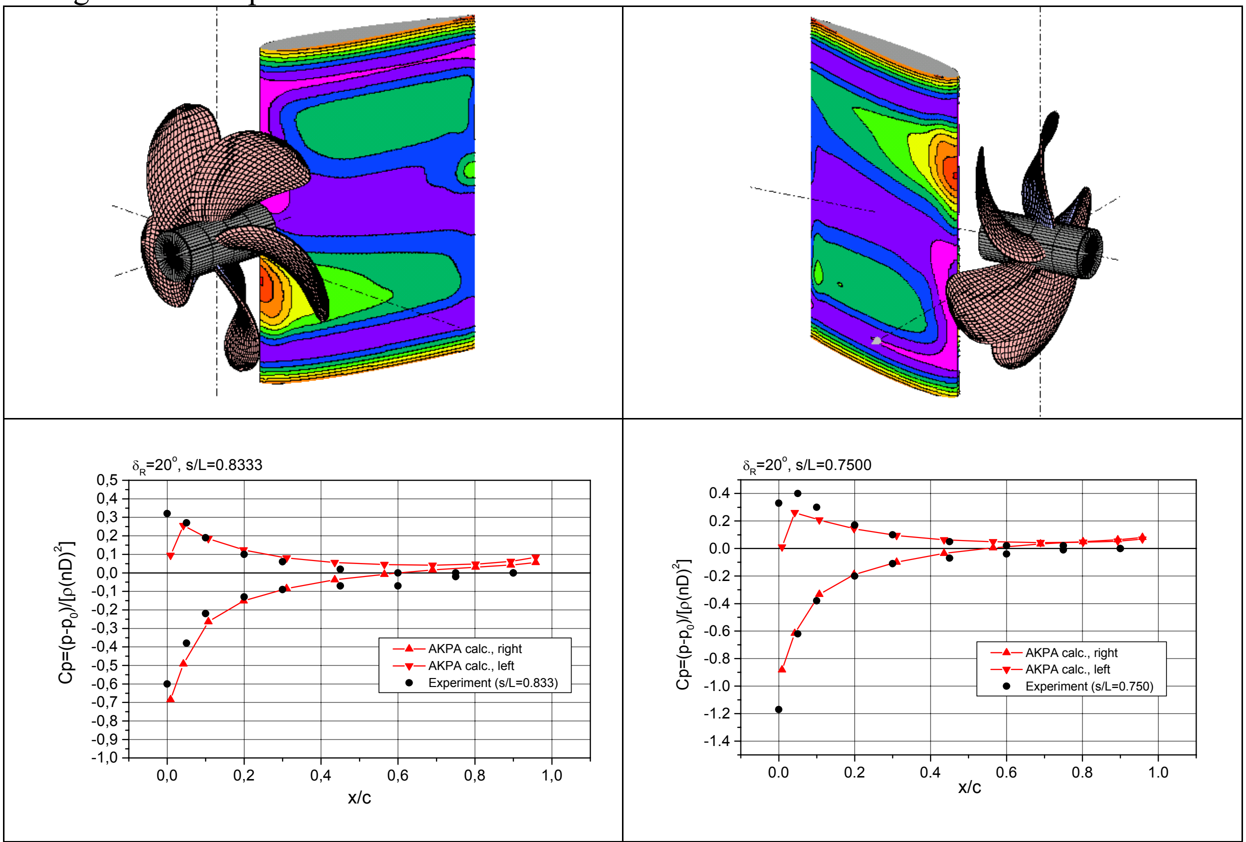


Calculated and measured open-water performance of propeller BL2122.



Comparison between calculated and measured velocity components in the wake behind propeller BL2122. J=0.6. C_{Th}=1.30. Wake section x/R=–0.6.

An example of prediction of pressure distribution on the rudder surface in the wake behind operating propeller is illustrated below. The upper figures show the arrangement and calculated pressure distribution on the rudder. The comparison between calculated pressure values and experimental data is given on the plots for rudder angle of 20 degrees at the two different sections along the rudder span.



Calculated pressure distribution on the rudder surface versus experimental data. C_{Th}=2.32. Rudder angle: +20°.

The latest validation results with the analysis program are available from the references [3], [4], [5] where the cases of single propeller, propeller/rudder system and podded arrangements are studied. The basic theory behind design and analysis algorithms is described in [1], [2].

References

1. ACHKINADZE, A.S. and KRASILNIKOV, V.I. “2003 A New Velocity Based BEM for Analysis of Non-cavitating and Cavitating Propellers and Foils.” *Oceanic Engineering International*, Vol. 7, No. 1.

2. ACHKINADZE, A.S., KRASILNIKOV, V.I. and STEPANOV, I.E. “2000 A Hydrodynamic Design Procedure for Multi-Stage Blade-Row Propulsors Using Generalized Linear Model of the Vortex Wake.” *Proceedings of the Propellers/Shafting’2000 Symposium*, SNAME, Virginia Beach, VA, USA, September 20-21.

3. ACHKINADZE, A.S., BERG, A., KRASILNIKOV, V.I. and STEPANOV, I.E. “2003 Numerical Analysis of Podded and Steering Systems Using a Velocity Based Source Boundary Element Method with Modified Trailing Edge.” *Proceedings of the Propellers/Shafting’2003 Symposium*, SNAME, Virginia Beach, VA, USA, September 17-18.

4. KRASILNIKOV, V.I., BERG, A., ACHKINADZE, A.S. and STEPANOV, I.E. ”2003 Interactive Program System for the Design/Analysis of Marine Propulsors.” *Proceedings of the International Symposium on Naval Architecture and Ocean Engineering ISNAOE’03*, Shanghai, China, September 23-26.

5. KRASILNIKOV, V.I., BERG, A. and ØYE, I.J. ”2003 Numerical Prediction of Sheet Cavitation on Rudder and Podded Propellers Using Potential and Viscous Flow Solutions.” *Proceedings of the 5th International Symposium on Cavitation CAV2003*, Osaka, Japan, November 1-4.

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