Theoretical, Numerical, and Experimental Studies of Bi-directional Hydrofoils

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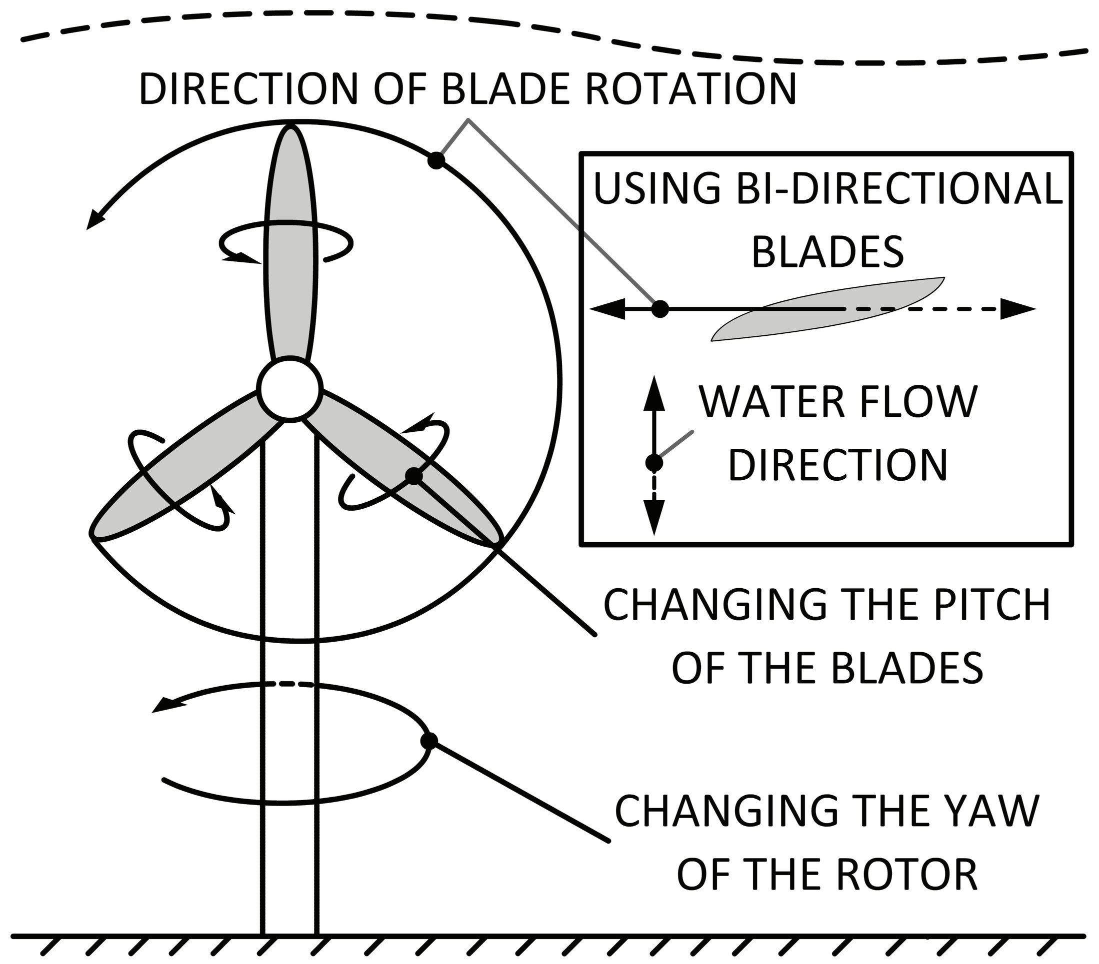
SAMPLE APPLICATION

Tidal current turbines encounter flows with reversing direction.

Some ways to account for the reversing flow direction are:

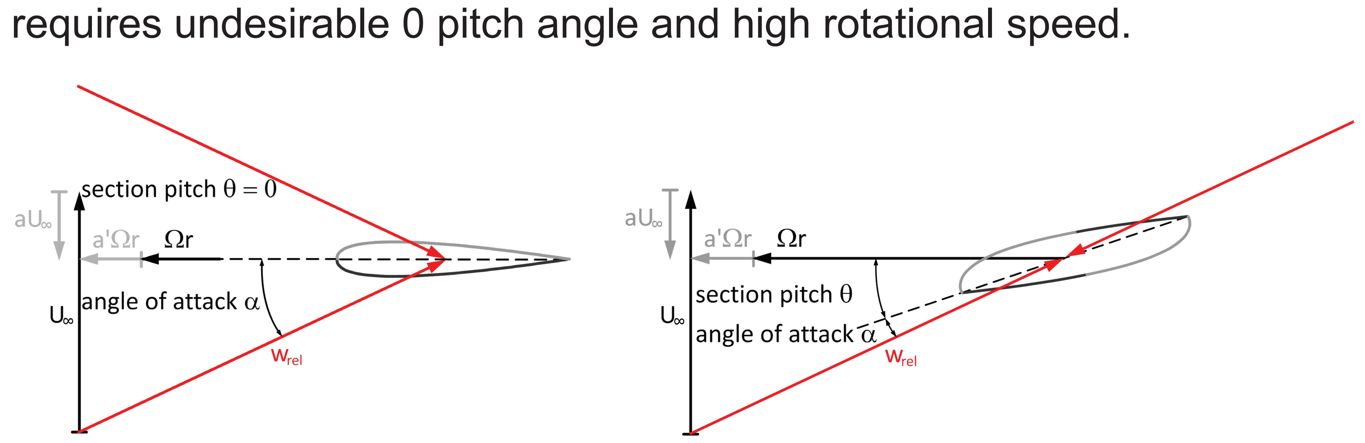
- Changing the yaw of the rotor
- Changing the pitch of the blades
- Using bi-directional blades



Using bi-directional foils may be cost-effective, as no yaw or pitch control mechanisms are required, reducing the complexity, hence decreasing initial and more importantly maintenance costs.

THEORY

In order for the flow to "see" the same foil shape, bi-directional foils must have symmetry about the chord if the blades remain rotating in the same direction; and rotational symmetry if the blades change their direction of rotation when the flow reverses direction. However, the first option requires undesirable 0 pitch angle and high rotational speed.

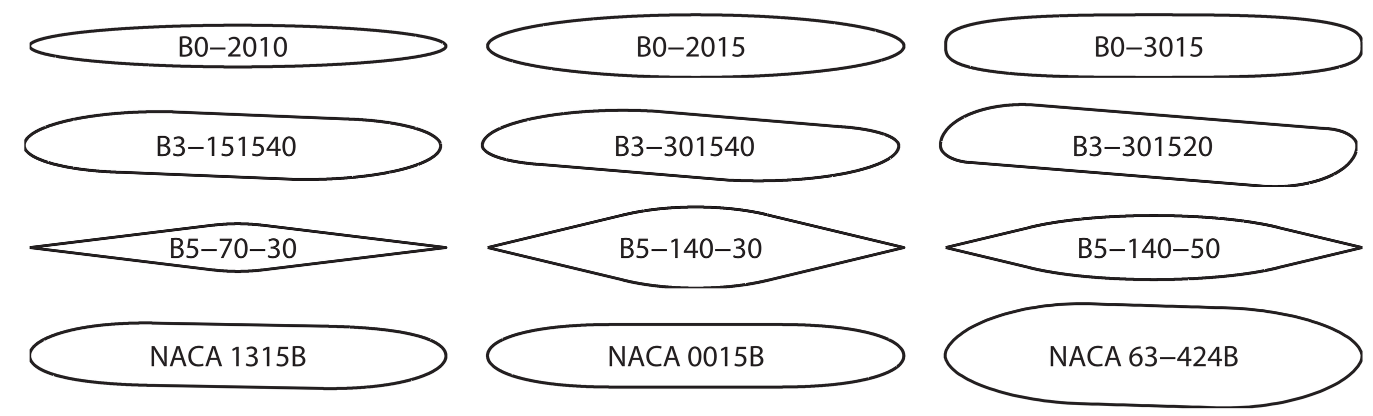


HYDROFOIL DESIGN GOALS

The foils should have:

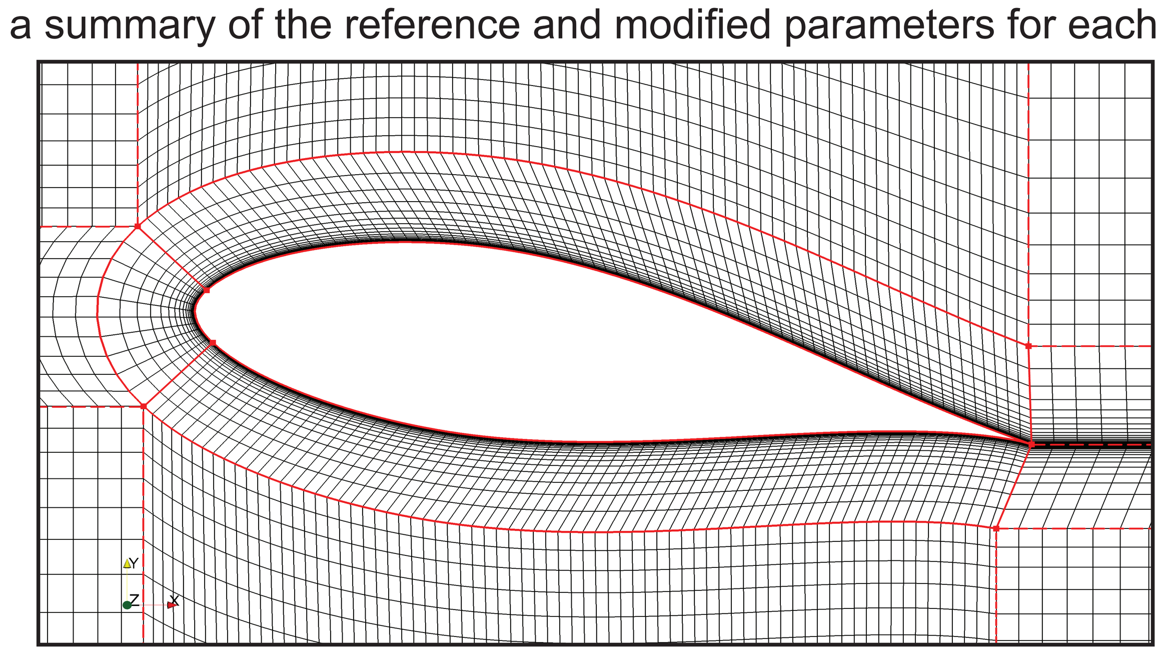
- High lift/drag ratios (over a wide range of angles-of-attack)
- Low cavitation inception numbers (for operational angles-of-attack)
- Low susceptibility and sensitivity to biofouling

A few foil classes were created and studied. Some sample foils are:

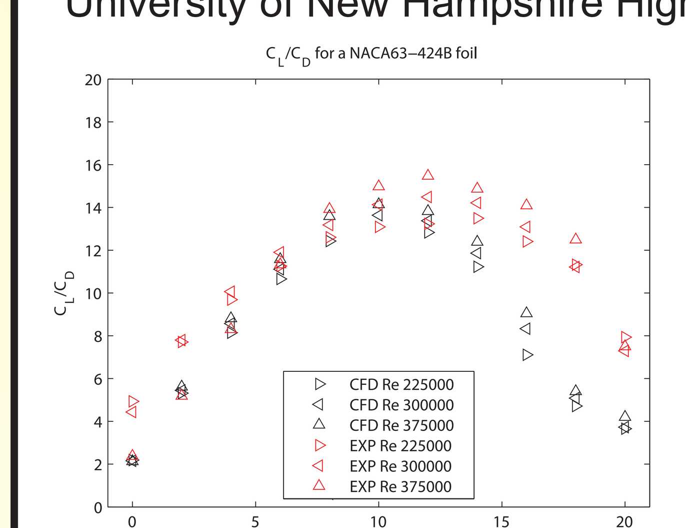


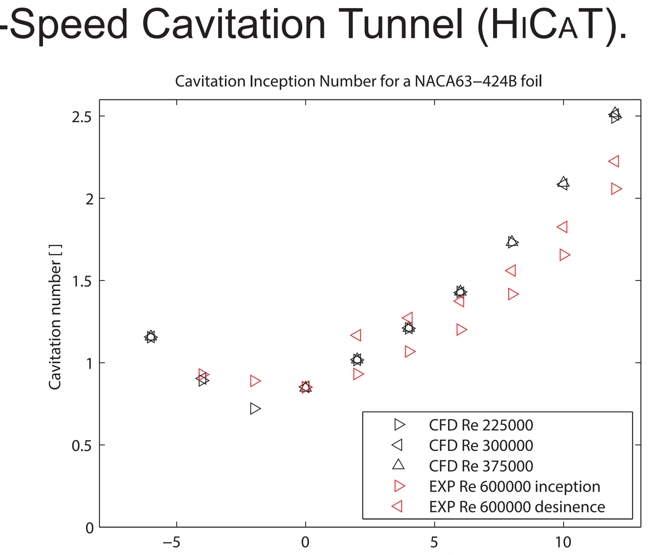
NUMERICAL TEST-BED

A numerical "test-bed" was developed to study (bidirectional) hydrofoils. It is a code written in MATLAB which generates all files required for OpenFOAM simulations. The algorithm finds any sharp edges, and points where the tangent line is at 45⁰ with respect to the x-axis, to create the mesh files for each foil geometry and angle-of-attack. The code also generates files for: the simulation parameters, boundary and initial conditions, automatic execution of all simulations in a case, reading and plotting data of interest, and a summary of the reference and modified parameters for each case.



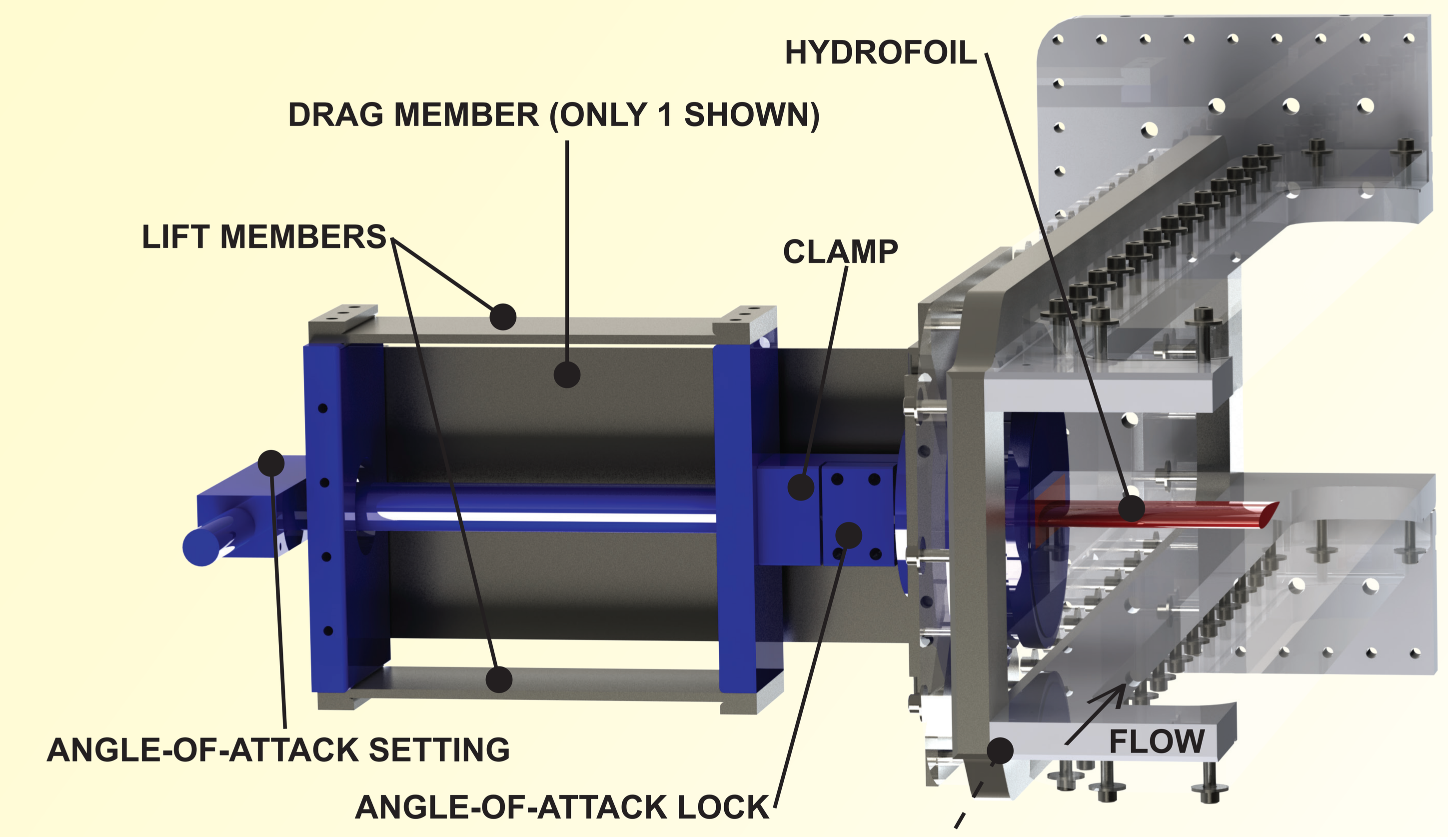
The lift, drag, and cavitation numbers obtained with the CFD code were compared to experimental data obtained for 3 reference foils at the University of New Hampshire High-Speed Cavitation Tunnel (HiCaT).

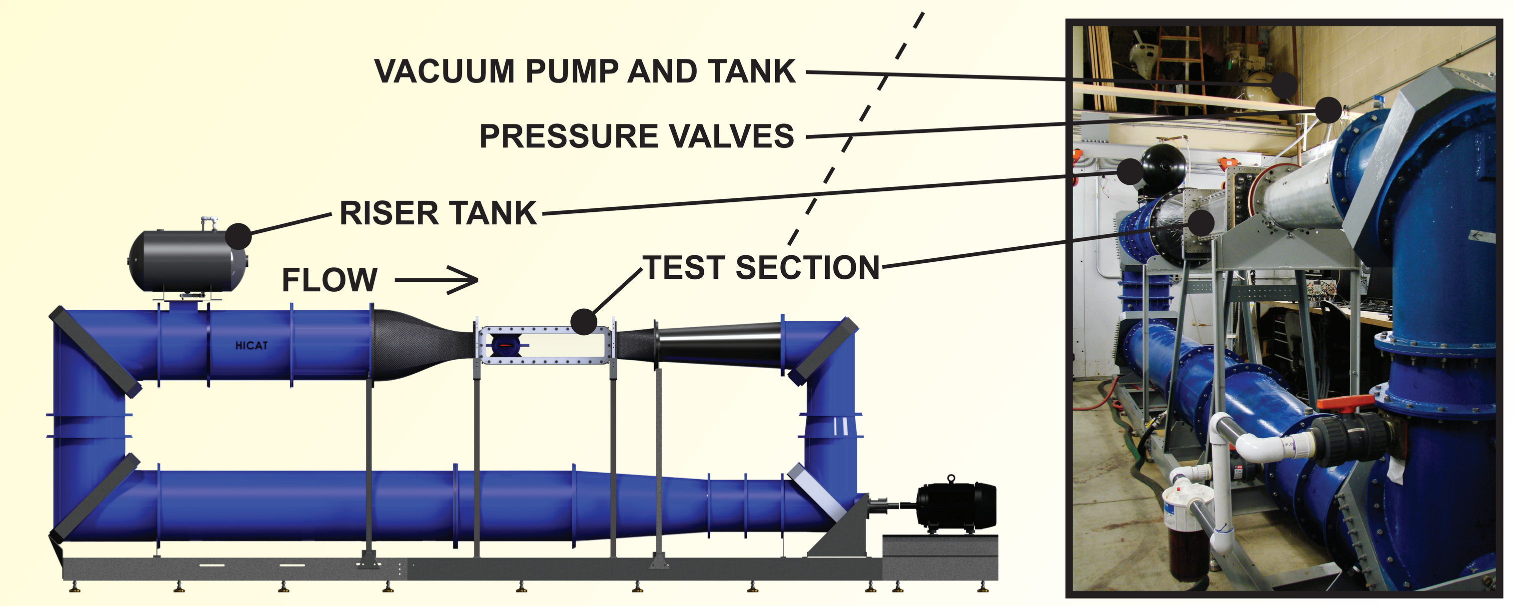


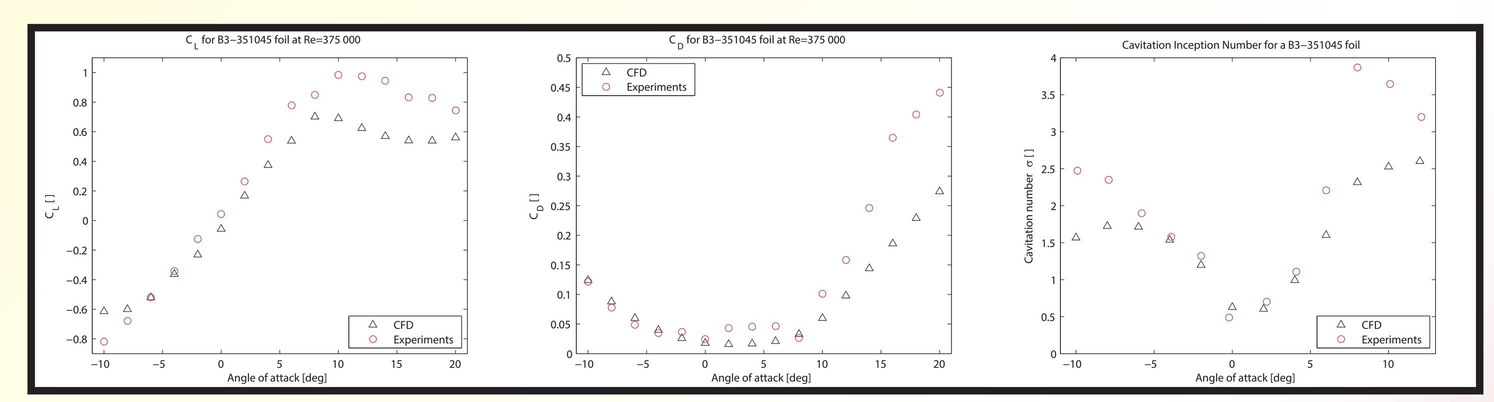


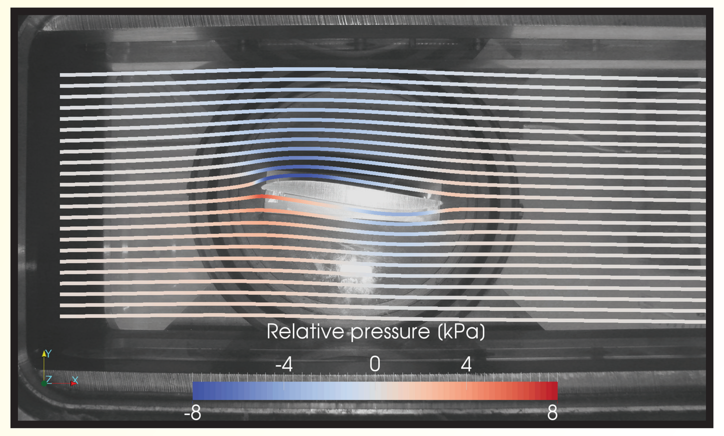
EXPERIMENTS

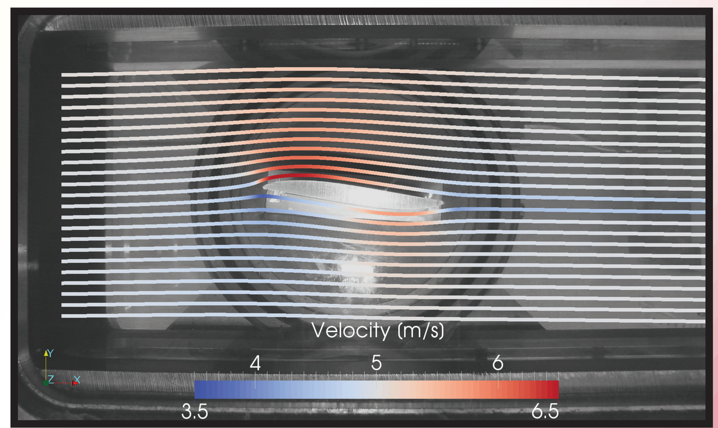
Foils are tested experimentally in the 6-inch X 6-inch X 36-inch test section of the UNH HiCaT. The speed in the test section can exceed 13 m/s and the pressure can be varied independently. A custom-designed force balance can simultaneously measure lift and drag forces. The test section has optical access from all four sides allowing the use of optical measurement techniques, and visual observation of cavitation.











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