Practical Propeller Modeling:
From Concept to 3D CAD Model

A HydroComp Technical Report
Report 131

Introduction

"I need a propeller design. Actually, what I need is a 3D solid model file so that I can get a propeller made for me."

Not just any propeller, I trust, but your own special propeller – for your own special project.

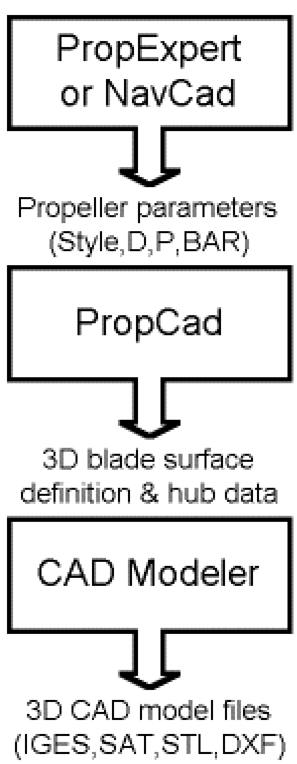
"Correct. I think I know what I need in the way of a basic design, but I'm completely baffled as to how I actually develop a CAD model."

It's a tough job. Propellers – more particularly the propeller blades – are complex shapes that require just the right hydrodynamic surface. General-case CAD tools can generally handle complex shapes and surfaces, but you have to tell the software exactly what shape you need. So what's the problem? Propellers do not easily conform to linear XYZ space. They rotate and advance along an axis. Their natural coordinate system is helical. You'll never find a 90-degree angle on a propeller.

Let's simplify the process of propeller design into three major steps:

1. identifying the proper hydrodynamic size and shape,
2. creating the blade surfaces and propeller design data, and
3. turning blade surfaces and propeller design data into a 3D CAD model.

The graphic to the right provides an overview of the software needed and the flow of information to get from concept to 3D CAD model.



Step 1. Identifying the proper hydrodynamic size and shape

From the perspective of thrust and torque performance, all that we really need to consider are the surfaces of the propeller blades. Of course, we eventually need things like the hub and root fillets, but they only minimally affect performance. They are basically along for the ride so that we can rotate the blades with adequate strength.

Naval architects eliminate the need to deal with the definition of the blade surfaces by using a collection of propeller parameters that ultimately represent the surface. These parameters include both global and detailed parameters. Global parameters define overall size and shape from the stand-point of the 2D blade sections (i.e., how the "wing" shape actually moves through the fluid). Detailed parameters typically identify where the 2D blade sections are located in space, as well as considerations for vibration, clearance, strength and manufacture.

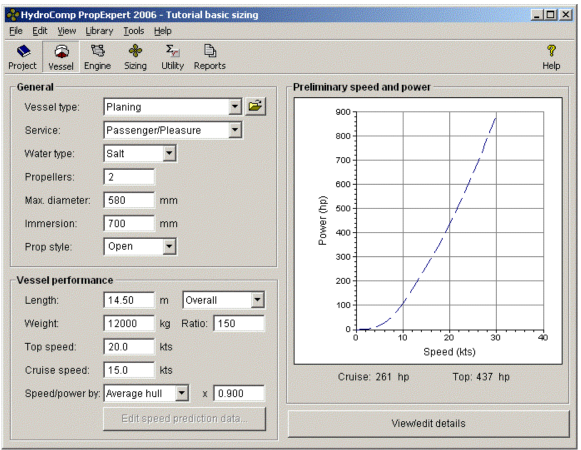
<u>Global parameters</u>
Section (e.g., B-series)
Number of blades
Diameter
Pitch (nominal)
Blade area ratio

<u>Detailed parameters</u>
Skew
Rake
Thickness distribution
Pitch distribution
Root fillet radius

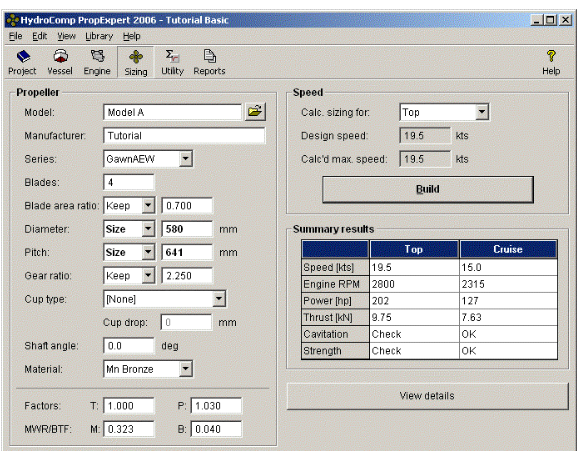
Tools like HydroComp's PropExpert or NavCad are used to define the global parameters of the propeller. Considerations about clearance, local flow properties and strength affect the detailed parameters.

PropExpert

PropExpert is a software tool for the sizing and analysis of propellers for workboats and pleasure craft. It was designed to provide reliable answers with a minimum of hull data and is principally used by vendors of engines, gears and propellers.



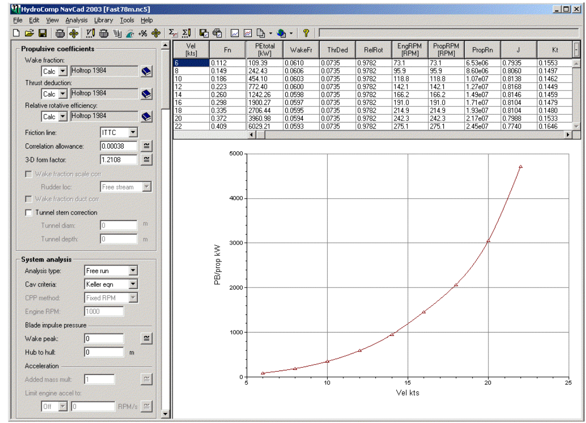
PropExpert Vessel information



PropExpert propeller Sizing

NavCad

NavCad is a more complex – and more thorough – tool for the prediction of resistance and power, and to size and analyze propulsion systems including the propeller. It requires a full description about the hull, so that complete predictions of drag and hull-propulsor interactions can be performed.



NavCad main form

At the conclusion of this step, we will know the global propeller parameters based on our analysis with either PropExpert or NavCad. We can now enter the world of geometric design.

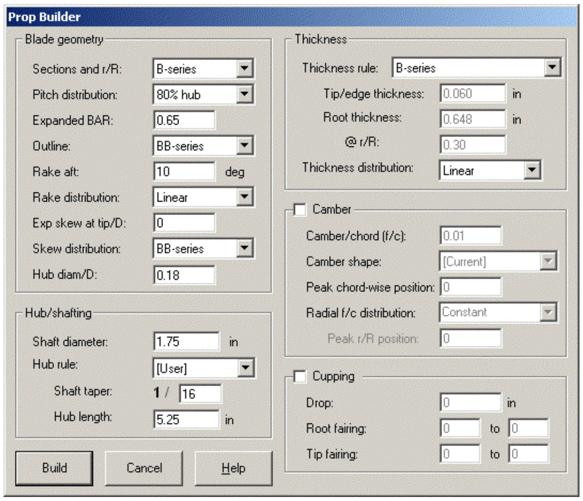
Step 2. Creating the blade surfaces and propeller design data

We know what we need for propeller parameters, so we can proceed to the creation of the 2D and 3D blade surfaces and propeller design data. Trying to do this with general-case CAD software is like wearing the shoebox instead of the shoe. Special software is needed to take our parameters and design constraints, and develop the blade surfaces and the propeller design documents. For this we call on HydroComp PropCad.

PropCad

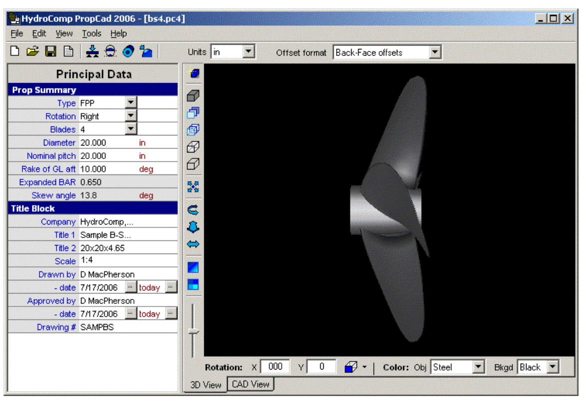
PropCad is a propeller design document and blade surface generator. It creates standard propeller design drawings and tables of offsets. It also develops a full 3D definition of the hydrodynamic blade surfaces and can package this data for export to conventional CAD, CAM and modeling software.

PropCad offers an interactive environment to rapidly build design documents and geometric properties from your parameters. A Builder wizard defines the complete design from a collection of standard industry propeller styles. You can also define any arbitrary section shape and use this as a "parent template" in conjunction with the Builder to create derivatives of your own proprietary design.



PropCad Builder wizard

The main PropCad design form allows us to review the design in 3D. The various menu commands call functions to define material, strength, tip, hub and drawing requirements.



Main PropCad project form

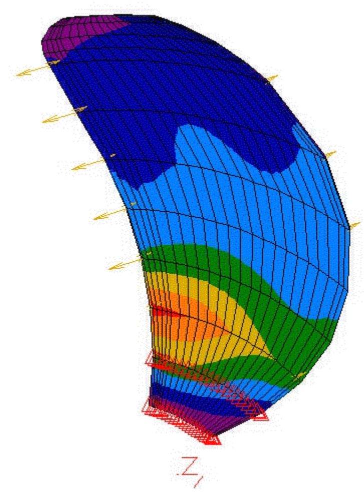
Once we are satisfied with the design, we can create standard propeller design drawings (as shown below) and table of offsets.

This is where many propeller-manufacturing companies end their design. Using well-established manual techniques, these companies will build their patterns using PropCad's various drawings and tables.

FEA and CFD

There are additional analyses that can be performed before taking the propeller geometry from PropCad into 3D CAD. These are strength analysis with FEA (finite element analysis) and detailed 3D performance analysis with CFD (computational fluid dynamics). FEA and CFD are broad topics beyond the scope of this report. However, it may be useful to point out that PropCad has proven to be a very useful geometric modeler for FEA and CFD.

The accompanying graphic shows a stress analysis plot for a propeller designed with PropCad. The calculation was performed with a popular PC-based FEA software package. Data was transferred to the FEA software via the 3D DXF document developed in PropCad (which is not a true surface definition, but a collection of faceted panels).



Example FEA stress graphic

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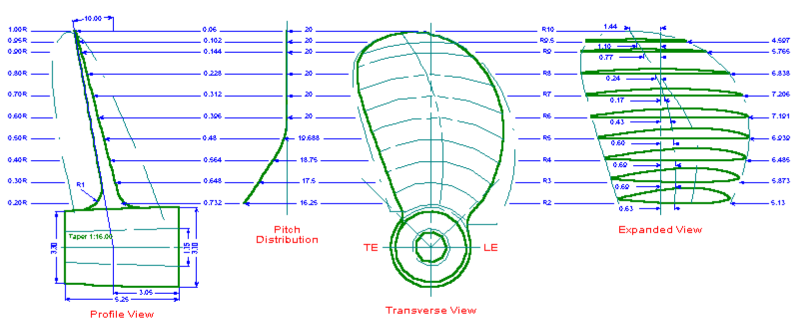


PropCad design drawing

Step 3. Turning blade surfaces and propeller design data into a 3D CAD model

Since our objective is to have a propeller built – either by milling, molding or rapid-prototyping – then we need to create a full 3D solid CAD model. Somehow we need to for PropCad to export the surface information to a CAD modeler. Why is a CAD modeler necessary? Why not add these features into PropCad?

The answer quite simply is…

1. It has already been done (and done well).
2. PropCad users do not universally require it.
3. We would prefer to add value into PropCad by addressing features that are unique to propeller design.

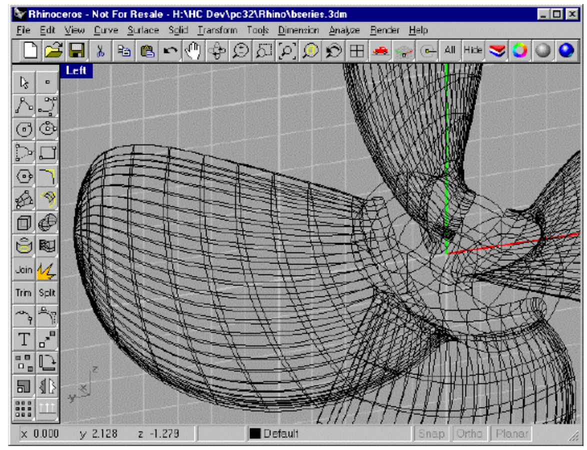
Writing and exporting native 3D CAD files is complicated. Each type of CAD modeling software represents and manipulates 3D surfaces in different ways, and modeling requirements differ between the various types of manufacture. For example, a milled product needs to have cutter path and milling instructions added to the design.

PropCad serves this broad collection of CAD modelers by creating and exporting ASCII files that instruct the CAD/CAM modeling software how to accurately "re-build" the principal blade and hub surfaces. With this approach there is no particular need to know how the CAD/CAM software relates to surfaces. These "instruction files" are sometimes known as macros or scripts. Some macro files are little more than a grid of the 3D XYZ points on the surface. Others include instructions to the software to manipulate the data. Some even directly build solid parts.

<u>CAD and CAM modelers</u>

Which CAD and CAM modelers can work with PropCad? PropCad currently exports macro files for SurfCAM, MasterCam, SolidWorks, CorelCAD, DELCAM, and Rhino. PropCad also exports surface data in general-case formats, such as DXF, VRML and a variety of custom formats. With a little manipulation of these available formats, PropCad data can be imported into virtually any modeler, as some users have done for UniGraphics.

The following graphic is of a PropCad design being finished off in a CAD modeler. (This example was done with Rhino.) The blade surface data was transferred via a macro file, along with the basic definition of the hub. In this example, commands were also included in the file to loft the blade surfaces according to the modeler's requirements and to revolve the hub. Other modelers have different command capabilities.



PropCad design finished off in Rhino

The surfaces were manually "stitched" together (adding edge surfaces where needed) to make a complete bounded body. Fillets were added at the root to fair the blade into the hub. The final step in the development of the part was to copy the blade around the hub, resulting in a single solid model. (Additional details – such as keyways, splines or puller holes – would be added here in the modeler.)

The final deliverable of general-purpose CAD modelers (e.g., Rhino, CorelCAD, SolidWorks) would be 3D part files (typically SAT, STL or IGES). If using a CAM-specific modeler (e.g., SurfCAM, MasterCam), the final product file would also include milling instructions.

Summary

General-case CAD software cannot be effectively applied to the creation of a 3D propeller design without extensive and costly in-house development. HydroComp's PropExpert, NavCad, and PropCad provide critical capabilities necessary for a viable and cost-effective propeller design solution – from concept to 3D CAD model.

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