Reliable Speed Prediction: Propulsion Analysis and a Calculation Example

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ABSTRACT

Speed prediction is more than just bare-hull resistance. Speed is a function of drag and *thrust. This paper will discuss propulsion relationships – and our ability to predict how power is converted into thrust for a given application. It will illustrate some of the more common shortcomings found in propulsion analysis, and it will provide a summary of features that must be part of reliable speed prediction software. Finally, it will offer a calculation example where resistance and propulsion analysis are combined to demonstrate various data requirements, decisions, and processes.*

INTRODUCTION

The first step to a reliable speed prediction is a proper prediction of resistance – but this is only the first step. *Speed is a function of both drag and thrust.*

Do you want to run at a faster speed? You can reduce drag, or you can increase thrust. Speed, drag and thrust are tightly connected. Of course, the actual measure of drag and thrust *themselves* are meaningless, except that they are steps to the really important measure of performance for a designer – *speed and power*. We purchase power to make a desired speed.

This paper will discuss propulsion relationships – and our ability to predict how power is converted into thrust for a given application. It will illustrate some of the more common shortcomings found in propulsion analysis, and it will provide a summary of features that must be part of reliable speed prediction software. Finally, it will offer a calculation example where resistance and propulsion analysis are combined to demonstrate various data requirements, decisions, and processes.

THE PHYSICS BEHIND THE SYSTEM

The goal of a speed prediction is to model a boat's performance over a range of boat speeds. Principally, we are looking to define the *hull-propulsor-engine* equilibrium (Figure 1), which will provide the structure for our propulsion analysis.

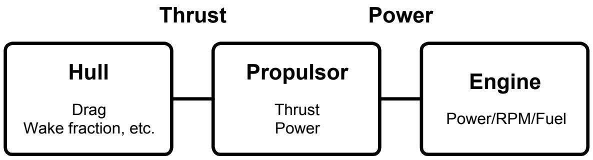

Figure 1. The hull-propulsor-engine equilibrium

Thrust-Drag equilibrium

Between the hull and its propulsor (e.g., propeller, waterjet) is an equilibrium of forces. The delivered thrust of the propulsor must exactly match the drag at each analysis speed. Therefore, we need to identify the characteristics that will provide just the right amount of thrust.

For a propeller, this means finding the right RPM. Let's use your knowledge of boat operation to help you understand this. We all know that there is one unique throttle position for each speed. Propeller RPM is controlled by the throttle position, and the connection between drag and thrust is through a unique RPM.

Finding the right RPM is all about properly modeling propeller performance on the boat. First, it is necessary to know how the propeller performs in

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service. We need a reliable model for a propeller's thrust and torque. In other words, we must accurately predict thrust and torque for each speed and RPM.

Second, it is necessary to understand that the force equilibrium described above is a match of drag and *delivered thrust*, not theoretical propeller thrust. Delivered thrust takes into account the effect of the boat on the propeller. This effect is described by two hull-propulsor interaction coefficients known as *wake fraction* and *thrust deduction*. (There is a third coefficient – *relative-rotative efficiency* – but its effect is quite small, so we will ignore it for this discussion.)

Wake fraction helps define the actual speed of the water reaching the propeller as it passes by the hull and underwater gear. *Thrust deduction* is a measure of the reduction of usable thrust due to the close proximity of the hull's afterbody immediately ahead of the propeller. Both affect a propeller's ability to generate useable delivered thrust.

Engine-propeller power equilibrium

So how do we get from propeller thrust to engine power? Engine power is simply a function of *propeller efficiency* and *propulsion system mechanical efficiency*.

Propeller efficiency is derived from the propeller performance calculations. In simple terms, it is the ratio of thrust-to-power. So, propeller thrust correlates to propeller power via its efficiency.

It is important to remember that the required *propeller power* for a particular speed is not the *brake power* generated by the engine. Brake power is somewhat greater, as we have to consider the propulsion system mechanical efficiency by adding shaft and bearing losses (1%-2%) and reduction gear losses (3%-4%).

Analysis procedure

A propulsion analysis will give us speed vs power. Before we can begin, however, we will need to know the following:

1. Range of boat speeds to consider.
2. The total in-service drag at these speeds.
3. An appropriate prediction model for wake fraction and thrust deduction.
4. A complete and reliable model of propeller performance.
5. An estimate of the mechanical system losses.

If we have this, then we can run a propulsion analysis by looking at each speed in isolation. The following are the steps to find each unique performance parameter:

1. *Drag* for a given speed.
2. *Wake fraction* and *thrust deduction* for a given speed.
3. *Delivered thrust* to match the drag.
4. *Theoretical propeller thrust* for a delivered thrust.
5. *Propeller RPM* to provide the right theoretical thrust.
6. *Propeller efficiency* at the propeller RPM.
7. *Propeller power* via the propeller efficiency.
8. *Engine power* given the mechanical losses.

WHEN *TRADITIONAL* MEANS *FICTIONAL*

Open any book on boat design and you'll see numerous ways to predict speed and power. Many of these were based on observations of boat performance from many years ago, and they no longer apply. They are either based on obsolete technology or are just too simplistic to be useful anymore.

Simplistic prediction of OPC

The ratio of all of the accumulated efficiencies in relating drag to engine power is called *OPC*, the *overall propulsive coefficient*. Many references suggest using a single value of OPC for all propulsion systems.

The problem with this approach is that the estimated OPC may, or may not, bear any resemblance to the actual performance of your boat. A single representative OPC (such as the ever-popular 0.55) cannot possibly account for the many differences in propeller operation that effect performance.

For example, contemporary OPC figures are often more than 0.65. Even if your drag prediction is spot on, this means that the power prediction is some 15% in error! On the other hand, we periodically see poor waterjet selections, which result in OPC of much less than 0.55 and insufficient engine power.

Increasing engine powers, higher cavitation levels, more cambered and cupped propellers, deeper gear ratios and higher pitches all contribute to changing trends in propulsor performance and OPC. It is therefore necessary to avoid using a simplistic estimate of OPC.

Obsolete propeller prediction models

Consider commercial fixed-pitch propellers, such as the popular DynaJet or DynaQuad propellers from Michigan Wheel, as well the commercial models of many other manufacturers. Most are derived from the Gawn series model (ogival, flat-faced). Unfortunately, many propeller prediction tools still improperly use B-series propellers (Troost) as the model for all propeller performance.

These tools also do not account for the effect of cup and cavitation, which is something we absolutely must consider these days. As engine power densities have risen over the years, more and more installations are showing very high levels of cavitation.

Modeling the effect of cavitation on performance is one correction to make. The next correction is to determine the effect of cup [MacPherson 1997]. After blade area, cup is probably the most frequently used means to control cavitation breakdown on work boats and pleasure craft. Corrections for both cavitation breakdown and cup modification are available to obtain a reliable model of actual propeller performance.

HOW PROPELLER SIZING DECISIONS AFFECT PERFORMANCE

We must not assume that we will necessarily have an optimum propeller delivering optimum efficiency across all speeds. There are many ways in which valid propeller sizing decisions mean we have a less than optimum propeller. Remember, we are looking to predict what will be, not what might be.

Potential propeller efficiency

Potential propeller efficiency is directly related to a propeller's pitch. Within the context of a good propeller sizing, potential efficiency can be increased with a higher pitch. Consider the following plot of propeller curves (Figure 2). For a moderate change in P/D ratio from 0.8 to 1.0, the peak *potential* propeller efficiency increases by some 6%.

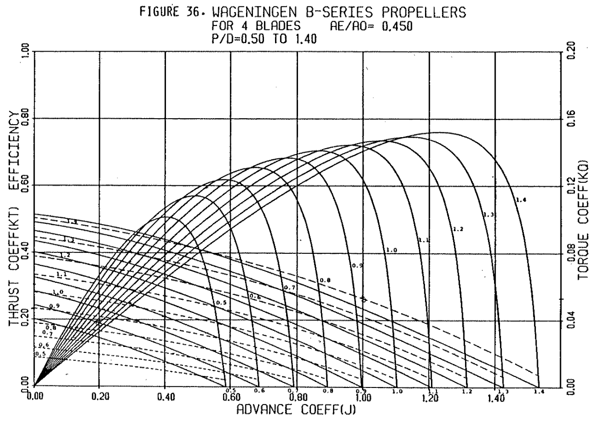


Figure 2. Propeller curves

Solving dynamic problems may affect all speeds

One example of where we might select a pitch less than optimum for top speed performance is when we have mid-range dynamic problems. For example, some boats have difficulty getting "over the hump" or "on plane". This is due to the relationship between the steady-state speed-power curve and the engine's power curve. When we encounter such a situation, our only course of action may be to use a different pitch to allow the boat to get on plane [MacPherson 2001].

The following plot (Figure 3) illustrates how the engine itself contributes to the ultimate selection of pitch – and, ultimately, the propeller efficiency at all speeds. The dashed line is the propeller's power-RPM curve; the other two lines are representative of an older naturally aspirated engine (with more power at low RPM) and a newer highly-turbocharged engine (with a narrower power-RPM curve).

Getting over the hump is all about surplus power – of which the new engine has very little at mid-range. To fix this problem, you might see a compromise where the pitch is reduced, resulting in lower mid-range propeller power. You will also see a loss of top speed (due to the governor's maximum RPM limit), as well as a loss of efficiency at all speeds due to the lower pitch.

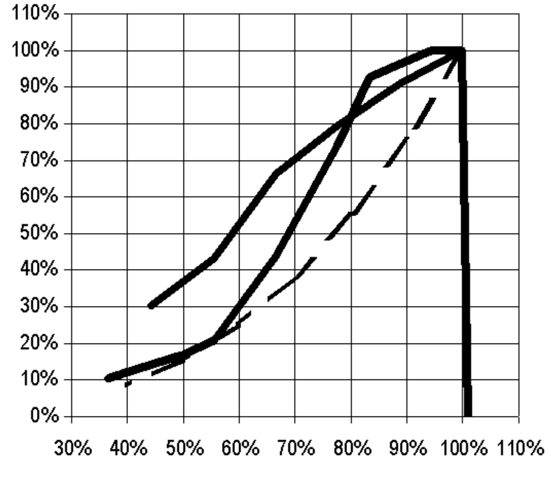


Figure 3. Engine-propeller power-RPM curves

PROPULSION ANALYSIS FOR WATERJETS

Techniques are available to predict thrust, power and efficiency for waterjets [MacPherson 1999, MacPherson 2000, MacPherson 2002]. However, it is probably more important for waterjets than for propellers that a proper "sizing" be conducted, as the implications of sizing an inappropriate waterjet are far-reaching.

Unlike propeller curves (as illustrated in Figure 2), waterjet efficiency is hidden in published performance data – you are only presented with thrust and power. This is enough, however, to select a waterjet model, and many designers do not even consider efficiency.

Waterjet peak efficiencies are commonly 0.60 or more – very comparable to propellers. Also like propellers, waterjets are designed to reach their peak efficiency over relatively narrow range of boat speeds, but this range of peak efficiency is rarely published. For example, in one project we were asked to evaluate, the selected waterjet was reaching its peak efficiencies above 35 knots, even though the boat speed was only 24 knots [MacPherson 2002]. At these lower operating speeds, the efficiency was less than 0.45. Without a proper waterjet propulsion analysis, we could have significantly missed our speed-power prediction.

PROPULSION ANALYSIS REQUIREMENTS

The following is a list of features and calculation techniques that must be part of any thorough and proper propulsion analysis. Use this list to help insure that your speed predictions are as reliable as possible.

☑ Prediction of wake fraction and thrust deduction

Use suitable prediction methods for these coefficients that are appropriate to the characteristics of your boat. You do not want to use one formula for all boats. You need to match your boat to the collection of available methods.

☑ Prediction of basic propeller performance

The propeller charts or software that you use must be of the correct propeller type. Many publications and software still rely exclusively on B-series propeller performance, which is not correct for the Gawn-style models that make up most of the small commercial propellers in service.

☑ Prediction of propeller cavitation and cup

As installed engine power continues to climb, we see more instances where boats are operating with very high levels of cavitation. We also see increased reliance on cupping as a means to control thrust breakdown. Your analysis must include the ability to model these characteristics.

☑ A thrust-drag solution for RPM at each speed

Efficiency will change at each speed, as the RPM changes to suit the required propeller thrust. One efficiency value cannot represent all speeds – each speed must be evaluated independently.

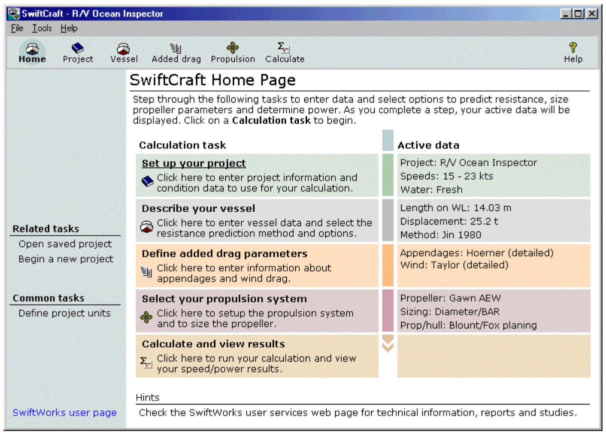
☑ Prediction of waterjet efficiency

If you are considering a waterjet-driven boat, you will need to be able to predict waterjet efficiency.

SPEED PREDICTION EXAMPLE

The following example will demonstrate how a propulsion analysis is conducted using contemporary software. It will also show data entry, drag prediction, and reporting.

HydroComp's *SwiftCraft*™ software is used for this illustration.



SwiftCraft Home Page

Step through the following tasks to enter data and select options to predict resistance, size propeller parameters and determine power. As you complete a step, your active data will be displayed. Click on a **Calculation task** to begin.

Calculation task	Active data
Set up your project Click here to enter project information and condition data to use for your calculation.	Project: R/V Ocean Inspector Speeds: 15 - 23 kts Water: Fresh
Describe your vessel Click here to enter vessel data and select the resistance prediction method and options.	Length on WL: 14.03 m Displacement: 25.2 t Method: Jin 1980
Define added drag parameters Click here to enter information about appendages and wind drag.	Appendages: Hoerner (detailed) Wind: Taylor (detailed)
Select your propulsion system Click here to setup the propulsion system and to size the propeller.	Propeller: Gawn AEW Sizing: Diameter/BAR Prop/hull: Blount/Fox planing
Calculate and view results Click here to run your calculation and view your speed/power results.	

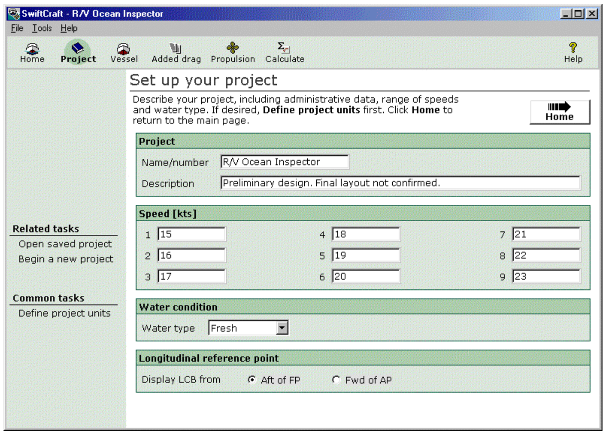
Hints

Check the SwiftWorks user services web page for technical information, reports and studies.

SwiftCraft Home Page

Set up your project

Each project will have its own unique name and description. In the *Project* page, you will enter this information, as well as data about the range of speeds, water type, and a measurement reference.



Set up your project

Describe your project, including administrative data, range of speeds and water type. If desired, **Define project units** first. Click **Home** to return to the main page.

Project

Name/number: R/V Ocean Inspector

Description: Preliminary design. Final layout not confirmed.

Speed [kts]

1	15	4	18	7	21
2	16	5	19	8	22
3	17	6	20	9	23

Water condition

Water type: Fresh

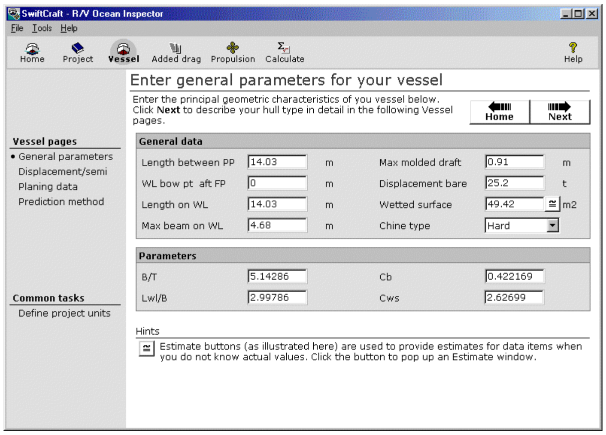
Longitudinal reference point

Display LCB from ● Aft of FP ○ Fwd of AP

Project page

General vessel parameters

A full and complete description of your hull is necessary for a reliable analysis. Four pages within this *Vessel* group are used to enter information about your hull. The information is parametric – meaning that the geometry is described by individual numerical values (such as length, beam or displacement) rather than by the three-dimensional geometry.



Enter general parameters for your vessel

Enter the principal geometric characteristics of you vessel below.
Click **Next** to describe your hull type in detail in the following Vessel pages.

General data

Length between PP	14.03	m	Max molded draft	0.91	m
WL bow pt aft FP	0	m	Displacement bare	25.2	t
Length on WL	14.03	m	Wetted surface	49.42	m2
Max beam on WL	4.68	m	Chine type	Hard	

Parameters

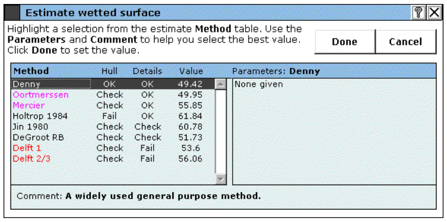
B/T	5.14286	Cb	0.422169
Lwl/B	2.99786	Cws	2.62699

Hints

Estimate buttons (as illustrated here) are used to provide estimates for data items when you do not know actual values. Click the button to pop up an Estimate window.

Vessel parameters page

Data accuracy is essential to a reliable prediction. In some cases, however, you may have to estimate values for certain data items. When needed, it is valuable to employ a collection of parametric estimates for a variety of different vessel types.



Estimate wetted surface

Highlight a selection from the estimate **Method** table. Use the **Parameters** and **Comment** to help you select the best value. Click **Done** to set the value.

Method	Hull	Details	Value
Denny	OK	OK	49.42
Oortmerssen	Check	OK	49.95
Mercier	Check	OK	55.85
Holtrop 1984	Fail	OK	61.84
Jin 1980	Check	Check	60.78
DeGroot RB	Check	Check	51.73
Delft 1	Check	Fail	53.6
Delft 2/3	Check	Fail	56.06

Parameters: **Denny**

None given

Comment: **A widely used general purpose method.**

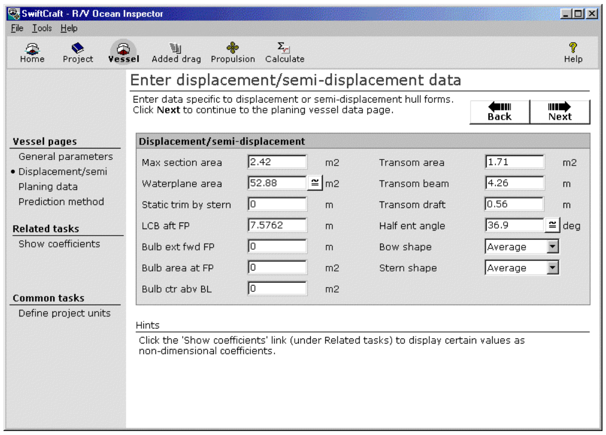
Wetted surface estimate

Vessel details

We often place boats into the general categories of *displacement*, *semi-displacement* or *planing*. While they may be useful to help us describe the nature of the design, they are not good hydrodynamic distinctions.

How do you describe a hard-chine boat that is running at low speed? Is it still a planing hull or is it operating in a semi-displacement mode? What about a displacement hull that is over-powered and runs beyond its "hull speed"?

Since we might be seeing operation across speed regimes, we must describe the boat as fully as possible. The definition of the boat should include all of the characteristics that might contribute to a boat's drag across its entire speed range, such as LCB, transom immersion, deadrise, and shaft angle.



Enter displacement/semi-displacement data

Enter data specific to displacement or semi-displacement hull forms.
Click **Next** to continue to the planing vessel data page.

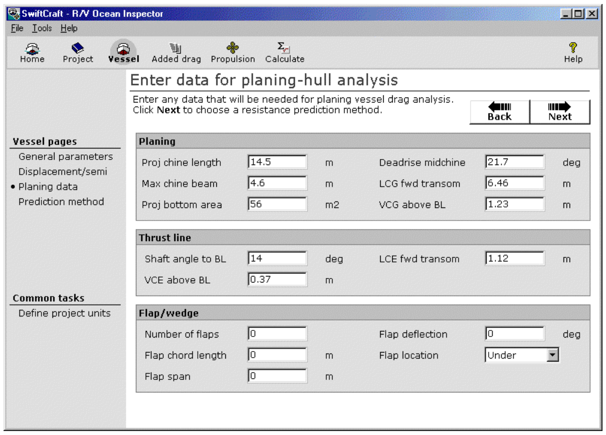
Displacement/semi-displacement

Max section area	2.42	m2	Transom area	1.71	m2
Waterplane area	52.88	m2	Transom beam	4.26	m
Static trim by stern	0	m	Transom draft	0.56	m
LCB aft FP	7.5762	m	Half ent angle	36.9	deg
Bulb ext fwd FP	0	m	Bow shape	Average	
Bulb area at FP	0	m2	Stern shape	Average	
Bulb ctr abv BL	0	m2			

Hints

Click the 'Show coefficients' link (under Related tasks) to display certain values as non-dimensional coefficients.

Displacement and semi-displacement data page



Enter data for planing-hull analysis

Enter any data that will be needed for planing vessel drag analysis.
Click **Next** to choose a resistance prediction method.

Planing

Proj chine length	14.5	m	Deadrise midchine	21.7	deg
Max chine beam	4.6	m	LCG fwd transom	6.46	m
Proj bottom area	56	m2	VCG above BL	1.23	m

Thrust line

Shaft angle to BL	14	deg	LCE fwd transom	1.12	m
VCE above BL	0.37	m			

Flap/wedge

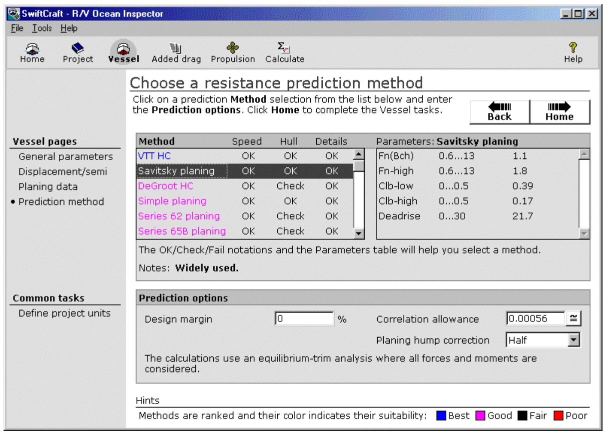
Number of flaps	0		Flap deflection	0	deg
Flap chord length	0	m	Flap location	Under	
Flap span	0	m			

Planing data page

Resistance prediction method

As we know, perhaps the most significant contributor to good prediction reliability is the appropriate selection of the prediction method. The selected prediction method should be built from hulls that share the same basic character as the vessel under review. You cannot rely on results from a method derived from a fundamentally different hull type. Referring to drawings of the method's hull forms is the first step to selecting a suitable method.

After principal hull type, the method's range of data set parameters must be considered. The most critical parameter to watch is speed (typically Froude number), then the hull form parameters. The obvious way to avoid difficulty is to evaluate many different methods and to select one that offers a good correlation between your boat and the method.



Choose a resistance prediction method

Click on a prediction **Method** selection from the list below and enter the **Prediction options**. Click **Home** to complete the Vessel tasks.

Method	Speed	Hull	Details
VTT HC	OK	OK	OK
Savitsky planing	OK	OK	OK
DeGroot HC	OK	Check	OK
Simple planing	OK	OK	OK
Series 62 planing	OK	Check	OK
Series 65B planing	OK	Check	OK

Parameters: **Savitsky planing**		
Fn(Bch)	0.6...13	1.1
Fn-high	0.6...13	1.8
Clb-low	0...0.5	0.39
Clb-high	0...0.5	0.17
Deadrise	0...30	21.7

The OK/Check/Fail notations and the Parameters table will help you select a method.

Notes: **Widely used.**

Prediction options

Design margin 0 %

Correlation allowance 0.00056

Planing hump correction Half

The calculations use an equilibrium-trim analysis where all forces and moments are considered.

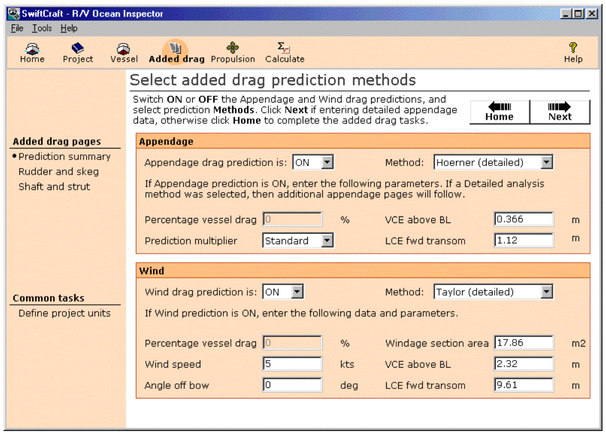
Hints

Methods are ranked and their color indicates their suitability: 🟦 Best 🟪 Good ⬛ Fair 🟥 Poor

Resistance prediction method page

Added drag from appendages and wind

The prediction of vessel drag is not complete with just the bare-hull drag. Added appendage and wind drag can be a significant portion of the total drag – especially for planing craft. Appendages alone can contribute over 25% for fast craft. Poor estimates of added drag can greatly reduce prediction accuracy.



Select added drag prediction methods

Switch **ON** or **OFF** the Appendage and Wind drag predictions, and select prediction **Methods**. Click **Next** if entering detailed appendage data, otherwise click **Home** to complete the added drag tasks.

Appendage

Appendage drag prediction is: ON

Method: Hoerner (detailed)

If Appendage prediction is ON, enter the following parameters. If a Detailed analysis method was selected, then additional appendage pages will follow.

Percentage vessel drag 0 %

VCE above BL 0.366 m

Prediction multiplier Standard

LCE fwd transom 1.12 m

Wind

Wind drag prediction is: ON

Method: Taylor (detailed)

If Wind prediction is ON, enter the following data and parameters.

Percentage vessel drag 0 %

Windage section area 17.86 m2

Wind speed 5 kts

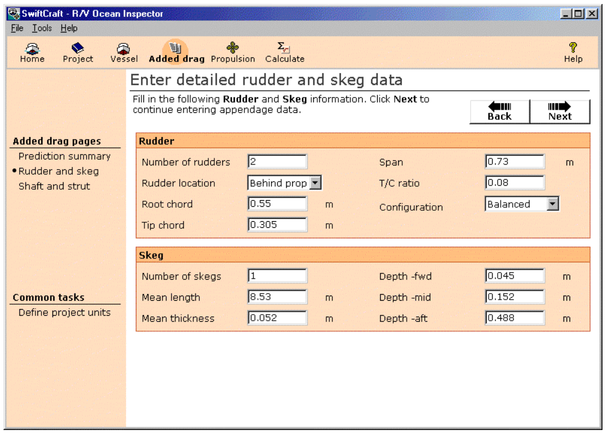
VCE above BL 2.32 m

Angle off bow 0 deg

LCE fwd transom 9.61 m

Added drag prediction page

In addition to summary estimates of appendage and wind drag, you can also define and evaluate the collection of individual appendages as part of the *Added drag* group.



Enter detailed rudder and skeg data

Fill in the following **Rudder** and **Skeg** information. Click **Next** to continue entering appendage data.

Rudder

Number of rudders 2

Span 0.73 m

Rudder location Behind prop

T/C ratio 0.08

Root chord 0.55 m

Configuration Balanced

Tip chord 0.305 m

Skeg

Number of skegs 1

Depth -fwd 0.045 m

Mean length 8.53 m

Depth -mid 0.152 m

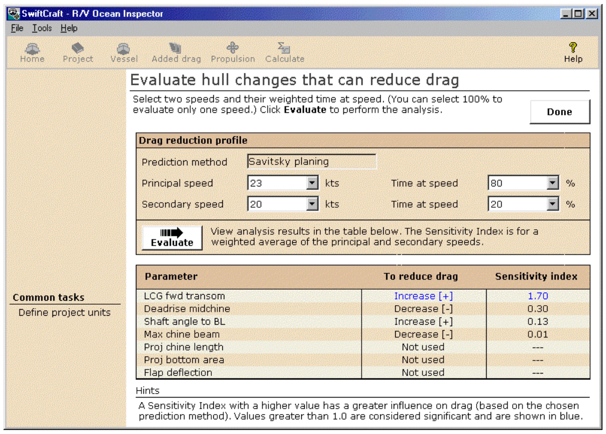
Mean thickness 0.052 m

Depth -aft 0.488 m

Appendage data page

Opportunities for drag reduction

During early stages of your design, you might be able to seek out ways to reduce the drag of your hull. For example, you might find that a change in transom immersion or a shift in LCG results in less drag.



Evaluate hull changes that can reduce drag

Select two speeds and their weighted time at speed. (You can select 100% to evaluate only one speed.) Click **Evaluate** to perform the analysis.

Drag reduction profile

Prediction method Savitsky planing

Principal speed 23 kts

Time at speed 80 %

Secondary speed 20 kts

Time at speed 20 %

View analysis results in the table below. The Sensitivity Index is for a weighted average of the principal and secondary speeds.

Parameter	To reduce drag	Sensitivity index
LCG fwd transom	Increase [+]	1.70
Deadrise midchine	Decrease [-]	0.30
Shaft angle to BL	Increase [+]	0.13
Max chine beam	Decrease [-]	0.01
Proj chine length	Not used	---
Proj bottom area	Not used	---
Flap deflection	Not used	---

Hints

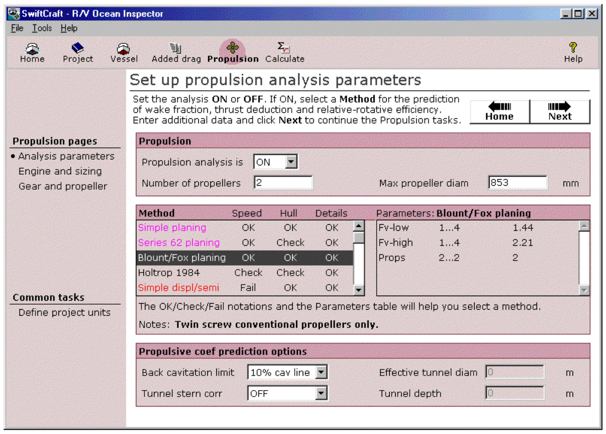
A Sensitivity Index with a higher value has a greater influence on drag (based on the chosen prediction method). Values greater than 1.0 are considered significant and are shown in blue.

Drag reduction page

Propulsion analysis parameters

As was described in the introduction of this paper, a speed prediction is not complete without a systematic propulsion analysis. The definition of a suitable prediction method for wake fraction and thrust deduction is the first of the *Propulsion* tasks.

In the same way that the vessel drag prediction methods were ranked, so too are the methods for the prediction wake fraction and thrust deduction. Do not forget any characteristics that affect the coefficients, such as whether the propellers are in tunnels (pockets).



Set up propulsion analysis parameters

Set the analysis **ON** or **OFF**. If ON, select a **Method** for the prediction of wake fraction, thrust deduction and relative-rotative efficiency. Enter additional data and click **Next** to continue the Propulsion tasks.

Propulsion

Propulsion analysis is: ON

Number of propellers: 2

Max propeller diam: 853 mm

Method	Speed	Hull	Details
Simple planing	OK	OK	OK
Series 62 planing	OK	Check	OK
Blount/Fox planing	OK	OK	OK
Holtrop 1984	Check	Check	OK
Simple displ/semi	Fail	OK	OK

Parameters: **Blount/Fox planing**

Fv-low	1...4	1.44
Fv-high	1...4	2.21
Props	2...2	2

The OK/Check/Fail notations and the Parameters table will help you select a method.

Notes: **Twin screw conventional propellers only.**

Propulsive coef prediction options

Back cavitation limit: 10% cav line

Tunnel stern corr: OFF

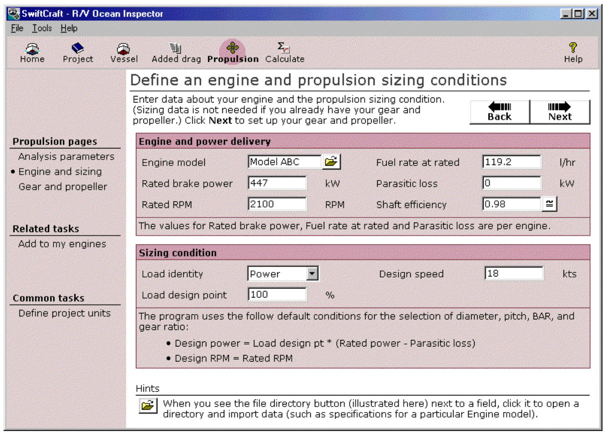
Effective tunnel diam: 0 m

Tunnel depth: 0 m

Propulsion analysis methods page

Engine data

As described above, the engine can affect propeller sizing decisions – particularly when the design point for the sizing results in reduced pitch. You will need to describe information about the engine and power delivery, as well as the propeller sizing objectives.



Define an engine and propulsion sizing conditions

Enter data about your engine and the propulsion sizing condition. (Sizing data is not needed if you already have your gear and propeller.) Click **Next** to set up your gear and propeller.

Engine and power delivery

Engine model: Model ABC

Rated brake power: 447 kW

Rated RPM: 2100 RPM

Fuel rate at rated: 119.2 l/hr

Parasitic loss: 0 kW

Shaft efficiency: 0.98

The values for Rated brake power, Fuel rate at rated and Parasitic loss are per engine.

Sizing condition

Load identity: Power

Load design point: 100 %

Design speed: 18 kts

The program uses the follow default conditions for the selection of diameter, pitch, BAR, and gear ratio:

- Design power = Load design pt * (Rated power - Parasitic loss)
- Design RPM = Rated RPM

Hints

When you see the file directory button (illustrated here) next to a field, click it to open a directory and import data (such as specifications for a particular Engine model).

Engine and sizing conditions page

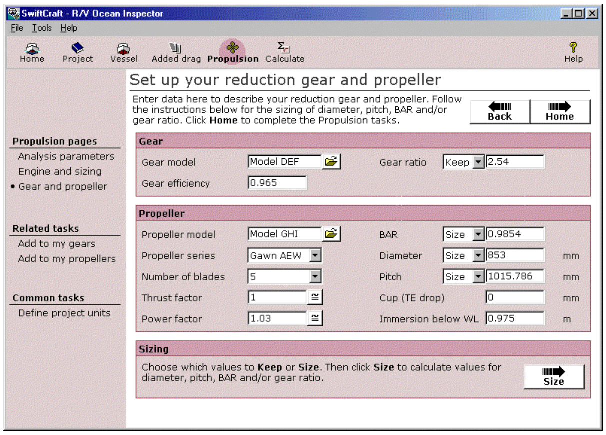
Reduction gear and propeller data

The reduction gear is defined by its ratio and gear efficiency. In advanced software, the reduction ratio will be integral to the propeller sizing process.

The definition of propeller performance conforms to the advice noted earlier – in that it allows for the correct basic propeller style (Gawn), as well as any needed correction for cup and cavitation. It also provides a means to correlate *theoretical* performance to what is *deliverable*.

Thrust (T) and power (P) factors are correlation multipliers that we use to better match real *on-the-water* performance for the propellers. The factors correct for small differences in performance that we might find with a commercial propeller.

A suitable propeller can be sized prior to a final analysis. The propeller BAR, diameter and pitch – as well as the reduction ratio – are found for the described design conditions.



Set up your reduction gear and propeller

Enter data here to describe your reduction gear and propeller. Follow the instructions below for the sizing of diameter, pitch, BAR and/or gear ratio. Click **Home** to complete the Propulsion tasks.

Gear

Gear model: Model DEF

Gear efficiency: 0.965

Gear ratio: Keep 2.54

Propeller

Propeller model: Model GHI

Propeller series: Gawn AEW

Number of blades: 5

Thrust factor: 1

Power factor: 1.03

BAR: Size 0.9854

Diameter: Size 853 mm

Pitch: Size 1015.786 mm

Cup (TE drop): 0 mm

Immersion below WL: 0.975 m

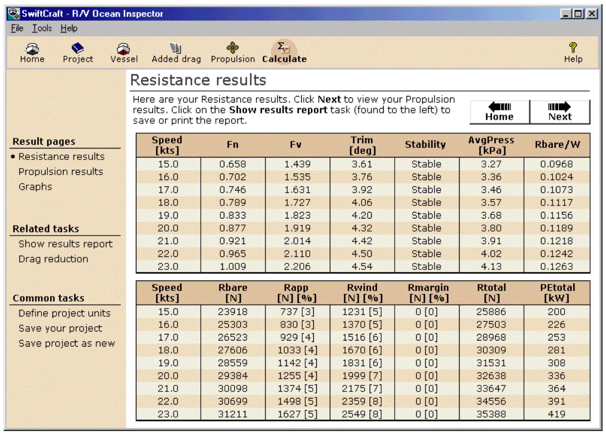
Sizing

Choose which values to **Keep** or **Size**. Then click **Size** to calculate values for diameter, pitch, BAR and/or gear ratio.

Reduction gear and propeller page

Analysis results

All data has been entered and intermediate calculations (such as propeller sizing) are completed. The only thing left is to *Calculate* the full resistance and propulsion results for your vessel.



Resistance results

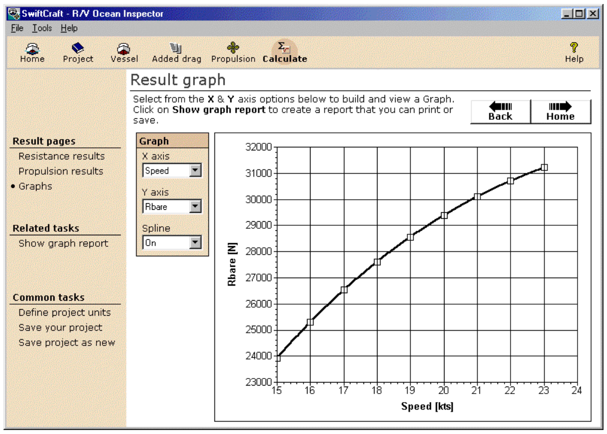
Here are your Resistance results. Click **Next** to view your Propulsion results. Click on the **Show results report** task (found to the left) to save or print the report.

Speed [kts]	Fn	Fv	Trim [deg]	Stability	AvgPress [kPa]	Rbare/W
15.0	0.658	1.439	3.61	Stable	3.27	0.0968
16.0	0.702	1.535	3.76	Stable	3.36	0.1024
17.0	0.746	1.631	3.92	Stable	3.46	0.1073
18.0	0.789	1.727	4.06	Stable	3.57	0.1117
19.0	0.833	1.823	4.20	Stable	3.68	0.1156
20.0	0.877	1.919	4.32	Stable	3.80	0.1189
21.0	0.921	2.014	4.42	Stable	3.91	0.1218
22.0	0.965	2.110	4.50	Stable	4.02	0.1242
23.0	1.009	2.206	4.54	Stable	4.13	0.1263

Speed [kts]	Rbare [N]	Rapp [N] [%]	Rwind [N] [%]	Rmargin [N] [%]	Rtotal [N]	PEtotal [kW]
15.0	23918	737 [3]	1231 [5]	0 [0]	25886	200
16.0	25303	830 [3]	1370 [5]	0 [0]	27503	226
17.0	26523	929 [4]	1516 [6]	0 [0]	28968	253
18.0	27606	1033 [4]	1670 [6]	0 [0]	30309	281
19.0	28559	1142 [4]	1831 [6]	0 [0]	31531	308
20.0	29384	1255 [4]	1999 [7]	0 [0]	32638	336
21.0	30098	1374 [5]	2175 [7]	0 [0]	33647	364
22.0	30699	1498 [5]	2359 [8]	0 [0]	34556	391
23.0	31211	1627 [5]	2549 [8]	0 [0]	35388	419

Tabular resistance results page

It is always useful to review the results in graphical form. This is the easiest way to check that the curve *shape* is reasonable. Does the shape of the drag curve correspond to what is expected as the boat approaches its principal drag hump? Do the drag coefficients follow a smooth curve, and if not, does this suggest potential error in the equations?



Select from the **X** & **Y** axis options below to build and view a Graph. Click on **Show graph report** to create a report that you can print or save.

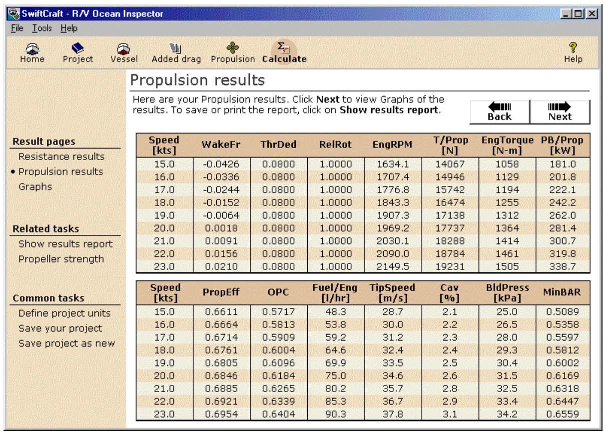
X axis: Speed

Y axis: Rbare

Spline: On

Graphical resistance results page

The propulsion analysis follows the equilibrium RPM thrust-drag solution at each speed. The results include various propulsion analysis figures – wake fraction and thrust deduction, RPM, thrust, torque, power, efficiency, cavitation, and even fuel rate.



Here are your Propulsion results. Click **Next** to view Graphs of the results. To save or print the report, click on **Show results report**.

Speed [kts]	WakeFr	ThrDed	RelRot	EngRPM	T/Prop [N]	EngTorque [N-m]	PB/Prop [kW]
15.0	-0.0426	0.0800	1.0000	1634.1	14067	1058	181.0
16.0	-0.0336	0.0800	1.0000	1707.4	14946	1129	201.8
17.0	-0.0244	0.0800	1.0000	1776.8	15742	1194	222.1
18.0	-0.0152	0.0800	1.0000	1843.3	16474	1255	242.2
19.0	-0.0064	0.0800	1.0000	1907.3	17138	1312	262.0
20.0	0.0018	0.0800	1.0000	1969.2	17737	1364	281.4
21.0	0.0091	0.0800	1.0000	2030.1	18288	1414	300.7
22.0	0.0156	0.0800	1.0000	2090.0	18784	1461	319.8
23.0	0.0210	0.0800	1.0000	2149.5	19231	1505	338.7

Speed [kts]	PropEff	OPC	Fuel/Eng [l/hr]	TipSpeed [m/s]	Cav [%]	BldPress [kPa]	MinBAR
15.0	0.6611	0.5717	48.3	28.7	2.1	25.0	0.5089
16.0	0.6664	0.5813	53.8	30.0	2.2	26.5	0.5358
17.0	0.6714	0.5909	59.2	31.2	2.3	28.0	0.5597
18.0	0.6761	0.6004	64.6	32.4	2.4	29.3	0.5812
19.0	0.6805	0.6096	69.9	33.5	2.5	30.4	0.6002
20.0	0.6846	0.6184	75.0	34.6	2.6	31.5	0.6169
21.0	0.6885	0.6265	80.2	35.7	2.8	32.5	0.6318
22.0	0.6921	0.6339	85.3	36.7	2.9	33.4	0.6447
23.0	0.6954	0.6404	90.3	37.8	3.1	34.2	0.6559

Tabular propulsion analysis page

Summary

This example has illustrated a number of important features that are necessary for a reliable propulsion analysis and speed prediction. Below is a list of "*ten commandments of reliable speed prediction*" [MacPherson 1996] that will provide a solid basis for anyone conducting speed-power predictions and propulsion analyses:

1. Use representations of real physical systems

Do not use simplistic calculations, such as a single OPC for all boats.

2. Use contemporary techniques

Follow the current calculation recommendations of the international hydrodynamic societies. For example, be sure to use recommended propeller scale correction and model expansion methodologies.

3. Use the right kind of prediction method

Some prediction methods are strong for design, others for analysis. Learn how the method's test data was developed into the numerical method.

4. Use a method that contains a suitable data set

Know what hulls were used to develop the methods you wish to use. Consider the speed range and hull parameters.

5. Correlate predictions to real test data

Compare your predictions to boat tests. In fact, we recommend instituting a rigorous sea trial program to analyze boat tests and compare them to predictions [MacPherson 1995, MacPherson 2003].

6. Remember all speed prediction components

Speed prediction is more than just bare-hull resistance. Don't forget appendage and wind drag, and the propulsion analysis.

7. Use a proper propulsor model

Make sure that the propeller definition uses the correct basic propeller style (e.g., Gawn), as well as any needed correction for cup and cavitation.

8. Test the results against established criteria

Compare your prediction against other predictions using non-dimensional measures, such as transport efficiency. View results graphically across a range of speeds to see that the curve shapes are sensible.

9. Use validated methods, algorithms and techniques

Simply plugging data through an equation is no guarantee of success. Publication and coding errors are all too common – especially with in-house software. Be careful to validate the code, not only with data from the original method hull forms, but with other hulls.

10. Follow a consistent prediction strategy

Remember your objective – to get reliable answers. If you have experience with a particular method that gives you a *consistent trend*, you are better off than with a method that is perfect sometimes and poor at others. Establish a process and then stick with it.

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