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Marine Performance Technology Exchange

The Marine Performance Technology Exchange is an electronic newsletter whose mission is to share contemporary propulsion and powering topics.

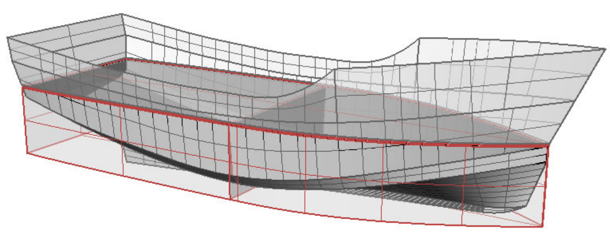
Vertical Prismatic: The Forgotten Coefficient

What is the vertical prismatic coefficient? Is it useful to tell me anything about my hull?

The vertical prismatic coefficient (C_{VP}) may well be the most overlooked of all of the volumetric hull design coefficients. We all are very comfortable with block coefficient (C_B), prismatic coefficient (C_P) and waterplane area coefficient (C_W), for example, but how many of us could explain, first, how to calculate the vertical prismatic, and second, its value in hull design.

In the manner that C_P reflects the ratio of immersed volume (∇) to the longitudinal extrusion of the maximum section area (A_X), C_{VP} reflects the ratio of ∇ to the vertical extrusion of the waterplane area (A_W).

To calculate C_{VP}, you cut the hull at the waterplane, and then extrude the waterplane area by the ship's calculation draft (T):



And, $C_{VP} = \nabla / (A_W * T)$, or alternatively $C_{VP} = C_B / C_W$.

We see from the graphic that C_{VP} is a measure of the vertical distribution of the immersed volume from waterplane down to the keel. Put another way, it gives us an idea if the volume is collected near the waterplane (low C_{VP}) or more evenly distributed from waterplane to keel. You'll often find that C_{VP} and C_W are inversely related – ships with high C_W will have low C_{VP}.

This coefficient also quantifies a traditional subjective description of the section shape – "V" or "U". A ship with a lot of flare or a buttock-flow stern (V-shaped) will have a low C_{VP}. Its volume will be positioned more near the waterplane. The opposite is true for a wall-sided ship (U-shaped). It will have a high C_{VP}.

Of course, it is quite common for a ship to have a U-shaped bow and a V-shaped stern, as is shown here. (This illustrative hull started from the UBC trawler series.) It therefore has a higher C_{VP} forward and a lower C_{VP} aft. For this reason, C_{VP} is very often also shown in Fore and Aft components, or C_{VPF} and C_{VPA}. A similar notation is used for C_{WF} and C_{WA}.

(Most definitions of C_{VPF} and C_{VPA} are based on a division of volume at mid-LWL. However, a division based on LCB – the centroid of volume – may actually be more meaningful.)

For example, C_{VPF} for the forward volume of this hull is shown below, and would equal $C_{VPF} = 0.76$ with $C_{WF} = 0.67$.

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Check your version

The following is a list of current program versions and dates. If you have a current MSU subscription, you can click on the appropriate link below to go to the update download page. (Note: users of SwiftTrial and SwiftCraft are on a perpetual subscription.)

NavCad 2007 [5.31.0114, Mar 2007]
PropCad 2007 [4.61.0156, Jan 2007]
PropExpert 2007 [5.30.0080, Jan 2007]

Look for new updates of SwiftCraft and SwiftTrial in 2007 Q2.

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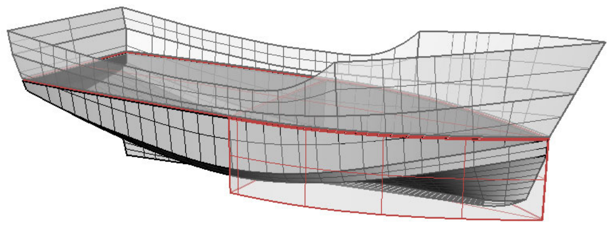
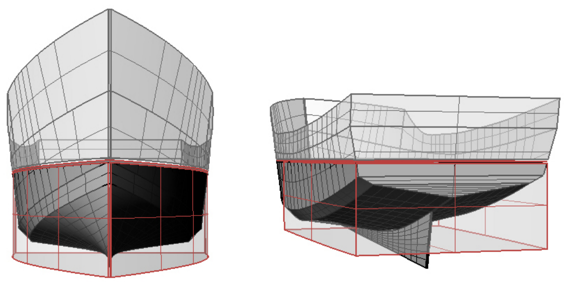


Its after components would be C_{VPA} = 0.69 and C_{WA} = 0.98. You can see the vertical distribution of forward and after volume in the end views below.



Vertical prismatic tells us a few things about the hydrodynamics of a hull. Its contribution to resistance and propulsion are generally only significant for single-screw vessels, where C_{VPA} has a small direct relationship with drag, wake fraction and thrust deduction (i.e., all increase with larger C_{VPA}).

While C_{VP} may have a small part to play in resistance and propulsion, it can be very useful in evaluating the pitch and heave seakeeping ability of a hull. Think about the parallels between pitching and rolling. The resistance to roll is created by increasing an offset transverse volume as the boat rolls, often by a virtual increase in the transverse waterplane area. A ship in pitching finds its "righting" energies by the increase in longitudinal volume as the boat pitches, and flare of the sections contributes to a quicker development of the longitudinal volume, or put another way, a greater wave damping. In other words, a wall-sided ship with high C_{VP} will not generate as much volumetric wave damping energy as a ship with flare and low C_{VP}.

An interesting measure of this was the development of a formula that used these coefficients to indicate a relative seakeeping rank [Bales, 1980]. This rank was based on a weighted pitch and heave response of a collection of destroyer-type hull forms to operation in head seas (L/B from 8.0 to 9.8 and B/T from 2.5 to 3.7).The results of this work, and the subsequent ranking formula, indicates that the design objective for improving seakeeping is to increase C_W and reduce C_{VP} (both fore and aft). The significance of the terms from most to least significant was C_{WF}, C_{VPF}, C_{VPA} and C_{WA}.

One caveat. This analysis did not consider slamming, so wide flat sections would not necessarily be a good design choice for extremely severe conditions – even though it had high C_W and low C_{VP}. So, even though increasing C_{WF} and reducing C_{VPF} suggests better seakeeping, there is a practical lower limit due to the potential for slamming. The dataset for the ranking had a lower limit of C_{VPF} of 0.68 and an upper limit of C_{WF} of 0.70.

Bales, N. K., "Optimizing the Seakeeping Performance of Destroyer-Type Hulls," *Proceedings* 13th ONR Symposium on Naval Hydrodynamics, Tokyo, Japan, Oct 1980.

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PropExpert
New Blade Scan Analysis tool
Average and Peak cavitation calcs
Improved reporting

PropCad
Support for thickness-camber format
Updated CAD drawing
Additional 3D export formats

Technical presentation notice

"Estimation of Propeller Properties for Vibration Analysis" is the working title of a paper to be delivered to the New England Section of SNAME in June 2007 by Don MacPherson, Mat Packard and Vin Puleo. The objective of the paper is to provide a summary survey of calculation methods that are available to estimate the material mass and wetted added mass properties of a propeller for vibration analysis. Ranging from simple parametric formula to more detailed radius-chord integration methods, the technical paper will acquaint readers with calculations for propeller weight, mass moment of inertia, axial added mass of entrained water , and torsional added mass moment of inertia of entrained water. Validation examples will also be presented.

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