Research Summary
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Summary

Modern planing hulls are characterized by having a useful load fraction, excellent cost-effectiveness ratios, simplicity of operation and good seakeeping characteristics over a wide range of speeds and sea states.

Planing hulls with hard chines are contrasted to the round bilge style hulls. Round bilge hulls are slower at higher speeds but "ride" better in a seaway. The hard chine hull was developed to improve seakeeping first, while retaining as much speed as possible, and improving lift-drag ratio. This led to a hull with a high length-beam ratio, high beam loading, double chine and moderate deadrise. This type of hull has a good capability for rough water operation.

Length is the principle dimension used to define speed-size relationships at low speeds, where formation of surface waves develop and these waves travel at the speed of the hull. In English units, this is expressed as the wave speed (in knots) divided by the square root of the wave length (in feet). Except in shallow water, this ration will equal 1.34. The speed-length ratio of a displacement vessel is defined as the speed (in knots) divided by the square root of the waterline length (in feet).

The dimensionless critical speed is defined as:

\[ \frac{v_s}{\sqrt{L}} = 3.36 \]

When \( \frac{v_s}{\sqrt{L}} = 1.34 \) marks the upper limit of true displacement operation, and the beginning of high speed. Below \( \frac{v_s}{\sqrt{L}} = 1 \), the hull is supported entirely by buoyant forces and the drag is predominantly frictional, so the hull should be tapered at the stern and curved upward toward the waterline to minimize flow separation. When \( \frac{v_s}{\sqrt{L}} = 1.34 \), wavemaking becomes a barrier to further increases in speed. In this case, a rounded hull will end up climbing up the back of its own bow wave. This is why high speed craft should have lower lift-drag ratios. Also, above \( \frac{v_s}{L} = 1.34 \), the buttock lines should be flatter, terminating in a transom stern. The high speed "semi-planing" range is between about 1.3 to about 3.0. After a speed-length ratio of 3.0, wave resistance is no longer an important factor. Frictional resistance remains the dominant factor. For this reason, keep the wetted surface area to a minimum.

Above semi-planing speeds, use a Froude number \( F_v = \frac{v}{\sqrt{gL}} \).

At lower speeds, longer hulls have a great advantage over shorter ones. The chief characteristic of the planing hull is effective flow separation, both at the transom and along the sides, to prevent the formation of negative pressure areas on the bottom of the hull. A hard chine hull accomplishes this. Spray rails, properly placed also helps with this, or, build the hull with local longitudinal convexity (rocker) in the transom. This will provide for negative pressure that leads to a trim up by bow moment, to keep the craft from running too flat.
A properly designed planing hull has an advantage over a regular displacement hull, when running at $v_k / \sqrt{L} > 3.0$, because wavemaking resistance, rather than becoming a barrier, actually decreases for planing craft as speed increases.

A good planing hull will operate effectively in high and low speed regimes and in rough water. The best hull form to meet this requirement is a hull with a high length-beam ratio, greater than 5.0. A good planing hull also has a moderate deadrise of about 15° aft, increasing to a high deadrise (about 45°) forward.

Planing craft is used extensively in military applications, with an explosion in the development of small warships. Major factors in evaluating these craft are speed, ability to maintain speed in a seaway, and seakeeping. Good seakeeping requirements lead to the use of deep-vee, or double-chine planing hulls. The construction of planing hulls for commercial purposes accounts for about 95% of planing hulls, primarily in the 10 to 100 foot range.
Summaries of Articles Used for Research in the Eureka Project


Summary

This paper outlines the history of progress in the development and design of stepped planing hulls. Advantages to stepped hull technology are speed and lower power requirements because of reduction in friction. Disadvantages are increased pressure drag and more difficult handling. Another possible reference cited in this article is the book, "Speedboat", by D.W. Fostle. The progression was from a single centrally located step to a multi-step hull including a degree of deadrise and vent pipes. Model testing by towing was later incorporated. Testing supported the conclusion that a single step amidship gave the better results. Load-carrying stepped boats were designed and used in WW1, using a 14° deadrise angle at the step – these vessels had proposing difficulties, however. The camber-curved “fantail” design with an adjustable stabilizer at the stern brought about improvement in handling. This vessel was found to have a greater speed when loaded than when light, due to the impingement on the afterbody creating drag rise. It was then showed that a small step, as small as 1/16 of an inch, along with a hull that decreases in width after midsection, can give satisfactory performance. Testing also showed that shifting LCG on a stepped hull as much as 4% of hull length has little effect. Also, it showed that variances in loading do not degrade the efficiency of a stepped hull, and that stern stabilizers reduce porpoising. Wake measurements have shown that an efficient design is one in which the main, forebody planing surface carries most of the load (80-90%) and afterbody shape should be determined by the shape of the wake. The afterbody should be clear of the water and the spray blister, which is accomplished by sweeping the step back. This sweep can also allow aspect ratio to increase as speed increases even after the stagnation line intersects the step. The optimum deadrise angle seems to be 15° with a sweepback of 40°.

Conclusions

The optimum angles for deadrise and sweepback (15° and 40°) should be employed, as well as a curved camber. The step should be within 4%L of the LCB and have a Vee forward planing surface. The "boomerang" shaped step we envisioned has actually been attempted with some success and we may attempt this rather than a plain transverse step.
2. "Performance Potential For Stepped Planing Monohull and Catamaran Runabouts and Motor Cruisers", Eugene P. Clement and Joseph G. Koebel, Jr.; SNAME Publication (date?)

Summary
This paper also indicates that the most efficient deadrise is 15° and that the step should be swept back. Camber curvature is advantageous when incorporated into the planing region. The biggest drawback to modern step designs is the lack of efficiency and handling required for non-racing vessels. Design of a step hull is more complex, and little modelling has been done for stepped boats. Pressure distributions and the format or spray and wake are critical. Low resistance and start-up stability have been the major emphasis of model tests to date. Testing from several countries has yielded similar results in the conclusions about efficient hull design: a simple hull with a single step, midlength of the hull at about the center of gravity, with most lift (at speed) provided by the forebody in front of the step. The best angle between forebody and afterbody keels is typically 4 or 5° for boats. The right trim angle is important to eliminate porpoising – a small hydrofoil can help reduce this problem and keep the vessel in a stable region. This paper also contrasts stepped and unstpped hulls of ∆ = 10,000 lb at 40 mph running speed. Comparisons are charted for reference. Trim control allows the vessel to run at the angle of least resistance. Wake behind the vessel is also assessed and results are plotted.
Lm = 6’
λ = 7
Ls = 42’

Deadrise angle = 15°
Sweepback angle = 40°
Estimated Δs = 600t dry, 630t wetted

Model will be designed with 20 stations and 7 waterlines.
Trim angle not yet determined.
Design will have an angle between forebody and afterbody keels of 5°.