
Ship Evaluation Method 2024

*by Prof. Dr.-Ing. Karl-Günter W. Hoppe, MD of Foil Assisted Ship Technologies cc,
Somerset West, South Africa*

Concerning ship design and especially the design of Fast-Light Craft the environmental pressure will increase in future as more catastrophic weather appearances will appear.

Naval Architecture requires new input as ships have to become more efficient to reduce carbon footprint.

The ships performance alone is not sufficient but requires now also highest possible efficiency to reduce carbon emissions which means "Greenboats" are in question.

Electric batteries are still very heavy for these kW-hours used in ships and on which the range of a ship is dependent. This applies especially to the so-called Fast Light Craft which are used as Yachts, Fishing boats, Ferries, Patrol Boats, Police and Military craft etc.

It was found that most efficient craft for these applications with good speed could be Hysucraft-type hulls. In the discussion below this shall be elaborated, see Hoppe [2].

During the Hysucraft development a tool was required which allows to compare the ship efficiency between craft. We already used a method to compare the quality of a foil wing with a planing craft by use of the aeronautical term lift/drag ratio which is publicly well understood.

In ship building the inverse is used to compare hull qualities, called the Resistance/Displacement weight ratio ϵ with R and D in Newtons it gives a dimensionless ratio, $\epsilon_s = R/D$ with (R) being resistance and (D) being weight force.

The ship weight D [t] is usually given in metric tonnes with t = 1000 kg, but as a force has to be expressed in Newtons or more commonly kN:

$D \text{ [kN]} = D \text{ [t]} * g \text{ [m/s}^2\text{]}$ with g being acceleration of earth, 9.81 [m/s²].

However, to consider the ship situation a propulsion system is used which creates a thrust force (T) which has to counter balance the resistance force and which is a horizontal force, to create equilibrium of horizontal forces. However, the propulsion efficiency is involved with $T = R/O.P.C.$ with O.P.C. being the overall propulsive coefficient, see Blount et all [4] for propeller efficiency.

The thrust force consists of aeronautical and hydrodynamic forces, but the sum of all has to be the resistance force.

All vertical forces have to be equal to the lift forces which also can be aeronautical and hydrodynamic or hydrostatic forces but their sum has to be equal to the weight force vertically down.

The Resistance / Displacement weight ratio ϵ_s can now be extended by multiplying both parts with the ships velocity V_s to compare the powers.

$$\epsilon_s * V_s = EPS = \frac{R[\text{kN}] / \text{O.P.C}}{D[\text{kN}]} * \frac{V_s [\text{m/s}]}{V_s [\text{m/s}]} = \frac{P_{\text{thrust}}}{P_{\text{basic}}}$$

which is a dimensionless ratio and defined by Gabrielli and von Karman as the Transport Efficiency (TE), see [1] and referred by Wright [3].

In the case of Hovercraft or SES this propulsion power has to include the power required for driving the lift fans.

The Transport Efficiency (TE) is defined as $TE = P_b [\text{kW}] / (D [\text{t}] * g [\text{m} / \text{s}^2] * V_s [\text{m/s}])$ and in other words our EPS is also the Transport Efficiency when the power P_b is known or measured on the ship propulsion system. So, the Transport Efficiency can be determined when the ship is running at 100% MCR (full power!) and the speed is measured and the full load weight is known. EPS and TE are interchangeable terms!

The Froude Displacement number is a kind of dimensionless speed and is:

$F_n \nabla = V_s [\text{m/s}] / \sqrt{g \left[\frac{\text{m}}{\text{s}^2} \right] * \nabla^{0.3333} [\text{m}]}$ with $\nabla [\text{m}^3]$ being the ship weight in [t] but for a ship in fresh water also in cubic meters and the acceleration due to gravity. For simplicity we compare the ships to operate in fresh water for which $D [\text{t}]$ is equal to $D [\text{m}^3]$. In sea water $F_n \nabla$ changes slightly but less than 3.5%.

The Transport Efficiency (TE) is recommended by Gabrielli and von Karman to be used when comparing ships and other forms of transportation. [1].

We determined the EPS ratios of many different ship and boat types from published data and collected them in Table I and plotted some of them over the dimensionless ship speed, (the Froude Displacement number) in Table 1, which also shows tendency curves of typical ship types. This gives a good idea how ships compare and for which non-dimensional speeds they are best suited.

There is still the problem of the power required to operate ships in waves and winds, but it shall be left for later studies.

We developed the Hydrodynamic Performance Ratio (HPR) by dividing the Froude number by the EPS value. The HPR indicates a ships quality by a single number. Unlike EPS, the largest number of HPR now indicates a most efficient craft. The most efficient ships hardly reach a HPR of 30, which would be a most efficient craft and well acceptable, see Table 1.

A company specializing in the development of Fast Light Craft (FLC) with hydrofoil support was established in 1998 and was called Foil Assisted Ship Technologies cc (FASTCC).

It was a ship design company established to collaborate with Naval Architects on the hydrofoil development and optimization of Hydrofoil Supported Craft (Hysucraft).

In the early years many Hysucraft model tests in the towing tanks were conducted on the preferred hulls of planing type catamarans. Model tests on the hulls without foils and after this, the designed foil systems free running in the towing tank and later with hull plus foils were conducted. It was found out that the foil system inside the Catamaran tunnel reached much higher efficiencies than in the free running condition of the hull without the foils.

The test results allowed the development of computer programs with empirical formula establishment which allowed the-so called “Mathematical Hysucraft Model” which also contains foil strength calculations and optimized power predictions.

The software was developed with feedback of built Hysucraft and new model tests continuously updated and now after more than 30 years development used to design optimized Hysucraft.

The use of the Transport Efficiency (TE) and the HPR Rating Number are included in the Performance print-out and allow an immediate judgement of craft efficiency in comparison to many other types of craft which are collected in Table 1 and shown on Fig. 1, EPS over Froude Displacement Number.

To determine the Transport Efficiency (TE) see the following example:

*The French A2V 24m for 60 passengers with a top speed of 60 knots (30.867 m/s), full load weight of 55 [t] and a power of 2 * 1440 kW (2880kW) at MCR,*

work out dimensionless speed (Froude Displacement Number):

$$Fn\bar{\nabla} = V / \sqrt{g * \bar{\nabla}^{0.3333}} = 30.867 \text{ (m/s)} / \sqrt{9.81 * 55^{0.3333}} = 5.0539$$

EPS = P [kW] / Δ [t] * g [m/s²] * Vs [m/s] = 2880 / (55 * 9.81 * 30.867) = 0.17296 which is also the Transport Efficiency, (TE).

The Hydrodynamic Rating Number HPR is then $Fn\bar{\nabla} / EPS$:

$$HPR = \frac{5.05696}{0.17296} = 29.2377$$

HPR is strongly dependent on the speed for the craft and reaches top values at very low speeds and also for very high speeds. For most craft the top speed is used for HPR. However, for ferries the cruising speed might be of interest.

If you compare the HPR of the A2V (number 64) with data of Table 1 it is one of the largest HPR number with 29.22 of all the ships in the Table and indicates a most efficient ship. Work out your own ship in a similar way.

The best Hydrofoils indicated on Table 1. reach about 22, Tucumcari 2 about 18.3, some Hovercraft about 26.3, SES Corsair about 22.54, ThunderChild 2 world record run has HPR = 26.176 at top speed and 24.117 at

45 knots cruising speed, Stealth Yachts 16m Hysucraft is 22.73, Halter E-Cat Hysuwac is 20.84, GEO Shipyard ferry 80' is 17.104, Alpha Yacht 80' is 28.765, most efficient high-speed Yacht. Hysucraft compete well with most other craft types.

The HySuGe-Cat (no. 67) stands for hydrofoil-supported-ground-effect Hysucraft Catamaran and is the latest development of an optimized Hydrodynamic and Aerodynamic design with the highest of the tabulated HPR of 44.37 which means it is the most efficient vessel design available of all the collected data. An example of the power prediction is shown in Table 2 with these Hydrodynamic Performance Ratio (HPR) calculated at 60 knots.

The HysuGe-Cat is the Alpha Yacht 80' platform with an optimized super structure (airfoil-like) and aerodynamic in Ground Effect which becomes extremely efficient at high speeds. It seems to be one of the most efficient Blue-Water Yacht world-wide. However, so far it is the result of the Optimization and we have still to find an Investor to support the build and approve the prediction.

The above evaluation method gives every vessel owner a tool to find out how his vessel performance compares to others.

Conventional Hydrofoils HPR data are somewhat disappointing which might be badly influenced by low O.P.C data of the propulsion system and by the additional drag associated with the still often-used surface piercing V-foils.

Hydrofoils are still used in certain countries with only a few new developments but are starting to make a come-back for electric ferry proposals etc.

The Canadian Hydrofoil Bras D'or has a HPR = 16.6, not that good for efficiency but it has great performance, due to Gas Turbine propulsion.

An advantage of this Evaluation Method is that fast and slow craft, small and large ships and ships with Internal Combustion Propulsion engines and even ships with electro-battery propulsion can be compared.

The use of Hydrogen Technology with fuel cells shall be investigated in future projects, for craft with long range requirements.

Literature:

- [1] Wasserfahrzeuge für hohe Geschwindigkeiten, by H.P. Radar, Schiff und Hafen Kommandobrücke, Heft 3 / 1981, 33. Jahrgang.
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