A TECHNICAL AND COMMERCIAL VIEW OF THE WATERJET PROPULSION MARKET

JetTorque from HamiltonJet

Issue 04
November 1994

From the Bridge...

"Tests have shown waterjets are approximately 15% more efficient than comparative propeller solutions."

Quote from Cruise & Ferry Info, Issue CFI No 9/93.

It is generally accepted that, at vessel speeds above 25 knots, waterjets return higher propulsive coefficients in suitable hull forms than conventional propulsors.

Essentially, this can be explained by the fact that the clean underwater installation of a waterjet does not adversely effect the hull resistance, whereas appendage drag of a conventional propulsor adds significantly to overall resistance as boat speeds increase. Given average boat speeds are increasing and 25 knots is now regarded as the bottom end of the 'high speed' spectrum, waterjets are routinely installed as the preferred propulsion option.

Spanish Civil Guard Patrol Craft
40 knots with twin HJ362 waterjets

Recent advances in design and manufacturing techniques have added to the efficiency gains. Leading manufacturers such as Hamilton Jet have extensive R&D programmes, resulting in major advances in pump and hydrodynamic technology. Better understanding of the relationship between hull and propulsor have allowed designers to produce optimum hull designs for a wide range of jet powered work and patrol craft and fast passenger ferries.

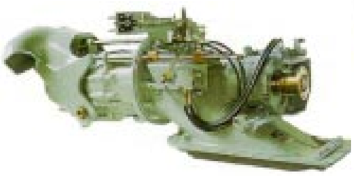
Expanded Product Range

Innovation and a continued commitment to meeting customers needs has seen the introduction of a new jet model to Hamilton's already extensive range.

Designated the model HJ321, this new jet features a 320mm diameter impeller, capable of accepting direct drive power inputs up to 480kW.

Available in single or multiple jet matched shipsets, the HJ321 represents a very competitive option for a variety of medium sized craft.

A synergistic approach to the design of the HJ321 optimises each individual function before assembly into a factory tested packaged. Installation and setup requirements by the shipyard are minimised. In addition to normal Hamilton Jet features such as integral intake and protection screen, innovations incorporated into the HJ321 jet are a completely self-contained hydraulic astern actuating system, with integral oil cooler and jet driven pump.



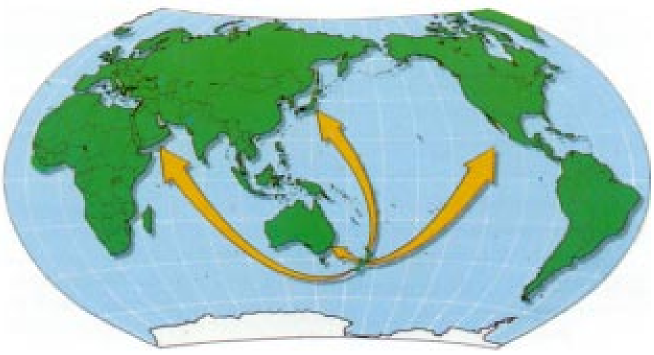
Expanded Support Network

Reinforcing Hamilton Jet's philosophy of recognising and meeting it's customers needs is an extensive global network providing logistic support at all levels.

Hamilton Jet distributors are located in most major marine centres of the world. Recent appointments in the Middle East brings the number of locations serviced by Authorised Distributors to over 45. All Hamilton Jet distributors have factory trained staff and are able to offer a complete range of services from initial jet unit selection to onboard servicing and maintenance work.

Factory Support

The global network is supplemented by a factory based "Ready Reaction Force" of highly skilled waterjet technicians on permanent stand-by to fly anywhere in the world at short notice. This team can provide installation and commissioning support services for all projects.



In this Issue...

Special Points of Interest:

- How to ensure optimal waterjet efficiency for your vessel.
- Hull shape affects vessel and waterjet performance.

USA Office

Supplementing the existing USA Distributor network, a Hamilton Jet office of Hamilton Jet has been established on the East Coast. This office will provide direct access for designers and builders involved in projects using larger HM Series jets, to the more intensive application engineering support services such projects demand.

AFFECTING EFFICIENCY –
Optimising Performance

For highest returns, designers optimise all elements of a craft and operators continually strive to improve operational efficiencies.

One of the elements which has a significant bearing on the craft's overall effectiveness is the propulsion system. There are a number of issues regarding this component that need to be considered so efficiencies can be maximised.

In Issue 3 of Jet Torque, Propulsive Efficiency (PC) was defined as…

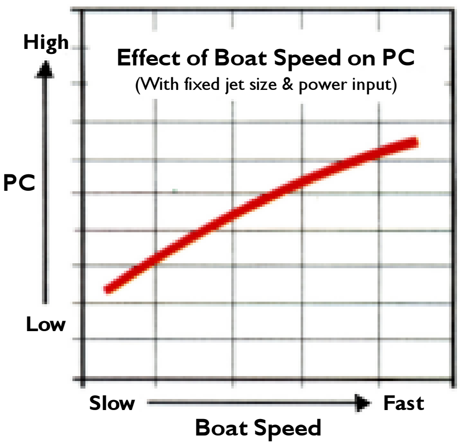
$$PC = \frac{\text{Effective Horsepower (EHP)}}{\text{Shaft Horsepower (SHP)}}$$

being the measure of the efficiency of the conversion of shaft power to thrust required to push the naked hull. As this measure includes specific craft parameters such as hull resistance and speed, then it is only appropriate for individual applications.

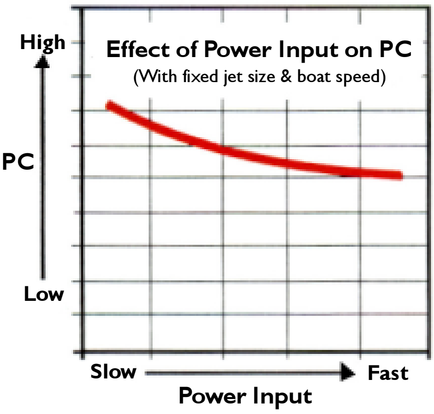
Of course there are many parameters that make up the design of a vessel and influence its performance, but three key factors which affect Propulsive Efficiency are…

• **Jet Size** – up to a point, the larger the jet diameter the higher the PC, since as the jet diameter increases the component pump and intake efficiencies also increase.

• **Boat Speed** – for a fixed jet size and power input, as boat speed increases, PC increases.



• **Power Input** – for a fixed jet size, if at a given constant boat speed the power input is reduced, then the PC increases.



The above factors can be summarised in two ways as follows…

A – **SMALL JET**
+ HIGH POWER
+ LOW BOAT SPEED
= LOW PC

A typical example of how this case can occur in practice is if displacement, and therefore resistance, is higher than design. Boat speed is then down, along with the PC. Awareness of maintaining weight within the design limits is critical in achieving highest PC.

B – **LARGE JET**
+ LOW POWER
+ HIGH BOAT SPEED
= HIGH PC

As this case is the converse of that described above, if vessel weight is minimised and the displacement/resistance is lower than expected, then the boat speed is up and a higher PC is achieved.

Often though, the compromise of a less than optimum jet can well provide higher Transport Efficiency Factors than a selection that indicates highest PC, when considered over the economic life of the vessel.

When selecting a propulsor for a particular vessel, the highest PC achieved will return the best fuel efficiency, etc. However, it may not necessarily be the most commercially practical selection. In real practice, PC alone is not usually the sole factor in determining the final configuration of the vessel.

Remembering that a waterjet nozzle size varies like propeller diameter, then to maintain efficiency, the nozzle size needs to increase as the vessel displacement increases and, as speed increases, the nozzle size decreases.

The selection of a waterjet for a particular application can have two solutions…

• One based on achieving **optimum propulsive efficiency**, considering direct operating costs only;

… or…

• The other based on achieving **optimum economic life**, taking into account capital costs as well as operating costs.

For **Optimum Propulsive Efficiency**, a jet nozzle size is selected that gives minimum power at the vessels design speed. Selection on this basis may result in the lowest operating costs but at the expense of high capital costs as the jet size will, by necessity, be relatively large.

For **Optimum Economic Life**, a smaller nozzle size (with correspondingly lower capital cost jet) may be required. Since weight savings are achieved through the employment of smaller jets, then only marginally more input power may be required to realise vessel design speed, compared with the power necessary to obtain optimum PC. Over the economic life of the vessel, the lower capital costs of a marginally less than optimum jet often offset the slightly higher day to day operating costs, ultimately providing the operator with higher returns.

Hamilton Jet have developed a software package for selecting an optimum nozzle size to suit the craft's proposed operational parameters. In addition to usual physical data necessary to select a model that provides maximum thrust for the broad design parameters, additional inputs can be entered into this program. These include definitive operational parameters such as operating hours per annum, refuelling schedules and depreciation period. Analysing this data enables a jet that provides the lowest costs over the economic life of the vessel to be selected.

MONOHEDRON OR WARPED? –
The Right Attitude

Propulsive Efficiency is just one of many components in a successful craft. If another component, such as the hull design, is unsuitable for the proposed usage, then no matter how efficient the propulsor is, the vessel will not perform to expectations.

Whilst Hamilton Jet is not in the hull design business, 30 years experience with waterjet propulsion has accumulated a considerable data base of compatibility with different hull forms.

Most commonly used design for high speed work and patrol craft, up to say 30 metres, is the planing monohull form. The design of this hull form is such that when driven beyond natural displacement speed, hydrodynamic lift is developed and the shape of the side/bottom interface allows the hull to break cleanly from the water and plane on the surface, minimising drag and allowing high speeds to be attained.

Example of a well trimmed planing monohull – 13.4m customs Patrol craft with twin 362 jets

The ability to transition easily from displacement to planing mode is critical and there is an interplay of many factors which affect the crafts ability to achieve this. These include deadrise angle, LCG position, hull loading and hull lines.

Hull Loading

The hull has to be designed with a bottom surface area large enough to carry the anticipated laden displacement or "All-Up-Weight" of the vessel (in operational trim). If a hull is over-loaded for it's size, very high 'hump' or pre-planing resistance is exhibited which, in some cases, can inhibit it's ability to flatten off and achieve planing speeds.

The following "Rule of Thumb" formula can be used to assess hull suitability for waterjet propulsion…

$$\text{LOADING (kg/m}^2\text{)} = \frac{\textbf{AUW}}{\textbf{LWL x BPX}}$$

AUW = All-Up-Weight **(kg)**
LWL = **Waterline Length (m)**
BPX = **maximum Chine Beam (m)**

Assuming length to beam ratios of between 2.5 to 4.0, then experience has shown that for loadings of…

- **200 - 250kg/m² –** the hull should plane off easily at or below 20 knots with moderate power input.
- **300kg/m² –** the same hull will be adopting a steep trim angle at the "hump" and may require more power to overcome the resistance and, a higher planing speed to avoid dropping off the plane.
- **400kg/m² –** the hull would be over-loaded and the power required to plane significantly increased. To avoid dropping off plane, the vessel would need to cruise at say 30 knots and for this would require sufficient power to enable a maximum speed of at least 40 knots.

Having determined that the hull should be capable of planing, it is next necessary to establish the best hull shape, which should be optimised for the craft displacement and design speed.

Monohedron Hull Lines

Monohedron lines (chine and keel parallel over planing area) are generally recommended for speeds 30 knots and above. They exhibit best handling and efficiency at these speeds. These hulls can have a relatively high resistance at the "hump" and often trim tabs or wedges are fitted to minimise this. However, wedges can add to the hull resistance at higher speeds so, for very high speed craft, design for minimum bottom loading to easily transition to planing mode. Minimum deadrise of 10° is recommended for jets. Resistance increases with deadrise angle but up to 25° may be required for good ride and handling characteristics.

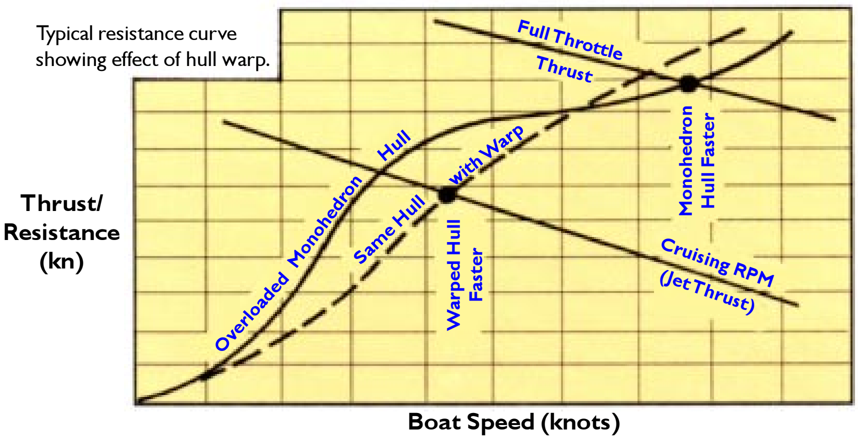
Warped Hull Lines

A large number of craft are limited to operating in the 10 to 30 knot speed range due to sea conditions and other factors encountered in day to day activities. For a heavily loaded craft, a warped hull, with reducing deadrise angles aft, exhibits less resistance at the "hump" and consequently will plane easier with less power input.

Maintaining full chine beam from midships through to the transom will also reduce "hump" resistance. Such a hull form has advantages for craft such as fishing vessels which are required to travel out to the fishing grounds at a reasonable turn of speed in a light condition, but be able to plane easily when laden for the return journey. Top speed for hulls with warped lines should be limited though to around 25 knots as the faster the hull is driven, the flatter it trims. This can result in the stem being driven into the water, causing bow-steer and subsequent handling problems.

The graph below shows a typical resistance curve for an overloaded monohedron hull compared with the same hull with some warp in it. It can be clearly seen that whilst the monohedron hull has a higher top speed, it has a pronounced hump to overcome and in this example the cruise position is right on the hump. The warped hull version has a flatter hump and a higher cruise speed but with a reduction in top speed.

Of course, many factors contribute to the performance of a vessel and the above comments are intended for guidance only on these specific components, based on experience.



From the Log Book...

Joint Research Projects Test Jets

Ongoing research and development is an essential element in ensuring technological superiority. Among other initiatives, Hamilton Jet is currently involved in joint research postgraduate projects with the University of Canterbury (NZ). The following account of these projects is reprinted from the School of Engineering's newsletter "Engineering Research", with kind permission of the University of Canterbury (NZ).

"One PhD student, Mr Hamish Coop, is working with the Hamilton Jet Test Boat (shown in the photo). His project involves instrumenting the 7 metre test boat in order to carry out field tests to gain better understanding of hull–waterjet interaction effects. The purpose of the project is to study the way in which the presence of the waterjet, and in particular the intake, alters the overall performance of the boat from that predicted from the shape of the hull. To uncover these effects, a comparison between the resistance of the bare hull and the self propelled hull will be made.

Seven-metre Hamilton Jet Test Boat undergoing flow calibration tests.

The resistance of the plain hull will be measured with the waterjet intake sealed off. These measurements will be made by towing the boat over calm deep water using an on-shore winch. The effects of the entrained water of the jet unit will be accounted for by adjusting the ballast in the boat. The towing force, or the hull resistance, will be measured by a load cell mounted on a towing arm at the bow of the boat. In addition to towing force, the trim angle, immersion level and the wind speed will be recorded by a computer mounted within the boat. Several runs will be made at various speeds, immersion levels and trim.

The boat will then be self-propelled at the same settings as before and the thrust estimated using a load cell support system on the waterjet unit and measurements of the jet flow momentum at the outlet nozzle. The hull displacement will have to be altered and the ballast shifted to achieve the same immersion and trim angle as before. Comparison between the two sets of hull resistance data will reveal any significant effects that the waterjet is having on the hull resistance.

Another PhD student, Mr Gavin Griffith-Jones, is involved with the numerical and experimental modelling of the flow through a typical waterjet intake. A wind tunnel test has been set up which will be used to validate computational investigations of the flow under different conditions. The overall efficiency of a waterjet unit is strongly affected by the waterflow through the intake unit.

Although the unit is mounted flush to the underside of the hull, the path of the waterflow through the intake is 3-dimensional and rather complex. This project seeks to optimise the performance of the waterjet by investigating the effects of the intake geometry on the behaviour and efficiency of the flow through the intake using experimental and numerical modelling.

A full size intake is mounted on a wall of the wind tunnel and is being tested under similar intake/boat velocity ratios that would normally occur with a planing boat hull. The air flow through this test intake is expected to exhibit the same behaviour as the waterflow in the real situation. A wide range of flow-visualisation tests using mini-tufts, paint smearing and smoke plumes are being used to identify areas of interest within the flow. These tests also help to select suitable positions for more detailed flow measurements using a 5 hole pitot-tube and later with miniature hot-wire anemometers.

The numerical modelling of the flow using a sophisticated software package called FLUENT has first involved a long period of familiarisation with the software. Then a series of simulations of simple benchmark flow situations were undertaken to investigate the accuracy of the calculated solutions by comparison with well established data on real flows. Preliminary exercises building up to the modelling of 3-dimensional internal flows such as the waterjet intake can now finally be undertaken.

The objective of the numerical modelling of the existing intake shape is to investigate and verify the accuracy and usefulness of the software in predicting the flows measured in the wind tunnel. Once the numerical modelling has been developed to a satisfactory level of accuracy through close comparisons of it's output with the experimental results, a more rapid assessment of the effects of intake shape and other boundary condition changes on the flow will then be possible without further tedious wind tunnel tests in the laboratory."

HOW TO CONTACT US

World Headquarters
Hamilton Jet
PO Box 709, Christchurch
New Zealand

Phone: +64 3 348 4179; Fax: +64 3 348 6969
Email: marketing@hamjet.co.nz
Internet: www.hamjet.co.nz

USA Regional Office
Hamilton Jet Inc.
1111 NW Ballard Way
Seattle, WA 98107, United States of America

Phone: +1 206 784 8400; Fax: +1 206 783 7323
Email: sales@hamiltonjet.com
Internet: www.hamiltonjet.com

European Regional Office
Hamilton Jet (UK) Ltd
Unit 4A, The Birches Industrial Estate. East Grinstead
West Sussex RH19 1XZ, United Kingdom

Phone: +44 1342 313 437; Fax: +44 1342 313 348
Email: sales@hamjetuk.com

Plus Authorised Distributors Worldwide