A TECHNICAL AND COMMERCIAL VIEW OF THE WATERJET PROPULSION MARKET

JetTorque from HamiltonJet

Issue 12
June 2002

In this Issue...

Special Points of Interest:

- Comparison between Waterjets and Surface Drives - which is better for you?
- New vessel for surf rescue in South Africa.
- Teknicraft Design & Hamilton Jet success.

Re-Think on Propulsion for Busy High Speed Patrol Boats

Many marine patrol agencies around the world operate ultra-fast vessels with surface drive propulsion, capable of over 60 knots . Now the Royal Oman Police has ordered a new fleet of high speed patrol craft, but has passed on surface drives in favour of Hamilton Waterjet propulsion.

This change is representative of the decision faced by many marine border patrol and customs agencies – to ensure vessels have the best balance of performance and cost effectiveness when carrying out increased patrol duties.

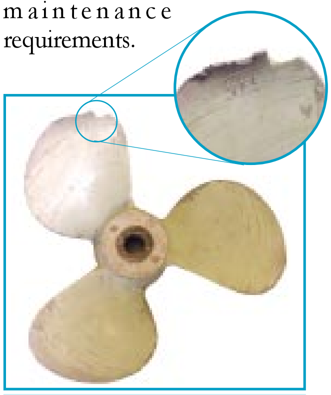
Changing Roles

Recent security situations and increasing drug and people trafficking around the world have placed extra demands on modern marine police, customs and navy patrol vessels. These are expected to patrol further and faster than ever before, with less maintenance requirements.

What's more, border patrol and customs organisations are expected to have more vessels in active service and fewer held in reserve.

While high speed is often a criteria for new patrol vessels, **reliability** is an increasingly important factor. The problem is that with most propulsion systems high speed leads to extra strain on engines and drive systems, and greater damage to running gear, particularly in debris-ridden waterways.

A recent article by Joel Milton printed in "Workboat" magazine detailed the extreme maintenance schedules and associated costs involved with coast guard boats in New York following the WTC terrorist attack. The dramatic increase in activity immediately resulted in a corresponding increase in maintenance requirements.



Typical Impact Damage on a High Speed Propeller

The article reports that by late October the US Coast Guard vessels involved in Operation Guarding Liberty required 87 new props, many replacement shafts and rudders, and 10 new engines. Parts alone cost over US$400,000, and this does not include costs and vessel down-time involved in out-hauling an average two vessels each night. And these conventionally-driven vessels were not even of particularly high speed.

In this type of situation, high speed vessels (over 25 knots) driven by propellers or surface drives, would likely suffer even greater wear and tear to the propulsion system through engine loading, gear shifting and debris damage.

To ensure patrol vessels are both fast and reliable, many state-owned marine patrol organisations are now turning to waterjet propulsion.

ROP Experience

In the case of the Royal Oman Police's new patrol boats, the governing criteria was high, but practical speed – in the range of 45 to 50 knots – along with superior reliability and reduced costs.

A speed of 60 knots is ideal for pursuit and emergency situations but has been found to cause considerable fatigue to both the boat and its crew. Also it is not particularly practical for close quarters/ slow speed situations such as intercept and boarding.

When contracting for 20 new 11-metre patrol vessels, ROP personnel decided waterjets, in the right kind of high speed hull, offered the best mix of pursuit speed, high and low speed manoeuvrability, reliability and cost.

Halmatic Cougar Enforcer 33 Ultra Fast Patrol Boats, with twin 420hp Yanmar engines and Hamilton HJ274 waterjets, were chosen. Based on the highly successful Cougar 33 raceboat deep "Vee" hull form, the boats will achieve service speeds in excess of 45 knots.

Artist impression of new ROP patrol boat with twin Hamilton HJ274 waterjets

This speed is more than sufficient to carry out patrol and pursuit duties. But of more importance was the fact that the propulsion system cost considerably less than surface drives to buy, and is expected to result in significant savings in annual maintenance costs.

Waterjets Versus Surface Drives

The designers of modern work and patrol boats have many options to consider when choosing the most effective propulsion system for their vessels. In the high-speed work and patrol boat market, waterjets have become the preferred propulsion choice. However, surface drives are providing strong competition in many sectors, particularly when very high speed is required.

The following compares the Hamilton waterjet system with a generic Surface Drive system over a range of criteria.

Propulsion Explained

Waterjets work by drawing water from beneath the boat's hull and forcing it out behind as a high pressure jetstream to push the boat forward.

Surface drives work in the same way as other propeller systems – a propeller within the body of water beneath the boat creates a "screw" effect to drive the boat forward. However, a surface drive is positioned aft of the vessel in such a way that at higher boat speeds a propeller blade is out of the water for half of each revolution – hence the "surface piercing propeller".

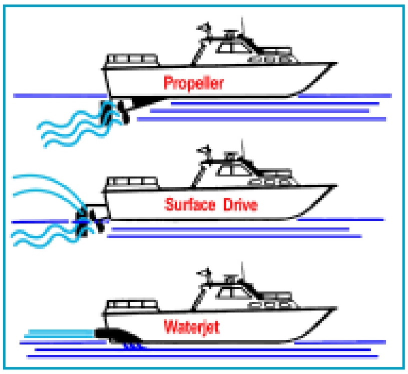


Fig 1. Three Propulsion Systems

Both waterjets and surface drives have unique characteristics that offer advantages in particular applications…

Waterjet Characteristics…

• **Pump efficiency** – waterjet efficiency is equal to or better than propeller systems at high boat speeds, generally over 25 knots.

• **Single direction pumping** – a waterjet unit always pumps in the same direction, whether the boat is going forward, astern or staying stationary. So in many small vessels a gearbox is not required.

• **Directional jetstream** – a waterjet angles the jetstream to steer a boat. Astern mode is achieved by directing the jetstream forward, thus reversing the thrust forces.

Surface Drive Characteristics…

• **Greater propeller efficiency** – the surface drive is located aft of the transom so is free of many of the propeller size and efficiency restrictions of conventional propellers, such as vessel draft and blade tip clearance. Also, with only half the surface piercing propeller in the water at a time, half the amount of blade slippage is experienced, giving greater high speed efficiency.

• **Reduced cavitation effect** – a surface piercing propeller begins to cavitate at a much higher speed than a conventional prop. This is due to ventilation – each time a blade enters the water it brings air into the vacuum region to ensure the propeller always operates at atmospheric pressure.

Normally aeration is undesirable, but surface drives are specially designed to operate in this way.

• **Steering control** – some makes of surface drive require rudders for steering control, while with others the whole drive can be angled from side to side. Steering is more responsive with the latter type.

• **Trim control** – propeller submergence can be controlled on some surface drives, to both trim the vessel and control absorbed horsepower, allowing for a flexible payload over a range of displacements.

Project Sizing

Different types of propulsion are sized for a project using quite different methods.

Waterjets are sized based on hull resistance, engine power/RPM and "cavitation margin" – the difference between maximum boat speed and minimum speed at which full power can be applied without risk of cavitation effects (refer Figure 2).

Impeller rating (pitch) is determined from the proposed engine's continuous power and RPM inputs, and will indicate the most appropriate direct-drive waterjet size.

Hull resistance and predicted waterjet thrust are then compared to determine the cavitation margin and expected top speed. If the cavitation margin (which includes a safety margin) is too narrow, a coarser pitched impeller must be used. Usually it is recommended a reduction gearbox is installed to reduce shaft RPM sufficiently to allow for a higher rated impeller.

If desired speed is not going to be achieved then either hull resistance must be reduced or higher powered engines used, generally along with larger waterjets.

Figure 2 shows a typical performance prediction graph for two waterjet options with different impeller ratings. Jet A (coarse impeller and gearbox) gives a slightly lower top speed than Jet B (fine impeller direct drive), but a better cavitation margin. This means Jet A will be more efficient when accelerating and when operating at lower speeds, particularly when heavily laden.

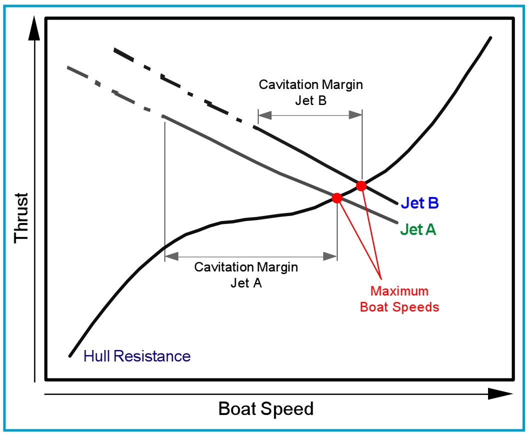


Figure 2 - Hull Resistance vs Waterjet Thrust

A surface piercing propeller is selected the same way as a conventional propeller – expected boat speed is calculated, then propeller size and pitch is selected to achieve this speed.

Expected speed of the vessel is calculated using a formula such as Crouch's Planing Speed Formula…

$$\textbf{Knots} = \textbf{Constant} \div (\textbf{LB/SHP})^{0.5}$$

Note: Constant depends on hull type and ranges between 150 (average runabouts) and 230 (racing power catamarans).

Propeller size is calculated using…

$$\textbf{Diameter (inches)} = \frac{\textbf{632.7 x SHP}^{0.2}}{\textbf{Shaft RPM}^{0.6}}$$

NB: These calculations make no allowance for propeller slip or blade loading factors.

Figure 3 plots RPM and propeller size for a range of power inputs.

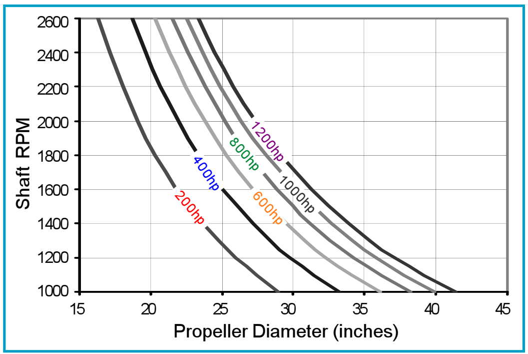


Figure 3 - Propeller Diameter / HP / RPM

In an example of a 20 tonne fast patrol vessel using twin 1200hp @ 2300rpm engines (plus reduction gearbox), the surface drive propellers will be 30 inches (760mm) in diameter and provide for 48 knots top speed (constant of 190). In comparison, the same vessel fitted with twin HJ391 waterjets (390mm impeller diameter) will make 47 knots.

As a rough guide, at 50 knots there is about one knot difference in boat speed between waterjets and surface drives, and the surface piercing propeller diameter will be nearly twice that of the waterjet impeller.

Performance Comparison

• **Efficiency** – surface piercing propellers are more efficient than waterjets at low boat speeds due to reduced cavitation (a problem that affects waterjets at low speed and propellers at high speed). At service speeds above 25 knots waterjets and surface drives offer very similar efficiency.

However, because waterjet size is not based on boat speed, they are more efficient over a wide range of displacements and speeds.

• **Boat speeds** – standard intake design restricts waterjet performance at speeds above about 55 knots. Surface piercing propellers don't have this restriction so are able to achieve speeds above 55 knots. Surface drives are also able to absorb more power at lower RPM than waterjets, which gives them greater acceleration, but will lead to engine overloading problems.

Note: Specialised waterjet intakes can allow for speeds in excess of 55 knots, but at the expense of load carrying ability, cruising efficiency, rough weather performance and reliability. Hamilton waterjets are designed for work and patrol vessels, where the latter performance characteristics are more important than extreme speed.

• **Engine loading** – waterjets are designed to absorb maximum engine power at any boat speed, so engines cannot be overloaded. This results in longer engine life and lower maintenance requirements. Surface drives are sized and pitched for a specific boat speed, so at lower speeds the drive can be made to absorb higher amounts of power than the engine is designed for – overload the engine and reducing engine life.

• **Load carrying** – surface drive performance is limited through propeller pitching and variable craft displacements. Propellers are necessarily pitched to suit a vessel's laden condition (to minimise engine overload) which limits maximum boat speed at reduced displacements.

Engine loading on a waterjet is independent of craft displacement and speed. Therefore, maximum potential boat speed is always available, regardless of displacement.

• **Manoeuvrability** – waterjets out-manoeuvre surface drives at all boat speeds. At high speeds waterjets have a much tighter turning circle and are able to perform an emergency "crash stop" manoeuvre.

The coarse pitch of a surface piercing propeller makes it difficult to maintain slow speeds, and requires constant gear shifts. The steering and astern functions of a Hamilton waterjet provide responsive manoeuvrability at very slow boat speeds, and even when holding position.

• **Ease of Operator Control** – because a surface drive is not fully submerged it is affected by variations in vessel trim caused by sea conditions. Constant changes in the depth of the surface piercing propeller result in engine loading and RPM fluctuations, which make it difficult to maintain the desired vessel speed.

A waterjet's performance is not affected by vessel trim so it provides consistent thrust force and steady RPM in all conditions.

• **Appendage drag** – waterjets have no parts exposed below the waterline, so there is virtually no appendage drag to add to hull resistance – and additional jet units can be added without increasing resistance.

Surface drives that use rudders add to overall resistance, so the more drives and rudders you have, the greater the effect.

• **Shallow Draft** – a waterjet intake is flush with the bottom of the boat, allowing the vessel to traverse very shallow waterways and even be grounded without significant damage to the drive system.

Surface drives have significantly reduced draft compared to other propeller systems. However, the propeller is exposed below and aft of the hull where it can be damaged. There have even been cases where the entire surface drive has been knocked off a boat.

• **Safety** – waterjets have no exposed moving parts so can remain running around swimmers or marine life. Surface drives require platforms and/or guards above and to the side of the propeller for protection, and for safety the drive must be disengaged when operating around people or animals in the water.

• **Reliability** – waterjets are very reliable in themselves, requiring little maintenance – most of which can be done inside the hull. And because waterjets put less stress on engine, gearbox and drive shaft than other propulsion systems, they increase the reliability of the total drive system.

• **Cost effectiveness** – small to medium sized waterjets will be less expensive to purchase, install and maintain compared to a surface drive for the same project. This is largely due to surface drive and propeller having to be purchased from separate manufacturers and the need to have a gearbox. With larger waterjets the purchase cost for either option is generally similar, but ongoing maintenance costs will be higher with the surface drive.

Conclusions...

For work and patrol boats operating over 50 knots, where engine life and risk of impact damage are not significant issues, surface drives could be the preferred option. In the 25 to 35 knot speed range waterjets provide greater flexibility and reliability.

Waterjets and surface drives really only compete in the 35 to 50 knot boat speed range. It is then that you have to weigh up the other pros and cons of each system before making the final choice. In most cases Hamilton waterjets provide more benefits and are the preferred option.

Hamilton Jet & Teknicraft Design

Many marine tourism operations are benefiting from vessels that bring together innovative Teknicraft Design hull designs with Hamilton waterjet propulsion.

“Condor Express”

Among the most recent vessels designed by Teknicraft and utilising Hamilton Jet propulsion are two high-speed passenger tourist ferries.

The whale watch ferry “Condor Express” began operation in Southern California early in 2002. With quadruple 740hp Detroit engines driving Hamilton Model HJ362 waterjets, this 23 metre catamaran is capable of 43 knots and cruises at 34 knots (at 85% power) with a full load of 149 passengers. The hull design and propulsion set-up of Condor Express give it amazing efficiency – it can operate at 28 knots fully laden at only 67% engine power.

In 2001 the 19-metre catamaran “Chilkat Express” joined a tourist operation out of Haines, Alaska. Chilkat Express is powered by quadruple 800hp engines and Hamilton Model HJ362 waterjets, giving a cruise speed of 42 knots with a full load of 63 passengers.

Reasons for the success of these vessels are many. The Teknicraft-designed hulls are foil assisted to provide extra lift, speed, agility and smoothness of ride. Foil assisted hull forms are ideal for waterjet propulsion, as the extra lift provided and the reduction in wetted area reduces hull resistance, allowing the waterjets to operate at their greatest efficiency. The hull’s inherent agility also adds to the manoeuvrability provided by the quadruple waterjet setup.

Teknicraft Design and Hamilton Jet are both extremely pleased with their many joint projects to date. And with the outstanding success and high profile of these vessels, this combination of design and propulsion system will become even more popular on the world’s coastal waterways in the future.

“Chilkat Express”

“Surfjet” to the Rescue

In 1976 “Major” Dougie van Riet, commander of Station 9 of the National Sea Rescue Institute (NSRI) in South Africa, began a campaign to develop a craft able to safely perform in turbulent surf conditions. A basic design was developed for a 6.5m waterjet powered trimaran, and in 1983 the prototype “Surfjet” entered operation at Station 9, Gordon’s Bay. This boat proved extremely successful and was involved in many rescues over the next 10 years.

In the early 1990s efforts began to replace the Surfjet with a MKII version, combining the successful design with modern composite boat building materials and more efficient propulsion system. It took eight years to gain official approval and secure funding for the project, but in late 2001 the Surfjet MKII was finally launched.

The craft is a tri-hulled, waterjet driven platform capable of speeds in excess of thirty knots, but its real prowess lies in the handling of shallow, rough water. With a draught of less than 0.40m the craft is ideal for work over the shallow reefs in the Gordon’s Bay area.

Stability in surf is crucial to the success of inshore operations. With a beam of 3m, Surfjet 2 is able to run parallel to a breaking sea with no danger of being rolled. Operators have described the stability of the craft as quite uncanny with no situation yet encountered proving unsettling for the crew.

With her wide beam she is able to accommodate 12 casualties in addition to her crew of two. Manoeuvrability is exceptional under all load and speed conditions.

Surfjet 2 is powered by a Steyr 236 diesel engine direct driving a Hamilton Model HJ213 waterjet.

In the short time Surfjet 2, now called “Vodacom Rescuer III”, has been in operation she has proven her worth many times over.

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

Historic Jet Boat Restoration

Part of CWF Hamilton & Co’s early history will be revived when a 46 year old jet boat is restored this year. The boat, “Orbit” was the 17th Hamilton Waterjet powered boat and the 10th using a Rainbow model waterjet – a direct drive centrifugal pump system designed by Sir William Hamilton and George Davison in 1955.

“Orbit” has been sitting in storage for many years, where its condition slowly deteriorated. So Hamilton Jet management decided to seek the restoration expertise of Ferrymead Historic Park.

Ferrymead has taken “Orbit” and will have the boat on display as it is being restored. Once finished it will remain at the Park and be used for local Hamilton Jet functions.

HamiltonJet
The Waterjet Specialists