A TECHNICAL AND COMMERCIAL VIEW OF THE WATERJET PROPULSION MARKET

JetTorque from HamiltonJet

Issue 7
September 1996

In this Issue...

From the Bridge – Oil Industry News

"The business of extracting oil from under the Gulf of Mexico is booming again. Utilization of supply boats has been running at better than 95%."

Editorial – Marine Log Magazine, April 1996 Vol. 101, No.4

Hamilton Jet is at the forefront of supplying propulsion systems for the new breed of waterjet powered crew boats currently being built to meet the demands of this boom.

Evaluation of the first vessel commissioned, the 143' monohull "Mr Mel" built by Swiftships for operator Diamond Services, showed the quadruple HM571 waterjet system offered significant competitive advantages over earlier vessels which used conventional propellers. The success of this vessel prompted the owner to commission a sister ship "Lisa Ann" plus a further two 165' versions. Other Gulf operators who have followed suit are SeaMac, who launched a 143' crew boat powered by quintuple HM521 jets built by Gulf Craft Inc., and Candy Fleets who commissioned Swiftships to build a series of five 135' crew boats with single HM521 jets fitted between conventional propellers for boost function.

Quadruple HM571 waterjet powered 143' Gulf of Mexico Crew Boat "Lisa Ann"

The present high utilisation rate of the crew boats is due in part to the fact that a significant portion of the existing propeller driven fleet is old and consequently often not available for service due to maintenance requirements. Operators who can offer a continuous service will therefore have a major competitive advantage and the new Hamilton Jet driven craft have shown themselves to be capable of this.

Utilising multiple jet installations ensures an inherent redundancy so the vessels can maintain service. In the event of a machinery breakdown, the vessels can safely and effectively maintain commitments with one engine shut down. Load on engines can be reduced too by shutting down one or more engines during extended periods of low speed loitering.

This high availability factor, together with the significant speed advantage of the jet driven craft, has resulted in operators of the new vessels being able to offer a much faster turnaround of crews and supplies. Crews are also delivered in better condition as the hull designs, modified for the higher speeds, provide a more comfortable ride. With no exposed underwater propulsion components, down time due to impact damage is eliminated with the jet boats contributing to the vessels availability. In fact, in any given 24 hour period, it has been recorded that one of the jet driven craft can complete one return trip more than its propeller driven counterparts.

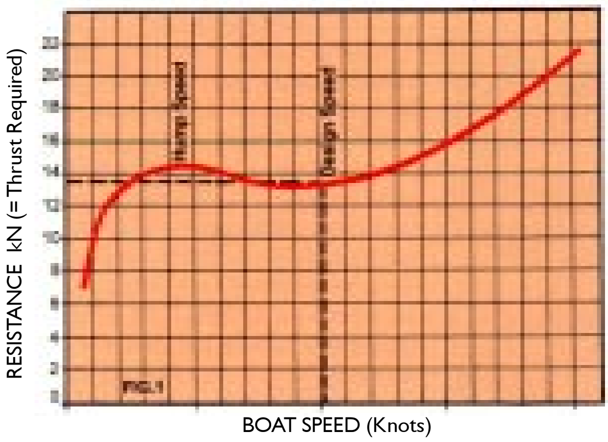
Manoeuvrability with the multiple jet installations has also proved to be outstanding. This is particularly important as these craft are required to manoeuvre and hold station under the rigs while crews and supplies are transferred. Given the number of thrust vectoring combinations available to the helmsman, manoeuvres such as sideways docking can be easily carried out through the electronic jet control systems installed in each of these vessels.

135' "Candy Cotton" with HM521 Booster Jet

THRUST – the Moving Force

RESISTANCE

To move a hull through the water, it is necessary to overcome resistance created by friction of the hull (skin friction), appendage drag, aerodynamic drag and other hull effects. This resistance varies depending upon a number of factors such as boat weight, hull form and speed and is normally determined by calculation and/or model testing. For a typical planing hull, the drag will be high at low speeds since the bottom and parts of the sides will be in contact with the water. As the hull begins to move and takes a bow-up attitude at slow speeds, the resistance increases to a peak at the "planing threshold" (hump). Once the hull achieves plane and commences riding on top of the water, the drag lessens as the sides of the hull "dry". At high speed with the hull running on its aft planing surfaces only, minimum resistance is experienced.



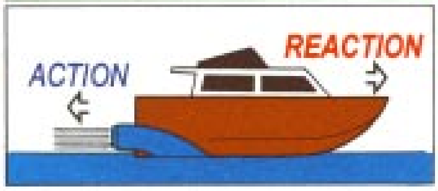
Resistance Curve for Typical Planing Monohull

OVERCOMING DRAG

Obviously then, to make the hull in Fig. 1 move at any given speed, it is necessary to apply a force equivalent to the resistance at that point. This force or energy is defined as thrust and is usually measured in kN (or lbsf). In marine hulls, the force can be generated by any propulsion device ie., sail, propeller, waterjet etc.

WATERJET THRUST

A waterjet generates propulsive thrust from the reaction of the change of momentum in a rearward directed stream of water. Simply, it is reaction propulsion, similar to an aircraft jet engine except the medium is water instead of air. As Newtons' Third law of Motion states, "for every action there is an equal and opposite reaction", so the thrust of the water column being expelled out the stern of the boat is transferred through the body of the jet to the craft's hull, causing it to move forward. This phenomena can be likened to the action of a cannon where the thrust of the cannonball



leaving the barrel is transferred in the opposite direction in the form of recoil.

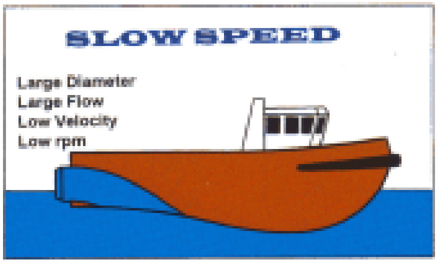
In a boats' hull, the jet unit is mounted inboard in the aft sections. Water enters the jet intake in the bottom of the hull at boat speed, is accelerated through the unit and discharged through the transom at approximately twice boat speed. The jet is driven (usually) by a gasolene or diesel engine whose power is absorbed by the pump impeller and transferred to the water.

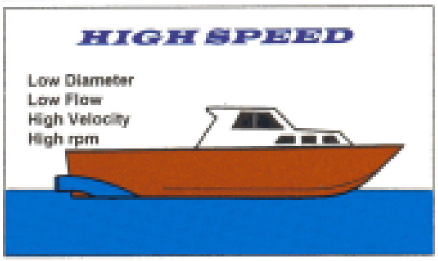
The acceleration caused by the pump accounts for the change of momentum.

THRUST REQUIREMENTS

The key factor for best efficiency of a waterjet system is the relationship between the mass flow and the velocity.

This must be correctly matched to the design boat speed and the result is similar to conventional propeller selection. A heavy slow boat requires a large volume of water at low velocity and a high speed craft should employ a small volume accelerated to high velocity, determined by the size of the machinery. Within these parameters, the most effective



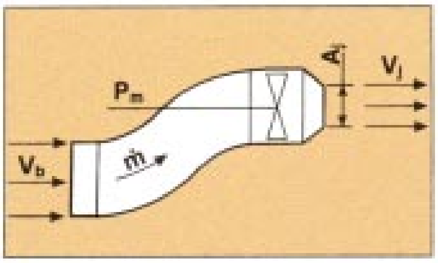


configuration should give the largest possible mass flow.

SIMPLE THRUST THEORY

The simple jet model below experiences a net thrust due to the change in momentum of the water passing through it. This change is due to the difference between the Jet Outlet Velocity (Y_j) and the jet's incoming water which, for simple analysis, is assumed to be the same as the Boat Velocity V_b.

If m is the Mass Flow Rate through the jet unit then Thrust (T) is given by…



$$T = m(V_j - V_b)$$

This is a simplified model of thrust and does not make allowances for other influencing factors.

OTHER FACTORS

Wake Factor – in reality, water entering the inlet beneath the hull travels slower than Vb due mainly to the boundary layer under the hull. This has the effect of improving the performance slightly as less power is required to accelerate the water to achieve the same momentum change (thrust). To achieve this modification in the basic theory, a new inlet velocity Vi is defined as the required average velocity entering the intake to provide the same overall momentum as the ingested boundary layer in the real case. Wake Factor then is related to V_b and V_i and would typically range from 3% to 8%.

Thrust Deduction Factor – total hull resistance (and thence thrust) is normally arrived at by determining the bare hull drag by calculation or tow testing. To this, appendage, wake and aerodynamic resistance are added. However, when the hull is self-propelled, the total resistance changes. This effect traditionally represents the additional resistance caused by the action of the propeller. The propeller must overcome this additional resistance so its known thrust must have this small amount of thrust deducted before it can be equated to bare hull resistance.

With waterjets the same thing happens – the measured bare hull resistance is altered by the presence of the jet. Recent work on the interaction between hull and waterjet has shown the Thrust Deduction Factor for a given hull can be either positive ie., adds to the overall resistance, or negative, depending on boat speed, trim etc. A negative Thrust Deduction Factor can mean that a jet boat will require less thrust at a given speed than one using another type of propulsion system.

Wind and Waves – allowance also has to be made for the effect wind and waves have on the overall resistance. Vessels with high topsides will have greater aerodynamic drag than streamlined designs and operation in heavy seas will add to the drag as the sides will be continuously wet. Both factors add to the overall resistance.

POWER, NOT RPM

It is a common misconception that if a boat is not achieving design speed through lack of thrust, simply increasing the speed of the jet by altering the impeller will increase thrust. However, with a waterjet, thrust is determined solely by power. The only way to increase thrust is to increase the power to the jet. For any particular jet, increasing rpm will increase the power and jet thrust, but this is not true if the rpm increase is achieved by fitting a "lower-rated" impeller. Each impeller has a fixed power/rpm rating curve which is virtually independent of boat speed. Fitting a "lower-rated" impeller will increase engine rpm but this will not necessarily increase the power since the engine power curve is often flat near its maximum. To match increased engine power, jet modifications may range from simply fitting a "higher-rating" impeller to the existing unit or replacing the jet completely with a larger diameter model.

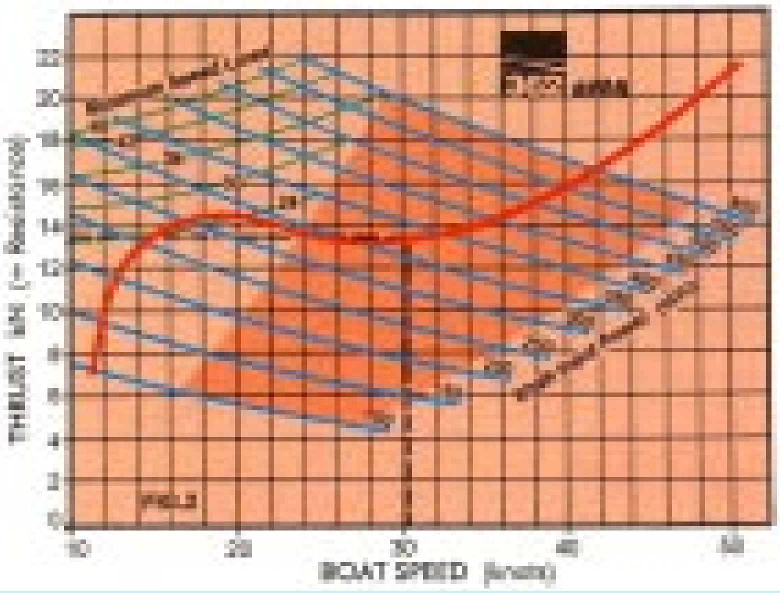
WHICH WATERJET?

Most waterjet manufacturers publish thrust curves for each model in their range. Hamilton Jet thrust curves have been established through a process of calculation, testing in a closed circuit water tunnel and field experience.

Superimposing the vessels resistance curve over the jet thrust lines will provide a picture of vessel performance.

This figure shows how jet thrust curves can be used to determine either the power input required to achieve desired boat speed, or the speed with a known power input. Bare hull resistance should be divided by the number of jets to be employed to arrive at thrust per jet. At the intersection of thrust with design boat speed, the power input can be read off, or alternatively, with a known power input, estimated boat speed can be established.

Minimum Speed Lines for a range of impeller options are included on Hamilton Jet thrust curves. These show the minimum boat speed at which full engine power can be applied continuously without danger of cavitation. Boat speed should exceed the intersection point of the thrust curve and the minimum speed line if cavitation damage is to be avoided. It is, however, acceptable to pass through this point momentarily as the vessel achieves plane, but continuous operation is to be avoided. The shaded area indicates where highest propulsive efficiencies will be achieved and the faster the boat speed, the higher the efficiency.



Hamilton Model HJ362 jet Thrust Superimposed on Hull Resistance Curve

THRUST VECTORING

Without a separate rudder for steering and no reversing gearbox (in most cases), a jet propelled craft is manoeuvred by appropriate vectoring of jet thrust. With the Hamilton Jet design, separate deflectors for steering and reverse are provided.

Steering Thrust – is available at all times whether going ahead, astern or at zero-speed by deflecting the jetstream to port or starboard. The deflector design maximises lateral thrust with minimum loss of forward thrust for responsiveness at all speeds. At manoeuvring speeds, full lock thrust at right angles to the hull is up to 42% of forward thrust.

Astern Thrust – directing the jetstream back under the hull via the split duct deflector results in astern thrust maintainable up to high throttle settings. Astern thrust can be up to 60% of ahead thrust.

Reverse thrust is infinitely variable either side of zero-speed from full ahead to full astern and, with independent steering available at all times, appropriate vectoring will result in outstanding manoeuvring capability.

Pretty Picnic Boat from Hinckley

The Hinckley Company's production jet boat, the 36 foot "Picnic Boat" is generating plenty of interest and sales for the Maine, USA based boatbuilder. The New England lobster-boat style yacht combines traditional elegance and modern construction materials and techniques together with appointments such as galley, head and twin berths. The hull is easily driven by a single Hamilton Model HJ291 waterjet powered by a 350hp Yanmar diesel engine, providing a top speed of 29 knots. At a cruising speed of 25 knots, the "Picnic Boat" can motor for 10 hours between refills. Hinckley's Shep McKenney describes the craft as "a friendly boat". Whether being used sedately with a dozen or more guests in the expansive cockpit or throwing it into spin-out turns at high speed, no vices are evident in the handling of the craft. The jet system, with its shallow draft capability and absence of exposed propeller, makes the craft an ideal platform for swimming or exploring hard-to-reach places. Damage to the propulsion system through impact with flotsam is eliminated and manoeuvrability with the jet for holding station or docking is excellent.

The 11 metre Hinckley "Picnic Boat" powered by a Model HJ291 jet makes an elegant party venue

INCAT Whale-Watch Ferry

"Friendship V", a 34 metre INCAT designed catamaran ferry powered by quadruple Hamilton Jet model HM461 jets recently entered service for the Bar Harbor Whale Watch Co. of Maine. Capable of carrying 316 passengers at 31.5 knots, the aluminium vessel was built at the Gladding-Hearn Shipyard in Massachusetts, USA. The four jets, each driven by a Detroit 12V-92 DDEC engine via a Reintjes gearbox, were supplied as complete packages with integral intake and transition ducts, reverse hydraulics and electronic control system. The modular electronic control system provides for three helm stations (main plus two wings) and is interfaced with the engines' electronics, gearboxes and autopilot. Given the variety of operations required on whale watch excursions, the quad jet system gives a level of flexibility not available with other propulsors. Full control of thrust vectoring throughout the vessel's speed range ensures outstanding manoeuvrability and the inherent redundancy of the multiple propulsors provides the opportunity to shut down two engines for extended slow speed loitering or service can be maintained on three engines if necessary.

Bar Harbor Whale Watch Co's 34 metre INCAT Catamaran Ferry "Friendship V" – Quad HM461 jets, 35 knots

Waterjets Subject of Thesis

A thesis entitled "Waterjet – Hull Interaction" has recently been published by Netherlands engineer Tom J.C. van Terwisga, who is employed by the Marine Research Institute of the Netherlands (MARIN). The aim of the work is *"the development and validation of tools to analyse interaction effects in powering characteristics of waterjet – hull systems"* and explores the effect of the hydrodynamic relationship between the jet and hull on performance. Experimental work included a number of parametric modelling, model testing and computational analysis procedures destined to identify and define the elements affecting waterjet powered vessel performance.

Validation of the theoretical work was done both by full scale tests using Hamilton Jet's test boat and comparative procedures in the MARIN deep water test tank using a scale model of the Hamilton boat.

This comprehensive study of waterjet – hull interaction will provide naval architects with a valuable reference for better understanding the interaction mechanisms involved and copies are available at a cost of Hfl100 each direct from:

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