A TECHNICAL AND COMMERCIAL VIEW OF THE WATERJET PROPULSION MARKET

JetTorque from HamiltonJet

Issue 11
September 2001

Hamilton Jet Powers New US Fast Ferries

Three new high-speed catamaran ferries launched in the United States this year add to Hamilton Jets extensive list of waterjet-powered fast passenger ferries.

High-speed passenger and tourist ferries have been a major growth area for Hamilton Jet in recent years. The greater efficiency and control provided by waterjets, along with lower maintenance requirements, have made them the most popular choice for demanding high-speed ferry services.

Hamilton Waterjets have been chosen as the best propulsion option for many fast ferries and tourist craft in Italy, Fiji, New Zealand, Singapore, Canada and the United States, and in many other areas of the world.

Quad Hamilton Model HM651 Waterjets pushed Jet Cat Express to over 40 knots during sea trials.

Catalina Express Lines

"Jet Cat Express" is the newest ferry to join the eight-boat fleet of Catalina Express Lines, San Pedro, California. Designed by Incat Designs of Sydney, Australia, and built by Nichols Brothers Boat-builders on Whidbey Island, Washington, USA, the 44-metre ferry is powered by quadruple Cummins 1,875hp engines and Hamilton Model HM651 waterjets.

Travelling at 37 knots, the 380-seat ferry will make the 24-mile passage between the mainland and Santa Catalina Island. The vessel has been fitted with an MDI T-foil ride control system and a central 'third bow' to help combat the coastal sea conditions encountered on this route.

Golden Gate Bridge District

In August 2001 a new 450-seat passenger ferry entered service for San Francisco's Golden Gate Bridge, Highway & Transportation District. "Mendocino" is a 42-metre catamaran designed by Incat and built by Nichols Brothers. Quadruple Hamilton Model HM571 waterjets and Cummins 1,600hp engines propel the vessel at 36 knots between Larkspur and San Francisco.

Boston Harbor

A third new Hamilton Jet powered vessel has begun work for Island Hi-Speed Ferry (a Boston Harbor Cruises Partnership). Built by Gladding-Hearn Shipbuilding of Massachusetts and designed by Incat Designs, this ferry is powered by quadruple 1,100hp Caterpillar 3412 E engines coupled to Hamilton Model HM521 waterjets. After its launch and sea trials recently, the 30-metre commuter ferry begun opeartions between Point Judith and Block Island, Rhode Island.

The vessel features Incat's single chine Z-bow shape, which improves high-speed performance and sea-keeping ability. Equipped with a Maritime Dynamics trim tab ride control system, this new 250 passenger vessel will give passengers a smoother journey at a top speed of 33 knots. It is the first vessel in

Incat Design's Concept for the new Golden Gate Fast Ferry

In this Issue...

Special Points of Interest:

- Hamilton Jet makes further inroads into lucrative US Fast Passenger/Tourist Ferry Market.
- Improving waterjet design using CFD software developed by Hamilton Jet.
- 15 Picnic Boats on a weekend cruise.

Boston Harbour Cruises' substantial fleet to be powered by Hamilton Waterjets.

When Sir William Hamilton first began building waterjets during the 1950s, each new development was based on "trial and error" and the process of elimination. Rough sketches on scraps of paper were turned into working units, which were tested and either discarded or refined to improve performance.

Trial and error experiments were successful, albeit time consuming, with significant gains in waterjet technology made in the first ten years.

Then during the last decade of the 20th century computer analysis began to take a significant role in waterjet design. Worldwide studies into fluid dynamics, vessel hull resistance, wake factors, and cavitation effects have all helped to improve waterjet performance, efficiency and application.

One of the most significant recent advances is the development of Computational Fluid Dynamics (CFD) software. These programs can predict fluid flow through a waterjet, allowing manufacturers to take the computer-assisted design phase further before moving on to actual physical testing of new designs.

Figure 1. Impeller Visualised

Hamilton Jet's research team, in association with the Department of Mechanical Engineering at the University of Canterbury (New Zealand) have developed 'in house' CFD software for the design of waterjet impeller and stator components.

Complexity in Predicting Water Flow

To understand fluid dynamics, consider the act of hitting a golf ball. Newton's Second Law of Motion says force equals mass multiplied by acceleration (f = ma). So all the force is put into a golf ball at the time of impact with the club – when it accelerates from stationary to flight speed.

Now consider one million golf balls being hit at the same time, in the same direction from a small tee area. Many of the balls will hit each other, some will hook or slice, some will hit trees and some will land in the rough instead of on the fairway. So even if all the balls were hit with the same force, no two will travel the same distance.

In simple terms the same thing happens to each particle of water as it travels through a waterjet. While the impeller and stator apply acceleration, other factors – such as turbulence and friction within the water flow and between water and metal – affect the flow and thus affect the overall thrust generated by the waterjet.

The challenge then is to calculate the forces acting on the fluid particles.

These forces are described by a complex set of mathematical equations called "the Navier Stokes Equations". The problem is these equations are extremely complicated and require too much computing power to be solved exactly.

In Hamilton Jet's case, the Navier Stokes equations are solved by making simplifications to the equations and by looking at only one blade passage. Even so it can take up to eight hours to converge a solution on a 'top of the range' desk top computer.

Hamilton Jet uses its Computational Fluid Dynamics software to predict the flow properties such as pressure and velocity throughout the water jet. By analysing these results, designs can be produced which have improved thrust and better margins against cavitation.

CFD Development Issues

When Hamilton Jet started developing CFD software in 1996 four main issues were taken into account…

Design Intent (uniform flow)

To simplify flow prediction, calculations must be done with uniform water flow. In Figure 2, the top picture shows uniform flow. The bottom two pictures show how flow is affected if water speed

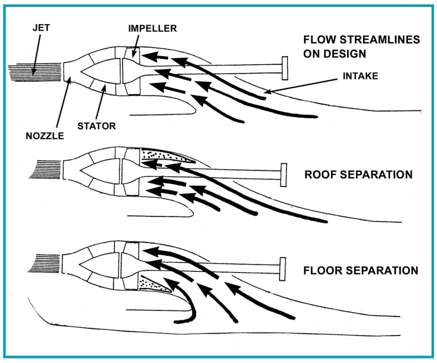

Figure 2. Water Flow Characteristics

through the pump is too fast (roof separation) or too slow (floor separation). These last two situations are researched using dedicated test boats.

Under uniform flow conditions the CFD software must be able to predict the flow turning (impeller rating) so that an impeller can be designed to match a particular engine power at a certain boat speed. The software must also be able to predict local pressures/velocities in order to assess cavitation, and then be able to model losses and predict blockage.

Visualisation – Ease of Prototyping

After calculating the above factors, the software must be able to visualize what the ideal impeller design looks like through integration with CAD programmes (Figure 1). This allows for rapid production of a prototype or tooling for manufacture.

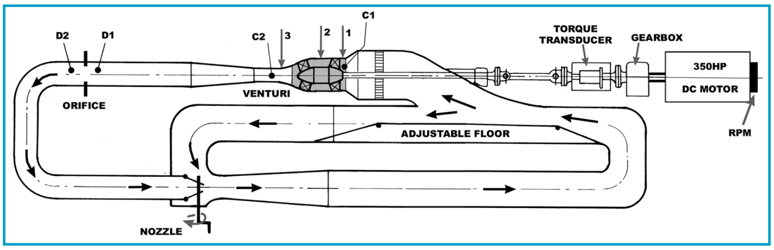

Figure 3. Hamilton Jet Test Rig Schematic.
Probe used to measure flow characteristics at positions 1, 2 &3

Ease of Use

Ease of data preparation is important.

Solution Speed

The whole process must be calculated and performance predictions made in as short a time as possible with current computing technology.

CFD Approach

Hamilton Jet's CFD software is designed using two elements –

Quasi 3D Design Method

The Quasi three-dimensional design method consists of a "throughflow" program that looks at the flow streamlines in the 'meridional' plane (the plane produced by cutting a waterjet in half along the shaft centre-line), a geometry creation program and a "panel" method. The panel method looks at the detailed fluid flow over a blade surface.

3D Flow Solvers

The 3D flow solver used provides a three dimensional picture of the flow through a water jet.

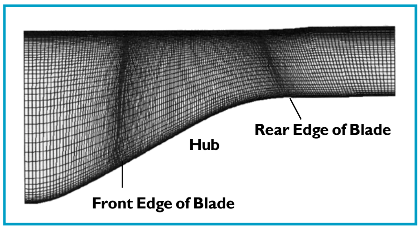

Figure 4. Mesh Elements

First a flow passage is "meshed". Mesh elements are like three dimensional "wire-framed" cubes that water can pass through. The forces affecting the liquid within each cube are calculated using the Navier Stokes equations. Typically 600,000 mesh elements can be used in one blade passage. To get the solution to converge to what actually happens in reality is similar to trying to juggle several hundred balls at once.

The accuracy of the 3D solver solution depends on the number, size and shape of the computational mesh elements. Figure 4 shows how a greater number of mesh "cubes" are used around the boundary layers of the impeller blades, hub and casing where effects on the flow are greatest.

Software Validation

Before any CFD programme can be used successfully it must be validated through experimental testing. The Hamilton Jet test rig (Figure 3) was used to test impellers and stators of varying blade geometry, hub/casing ratios and profiles.

The rig is a closed circuit arrangement in which the pressure can be adjusted. The test section (shaded area) includes an impeller mounted in a Perspex housing to allow for flow visualisation and cavitation studies, and a stator (tailpipe). Flow straighteners and settling lengths are employed to ensure uniform flow upstream of the impeller and upstream of the orifice flow-measuring device. Water temperature is monitored and held at around 15 degrees Celsius.

Flow rate is measured at the orifice and is adjusted with the nozzle. Head rise across the pump is measured by differential pressure transducers at stations C1 and C2, and this can be adjusted by selecting venturis (flow restrictors) of different sizes. Local velocities and pressures were measured using specially designed probes.

Agreement between the software and the experimental results has so far been very good. Predicted flow angles and measured flow angles are very similar.

Loss Prediction

Understanding and predicting the different causes of energy loss is the key to developing ways to improve water jet efficiency. Hamilton Jet's 3D solver software predicts the magnitude of these losses, how they build up through the waterjet impeller and can show relevant changes for different design solutions.

For example how many blades should a particular impeller have? Figure 5 shows the variation in loss with blade number for a particular application.

Figure 6a shows an impeller is divided into sections to calculate loss factors.

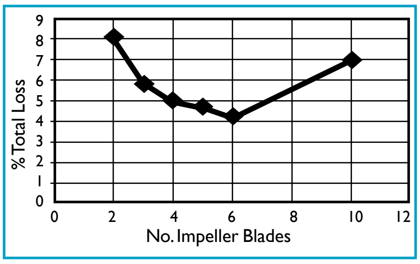

Figure 5. Impeller Losses Reletive to Blade Number

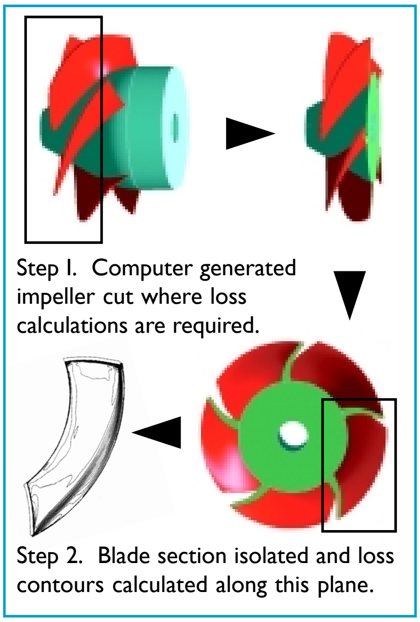

Figure 6a. Creating Blade Cross-Sections

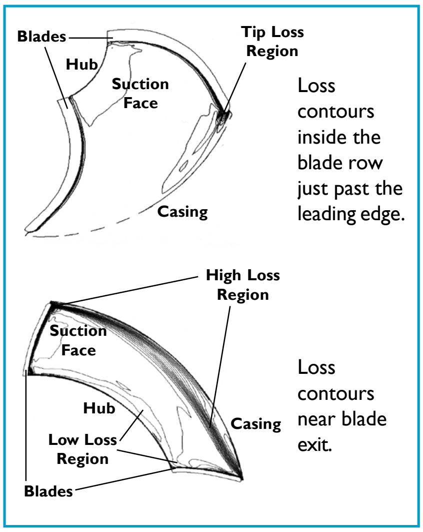

Figure 6b. Mapping Loss Contours on Blade Cross-Sections

Figure 6b shows loss contours at two points along the impeller. Like a weather map, the closer the lines are together indicates increased disturbance, with the greatest losses experienced in these areas.

Software Integration & Continual Development

Hamilton Jet is now using its 'state of the art' CFD software extensively for the design of impellers and stators for a range of different size waterjets. The company also has on going research in areas of CFD flow analysis of intakes and multiple blade rows.

HOW TO CONTACT US

World Headquarters
Hamilton Jet
PO Box 709, Christchurch
New Zealand

Phone: +64 3 348 4179
Fax: +64 3 348 6969
E-mail: 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
E-mail: 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
E-mail: sales@hamjetuk.com

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A Big Catch

Waterjet propulsion helped a New Zealand farmer and amateur angler land a 458.5kg Mako shark off the Gisborne coast early this year. Neville Clark, aboard the Hamilton Jet powered catamaran 'Marcella', played the shark for eight hours to win the Gisborne Tatapouri sports fishing club annual competition and break the competition's record by 200kgs. It was one of the biggest sharks ever caught in NZ waters.

Excellent manoeuvrability provided by the twin Hamilton HJ291 waterjets was crucial during this time. The boat was easily positioned correctly in relation to the fish, and there was no risk of snagging on exposed props or rudders.

HamiltonJet
The Waterjet Specialists

Jet Boating American Style

What do you call it when you get 15 luxury Hinckley Picnic Boat pleasure cruisers together for a weekend trip? You call it a Jetboat Round Up, and the first one took place on the North East coast of the US last year.

Bridge to the Annisquam opens for the Picnic Boats

The three-day, 240-mile adventure was organised by the Hinckley Company of Southwest Harbor, Maine. It involved cruising coastal and inland waterways between Marion, Massachucets and Southwest Harbor, with overnight stopovers at Marblehead and Boothbay Harbor.

On the first day the fleet battled challenging 15-20 knot winds and 3-5 foot high seas for 63 nautical miles. The boats and crews both handled these conditions very well and all vessels reached port unscathed.

The second day started with perfect conditions for the scenic trip through the Annisquam River and the Isles of Shoals. However, leaving the Isles the 15 jetboats were faced with 20 knot winds and 6-8 foot seas. Again, all boats and skippers conquered the conditions with ease.

That night the Hinckley Company hosted a dinner for the boaters, which was attended by Bruce King, designer of the Hinckley jet boats. He was very pleased to hear all the positive reports of how well the boats performed in the rough conditions.

The final day featured a scenic jaunt along the coast of Maine into Southwest Harbor. The fleet was escorted into the harbor by a number of local Picnic Boats and was warmly welcomed by the Hinckley Dock Crew.

All participants thoroughly enjoyed the weekend, and are looking forward to this year's trip. The organisers are hoping to attract more boats and visit some new ports of call during the next event.

Group photo of JetBoat Round-Up 2000

Hamilton Jet's Hidden Power

The Florida Everglades are famous for alligators and air screw driven skiffs, which are ideally suited to the shallow, heavily vegetated waterways of the area. Many tourism ventures around Everglades National Park offer "traditional" airboat rides. The problem is that airboats are expensive to operate and maintain, so many are now powered by waterjets, with the propeller idling for show while the jet does the work.

Airboat with Hamilton Jet Propulsion

One such operator is Captain Doug House of Everglades City, FL, who has been using Hamilton Waterjets for six years. He has one 40-seat boat with twin HJ212 jets and two 15-seat boats with single HJ212s. Another single jet boat is under construction and one boat has an older Jacuzzi jet. All are driven by big block Chevy engines.

Captain Doug's favorite features are the positive control provided by the jets and the reduced costs to run and maintain. The boats operate for some 320 days per year and so far have only been delayed by one jet incident.

Unfortunatley air/jet boat operations in the Everglades have been suspended due to environmental issues, so tourism operators have been forced to run trips outside the park.