JetTorque from HamiltonJet

A TECHNICAL AND COMMERCIAL
VIEW OF THE WATERJET PROPULSION MARKET

Maximising Manoeuvrability

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A waterjet moves a vessel through the water by generating propulsive thrust which is a reaction to the change in momentum in a directed stream of water. This is generally well understood and is described in detail in earlier issues of Jet-

Fig 1 - Norwegian Coastguard boarding vessel with twin HamiltonJet HJ274 waterjets

Torque (particularly JetTorque 07 – Waterjet Thrust Issues). Perhaps less well understood however is the significance that control deflector efficiency, speed of controls response and low speed performance can have, not only on forward thrust, but reverse and lateral thrust also. These three factors are central to how modern vessels can be utilised in critical manoeuvring, such as in close quarter situations alongside other vessels or obstacles, similar to those shown in Figure 1.

Control of Thrust

The first factor to examine when looking at the overall maneuverability of a vessel is how thrust is actually controlled. In a waterjet this is achieved not by rudder and/or changing engine direction but by splitting the jet stream into different components and varying the ratio of flow between these components. There are two different design approaches to achieving this in common use.

One method, common in some larger (non-HamiltonJet) waterjets, uses a box shaped steering deflector with a reverse deflector 'flap' mounted on it so that the whole assembly swivels when the steering is actuated. When the reverse deflector is deployed the flow is split into two components that are opposed by 180 degrees at all steering angles. When the reverse deflector is set so as to balance the ahead and astern components of flow (zero speed), no side thrust vector can be generated since the flow components remain opposed by 180 degrees at all steering angles. Waterjets using this mechanism are not well suited to operations where high manoeuvring thrust is required.

The second design approach, pioneered and refined by HamiltonJet, has the reverse duct attached to the waterjet housing and pivots in the vertical direction independently of the steering deflector. It intercepts the jet stream after it has passed through the steering deflector and turns part or all of the flow back under the hull to produce reverse thrust. The HamiltonJet type of reverse duct has split passages, which allow either two or three flow components to be generated.

Figure 2 shows a view looking aft along the jet axis into a HamiltonJet reverse duct, which is partly lowered into the jet stream. In this view the steering deflector is angled slightly to starboard. The jet stream is split into three components as follows:-

- The 'Ahead' component (blue) which goes underneath the reverse duct.
- The 'Port' component (red) which goes into the port side of the reverse duct.
- The 'Starboard' component (green) which goes into the starboard side of the reverse duct.

The 'Ahead' component is only acted on by the steering deflector. The volume of flow in this component is dependent on how far the reverse duct is lowered. The remaining flow going into the reverse duct is further split into port and starboard components with the ratio determined by the steering deflector position.

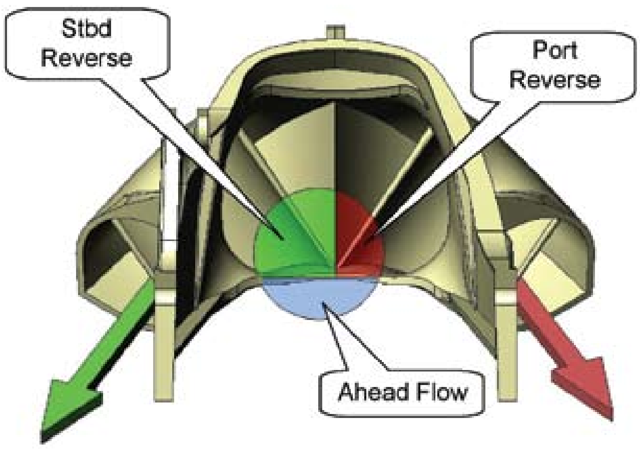

Fig 2. HamiltonJet split duct reverse deflector as viewed from jet steering nozzle.

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The efficiency of the reverse deflector design and also steering deflector design has a direct effect on the amount of thrust available for manoeuvring. HamiltonJet have been through several generations of design in order to maximise the available manoeuvring thrust (for example see JetTorque 9 for a description of the evolution of the JT steering nozzle and the performance gains this offers). HamiltonJet reverse deflector design ensures up to 60% of forward thrust is available in reverse and HamiltonJet JT steering

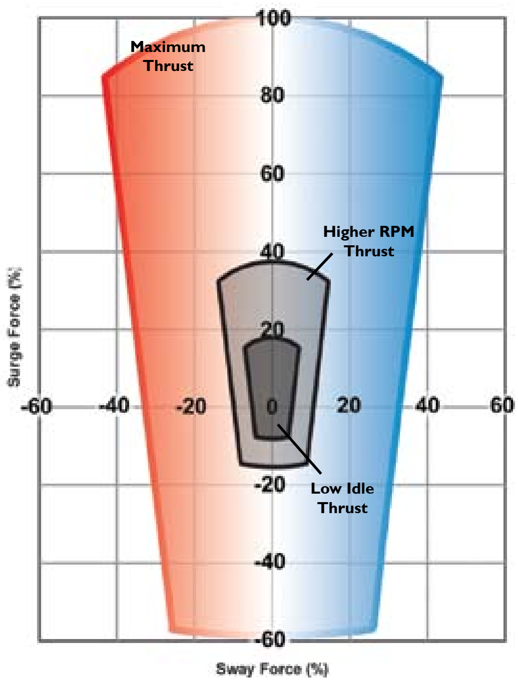

Fig 3. Typical Thrust Envelope for HamiltonJet

ensures up to 33% of forward thrust is available as lateral thrust. The thrust envelope for a typical HamitlonJet case is shown in Figure 3 above.

Thrust vectoring in a multiple HamiltonJet application.

The description above of how individual HamiltonJet units control thrust can be extended to a vessel where there are two or more units installed, which incidentally accounts for the vast majority of installations.

If the HamiltonJet controls are synchronised then the thrust applied to the vessel is the same as described above, but with greater magnitude. However if the units are controlled independently it is possible to add the two (or more) individual thrust vectors to generate a resultant thrust that is entirely lateral and as a result move a vessel sideways as shown in Figure 4 below. Note this is easily achieved with a common steering control but separate reverse controls for each unit.

Control Response Speed

The second key factor in a highly manoeuvrable vessel is how responsive the controls are to the operator. When fine and immediate control of a vessel is required, such as when coming alongside a vessel in rough conditions, or avoiding a hazard, the ability of the propulsion system to rapidly produce high thrust in a different direction is paramount.

As discussed above with a waterjet the engine runs continuously in the same direction and a thrust change is carried out by movement of the steering and/or reverse deflectors. Note there is negligible change in the engine loading during a thrust reversal (apart from that due to any demanded RPM change) and no action required from the gearbox. The speed of the control system and jet hydraulic actuators moving the deflectors becomes the limiting factor.

The effect of any delay in control reaction is well studied by Dynamic Positioning (DP) practitioners. As shown in Figure 5 (page opposite) in a typical case any delay in executing a thrust demand has an exponential negative effect on the accuracy of the system, in DP terms reflected in an increased position error and a longer time required to return to the desired position. In practical terms for a vessel manoeuvring in difficult circumstances this means that any slight delay in control system response equates with an increased lack of control of the vessel. For this reason minimum control response times are critical.

Having fast responding controls has been a focus of much development work for HamiltonJet and this can be seen in the speed of controls response achieved today. For example a HamiltonJet HJ292 has steering travel time (full port to full starboard) of 0.8 seconds, and reverse travel time (fully raised to fully lowered) of 1.6 seconds. This means for smaller craft the vessel is very nimble and easy to manoeuvre. Even on the larger HamiltonJet ranges very quick times have also been achieved. For example the HM811 has steering travel time (full port to full starboard) of 3 seconds, and reverse travel time (fully raised to fully lowered) of 4.5 seconds. This means that even for large vessels the operator is able to very quickly respond to any changing conditions or situation.

HamiltonJet controls and hydraulic actuators are designed and manufactured as an integral part of the unit itself and are driven by the Jet Hydraulic Power Unit (JHPU) on each

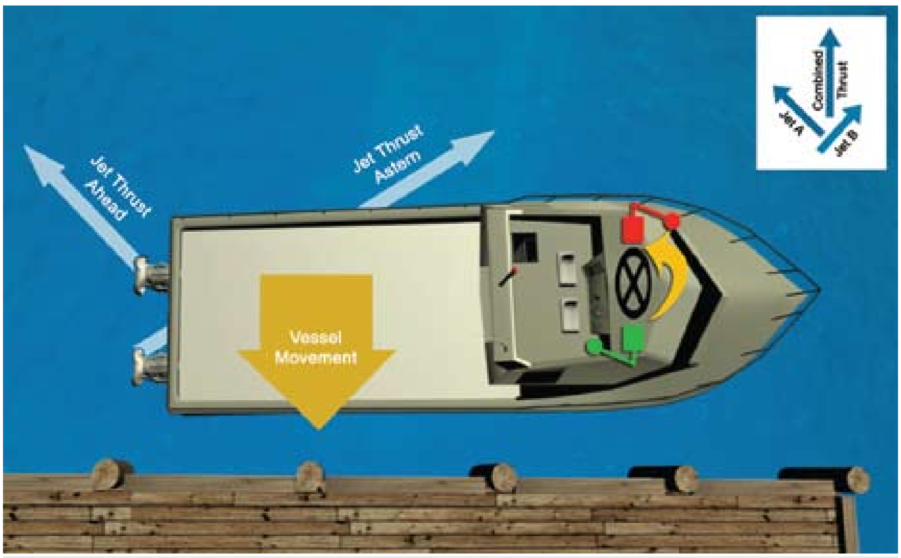

Fig 4. The resulting sideways movement when twin waterjet thrust is vectored appropriately.

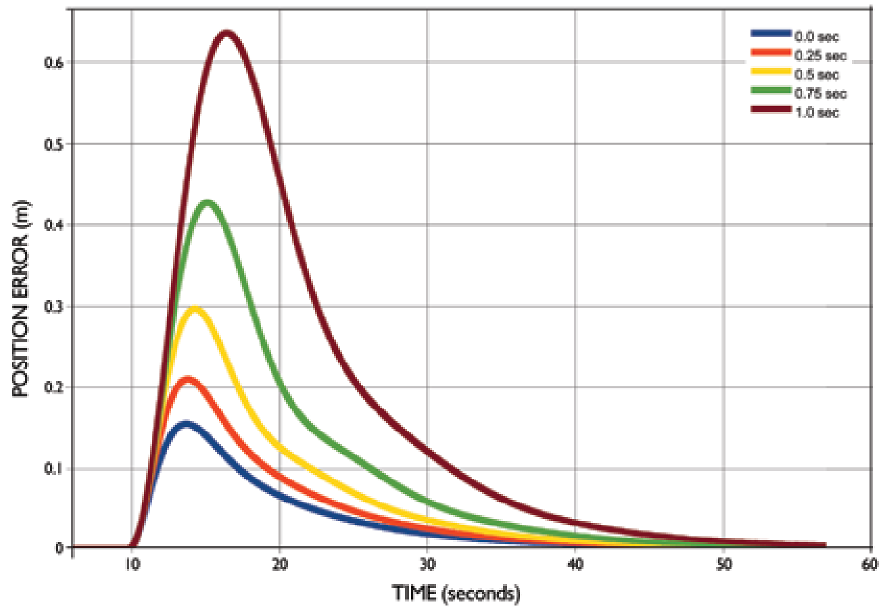

Fig 5. Delay or slow controls response has exponentially negative effect on ability to hold location.

individual jet. This is done in order to ensure a compact hydraulic solution which ensures very rapid response and also has additional benefits of being able to be fully factory assembled and tested while also simplifying installation, and improving the overall redundancy of the vessel's propulsion system.

Low Speed Performance

The third factor in achieving good manoeuvring performace is the ability of the waterjet pump itself to deliver high thrust at low boat speeds. Optimal waterjet design is balanced around achieving good high speed efficiency while not sacrificing low speed performance. Maintaining sufficient margins over low speed cavitation involves careful design of various elements of the waterjet including impeller blade area, blade loading and inlet size and geometry, (for more details on cavitation see Jet Torque 2). In some applications, such as vessels involved in close quarter manoeuvring and other difficult operations, low speed performance should be given greater importance as it is this ability which affects acceleration, manoeuvring thrust, towing capability and how forgiving the jet is to difficult conditions.

HamiltonJet's mixed flow pump design and hydrodynamic optimization based on extensive R&D and over 50 years experience has resulted in up to 25% more thrust than other waterjets between 0 and 20 knots. Manoeuvrability at low speeds and acceleration to higher speeds are superior to any other waterjet on the market.

Conclusion

In order for a vessel to achieve a high degree of manoeuvrability in a wide range of conditions, the three aspects of thrust deflector efficiency, speed of controls and low speed performance must each work together to provide high degrees of thrust available in all directions. When this balance is achieved a vessel can perform more complex tasks and operate in difficult situations such as alongside other vessels, in rougher conditions, close to obstacles or people in the water.

Application Reviews

The combination of highly effective control deflectors, fast controls response and excellent low speed performance of HamiltonJet units has led them to be installed in many vessels where close quarters precise manoeuvring is an essential part of the function of the vessel. One example of such vessels that are constantly performing these tasks is pilot vessels.

Dutch Pilot Service (Loodswezen), Netherlands (figure 6 below)**:**

The Dutch Pilots have a series of ten 66ft (20m) HamiltonJet propelled vessels that entered service in 1994 and they are currently adding to their fleet with more vessels. The pilots selected HamiltonJet propulsion, and continue to do so, for the ability to hold the vessel alongside a ship in the difficult conditions they face in the North Sea and breakaway rapidly when desired, as shown below.

Fig 6. Dutch Pilot Vessel picking up a pilot and positioning its stern to quickly pull away from a ship.

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Fig 7. Puget Sound Pilot vessel approaching the pilot ladder.

Puget Sound Pilots, Washington State, USA (figure 7)**:**

This Pilot organisation undertook extensive research prior to building their two 72ft (22m) vessels with HamiltonJet propulsion in order to ensure they had the best configuration possible to provide a stable platform for pilot transfers and the ability to perform a quick breakaway from larger ships with ease.

Captain John Harris of the Puget Sound Pilots comments;

"Hamilton Jets provide our boat operators instantaneous control of the boats when along side a ship. They are never out of control. Our Hamilton jet boats can maneuver in ways beneficial specifically to the pilot transfer process that we were never able to accomplish with our twin screw conventional boats. The whole operation is safer due to the command and control plus if a pilot were to fall into the water he does not have to worry about being hit by rotating propellers or fixed rudders. Within the speeds that we operate when transferring pilots, there is never a problem coming alongside or breaking away from a ship. We always have reserve thrust to maneuver through any situation that might occur."

Colombia River Bar Pilots Oregon, USA (figure 8 below)**:**

Carrying two crew and four pilots, Chinook has a range of 250 nautical miles at an operational speed of 25 knots, and top speed of 30 knots propelled by HamiltonJet model HM651. Again, HamiltonJet propulsion was selected to ensure full control of the vessel is available when coming alongside and breaking away from a ship.

HamiltonJet propulsion is also in use in many other pilot vessels around the world including;

- Houston Pilots (Texas, USA)
- Savannah Pilots (Georgia, USA)
- Pacific Pilotage Autority (British Colombia, Canada)
- Sabine Pilots (Texas, USA)
- Galveston Pilots (Texas, USA)
- Virginia Beach Pilots (Virginia, USA)
- Bordeaux Pilots (France)
- Humber Pilots (England)
- Irshad Pilots (United Arab Emirates)
- Port of Taranaki Pilots (New Zealand)
- Brunswick Pilots (Georgia, USA)

Fig 8. Colombia Bar Pilots coming alongside a ship.

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