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JetTorque

A Technical and Commercial View of the Waterjet Propulsion Market from HamiltonJet

FROM THE BRIDGE

"The mammoth steam-ship Great Britain arrived in New York on Saturday morning, 20 days from Liverpool. Her propellers have been remodelled, but there appears to have been no improvement in her speed. It is truly astonishing that men of capital in England persist in keeping themselves so totally ignorant of the plain philosophical principles of Mechanics, as to suppose that a propeller of any form of the screw principle, can compete with the simple Fultonian paddle-wheel".

Quote from 'Scientific American' magazine - June 1846

Controversy regarding best propulsion and hull forms has always been a part of the quest for higher speeds at sea, just as the proponents of propellers encountered 150 years ago. But, as history tells us, the convention for marine propulsion did change as paddle-wheel vessels are today relegated to operations is calm inland waterways.

However, another generation of innovators and visionaries have carried the process of change forward to the point where today, waterjets are the acknowledged propulsion option for a wide range of high speed vessels.

1 *"The merits of waterjet propulsion have long been appreciated by designers of small high speed vessels . . . . . But new generations of large high speed car/passenger ferries and fast freight carrier projects have stimulated the development of more powerful waterjet designs"* and,

2 *"Wherever the mission speed is greater than 25 knots, waterjets become a comparative candidate with propellers with regard to propulsive efficiency."*

With over 20,000 jets installed since the Company's first model performed successfully in 1953, HamiltonJet has been at the forefront of this development and is committed to carrying the technology forward for the next generation of high speed work and patrol craft and fast passenger ferries.

References:

1 Speed at Sea Magazine - June 1996

2 Blount, D. 'Fast Attack Combatant for Near-Shore Operations' - Naval Engineers Journal - January 1996

More Power

"Famille Dufour II", a 40 metre Canadian catamaran passenger ferry, is powered by a twin shipset of the largest jets in the HamiltonJet range, model HM811's. When first launched in 1995, the Caterpillar V16 engines driving the jets were rated at a modest 1640kW each which enabled the vessel to attain a speed of 30 knots in a lightly laden state. However, upgrading work on the engines was undertaken during the northern winter of 1996, boosting the power output to 2066kW apiece. **This has resulted in a maximum speed of 35 knots being achieved, in fully laden condition with 300 passengers aboard.** In addition to increasing the power output of the engines, adjustable trim-tabs were fitted to the hulls and the ratio of the gearboxes changed.

40 metre TWIN HM811 JET POWERED CATAMARAN FERRY "FAMILLE DUFOUR II" TRANSITS THE ST.LAWRENCE RIVER AT 35 KNOTS

The waterjet's electronic control system was reprogrammed, by technicians from HamiltonJet's factory-based field service team, to interface directly with new electronic engine governors fitted to replace the mechanical types originally installed. Because of the flexibility of the HamiltonJet design, which allows each model to operate over a relatively broad power envelope, no major work was required on the propulsors to accomodate the increased engine power - the impeller blades were simply repitched to suit. The upgrade has provided the operators with the facility to reduce transit times and, as Propulsive Efficiency generally rises as boat speed increases, it is expected higher Transport Efficiency Factors will be achieved, despite the increase in power input.

INTEGRATED ELECTRONIC CONTROLS ENSURE PRECISE HIGH SPEED AND MANOEUVRING CAPABILITY

FROM THE ENGINE ROOM

WHICH PUMP - Axial or Mixed Flow ?

It is not easy to define the efficiency of any waterjet for purposes of comparison as there are many influencing factors. For example, since a jet is part of the ships hull, the interaction that occurs between the jet intake and boundary layer has an effect. Additionally, the many individual elements of a waterjet contribute to the units overall efficiency.

One such component is the pump. In a waterjet, the pump exists to accelerate the water flow and create pressure to produce the mass flow rate and velocity necessary to achieve desired thrust. For high speed craft, the ideal waterjet is one that accelerates the volume of water necessary to produce the largest possible mass flow to high velocity *(refer JetTorque No. 7, Sept. 1996)*.

There are three fundamental types of pump that could be used in waterjet design -

- **Centrifugal** (radial) **Flow**
- **Axial Flow** (inline) **Flow**
- **Mixed Flow**

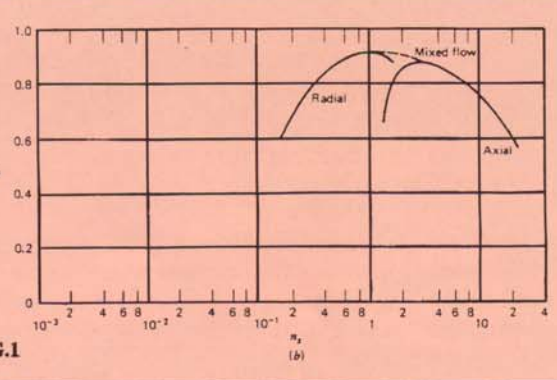


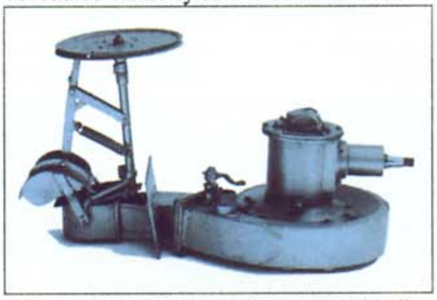
FIG.1

Figure 1 above *(from "Turbomachines" by O.E. Balje)* illustrates trends in pump efficiency depending on the degree of radial and axial flow. Pumps with centrifugal and mixed flow characteristics are seen to occupy the higher efficiency regions.

However, as this graph applies to pumps, is should be used with caution in respect of waterjets. Waterjets are not strictly pumps as their main aim is to accelerate the flow, with the requirement of pressure generation being less significant. This theory indicates a trend towards a greater axial flow component than radial component being desirable.

CENTRIFUGAL PUMPS

These pumps use centripetal acceleration to generate pressure. Radial blades whirl the water around, increasing both its pressure and velocity at exit around the impeller periphery (radial outflow). A standard centrifugal pump would have a scroll around the impeller periphery to diffuse the flow to further increase the pressure. However, in waterjets, the scroll casing is designed to collect the water without diffusion and, the pressure that was added due to centrifugal action, is converted to velocity at the exit nozzle.



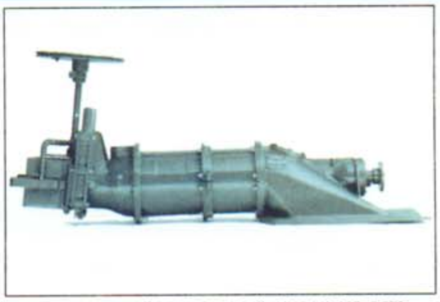
HAMILTON "QUINNAT" CENTRIFUGAL PUMP WATERJET, CIRCA 1954

Early HamiltonJet development centred on the centrifugal pump but, since the principle characteristic of a centrifugal pump is its ability to produce high pressure with low flow rate, it was better suited for applications where pressure generation is most important, such as fire pumps. Compared to an Axial Flow pump, for the same thrust and power input, the Centrifugal Pump concept was larger and heavier and required a gearbox as its rpm would generally be low. Later development turned to the axial flow concept.

AXIAL FLOW PUMPS

In an axial flow pump, pressure is increased by diffusing the flow as it passes through the impeller blades and stator vanes. The waterjet nozzle converts the pressure energy of the flow into velocity, thus producing thrust. High flow (and thus mass) and low pressure output characteristics of the axial flow pump better suit application of this pump type in waterjets.

Compared to a centrifugal pump of same thrust and power input, an axial flow equivalent would be a much smaller diameter, run at higher rpm (permitting direct drive in many cases) and be lighter weight. The ability of the



HAMILTON "CHINOOK" AXIAL FLOW PUMP WATERJET, CIRCA 1959

axial flow pump to pass large volumes of water gives better acceleration, load carrying capability and cruising economy, all very important operational considerations necessary for waterjet propulsion.

However, there is a limit to how much the flow can be diffused before flow separation occurs, resulting in a loss of thrust. Multi-staging of axial flow design provides one means to increase the thrust without increasing the jet diameter. Refinement of impeller designs provides another option.

MIXED FLOW PUMPS

Mixed flow waterjet designs incorporate characteristics of both the Centrifugal and Axial Flow concepts. Pressure is developed by both diffusion and radial outflow and manufacturers of mixed flow jets determine the pump flow/pressure (or head) characteristics by splitting the axial and centrifugal components to suit their own design philosophies.

The modern Hamilton waterjet, with its origins in true axial flow form, appears at first glance to still retain this concept. However, whilst evolution has carried forward many of the desirable axial flow characteristics, the parallel outside diameter and large tapered hub configuration of the impeller imparts an important radial outflow component to the flow.

Therefore, the modern Hamilton waterjet can be correctly categorised as a Mixed Flow design.

PROFILE OF STANDARD HAMILTONJET IMPELLER

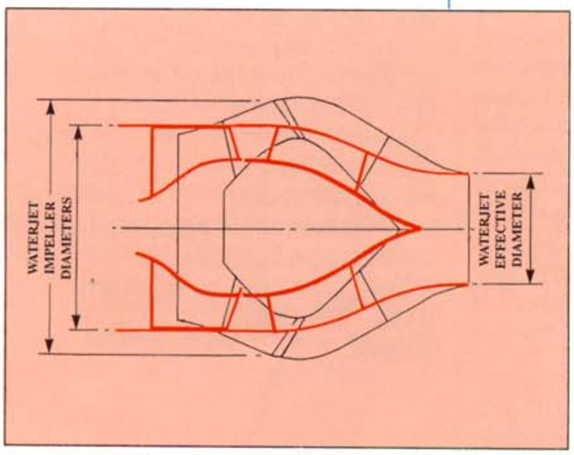
DESIGN CONSIDERATIONS

The impeller is the heart of a waterjet. Whilst conventional fluid mechanics are used in waterjet design, manufacturers also need to cope with departures from the idealised one dimensional case to account for unique features, which include:

- the flow is not uniform or steady, influencing incidence angles and losses.
- cavitation sets limits on fluid velocities and blade loading.
- the finite number of blades influences the flow.
- the flow deviates from the direction of the trailing edges.
- boundary layer growth (fluid friction) has to be minimised without the condition of flow separation or stall occuring in the blade passages.

Good design achieves a high pump efficiency and maximises intake efficiency by best utilising the approaching entry flow. The design of the standard HamiltonJet impeller takes full advantage of the requirement that the waterjet is a device for increasing the velocity of the flow and is not principally for generating pressure, as in most pumps. Consequently, it is capable of pumping large volumes of water at relatively low pressures, permitting high propulsive coefficients to be achieved at fast boat speeds. Important characteristics of the "parallel O/D-mixed flow" impeller design include:

- **optimum flow/thrust** for a given diameter ie., high volumetric/weight efficiency. Some waterjet manufacturers incorporate a greater radial outflow component in their designs but this results in a larger jet diameter at the transom for the same nozzle size ie., the same thrust performance.
- **high resistance to cavitation** (important to ensure heavily displaced hulls can reach planing speed).
- **high wear tolerance**. Tip clearances are not absolutely critical to performance, a feature which allows a simple and reliable wear-lubricated marine cutless bearing to be utilised. Moreover, the parallel bore enables the provision of a low cost replacable liner (wear-ring) around the impeller. Tapered O/D impeller designs cannot readily provide such a liner and additionally require shimming axially to maintain tip clearance.



PROFILE OF PARALLEL O/D IMPELLER PUMP COMPARED WITH TAPERED O/D DESIGN

CAVITATION

Cavitation is the rapid formation and collapse of vapour cavities within a liquid where the impact force of the collapsing fluids is beyond the strength of most metal surfaces, resulting in damage *(refer JetTorque No. 2 March 1993)*. The jet impeller is most likely to suffer cavitation damage but in the worst conditions the stator blades and tailpipe housing may also suffer.

Design factors which increase cavitation resistance are -

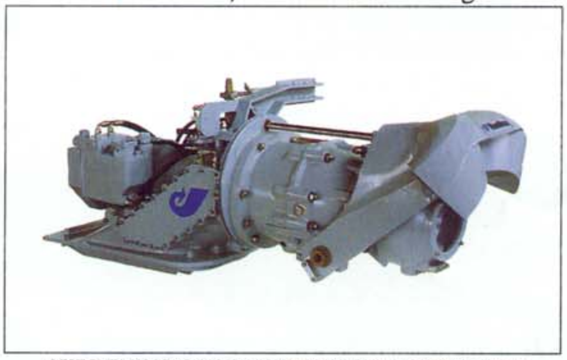
- greater impeller blade area ie., longer blades or more blades of same size. Pump efficiency may reduce as blade area increases due to the frictional effect of the increased surface area. Therefore, a practical compromise may have to be achieved between cavitation and efficiency (thrust).
- blade loading design. The blade profile controls the load distribution across the blade surface, a critical factor for cavitation performance.
- smaller nozzle size. Reducing below optimum nozzle size tends towards a smaller, less efficient jet.
- larger inlet. As hull speed increases, too large an intake can cause additional hull resustance.

Two options available from HamiltonJet which improve cavitation performance are multi-staging (HS Series of jets), where multiple impellers are employed to provide a higher power density package and the "Turbo" impeller option, which uses a 'tandem cascade' design. Two rows of blades are employed to avoid separation (which might occur with a long blade passage) and maintain impeller efficiency. The large blade area improves caviation resistance, aerated water performance and bollard pull.

PROFILE OF 'TURBO' HAMILTONJET IMPELLER

INTAKE/PUMP INTERACTION

For best efficiency, the pump ideally requires uniform flow at entry. To achieve this, the intake usually needs to be very long but such an intake carries a weight penalty. Uniform flow can be improved if the intake bend can accelerate the flow, an arrangement that enhances cavitation performance at low speed . HamiltonJet's streamlined, low loss, low lift intake design offers acceptable uniform flow whilst keeping intake and entrained water weight down to contribute to good overall performance. Impeller design can also be matched to the intake flow, maximising intake efficiency. By comparison, some mixed flow jet designs have narrow, steeply angled intakes which create a tortuous, complex water passage.



CURRENT HAMILTONJET MIXED FLOW PUMP
(Model 321 illustrated)

The HamiltonJet package is an extremely rugged and practical waterjet which combines high performance with reliability and simple low cost maintenance.

HamiltonJet believes their design ensures the best match of volume/velocity relationship for the important operational parameters of better acceleration, load carrying capability and cruising economy.

FROM THE LOG BOOK

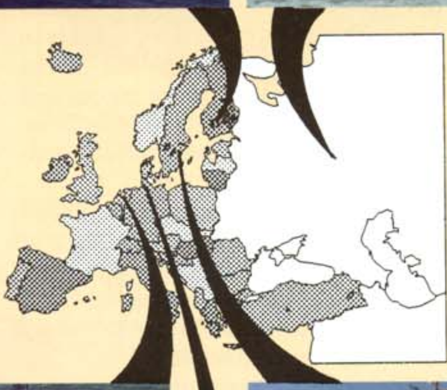
Europe - Some Recent Installations

FINLAND

"Meri 82", a 15 metre Oil Recovery/Rescue/Fire boat is report to be the fastest in its class (F) in Finland. Triple Hamilton 321 jets driven by Caterpillar 3126TA diesel engines deliver a top speed of 34 knots.

RUSSIA

The Russian Fishing and Game Protection Police use a series of Finnish built 8.4 metre high speed craft powered by single Model 273 jets to patrol in diverse locations throughout Russia.



NETHERLANDS

A series of advanced high speed boats, each powered by twin HamiltonJet HM571 jets, are used by the Loodswezen Pilotage Organisation for pilot and rescue services around the Dutch coast.

SWEDEN

The Swedish National Administration of Shipping and Navigation have launched a purpose built Pilot/Rescue craft powered by a single Model HM422 jet with CMU Electronic Control. A Volvo TAMD163P diesel engine drives the jet.

DENMARK

Twin 291 jets driven by Cummins 6BTA 5.9 diesels power a series of 10.5 metre LRB10 rescue craft to a top speed of 38 knots for the Royal Danish Administration of Navigation and Hydrography.

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