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JetTorque

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

FROM THE BRIDGE

In the quest for higher speeds, lightweight materials such as aluminium and composites used in modern vessels are subjected to loads imposed by relatively high power inputs.

It is essential then that all elements of the vessel are compatable and capable of meeting the loads imposed, with adequate safety margins.

In the case of waterjet propulsors where thrust and control loads must be transferred to the mass of the craft, some designs are such that these are carried to the hull through the transom, requiring substantial stiffening of this structure. Analysis has shown that, while a transom can be stiff laterally and easily capable of carrying the control loads, it is difficult to stiffen in the fore and aft direction for the thrust load.

> **". . . . .reinforcing the view that load transfer occurs in the duct region forward of the transom and not at the transom itself".**
>
> N.F.Warren, RINA Waterjet Conference, 1994

The jet intake duct is stiff in this longitudinal direction but is often only designed to deliver water to the pump and not carry the thrust load. Consequently, failures can occur in the duct and its support structure.

The HamiltonJet design approach incorporates heavy ducts to carry these major thrust loads and transfer them to the hull bottom, a structure that is already strong in the fore and aft direction. This means lighter transom structures can be incorporated in the vessel.

The technical article in this issue of JetTorque examines waterjet loads and moments and looks at the implications of the different philosophies for transferring these to the hull.

Military Advantages

Recent applications of Hamilton waterjets into a variety of military and para-military craft around the world have highlighted a number of key features which show why they are the preferred propulsion system for these types of craft.

42' COASTAL PATROL CRAFT WITH TWIN HAMILTON MODEL 362 JETS - 36 KNOTS

With all the ahead/astern and steering hydraulics inboard, there are no hydraulic lines vulnerable to outside damage and the design also enables most routine maintenance procedures to be carried out without slipping the craft. The high efficiency mixed flow style pump provides excellent cavitation resistance for rapid acceleration while the split duct astern deflector provides a powerful reverse thrust capability for backing off beaches or 'emergency' braking.

'CRASH STOP' BY 48' FAST PATROL CRAFT EQUIPPED WITH TWIN MODEL 391 JETS.

Precise manoeuvring, regardless of boat speed, can be achieved simply by appropriate thrust vectoring, without the need for complex control systems.

New Small Jet Proves A Big Hit

While large jet installations in craft such as fast ferries tend to steal the limelight, the popularity of waterjets in smaller pleasure craft continues to grow. The HamiltonJet model 212, recently introduced as a replacement for the popular 770 Series, has been designed specifically for trailerable craft with engines up to 260kW, typically being 5 to 8 litre gasoline engines.

HAMILTONJET MODEL 212 JET FOR TRAILERABLE CRAFT

Incorporating many of the features found in larger HamiltonJet 'commercial' models such as the high efficiency split duct astern deflector, the 212 can be close-coupled to the engine to maximise space onboard. Stainless steel impeller, integral intake

TYPICAL 212 JET APPLICATION - 5 metre PLEASURE CRAFT N.Z.

screen, infinitely variable reverse detent, trimmable steering nozzle and demountable impeller wearring are other standard features. As an option on the 212 jet, the new 'turbo' impeller with extended blade area provides enhanced grip for craft which are required to operate in white (aerated) water. Full details are available from HamiltonJet Distributors worldwide.

Waterjet to Hull Load Transfer

WATERJET FORCES

Jet forces as seen by the hull have been well established and can be summarised as follows.

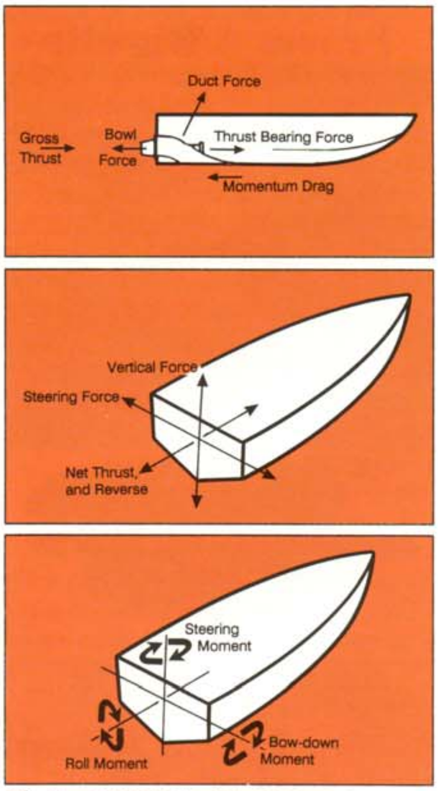


Fig.1 MAIN WATERJET FORCES

Thrust - in normal operation, the Nett Thrust created by the jet is the reaction of the acceleration of the flow through the jet. Nett Thrust is the sum of the Gross Thrust less momentum drag and, at boat speeds of 35 knots, is about 50% of Gross Thrust for most applications.

Steering Forces - are a function of the Gross Thrust of the jet and the angle through which the jetstream is deflected. Since the Gross thrust available at normal boat speeds is about twice the Nett Thrust, at 30° steering deflection the steering forces can be equivalent to the Nett Thrust available to propel the craft. This is the reason for the excellent turning ability of waterjet craft.

Reverse Forces - reverse thrust is achieved by deflecting the flow down and forwards under the craft. As it is normally only used for manoeuvring, the forces are relatively low, however, it is always necessary to design for the worst case so the 'crash stop' situation, where waterjets are capable of exerting enormous stopping power, must be addressed. This is because, in addition to the Reverse Thrust being employed, momentum drag and craft drag each of the same order as the Nett Force create the stopping force. The resultant force can be more than the Gross Thrust and something over 3 times hull resistance.

Intake Duct Forces - large vertical forces in the intake are cancelled by large opposing forces acting on the hull bottom. These forces, which exist because the water must be turned twice in its path through the duct, must be taken into account for anchoring the intake ducting to the hull as, while their nett result is virtually nil, they are offset and produce a bow-down moment.

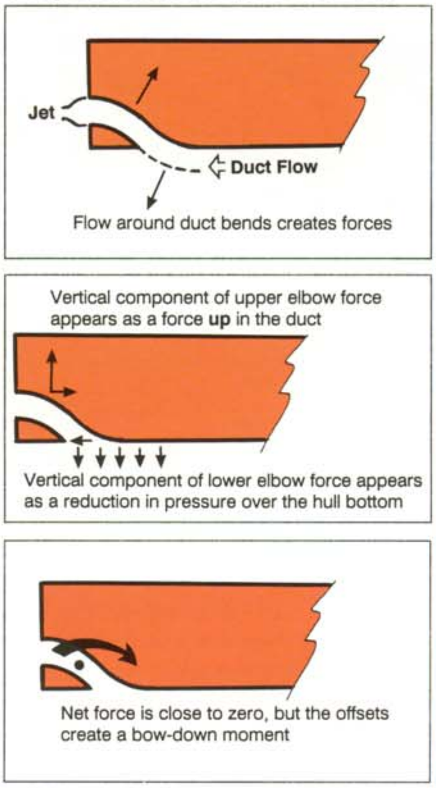


Fig.2 INTAKE DUCT FORCES and RESULTING MOMENT

Thrust Bearing Forces - arise from the axial forces on the impeller with the resultant impeller load appearing at the thrust bearing which, depending upon the waterjet design, may be internal to the jet or mounted in the ship structure.

Waterjet Bowl Forces - are the nett axial force on the waterjet bowl, or the stator section. They arise from the nett difference between the pressure and momentum after the impeller, the flow straightening and nozzle flow and would normally be internal to the waterjet system. However, in cases where the thrust bearing is separated from the pump, these bowl forces must be accounted for.

Internal Waterjet Forces - some of these forces, depending on how well integrated the jet package is, will have to be contended with. Obviously, from a contractural point of view, it is desirable that the jet manufacturer supplies an integrated package that keeps all the forces, other than those necessary for propulsion and control, internal to the jet system. The manufacturer should advise what these forces are and where they are reacted, enabling designers and builders to concentrate on their own areas of expertise without becoming involved in waterjet design.

WHERE THE MAIN LOADS ARE REACTED

As a structure, the hull afterbody has (more or less) horizontal plating in the bottom connected to (more or less) vertical plating in the transom. This arrangement has it's own inherent strength, quite apart from any added structural members.

The waterjet exists to apply forces to the hull. These will be transferred most effectively when the inherent strengths of this structure are used, necessitating the minimum amount of extra stiffening and resulting in the ideal load transfer system.

The Table below shows which planes in the hull afterbody are most effective in accepting each of the different loads and moments of the waterjet system, identified earlier in Figure 1.

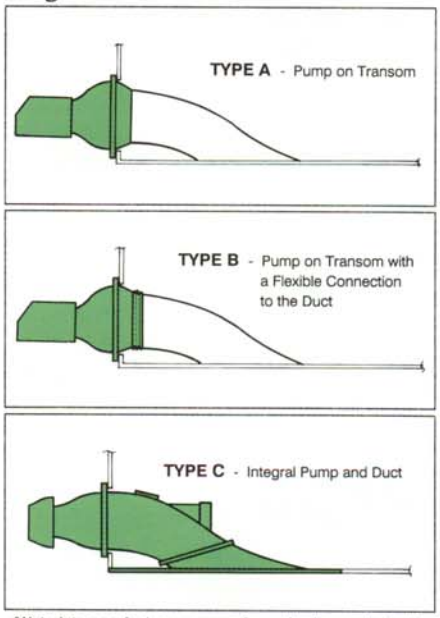
WATERJET FORCES	HULL STRENGTHS Transom	Bottom
Fore & Aft Forces	Weak & Flexible	Strong & Stiff
Port to Starbd. Forces	Strong & Stiff	Strong & Stiff
Vertical Forces	Strong & Stiff	Weak
MOMENTS		
Bow Down Moments	Weak & Flexible	Weak & Flexible
Turning Moments	Weak	Strong & Stiff
Roll	Strong & Stiff	Weak & Flexible

The hull bottom plane is ideally suited to carry horizontal forces and moments. Normally it is already stiffened in the vertical plane by longitudinals and transverse frames. The transom is

best suited to carry vertical and sideways forces only as it is very weak in the fore and aft direction and cannot take moments. The best waterjet system will make use of these hull features with little additional stiffening being required. Other systems will require additional stiffening of the structure to prevent bending of the transom or intake ducting.

COMMON WATERJET MOUNTING SYSTEMS

To examine common waterjet mount systems in relation to the ideal load transfer system, Figure 3 below shows schematically three common arrangements.



(Waterjet manufacturer scope of supply shown shaded)

Fig.3 COMMON WATERJET MOUNT SYSTEMS

In the Table below, these systems are listed and the ideal load transfer cases which make use of the inherent strengths of the hull plating are highlighted.

From the Table, it can be seen the most effective waterjet system is one which has an integral intake duct and pump, transfers the horizontal loads via this duct to the hull bottom plating and transfers the lateral and vertical loads out through the transom.

The Table also suggests where extra structure must be added by the boat designer and builder to accomodate non-ideal load transfer cases.

DUCT STRESS ANALYSIS

Since the loads, and the inlet duct function, are properly understood by the waterjet manufacturer then it is preferable that he be involved in, and take some responsibility for, the duct structural design and integrity. At best, the jet manufacturer should design, build and have responsibility for the inlet ducting and the main bearing mount completely. Design and FEA stress analysis for the duct and bearing mount should be undertaken by the jet manufacturer, relieving the boat designer of responsibility for items that are largely outside their area of expertise.

DESIGN FOR FATIGUE

Waterjets, especially in light ship structures, apply loads that are cyclic in nature and in the design of the support structure for the waterjet, stresses need to be considered as fatigue stresses. This involves determining the mean stress levels, alternating stresses and frequencies of applications.

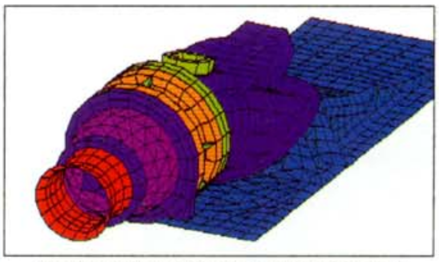
Materials - Whatever materials are used, the issues to consider are the static strength, the fatigue strength in air, the corrosion fatigue strength in water, the effects of welds and stress amplification factors. Analysis of fatigue strengths of both aluminiums and steels, in the design cycle range typically encountered in high speed craft, shows high strength plate has no advantage over materials such as aluminium castings.

Welds - must have stress levels suitably low if fatigue failures are to avoided, as set out in appropriate Standards. Allowable stress levels in welds may be anything down to $^{1}/_{5}$ of those allowed in the parent plate.

Stress patterns change wherever sudden changes in section, corners, webs, brackets, holes or other structural change occurs, altering the fatigue resistance of the load carrying members. Typically, fatigue failures arise at welds and where bending occurs, making it apparent that the builder has substantially more work and responsibility to ensure good quality welds in installation arrangements requiring same.

Castings - on the other hand, are well suited to making the complex doubly curved shapes required in a waterjet pump and inlet duct.

The casting wall-thickness can be tailored to the expected stresses and changes in section can be made as gradual as required to avoid stress amplification. Where cast components are bolted together, they can have significant advantage in allowable stress levels for fatigue, over welded plate.



TYPICAL FEA STRESS ANALYSIS OF HAMILTONJET CAST INTAKE DUCT

Waterjet Type	Forces & where they act			Moments & where they act		
	Horizontal Fore & Aft Forces	Horizontal Port to Stbd Forces	Vertical Forces	Bow-down Moment	Steering Moment	Torque Moment
A Pump on transom	Transom or duct	Transom	Transom	Transom or duct	Transom or duct	Transom
B Pump on transom with flexible duct joint	Transom	Transom	Transom	Transom	Transom	Transom
C Integral pump and duct	Hull bottom	Transom	Transom	Hull bottom	Hull bottom	Transom

WATERJET LOAD TRANSFER TYPES - Ideal Load Transfer Highlighted

CONCLUSION

The foregoing analysis points to the most advantageous type of waterjet installation for the transmission of loads to the hull is one where:

- the loads are transferred making best use of the hulls inherent strengths.
- the complete jet system is designed and built by the jet manufacturer.
- fatigue stresses and frequency spectra are designed for from the outset.
- a bolted castings configuration can have advantages over welded fabrications.

Reference: Dr.K.V.Alexander - 12th Fast Ferry Intl.Conference - Amsterdam 1996

FROM THE LOG BOOK

TWINS ....

1995 recipients of the prestigious British Airways Eco-Tourism Award, Whalewatch Kaikoura Ltd of New Zealand, have recently commissioned two new catamarans for their fleet of excursion craft. Both new craft are powered by twin HamiltonJet model 362 waterjets.

ONE OF WHALEWATCH KAIKOURA LTD's TWIN 362 JET POWERED CATAMARANS

Photo Courtesy Whalewatch Kaikoura Ltd

The first vessel, at 12.6 metres LOA with a payload of 45 passengers, has a maximum speed of 30 knots. The 362 jets are each driven by 309kW Yanmar 6CX(M)-ETE diesel engines.

The second vessel is slightly longer at 14.5 metres, giving room for 60 passengers. Twin Mack-Daytona 377kW diesels power the 362 jets to give this vessel a maximum speed of 35 knots.

Some of the key factors why Hamilton waterjets were chosen for these vessels include -

* no exposed propellor and low underwater noise levels for minimum risk of damage and disturbance to marine life.
* low maintenance requirements for minimum costs and downtime.
* excellent manoeuvrability for close quarters viewing of marine life.
* greater load carrying capability and reduced fuel costs compared to previously operated gasolene engine/propeller driven craft.

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TRIPLES ....

Singapore fast ferry operator, Sea Flyte Ferries have added a new triple HamiltonJet HM521 jet powered craft to their fleet. Designed and built by West Australian yard, Wavemaster International Pty., the 31.3 metre "Ocean Flyte" has a payload of 196 passengers and a maximum lightship speed of 31 knots. The HM 521 jets are driven by MTU 12V 183 TE92 diesel engines via ZF model BW190 reduction/reversing gearboxes.

Propulsion system control is affected by a HamiltonJet DECS Digital Electronic Control System. This modular microprocessor based system is customised for this vessel. All the jets have steering and ahead/astern functions. Reverse on the outboard jets is independently controlled by single levers at the helm station which are interfaced with the jets and engine systems. Steering is by joystick. The control functions of the centre jet are "mapped" through the control software to the outer jets so that response to helm commands is automatic. This arrangement provides full control of thrust vectoring for all vessel manoeuvres. A Roving Manoeuvring Control (RMC) is provided for use on the bridge wings and push button electric gearbox shift for backflushing the jets is included.

31 METRE WAVEMASTER FERRY 'OCEAN FLYTE' TRIPLE HAMILTONJET HM521 WATERJETS

and QUADS

Following the success of the jet powered Gulf Crew Boat "Mr.Mel" which was fitted with quadruple model HM571 jets (see JetTorque 5 and JetBrief 261), operators in the oil rig servicing industry in the Gulf of Mexico are moving to HamiltonJet propulsion systems.

QUADRUPLE HM571 JETS IN THE 43 METRE CREW BOAT "MR.MEL"

Operational experience with "Mr.Mel" has shown the vessel to be substantially faster than conventionally powered crew boats of the same size and at these higher speeds, better propulsive coefficients are achieved. The higher speed allows a quicker turnaround in trips out to the oilrigs. The hull, designed for the higher speed, has shown better ride characteristics resulting in less stress to crews. The quad jet configuration provides the operators with a new level of flexibility in vessel loading.

So impressed with the performance of this craft, the operators have another of these 43 metre long vessels currently under construction at the Swiftships yard with yet another on order.

In a variation on the theme, also recently commissioned is a 41 metre Crew Boat with a single HM571 jet installed between conventional propellers. Sea trials have shown the jet to significantly boost top speed and, since jet power absorption is independent of boat speed, it can be employed throughout the transition from slow to high speed. Relatively low powered loitering and manoeuvring capability is another bonus of the jet system.