Utilising computational design for better efficiency

Increasingly affordable CFD, computer simulation and 3D packages are enabling marine engineers to design more accurate solutions than is the case with building and testing, argues IntelliJet's Jeff Jordan

Computational fluid dynamics (CFD), computer simulation and 3D printing and prototyping are fast becoming essential ingredients of efficient waterjet development, replacing more traditional water-tunnel or in-craft testing methods.

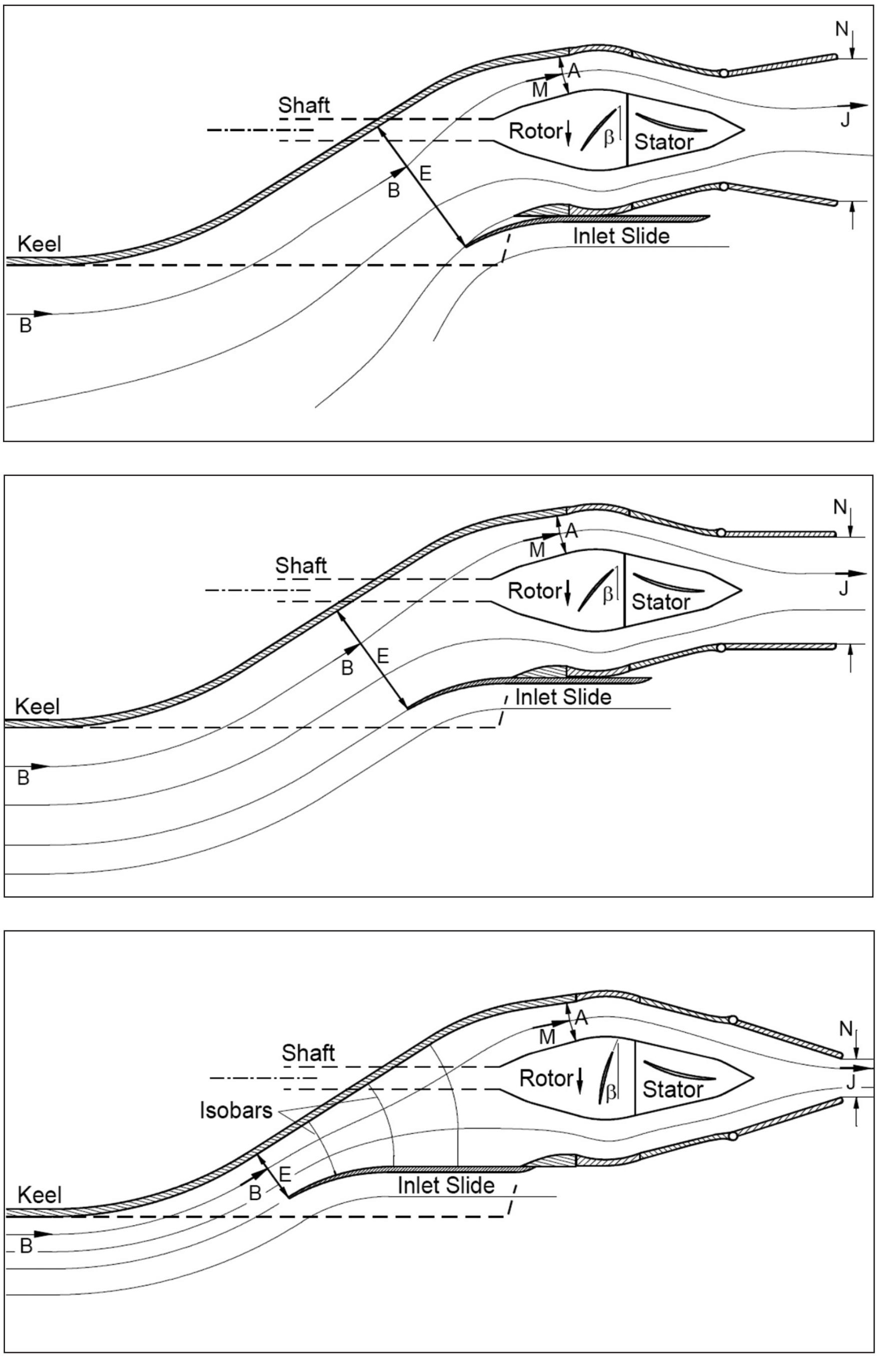
That is the view of IntelliJet Marine, a US-headquartered venture whose president (and former US Navy officer), Jeff Jordan, argues that the marine sector has not taken advantage of these technological tools to the extent that other sectors, especially the aero industry, have.

In a paper entitled *Electronically controlled marine jet propulsion and modelling*, delivered to the American Society of Naval Engineers in March 2015, Jordan claims: "CFD pump modelling is now more accurate than designs and performance parameters developed using water-tunnel testing. CFD produces accurate models of controllable pump inlets and nozzles throughout their range of action. The parts created in this process can be quickly and accurately converted to metal prototypes."

One of the major advantages of the increased availability of these tools, Jordan contends, is that they can enable designers to think outside the box and to develop alternatives to the traditional, industry-accepted waterjet template.

FMJ limitations

"Conventional marine jets have many operational advantages, but they have a narrow range of efficient operation in terms of speed and load," Jordan's presentation continues. "In particular, they have poor propulsion efficiency and high fuel consumption at lower speeds and at higher loads. Also, the motor is only efficiently loaded when the system is operating close to full power." Referring to these jet types as 'fixed marine jets'



A schematic drawing of a VMJ with the boat operating at low speed in the top view; an efficient planing speed in the middle view; and at top speed in the bottom view. The drawing shows the range of variation in the inlet slide, pump rotor and nozzle required to maintain efficient operation (credit: Jeff Jordan)

(FMJs) – due to the fixed nature of their inlet areas, impellers and nozzle diameters – Jordan notes that, while their pump and jet diameters have been optimised for performance at high speeds, they are usually too small for efficient operation at lower speeds, "where many jets spend their time".

"The pump operates below its highest efficiency, because the nozzle restricts the flow; the jet velocity is too high for efficient propulsion because of the small jet diameter; and the motor is too lightly loaded, because the small pump demands too little power," he says. "In actual operations, there are many variations from the design operating conditions, including sea conditions, wind, lading, COG and low-speed lingering. All of these take the FMJ system further away from its efficient operating range. It is sometimes possible to achieve a more efficient compromise by changing impellers and nozzles for the new set of average operating conditions, but this is frequently not an ideal solution."

Developing the IntelliJet

At present, IntelliJet is in discussions with a series of prospective partners, with a view to developing its ground-breaking waterjet design. The IntelliJet model constitutes a refined and optimised version of the company's previous QuickJet prototype.

"QuickJet was our first design and prototype, which incorporated a high-capacity waterjet with variable inlet and variable nozzle to allow it to operate efficiently over the 0-40knots range," Jordan tells *Ship & Boat International*. "QuickJet used a conventional fixed pitch impeller and incorporated a very large reversing bucket to redirect the very large jet. It had significantly better acceleration, load-carrying and manoeuvrability than conventional jets – it was as good as the original propeller in pulling up water skiers, and went 5-10% faster."

Even so, Jordan was convinced that he could achieve superior results by adopting a variable marine jet (VMJ) configuration for a new model, which has subsequently become the IntelliJet. The VMJ concept incorporates a controllable pitch pump, a controllable nozzle, a controllable inlet and an embedded microcontroller. The latter is essential for regulating: the pump, to ensure motor efficiency and low jet velocity; the nozzle, to maintain pump efficiency; and the inlet, to maintain recovery efficiency. Theoretically, this set-up would mean that the system functions at peak efficiency at all speeds and under all loads and accelerations.

"IntelliJet's controllable pitch pump works efficiently to produce a jet with about twice the cross-section area of a QuickJet, which very significantly increases low-speed efficiency, but would have required a very unwieldy reversing bucket or alternate structure," Jordan explains. "By making the controllable pitch propeller reversible and adapting the large variable nozzle to serve as an efficient inlet, the design achieves a high reverse thrust as a result of reverse flow through the system. The adjustable inlet now becomes an adjustable nozzle.

"The manoeuvring thrust is continuously variable with the pitch pump, so can change very rapidly with a constant rpm on the motor. Also, in most common hull designs, the reverse thrust flow clings to the bottom of the hull – as a result of the Coanda Effect – so it does not disturb the debris, nor dredge it up into the inlet to damage the pump, as is common with reversing bucket designs.

"At high accelerations and forward speeds, the electronic control is programmed to adjust pump pitch to adjust shaft power demand, to keep the motor supply on its most efficient power curve, just as an automobile transmission does. This is the system's continuous variable power transmission function to optimise motor efficiency. The electronic control is also programmed to adjust the nozzle to maintain the most efficient head and flow on the pump and also the most efficient inlet configuration for the current boat speed and system flow.

"As a natural result of these electronic control tasks, the system has a big jet at low speeds for higher mass-flow propulsion efficiency – or more thrust for a given power input. This is in addition to the increased motor efficiency and the two efficiency gains compound. For example, in a particular low-speed condition, the motor uses 80% of the fuel to produce power and the power to thrust conversion is 2x, so the motor uses 40% of the fuel to produce the same thrust as a fixed conventional jet. At top speed, the gain is minimal, but most craft spend very little time at top speed."

Patrol boats to USVs

Again, the availability of a wide range of computational design tools made it easy for IntelliJet to draw comparisons between its concept and traditional waterjets. As Jordan put it in his paper, this technology "makes it possible to compare FMJ and VMJ performance and fuel savings in any operational profile in any craft design. This is a valuable tool for marine architects and naval engineers in search of the most sustainable solutions. Not only is it increasingly more accurate, it is also faster and more economical than development by building and testing.

"Also, once the system has been developed and tested on the computer, 3D printing of patterns, moulds and actual parts makes it possible to accurately and rapidly produce the parts in the materials of choice for assembly, installation and demonstration in the boat."

Subsequently, the IntelliJet will realise its "largest economic advantages" in sectors where "the craft must have a sustained high-speed capability, but spends most of its time carrying a variety of loads at lower speeds," Jordan notes. "For example," he adds, "there are about 2 million recreational propeller-driven boats in service in the US. By incorporating IntelliJets, their owners could reduce fuel consumption and carbon emissions by 20-40%; eliminate propeller injuries to people and marine life; and significantly improve reliability, manoeuvrability and ease of operation.

"Patrol boats, pursuit boats and many similar craft have already abandoned propellers for waterjets for reasons of shallow draught, safety and reliability. IntelliJet can typically provide 30-40% fuel savings/carbon reductions and other operational advantages in many of these applications."

Jordan also identifies unmanned surface vehicles (USVs) as a prime candidate for IntelliJet installation. "These craft favour waterjets for reliability and safety," he says. "Their range and time on station are limited by fuel, so they go out heavily loaded with fuel and come back lightly loaded. IntelliJet installation is likely to save about 40% in fuel costs compared to a conventional jet, and, perhaps more significantly, extend the mission by 40%." ***SBI***