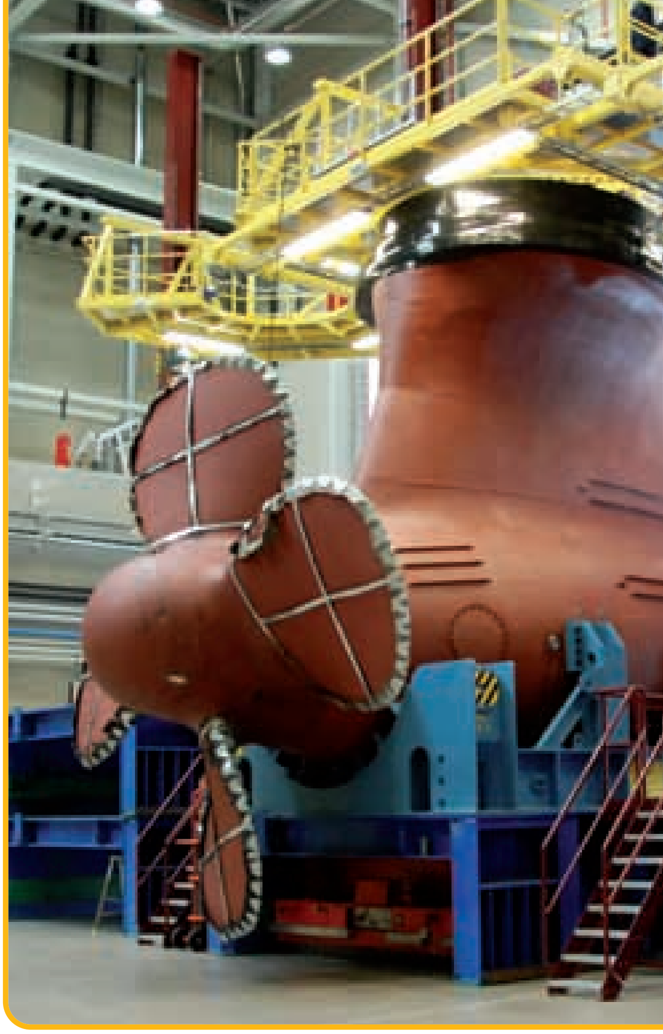
Propeller head

Electric motors slung beneath ships are signalling a new era of fast-response, flexible propulsion. Brian Tinham visits ABB's Azipod factory in Finland to find out how they work



Ask any engineer about electric motors and most of us visualise low- or medium-voltage three-phase equipment, either precision synchronous motors, driving machines or, more likely, standard asynchronous induction motors running pumps, fans and sometimes compressors. We see them everywhere, on all manner of industrial and utility plant, as well as heating and ventilating systems.

Some of us will also have come across the more efficient (and more expensive) permanent magnet (synchronous) motors on at least a few applications. Many more will, by now, have installed and commissioned banks of frequency converters (variable speed drives, VSDs) for speed and/or torque control of both asynchronous and synchronous motors. We may even be familiar with automatic, fast load and speed handling systems on fairly demanding applications – such as those enabled by direct torque control (DTC), sensorless vector control, flux vector modulation and the other advanced motor control derivatives.

But how many of us have come across 20MW electric motors, working in slow speed, high torque operation, driving propellers – and in 'pull', rather than conventional 'push', mode? And how many have heard of such units sealed inside sub-sea pods under the stern of ships, providing motive power – in place of (or, in some cases, as well as) conventional shaft and screw arrangements?

What if I told you that such units not only exist, but have also been engineered to turn (and keep turning) through a full 360° – transforming ships' manoeuvrability and propulsion efficiency through improved hydrodynamics? And that they have resulted in a mini-revolution in naval architecture, not to mention comfort – in terms of space saving, and noise and vibration reduction, by eliminating the screw shaft line, but also, in the case of icebreakers, by enabling brand new designs with reinforced sterns for icebreaking, but conventional bows for forward motion through clear water?

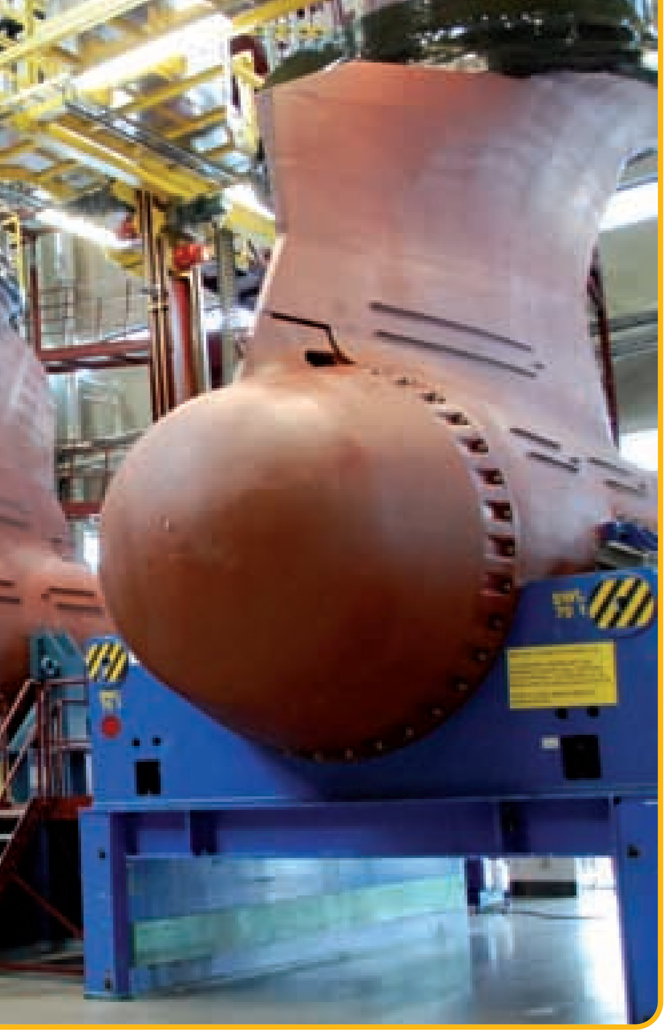
Royal Carribean's 'Liberty of the Seas', one of the world's biggest liners and driven by Azipod propulsion units

Big boys' toys

These motors are impressive. As you will have guessed, we're talking about very big packages, some 12m high and 10m long, supported by a bunch of mechanical, electrical, electronic, control, instrumentation, plant and naval engineering – and they have taken many years to develop and perfect. ABB Marine calls them Azipods (azimuth propulsion system), while Rolls-Royce competes with its Mermaid units, as used on the Queen Mary 2.

But there aren't many: although ABB built its first Azipod in 1990 (following its development work with Kvaerner Masa-Yards in Finland) and the first cruise vessel (Elation) was equipped with one in 1998, at time of writing only 165 have been installed for operation on around 75 ships, ranging from icebreakers to offshore supply vessels, drilling rigs, ferries, LNG tankers and, most spectacularly, the world's largest cruise liners (left).

Azipods currently under construction at ABB Marine's new purpose-built production plant in Vuosaari harbour, Helsinki, Finland, weigh in at



between 200 and 300 tonnes each. One 8.5MW Azipod, weighing 286 tonnes, has just left the factory, bound for an ice-going tanker. Another, now undergoing factory acceptance, will adorn the first of the Genesis Class cruisers, the 220,000 tonne 'Oasis of the Seas', due to be launched later this year by STX Europe at Turku, Finland. Carrying a record 5,400 passengers and 3,000 crew, this ship will be powered by three 20MW Azipods.

So how do they work? Azipods use variants of electric motor technology, with direct, gearbox-less propeller drives on short shafts. Permanent magnet motors – chosen for their high efficiency and minimal cooling – power ABB's Compact Azipods, which can provide 4.5MW in a 'slimline', package. Alternatively, induction motor technology can be used for this power (to keep capital cost down), although there are size and air-cooling penalties.

However, for the larger Azipods, you're into big synchronous motor technology, with electromagnet rotors and shaft-mounted excitation machines under VSD control – providing full nominal torque bidirectionally throughout the (low) speed range, all the way from stopped, without the need for squirrel cage amotisseur windings for start-up.

But that's just the start of the story. Transferring electrical energy to these rotatable sub-sea pods from the ship has to be achieved via massive cast and machined bronze copper slip rings, capable of handling 20MW. Power generation is then typically provided by diesel engine or turbine arrangements on board ship, turning generators and driving through MV switchgear and marine derivatives of ABB's ACS 6000 MV frequency converters (on the large Azipods) or ACS 800 LV frequency converters (on the Compact units) for motor torque and speed control. ABB is almost always responsible for the switchgear, transformers and distribution arrangements onboard, running auxiliary systems, including the ship's air conditioning – with a substantial proportion of cooling air directed down to the pods for force ventilation motor cooling.

Returning to the Azipods, construction of the main rotating machinery in ABB's factory is as impressive as the units themselves. It commences with precison mating of the hub assembly and propeller shaft end. Following this, a bespoke three-phase stator is fitted into each prefabricated Azipod hull by lowering it into the up-ended shell, pre-heated to 100°C in a giant pit. With the shrink fit complete and locking nuts in place on the non-drive end, each substantial assembly is moved on mobile hydraulic lifts to the main assembly area.

At this point, on one side of the factory floor, ABB's fitters equip each hull with ancillary plant, including: bilge pumps and valve systems; instrumentation for pulse encoder speed feedback (not for control, which is via DTC on the frequency converter, but to meet maritime regulations), as well as for motor temperature monitoring; and automatic oil lubrication lines for the bearings.

Precison mating

Meanwhile, opposite and in parallel, the specially designed wound rotors and brushless exciter machines (that energise the rotors), delivered from ABB Machines, are mounted on each Azipod's forged propeller shaft, and thereafter equipped with the thrust end roller bearing (typically SKF or FAG, and accommodating radial and axial loads) and propeller bearing (radial loads only) assembly.

Other equipment fitted includes a hydraulic parking brake and small induction machine-turning motor, the latter being optional and aimed at easing plant maintenance operations. As for the propellers, all are fixed pitch, but both the profile and materials of construction are matched to the application – the latter ranging from stainless steel, for icebreakers, to aluminium bronze for clear water cruise liners.

With fitting complete, each rotor and shaft assembly is fitted into its Azipod hull – a procedure that ABB sales manager Antti Lehtela says requires 10mm precision. Then comes the acceptance test and massive air cooling, which puts significant demand on the air conditioning plant, installed to manage the factory and ABB's adjacent offices.

Altogether no mean feat and, plainly, the technology behind not just the Azipods – their drives, motors, sealing technology etc – but their assembly operations, is a tribute to multi-disciplinary engineering. Next time you book your holiday on board a Royal Caribbean Cruise Lines ship, ask to see the engine room. PE

Sub-sea Azipod drives are enabling revolutionary icebreaker designs

Pointers

- Azipods are large, electric motor-driven sub-sea propulsion units for ships
- They are leading a mini revolution in naval architecture, enabling innovative designs
- Azipods use marine variable speed drives for high torque, slow speed control
- Technologies adapted include permanent magnet motors, synchronous motors and shaft-mounted excitation machines
- Massive cast and machined bronze copper slip rings, capable of handling 20MW, transfer power from the ship to the propulsion unit